BULLETIN NO. LR-7

No. 7

PLUMBING, HEATING AND VENTILATION...

one of a series of

HOUSING DESIGN NOTES

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LIST OF BULLETINS

WHICH HAVE BEEN PUBLISHED

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PLUMBING, HEATING AND VENTILATION

INTRODUCTION

This Bulletin is one of a series of eight technical bulletins, designated as Housing Design Notes. These bulletins are divided into parts, each of which will deal with some element of technical design.

The following Parts are issued with this Introduction:

PART I - THERMAL ENVIRONMENT AND COMFORT
PART II - SPACE HEATERS
PART III - TENANT-OPERATED HEATING SYSTEMS (STEAM, WATER, AIR), FUEL STORAGE AND CHIMNEYS

Other parts will be issued, from time to time, as they are completed. This connected series of Housing Design Notes will contain technical data, notes, observations and recommendations relating to the design problems which are concerned with low-rent housing based on the continuing observation and intensive study of public housing projects which have been in operation for more than ten years. It should be noted that all recommendations are advisory only, except to the extent that they refer to or reflect the mandatory requirements of the current, published PHA Minimum Physical Standards and Criteria.

These bulletins are not offered as textbook material, or with any pretense that they deal exhaustively with any particular subject. In many instances they express opinions which may be subject to challenge, and they are written with a frank acknowledgment that many readers - particularly professionals - may be as well informed in specific fields as the writers - perhaps more so. The PHA believes, however, that careful consideration of the experience recorded and the suggestions offered should result in the avoidance of certain shortcomings which have been noted in existing projects and in profiting from the knowledge of the many good characteristics which have been observed and studied.

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PART I

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PLUMBING, HEATING AND VENTILATION

PART I - THERMAL ENVIRONMENT AND COMFORT

Thermal comfort is guaged by the rate and manner in which the human body liberates the heat which it generates. If it is freed too rapidly a chilling effect is noted; if liberated too slowly a feel of uncomfortable warmth and depression is apparent.

Heat is dissipated from the body as the result of surface evaporation of moisture, and through convection, radiation and conduction. The body tends to adapt itself to these conditions, and sensations of discomfort are not experienced so long as conditions or combinations of conditions remain within certain limits. The problem is to maintain an equitable balance between the body heat produced and liberated.

The principal factors of environment which affect this balance are air motion, humidity, air temperature, and temperature of enclosing surfaces; all of these are subject to control through the design of the structure and its heating system in proper relation to each other. Thus, under ideal conditions one may experience thermal comfort in an air temperature of 68° F. or lower, whereas one would feel cold in a temperature of 74° F. or higher under adverse conditions.

These are not new or startling theories; they are now well understood by heating engineers. It is no longer the practice to require merely that "the system be designed to provide an inside temperature of 70° F. under the local design conditions." These theories are discussed, because they are of particular importance to low-rent housing through the economies of cost - initial and operating - they offer, and because methods of putting them into practice are passing through a period of significant change. New practices involve the architect to a far greater extent than formerly, and full cooperation between him and the heating engineer is vital to satisfactory and economical functioning of heating systems.

a. Air Movement increases the rate of surface evaporation and the amount of heat removed from the body by convection. Air velocities above 25 feet per minute usually produce discomfort.

b. Humidity. The amount of moisture in the air controls the rate of evaporation from the body, since evaporation decreases as the moisture content of the air increases; thus, within limits, lower air temperature could be compensated by raising the relative humidity. However, from the practical standpoint, it is easier to raise the air temperature; humidity control is difficult, and hardly practicable in low-rent housing.

c. Air Temperature. Heat transferred by convection is dependent upon air temperature. The rate of convection loss is proportionate to the difference in temperature between the body surface and the air; as the temperature difference decreases, heat loss from the body decreases. When there is little or no heat loss by this process, loss by evaporation is the only means for avoiding the sensation of too much warmth.

d. Surface (Enclosure) Temperature. Thermal radiation from the body is affected by the surface temperatures of the enclosure and the objects within the room. When these surfaces are cold, heat loss from the body by radiation is rapid, regardless of air temperature, and a sensation of chilliness is promoted. The surface temperature of the surrounding surfaces is termed "mean radiant temperature" (MRT) and is equivalent to the average rate of emission by radiation of all surfaces.

An inactive adult person normally dissipates about 400 Btu per hour. Under average room temperature conditions, with low air movement evaporation accounts for about 90 to 100 Btu and the balance is dissipated by convection and radiation. A well-controlled heating system combined with building surface temperatures within proper limits will produce an equitable comfort of air temperature and mean radiant temperature. The exterior construction of buildings thus plays an important part in heating and comfort, while the surfaces of interior partition construction, having about the same temperatures as the surrounding air, are not significant factors.

It has been the practice to measure comfort by combined dry and wet bulb temperatures of the surrounding air. The American Society of Heating and Ventilating Engineers' Research Laboratory has conducted a series of studies to determine the conditions under which normal persons feel comfortable. One result of this work was the establishment of the "effective temperature" index or scale plotted on a "Comfort Chart for Still Air".

Effective temperature is not a temperature that can be measured by a thermometer. Determined empirically, it is an index of various combinations of dry and wet bulb temperatures under which comfort has been experienced. For example, during the winter, with conventional heating systems (not radiant) 97 percent of the subjects felt comfortable with an effective temperature of 66° (68 to 72°, dry bulb; 54 to 62°, wet bulb.) All the above dry and wet bulb temperatures fall within 30 to 70 per cent relative humidities.

Excessive heat loss through the exterior building construction can produce a sensation of chilliness even in a room with air temperatures 70 - 75 . Heat loss by radiation from the body to the colder building surfaces is too rapid, and will cause discomfort unless the air temperature is raised to help counter-balance the body radiation loss. If surface temperatures are not raised, the effect on comfort by raising the air temperature may, be nil. The measure of comfort to be attained in a room is definitely related to the rate of heat loss from the body and the mean surface temperature of the building surfaces.

The mean surface temperature can be calculated with a fair degree of accuracy, since temperature drops through building construction are proportional to the resistances to the heat flow. For an assumed total resistance factor of 3.00 through a wall, (sq.ft./hr/°F / Btu), an inside film (still air) resistance factor of 0.606 and a temperature difference of 70° between inside and outside air, the temperature difference between indoor air and inside wall surface is (0.606/3.00) x 70 = 14.14°; the inside wall surface temperature is 70 - 14.14 = 55.86 or about 56°. For a total resistance factor of 6.00 under the same conditions as above, the temperature difference between indoor air and inside surface is (0.606/6.00) x 70 = 7.07°; the wall surface temperature is 70 - 7.07 = 62.93°; or approximately 63°. The higher wall temperature in the second case may be the compensating factor in producing comfort.

Comfort at or near the floor line is important, if for no other reason, because it is the area in which children live and play and where they lose heat by conduction to cold floors. In the cold climates an effective method of heat distribution in each room will help keep a floor warmer. In zones where a space heater generally supplies the necessary heat, temperature distribution is not as effective, and ordinarily higher gradients between floor and ceiling exist (sometimes higher than 25°). In any case, it is essential to keep floor temperatures warm through adequate insulation, warm crawl spaces or other means, such as directly heated floor panels where economically feasible.

2. HEATING SYSTEMS AND COMFORT. As pointed out above, the type of heating and the methods and the points in the room from which heat is delivered, share in the comfort relationship. For example, it should not be expected that space heaters at the higher outputs necessary in cold climates will give the same degree of satisfaction as more extensive systems where heat is supplied to each room proportionate to the room's heat loss.

Excluding panel heating methods, radiating surfaces at or near the floor line promote comfort. When radiators are used, they should be placed preferably along the cold walls under windows to prevent the flow of cold air down the wall and across the floor. The radiator system for tenant-operated plants (more so with hot water as the heating medium) seems to offer its fullest advantage in colder climates where fairly constant outside temperatures are sustained over long periods of time, in spite of the radiator system's inherent lag (resistance to heating up and cooling down). Yet lag, while not too important a factor in colder areas, has been overcome to some extent with proper control devices and settings.

Particularly in tenant-operated plants the aquastat in hot-water heating has served successfully in regulating water temperatures to coordinate with outside temperatures.

An otherwise good heat distribution system in project plants has been sacrificed, at times, for savings in piping and other items of initial cost. Some projects have mains within dwelling units which run exposed under the first floor ceiling at the approximate center of a two-story building. A single steam supply line feeds up and down to radiators located along the inside walls and the return main is run in the crawl space. This method, although apparently cutting down the cast iron radiation load, has tended to pocket a blanket of warm air at the first floor ceiling and has kept the second floor uncomfortably warm. Rooms on the second floor are thus overheated in mild weather. Radiators placed along inside walls near the center partition frequently result in cold areas in other parts of the room.

The warm air system for tenant plants shows its full advantage in warmer areas where temperature changes are sudden, and a quick supply of heat is needed. Adequate return air circulation through ducts in both gravity and forced systems is very important, and will preclude cold air sweeping across the floor.

The baseboard or floor type register will give satisfactory results in gravity warm air systems, although the former type should be given preference. While it may be true that high side wall registers will deliver more heat because of the greater head between furnace and room outlets, the additional heat will create a higher temperature difference between floor and ceiling and result in discomfort.

In a well designed and balanced forced air system, baseboard or high side wall registers should give equally as good results in comfort, although it would appear that air delivered from baseboard registers would make for warmer floors. Reversed circulation (returning air through the top grilles and supplying air through baseboard registers) has reduced stratification. Satisfaction can be increased generally with low air velocities and low air temperatures, with blower operating for longer periods and careful adjustment of register deflecting vanes.

Fuels also have a part in comfort, particularly in the case of tenant-operated plants. It is easier to control the burning of gas or oil than coal which is "hand-fired". Gas equipment can be regulated to operate all-on or all-off; oil equipment can be regulated for all-on or all-off, or between high-fire and pilot-fire in the vaporizing pot-type burners. With coal burning, there is the tendency toward "runaway" fires under high draft, unless control is included to limit the burning rate. Runaway fires produce high temperatures of the heating medium and cause discomfort.

In the foregoing discussion on physical factors affecting comfort, it is stated that humidity within the dwelling is difficult to control, and generally not attempted in low-rent housing. To compensate for this deficiency, the comfort equation must therefore be resolved in terms of the remaining factors; air movement, air temperature and surface (enclosure) temperature. To achieve this objective, certain basic principles gained through experience should be followed. While these points are touched upon herein, they will be covered more fully in subsequent bulletins dealing with particular heating methods.

3. PERFORMANCE DATA ON TEMPERATURE GRADIENTS. Control of temperature gradients constitutes a challenging problem. Comfort temperatures as referred to herein are essential, since unusually high gradients between floor and ceiling will cause the body to feel cold at the lower levels of the room and to sense uncomfortable stuffiness at the 5-foot level. Persons of low vitality subject to these temperature extremes, suffer more severely than they would under more normal temperature gradients. Further, excessive heat at the top of the room represents waste in fuel, especially when the ceiling is not well insulated. If the ceiling is well insulated, some of the excess heat will be radiated to the floor.

Recognizing the need for more information along these lines, the Bureau of Standards has conducted a series of tests. Various heating devices were used to obtain valuable data on temperature distribution.

The test house is one story, two bedrooms with full basement. Heat loss approximates 55 Btu per square foot of floor area. It is fully enclosed within an insulated outside structure; a refrigeration system maintains desired air temperature in the enclosed spaces between house and outside structure.

The results of thirteen tests with various heating devices and methods are plotted in Figure 1, Page 6, in a series of straight lines. Part A shows the temperatures at points 2", 60" and 94" from floor; the last point is 2" under ceiling. Part B shows temperature differences between 60" and 2", and 94" and 2" from floor. The heating device, fuel or energy used, the system of heating and the outside temperature at which the system was tested are described with each series of gradients.

The system which showed the least gradients was the forced hot water system through baseboard convector radiation. Two tests were made: one with a pump, controlled from a room thermostat and operating intermittently (test no. 12), and the other with an outside thermostat controlling a mixing valve and with the pump running continuously (test no. 13). The gradients resulting from these tests varied but slightly.

Other systems which showed good results were (a) a gravity hot water system through cast iron radiators (test no. 11); (b) a forced warm air system through a floor furnace fitted with a disc fan inside furnace casing and

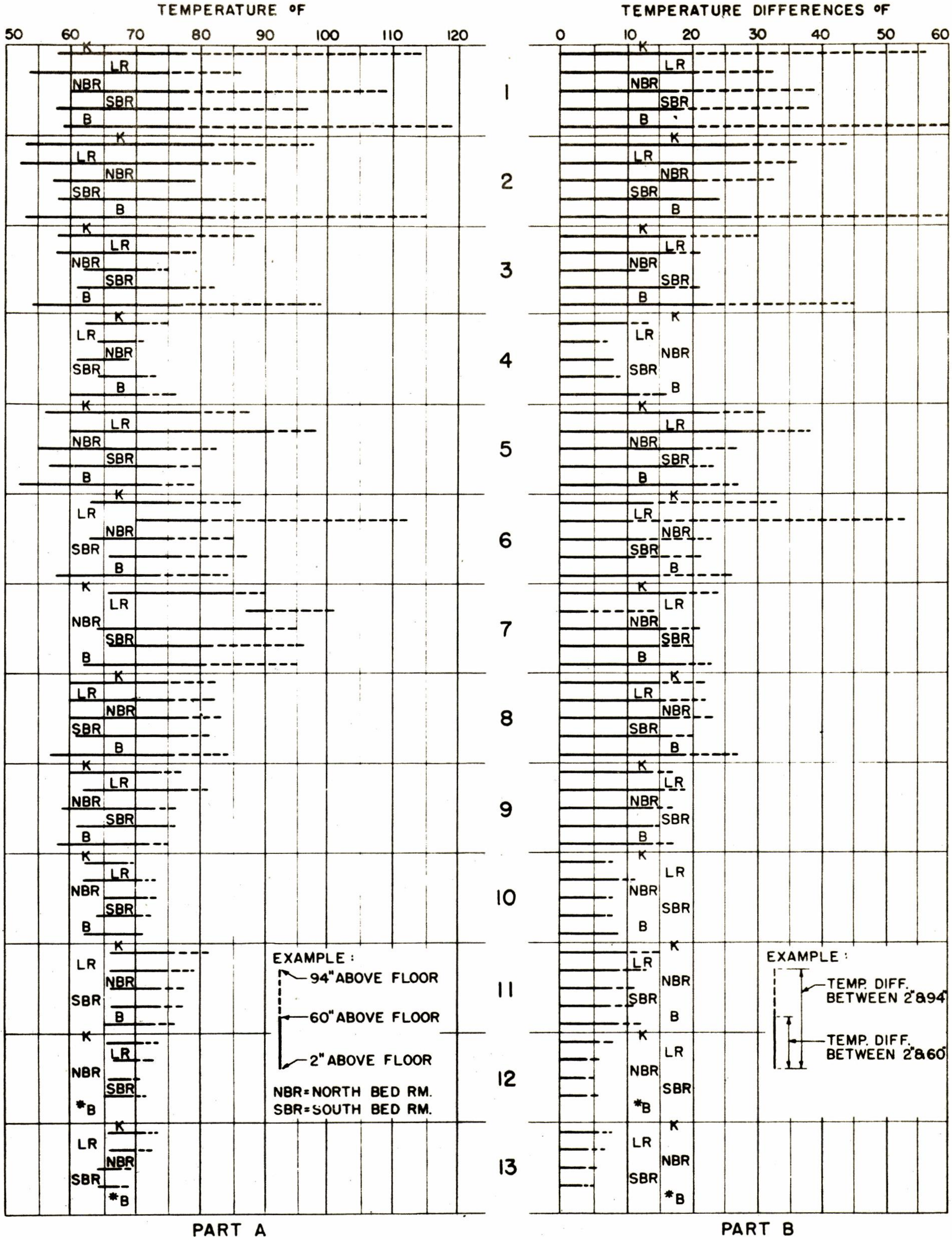

FIGURE 1 TEMPERATURES IN NATIONAL BUREAU OF STANDARDS TEST BUNGALOW WITH VARIOUS HEATING DEVICES

* No temperature lines included for bathroom because heater was installed therein.

CHART A
Temperature at points 2", 60" and 94" above floor (2" below ceiling). Where there is no broken line, the temperature at the 94" level was not higher than at the 60" level.

CHART B
Temperature differences between 60" and 2", and 94" and 2" above floor. Where there is no broken line, the temperature difference between 94" and 2" was not higher than the difference between 60" and 2".

1. Electric heater in utility space. Gravity warm air circulation through plenum chamber. Outside temperature 12 - 14°.

2. Electric heater in utility space. Forced air circulation through plenum chamber-780 cfm - intermittent circulation. Outside temperature 8 - 10°.

3. Electric heater in utility space. Forced air circulation through plenum chamber-1460 cfm - intermittent circulation. Outside temperature 16 - 20°.

4. Electric heater in utility space. Forced air circulation through plenum chamber-1460 cfm - continuous circulation. Outside temperature 34 - 38°.

5. Gas-fired space heater (jacketed), in living room. Gravity air circulation. Outside temperature 23°.

6. Oil-fired space heater (jacketed), in living room. Gravity air circulation. Outside temperature 43°.

7. Oil-fired jacketed heater in living room. Forced circulation by disc fan inside heater jacket. Downward air flow. Outside temperature 48°.

8. Gas-fired floor furnace in hallway. Gravity air circulation. Outside temperature 34°.

9. Two gas-fired floor furnaces - one in living room, other in hallway Gravity air circulation. Outside temperature 27°.

10. Gas-fired floor furnace in hallway. Forced circulation by disc fan inside furnace casing - connected air returns under floor. Outside temperature 35°.

11. Oil-fired boiler in basement. Gravity hot water circulation through cast iron radiators. Outside temperature 19°.

12. Electric water heater in bathroom Forced hot water through baseboard convector radiation. Room thermostat control. Pump operation intermittent Outside temperature 49°.

13. Electric water heater in bathroom Forced hot water through baseboard convector radiation. Outside thermostat with mixing valve control. Pump operation continuous. Outside temperature 0.9°.

connected air returns run under floor (test no. 10); (c) gravity warm air system through two floor furnaces, one located in hallway and the other in living room (test no. 9) and (d) forced warm air system with the fan operating continuously (test no. 4).

The better results were obtained from four systems which delivered heat at or near the floor line, and from one system which delivered heat near the ceiling but where air was forced around the dwelling continuously. The gravity air system with heater (on the floor) connected to an overhead plenum (test no. 1), and a space heater with forced air distribution (test no. 2) showed higher gradients than those systems listed above.

The results of these tests have proved the importance of coordinating heating design and dwelling unit planning, and the correct points from which heat should be distributed. Planning for comfort is not only good policy; it is sound economy.

PLUMBING, HEATING AND VENTILATION

PART I - THERMAL ENVIRONMENT AND COMFORT

1. THERMAL COMFORT is gauged by the rate and manner in which the human body liberates the heat which it generates. If heat is freed too rapidly, a chilling effect is noted; if liberated too slowly, a feeling of uncomfortable warmth and depression is apparent.

Heat is dissipated from the body principally through convection, surface evaporation of moisture, and radiation. The body tends to adapt itself to these conditions, and sensations of discomfort are not experienced so long as there is an equitable balance between the body heat produced and liberated.

The principal factors of interior building environment which affect this balance are air motion, humidity, air temperature, and temperature of enclosing building surfaces; all of these are subject to control through the design of the structure and its heating system in proper relation to each other.

Excessive heat loss through the exterior building construction can produce a sensation of chilliness even in a room with an air temperature of 70°F; heat loss by radiation from the body to the colder building surfaces is too rapid and will cause discomfort unless the air temperature is raised to help counterbalance the effect of the rapid body radiation loss. Comfort is particularly apparent to the elderly, who sense "cold" more keenly. In fact, an inside design temperature of 75°F. is recommended.

The surface temperature can be calculated with a fair degree of accuracy, since temperature drops through building construction are proportional to the resistances to the heat flow. For an assumed total resistance factor of 3.00 (the reciprocal of the overall thermal conductivity), through a wall, having an inside film (still air) resistance factor of 0.606 and a temperature difference of 70°F. between inside and outside air, the temperature difference between inside air and inside wall surface is (0.606/3.00) x 70 = 14.14°; the inside wall surface temperature is 70 - 14.14 = 55.86 or about 56°. For a total resistance factor of 6.00, (accomplished with insulation), under the same conditions as above, the temperature difference between inside air and inside surface is (0.606/6.00) x 70 = 7.07°; the wall surface temperature is 70 - 7.07 = 62.93°; or approximately 63°. The higher wall temperature in the second case may be the compensating factor in producing comfort. As a guide, PHA recommends not over the following in Btu per hour per square foot of living dwelling unit floor area: more than 3 story height buildings, 30; 2 and 3 story, 40; 1 story, 50.

NOTE: This Part supersedes Part I of Bulletin No. LR-7, dated 3-24-50. It has been revised throughout.

These limitations are cited to encourage the use of thermal insulation (see Part XI, LR-5) particularly in the colder areas, as designated below. It is realized that the greatest heat loss occurs through windows and doors; here storm sash and storm doors should be considered; a good starting point would seem to be where the outside design temperature is about -10°F., and where the degree days are 5500-6000.

These theories and practices are discussed here, because they are of particular importance to public low-rent housing through the economies of costs--initial, maintenance, and operating. Present practices involve the architect to a greater extent than formerly, and full cooperation between him and the heating engineer is vital for satisfactory and economical functioning of the heating system.

2. HEATING SYSTEMS AND COMFORT. The type of heating and the points in the room from which heat is delivered share in the comfort relationship. For example, it should not be expected that free-standing room heaters at the higher outputs necessary in cold climates for entire dwelling units will give the same degree of satisfaction as more extensive systems where heat is supplied to each room proportionate to the room's heat loss. The use of the room heater may be governed by local practice. PHA believes the following is a fair and practicable gauge: Where the average daily January temperature for not less than a ten-year period (U.S. Weather Bureau Statistics) is: (a) 35°F. and colder, the heating system should include means of distributing heat to all rooms proportionate to their heat loss; (b) more than 35°F., the heating system can be room heaters if consistent with local custom.

Radiating surfaces at or near the floor line promote comfort. Radiation placed along the walls under windows will counteract the flow of cold air down the wall and across the floor. The radiator system seems to offer its full advantage in colder climates where fairly constant low outside temperatures are sustained over long periods of time. Gas or oil-fired forced warm air systems (in individual tenant plants) have also offered a good share of comfort, provided the controls are set to produce frequent cycling of the burner, and infrequent cycling of the blower.

The warm air system for tenant plants shows its best advantage in geographic areas where a quick supply of heat is needed. Proper return air circulation through a single central duct at the furnace, or individual ducts in both gravity and forced systems is important, and will preclude cold air sweeping across the floor.

The baseboard or floor type register (under the window) will give satisfactory results in gravity warm air systems. While it may be true that high side wall registers in the gravity system will deliver more heat because of the greater head between furnace and room outlets, the additional heat will create a higher temperature gradient between floor and ceiling, and could result in discomfort.

In a well designed and balanced forced air system, high side wall registers should give fairly good results in comfort, although air delivered from baseboard registers (where there is no furniture interference) or narrow registers in the floor under the windows would make for warmer floors and lower temperature gradients between floor and ceiling; irrespective, returns in this direct system of air circulation should be at the floor. Reversed circulation (returning air through the top grilles and supplying air through baseboard registers or narrow floor registers under windows) has reduced stratification. Satisfaction can be increased generally with low air velocities and low supply air temperatures, with blower operating for longer periods and careful adjustment of register deflecting vanes.

Fuels also have a part in comfort, particularly in the case of tenant-operated plants. Gas equipment can be regulated to operate all-on or all-off; oil equipment can be regulated for all-on or all-off, or between high-fire and pilot-fire in the vaporizing pot-type burners. With coal burning, there is the tendency toward "runaway" fires under high draft, unless control is included to limit the burning rate. Runaway fires produce high temperatures of the heating medium, wasting fuel, and resulting in discomfort.

To compensate for the inadequacy in controlling humidity, the comfort equation must therefore be resolved in terms of the remaining factors: air movement, air temperature, and building surface (enclosure) temperature. To achieve this objective, certain basic principles gained through experience should be followed. They are covered in subsequent parts of this bulletin: II--Room Heaters; III--Tenant-Operated Heating Plants (Air, Water, Steam), Fuel Storage and Chimneys; XII--Project-Operated Heating Plants--Central, Group, and Building; XVI--Floor Line, Perimeter, and Panel Heating. The economic factors which determine the use of project versus individual tenant plants are identified in Bulletin LR-11, Selection of Utilities.

3. PERFORMANCE DATA ON TEMPERATURE GRADIENTS. Control of temperature gradients from floor to ceiling constitutes a challenging problem. Unusually high gradients (in excess of 20°F.) between floor and ceiling can cause the body to sense discomfort. Persons of low vitality, subject to these temperature extremes, suffer more severely than they would under more normal temperature gradients. Further, excessive heat at the top of the room represents waste in fuel, especially when the ceiling is not well insulated. If the ceiling is well insulated, the excess heat will tend to radiate to the floor. Also, uniformity of temperature within the different rooms of a dwelling is generally accepted as approaching an ideal in comfort heating.

Recognizing the need for more information along these lines, the National Bureau of Standards has conducted a series of temperature tests. Various heating devices were used to obtain data on air temperature distribution. The test house, a one story (bungalow type) located on the Bureau grounds in Washington, has four rooms and bath, with full basement; a small hallway in approximately the middle of the house connects the rooms. Adjacent to the hallway is a utility closet, intended to accommodate the heating equipment.

Observations, results, and conclusions of the tests are fully described in the Building Materials and Structures Report BMS108, "Temperature Distribution in a Bungalow with Various Heating Devices." Information on this report may be obtained from the National Bureau of Standards, Washington, D.C. 20234 (Mechanical Systems Section). Air temperature readings inside the dwelling were taken at points 2", 30", 60", 78", and 94" from the floor; the last point is 2" under the ceiling. Outside temperature at which each system was tested was also recorded.

The system which showed the least vertical temperature gradient was the forced hot water system through baseboard radiation. While the forced hot water system should be considered favorably in project-operated plants, its use in tenant plants is hardly justifiable essentially because of higher costs over the forced warm air system; the latter has proved good overall results with the air distribution properly balanced and correctly operated (frequent cycling of the burner and infrequent cycling of the blower, as pointed out herein above).

Good results were obtained from four systems which delivered heat at or near the floor line, and from a forced air system, where the heat was delivered through outlets near the ceiling, with the blower operating continuously. The gravity air system with heater on the floor of the bungalow and connected to an overhead plenum, and a room heater, showed higher gradients than the systems listed above. The gradient between the two extreme points increased as the outside temperature decreased. Particularly does this condition become aggravated when the heating system tends to produce stratification, such as the room heater or the gravity air system. A system operating where the vertical gradient between extreme points is 10°F. or less can be considered within the comfort range; a system operating where the gradient approaches 20°F. or more will prove uncomfortable.

The results of these tests proved the importance of coordinating dwelling unit planning and heating design, and the correct points from which heat should be distributed. Planning for environmental comfort is not only good policy, it is sound economy.

4. <u>VENTILATION</u>. Admission of fresh air into the dwelling units is by natural means of infiltration. For purposes here and for estimating heat losses, the rate of admission depends upon the pressure difference between the air inside and outside the structure, governed by the wind intensity and by the resistance to air flow around the perimeter crack of windows and doors. Reference should be made to the American Society of Heating, Refrigerating, and Air Conditioning Engineers Guide for infiltration constants, and other heat loss constants through building construction.

Where interior bathrooms are designed for mechanical ventilation, the exhaust should be sufficient to provide a minimum of eight air changes per hour, unless the local code demands a greater amount; recommended velocity through grille should not exceed 500 feet per minute. Mechanical ventilation for kitchens should be governed by local code requirements.

The subject of condensation is covered in PHA Bulletin LR-5, Part II, Condensation in Dwelling Structures, Its Causes and Control.

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PLUMBING, HEATING AND VENTILATION

PART II - SPACE HEATERS

1. INTRODUCTION. The present day space heater, concealed within an enameled jacket which, too often, is "styled" to resemble poorly designed radios, seems to have little in common with the old fashioned, sheet metal, airtight heater or the cast-iron pot-bellied stove with which one scorched in front and froze in back. Yet these were the forerunners of what has come to be a common and important piece of heating equipment.

The jacket has been added to induce convection, and some manufacturers have added fans to increase the range of circulation. Wood and coal are no longer the only fuels that may be used; heaters have been adapted to use gas and fuel oil. Thermostatic control has been introduced. Most important of all, many of these improvements, singly or in combination, have increased the overall usefulness of the device.

Nevertheless, this type of heating has its limitations and disadvantages. It cannot be used with satisfaction where normal January temperatures are below 40° F. Since its effective heating range is approximately fifteen feet, the heater must be placed in or near the center of the dwelling. Good insulation, especially of the first-story floor, is essential with this type of heating to help reduce air temperature gradient between floor and ceiling and, thus, promote comfort.

The subject of utility selection, of which the heating fuel and heating method form an integral part, is discussed in another bulletin. The objective is to obtain a combination of utilities providing "adequate and safe utility services for the lowest possible annual contribution (subsidy) by the Federal Government during the life of the project". For better livability, it is feasible to select a reasonably higher cost heating fuel or heating method than that otherwise incorporated in the lowest cost utility combination.

To illustrate: The cost of fuel is obviously the governing economic factor in selecting the equipment for the "space heater" method of heating, since the cost of the system and the inefficacies of heat distribution are very much the same whether the heater is coal, oil or gas fired. Should gas fuel, supplied by local utility, be the most economical, the problem of selection would be resolved quickly. Should the reverse be true, and coal or oil be the most economical fuel, the problem of selection becomes somewhat more complex. Then the potentials favoring gas such as cleanliness, safety and ease in handling should be balanced against: (1) the higher gas cost and, (2) certain tangible factors adverse to coal or oil including storage, handling and firing, plus more frequent painting of dwelling unit.

A condition certain to influence the selection of gas heaters, even though cost of gas is higher than other fuels, is the use of the "flat" type dwelling unit above the first floor. Carrying coal above the first floor, and the ashes down, definitely make the coal heater undesirable. As for oil, continuous supply of the fuel to the heater is accomplished by piping directly to the equipment from outside supply tank; but this refueling scheme requires, in addition, an electric pumping device when the heater is on second floor units. Oil refueling by hand into a container on the heater becomes almost as undesirable as coal handling. The gas-fired heater is equally well suited to the first and upper floor installations.

It is not intended here to discourage the use of coal or oil. These fuels are expected to have their proportionate share of use in Public Housing, primarily in project-operated plants and in tenant-operated warm air, radiator or panel systems where the furnace or boiler is placed in the basement or in a well-ventilated utility room away from the living quarters of the unit. In these cases, economics will guide, to a major extent, the selection of one fuel or system over another. But in the case of space heaters, used as they are where the heating season is short and where the outside temperatures are not low, the added cost, if any, of gas is frequently not large enough to be overbalanced by the lesser cost of coal or oil, when considering the favorable and adverse factors mentioned above.

In areas where utility company's gas is not available or where it is available only at excessive costs, then there seems no other alternative but use the coal or oil heaters, but not before the practicability of storing and using liquified petroleum gas is explored.

The space taken up by the heater and the free area which must be maintained around it, are not inconsiderable items. The PHA Minimum Physical Standards and Criteria quite properly call for an addition of 16 square feet to the size of a room in which it is located.

However, the greatest drawback to the space heater, especially when it is used in any but very temperate climates, is its lack of uniform heat distribution. This general problem, in its relation to comfort, will be treated in another bulletin. Here, it need only be said that use of space heaters creates a demand that the system and the dwelling plan be coordinated in design. This need for coordination imposes a definite restriction upon planning.

To meet this particular problem of distribution in one-story structures, some thought has been given to the utilization of the underfloor space as plenum, returning the cold air from near the floor to an opening below the space heater, where it is reheated and circulated. Fair success has been obtained in some experiments along these lines, but extensive work at the National Bureau of Standards seemed to establish conclusively that the plenum could not be made sufficiently tight in actual practice to prevent outside air from being discharged upward through the registers at the outside walls, thus defeating the purpose for which the plenum was intended.

Notwithstanding the stated drawbacks of space heaters, this equipment has legitimate uses. The essential points to consider are (1) local climatic limitations upon its use, (2) proper coordination of planning with this

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type of system, (3) use of effective insulation especially in the right location, (4) selection of the proper and most efficient types and design of heaters and their correct adaptation to the fuel to be used, (5) selection of the proper capacities, and, (6) correct installation.

2. GENERAL TYPES OF SPACE HEATERS. General types of space heaters can be classified as radiant, circulator, and combined radiant and circulator; the second and third types are sometimes equipped with integral, motor-driven fans to assist in more effective air circulation, but there is little evidence that the increased effectiveness is commensurate with the extra capital and operating costs.

The radiant type space heater, Figure 1, has less than 75% of its heating surface area surrounded by a casing, and is designed primarily for heating one room. Hence this type is applicable only to dwellings located where cold spells are infrequent and of very moderate intensity.

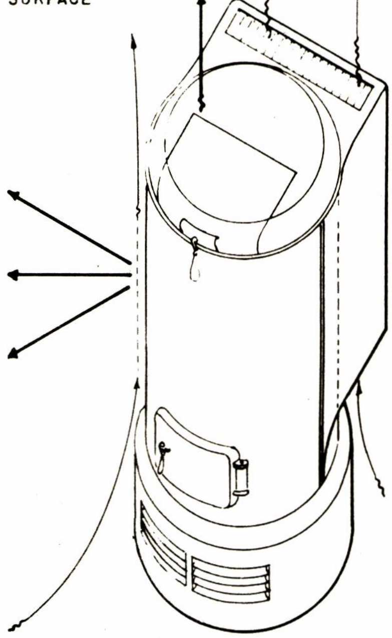

FIGURE 1 RADIANT HEATER

The circulator or jacketed heater, Figure 2, has 75% or more of its heating surface surrounded by an outer casing. Heated air is discharged through a grille or louvers in the top of the casing or in its front near the top. Preferably, to obtain the widest possible heat distribution, the jacket should be solid between bottom and top of combustion chamber.

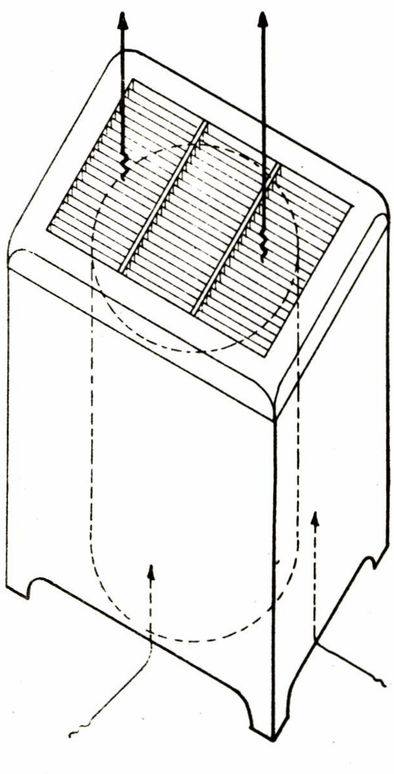

FIGURE 2 CIRCULATOR

The combined type, Figure 3, is made with two general designs of jackets: (1) with perforations between the bottom and top of the combustion chamber, and (2) doors or adjustable louvers within the combustion chamber area. The first provides little more heat through convection than does the radiant type, where the latter can provide a predominance of heat <u>either</u> by radiation or convection through the control of the doors or louvers. In a gas heater of this type, the radiant feature may include heat-reflecting refractory elements which are protected across the front with a guard grille or rails to harmonize with the heater construction.

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Coal types are designed for surface firing or magazine feeding, the latter holding fuel charges for at least a day's operation under normal conditions. Either bituminous coal or anthracite burning types may be obtained.

Oil-fired types are fitted with vaporizing pot burners for natural or mechanical draft, and with sleeve burners for natural draft essentially.

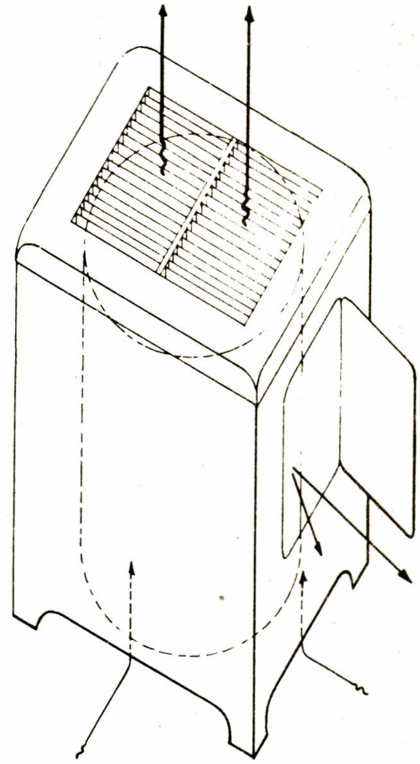


FIGURE 3 COMBINED CIRCULATOR & RADIANT HEATER

The pot burner consists of a pot with perforated walls, and is generally fitted with two rings. The pilot or low-fire ring is set within and across the pot just above the oil entrance and the low-fire is concentrated directly over this ring. The high-fire ring is set almost flush with the top rim of the pot and the high-fire is concentrated directly above this ring. After the oil is ignited, heat generated in the bottom plate of the pot transforms the oil into a combustible vapor which mixes with the air as it is drawn through the wall perforations. Dependent upon the amount of oil admitted to the burner, the oil will burn either over the pilot or the high-fire ring. This type burner will burn light fuel oil distillates such as No. 1 and 2, although better results seem to have been attained with No. 1 oil.

The sleeve burner consists of perforated cylinders of different diameters set concentrically within each other. Oil flowing to the burner soaks the asbestos kindlers inside the bowls and is ignited. As the burner bowl is heated, the oil is vaporized and drawn up between the cylinder walls where it is mixed with air admitted through the cylinder perforations. This type burner will burn only No. 1 fuel oil distillate or kerosene, and can operate with lower draft than the pot burner; however, in the larger heaters (over approximately 35000 Btu capacity) two sleeve burners are necessary (where only one burner of the pot type would be required.

Gas-fired types are generally fitted with burners of multiple port or ribbon style operating on the Bunsen principle; burners are made for natural, manufactured or liquefied petroleum gas.

3. COORDINATION OF HEATER LOCATION WITH DWELLING PLAN. Correct placement of the space heater at or near the center of the dwelling unit is of paramount importance in achieving more uniform temperature distribution since circulation is by gravity. Figure 4 gives some examples, in the form of sketch plans, showing desirable and undesirable arrangements from the heating standpoint. The intention is to provide the most direct path for air movement from heater to all parts of the dwelling. It has been found helpful to place grilled

openings in the upper part of rooms, distant from the heater, but such openings are of little value (when bedroom doors are closed) unless an additional opening is provided near floor.

Figure 4 (Plan "A" two bedroom unit) shows two methods of space heater use for oil and gas-fired equipment. With the heater installed in a partially enclosed space, a duct would be flanged to the heater top grille and rise to a plenum over the hall passageway with a supply opening to each room. Theoretically, arguments may favor this method, since it precludes taking up living space with heating equipment. From the heating standpoint, air distribution is not as uniform as when air is delivered directly from heater grille. Both methods utilize the principle of gravity circulation, but when air is delivered at one point, and at ceiling, the effectiveness of circulation is diminished. The air in its path along the ceiling will decrease in temperature as it moves farther away from the delivery outlet; the greater the distance from this outlet the less will be its warming effect at or near the floor line. Removing the partition at "A" and relocating the heater forward will obviate the necessity of a duct and plenum arrangement and permit freer gravity circulation.

In addition to the method shown on Figure 4 (Plans C & D) for heating two story dwellings, the problem of air circulation has been met with some degree of satisfaction by taking a duct, flanged to part of heater grille, to the second floor and discharging through registers. When two rooms are thus served by one duct the distribution is made through a volume damper and splitter. Such a system has operated well when used in connection with a gas-fired heater of the circulator type (see Figure 5).

4. PLACEMENT TO AVOID FIRE HAZARD. In locating heater every precaution must be taken to avoid fire hazards. Safe distances from combustible construction, at which such equipment can be placed to avoid risk, have been established by the National Board of Fire Underwriters. These distances are incorporated in Table 1. Combustible construction is defined as that containing wood, whether protected by plaster or gypsum board or not. Noncombustible stoveboards set under coal or oil-fired space heaters are a recommended precaution.

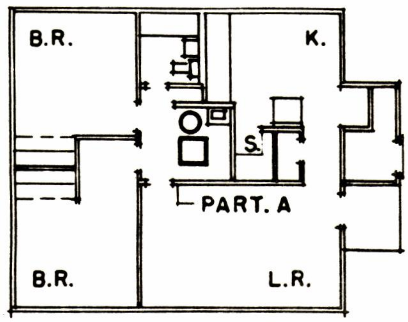
TABLE I

Equipment	Measured From	Distance Required to Combustible Construction A 1/	B 2/
Coal or Oil	Casing	6"	12"
	Smoke Pipe	9"	18"
Gas	Casing	4"	12"
	Ferrous Metal Vent	2"	6" 3/

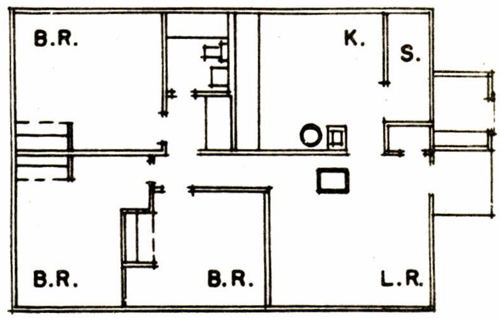
1/ Column A: Minimum distance required when combustible construction is protected with 28 gauge sheet metal, supported on 1" noncombustible spacers, and extending from point 2" above floor to 2" underneath ceiling.

2/ Column B: Minimum clearances when no protection is provided.

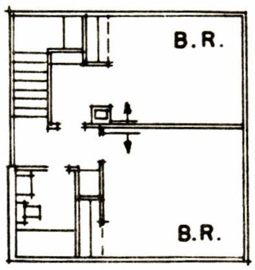
3/ Where flue gases are expected to exceed 550°F., increase the dimensions in Columns A and B to 4" and 9", respectively.



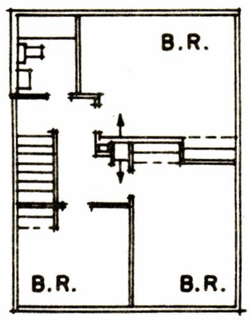
FLOOR PLAN A (UNDESIRABLE, from heating standpoint)



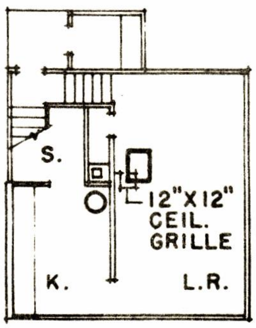
FLOOR PLAN B (UNDESIRABLE, from heating standpoint)



SECOND FLOOR PLAN

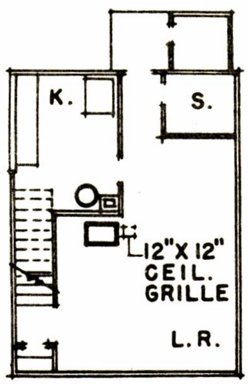


SECOND FLOOR PLAN



FIRST FLOOR PLAN

PLAN C (DESIRABLE, from heating standpoint)



FIRST FLOOR PLAN

PLAN D (DESIRABLE, from heating standpoint)

These plans not to be used for dwelling design purposes.

FIGURE 4

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5. STANDARDS FOR SPACE HEATERS. The advantages, as to safety and efficiency afforded by requiring labels on the equipment are obvious and should be encouraged. For example, the Underwriters' Laboratories label assures safe construction. The American Gas Association label indicates compliance with requirements of basic standards for safe operation, substantial and durable construction, and acceptable performance. The Commerical Standards promulgated by the National Bureau of Standards are the requirements agreed upon by mutual consent of those concerned, and may embody the requirements of the Underwriters' Laboratories or the American Gas Association plus assurance of capacity output.

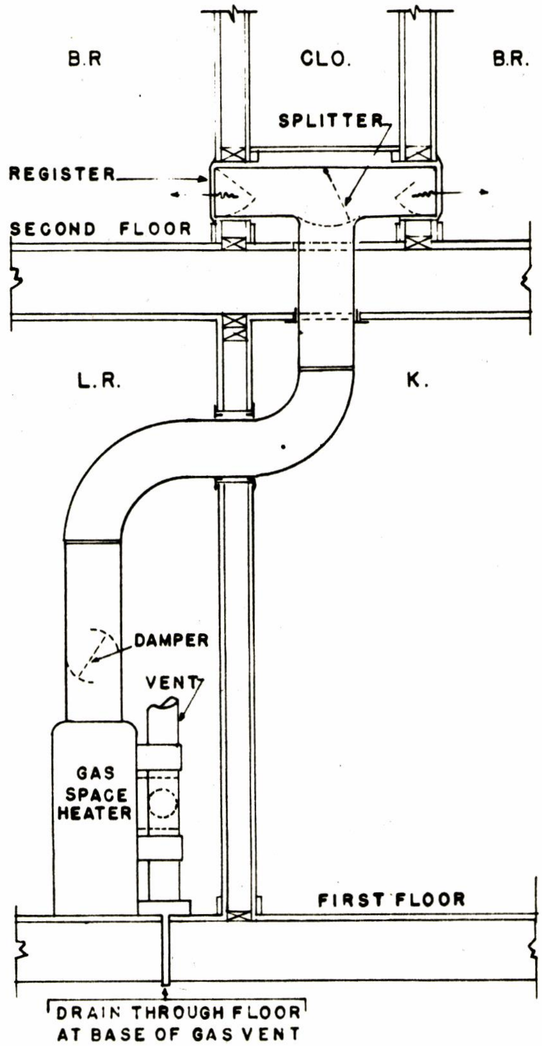

FIGURE 5

Coal-fired equipment, both surface fired and magazine feed, (until such time as applicable permanent standards are promulgated) should comply with "Proposed Commercial Standard (Emergency) for Coal Burning Space Heater, TS 3443, dated June 23, 1942 and Adjusted on February 23, 1943", except that it may be necessary to reduce the prescribed efficiency requirements pending the adoption of permanent standards.

Oil-fired heaters fitted with vaporizing pot-type burners should be constructed, rated and field tested or adjusted in accordance with Commercial Standard (CS 101-43) "Flue Connected Space Heaters Equipped with Vaporizing Pot-Type Burners," except that the specified 70 per cent efficiency requirements may have to be reduced to 60-65 per cent until such time as burners are more suitably constructed for catalytically cracked oils.

Since no Commercial Standard has (as of this writing) been promulgated for oil equipment fitted with the sleeve burner, it is recommended that this equipment bear the Underwriters Laboratories' label. In the absence of further information, the manufacturers' indicated heater output should be acceptable.

Gas-fired space heaters should carry the approval label of the American Gas Association. Cast iron heat exchange surfaces are recommended where gas contains sulphur; local utility companies have information on this subject and generally are prepared to release data on the comparative life expectancy of equipment constructed of various metals and alloys. Whether the gas intended for use is natural, manufactured, or of the liquefied petroleum family, the manufacturer or distributor should know the type, heat content, physical characteristics of the gas to be used and the pressure at which it is to be supplied. Such information is needed to assure that proper burners with correct orifice sizes are supplied; too often equipment is furnished with inaccurately sized fittings or incorrect adjustments, thus necessitating costly subsequent changes. Final adjustments should be made by the gas supplier.

6. RATINGS AND CAPACITIES OF HEATER. Equipment should be selected with adequate output capacity to compensate for hourly heat loss of the space to be heated plus a minimum pick-up factor of 10 per cent for coal and gas-fired equipment and 25 per cent for oil-fired equipment.

In addition to the pick-up factor used to select coal heater size, an arbitrary coal correction factor of 5 per cent for each 500 Btu (or fraction) less than 13,000 may be applied; this coal factor should be applied to the sum of the heat loss plus the pick-up.

Example for the selection of coal heater:

a.	Heat Loss in Dwelling	31250 Btu
b.	Pick-up (factor - 10%)	3125 Btu
c.	Total (heat loss plus pick-up)	34375 Btu
d.	Coal Correction - 0.15 x 34,375 (Assume 11,700 Btu Coal)	5155 Btu
e.	Indicated Minimum Required Output (Nearest larger standard size should be selected)	39530 Btu

Since oil equipment is also rated on an output basis, the method used in figuring the required size should be the same as recommended above for the coal heater, <u>except</u> that the pick-up factor should be 25 per cent.

Of interest in the selection of equipment burning oil distillates is the use of catalytically cracked oil. This type of fuel, so classified by reason of its distillation process and resulting component structure has caused smoking under high-fire burner operation with evident loss in efficiency. Oil input will obviously have to be increased, and chimney sizes checked to produce the proper draft for increased oil supply. Flow of oil in excess of that which can be properly burned with the available draft will cause smoking and an accumulation of soot.

Contrary to coal or oil, gas equipment is rated on the basis of Btu per hour input. American Gas Association requirements specify generally, that space heaters, in the classification discussed here, having input ratings in excess of 20,000 Btu per hour shall have a heating rating efficiency of not less than 70 per cent based upon the total heat value of the gas, and that such equipment having input ratings of 20,000 Btu per hour or less shall have an efficiency of not less than 65 per cent These efficiencies should be used in selecting the required space heater.

Example for the selection of gas equipment:

A.	Heat Loss in Dwellings	31,250 Btu
b.	Pick-up (factor 10%)	3,125 Btu
c.	Total (heat loss plus pick-up)	34,375 Btu
d.	Input to equipment - 34,375 ÷ 70% (Nearest larger standard size heater should be selected).	49,100 Btu

7. CONTROLS. The controls referred to below, except temperature controls, are required by the respective standards under which the equipment is manufactured and tested.

For the coal-fired heater, the required automatic draft regulator (installed at the heater smoke pipe outlet or in the smoke pipe not over 24 inches away from elbow at heater smoke outlet) is set to limit the coal burning rate to the maximum rated output of the heater. The draft regulator would not be necessary where the heater is equipped with a thermostatic device integral with the heater to limit maximum fuel burning rate. The draft regulator or the integral thermostatic device will be of little value if means are not provided on the heater to regulate the supply of primary and secondary air. Also, all doors should fit at least paper tight. Excess air drawn into the heater through leaks can be so large as to reduce heater efficiency to 40 per cent or lower. A choke damper with ample opening for passage of gases when in a closed position, and set in the smoke pipe between the heater outlet and the draft regulator will limit the burning rate when fire is banked.

For oil-fired space heaters, an even supply of fuel to the burner is maintained through a constant level valve or a "barometric feed". Either type should be arranged to preclude the further supply of oil to heater upon the oil reaching a predetermined level in the burner. The former type control is of the float and trip type and is used exclusively where the heater is piped to fuel tank located away from the heater. The barometric feed operates on the same principle as the inverted water bottle on a cooler. The required automatic draft regulator (installed as indicated above for the coal heater) coordinates the air supplied with the fuel burning rate.

The mechanical draft fan has not been used to any appreciable extent in oil gravity circulating equipment. Where such device is employed, the fan is directly connected to an electric motor and securely attached to the heating equipment. The device is arranged to supply sufficient air to support combustion.

Two items important for successful and safe operation of oil equipment are: (1) a level burner and level control valve and (2) danger in relighting a hot burner. Level equipment is assurance for correct oil flow and, other things being equal, proper combustion. Oil flowing into a hot burner will result in immediate vaporization, filling the combustion chamber with oil vapor and forming a possible explosive mixture. It is essential to wait until the burner pot has cooled before relighting.

For gas equipment, lighting is generally done by a pilot burner which is usually fitted with an automatic safety feature arranged to shut off the supply of gas to the main burner in the event of flame failure. Where liquefied petroleum gas is used, the safety feature must also include automatic means to shut off the supply of gas to the pilot burner, since this type of gas in a raw state is heavier than air and may not dissipate upward through the flue. Gas valves, especially those designed with a seat and disc, must have tight fit. Foreign material (often almost imperceptable) collecting on the disc will prevent tight closing and permit gas to pass through valve when supposedly in a closed position. This is particularly important when burning liquefied petroleum gas because this gas will seek the lowest point and settle in the venturi throat of the burner. The gas will ignite from the heat generated by the pilot flame or may be ignited as a result of the heat contained in the casting, and continue to burn near the air inlet thus creating a potential operating hazard.

The pilot burner with safety feature or features is optional (but definitely advantageous) in manually operated burners, but is required with automatically operated equipment. A draft hood to prevent back draft from entering appliance and prevent excessive draft is required to be placed in the flue pipe at the heater outlet. The draft hood sometimes is constructed integrally with the equipment.

Another method of automatic control of the gas heater can be accomplished by a self-contained thermostatic device (actuated by room temperature) installed in the gas line near the equipment where it will not be effected by heat radiated from the heater. Another method for controlling automatic operation of the heater is by a wall mounted room-temperature-actuated thermostat. Although the latter method could be more effective as a control medium, the added cost of the incidental items involved in this control method may not warrant its consideration.

Strict supervision over consumption may be secured by a hand or electrically wound timing mechanism controlling a group of heaters. The timing mechanism, irrespective of whether each heater is individually controlled automatically, would serve the purpose of shutting off the gas supply to the equipment after a predetermined period of operation (as originally set on the timber).

PLUMBING, HEATING AND VENTILATION

PART II - ROOM HEATERS

1. INTRODUCTION. The room heater is a self-contained, free standing, nonrecessed air heating appliance intended, for purposes of discussion here, to heat more than one room. Concealed within a steel enameled jacket to induce convection, it has become a useful piece of heating equipment in public low-rent housing. Nevertheless, this method of heating has its limitations. Unlike the radiator or air outlet set in each room and sized to compensate for the room heat loss, the room heater cannot be used with satisfaction where normal January temperatures are below 35°- 40°F.

The cost of fuel is obviously the governing factor when selecting the "room heater" method of heating, since the cost of the equipment does not vary materially, and the inefficacies of heat distribution are much the same, whether the heater is coal, oil, or gas fired. Should gas fuel be the most economical, the problem of selection would be resolved quickly. Should the reverse be true, and coal or oil be the most economical fuel, the problem of selection becomes somewhat more complex. Then the potentials favoring gas such as ease in handling should be balanced against: (a) the higher gas cost and (b) certain tangible factors adverse to coal or oil including storage, handling, and firing, plus probable more frequent painting of the dwelling unit.

The essential points to consider in the selection of the room heater are: (a) local climatic limitations upon its use, (b) proper coordination of dwelling unit planning with this type of equipment, (c) use of effective building insulation especially in the right location, (d) selection of the proper and most efficient types and design of heaters and their correct adaptation to the fuel to be used, (e) selection of the proper capacities, and (f) correct installation.

2. GENERAL TYPES OF ROOM HEATERS. Heaters adaptable to low-rent housing can be more specifically classified as the circulator and combined circulator and radiant types. The circulator delivers its heat principally by convection air currents. The combined circulator and radiant type delivers its heat by both convection air currents and radiation. The latter type appears exclusive to gas-firing, and the radiant feature may include heat-reflecting refractory elements which are protected across the front with a guard grille or rails to harmonize with the heater construction. Electric motor-operated fans have been integrally added to the heaters to assist in more effective air circulation, but there is little evidence that the increased effectiveness is commensurate with the extra initial and operating and maintenance costs.

Coal types are designed for surface (front) firing, or (on a smaller scale)

NOTE: This Part supersedes PART II of Bulletin No. LR-7, dated March 24, 1950. It has been revised throughout.

magazine (top) feeding, the latter holding fuel charges for about a day's operation under normal conditions. Either bituminous or anthracite burning types may be obtained.

Oil-fired types are most usually fitted with the "pot" burner, operating on the "vaporizing" principal of burning the oil, contrary to the "mechanical atomization" type which has not been adopted for use with the average size room heater. Kerosene or the light fuel distillates (not over No. 1) are recommended.

Gas-fired types are generally fitted with burners of the multiple port or ribbon type operating on the Bunsen principle; burners are made suitable for natural, manufactured, or liquified petroleum gas.

3. COORDINATION OF HEATER LOCATION WITH DWELLING UNIT PLAN. Correct placement of the room heater is important to achieve more uniform air distribution. The intention is to provide the most direct path for air movement from the heater. Since the effective range of heat distribution is about 15-18 feet, dwelling units (four bedrooms and larger on one floor) demand an additional heater for added comfort in the bedroom areas. This condition can be met simply when gas is the fuel selection. The heater most usually used is the recessed wall type and is set recessed (as the name implies) so the heater front is approximately flush with the partition; it is located in the hallway near the end bedrooms. The problem becomes more complicated when coal or oil is the selected fuel; here it may be necessary to use the forced warm air system. In fact, forced warm air under similar circumstances could be used with gas fuels. The same method can be applied in two-story units of the same size, by placing the auxiliary gas heater in the second floor hallway, or as outlined for the one-story units, use forced warm air for all fuels. Since the units are slab-on-ground type, perimeter insulation is important and necessary to help keep the floor warmer; so is ceiling insulation obvious.

4. PLACEMENT TO AVOID FIRE HAZARD. In locating the heater, precaution must be taken to avoid fire hazard. Safe distances from combustible construction, at which such equipment can be placed to avoid risk, have been established by the National Board of Fire Underwriters, listed in its National Building Code. The recommendations in this Code (or the requirements of the Local Codes if more restrictive) should be followed. Combustible construction is defined as that containing wood, whether or not protected by plaster or gypsum board. Noncombustible stoveboards set under coal or oil-fired heaters are a recommended precaution. Requirements for gas heater locations have also been established by the American Gas Association in its Directory of Approved Appliances.

5. STANDARDS FOR ROOM HEATERS. Venting is recommended whether or not required by code. The advantages, as to safety and efficiency afforded by conformance to the requirements of organizations such as the Underwriters' Laboratories or the American Gas Association, where applicable, should be encouraged. The Commercial Standards promulgated by the Commodity Standards Division of the U. S. Department of Commerce are the requirements agreed upon

by mutual consent of those concerned and may embody the requirements of the Underwriters' Laboratories or the American Gas Association plus assurance of listed capacity output.

6. RATINGS AND CAPACITIES OF HEATERS. Heaters should be selected with adequate output capacity to compensate for hourly heat loss of the space to be heated plus a minimum pickup factor of 10 percent.

In addition to the pickup factor used to select the coal heater size, an arbitrary coal correction factor of 5 percent for each 500 Btu per pound (or fraction) less than 13,000 Btu may be applied; this coal factor should be applied to the sum of the heat loss plus the pickup

Contrary to coal or oil, gas equipment is rated on the basis of Btu per hour input. American Gas Association requirements indicate that room heaters, having input ratings in excess of 20,000 Btu per hour shall have a rating efficiency of not less than 70 percent based upon the total heat value of the gas, and that such equipment having input ratings of 20,000 Btu per hour or less shall have an efficiency of not less than 65 percent. These efficiencies should be used in selecting the required heater size.

7. CONTROLS. The controls referred to below, except temperature controls, are required by the respective standards under which the equipment is manufactured and tested.

For the coal-fired heater, the required automatic draft regulator is set to limit the coal burning rate to the maximum rated output of the heater. A choke damper with ample opening for passage of gases when in a closed position and set in the smoke pipe between the heater outlet and the draft regulator will limit the burning rate when fire is banked.

For the oil-fired heater, an even supply of fuel to the burner is maintained through a constant level valve or a "barometric feed." The former type control is of the float and trip type and is used exclusively where the heater is piped to fuel tank located away from the heater. The barometric feed operates on the same principle as the inverted water bottle on a cooler. The required automatic draft regulator (installed as indicated above for the coal heater) is intended to control the supply of air for proper fuel burning.

For the gas-fired heater, a thermostatic device to control the operation can be furnished as an integral part of the heater.

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PLUMBING, HEATING AND VENTILATION

PART III - TENANT-OPERATED HEATING SYSTEMS (STEAM, WATER, AIR), FUEL STORAGE AND CHIMNEYS

1. GENERAL. While there has been an increasing tendency to provide heating and hot water for low-rent public housing projects from group or central plants, there will continue to be a large percentage of projects where the consideration of all factors will suggest or necessitate the use of individual tenant-operated heating systems. This release does not include a discussion of these factors but is directed to cases where, for sound and economic reasons, individual heating systems should be used. However, the system as designed and installed should, in each case, be consistant with and reflect the line of reasoning that lead to its choice. Thus the designer should be familiar with the utility analysis and all other data on which the determination was based.

The term "tenant-operated heating systems", as used herein, includes all types of steam, water and air heating systems but excludes space heaters which, because of their particular variations from the principles of other methods of heating, are the subject of a separate, forthcoming release in this Bulletin.

Certain new developments in hot water, steam and air distribution such as baseboard radiation or panels (radiant heating) are mentioned briefly here; they will be discussed in some detail later in this series.

The information contained herein reflects experience gained through the operation of many public low-rent housing projects. It is believed that engineers will find it of assistance in selecting equipment and specifying the manner of installation considered best in each specific case, and which will result in the lowest operating and maintenance expense.

2. COORDINATION OF SYSTEM WITH BUILDING DESIGN. Variations in the building type, the particular layout and the details of construction will affect the arrangement used to distribute the heat to each room or space, i.e. by hot water, steam or air-by gravity or under pressure. The nature and location of the heat source will be related to the decision as to slab-on-ground, crawl-space, or basement construction. The location of radiators, registers and grilles, and the extent and method of concealment of ducts will be affected further by such consideration as: whether roofs are flat or pitched; the location of door and window openings; and upon the method of constructing the floors and partitions. All of these factors should be weighed in reaching a decision as to the type and details of the individual tenant-operated heating system. Likewise, the heating engineer should discuss with the architect the feasibility of making minor adjustments in the plan and details of construction where such adjustments would aid in bettering the system

3. SYSTEM TYPES AND THEIR EVALUATIONS. Following is a list of system types and generalized statements as to the advantages and disadvantages of each:

a. Gravity Warm Air Systems either with supply and return ducts, or the "pipeless" type should be installed only where the furnace can be located a sufficient distance below the first floor registers to produce an adequate head for air circulation. Floor furnaces can be installed where crawl spaces are of sufficient depth.

Advantages: quick heating; no danger of freezing; properly located registers and grilles will not interfere with furniture placement or window decoration; generally lower in first cost than other systems mentioned here; no power consumption.

Disadvantages: supply and return ducts require considerable grade and restrict storage space when located in basement; systems may be thrown out of balance when high winds prevail; crawl spaces and basement must be dry and properly drained to prevent rusting of furnace casing and duct work; high temperatures, dangerous to young children crawling on the floor, will exist at grilles of floor furnaces.

b. Forced Warm Air Systems are generally satisfactory and can be economically installed where basement or crawl spaces are provided.

Advantages: generally lower in first cost than hot water and steam systems; quick heating; no danger of freezing; registers and grilles will not interfere with furniture placement or window decoration; low supply registers have been found to maintain low temperature gradients between floor and ceiling; provides even heat distribution if properly balanced.

Disadvantages: exposed duct work is unsightly; may require special framing for concealment; high power consumption; filters require periodic cleaning and replacement; cold drafts will be present if return grilles are not installed at points of greatest infiltration; discoloration of ceilings if registers are set high; expense for motor repairs, belt adjustments, and replacements.

c. Gravity Hot Water Systems either open or closed type is satisfactory where return piping can be installed in crawl spaces or basement; or along walls above the floor if first floor slab is on the ground.

Advantages: generally more economical to operate than warm air or steam as water temperature can be regulated to produce a moderate and steady flow of heat; low, well placed radiators have been found to maintain low temperature gradients between floor and ceiling; piping can be concealed in frame construction and carefully located exposed piping need not be objectionable.

Disadvantages: radiators interfere with furniture placement and window decoration; and tend to discolor wall; possibility of freezing; heat lag may be unsatisfactory where rapid changes in temperature occur.

d. Forced Hot Water Systems have not been used in low-rent housing, but have been developed to a point where they might be considered. These systems can be installed in any dwelling with or without crawl spaces or basements. The initial cost will be higher than the other types of tenant-operated systems.

Advantages: generally the same as other hot water systems; smaller piping and radiators may be used; quicker response to temperature changes.

Disadvantages: higher initial cost; higher power consumption; increase in project maintenance costs; cannot be satisfactorily adapted to hand fired installations unless special controls are installed.

e. Steam Systems either one or two pipe, are generally lower in first cost than hot water but can be installed only where the vertical distance between the boiler water line and the lowest radiator will produce sufficient head to return the condensate to the boiler by gravity. Automatic devices, such as pumps or traps, are not appropriate for individual tenant-operated plants.

Advantages: generally lower in first cost than hot water systems; has quick pick-up; piping can be concealed in frame construction; exposed piping is not too objectionable.

Disadvantages: more expensive to operate as it is difficult to accurately regulate room temperatures under varying outside temperatures, due to the lack of controls for this type of system; difficult to balance system; air valves require periodic replacements.

4. SYSTEM DESIGN AND INSTALLATION. When the system has been determined its design should be the responsibility of an engineer technically qualified and capable of solving any problem encountered. The system should be adapted to the dwelling without major structural changes. The minimum requirements of the American Society of Heating and Ventilating Engineers should be used as the design basis of the system. Equipment specified and installed should conform to the applicable requirements of the National Board of Fire Underwriters, and other applicable codes.

a. Boilers and Furnaces using solid fuel should be located near a rear exterior door to eliminate bringing fuel and ashes through the dwelling space. When solid or liquid fuels are used, the boilers or furnaces should never be located above the first floor, since carrying fuel to the upper floors is undesirable.

b. Domestic Water should not be heated by the same boiler or furnace that is used for space heating; because although domestic hot water will be required in varying amounts at different times each day of the year, space heating will be required during the winter months only. With additional controls it is possible to obtain adequate domestic hot water with automatically fired steam and water heating boilers. This cannot be accomplished with warm air furnaces or hand fired coal boilers.

c. Maintenance. Adequate working space must be provided around all boilers and furnaces for repairs.

d. Gravity Warm Air Systems. Duct work, if used, may be sheet steel or aluminum, with all joints air tight. Supply registers and return grilles should be located where furniture and carpets are not likely to be placed. Supply registers should have hand dampers for individual room control by the tenant. Registers and grilles may be stamped or cast, steel or iron. Return air grilles should be located near the point of greatest outside air infiltration. A variation of the typical floor furnace with which the registers are set in walls, are preferable as the high register temperature will be away from the floor areas.

e. Forced Warm Air Systems. Motors and fans should be specified with bearings which require lubrication not oftener than once a year. Blower control should be factory set to discharge moderately heated air for extended periods, instead of higher temperature air for short periods. Control should be such as to prevent the use of the fan by the tenant for summer cooling.

f. Gravity Hot Water Systems (Open or Closed). Piping should be black steel standard weight with black cast iron threaded fittings; boiler should be of the insulated jacketed type, with relief valve, make-up water connection, altitude gauge and thermometer. Radiators may be either standing cast iron or convector with enclosures; (on smaller sizes the convectors may prove more expensive when the enclosure cost is considered, also the convector must be cleaned periodically, resulting in maintenance cost). Piping exposed to freezing temperature must be insulated and frost-proofed. Exposed horizontal piping under painted ceilings should be insulated to prevent discoloring the ceilings; drain valves should be installed at all low points; hand operated valves should be included on connection to each radiator for tenant-control of each room; balancing fitting or orifice should be installed on each radiator and adjusted to provide even heat distribution. Expansion tank should be steel. Tanks for open systems should be installed in the attic space above the highest point in the system, with open vent and overflow. Tanks for closed systems should be installed in boiler room with a relief valve set to open at approximately 15 P.S.I. Automatic feed water valves are not essential for tenant-operated systems. Piping and expansion tank, in attic spaces, should be insulated and frost-proofed.

g. Forced Hot Water System. Materials should be the same as for a gravity hot water system except that radiators should be sized for higher water temperature; and piping sized for higher velocity.

h. Steam Systems. Material should be the same as for hot water system except that boilers will be equipped with water column and pressure gage in lieu of thermometer and altitude gage. Balancing fittings or orifices will not be required. Air valves should be installed on each radiator and at end of steam main. Boiler should have safety valve and water column. Shut-off valve on main steam supply at boiler should be omitted.

5. CONTROLS. Controls should be ruggedly constructed and simple in design. They should be factory set with adjustments (if required) to be made by the management only. Control devices should be kept to the minimum which will provide adequate comfort. Controls should be the product of a reliable manufacturer, experienced in temperature control. Hand fired coal equipment should be regulated by means of a room thermostat operating the dampers on the boiler or furnaces. For oil and gas fired equipment, the firing rate should be regulated by means of a room thermostat operating the firing device. Controls should be equipped with springs or other devices that will shut down the firing mechanism in the event of electric current failure. Approved safety devices such as relief valves, high limit and combustion etc., must be included as required for each system.

6. FUEL STORAGE. The utility analysis which indicates a tenant-operated plant to be best suited for the project, also determines the type of fuel. If it is coal or oil, ample and satisfactory storage facilities must be provided. If it is gas, then particular attention is directed to another release entitled "Safety Consideration in the Installation of Gas Piping".

Storage of coal or oil will affect the site and dwelling plan, as fuel delivery will be influenced by the location of roads and walks. Coal burning equipment should be located in relation to the storage bin to eliminate carrying coal and ashes through finished rooms.

Coal should be stored in bins sized to hold at least one and a half tons which will allow the tenants to purchase at least one ton at a time, before the supply is exhausted. Prefabricated concrete bins have proven satisfactory and durable. Covers should be of light weight construction, with means for locking. Coal should not be stored inside the dwelling as snow and rain brought in with the coal will increase the moisture content of the dwelling.

Oil should be stored in tanks bearing the Underwriters label, and may be set inside the building if suitable and safe space is available; if not, it should be set outside above grade on a stand firmly braced. Vent, whether from inside or outside tanks, should terminate not less than eight feet above grade on the outside of the building. Fill-pipe for inside tanks should be extended to the outside with a fill-plug. Tanks should be sized to hold not less than ten days supply based on the maximum daily use; fuel delivery may be such as to warrant larger tanks. Tanks exposed to the weather should be properly coated for protection.

7. CHIMNEYS. Unless the chimney is properly designed and constructed to serve the selected equipment, the heating system will not function properly, regardless of how well the system may be designed. Recent tests conducted

by the National Bureau of Standards on the "Performance of Masonry Chimneys for Houses" has been published as Technical Paper Number 13 by the Housing and Home Finance Agency, Washington, D.C. It is recommended that this information be used as the basis of the chimney design. The tests indicate that the flue size should be based on the volume of flue gases; that lining be included for all chimneys, continuous from the breeching opening to the chimney tops; and that round flues are more effective than rectangular flues of larger areas. The top of the chimney should extend not less than two feet above the highest point of a pitched roof. When the roof is the equivalent of two stories above the heater room floor, ample height will be obtained. When the roof is only one story above the heater room it will be necessary to extend the chimney to achieve adequate draft. Flue lining and mortar should be such as to withstand the action of flue gases, and mortar must be finished smooth and flush with the interior face of the lining. The liner and masonry should be constructed with all joints air tight. Clean-out doors should be located at the base of each chimney.

Breeching from chimney to heater or boiler should be as direct and short as possible. Control devices should be set to stabilize the draft during all ranges of operation.

GPO DSO 25-178-B

PLUMBING, HEATING AND VENTILATION

PART III - TENANT-OPERATED HEATING PLANTS (AIR, WATER, STEAM), FUEL STORAGE AND CHIMNEYS

1. GENERAL. While there has been an increasing tendency to provide heating and domestic hot water for low-rent public housing projects from project-operated plants, there will continue to be a large percentage of projects where the consideration of all factors will suggest or necessitate the use of individual tenant-operated heating plants. This release is directed to cases where, for sound and economic reasons, individual heating systems should be used. Thus the designer should be familiar with the utility analysis and all other data on which the determination was based.

The term "tenant-operated heating plants," includes air, water, and steam heating systems, but excludes room heaters which, because of their particular variations from the principles of other methods of heating, are the subject of a separate release in this Bulletin. Newer developments in hot water, steam, and air distribution such as floor line, perimeter, and panel heating will be discussed later in this series.

2. COORDINATION OF SYSTEM WITH BUILDING DESIGN. The building type, the architectural layout, and the details of construction can influence the medium used to distribute the heat to each room; i.e., by air, water, or steam. These factors should be weighed in selecting the type and details of the heating system. The heating engineer should discuss with the architect the feasibility of making minor adjustments in the plan and details of construction where such adjustments would aid in bettering the heating system. There must always be an adequate supply of air to the space where the heat source is located to assure proper combustion of fuel.

3. SYSTEM TYPES AND THEIR EVALUATIONS. Following is a list of system types, and a recitation of the advantages and disadvantages of each:

a. Gravity Warm Air Systems should be installed only where the furnace can be located a sufficient distance below the first floor registers to produce an adequate head for air circulation. Circulation of air is induced by the temperature head differential between supply and return air.

Advantages: quick heating; no danger of freezing heating medium; properly located registers and grilles will not interfere with furniture placement or window decoration; generally lower in first cost than other systems mentioned here; no power consumption.

Disadvantages: exposed duct work in habitable areas is unsightly; may require special structural framing for concealment; furnace and greater network of ductwork requiring large sizes restrict storage space in basement;

NOTE: This Part supersedes Part III of Bulletin No. LR-7, dated March 24, 1950. It has been revised throughout.

system is difficult to balance for equitable air distribution to rooms. Cold drafts will be present if return grilles are not installed at points of greatest air infiltration; discoloration of walls if air temperature at supply registers exceeds about 135° F., particularly with coal and oil fuels. Coal fuels without adequate controls can cause excessive supply air temperatures.

b. Forced Warm Air Systems can be economically installed, even with slab-on-ground construction. Circulation of air is accomplished by a blower, sized consistent with the total air to be circulated, and the total pressure drop over the entire system.

Advantages: generally lower in first cost than hot water and steam systems; quick heating; no danger of freezing heating medium, properly located registers and grilles will not interfere with furniture placement or window decoration; low supply registers have been found to maintain low temperature gradients between floor and ceiling; provides even heat distribution if properly balanced and if arranged to operate on infrequent cycling of blower.

Disadvantages: exposed ductwork is unsightly; may require special structural framing for concealment; power consumption; filters require periodic cleaning and replacement; cold drafts will be present if return grilles are not installed at points of greatest air infiltration; discoloration of walls if air supply temperature at supply registers exceeds about 135° F., particularly with coal and oil fuels; expense for motor repairs and belt adjustments. Coal fuels without adequate controls can cause excessive supply air temperatures.

c. Gravity Hot Water Systems (either open or closed type) are satisfactory where return piping can be installed in crawl space or basement or along walls above the floor if first floor slab is on the ground. Circulation of water is induced by the temperature head differential between supply and return water.

Advantages: generally more economical to operate than warm air or steam, since water temperature can be regulated to produce a moderate and steady flow of heat; low, well placed radiators have been found to maintain low temperature gradients between floor and ceiling; piping may be concealed in frame construction and carefully located exposed piping need not be objectionable.

Disadvantages: radiators can interfere with furniture placement or window decoration; possibility of freezing heating medium; heat lag may be an unsatisfactory condition where rapid changes in outside temperature occur.

d. Forced Hot Water Systems have seldom been used in tenant-plants because of high cost. These systems can be installed in any dwelling with or without crawl space or basement. Circulation of water is accomplished by a pump, sized consistent with the radiation load, pressure head on the system, and designed water temperature drop across the supply and return. The initial cost will be higher than the other types of tenant-operated systems.

Advantages: generally the same as gravity hot water systems; smaller piping and radiators are used; quicker response to outside temperature changes than the gravity system.

Disadvantages: higher initial cost; electric power consumption; increase in project maintenance costs; cannot be satisfactorily adapted to coal hand fired installations unless special controls are installed.

e. Steam Systems are generally lower in first cost than hot water, but can be installed only where the vertical distance between the boiler water line and the lowest radiator will produce sufficient head to return the condensate to the boiler by gravity. Automatic devices, such as pumps or traps, are not appropriate for tenant-operated plants.

Advantages: generally lower in first cost than hot water systems; has quick pick-up; piping can be concealed in frame construction; exposed piping is not too objectionable.

Disadvantages: more expensive to operate than hot water; it is difficult to accurately regulate room temperatures under varying outside temperatures, due to the ineffective controls for this type of system; difficult to balance system; air valves require periodic replacements. Radiators can interfere with furniture placement or window decoration.

4. SYSTEM DESIGN AND INSTALLATION. The system should be adapted to the dwelling. The recommendations of the American Society of Heating, Refrigerating and Air-Conditioning Engineers should be used as the design basis of the system. For air systems, the recommendations of the National Warm Air Heating and Air-Conditioning Association may be followed. Equipment specified and installed should conform to the applicable requirements of the National Board of Fire Underwriters and other applicable requirements or local codes.

a. Air Furnaces and Boilers using coal fuels should be located near a rear exterior door to eliminate carrying fuel and ashes through the dwelling space. When coal or oil fuels are used, the furnaces or boilers should never be located above the first floor, since carrying or feeding fuel to the upper floors is undesirable.

b. Maintenance. Adequate working space must be provided around all furnaces and boilers for repairs.

5. CONTROLS. Controls should be of good quality, but simple in design. They should be factory set with adjustments (if required) to be made by the management only. Control devices should be kept to the minimum consistent with comfort. Controls should be the product of a reliable manufacturer,

experienced in temperature control. Hand fired coal equipment should be regulated by means of a room thermostat operating the automatic damper on the furnace or boiler. In gas or oil-fired equipment (except for that noted below in forced hot water systems) the firing mechanism should be controlled by a room thermostat superimposed (at the warm air furnace or boiler) by a limiting air temperature or water temperature or pressure device (dependent whether the heating medium is air, water, or steam). Operation of the blower in forced air systems should be actuated by an air temperature control. However, in forced hot water systems the room thermostat should control the operation of the water circulating pump, and the water temperature limiting device should actuate the firing mechanism.

6. FUEL STORAGE. The utility analysis which indicates a tenant-operated plant to be the more economically suited for the project also determines the type of fuel. If it is coal or oil, ample and satisfactory storage facilities must be provided. If it is liquified petroleum gas, then particular attention is directed to another release entitled "SAFETY CONSIDERATIONS IN THE INSTALLATION OF GAS PIPING."

Storage of coal or oil will affect the site and dwelling plan, as fuel delivery will be influenced by the location of roads and walks. Coal burning equipment should be located proximate to the storage bin to eliminate carrying coal and ashes through finished rooms as previously mentioned.

Coal should be stored in outside bins sized to hold at least one and a quarter tons, allowing the tenants to purchase at least one ton at a time, before the supply is exhausted. Prefabricated concrete bins have proven satisfactory and durable. Covers should be of lightweight construction, with means for locking.

Oil should be stored in tanks constructed to conform to the requirements of the Underwriters' Laboratories and the oil system should comply with the Underwriters' Laboratories and local regulations. Tanks should be sized to hold not less than a 2-3 weeks supply, based on the maximum daily use in coldest weather.

7. CHIMNEYS. Unless the chimney is properly sized and constructed to serve the selected equipment, the heating system will not function properly, regardless of how well the system may be designed. Tests conducted by the National Bureau of Standards on the "Performance of Masonry Chimneys for Houses" have been published as Technical Paper Number 13 by the Housing and Home Finance Agency, Washington, D.C. This information should be used as the basis of the chimney design for masonry chimneys. The tests indicate that the flue size should be based on the volume of flue gases; that lining should be included for all chimneys, continuous from the breeching opening to the chimney tops; and that round flues are more effective than rectangular flues of larger areas. Clean-out doors should be located at the base of each chimney.

Prefabricated chimneys are available and are constructed to suit the type of fuel. They should be selected on such basis and to conform at least to the requirements of the Underwriters' Laboratories.

The top of the chimney should extend not less than two feet above the highest point of a pitched roof. When the roof is the equivalent of two stories above the heater room floor, ample height will be obtained. When the roof is only one story above the heater room it may be necessary to extend the chimney to achieve adequate draft specially for coal or oil fuels.

Breeching from chimney to heater or boiler should be as direct and short as possible. Control devices in the breeching for coal or oil-fired installations should be set to stabilize the draft during all ranges of operation.

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PLUMBING, HEATING AND VENTILATION

PART IV - PLUMBING FIXTURES FOR DWELLING UNITS AND COMMUNITY FACILITIES

1. INTRODUCTION. To assure the provision of adequate sanitary facilities and to meet accepted standards of health, each dwelling erected in urban communities is required (by the PHA Minimum Physical Standards) to have plumbing facilities for toilets, bathing, food preparation, and laundry work. In addition, community facilities erected in conjunction with groups of dwelling units will have plumbing facilities designed for public usage.

Advances made by manufacturers, during the past half century, in the design of fixtures and improvements in methods of installation have been outstanding. But, in spite of this fact, it cannot be taken for granted that all fixtures are completely safe as to their sanitary features, or are equally desirable from the user's point of view. All types should be given critical examination as to basic economy, both initial and in operation over their expectant life.

Another factor that should be seriously considered in choosing plumbing fixtures is the desirability of selecting fixtures and trim that tend to minimize the amount of water to be used. Such features as combination spouts and small sized tanks will definitely affect appreciable savings in water consumption. With the general dropping of water-table levels throughout the country, all methods that will help to conserve the Nation's water supply should be given thoughtful consideration.

The following discussion is offered as an aid in selecting fixtures which will prove satisfactory in all respects and avoiding serious errors which might result from inadequate consideration.

2. FIXTURE TRIM. All fixture trim specified for use in a project should be standardized as completely as possible so that similar fixtures will be provided with identical trim throughout. The fittings chosen should be a common easily procurable type, of plain design and appearance, for which replacement parts will be readily obtainable. Faucets should be compression type with replaceable seats. Mechanically operated wastes or drains, or special features of any kind such as hose sprays, should be avoided. Brass trim, chromium plated over nickel, has the best appearance and gives the longest service. Iron faucets or spouts should never be used, as corrosion will color the water.

3. WATER CLOSETS are manufactured of vitreous china (since experiments by manufacturers in the use of other materials have been unsuccessful). The principal types of water closet bowls are:

a. The siphon jet which operates by creating a siphon action in the trap with a jet at the bottom of the trap furnishing the initial impetus to the siphonic action.

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b. The wash-down with a jet which functions by filling the closet bowl to a height sufficient to fill the rear leg of the trap and start siphon action which empties the bowl.

c. The blow-out which is flushed by a heavy discharge of water at relatively high pressure.

d. The reverse-trap which is a wash-down bowl with the trap reversed.

In selecting water closets for dwelling units it is advisable to give due attention to the following:

a. The contents of the bowl should discharge by siphonic action and the seal should be maintained by refilling action of the tank or flush valve.

b. The flushing rim should be constructed to flush the entire interior surface of the bowl.

c. The siphon "jet" should be visible and accessible and should be placed on a line with or below the bottom of the trap seal.

Types most commonly used in low-rent dwelling units are the moderately priced siphon jet and the wash-down or reverse trap with jet action, fitted either with a low wall-hung tank or a close-coupled tank. The full siphon jet or other better type bowls offer a number of advantages lacking in the lower priced bowls, but their use is not a real economy nor is it warranted. The close-coupled tank is somewhat easier to install than the wall-hung tank because hangers are not required, and additional construction is not required to carry the weight of the tank and its water contents. However, because the close-coupled tank rests on the closet bowl and is free from any wall support, it has been found to crack at the bottom where it connects with the spud. While in some cases this has been due to poor workmanship or defective design, the trouble is frequently due to external pressure exerted against the tank, the spud constituting a fulcrum with the tank acting as a lever. One way to overcome this situation is to provide a close fitting cleat on the wall back of the tank near the top to prevent leverage strain. Because the wall-hung tank is independently supported and presents no possibility of this type of breakage, its use is preferable.

A vacuum breaker is a very essential requirement for all types of water closet tank valves or flush valves. Some manufacturers of tanks, in order to reduce costs, provide an "air gap" in the supply valve by eliminating the hush tube or submerged supply pipe. Such an arrangement tends to increase noise within the tank and is not a positive safeguard against back-siphonage and, therefore, should not be used.

The working parts of the tank must be of good quality since otherwise this part of the fixture is likely to be out of order quite often and, thus create a considerable and continuing maintenance expense. Any difference in maintenance costs between the competitive type flush valve and a tank with good quality working parts is slight. The cost of installation, however, is definitely in favor of the tank as long as a 1 or 1-1/4 inch supply line is essential for the satisfactory operation of the flush valve. Some managers may favor the installation of flush valves from the standpoint of maintenance expense but the additional initial cost does not warrant their use, especially when the saving in maintenance is admittedly slight.

The blow-out water closet bowl is suitable for use in community facility toilets where the noise caused by its operation would not be considered objectionable. This type of bowl requires a flush valve because of the water pressure necessary for flushing action. Since a tank in a public toilet is not desirable because of possible vandalism or tampering with the tank mechanism, the use of the flush valve and blow-out bowl becomes warranted.

4. WATER CLOSET SEATS should be of some material which does not absorb moisture, is a poor conductor of heat, can be easily cleaned, and appears as one piece without surface joints or cracks. Seats made of varnished hardwood, riveted, bolted or glued together are the lowest in cost, but do not fulfill the requirements for durability and cleanliness.

Seats of spray-painted wood, sheet-covered wood or composition, or solid plastic are generally available. The spray-painted type are low in initial cost, but the paint tends to wear or flake off, requiring replacement of the seat or repainting. The plastic sheet that is wrapped around the more desirable sheet-covered seat must be properly welded at the edges to prevent peeling and must be of proper thickness. A solid plastic seat should be substantially built, especially at the hinge connections.

A seat with extended back, secured to the bowl with hinged parts and a rod within a sleeve extending across the full length of the back, will provide the longest service. The cost will be only slightly higher than the cheaper type of seat secured to the bowl by two leaf hinges. In addition substantial cleats permanently attached near the front of the seat will serve to avoid breakage or distortion.

In dwelling units all seats should be provided with a cover; this is not only desirable for appearance but has definite practical value, such as serving as a seat and preventing articles from falling into the bowl.

Seats for water closets in community facilities should be the open-front type without cover, made of a durable material such as hard black rubber with or without a solid core.

5. URINALS may be required in the community facilities. Urinals are usually constructed of vitreous china and are wall-hung or floor supported. Because of its location in a public toilet, a urinal should be provided with a flush valve (rather than a flush tank). Whether valve or tank is used, a vacuum breaker should be provided with a flushing-rim type of urinal to guard against any possibility of back-flow into the water supply system. A strainer should be provided at the drain connection to prevent clogging of the outlet.

6. LAVATORIES are made in many different styles, sizes, and materials and with varied methods of support. The type best adapted for use is one that is low in initial cost, durable, and easy to keep clean. The most commonly used lavatories are made of enameled cast iron, enameled formed steel, or vitreous china. Contrary to some opinions, vitreous china lavatories will give service equal to enameled cast iron or formed steel, since breakage and marring can and does occur in all types. From the sanitary standpoint all of these materials are satisfactory.

In selecting a lavatory it is advisable to limit the size to the nominal 18" x 20" dimension with as large a bowl area as is available in that size. The bowl should be oval or D-shaped, with minimum obstructions on the slab or top. A back ledge type with low back fitted with 4 inch centerset combination compression faucets is the most satisfactory and the least cumbersome, and provides mixed water through a single short spout. Most permanent projects built before the war were fitted with separate hot and cold water faucets, which are not nearly as convenient as the more recently developed compact centerset combination which costs less than the separate faucets and permits tempering of the water through the spout. The air gap between the spout outlet and the over-flow rim of the lavatory should never be less than 1 inch. The back ledge or shelf, as an integral part of the lavatory, provides a convenient area for the temporary placing of brushes, combs, and various toilet articles.

The wall-hung lavatory is the most economical type from the standpoint of initial cost and occupying the minimum amount of space in a bathroom. However, experience has shown that it may be necessary to strengthen the supporting wall or partition so that it can carry the weight of the lavatory plus the additional loads that may be imposed by abnormal misuse, such as the strains imposed by a child who tries to lift itself to the top of the lavatory, or those caused by a person resting his weight on the outer edge of the fixture.

Rubber stoppers with heavy chain and chain stay have been found most satisfactory; pop-up wastes have been found to add considerably to maintenance expense since they are difficult to keep in good working order. The chain and chain stay should be of good quality since if they become defective, great demand is made on the maintenance staff.

Waste and supply connections should be made from the wall (rather than from the floor) to permit greater ease in cleaning the floor. In addition the waste, if installed at the floor, forms a siphonic leg with the possibility of self-siphonage of the trap seal. If the supply pipes connect to the wall at least 22 inches above the floor, chromium plating may be omitted, since these pipes are not readily seen at that height.

Enameled lavatories should be acid resisting. (It is expected that in the near future all manufacturers of cast iron fixtures will produce only this type of finish, as is now the case with almost all of the formed steel fixtures.)

7. BATHTUBS are required by the PHA Minimum Physical Standards. As a general rule tubs, either enameled cast iron or formed steel, are recessed, though occasionally corner tubs are used. Flat bottoms and straight sides diminish the possibility of accidents and a grab rail in the rim or built into the wall helps to prevent falls.

Shower compartments (in place of bathtubs) are ordinarily not desirable. Such a compartment in a dwelling may have some advantages but it does not meet the essential requirements of the average household. While showers installed in combination with the bathtubs have all the advantages of the separate fixtures, the increase in both initial installation cost and annual operating expense makes their use unwarranted in view of the limited funds available.

Attaching a hose with spray head to the bath nozzle has been found to be a common practice in a large number of dwelling units in public housing. This appendage is a definite violation of most plumbing codes and the recommendations of the U.S. Public Health Service, since the spray head, dropped into the bath water and acting as a submerged outlet may permit back siphonage and cause contamination of the water supply system of the entire building and possibly the community. To discourage this practice a smooth spout with a large opening (to which it will be difficult to attach a hose) should be provided.

A source of trouble with recessed or built-in tubs is caused by shrinkage in building materials and consequent settlement of the bathroom floor. This causes a separation above the edges of the tub at the wall, thus permitting water seepage, which becomes particularly aggravated when showers are installed, and causes maintenance trouble and expense. Where wood frame construction is used, it is advisable to install tub hangers in the wall to support the tub on the wall structure and, thus, prevent this separation.

The bathtub valves and nozzle should be of the built-in type or surface mounted. If built-in, they should be so designed that washer changes can be made readily from the surface of the wall. The valve should provide a full waterway for quick filling of the tub and the seats should be replaceable from the front. The fitting design should have a plain surface for economy and easy cleaning. When the supply outlets are not located in a wall or partition, the spout should be the goose neck type with the outlet end of the spout at least 1-1/2 inches higher than the overflow rim of the tub.

The connected waste and overflow with heavy chain and rubber stopper is the most economical and least troublesome in operation. Pop-up wastes should not be considered, as they are troublesome and costly.

8. KITCHEN SINK AND TRAY. The kitchen sink and tray that has the best appearance and is most desirable for practical use is the wall-hung ledge sink and tray with back, with a single adjustable enameled leg beneath the tray compartment. This sink is preferred over the flat rim type because no fabricated

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sink top will be required. If separate laundry trays are provided within the dwelling, a kitchen sink without a tray may be installed. Such a sink should be a wall-hung ledge type with back, provided with an integral drainboard on the left side. Sinks and sink-tray combinations should be acid resisting enameled cast iron or formed steel, 42 inches long.

Most codes permit the use of one trap for both the sink and the tray. However, in many public housing projects the use of improper fittings and improperly located traps has caused a backflow between the sink and tray. This can be avoided by the use of a tubing fitting, with the proper turn or sweep, at the point where both fixture drains connect near the inlet of the trap. If the trap is located under the sink and the waste from the tray is connected within the seal of the trap, there are two advantages; there is no backflow between the compartments, and odors are eliminated since circulation of air in the wastes connecting the compartments is prevented.

The sink and tray supply fitting should be a combination swing spout type since separate faucets are more costly and less desirable. Removable cup strainers in the waste outlet of the sink are usually provided since they facilitate the use of the sink for washing dishes or pots and pans. When this type of strainer is used, a secondary cross bar strainer should be permanently installed within the sink plug to prevent waste material from entering the waste pipe and causing stoppages. The drainboard over the tray should be porcelain-enameled steel for durability and clean appearance, and sufficiently light to be lifted easily. It should, of course, drain readily into the sink bowl.

9. LAUNDRY TRAYS. When laundry work is to be done in locations other than the kitchen, experience has shown that a double compartment laundry tray is essential. Such laundry trays are usually made of concrete, soapstone or alberene stone, supported on a galvanized angle iron frame. The trim should be rough plated, and should consist of a swing spout faucet and soap dish, a chain and rubber stopper, and a cross-bar drain plug. One trap and a twin waste serves both tray compartments. The method of grouping the trays in the project laundry rooms should depend on whether washing machines are to be used.

If water supply connections for washing machines are provided in the laundry room, it is essential that vacuum breakers be installed at the inlet to the machines, unless the machines themselves are provided with effective integral vacuum breakers.

10. SERVICE SINKS are installed in maintenance or boiler rooms for the use of maintenance personnel. Since these sinks are rarely visible, those built of galvanized steel will serve the purpose equally as well as more costly vitreous china or enameled cast iron sinks. Each sink should be provided with a rim guard, a metal plug strainer and a supporting trap standard with a cleanout in the trap seal. The supply fittings should be the rough plated combination type with short mixing spout and pail hook.

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11. SCULLERY SINKS will occasionally be required in community kitchens. A wide choice of types can be made, such as soapstone, galvanized steel, or acid-resisting enameled cast iron. These sinks will be subject to infrequent but fairly hard usage, and therefore all trim should be as durable as possible. The supply fittings should be heavy pattern faucets with a heavy swing spout. A drain plug with cross-bars, and a heavy chain and rubber stopper is preferable over any type of removable strainer. Drainboards should be large and should drain readily into the sink. As far as possible all fittings should be non-removable.

12. DRINKING FOUNTAINS can be a decided menance to health unless properly designed and installed. Only such drinking fountains that meet all the requirements of the U.S. Public Health Service as set forth in the American Standard A40.4-1942 and ASA 24.2 1/ are considered to be acceptable. In addition, all drinking fountain nozzles with orifice diameter of 7/16 inch or less should extend 3/4 inch above the flood-level rim of the receptacle.

The drinking fountains which will maintain the cleanest appearance are those constructed of white vitreous china or enameled cast iron. In spite of the hard usage to which a public fixture may be subjected, the advantage of a continuing clean fountain will offset the disadvantage of the possibility of damage to the fixture.

Drinking fountains are commonly made as wall bracket or recessed types, and as free-standing pedestal types. A bracket fountain is the least costly and answers most purposes of indoor use, while the pedestal type is best suited for outdoor installation. All visible fittings should be chromium plated over nickel. The supply valve should be self-closing, the supply stop should be key-operated, and the supply outlet should be provided with a regulating screw. The bowl should be provided with a durable strainer.

13. RECOMMENDED FIXTURES. In line with the foregoing discussion the types of fixtures recommended as best suited for use are as follows:

a. Water Closets for Dwelling Units: Wash-down or reverse trap vitreous china closet bowl with low wall-hung tank and white sheet-covered closed front seat and cover.

b. Water Closets for Community Facilities: Blow-out or siphon jet vitreous china closet bowl with flush valve and black rubber open-front seat without cover.

c. Urinals: Vitreous china stall urinal with flush valve.

d. Lavatories: Wall-hung back ledge type, acid resisting enameled cast iron, formed steel or vitreous china; nominal 18" x 20" dimension, with centerset supply fitting and chain and stopper.

1/ American Standards approved by the American Standards Association, 70 East 45th Street, New York 7, New York.

e. Bathtubs: Built-in type with large over-rim spout and chain and stopper; 5 feet long, enameled cast iron or formed steel.

f. Kitchen Sinks and Tray: Wall hung ledge type, acid resisting cast iron or formed steel with supporting leg; 42 inches long, having sink bowl on right side and sliding enameled steel drainboard over the tray; swing spout faucet and removable cup strainer in the sink bowl.

g. Laundry Trays: Double compartment concrete laundry tray on angle iron frame with rough plated fittings and chain and stopper.

h. Service Sinks: Sink with back, galvanized steel or enameled cast iron, with trap standard and rough plated fittings.

i. Scullery Sinks: Single compartment galvanized steel type with double drain boards and heavy pattern fittings with chain and stopper. Nominal dimensions, 78 inches by 24 inches.

j. Indoor Drinking Fountains: Wall-hung bracket type, acid-resisting enameled cast iron or vitreous china with exposed trap, non-squirting guarded angle steam nozzle, self-closing control valve and regulator.

k. Outdoor Drinking Fountains: Pedestal type, acid resisting enameled cast iron or vitreous china, with suitable cut-off to prevent freezing, galvanized steel stand bolted to the ground, trap below the frost line, non-squirting guarded angle steam nozzle, self-closing valve, and regulator.

14. REFERENCES. For information on the standard sizes, dimensions, appearance, and thickness of surfacings of the commonly used fixtures and trimmings reference can be made to the following: Federal Specification WW-P-541a Plumbing Fixtures; Federal Specifications WW-P-542 Formed Metal Plumbing Fixtures; Commercial Standard CS-20-49 Staple Vitreous China Plumbing Fixtures; Commercial Standard CS-77-48 Enameled Cast-iron Plumbing Fixtures, and Commercial Standard 144-47 Formed Metal Porcelain Enameled Sanitary Ware. These publications can be obtained from the Superintendent of Documents, Washington 25, D. C., at a nominal cost.

PLUMBING, HEATING AND VENTILATION

PART IV - PLUMBING FIXTURES FOR DWELLING UNITS AND COMMUNITY FACILITIES

1. INTRODUCTION. To ensure the provision of adequate sanitary facilities and to meet accepted standards of health, each dwelling erected in urban communities is required (by the PHA Minimum Physical Standards) to have plumbing facilities for toilets, bathing, food preparation, and laundry work. In addition, community facilities erected in conjunction with groups of dwelling units will have plumbing facilities designed for public usage.

Advances made by manufacturers, during the past half century, in the design of fixtures and improvements in methods of installation have been outstanding. But in spite of this fact, it cannot be taken for granted that all fixtures are completely safe as to their sanitary features or are equally desirable from the user's point of view. All types should be given critical examination as to basic economy, both initial and in operation,over their expectant life.

Another factor that should be seriously considered in choosing plumbing fixtures is the desirability of selecting fixtures and trim that tend to minimize the amount of water to be used. Such features as combination spouts and small-sized tanks will definitely effect appreciable savings in water consumption. With the general dropping of water-table levels throughout the country, all methods that will help to conserve the nation's water supply should be given thoughtful consideration.

The following discussion is offered as an aid in selecting fixtures which will prove satisfactory in all respects and avoiding serious errors which might result from inadequate consideration.

2. FIXTURE TRIM. All fixture trim specified for use in a project should be standardized as completely as possible so that similar fixtures will be provided with identical trim throughout. The fittings chosen should be a common easily procurable type, of plain design and appearance, for which replacement parts will be readily obtainable. Faucets should be compression type with replaceable seats. All brass trim, chromium plated over nickel, gives the longest service and should be used in lieu of optional metals. The use of die-cast zinc alloy for trim should never be used. Also iron faucets or spouts should never be used as corrosion will color the water and life will be short. Mechanically operated wastes or drains, or special features, such as hose sprays, should be avoided.

NOTE: This Part supersedes Part IV of Bulletin No. LR-7 dated 4-24-50. It has been revised throughout to reflect current information and practices.

3. WATER CLOSETS are manufactured of vitreous china, since experiments by manufacturers in the use of other materials have been unsuccessful. The principal types of water-closet bowls are:

a. The siphon jet - which operates by creating a siphon action in the trap, with a jet at the bottom of the trap furnishing the initial impetus to the siphonic action.

b. The wash-down - with a jet which functions by filling the closet bowl to a height sufficient to fill the rear leg of the trap and start siphon action which empties the bowl.

c. The blow-out - which is flushed by a heavy discharge of water at relatively high pressure.

d. The reverse-trap - which is a wash-down bowl with the trap reversed.

In selecting water closets for dwelling units it is advisable to give due attention to the following:

a. The contents of the bowl should discharge by siphonic action, and the seal should be maintained by refilling action of the tank or flush valve.

b. The flushing rim should be constructed to flush the entire interior surface of the bowl.

c. The siphon "jet" should be visible and accessible and should be placed on a line with, or below, the bottom of the trap seal.

Types most commonly used in low-rent dwelling units are the moderately priced siphon jet and the wash-down or reverse trap with jet action, fitted either with a low wall-hung tank or a close-coupled tank. The full siphon jet or other better-type bowls offer a number of advantages lacking in the lower-priced bowls, but their use is not a real economy nor is it warranted. The close-coupled tank is somewhat easier to install than the wall-hung tank, because hangers are not required and additional construction is not required to carry the weight of the tank and its water contents. However, because the close-coupled tank rests on the closet bowl and is free from any wall support, it has been found to crack at the bottom where it connects with the spud. While in some cases this has been due to poor workmanship or defective design, the trouble is frequently due to external pressure exerted against the tank, the spud constituting a fulcrum with the tank acting as a lever. One way to overcome this situation is to provide a close-fitting cleat on the wall back of the tank near the top, to prevent leverage strain. Because the wall-hung tank is independently supported and presents no possibility of this type of breakage, its use is preferable.

A vacuum breaker is a very essential requirement for all types of water-closet tank valves or flush valves. Some manufacturers of tanks, in order to reduce costs, provide an "air gap" in the supply valve by eliminating the hush tube or submerged supply pipe. Such an arrangement tends to increase noise within the tank and is not a positive safeguard against back-siphonage, and therefore should not be used.

The working parts of the tank must be of good quality, since otherwise this part of the fixture is likely to be out of order quite often and thus create a considerable and continuing maintenance expense. Any difference in maintenance costs between the competitive type flush valve and a tank with good quality working parts is slight. The cost of installation, however, is definitely in favor of the tank so long as a 1 or 1-1/4 inch supply line is essential for the satisfactory operation of the flush valve. Some managers may favor the installation of flush valves from the standpoint of maintenance expense, but the additional initial cost does not warrant their use, especially when the saving in maintenance is admittedly slight.

The type of water-closet bowl which is generally recommended for use in community-facility toilet rooms is the siphon-jet elongated-bowl type with flush valve. The flushing action and general appearance of the reverse-trap bowl is similar to the siphon-jet bowl. The water surface and size of trapway are smaller and the depth of the seal is less, requiring less water for operation. Generally, reverse-trap bowls are suitable for installation with flush valves or flush tanks. However, since a tank in a public toilet is not desirable because of possible vandalism or tampering with tank mechanism, the use of the flush valve becomes warranted.

4. WATER CLOSET SEATS should be of some material which does not absorb moisture, is a poor conductor of heat, can be easily cleaned, and appears as one piece without surface joints or cracks.

Seats of spray-painted wood, sheet-covered wood, molded plastic compound, or of the composition type (consisting of hard rubber compound or plastic) are generally available. The spray-painted wood type and the molded plastic-compound type are the least expensive. However, the paint on the wood type tends to wear or flake off, requiring replacement of the seat or repainting. The finish of the molded plastic type has a much better service record.

A seat with extended back, secured to the bowl with hinged parts and a rod within a sleeve extending across the full length of the back, will provide the longest service. The cost will be only slightly higher than the cheaper type of seat secured to the bowl by two leaf hinges. In addition, substantial cleats permanently attached near the front of the seat will serve to avoid breakage or distortion.

In dwelling units, all seats should be provided with a cover; this is not only desirable for appearance but has definite practical value, such as serving as a seat and preventing articles from falling into the bowl.

Seats for water closets in community facilities should be open-front type without cover, made of a durable material such as hard black rubber with or without a solid core.

5. URINALS may be required in the community facilities. Urinals are usually constructed of vitreous china and are wall-hung or floor-supported. Because of its location in a public toilet, a urinal should be provided with a flush valve (rather than a flush tank). Whether valve or tank is used, a vacuum breaker should be provided with a flushing-rim type of urinal, to guard against any possibility of back-flow into the water supply system. A strainer should be provided at the drain connection, to prevent clogging of the outlet.

6. LAVATORIES are made in many different styles, sizes, and materials and with varied methods of support. The type best adapted for use is one that is low in initial cost, durable, and easy to keep clean. The most commonly used lavatories are made of enameled cast-iron, enameled formed steel, or vitreous china. From the sanitary standpoint, all of these materials are satisfactory.

In selecting a lavatory it is advisable to limit the size to the nominal 18" x 20" dimension with as large a bowl area as is available in that size. The bowl should be oval or D-shaped, with minimum obstructions on the slab or top. A back-ledge type with low back, fitted with 4-inch centerset combination compression faucets, is the most satisfactory and the least cumbersome, and provides mixed water through a single short spout. The air gap between the spout outlet and the overflow rim of the lavatory should never be less than one inch.

The wall-hung lavatory is the most economical type from the standpoint of initial cost and occupying the minimum amount of space in a bathroom. Each fixture should be furnished with a fully concealed metal wall hanger. However, experience has shown that it may be necessary to strengthen the supporting wall or partition so that it can carry the weight of the lavatory plus the additional loads that may be imposed by abnormal misuse, such as the strains imposed by a child who tries to lift himself to the top of the lavatory or those caused by a person resting his weight on the outer edge of the fixture.

Rubber stoppers with heavy chain and chain stay have been found most satisfactory; pop-up wastes have been found to add considerably to maintenance expense, since they are difficult to keep in good working order. The chain and chain stay should be of good quality, since if they become defective great demand is made on the maintenance staff.

Waste and supply connections should be made from the wall (rather than from the floor), to permit greater ease in cleaning the floor. In addition, the waste, if installed at the floor, forms a siphonic leg, with the possibility of self-siphonage of the trap seal. Exposed connections from supply fittings for fixtures to building supply pipes shall be chromium-plated brass.

7. BATHTUBS are required by the PHA Low-Rent Housing Manual. As a general rule tubs, either enameled cast-iron or formed steel, are recessed; though occasionally corner tubs are used. Flat bottoms and straight sides diminish the possibility of accidents, and a grab rail in the rim or built into the wall helps to prevent falls.

Shower compartments (in place of bathtubs) are ordinarily not desirable. Such a compartment in a dwelling may have some advantages, but it does not meet the essential requirements of the average household. At the option of the Local Authority, shower over tub may be installed. However, the increase in both initial installation cost and annual operating expense may make the use of the shower unwarranted, in view of the limited funds available. The increase in the initial cost results primarily from the necessity to protect the walls adjacent to the tub with a tile wainscot.

Attaching a hose with spray head to the bath nozzle has been found to be a common practice in a large number of dwelling units in public housing when shower over tub is not provided. This appendage is a definite violation of most plumbing codes and the recommendations of the U. S. Public Health Service, since the spray head, dropped into the bath water and acting as a submerged outlet, may permit back-siphonage and cause contamination of the water supply system of the entire building and possibly the community. To discourage this practice, a smooth spout with a large opening (to which it will be difficult to attach a hose) should be provided.

A source of trouble with recessed or built-in tubs is caused by shrinkage in building materials and consequent settlement of the bathroom floor. This causes a separation above the edges of the tub at the wall, thus permitting water seepage, which becomes particularly aggravated when showers are installed, and causes maintenance trouble and expense. Where wood frame construction is used, it is advisable to install tub hangers in the wall, to support the tub on the wall structure and thus prevent this separation.

Supply fitting for bathtub without shower should be the concealed combination type with over-rim spout. Supply fitting for bathtub with shower should be the concealed-type combination shower and bath supply fitting, with over-rim spout and diverter. When valves are in place, the bonnets shall be removable at the front for repairs and replacements.

The connected waste and overflow with heavy chain and rubber stopper is the most economical and least troublesome in operation. Pop-up wastes should not be considered, as they are troublesome and costly.

8. KITCHEN SINK AND TRAY. Many of the larger Local Authorities are using the wall-hung ledge-type combination kitchen sink and tray with back and equipped with a single adjustable enameled leg beneath the tray compartment. This type sink is considered more practical and is preferred over the flat-rim type because no fabricated sink-top will be required. If separate laundry trays are provided within the dwelling, a kitchen sink without a tray may be installed. Such a sink should be a wall-hung ledge type with back, provided with integral drainboard. Sinks and sink-tray combinations should be acid resisting enameled cast iron or formed steel. In lieu of separate laundry trays in the dwelling, provisions for a tenant-owned automatic washing machine may be made.

Most codes permit the use of one trap for both the sink and the tray. However, in many public housing projects the use of improper fittings and improperly located traps has caused a backflow between the sink and tray. This can be avoided by the use of a tubing fitting, with the proper turn or sweep, at the point where both fixture drains connect near the inlet of the trap. If the trap is located under the sink and the waste from the tray is connected within the seal of the trap, there are two advantages: (1) there is no backflow between the compartments; (2) odors are eliminated, since circulation of air in the wastes connecting the compartments is prevented.

The sink and tray supply fitting should be a combination type with cast-brass (or other heavy-duty) swing spout. Removable cup strainers in the waste outlet of the sink are usually provided, since they facilitate the use of the sink for washing dishes or pots and pans. When this type of strainer is used, a secondary cross-bar strainer should be permanently installed within the sink plug, to prevent waste material from entering the waste pipe and causing stoppages. The drainboard over the tray should be porcelain-enameled steel, for durability and clean appearance, and sufficiently light to be lifted easily. It should, of course, drain readily into the sink bowl.

9. WASHING MACHINES. Many Local Authorities are providing facilities for automatic washing machines in one- and two-story dwelling structures. PHA Low-Rent Housing Manual, Section 207.1, states that provision for a tenant-owned automatic washing machine (plumbing and electric) may be made in the kitchen, preferably adjacent to combination sink and laundry tray. As a space saver, it is suggested that waste and water piping be run in partition behind washing machine, with the waste outlet and water supply valves located in a recessed cabinet. Concealing the piping presents a nicer-looking installation and will permit washing machine to fit close against wall. (Prefabricated recess-type cabinets complete with supply valves, drain-pipe connection and electric receptacle are available for this purpose.)

10. LAUNDRY TRAYS. When laundry work is to be done in locations other than the kitchen, experience has shown that a double-compartment laundry tray is essential. Such laundry trays are usually made of concrete, soapstone, or alberene stone, supported on a galvanized angle-iron frame. The trim should be rough-plated, and should consist of a swing-spout faucet and soap dish, a chain and rubber stopper, and a cross-bar drain plug. One trap and a twin waste serves both tray compartments. The method of grouping the trays in the project laundry rooms should depend on whether washing machines are to be used.

When laundry tray in the kitchen is to be a separate fixture, installed apart from the kitchen sink, it is advisable to use a single-compartment tray. Fixture should be enameled cast-iron with roll-rim and splashback type, equipped with combination faucet and adjustable cast-iron pedestal or leg.

If water supply connections for washing machines are provided in the laundry room, it is essential that vacuum breakers be installed at the inlet to the machines, unless the machines themselves are provided with effective integral vacuum breakers.

11. SERVICE SINKS. When such sinks are required for janitorial service they should be enameled cast-iron roll-rim type with rim guard and back. The supply fitting should be rough-plated combination type with backflow preventer. Each sink should be provided with a rim guard, a drain plug with strainer, and a supporting trap standard with a cleanout in the trap seal. Service sinks installed in maintenance and boiler rooms may be galvanized or zinc-coated steel, and will serve the purpose equally as well as the more costly enameled cast-iron sinks.

12. SCULLERY SINKS will occasionally be required in community kitchens. The sink generally used is a zinc-coated steel type with integral drainboards and back. Sink should be supported on a rigid frame of zinc-coated steel angles with provisions for adjusting legs of frame. The supply fittings should be extra-heavy pattern faucets with a heavy swing spout. The spout nozzle should have anti-splash device and be without hose thread. Valve should be of a type that has replaceable seats accessible from the front. A drain plug with cross-bars, and a heavy chain and rubber stopper, is preferable over any type of removable strainer.

13. DRINKING FOUNTAINS used in community, maintenance, or project office space are generally the semi-recessed or recessed types or the type that is mounted on wall surface. Fixtures should be one-piece white vitreous china with integral bowl, designed for minimum splashing of water. Each fixture should be provided with a concealed metal wall hanger or other support of suitable design. Supply fitting should have angle-stream anti-squirt bubbler with integral guard. The supply valve should be self-closing type; the stop valve should be screwdriver type; and the supply outlet should be provided with automatic volume regulator. The bowl should be provided with a durable strainer.

14. RECOMMENDED FIXTURES. In line with the foregoing discussion, the types of fixtures recommended as best suited for use are as follows:

a. Water Closets for Dwelling Units: Reverse trap, with vitreous china closet bowl, close-coupled vitreous china tank, and white closed-front seat and cover of molded plastic compound.

b. Water Closets for Public Facilities: Siphon-jet, vitreous china elongated closet bowl with flush valve and elongated open front, regular-weight black toilet seats of solid plastic or hard rubber compound of solid construction. Seats shall be without covers.

c. Urinals for Public Facilities: Vitreous china stall urinal with flush valve.

d. Lavatories: Wall-hung type with straight back and straight front apron, acid-resisting enameled cast-iron, formed steel, or vitreous china; nominal 18" x 20" dimension, with centerset supply fitting and chain and stopper.

e. <u>Bathtubs</u>: Built-in recess or corner type, double shell; 5 feet long, enameled cast-iron or porcelain-enameled formed steel.

f. <u>Kitchen Sinks With Tray</u>: Wall-hung rim-ledge type with back, acid-resisting enameled cast-iron or porcelain-enameled formed steel, with supporting leg; 42 inches long, having sink bowl on right side and sliding porcelain-enameled steel drainboard over tray; swing-spout faucet, metal soap dish, and removable cup strainer in the sink bowl.

g. <u>Kitchen Sinks Without Tray</u>: Wall-hung ledge type with back, acid-resisting enameled cast-iron or porcelain-enameled formed steel, with hanger and brackets; 42 inches long with single integral drainboard; swing-spout faucet, metal soap dish, and removable cup strainer.

h. <u>Laundry Trays</u>: Double-compartment concrete laundry tray on angle-iron frame, with rough-plated fittings and chain and stopper.

i. <u>Laundry Tray for Kitchen</u>: Single-compartment type, acid-resisting enameled cast-iron, with roll-rim and splashback, combination faucet, and chain and stopper.

j. <u>Service Sinks</u>: Acid-resisting enameled cast-iron roll-rim type with rim guard and back, with rough-plated fittings and chain and stopper.

k. <u>Scullery Sinks</u>: Zinc-coated steel type with integral drainboards and back, heavy pattern fittings with chain and stopper.

l. <u>Drinking Fountain</u>: Wall-mounted type, vitreous china with integral bowl, anti-squirt bubbler, automatic volume regulator, and screwdriver-type stop valve.

m. <u>References</u>: For information on the standard size, dimensions, appearance, and thickness of surfacing of the fixtures and trimmings mentioned hereinbefore, reference can be made to Federal Specification WW-P-541-b, "Plumbing Fixtures, Land Use."

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PLUMBING, HEATING AND VENTILATION

PART V - SAFETY CONSIDERATIONS IN THE INSTALLATION OF GAS PIPING

1. INTRODUCTION. The use of gas is so commonplace and the pipework for this fuel so simple that there is some tendency to ignore inherent dangers of leakage and explosions lying in faulty design and installations. Asphyxiation and disastrous gas explosions frequently are recorded in the press, and public housing has not escaped. At least five bad explosions have occurred, and two had unusually serious consequences. Investigation of these and other cases made it clear that carelessness and thoughtlessness were responsible.

The subject has become one of extreme concern, and while there is no information to cause PHA to believe its actuarial record is comparatively bad, it is obvious that the record can and should be improved. In fact, there is every reason to believe that if all known precautions are taken, the risk will become negligible.

As a result of current investigations, the Minimum Physical Standards and Criteria have been supplemented by the following requirements:

> "Gas installations, both within and outside of building structures, shall be designed to minimize the danger of mechanical damage and corrosive actions. Exterior gas piping shall not be placed in the same trenches as other pipe work. Gas lines shall, so far as practicable, be laid at higher elevations than adjacent pipe lines for other utilities. Positive means for preventing the entrance of gas seepage from the outside to the inside of structure shall include, but not be limited to, the venting of trenches to the outside air and, in the case of grade-beam construction, permanent deflecting barriers at the points where outside lines rise to service connections. Gas service connections from outside gas lines shall rise above the outside grade before entering a concealed or unused space under a building. Likewise, where the first floor is a slab-on-ground, the service connection shall rise above the outside grade and shall enter the structure above the floor line, and no gas piping shall be placed within or buried below the slab. Piping exposed to outside air, shall be insulated adequately in climates where the air temperature may fall below the dew point temperature of the gas. Between outside lines and entrance of service connection, positive means shall be provided to guard against breaking of pipes or loosening of joints, due to settlement of the building and/or the pipe itself; such means shall be in the form of swing-joints or other positive and permanent means. All interior gas piping that is concealed shall, to the fullest extent practicable, be vented to the outside air at the top of the concealed space.

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> When the interior gas piping is concealed in a continuous space with plumbing lines, the whole space shall be vented. Where the structure includes a basement or crawl-space, the ventilated space shall start with an opening at the basement or crawl-space; where the first floor is a slab-on-ground the ventilated space shall start with an opening from the dwelling space directly above the slab. In connection with the venting of areas subject to accumulation of leaking gas, attention is directed to the requirements herein for venting of crawl spaces".

Obviously, no gas explosions would ever occur if there were no escape of gas. Leakages may occur outside of building and find their way within closed spaces by following pipelines or by soil permeation until a point of entrance is found, or the leakages may occur within the structure itself. Leakages may occur from mechanical breaks or from disintegration of the pipe. Hence, it follows that (1) the pipe work should be so installed that the chances of mechanical breakage are reduced to the minimum, (2) the pipe should be of such nature and so installed and protected that the effects of corrosive actions are minimized, and (3) in addition to such precautions, gas pipe trenches and interior spaces which conceal gas lines should be effectively vented. This bulletin discusses means for achieving these ends, as well as for the taking of other incidental precautions but the foregoing should be taken as the basic principles which must be followed, to eliminate or minimize latent hazards.

Regulations governing gas installations have been established by most utility companies and municipalities, but these regulations vary and in some instances may not be sufficiently extensive to assure safety. The mere existence of sound requirements is of no value if the designing engineer does not recognize the basic, underlying principles or apply these in his plans and specifications, <u>or if non-compliances are permitted in the installation</u>.

A majority of the recommendations prescribed herein stem from experiences gained in public housing projects, and from conferences with experts from the Bureau of Mines and others concerned with safety in gas piping installations. The recommendations are sufficiently general in scope not to conflict with local policies which are in accord with safe practices. Some recommendations will, no doubt, be found in standards and regulations promulgated by the American Standards Association and utility companies, but it is the purpose here to emphasize those items which affect safety and are frequently overlooked in gas piping installations. Recommendations generally should apply equally to liquefied petroleum gases as well as to natural and manufactured gases. Specific requirements for the storage and handling of heavier than air petroleum gases are defined in the National Board of Fire Underwriters' Pamphlets Nos. 58 and 59.

While it is realized that the discussion of this subject may not be complete the material should prove valuable in the interest of safety. Investigations are continuously being made, and bodies responsible for public housing developments will be told the results of further studies on this very important item by special reports or bulletins.

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2. PLANNING. Careful planning and design, and knowledge of all related factors in safety considerations are necessary no matter how simple the installation and gas usage requirements appear to be. Lurking hazards with the possibility of fatal accidents may be the direct result of failure to recognize and plan to avoid them.

3. CORROSION. Corrosion is the process of disintegration by slow degrees, caused principally by chemical or electro-chemical reactions. Chemical reaction is one in which the slow union of the elements with oxygen occurs, and is called oxidation. Electro-chemical reaction in which interest is centered here occurs when the element (pipe line) is in contact with dissolved constituents in the soil, and together, cause low voltage currents to be induced. By the latter method, microscopic quantities of metal continuously leave the pipe at points where current flows from cleaner or purer areas of the pipe to other areas in which mill scale is deposited, or from gas pipe to water lines or other installations. Corrosion (pitting) is hastened at points where the current flows from the pipe to foreign elements.

The theory of protection to arrest corrosion is fundamentally simple, yet specialized technical skill is needed to resolve both technical and economic problems with which the whole subject of protection is concerned. In some localities, where the soil is uniformly sandy and of high resistivity, protection of pipes may not even be required; in others mechanical protection may be the only means needed to resist corrosion; and there may be localities where mechanical and electrical (discussed below) protection will be required. Corrosivity, moisture content and temperature conditions of the soil are ever present factors that the engineer must consider in prescribing methods of protection.

For example, a serious condition which has been found to have accelerated corrosion in public housing was the installation of unprotected mains in (a) ground water, (b) moist ground where the water level changes constantly, (c) corrosive soils of low resistivity or filled-in areas and (d) less frequently, in ground near street car lines or within stray current areas from nearby industrial plants. While electric current is one of the methods used to retard corrosion, induced currents which are uncontrolled (as they could be under any of the above situations), invariably will flow from the p pe rather than to the pipe. The uncontrolled current tends to speed rather than retard corrosion.

Where conditions are similar to those mentioned above or where other conditions might influence corrosion, the need for protected piping is evident. Local utilities have devised various ways of protecting their distribution lines mechanically. They should be prepared to advise local engineers or Local Authorities on the efficacy of one protective method over another, and to offer the benefits of their experience on corrosive actions on metal buried in the soil. The following types of coatings or coverings have been used successfully in varying degrees, and should be considered. (Other types may be equally as effective):

a. Three layers, alternately applied, of coal tar impregnated paper and hot pitch.

b. Hot applied coal tar enamel on pipe, and hot pitch on pipe threads and connections.

c. Same as (b), plus one wrap of 15 lb. asbestos felt and one wrap of 60 lb. kraft paper.

d. Hot applied bituminous tape.

e. Same as (d), plus one wrap of asbestos tape impregnated with bitumens.

f. Vinyl-plastic tape.

Cinders or rubbish should not be used for any backfill. In grounds within proximity of streetcar lines or other stray current sources, the pipe should be grounded to the source of current if at all practicable.

With all of these protective schemes it is necessary that the pipe be thoroughly primed before processing. Mechanical protection should be complete, and care in handling the pipe during installation should be intensive. A coated or covered pipe is only as good as its weakest point, where it may be left unprotected. Incomplete protection will leave "holidays" which are subject to severe corrosive attack. Also, isolation (discussed elsewhere in this bulletin) is required to reduce the probabilities of electrical contact between the gas and water systems or other metallic installations.

Regardless of the quality of mechanical protection, there is the possibility of its damage during handling and backfilling, and due to earth movements. Therefore, it is good insurance against corrosion to provide electro-chemical or "cathodic" protection in addition to the pipe treatment. The better the pipe treatment, the less electrical energy will be required to effect cathodic protection which is relatively inexpensive to install and will minimize both explosion hazard and operating expense. Further the better the pipe treatment, the greater is the protection afforded against exposure of flaws in the pipe to corrosive elements in the soil.

Cathodic protection is accomplished, by making the gas piping the cathode or negative pole, in two ways. First is to select a "galvanic" anode (positive pole), constructed of zinc or magnesium-dependent upon the resistivity (resistance to the flow of electric current) and chemical composition of the soil-both of which metals are of higher potential than the ferrous pipe to be protected. The current induced by electro-chemical action will flow from the zinc or magnesium across the earth (electrolyte) to the pipe, then from the pipe by wire back to the anode to complete the circuit; (see Figure 1). The second way is to use rectifiers, receiving electrical current from continuous source of supply. Alternating current is tapped to the rectifiers which convert the current to the required low voltage direct current. Connection by wire is made from the rectifier to anode beds buried in the

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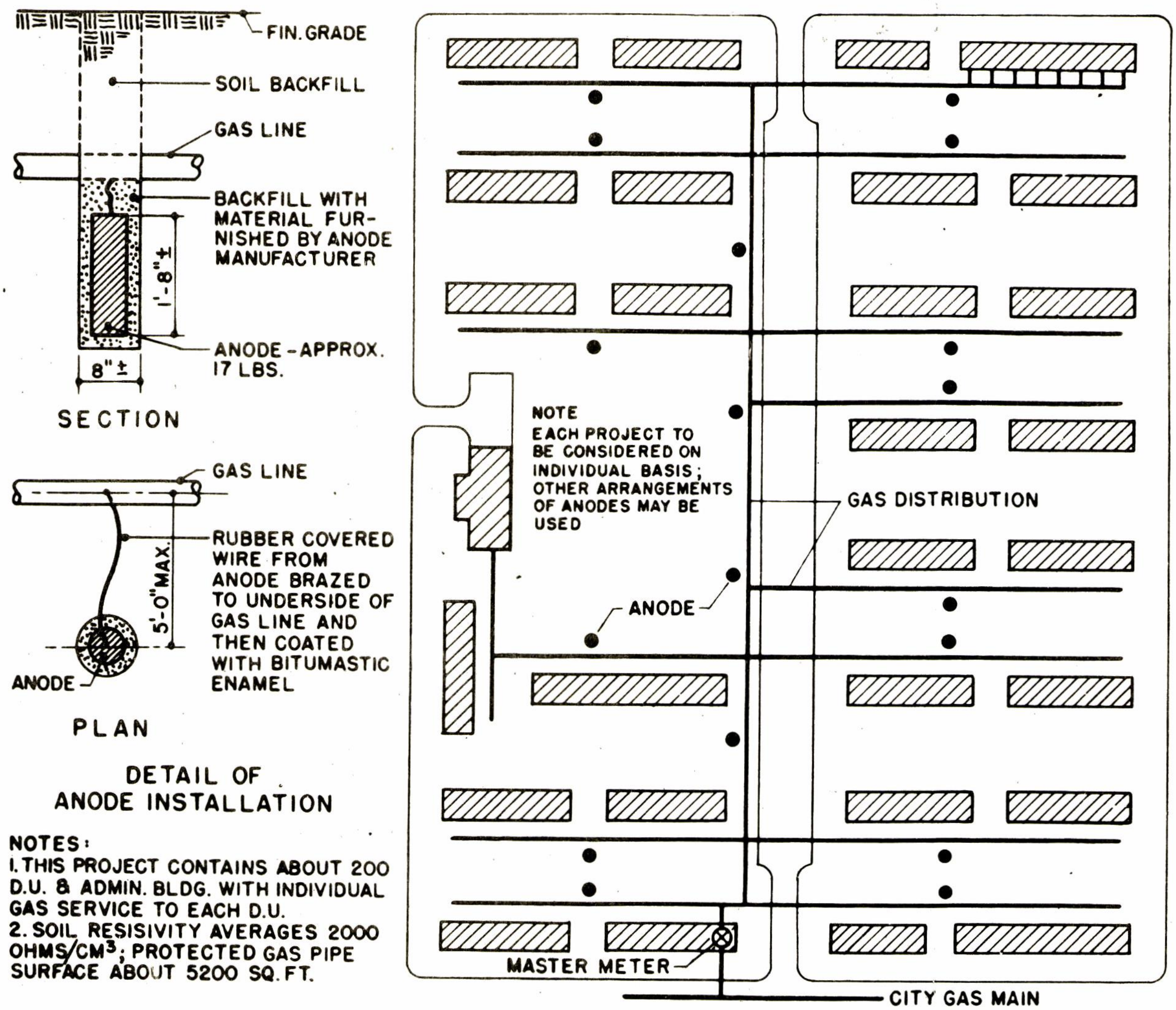

FIGURE I GALVANIC ANODE METHOD OF CATHODIC PROTECTION

ground. Here again the earth serves as the electrolyte between the anode and the pipe. The circuit is completed by wire from the pipe back to the rectifier. By both ways, corrosion is mitigated because electric current flows from the soil to the pipe, (not from the pipe to the soil).

In the first (galvanic anode) method, zinc and magnesium have been used interchangeably, although it appears that magensium, because it has a higher potential than zinc, makes it more desirable in (a), soils with a resistivity in excess of about 2500 ohms per cubic centimeter and (b), protecting older piping systems. Magnesium, in either case, is capable of producing the higher voltage, and stronger current necessary. Zinc can be used successfully in well coated systems and in soils of low resistivity, because of the lower current needed to protect the pipe; also zinc is known to have a longer life than magnesium.

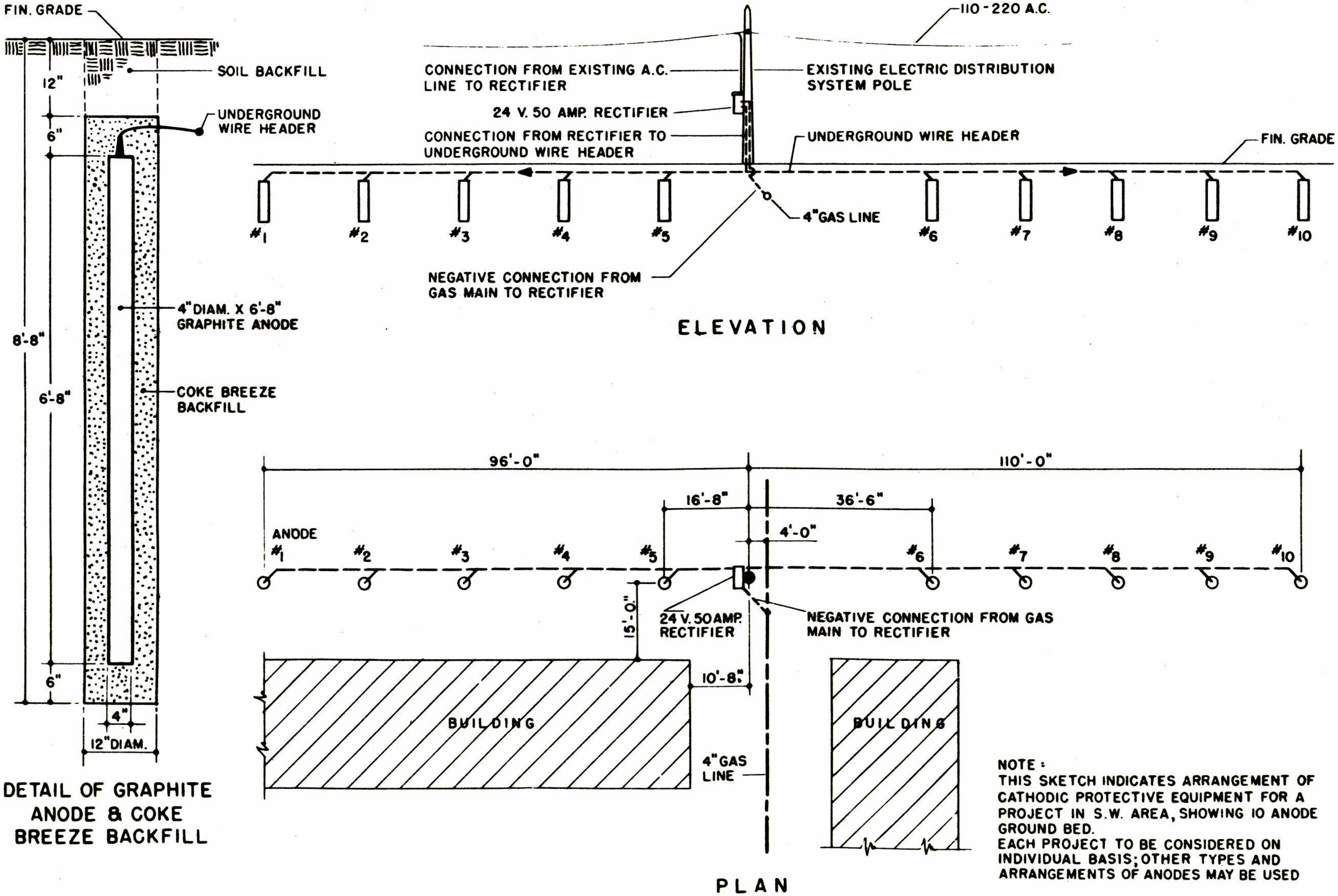

FIGURE 2 RECTIFIER METHOD OF CATHODIC PROTECTION

In the second (rectifier) method, one project in the southwest reports: "The direct current delivered to the ground beds from the rectifiers will usually have a voltage of from 7 to 20, and generally average about 13 volts. Amperage will vary from 12 to 50, and average about 30 amperes." The ground area protection for one rectifier averages approximately 500,000 square feet. The anode rods for the ground beds are 4 inches in diameter and about 7 feet long. Generally about ten are required for each rectifier, installed vertically in holes from 12 inches to 16 inches in diameter and spaced from 10 to 20 feet apart. Space in the hole surrounding the anode is backfilled generally with material dependent upon type of anode. (See Figure 2.)

Whatever the method, galvanic anode or rectifier and anode bed, the entire system should be so designed and constructed that it offers no electrical resistance other than that normally encountered by the metal in the system itself. In other words, the cathodically protected system should be isolated from foreign metallic structures.

Cathodic protection need not be limited to gas systems. Its advantages can well be extended to water systems, and hot water generators or tanks. While cathodic protection will reduce electro-chemical reaction to a minimum, it will not prevent leaks in gas lines originating from mechanical damage.

This discussion on corrosion has been **predicated** on the use of steel pipe. Question may be raised as to why cast iron or copper can not be used, and so obviate the need for elaborate protective devices.

Cast iron, owing to its greater thickness, has a longer life than steel without cathodic protection, but has been comparatively little used for gas lines in public housing because in most projects the major part of the piping is small size, not obtainable in cast iron. Further, cast iron is more susceptible to fracture than steel, and should not be used in lines laid in unstable ground.

Copper is less subject to corrosive attack than ferrous metals, but is more expensive than steel pipe; its use, therefore, has been an economic problem in balancing cost of ferrous pipe and protection against added cost of the copper. Also copper is liable to corrosion when placed in soils which yield sulphur dioxide; when used, copper should be Type K, hard drawn, with solder fittings.

Some interest is being developed in the use of pipe extruded from an organic plastic. This pipe, light in weight and flexible enough to be bent to follow the path of the trench, is considered an insulator and will not become part of a galvanic couple. But public housing does not have sufficient experience with this pipe to recommend it or advise against its use.

Reduced to simplest terms, the following are believed safe rules to consider in protection of underground gas lines: (a) where resistivity of the soil is less than 3000 ohms per cubic centimeter, cathodic protection should be applied,

NOTE: This sheet supersedes the corresponding sheet dated 4-24-50. The 4th and 5th paragraphs on this page have been revised. Page 8 is re-issued without substantial charge.

(b) where resistivity of the soil varies from 3,000-10,000 ohms per cubic centimeter, cathodic protection may be necessary but further study of soil will be required, (c) where resistivity exceeds 10,000 ohms per cubic centimeter, no cathodic protection is needed, (d) regardless of soil characteristics, and whether or not cathodic protection is applied, the piping should be coated and/or wrapped.

4. PROTECTING BUILDINGS AGAINST OUTSIDE GAS LEAKS. In cases where leaks have occurred from corrosion or mechanical cracks or breaks in the distribution main or in the main serving a building, escaping gas travelled the path of the pipe trench to spaces under the building, then up to the dwelling unit. Such leaks may go unnoticed until it is too late. A momentary flash caused by a match, pilot, open flame or defective electric switch is sufficient to cause an explosion.

Gas should never be allowed to collect in confined areas such as crawl spaces, pipe spaces or utility rooms. Ignition may be in a dwelling unit, not necessarily in the area where the gas has accumulated. A flame tends to travel from lean to richer gas concentration areas, building up force as it propagates and compresses the gas ahead until the mixture is exploded. Explosion damage, many times, is greatest at locations away from the origin of the flame and generally occurs with maximum intensity when the gas concentration has reached the highest point within its range of inflammability.

Figures 3 and 4 illustrate a method of venting trenches, with three types of construction. Figure 3 shows venting with (a) crawl space on continuous footing construction and (b) crawl space with grade beam; figure 4 shows venting with slab-on-ground. It should be noted that, in each case, the gas line rises above grade before entry into building. The walls of the building serve as carriers, and are parged with waterproofing cement unless walls are solid dense concrete. In warmer climates where check metering is required, the meter may be installed before gas line enters the building. The piping exposed to the outer air should be insulated adequately where the outside temperatures fall below the dew-point temperature of the water vapor in the gas; the local utility will generally furnish information on dew-point temperatures.

Where gas pipe enters a basement, pipe rise above grade will not be necessary, but venting of trench, parging of walls and sealing of sleeve before gas pipe enters building should be provided.

There are other methods for venting, such as, carrying the gas pipe before entering the building, concentrically within a tile or cast iron pipe not less than 4 inches diameter, extending a few inches above finished grade. Coarse gravel should fill the vent pipe and, in addition, be arranged similar to that shown on the sketches.

The purpose of the vent is to relieve the trench of any escaping gas, and preclude the probability of gas entering the building. The character of the soil is irrelevant to the need for venting. Whatever the soil, the vent should be installed. The soil covering the gravel should be of a permeable consistency to permit freer flow of escaping gas to the outside air.

In the second (rectifier) method, one project in the southwest reports: "The direct current delivered to the ground beds from the rectifiers will usually have a voltage of from 7 to 20 and generally average about 13 volts. Amperage will vary from 12 to 50 and average about 30 amperes". The ground area protection for one rectifier averages approximately 500,000 square feet. The anode rods for the ground beds are 4 inches in diameter and about 7 feet long. Generally about ten are required for each rectifier, installed vertically in holes from 12 inches to 16 inches in diameter and spaced from 10 to 20 feet apart. Space in the hole surrounding the anode is backfilled generally with material dependent upon type of anode. (See Figure 2).

Whatever the method, galvanic anode or rectifier and anode bed, the entire system should be so designed and constructed that it offers no electrical resistance other than that normally encountered by the metal in the system itself. In other words the cathodically protected system should be isolated from foreign metallic structures.

Cathodic protection need not be limited to gas systems. Its advantages can well be extended to water systems, and hot water generators or tanks. While cathodic protection will reduce electro-chemical reaction to a minimum, it will not prevent leaks in gas lines originating from mechanical damage.

This discussion on corrosion was predicated on the use of steel piping. The argument might be raised as to why cast iron or copper cannot be used, and so obviate the need for elaborate protective devices. Cast iron has been used for large size mains (3 inches and over), but being brittle, this metal tends to crack when installed in filled-in ground subject to movement.

Further, field tests and installations have shown that all ferrous metals corrode at the same rate in the same soil environment. If steel had the same wall thickness as cast iron and both were buried in identical soils, the rate of corrosion would be the same for both ferrous metals. Cast iron, therefore, should not be used for gas lines.

Copper is less subject to corrosive attack than ferrous metals, but is more expensive than steel pipe; its use therefore has been an economic problem in balancing cost of ferrous pipe and protection against added cost of the copper. Also copper is liable to corrosion when placed in soils which yield sulphur dioxide; when used, however, copper should be Type K, hard drawn, with solder fittings.

Some interest is being developed in the use of pipe extruded from an organic plastic. This pipe, light in weight and flexible enough to be bent to follow the path of the trench, is considered an insulator and will not become part of a galvanic couple. But public housing does not have sufficient experience with this pipe to recommend it or advise against its use.

Reduced to simplest terms, the following are believed safe rules to consider in protection of underground gas lines: (a) where resistivity of the soil is less than 3000 ohms per cubic centimeter, cathodic protection should be applied, (b) where resistivity of the soil varies from 3000-10000 ohms per cubic centimeter, cathodic protection may be necessary but further study of soil will be required, (c) where resistivity exceeds 10,000 ohms per cubic centimeter, no cathodic protection is needed, (d) irrespective of soil characteristics, and whether or not cathodic protection is applied, the piping should be coated and/or wrapped.

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Figures 3 and 4 illustrate a method of venting trench in three types of construction. Figure 3 shows venting with (a) crawl space on continuous footing construction and (b) crawl space with grade beam; figure 4 shows venting with slab-on-ground. It should be noted that in each case, the gas line rises above grade before entry into building. The walls of the building serve as barriers, and are parged with waterproofing cement unless walls are solid dense concrete. In warmer climates where check metering is required, the meter may be installed before gas line enters the building. The piping exposed to the outer air should be insulated adequately where the outside temperatures fall below the dew-point temperature of the water vapor in the gas; the local utility will generally furnish information on dew-point temperatures.

Where gas pipe enters a basement pipe, rise above grade will not be necessary, but venting a trench, parging of walls and sealing of sleeve before gas pipe enters building should be provided.

There may be other methods for venting, such as, carrying the gas line before entering the building, concentrically within a tile or cast iron pipe not less than 4 inches diameter, extending a few inches above finished grade. Coarse gravel should fill the vent pipe and, in addition, be arranged similar to that shown on the sketches.

The purpose of the vent is to relieve the trench of any escaping gas, and preclude the probability of gas entering the building. The character of the soil is irrelevant to the need for venting. Whatever the soil, the vent should be installed. The soil covering the gravel should be of a permeable consistency to permit freer flow of escaping gas to the outside air.

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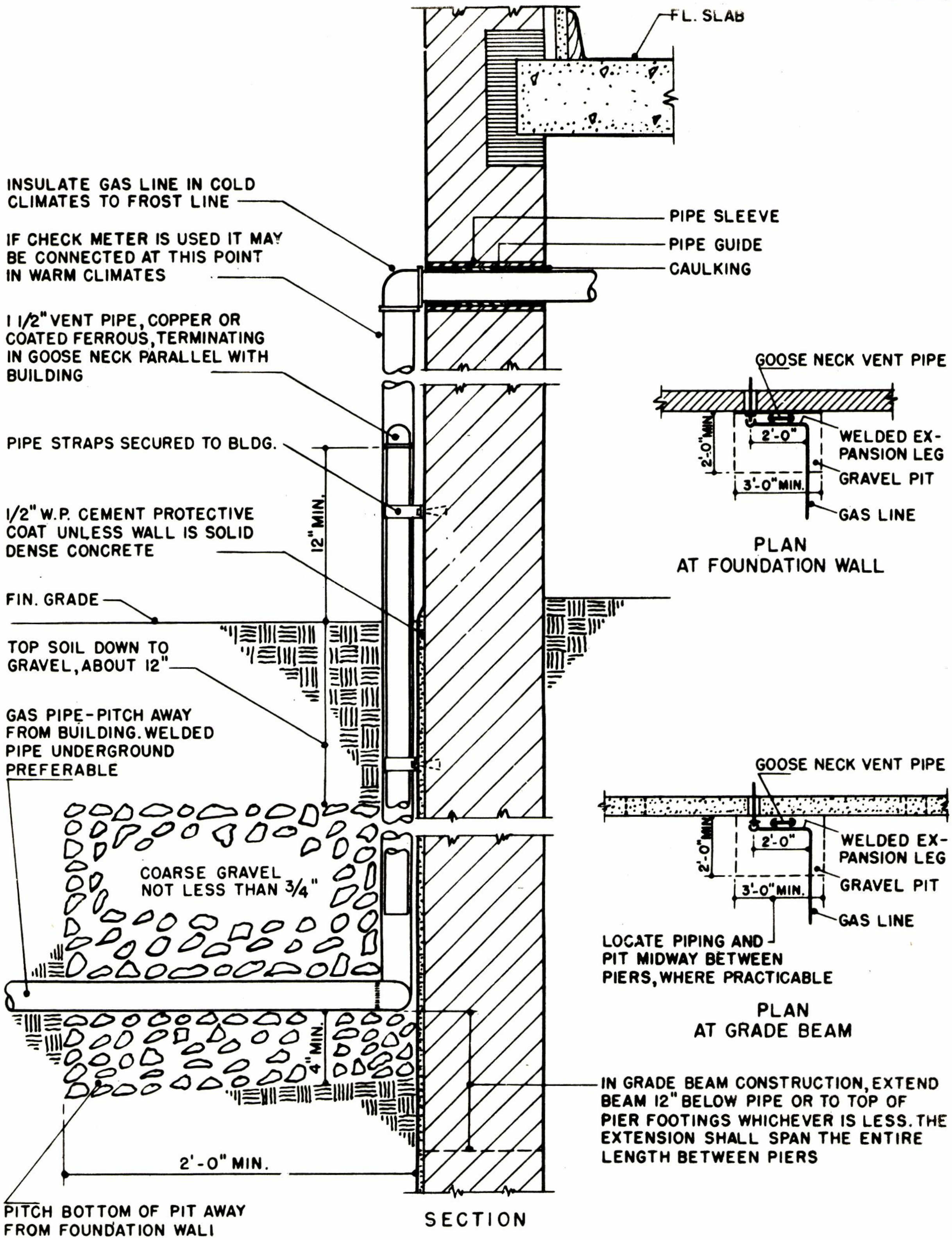
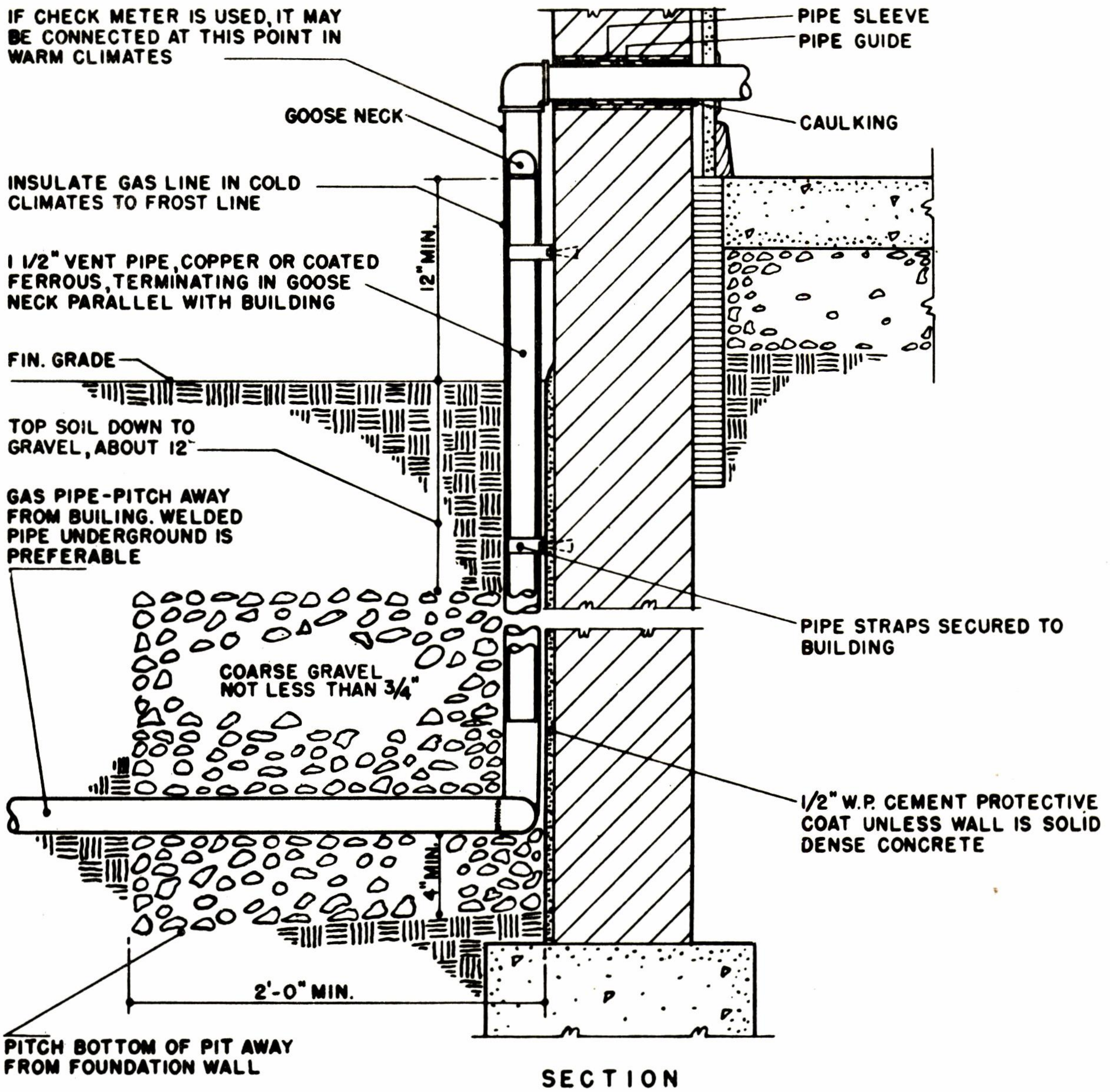


FIGURE 3 METHOD OF VENTING GAS PIPE TRENCH AT BUILDING ENTRANCE WITH CRAWL SPACE CONDITION - 1. WITH CONTINUOUS FOOTING CONSTRUCTION. 2. WITH GRADE BEAM CONSTRUCTION



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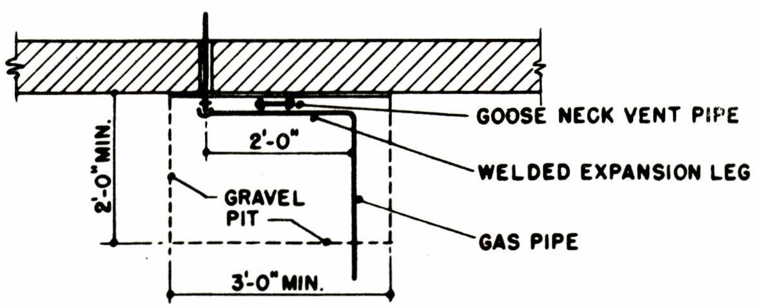

PLAN

FIGURE 4 METHOD OF VENTING GAS PIPE TRENCH AT BUILDING ENTRANCE WITH SLAB ON GROUND CONSTRUCTION

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Gas piping should not be housed in the same trench along with other utility lines. The gas pipe trench should be separate and above all other trenches, below frost line, particularly in manufactured gas installations. When water lines are placed in the same trench with gas piping and then branch away, escaping gas will tend to follow the path of all trenches and may enter the building in as many places as the two utility lines pierce the building wall. With gas piping in a separate trench, the hazards of escaping gas (otherwise following all trench paths) will be reduced, and the gas generally will be confined only to one path. On the other hand, care should be exercised where gas lines cross over other utility services; backfill over the lower line should be tamped hard, preferably with an impermeable material, up to the gas trench. Backfill for the gas trench should be coarse gravel, not less than 3/4" size, extending up to within 6-12 inches of the grade; top soil should be of a permeable structure.

Other methods necessary or helpful for increasing protection are:

a. Running service lines to point of connection with interior system, (generally not over 5 feet from outside building wall) without intermediate joints.

b. Use of Dresser or similar type couplings. If the system is protected from corrosion electrically, it is necessary to have a bonded wire jumper across a coupling to make the electric circuit continuous. Insulating type nipples, couplings or flanges should be used at master meters to isolate the project distribution system from the local utilities' transmission lines, and, at or in buildings, to isolate the interior from the exterior distribution; there should be at least as many points of isolation as there are points of entry into buildings from the underground system.

c. Grouting the opening or tightly packing the annular space between pipe and sleeve, where pipe pierces building wall. Guides installed in the sleeve will help to center the pipe therein. Before entering building, there should be means for expansion to relieve the thrust on the pipe at the point where it pierces the building wall. Other utility lines in the vicinity of the gas line should also be well grouted where they pierce building wall.

d. Selectionalizing piping by accessible valves into a minimum of two sections for small projects, and additional valved sections for larger projects.

e. Valved service for each building, or for each dwelling unit if separate service connections are provided therefor, installed preferably in curb box away from the building. The curb box has the added advantage of venting escaping gas. Omission of such valves has been the source of costly maintenance. The curb cock should be iron body, brass core type. Two dissimilar metals (iron and copper) will permit easier operation of the valve and prevent freezing; galvanic action will not be a serious factor.

f. Draining piping at the low point, but not in buildings.

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g. Welding fittings to be used in greater proportion to screwed joints than has been in the past. In fact, it is preferable that all underground lines be welded. Welding specifications have been issued by code bodies like The American Standards Association and will serve as an excellent guide to engineer and installer. The American Gas Association suggests the "Welding Code for Steel and Wrought Iron Pipe" adopted by the "Heating, Piping and Air Conditioning Contractors" National Association, 1250 Sixth Avenue, New York.

h. Installing curb boxes away from graveled parking areas. A motor vehicle riding over or resting on a curb box will transmit its weight through the box to the pipe at the gas cock connection. Such vibrations or loads have strained or fatigued the connection enough to cause leaks.

5. HOUSE PIPING AND CONNECTIONS. Within the framework of safety and often just as important as adequate protection for the exterior distributing system is the need for the correct installation of gas piping within buildings. There are a few practical and yet simple rules to remember to increase the safety factor. Some of the important rules are listed below, but detailed requirements may be found in regulations promulgated by local jurisdictional bodies.

Piping should be free from sags where condensate may collect and cause operating problems. Well supported piping will preclude such problems. Condensate should only be collected in drain pockets at locations where there is no danger of freezing and where removal into a container or pit is feasible. If at all practicable, drain pockets collecting condensate from the exterior distribution should not be installed within buildings. With the increased use of natural gas (which is drier than manufactured gas), the need for condensate pockets diminishes proportionately.

Where piping must be run in the crawl space under a building, the designing engineer should insist that the space be adequately ventilated, to prevent any possible concentration of gases. Ventilation through crawl space at or near ceiling level is most important. In addition, all openings under the first floor where pipes, ducts or conduits pass through the floor, except for ventilated pipe spaces, must be sealed tightly to prevent gas infiltration into the superstructure. Where gas pipes pass through concrete floors, a steel pipe sleeve should be used, extending at least ¼ inch above the floor.

In the case of slab-on-ground construction, there is no alternative except to require entrance into building above the floor line. The requirement imposes the necessity for as many pipe entries as there are dwelling units in one building, because it may not be possible to distribute the interior piping from one unit to the other, unless there were an attic space through which the distribution could be made. <u>Gas lines should never be run within or be buried beneath a slab-on-ground</u>.

In the case of a crawl space or basement, it is obvious that distribution from unit to unit could be under the first floor level. If the necessary precautions are taken, the crawl space or basement should cease to be a hazard for gas installations. There should be no objection for the pipe to enter each dwelling unit, in twin or row-house construction, provided the outside distribution is patterned to suit individual entry.

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Yet, whether the construction be slab-on-ground or crawl space, the horizontal distribution piping within the building could be run in a well-ventilated attic space of one-story buildings. Rise to attic space may be at one point only, either on the outside or inside of the building. Insulation will be necessary in cold climates where pipe is carried on outside of building.

Venting to the fullest extent practicable, concealed gas piping to the outside air at the top of the concealed space. When the gas piping is concealed in a continuous space with plumbing lines, the whole space should be vented. Where the structure includes a basement or crawl space, the ventilated space should start with an opening at the basement or crawl space. Where the structure includes a slab-on-ground, ventilation should start with an opening directly above the slab in the dwelling unit where the pipe enters the concealed space.

Venting may be through roof terminating with a hood, or through outside wall terminating with a grille and deflector (preventing wind back drafts). If venting is through a pitched roof, and if the gas line is enclosed in a plumbing space, the area of the space may be reduced at the attic level to include only that portion confined to the gas line; an "anti-sweat" insulated duct can then proceed from that point to roof. If venting is through wall, the top of the ventilated space should be sealed, and the grille and reflector located in outside wall directly under top of the space.

The partitions or walls enclosing the ventilation space should be fire resistant at least ½ hour fire rating. Stack action in the ventilation space will be increased if space heating or domestic water heating lines are placed therein.

Piping should be so installed as to be readily accessible with the least damage to building structure. In no event must piping be installed in chimneys, ventilating shafts or other similar locations. Chimneys or flues should not be used for pipe chases.

Branch connections should be taken from the top or side of the main (not from the bottom) so the branch will drain to the main.

Lead or other pipe joint compound will sometimes cause stoppage unless applied to the male thread only, and rather sparingly. Compounds should be resistant to any corrosive action of the gases. Pipe should be protected with two coats of red lead and linseed oil paint.

No high pressure lines should be run into dwelling units. Regulation to low pressure, not over 11 inches water column, should be made before entry into unit.

Devices such as gas saving inserts and patented condensation traps are sometimes specified or installed on gas piping. None of these seem to have the approval of code or regulatory bodies. Unions, if used, should be of the metal-to-metal type with ground joint, and then only installed on exposed piping adjacent to meter or gas burning appliances. Fittings should engage a minimum of five pipe threads.

6. ACCESSORIES AND APPLIANCES. Two important components to a piping system are the meter and the regulating device, the latter controlling the pressure and steady flow of gas. Their correct location and method of installation deserve mention. In many projects the Local Authority will purchase gas under a commercial or wholesale rate structure. Under such purchase schemes, the local utility is expected to supply and install, and be responsible for maintaining the master meter or meters measuring the flow for the entire project. However, tenant check meters are furnished and installed by the Local Authority, and the local utility has no jurisdiction over these meters. In some instances, the location of check meters has been found unsatisfactory and even dangerous. They should not be located under stairs or windows, in unventilated closets, near a furnace, boiler or other heating equipment, in bedrooms or bathrooms, coal bins or ash vaults, shafts or other locations where they will be subject to freezing temperatures or corrosion. Meters may be located under fireproof stairways provided there is ample ventilation, or at any other location where they are readily accessible for reading or repair, within or outside the dwelling, arranged singly or in groups.

In warmer climates where piping may be exposed on the outside building wall, check meters, too, may be located on the outside provided they are adequately housed for weather protection and longer life.

Pressure regulators or governors when controlling the supply of gas for the entire project or for a group of dwelling units within a building may be placed inside the building (but not in any dwelling unit) if vented to the outer air. The vent should be protected, however, so that water, insects or other foreign matter cannot enter the vent pipe. These recommendations, governing the location of the meter, inside or outside the building, should apply for regulators as well. The requirement for choosing an adequately sized regulator is manifest, since it is only by proper regulation of gas flow that the necessary pressures for safe operation can be sustained at the appliances, and fluctuations in pressure avoided. In many cases individual appliances are required to have a regulator, in which event this regulator vent may be extended with open end into the appliance combustion chamber.

The subject of appliance selection and use is broad enough to permit separate discussion, but the cooking range, water heater, furnace or boiler should each bear the label of the American Gas Association. Such label, at least, assures that minimum construction requirements for safety and performance have been met. The requirements are developed in accordance with American Standards Association procedure.

7. TESTING. More important than testing any other piping system is the need for testing the gas system because of the inherent hazards. Local regulations generally specify the pressures and conditions under which tests should be made. Welded piping should be tested to the same requirements for intermediate pressure gas piping, but not less than 50 pounds gage.

Before any gas is turned into the system, it is good practice to make a thorough check (even after successful testing) to insure that there are no openings from which gas may escape, that appliance connections are tight and all gas cocks at appliances are shut. A further satisfactory check for leaks (with all appliance connections closed) is to watch for any movement of the dial in the gas meter. After making sure that the system is tight, the piping should be purged. At this time the meter could be used for checking consumption of a representative burner or burners against the manufacturer's rating.

8. RESPONSIBILITY. The safety factor around which the foregoing is written is a pressing one and intense to its very end. The work imposed upon the designing engineer is challenging and should be unerring. The work imposed upon the installer should be exacting. The work imposed upon the inspector should be unremitting. By meeting this collective responsibility, the ultimate in safety should be reached.

PLUMBING, HEATING AND VENTILATION

PART V - SAFETY CONSIDERATIONS IN THE INSTALLATION OF GAS PIPING

1. INTRODUCTION. The pipework for this fuel is simple, yet there is some tendency to ignore inherent dangers of leakage caused by inadequate design and faulty installations. While there is no information to cause PHA to believe its actual record exceeds that in private industry, there is reason to believe that if known precautions are taken, the risk will become negligible.

Obviously, there is no risk if there were no escape of gas. Leakages may occur outside of building and find their way within closed spaces by following pipelines or by soil permeation until a point of entrance is found, or the leakages may occur within the structure itself. Leakages may occur from mechanical breaks or from disintegration (corrosion) of the pipe. Hence, it follows that: (a) the pipe work should be so installed that the chances of mechanical breakage are reduced to the minimum; (b) the pipe should be of such nature and so installed and protected that the effects of corrosive actions are mitigated; (c) the gas system should be isolated, electrically and physically, from the other utility systems; (d) gas pipe should enter structure above grade; and (e) interior building spaces which conceal gas piping should be vented.

The herein recommendations from experiences in public housing projects are sufficiently general in scope not to conflict with local policies which are in accord with safe practices. Some recommendations will, no doubt, be found in standards and regulations issued by the American Standards Association (Pamphlet, ASA, Z21.30) and utility companies, but it is the purpose here to emphasize those items which affect safety. Recommendations generally should apply equally to liquefied petroleum gases as well as to natural and manufactured gases. Specific requirements for the storage and handling of heavier than air petroleum gases are defined in the National Board of Fire Underwriters' Pamphlets Nos. 58 and 59.

2. CORROSION. The definition of corrosion, its forces, and the mechanics of its control have been comprehensively identified in the Local Housing Authority Handbook, Part V, Section 7, "Maintenance of Underground Utilities," prepared by the Maintenance Engineering Branch of PHA. Reference should be made to this Handbook Section. For purposes of identification here, mechanical protection of piping means coating and wrapping of both pipe and fittings; electrical or cathodic protection of piping means protection by the sacrificial anode method or the rectifier method. All of the above are explained in the Handbook Section.

NOTE: This part supersedes Part V of Bulletin No. LR-7, pages 1-6, 9-15 dated 4-24-50, and pages 7-8 dated 3-22-51. It has been revised throughout.

Specialized technical skill is needed to resolve both technical and economic problems with which the whole subject of protection is concerned. In some localities, where the soil is uniformly sandy and of high resistivity to the current flow, mechanical protection may be the only means needed to resist corrosion; and there will be localities where mechanical and electrical protection will be required.

For example, a serious condition found to have accelerated corrosion is the installation of unprotected mains in (a) ground water; (b) moist ground where the water level changes constantly; (c) corrosive soils of low resistivity or filled-in areas; (d) use of different metals without separation by insulating fittings; and (e) less frequently, in ground near street car lines or within stray current areas from nearby industrial plants.

Local utilities have devised various ways of protecting their distribution lines mechanically. They should be prepared to advise local engineers or Local Authorities on the efficacy of one protective method over another, and to offer the benefits of their experience on corrosive actions on metal pipe buried in the soil. Types of coatings and wrappings have been used successfully in varying degrees and are described in the above-mentioned Handbook Section, and in Low-Rent Manual Section 207.1.

Cinders or rubbish should not be used for any backfill. In grounds within proximity of streetcar lines or other stray current sources, the pipe should be grounded to the source of current if at all practicable.

Mechanical protection should be complete, and care in handling the pipe during installation should be intensive. A coated and wrapped pipe is only as good as its weakest point, where it may be left unprotected. Incomplete protection or damage to coating and wrapping will leave "holidays" which are subject to severe corrosive attack. Also, isolation (discussed elsewhere in this Bulletin) is required to reduce the probabilities of electrical contact between the gas and water systems or other metallic installations. The better the pipe protection, the less electrical energy will be required to effect cathodic protection which is relatively inexpensive to install and will minimize both hazard and operating expense. Further, the better the pipe treatment, the greater is the protection afforded against exposure of flaws in the pipe to corrosive elements in the soil.

This discussion has been predicated on the use of steel pipe. Questions may be raised as to why other materials cannot be used, and so obviate the need for elaborate protective devices.

Cast iron, owing to its greater thickness, has a longer life than steel without cathodic protection, but has been comparatively little used for gas lines in public housing because, in most projects, the major part of the piping is small size, not obtainable in cast iron. Further, cast iron is more susceptible to fracture than steel, and should not be used in lines laid in unstable ground.

Copper is less subject to corrosive attack than ferrous metals, but is more expensive than steel pipe; its use for gas, therefore, has been an economic problem in balancing cost of ferrous pipe and protection against added cost of the copper. Also, copper is liable to corrosion when placed in soils which yield sulphur dioxide.

Plastic pipe of organic chemical compound, and of structure suited to the intended service has been given increasing and progressive consideration. Electrically inert, it needs no mechanical protection and is not subject to corrosion. Before this material is used, opinion should be determined locally from the utility company, and permission should be secured from the code body if not included in the regulations.

Reduced to simplest terms, the following are believed safe rules to consider in protection of underground gas lines: (a) where resistivity of the soil is less than 2000 ohms per cubic centimeter, cathodic protection should be applied; (b) where resistivity of the soil varies from 2,000-10,000 ohms per cubic centimeter, cathodic protection will usually be required; (c) where resistivity exceeds 10,000 ohms per cubic centimeter, cathodic protection may be required, but further study of the soil is advisable; (d) regardless of soil characteristics, and whether or not cathodic protection is applied, the piping must be coated and wrapped as per PHA requirements.

In somewhat contradiction to the above, it is generally not advisable to install a cathodic protection system simultaneous with laying the pipes in the ground, because of the variable factors influencing the need of such protection, such as, the type of soil, the amount of grading, the type of backfill, and the position and relation of the different utility pipes in the ground. By proper instrumentation after completion, the need for, and the correct amd economical method of, cathodic protection can be accurately determined, rather than guess what the needs might be during the design and construction stages. To facilitate these measurements, leads should be welded to pipe at strategic locations, and brought to the surface in test boxes to permit readings with the copper sulphate half cell and high resistance volt-meter.

The copper sulphate half cell together with the high resistance voltmeter will determine the pipe-to-soil potential, indicating the degree of protection, or whether corrosion of the pipe is taking place. The degree of soil resistivity measurements will determine what type (sacrificial anode or rectifier system) is the correct method to apply. Various types of instruments are available to determine soil resistivity. Sacrificial anodes should be given preference if they are practically and economically feasible.

3. <u>PROTECTING BUILDINGS AGAINST OUTSIDE GAS LEAKS</u>. In cases where leaks have occurred from corrosion or mechanical breaks in the distribution main or in the main serving a building, escaping gas travelled the path of the pipe trench to spaces under the building, then up to the dwelling unit. Such leaks may go unnoticed until it is too late. A momentary flash caused by a match, pilot, open flame, or electric spark is sufficient to cause an explosion.

Gas should never be allowed to collect in confined areas such as crawl spaces, pipe spaces, or utility rooms. Ignition may be in a dwelling unit, not necessarily in the area where the gas has accumulated. A flame tends to build force as it spreads, and compresses the gas ahead until the mixture becomes explosive. Explosion damage, many times, is greatest at locations away from the origin of the flame and generally occurs with maximum intensity when the gas concentration has reached the highest point within its range of inflammability.

So important is the need to minimize the entry of a gas leak within building spaces from the outside that the means for entering a structure above grade now contained in Manual Section 207.1 is expected to be strengthened by the following:

> Insulating fittings shall be installed in ferrous gas service lines prior to take-off of any connections, preferably on the service side of the meter. When natural or liquefied petroleum gas is to be supplied, service connections from outside gas lines shall rise above grade before entering a crawl space or basement of a structure. Where the first floor is slab-on-grade, such gas piping shall enter the structure above the first floor slab. When manufactured or mixed gas is to be supplied, service connections may enter the crawl space or basement without rising above grade. Where the first floor is slab-on-grade, such gas piping shall enter the structure above the first floor slab and shall be adequately protected against freezing temperatures, and damage to insulation.

Gas piping should not be housed in the same trench with other utility lines. The gas pipe trench should be separate and above all other trenches, and below frost line. With gas piping in a separate trench, the hazards of escaping gas (otherwise following all trench paths) will be reduced, and the gas will be confined only to one path.

Other methods necessary or helpful for increasing protection are:

a. Running service lines to a point of connection with interior system, (generally not over five feet from outside building wall) without intermediate joints.

b. Use of flexible type couplings. Except for welded joints, all joints as per PHA requirements, must be electrically bonded, to make project gas system electrically continuous. In addition to insulating fittings at master meters to isolate the project distribution system from the utility company's transmission lines, insulating fittings, at or in buildings, should isolate the underground gas from the water distribution system. There should be at least as many points of isolation as there are points of entry into buildings from the underground gas system.

c. Grouting the opening or tightly packing the annular space between pipe and sleeve, where pipe pierces building wall, and centering the pipe within the sleeve. Before entering building, there should be means for expansion to relieve the thrust on the pipe at the point where it pierces the building wall. Other utility lines in the vicinity of the gas line should also be well grouted where they pierce building wall.

d. Selectionalizing piping by accessible valves into a minimum of two sections for small projects, and additional valved sections for larger projects.

e. Coating and wrapping of the pipes and fittings (even if cast-iron or copper) as per PHA requirements when insulating fittings are used on underground piping. The coating and wrapping should extend for a minimum distance of 12 inches in all directions from the insulating fitting.

f. Valved service for each building, or for each dwelling unit if separate service connections are provided therefor, installed preferably in curb box away from the building. The curb box has the added advantage of venting escaping gas. Omission of such valves has been the source of costly maintenance. The curb cock should be iron body, brass core type. Two dissimilar metals (iron and copper) will permit easier operation of the valve and prevent freezing; electrochemical action because of two dissimilar metals will not be a serious factor.

g. Draining piping at the low point, but not in buildings.

h. Welding joints in preference to screwed joints. In fact, it is preferable that all underground lines be welded. Welding specifications have been issued by code bodies like the American Standards Association and will serve as a guide to engineer and installer.

i. Installing curb boxes away from graveled parking areas. A motor vehicle riding over or resting on a curb box will transmit its weight through the box to the pipe at the gas cock connection. Such vibrations or loads have strained or fatigued the connection enough to cause leaks.

4. HOUSE PIPING AND CONNECTIONS. There are a few practical rules to remember to increase the safety factor. Some of the important rules are listed below, but detailed requirements may be found in regulations issued by the American Gas Association and by local jurisdictional bodies.

Piping should be free from sags where condensate may collect. Well-supported piping will preclude such problems. Condensate should only be collected in drain pockets at locations where there is no danger of freezing and where removal into a container or pit is feasible. If at all practicable, drain pockets collecting condensate from the exterior distribution should not be installed within buildings. With the increased use of natural gas (which is drier than manufactured gas), the need for condensate pockets diminishes proportionately.

Where piping must be run in the crawl space, the design engineer should insist that the space be adequately ventilated (see Manual Section 207.1) to prevent any possible concentration of gases. In addition, all openings under the first floor where pipes, ducts,or conduits pass through the floor, except for ventilated gas pipe spaces, should be caulked tightly to prevent gas infiltration into the superstructure. Piping should not be run within or buried beneath a slab-on-ground. In such construction, and in row houses with pitched roof, distribution piping from one dwelling unit to another (if gas pipe entry from outside is at one point only) can be run in a well-ventilated attic space.

Concealed gas piping should be vented to the outside air at the top of the concealed space. When the gas piping is concealed in a continuous space with plumbing lines, the whole space should be vented. Where the structure includes a basement or crawl space, the ventilated space should start with an opening at the basement or crawl space. Where the structure includes a slab-on-ground, ventilation should start with an opening directly above the slab in the dwelling unit where the pipe enters the concealed space.

Main distribution piping should be so installed as to be readily accessible with the least damage to building structure. In no event must piping be installed in chimneys, ventilating shafts, or other similar locations. Chimneys or flues should not be used for pipe chases.

Branch connections should be taken from the top or side of the main, so the branch will drain to the main.

No high pressure lines should be run into dwelling units. Regulation to low pressure, not over 11 inches water column, should be made before entry into unit.

Devices such as gas saving inserts and patented condensation traps are sometimes specified or installed on gas piping. Careful check by the design engineer should be made to determine whether such devices are approved by local or regulatory bodies.

5. ACCESSORIES AND APPLIANCES. Two important components to a piping system are the meter and the regulating device, the latter controlling the pressure and steady flow of gas. Their correct location and method of installation deserve mention. In many projects the Local Authority will purchase gas under a commercial or wholesale rate structure. Under such purchase schemes, the local utility is expected to supply and install, and be responsible for maintaining the master meter or meters measuring the flow for the entire project. However, tenant check meters are furnished and installed by the Local Authority. They should not be located under stairs or windows; in unventilated closets; near a furnace, boiler,or other heating equipment; in bedrooms or bathrooms; coal bins or ash vaults; shafts; or other locations where they will be subject to freezing temperatures or corrosion. Meters may be located under fireproof stairways provided there is ample ventilation, or at any other location where they are readily accessible for reading or repair, within or outside the dwelling, arranged singly or in groups.

In warmer climates where piping may be exposed on the outside building wall, check meters, too, may be located on the outside provided they are adequately housed for weather protection and longer life.

Pressure regulators when controlling the supply of gas for the entire project or for a group of dwelling units within a building may be placed inside the building (but not in any dwelling unit) if vented to the outer air. The vent should be protected, however, so that water, insects, or other foreign matter cannot enter the vent pipe. The recommendations, governing the location of the meter, inside or outside the building, should apply for regulators as well. The requirement for choosing an adequately sized regulator is manifest, since it is only by proper regulation of gas flow that the necessary pressures for safe operation can be sustained at the appliances, and fluctuations in pressure avoided. In many cases individual appliances are required to have a regulator, in which event the regulator vent may be extended with open end into the appliance combustion chamber.

The subject of gas appliance selection and use is broad enough to permit separate discussion, but, for general information here, the cooking range, domestic water heater, furnace or boiler, and other gas appliances should comply with the standards of the American Gas Association. Its label affixed to the appliance at least assures that durable and substantial construction requirements for safety and performance have been met. The requirements are issued in accordance with the American Standards Association procedure, and have their approval.

6. TESTING. The piping should be purged after specified tests have been successfully completed. Before any gas is turned into the system, it is good practice to make a thorough check (even after successful testing) to ensure that there are no openings from which gas may escape, that appliance connections are tight and all gas cocks at appliances are shut. A satisfactory check for leaks (with all appliance connections closed) is to watch for any movement of the dial in the gas meter. At this time the meter could be used for checking consumption of a representative burner or burners against the manufacturer's rating.

7. RESPONSIBILITY. The safety factor around which the foregoing is written is intense to its very end. The work imposed upon the design engineer should be unerring. The work imposed upon the installer should be exacting. The work imposed upon the inspector should be unremitting. By meeting this collective responsibility, the ultimate in safety should be reached.

PLUMBING, HEATING AND VENTILATION

PART VI - PLUMBING CODES

The installation of domestic plumbing systems is closely related to a fundamental objective of public housing: providing low-rent dwellings with due regard to safety, sanitation, health and economy. It may properly be said that PHA low-rent housing construction has met these objectives with a relatively high degree of success, but experience has demonstrated that further advances are possible in the installation of satisfactory plumbing systems at decreased initial cost and lower annual operating expenses.

Current research in various phases of household plumbing will undoubtedly increase the store of basic information and point the way to more economical plumbing design, but the greatest present need seems to be the adaptation of current knowledge into usable form and the acceptance of the resulting simplified rules as a basis for correct uniform practice.

Simplified plumbing practice recommendations are presented in Report BH 13 of the National Bureau of Standards 1/, in the more recent Report of the Uniform Plumbing Code Committee 2/, and in the American Standard Association Plumbing Code 3/. There is a definite effort underway to promote further acceptance of uniform simplified practices through a National Plumbing Code being prepared by the National Plumbing Code Committee, sponsored by the U.S. Department of Commerce and the Housing and Home Finance Agency.

1. BASIC PRINCIPLES OF PLUMBING.

The goal of environmental sanitation is to prevent faulty plumbing installations which may cause outbreaks of disease of localized or epidemic proportions; this is obtained through properly designed, acceptably installed, and adequately maintained plumbing systems. The principles for such design, installation, and maintenance may be stated as follows:

1/ Recommended Minimum Requirements for Plumbing BH 13, National Bureau of Standards, 1932. Available from the Superintendent of Documents, Washington, 25, D.C. Price 75 cents.

2/ Report of the Uniform Plumbing Code Committee, U.S. Department of Commerce and Housing and Home Finance Agency, 1949. Available from the Superintendent of Documents, Washington 25, D.C. Price 40 cents.

3/ American Standard Association Plumbing Code, ASA A40.7-1949. Sponsored by American Public Health Association and American Society of Mechanical Engineers. Available from the American Society of Mechanical Engineers, 29 West 39th Street, New York, New York.

a. Premises intended for human habitation should be provided with an adequate supply of pure and wholesome water, which should not be connected with unsafe water supplies or be subject to the hazards of backflow or back-siphonage.

b. Water for plumbing fixtures and devices should be supplied in sufficient volume and at pressures adequate to enable the fixtures to function satisfactorily and without undue noise under all normal conditions of use, but such volumes and pressures should not be so excessive as to result in wasteful use of water.

c. Devices for heating and storing water should be designed and installed to prevent all dangers from explosion through overheating.

d. Plumbing fixtures should have smooth, non-absorbent surfaces, be free from concealed fouling surfaces, and have long life-expectancy.

e. Drainage systems should be designed, constructed and maintained so as to prevent fouling, deposit of solids and clogging; be free from defective workmanship, and give satisfactory service for a reasonable expected life.

f. Underground water supply piping and drainage piping should be installed in separate trenches, unless the joints of both water supply and drainage piping possess the strength and durability to remain leak-proof, and unless the bottom of the water supply piping is at least 12 inches above the top of the drainage line at all points.

g. Circulation of air in the drainage system should be adequate throughout to prevent danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use.

h. Spacing of plumbing fixtures should be such that the fixtures are reasonably accessible for their intended use.

i. Testing of piping systems should be such that the tests will effectively disclose all leaks and defects in the work.

j. Maintenance of water supply, drainage and sewage disposal systems should be such that the systems will remain sanitary and serviceable.

2. LOCAL CODES.

Plumbing codes are usually promulgated by local authorities for use in a limited area. Because of their origin, individual requirements of the various codes will differ in a greater or lesser degree. Minor differences in regulations in different parts of the country may sometimes be justified by variations in climate or other local conditions, but many of the radical deviations, found even in the codes of the municipalities of a single state, are unjustifiable. It seems obvious that prejudice in favor of some particular method of construction has brought about many of these differences. The plumbing installations of low-rent public housing projects built in areas that are within the jurisdiction of a particular plumbing code must, of course, comply with the requirements of that code, and with any additional requirements contained in the PHA Minimum Physical Standards. However, where requirements of the codes are believed to invoke needless expense, efforts should be made to obtain waivers of such provisions, in the interest of obtaining a better system with greater economy. Items such as grease traps, house traps, priming systems for floor drain traps, and similar features are generally unnecessary, and should be eliminated wherever possible.

3. UNIFORM PLUMBING CODE.

Many local governments have adopted the simplified practices recommended by Government publications and various standards associations, and it is expected that more will do so. The Report of the Uniform Plumbing Code Committee is in the form of a proposed "Uniform Plumbing Code" and includes a section on administration which can be used as a guide in framing an enacting ordinance. Any community which wishes to adopt this Uniform Plumbing Code for local use can do so in the knowledge that the elements of this Code are based on legal principles, the application of modern scientific knowledge, and the lessons gained through practical experience.

In areas where no plumbing code exists or where local codes are obviously inadequate, it is urged that the contract Specifications specifically state that all plumbing work must conform with the Uniform Plumbing Code as issued by the Department of Commerce and the Housing and Home Finance Agency, July 1949. In addition, the plumbing piping layout shown on the contract Drawings should be based on the simplified practices advocated by this Code, the fullest utilization of which will insure a safe, economical, and easily maintained system. (Subsequent PHA bulletins, based on the recommendations of the Uniform Plumbing Code or any later information that becomes available will be issued on various phases of simplified plumbing practice and design.)

PLUMBING, HEATING AND VENTILATION

PART VI - PLUMBING CODES

The installation of domestic plumbing systems is closely related to a fundamental objective of public housing: providing low-rent dwellings with due regard to safety, sanitation, health, and economy. It may properly be said that PHA low-rent housing construction has met these objectives with a relatively high degree of success, but experience has demonstrated that further advances are possible in the installation of satisfactory plumbing systems at decreased initial cost and lower annual operating expenses.

Current research in various phases of household plumbing will undoubtedly increase the store of basic information and point the way to more economical plumbing design. New materials, notably plastics, have appeared in the plumbing industry and it is to be assumed that after such materials have been proven acceptable, they will be incorporated into plumbing installations.

1. BASIC PRINCIPLES OF PLUMBING.

The goal of environmental sanitation is to provide plumbing installations to protect the health of people; this is obtained through properly designed, acceptably installed and adequately maintained plumbing systems. The principles for such design, installation, and maintenance may be stated as follows:

a. Premises intended for human habitation should be provided with an adequate supply of pure and wholesome water, which should not be connected with unsafe water supplies or be subject to the hazards of backflow or backsiphonage.

b. Water for plumbing fixtures and devices should be supplied in sufficient volume and at pressures adequate to enable the fixtures to function satisfactorily and without undue noise under all normal conditions of use, but such volumes and pressures should not be so excessive as to result in wasteful use of water.

c. Hot water shall be supplied to all plumbing fixtures which normally need or require hot water for their proper use and function.

d. Devices for heating and storing water should be designed and installed to prevent all dangers from explosion through overheating.

e. Plumbing fixtures should have smooth, nonabsorbent surfaces, be free from concealed fouling surfaces, and have long life-expectancy. Each family dwelling unit shall have at least one water closet, one lavatory, one bathtub or shower and one kitchen sink or kitchen sink and laundry tray combination type fixture to meet basic requirements of sanitation and personal hygiene.

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f. Drainage systems should be designed, constructed, and maintained so as to prevent fouling, deposit of solids, and clogging; and with adequate cleanouts so arranged that pipes may be readily cleaned. The piping shall be of durable material, free from defective workmanship and so designed and constructed as to give satisfactory service for its reasonable expected life.

g. Each fixture directly connected to the drainage system shall be equipped with a liquid-seal trap.

h. The drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use.

i. Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building.

j. All plumbing fixtures shall be so installed with regard to spacing as to be accessible for their intended use and cleansing.

k. Where a plumbing drainage system is subject to backflow of sewage from the public sewer, suitable provision shall be made to prevent its overflow in the building.

l. Where plumbing fixtures are installed in buildings where there is no public sewer, suitable provision shall be made for disposing of the sewage by some accepted method of sewage treatment and disposal.

m. Provide separate trenches for underground drainage piping and water supply piping, with a minimum of 3 feet of undisturbed earth between trenches. In locations, close to buildings, where separate trenches are impracticable, lay the water pipe on a shelf 12 inches above top of drainage pipe.

n. No water closet or similar fixture shall be located in a room which is not properly lighted and ventilated.

o. Plumbing shall be installed with due regard to preservation of the strength of structural members and prevention of damage to walls and other surfaces through fixture usage.

p. The plumbing system shall be subjected to such tests as will effectively disclose all leaks and defects in the work or the material.

2. LOCAL CODES.

Plumbing codes are usually promulgated by Local Authorities for use in a limited area. Because of their origin, individual requirements of the various codes will

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differ in a greater or lesser degree. Minor differences in regulations in different parts of the country may sometimes be justified by variations in climate or other local conditions, but many of the radical deviations, found even in the codes of the municipalities of a single state, are unjustifiable. It seems obvious that prejudice in favor of some particular method of construction has brought about many of these differences. The plumbing installations of low-rent public housing projects built in areas that are within the jurisdiction of a particular plumbing code must, of course, comply with the requirements of that code, and with any additional requirements contained in the PHA Standards for Planning and Design. However, where requirements of the codes are believed to invoke needless expense, efforts should be made to obtain waivers of such provisions, in the interest of obtaining a better system with greater economy. Items such as grease traps, house traps, priming systems for floor drain traps, and similar features are generally unnecessary, and should be eliminated wherever possible.

3. NATIONAL PLUMBING CODE.

The American Standard Association's "National Plumbing Code," ASA A40.8 represents the consensus of national organizations for a standard of uniform plumbing practice suitable for State and local application. Since its issuance in 1955, it has been particularly useful to cities and municipalities as an authoritative guide in revising and up-dating their standards on plumbing installations. This code is founded upon certain basic principles of environmental sanitation and safety through properly designed, acceptably installed, and adequately maintained plumbing systems. This code sponsored by American Public Health Association and American Society of Mechanical Engineers is available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017. The American Standard Association recognized the need for periodic revision of the Standard to keep pace with research findings and material developments and there is a definite effort underway to up-date this Standard.

Any community which wishes to adopt the National Plumbing Code for local use can do so in the knowledge that the elements of this Code are based on the application of modern scientific knowledge and lessons gained through practical experience. In areas where no plumbing code exists or where local codes are obviously inadequate, it is urged that the contract Specifications specifically state that all plumbing work must conform to the National Plumbing Code. In addition, the plumbing piping layout of contract drawings should be based on simplified practices advocated by this Code, the fullest utilization of which will insure a safe, economical, and easily maintained system.

PLUMBING, HEATING AND VENTILATION

PART VII - PREVENTION OF WATER SUPPLY POLLUTION IN BUILDINGS

Most communities have ordinances or codes regulating the installation of plumbing. However, many of these plumbing codes were enacted many years ago, before it was generally realized that defective or improperly installed plumbing piping or equipment could cause pollution of the water supply within a building. Research during the past decade and experience in complex modern plumbing installations have brought forth much new knowledge on the causes of pollution within buildings, and application of this knowledge to particular installations should result in safer and more economical systems.

The correct design and installation of a plumbing system is most important in any type of building, but particularly so in the buildings of a housing development which consists of a concentrated and interrelated group of family dwellings. The possibility of water pollution from faulty plumbing connections and fixtures, or from the incorrect use of such fixtures, constitutes a serious health hazard for the many residents in the development.

The most common disease-carrying organisms found in polluted water are those organisms that cause typhoid fever, bacillary dysentery, amebic dysentery or any of several other gastroenteritic disturbances. While sufficient amounts of residual chlorine in the water will probably destroy most of these bacteria, that type causing amebic dysentery will not be destroyed while it is in its cyst stage, except by boiling the water or a concentration of bichloride of mercury not desirable in a potable water.

Cases of water pollution have been reported from many projects constructed during the past ten years, and it is highly probable that almost all of these cases could have been prevented if more care had been taken in the design and installation of the plumbing system. This bulletin, therefore, directs attention to the pollution possibilities that exist in plumbing systems. The subject is a serious one, as is evidenced by the fact that reports from U.S. Public Health authorities indicate the weekly occurrence of 60 to 100 cases of amebic dysentery and about twice that many cases of dysentery each week which are "unspecified" as to type.

1. CAUSES OF WATER POLLUTION IN BUILDINGS.

A cross-connection is any physical connection or arrangement of pipes between two water-piping systems whereby water may flow from one system to the other. A cross-connection becomes a hazard to health when one system carries a potable water and the other contains water of unknown or questionable quality which can contaminate the potable water. Contamination of the safe water supply may be effected under either of the following conditions:

a. A direct connection, whereby safe and unsafe water are separated by a piped connection and a valve.

b. An indirect connection, whereby the completion of the cross-connection is dependent on a change in normally existing conditions.

In general, when a building contains only one water supply system, a vacuum (or drop in water pressure) must occur in this system before water from another source can flow into it. Such a vacuum may be caused by any of the following conditions within the system:

a. Water hammers, setting up waves of positive and negative pressure.

b. Formation of water vapor in parts of the system (usually in pocketed portions of the piping) and condensation of this vapor.

c. Flow of water past localized restrictions (due to corrosion or caking of the interior of the piping, or to improper workmanship in assembling the piping) resulting in pressure drops at the restrictions.

d. Draining water from the system.

When back flow occurs, the unsafe or polluted water may be distributed throughout an entire building, especially if the vacuum is caused by the action of a fixture on a lower floor of the building. If large quantities of water are being used, or if part of the street main has been shut off and drained, the pollution may extend as far back as the main.

Since a vacuum may occur even in carefully designed systems, the obvious safeguard would be to avoid the installation of cross-connections and to correct any such connections already in place. However, in all types of plumbing systems, there exist many possibilities of cross-connections, particularly those that result from submerged outlets, and it would be virtually impossible to eliminate all of them. The designer should be thoroughly aware of the dangers of back-siphonage and of the means to prevent such back flows whenever a vacuum does occur in the supply system; and he should make certain that proper measures are taken to prevent the possibilities of pollution at these connections.

2. METHODS OF PREVENTING BACKFLOW AT FIXTURES.

Air gaps at supply outlets and vacuum breakers in the supply piping are the usual means for providing back-siphonage protection at fixtures. An air gap is the free unobstructed vertical distance between the lowest opening from any pipe or faucet supplying water to a fixture and the flood level rim of the receptacle of the fixture. The minimum required air gap should be twice the diameter of the effective opening, but in no case less than the distance specified in the following:

Minimum Air Gaps for Generally Used Plumbing Fixtures

	Minimum Air Gaps, inches	
	When not affected by nearby vertical surface. 1/	When affected by nearby vertical surface. 2/
Lavatories with effective openings not greater than 1/2 inch diameter....	1.0	1.50
Sinks, laundry trays, and gooseneck bath faucets with effective openings not greater than 3/4 inch diameter....	1.5	2.25
Overrim bath fillers with effective openings not greater than 1 inch diameter............................	2.0	3.00
Effective openings greater than 1 inch	Twice the effective opening.	3 times the effective opening

1/ Vertical surfaces do not affect the air gaps when spaced from inside edge of spout opening, a distance greater than 3 times the diameter of the effective opening for a single surface, or a distance greater than 4 times the diameter of the effective opening for 2 intersecting surfaces.

2/ Vertical surfaces extending from the water level to or above the horizontal plane of the spout opening require a greater air gap when spaced closer to the nearest inside edge of spout than specified in note 1 above. The effect of 3 or more such vertical surfaces has not been determined. In such cases the air gap should be measured from the top of the surfaces to the spout opening.

When an air gap between the fixture and the supply outlet is impracticable or undesirable, a vacuum breaker can be installed in the piping between the fixture control valve and the outlet to the fixture. The function of the vacuum breaker is to introduce air at atmospheric pressure into the supply piping whenever the pressure inside the piping drops below that of the atmosphere. For each different model there is a definite minimum limit to the distance which the device may be set above the top of the flood rim of the fixture and still be completely effective in preventing back-siphonage. An adequate vacuum breaker should have the following characteristics:

a. It should not permit water to rise more than 1 inch above the supply outlet under any vacuum conditions.

b. It should be so constructed that the air intake openings can be inspected visually at all times.

c. All parts should be non-corrosive, and water characteristics should not affect their operation.

d. The air intake should always be open to the atmosphere, except when water is flowing through the supply outlet.

e. It should not reduce the flow of water to the supply outlet.

f. It should function effectively when installed on the discharge side of the controlling valve of the fixture.

3. THE WATER CLOSET.

The water closet is the fixture most likely to be the cause of polluting the water supply system. Any closet bowl which is made with a direct submerged inlet, such as the side inlet bowl, should not be permitted in dwellings. For closet bowls used in combination with tanks, the danger arises from pollution of the tank contents by backflow from the bowl, and subsequent back-siphonage of the tank contents through the ballcock of the submerged tank inlet into the water supply. Contamination of the water in the tank will depend on the height of the bottom of the tank in relation to the height of the flood rim of the bowl. In the case of the one-piece combination tank and closet where the tank is integral with the bowl, and also for the close-coupled tank where the bottom of the tank is below the rim of the bowl, all that is necessary for tank pollution is a stoppage of the bowl and simultaneous operation of the tank valve mechanism. This will cause some of the contents of the bowl to overflow into the tank. A tank whose bottom is above the rim of the bowl would not be polluted in this way. However, it should be realized that any closet tank can be contaminated by backflow from a polluted tank on a higher floor whenever a vacuum occurs in the water supply system, and the ballcocks in each tank are not protected from back-siphonage.

It is, therefore, obvious that all tanks for water closets should unquestionably be provided with back-siphonage protection by either of the following provisions:

a. A water supply outlet discharging at least 1 inch above the overflow level.

b. A vacuum breaker placed above the overflow level.

The air gap arrangement is not as desirable as the vacuum breaker because of the noise of the water splash, and because the safe air gap may be reduced. In either arrangement the cover of the tank should not be so tightfitting that the difference in pressure between the air in the tank and the room atmospheric pressure will equal 1/2 inch of water, since if this occurs, both the air gap and the vacuum breaker within the tank would become ineffective.

For water closets with flush valves or for any other similar types of fixture with flush valves (such as flush-rim urinals, bedpan washers, and similar devices), a vacuum breaker is not only desirable but essential, since back-siphonage can occur under a very small vacuum.

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4. OTHER FIXTURES.

The water closet is not the only plumbing fixture that can pollute the water supply. However, the potential contamination from this source is greater than from other fixtures. Most modern fixtures and their trim incorporate a safe air gap, or provide for a vacuum breaker, but there remain numerous possibilities for cross-connections.

In this connection only such drinking fountains as meet the requirements of the United States Public Health Service should be considered acceptable. All drinking fountain nozzles with orifice diameters of 7/16 inch or less should extend at least 3/4 inch above the flood level rim of the receptacle to provide a safe air gap.

5. APPENDAGES TO FIXTURES.

Probably one of the greatest causes of dangerous cross-connections results from changes and additions made by inexperienced individuals who are not acquainted with the safeguards necessary to maintain a safe system. Tenants, as a rule, do not know that by placing an addition to a fixture, there is created a possible source of contamination for themselves as well as for others. One of the most common attachments is the hose connection made to a bathtub spout for use as a spray shower. This type of attachment is particularly prevalent in public housing projects where overhead showers are not usually provided. The cross-connection occurs when the spray head is allowed to remain at the bottom of a tub partially filled with water, instead of being removed or hung above the tub to drain. The same sort of cross-connection can occur when the dish-spraying hose of a kitchen sink is allowed to dip below the water level in the sink, but since this hose spray is normally held at the faucet level when not being used, this danger is not quite as serious as the tub spray.

Hose connections to washing machines constitute a similar hazard; such connections should not be made unless adequate protection has been provided by means of vacuum breakers within the machines or at the connections to the water piping.

6. DRAINS AND DRAIN CONNECTIONS.

Many plumbing codes require that a floor drain be provided with a water supply connection to maintain the trap seal. Such a connection should be so hooked-up that back-siphonage from the drain is impossible; hence a vacuum breaker between the controlling supply valve and the piping to the drain is a definite necessity. Similarly, the water connection used to prime a pump is subjected to this danger and requires the same protection.

A common practice is to connect the discharge from various types of condensers directly into the drainage system. Such connections are subject to backflow and should not be used. The condensate, instead, should discharge into an open well of some kind and from there flow into the drainage system. If such an indirect connection is impossible or undesirable, a vacuum breaker should be installed in the condensate line.

Many types of cross-connections are created either during the initial installation or after completion when it is found necessary to overcome some unforeseen deficiency. One such cross-connection results from the installation of a water-operated cellar drainer, to pump water from a flooded crawl space or basement. Such drainers waste water and should not be permitted, but if used, they should be provided with a control valve installed at least 12 inches above the overflow line of the pit, and a check valve and vacuum breaker installed on the discharge side of the control valve. With this type of hook-up the vacuum breaker is under pressure only when water is actually flowing through the supply pipe.

7. SUMMARY.

A great many types of equipment, (including types not generally found in housing developments, such as certain hospital fixtures and industrial equipment), contain dangerous cross-connections. It is beyond the scope of this bulletin to enumerate every possible cross-connection that may be found. A consideration of the common types mentioned should serve to show that direct cross-connections should be avoided during the design of the plumbing system, that adequate protection be provided where necessary, and that the equipment specified be of such types as to make it difficult or impossible for anyone to produce a cross-connection by appendages or changes.

The responsibility for minimizing the possibilities of contamination of a water supply system rests with the designing engineer, and only a competent engineer fully acquainted with the hydraulics of plumbing systems should be entrusted with the design of such systems.

PLUMBING, HEATING AND VENTILATION

PART VII - PREVENTION OF WATER SUPPLY POLLUTION IN BUILDINGS

Most communities have ordinances or codes regulating the installation of plumbing. However, many of these plumbing codes were enacted many years ago, before it was generally realized that defective or improperly installed plumbing piping or equipment could cause pollution of the water supply within a building. Research during the past decade and experience in complex modern plumbing installations have brought forth much new knowledge on the causes of pollution within buildings, and application of this knowledge to particular installations should result in safer and more economical systems.

The correct design and installation of a plumbing system is most important in any type of building, but particularly so in the buildings of a housing development which consists of a concentrated and interrelated group of family dwellings. The possibility of water pollution from faulty plumbing connections and fixtures, or from the incorrect use of such fixtures, constitutes a serious health hazard for the many residents in the development.

The most common disease-carrying organisms found in polluted water are those organisms that cause bacillary dysentery, amebic dysentery or any of several other gastroenteritic disturbances. While sufficient amounts of residual chlorine in the water will probably destroy most of these bacteria, that type causing amebic dysentery will not be destroyed while it is in its cyst stage, except by boiling the water or a concentration of bichloride of mercury not desirable in a potable water.

Many cases of water pollution have been reported by U.S. Public Health authorities in recent years and it is highly probable that most of these cases could have been prevented if more care had been taken in the design and installation of the plumbing systems. This Bulletin, therefore, directs attention to the pollution possibilities that exist in plumbing systems. The subject is a serious one, as is evidenced by the information contained in the U.S. Public Health Service Publication No. 957, Hazards in Household and Community Supply Systems.1/

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1/ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

NOTE: This Part VII supersedes Part VII of Bulletin No. LR-7 dated 6-15-50. It has been revised to clarify the text.

1. CAUSES OF WATER POLLUTION IN BUILDINGS.

A cross-connection is any physical connection or arrangement of pipes between two water-piping systems whereby water may flow from one system to the other. A cross-connection becomes a hazard to health when one system carries a potable water and the other contains water of unknown or questionable quality which can contaminate the potable water. Contamination of the safe water supply may be effected under either of the following conditions:

a. A direct connection, whereby safe and unsafe water are separated by a piped connection and a valve.

b. An indirect connection, whereby the completion of the cross-connection is dependent on a change in normally existing conditions.

In general, when a building contains only one water supply system, a vacuum (or drop in water pressure) must occur in this system before water from another source can flow into it. Such a vacuum may be caused by any of the following conditions within the system:

a. Water hammers setting up waves of positive and negative pressure.

b. Formation of water vapor in parts of the system (usually in pocketed portions of the piping) and condensation of this vapor.

c. Flow of water past localized restrictions (due to corrosion or caking of the interior of the piping, or to improper workmanship in assembling the piping resulting in pressure drops at the restrictions).

d. Draining water from the system.

When back flow occurs, the unsafe or polluted water may be distributed throughout an entire building, especially if the vacuum is caused by the action of a fixture on a lower floor of the building. If large quantities of water are being used, or if part of the street main has been shut off and drained, the pollution may extend as far as the main.

Since a vacuum may occur even in carefully designed systems, the obvious safeguard would be to avoid the installation of cross-connections and to correct any such connections already in place. However, in all types of plumbing systems, there exist many possibilities of cross-connections, particularly those that result from submerged outlets, and it would be virtually impossible to eliminate all of them. The designer should be thoroughly aware of the dangers of back-siphonage and of the means to prevent such back flows whenever a vacuum does occur in the supply system; and he should make certain that proper measures are taken to prevent the possibilities of pollution at these connections.

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2. METHODS OF PREVENTING BACKFLOW AT FIXTURES.

Air gaps at supply outlets and vacuum breakers in the supply piping are the usual means for providing back-siphonage protection at fixtures. An air gap is the free unobstructed vertical distance between the lowest opening from any pipe or faucet supplying water to a fixture and the flood level rim of the receptacle of the fixture. The minimum required air gap should be twice the diameter of the effective opening, but in no case less than the distance specified in the following:

Minimum Air Gaps for Generally Used Plumbing Fixtures

	Minimum Air Gaps, inches	
	When not affected by nearly vertical surface 1/	When affected by nearby vertical surface 2/
Lavatories with effective openings not greater than 1/2 inch diameter.	1.0	1.50
Sinks, laundry trays, and gooseneck bath faucets with effective openings not greater than 3/4 inch diameter.	1.5	2.25
Overrim bath fillers with effective openings not greater than 1 inch diameter . . .	2.0	3.00
Effective openings greater than 1 inch. . .	Twice the effective opening	3 times the effective opening

1/ Vertical surfaces do not affect the air gaps when spaced from inside edge of spout opening, a distance greater than 3 times the diameter of the effective opening for a single surface, or a distance greater than 4 times the diameter of the effective opening for 2 intersecting surfaces.

2/ Vertical surfaces extending from the water level to or above the horizontal plane of the spout opening require a greater air gap when spaced closer to the nearest inside edge of spout than specified in footnote 1 above. The effect of 3 or more such vertical surfaces has not been determined. In such cases the air gap should be measured from the top of the surfaces to the spout opening.

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When an air gap between the fixture and the supply outlet is impracticable or undesirable, a vacuum breaker can be installed in the piping between the fixture control valve and the outlet to the fixture. The function of the vaccum breaker is to introduce air at atmospheric pressure into the supply piping whenever the pressure inside the piping drops below that of the atmosphere. For each different model there is a definite minimum limit to the distance which the devise may be set above the top of the flood rim of the fixture and still be completely effective in preventing back-siphonage. An adequate vacuum breaker should have the following characteristics:

a. It should not permit water to rise more than 1 inch above the supply outlet under any vacuum conditions.

b. It should be so constructed that the air intake openings can be inspected visually at all times.

c. All parts should be non-corrosive, and water characteristics should not affect their operation.

d. The air intake should always be open to the atmosphere, except when water is flowing through the supply outlet.

e. It should not reduce the flow of water to the supply outlet.

f. It should function effectively when installed on the discharge side of the controlling valve of the fixture.

3. THE WATER CLOSET.

The water closet is the fixture most likely to be the cause of polluting the water supply system. Any closet bowl which is made with a direct submerged inlet, such as the side inlet bowl, should not be permitted in dwellings. For closet bowls used in combination with tanks, the danger arises from pollution of the tank contents by backflow from the bowl, and subsequent back-siphonage of the tank contents through the ballcock of the submerged tank inlet into the water supply. Contamination of the water in the tank will depend on the height of the bottom of the tank in relation to the height of the flood rim of the bowl. In the case of the one-piece combination tank and closet where the tank is integral with the bowl, and also for the close-coupled tank where the bottom of the tank is below the rim of the bowl, all that is necessary for tank pollution is a stoppage of the bowl and simultaneous operation of the tank valve mechanism. This will cause some of the contents of the bowl to overflow into the tank. A tank whose bottom is above the rim of the bowl would not be polluted in this way. However, it should be realized that any closet tank can be contaminated by backflow from a polluted tank on a higher floor whenever a vacuum occurs in the water supply system, and the ballcocks in each tank are not protected from back-siphonage.

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In this connection only such drinking fountains as meet the requirements of the United States Public Health Service should be considered acceptable. All drinking fountain nozzles with orifice diameters of 7/16 inch or less should extend at least 3/4 inch above the flood level rim of the receptacle to provide a safe air gap. Special conditions and certain other material related to drinking fountains should meet the requirements set forth in American Standard A40.4 and American Standard ASA Z4.2 respectively.[1]

5. APPENDAGES TO FIXTURES.

Probably one of the greatest causes of dangerous cross-connections results from changes and additions made by inexperienced individuals who are not acquainted with the safeguards necessary to maintain a safe system. Tenants, as a rule, do not know that by placing an addition to a fixture, there is created a possible source of contamination for themselves as well

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[1] Available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

as for others. One of the most common attachments is the hose connection made to a bathtub spout for use as a spray shower. This type of attachment is more likely to be found in the older public housing projects where shower heads were not provided over the bathtubs. The cross-connection occurs when the spray head is allowed to remain at the bottom of a tub partially filled with water, instead of being removed or hung above the tub to drain. The same sort of cross-connection can occur when the dish-spraying hose of a kitchen sink is allowed to dip below the water level in the sink, but since this hose spray is normally held at the faucet level when not being used, this danger is not quite as serious as the tub spray.

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Many plumbing codes require that a floor drain be provided with a water supply connection to maintain the trap seal. Such a connection should be so hooked-up that back-siphonage from the drain is impossible; hence a vacuum breaker between the controlling supply valve and the piping to the drain is a definite necessity. Similarly, the water connection used to prime a pump is subjected to this danger and requires the same protection.

A common practice is to connect the discharge from various types of condensers directly into the drainage system. Such connections are subject to backflow and should not be used. The condensate, instead, should discharge into an open well of some kind and from there flow into the drainage system. If such an indirect connection is impossible or undesirable, a vacuum breaker should be installed in the condensate line.

Many types of cross-connections are created either during the initial installation or after completion when it is found necessary to overcome some unforeseen deficiency. One such cross-connection results from the installation of a water-operated cellar drainer to pump water from a flooded crawl space or basement. Such drainers waste water and should not be permitted, but if used, they should be provided with a control valve installed at least 12 inches above the overflow line of the pit, and a check valve and vacuum breaker installed on the discharge side of the control valve. With this type of hook-up the vacuum breaker is under pressure only when water is actually flowing through the supply pipe.

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A great many types of equipment (including types not generally found in housing developments, such as certain hospital fixtures and industrial

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equipment), contain dangerous cross-connections. It is beyond the scope of this bulletin to enumerate every possible cross-connection that may be found. A consideration of the common types mentioned should serve to show that direct cross-connections should be avoided during the design of the plumbing system, that adequate protection be provided where necessary, and that the equipment specified be of such types as to make it difficult or impossible for anyone to produce a cross-connection by appendages or changes.

The responsibility for minimizing the possibilities of contamination of a water supply system rests with the designing engineer, and only a competent engineer fully acquainted with the hydraulics of plumbing systems should be entrusted with the design of such systems.

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PLUMBING, HEATING AND VENTILATION

PART VIII - DRAINAGE SYSTEMS IN BUILDINGS
(Based on the Uniform Plumbing Code 1/)

The function of a building drainage system is to carry away from plumbing fixtures and surface drains all water-bourne wastes that may reasonably be expected to be deposited in such fixtures or drains. Because of the possible presence of disease-producing organisms in these wastes, the method of disposal must be such that there will be no possibility of affecting the health or well-being of the occupants of the building. In addition, the sewer gas or air within the drainage system must be kept from entering the living spaces, as the odor of such gases is not only objectionable but probably has a deleterious effect on health.

The design of effective drainage systems should be based on the results of scientific research and practical experience with due regard for economy. Necessarily, the provisions of the applicable plumbing code will also determine the details of the design. However, because of irregularities and inconsistencies among various local plumbing codes, the data presented herein is based on the Uniform Plumbing Code 1/. This suggested code is the result of studies of the entire problem of drainage and venting and the conclusions expressed have a rational basis. Where local codes permit, it is hoped that the methods presented will be used as the basis for the design of building drainage systems. These design methods provide the means of reducing construction costs by simplifying and standardizing plumbing installations.

1. GENERAL PRINCIPLES

In almost every instance, the simplest and most direct drainage and venting layout has proved to be the most satisfactory. To secure a simple system the fixtures should be grouped around the stack into which they drain, and the arrangement of the fixtures should be such that the paths of branch wastes and vents through the walls and floor to the stack should be direct, short, and without detriment to structural members. Placing the stack between adjacent bathrooms or kitchens, or locating the bathrooms and kitchens vertically one above the other, are obvious means of simplifying the layouts.

The peak loading of the elements of a drainage system is the result of simultaneous discharges of a number of the fixtures at various locations. The pipe sizes herein recommended are based on mathematical estimates of peak loadings combined with factors of safety and, therefore, it is highly improbable that the indicated capacities will ever be exceeded in any actual installation.

1/ Report of the Uniform Plumbing Code Committee, U.S. Department of Commerce and Housing and Home Finance Agency, 1949. Available from the Superintendent of Documents, Washington 25, D.C. Price 40 cents.

2. FIXTURE UNITS

Most modern plumbing codes have accepted the use of fixture unit loading for determining pipe sizing of the drainage and venting systems. A fixture unit is a design factor for the drainage system, so chosen that the load producing values of plumbing fixtures can be expressed approximately as multiples of that factor. The accepted values for the common types of plumbing fixtures are listed in Table 1.

Table 1
Fixture Unit Values

Fixture Type	No. of fixture units		Minimum size of trap and fixture drain (inches)
	Dwelling	Non-Dwelling	
Column Number 1	2	3	4
1 bathroom group consisting of 1 lavatory, 1 water closet, 1 bathtub or shower stall	8	....	....
Bathtub 1/	(2 (3	4 6	$1\frac{1}{2}$ 2
Combination sink and tray	3	....	$1\frac{1}{2}$
Do 2/	4	....	$1\frac{1}{2}$
Drinking fountain	....	$\frac{1}{2}$	$1\frac{1}{4}$
Dish washer	2	....	$1\frac{1}{2}$
Floor drain	1	....	2
Kitchen sink	2	4	$1\frac{1}{2}$
Do 2/	4	....	$1\frac{1}{2}$
Lavatory 3/	1	2	$1\frac{1}{4}$
Laundry tray (1 or 2 compartment)	2	4	$1\frac{1}{2}$
Shower stall (per head)	2	4	2
Sink, scullery	....	(4 (5	$1\frac{1}{2}$ 2
Sink, service (trap standard)	....	3	3
Sink, service (P trap)	....	3	2
Urinal, pedestal, siphon jet blow-out	....	10	3
Urinal, wall lip	....	5	$1\frac{1}{2}$
Urinal, stall wash-put	....	5	2
Water closet	6	12	3

1/ Shower head over bathtub adds no fixture units.
2/ Sink with garbage grinder. Each compartment should be trapped separately. (This type of equipment is rarely justifiable in low-rent public housing but may, occasionally, be required by some local codes.)
3/ Lavatory with $1\frac{1}{4}$ or $1\frac{1}{2}$ inch trap has same fixture unit value.

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3. SIZING OF SOIL AND WASTE PIPING

Column 4 of Table 1 lists the minimum size of trap and fixture drain that should be used for the various fixtures. Table 2 indicates the estimated maximum number of fixture units which may be drained safely into the various sections of a sanitary drainage system.

Table 2

Maximum Capacity of the Elements of Drainage Systems in Fixture Units

Diameter of pipe (inches)	Building drain or sewer Fall in inches per foot				One horizontal branch	One branch interval in any stack 1/	Stacks with 3 or more branch intervals. 2/	
	1/16	1/8	1/4	1/2			In each branch interval	Total in stack
1	2	3	4	5	6	7	8	9
1¼	......	......	......	......	1	2	1	2
1½	......	......	......	......	3	4	2	8
2	......	......	21	26	6	10	6	24
2½	......	......	24	31	12	20	9	42
3	......	......	27 3/	36 3/	20 3/	30	11	60
4	......	180	216	250	160	240	90	500
5	......	390	480	575	360	540	200	1,100
6	......	700	840	1,000	620	960	350	1,900
8	1,400	1,600	1,920	2,300	1,400	2,200	660	3,600

1/ A branch interval is a length of soil or waste stack corresponding in general to a one-story height, but in no case less than 8 feet, within which horizontal branches are connected to the stack.

2/ Column 7 will ordinarily be found most economical for stacks with less than 3 branch intervals, and columns 8 and 9 most economical for stacks with 3 or more branch intervals. However, in certain circumstances the use of column 7 will give more economical sizing of tall stacks than will the use of column 8 and 9. Where such is the case, the use of column 7 on a stack of any height is permissable.

3/ Not more than 2 water closets.

Reduction of the size of the drainage piping in the direction of flow should be prohibited, except where a 4-inch water closet bend is connected to a 3-inch soil stack. Since Table 1 specifies that the minimum size of fixture drain for a water closet should be 3 inches, water closets should be connected only to soil stacks and building drains which are 3 inches or more in diameter.

Table 2 indicates that any 3-inch soil stack can safely drain three bathroom groups (as defined in Table 1), and in addition two kitchen sink and tray combination fixtures. If the 3-inch stack has 3 or more branch intervals, one bathroom group plus the combination fixture can be connected at each branch interval up to a total of 5 branch intervals, or if bathroom groups alone are so connected, up to a total of 7 branch intervals.

Table 2 indicates that the slope of building drains or sewers should be not less than $\frac{1}{4}$ inch per foot for 3-inch and smaller pipe sizes, not less than 1/8 per foot for the 4 to 8-inch sizes, and not less than 1/16 inch per foot for the 10 to 15-inch size. These slopes are designed to maintain proper scouring velocities in the drain and sewer. Table 2 indicates further that a 3-inch building drain sloping 1/4 inch per foot is adequate for two bathroom groups plus three kitchen sink and tray combination fixtures.

To minimize the effects of corrosion, leaks, and injury to the piping, all underground building drains within the building and extending five feet outside the building should be extra-heavy cast-iron soil pipe and fittings. Since cast-iron soil pipe is not made smaller than 2 inches, it follows that to insure the use of underground drainage piping of this material, and to reduce maintenance work, no portion of the drainage system installed underground or below a basement or cellar floor should be less than 2 inches in diameter.

4. SOIL AND WASTE CONNECTIONS

Connections for drainage piping should be made with recessed drainage fittings to provide smooth unobstructed flow. Short pattern sanitary tee fittings can generally be used to connect horizontal branches to vertical drains or stacks. However, when two fixtures, such as lavatories, sinks, or combination fixtures, are installed back to back, the connections to the common vertical drain should be made with long-turn sanitary pattern TYs, to prevent cross-flow from one fixture to the other. Since clogging of a common drain is likely to occur more frequently than with a drain which serves a single fixture, another reason for using the long-turn TY is that it is more easily rodded and cleaned than is the sanitary tee. To further minimize the possibility of stoppages the common drain for two fixtures should be at least 2 inches in size.

The connections from vertical to horizontal piping should be made by long-turn bends, long-turn TYs, or combination Y and eighth bend fittings. Such fittings serve to prevent clogging of the piping which tends to occur because of the decrease in velocity of the discharge at these points.

Branches from kitchen sinks or sink and tray combinations (which usually carry grease and food scraps) should have the shortest possible horizontal runs to prevent depositing of the grease and solids in the branch. Similarly, changes in direction of any drainage piping should be kept to a minimum to prevent the settling of solids. No change of direction greater than 90° should be permitted. In horizontal piping such changes should be made by use of 45° Ys, half Ys, and long sweep quarter, sixth, eighth, or sixteenth bends. Where the piping size changes, standard increasers and reducers should be used.

Obstructions in the horizontal lines, such as house traps or grease traps, decrease the capacity of the drain and increase maintenance problems considerably, yet provide little or no benefit to the drainage systems. It is strongly recommended that all such obstructions be omitted.

5. CLEANOUTS

Cleanouts serve two purposes. They provide openings to be used in relieving pipe stoppages and testing the drainage systems. Experience has shown that frequently the installation of cleanouts at favorable points has been completely overlooked, or they have been installed in locations where utilization was impossible or undesirable. To best serve their purpose, cleanouts should be installed in accessible positions at the following locations:

a. At each change of direction of the building drain greater than 45°.

b. At or near the foot of each vertical soil stack, waste stack, or inside leader.

c. Near the point of exit of the building drain from large buildings.

d. Not more than 50 feet apart on horizontal soil lines. (This distance is considered most convenient for use of one man operating a rodding cable.)

Overhead cleanouts should not be placed above any space where food is to be stored, prepared or consumed, or above domestic hot water storage tanks or heaters. Cleanouts at finish floor level in corridors, passageways, boiler rooms, or other spaces where equipment is moved across the floor, should be provided with countersunk heads.

6. VENTS AND VENTING

Various parts of a drainage system are opened to the atmosphere by means of vents for the following purposes:

a. Prevention of back pressures (pressures above atmospheric) that would obstruct the free flow of wastes through the drainage system.

b. Prevention of the loss of a trap seal, due to fluctuations in pressure caused by flow from other fixtures attached to the system.

c. Prevention of self-siphonage of a trap seal, due to flow through the trap.

The location and size of the vents required for a particular drainage system will depend on the laws of flow of air in piping; the type and arrangement of the connections; the size, slope and developed length of the stack and drains; the type and number of fixtures connected; and the size and developed length of the vents. (The developed length of vent piping is the length measured along the center line of the pipe and fitting from the connection to the drainage system to the terminus of the vent in the open air). To protect the trap seal, each fixture should have a vent in its drain line not closer than two pipe diameters to the trap weir to prevent fouling of the end of the vent, and not further from the weir than the distance indicated in Table 3 to prevent self-siphonage of the trap.

Table 3

Distance of Trap from Vent

Size of fixture drain (inches)	Permissible length in feet							
	Sanitary tee				Longturn TY of combination Y and 1/8 bend			
	¼ inch slope		½ inch slope		¼ inch slope		½ inch slope	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1¼	4	0	2	6	1	6	1	0
1½	4	6	3	0	4	0	2	0
2	5	0	4	0	4	6	4	0
3	6	0	6	0	6	0	6	0
4	8	0	8	0	8	0	8	0

7. METHODS OF VENTING

Venting can be accomplished by any of the following methods, under the conditions outlined and in accordance with Table 3.

a. Individual (back) venting - piping installed for the purpose of venting a fixture trap by connecting the fixture drain to the venting system above the fixture. Generally this method can be applied in any installation but it is the most expensive and does not always produce the best protection, since the end of the vent pipe where it connects to the drain line may become fouled.

b. Stack venting - the extension of a soil or waste stack through the roof to the open air and the use of this extension as a means of venting the uppermost fixture or group of fixtures. The maximum number of fixtures to be so vented should consist of a bathtub, lavatory, water closet, and sink and tray combination fixture (or kitchen sink). Each fixture drain should connect independently to the stack with the bathtub and water closet drains entering at the same level, below the level of the lavatory and combination fixture connections, as shown in Figure 1 (see page 7). However, if such a fixture group is vented in this manner and if the street sewer is so overloaded that it causes frequent submersion of the building sewer, a relief vent (or a back vented fixture) should be connected to the stack at or below the bathtub and water closet connections. If the combination fixture (or kitchen sink) is omitted from the stack-vented group of fixtures, the relief vent or back-vented fixture is unnecessary. An experimental investigation of stack venting is detailed in National Bureau of Standards report BMS 118 1/.

1/ Stack Venting of Plumbing Fixtures, BMS 118. Building Materials and Structures Reports, National Bureau of Standards, 1950. Available from the Superintendent of Documents, Washington 25, D.C. Price 15 cents.

c. Common (dual) venting - the use of one vent pipe for two fixtures. Both fixture drains should connect to a vertical drain at the same level, or if they connect at different levels the cross-sectional area of the upper fixture branch should be less than half the cross-sectional area of the vertical drain and be located not more than 5 pipe diameters above the lower branch. The vent should be a continuation of the vertical drain. This type of venting should be used for two fixtures installed back to back, as shown in Figure 2.

d. Wet venting - the use of a fixture drain as a vent pipe for other fixtures. For a single bathroom group on the top floor or next lower floor, the drain from a back-vented lavatory (the drain to be not less than 2 inches in size) can serve as a vent for a bathtub and water closet, provided the horizontal branch draining these fixtures connects to the stack at the same level as the water closet drain, (or, in the case of the top floor only, at or below the water closet drain connection). For two-bathroom groups installed back to back on the top floor, two lavatories and two bathtubs may be installed on the same horizontal branch, with a common vent for the lavatories and with no back vent for the bathtubs, provided the wet vent is 2 inches in size. Figure 3 illustrates this method of venting.

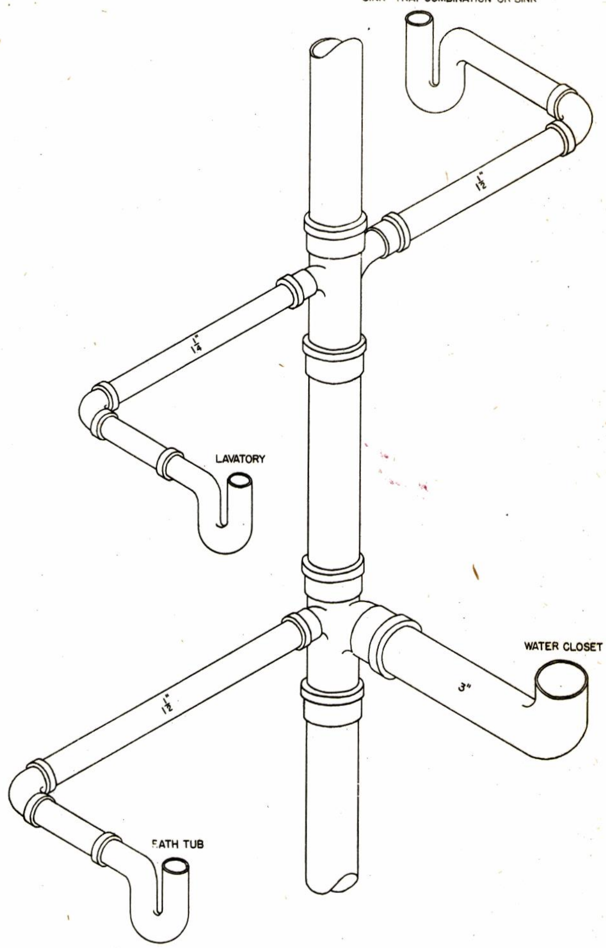

FIGURE I. STACK VENTED BATHROOM GROUP AND SINK OR SINK-TRAY COMBINATION

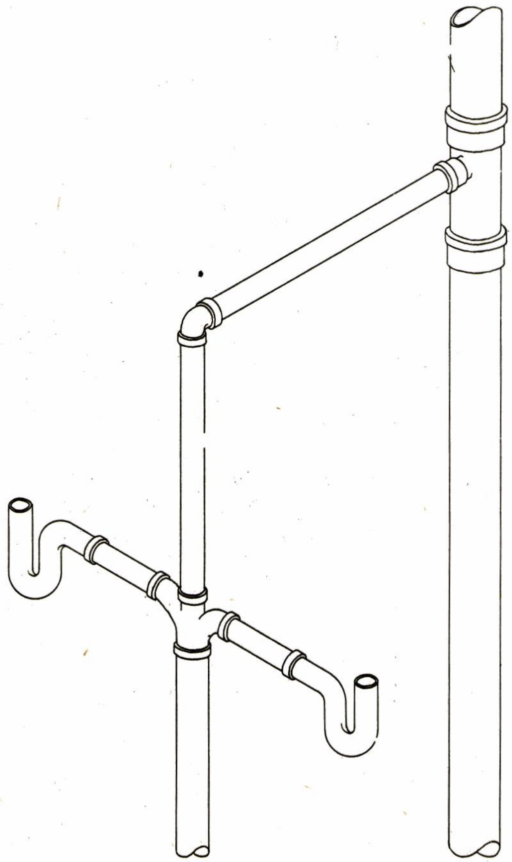

FIGURE 2. COMMON VENTING OF TWO FIXTURES CONNECTED BACK TO BACK.

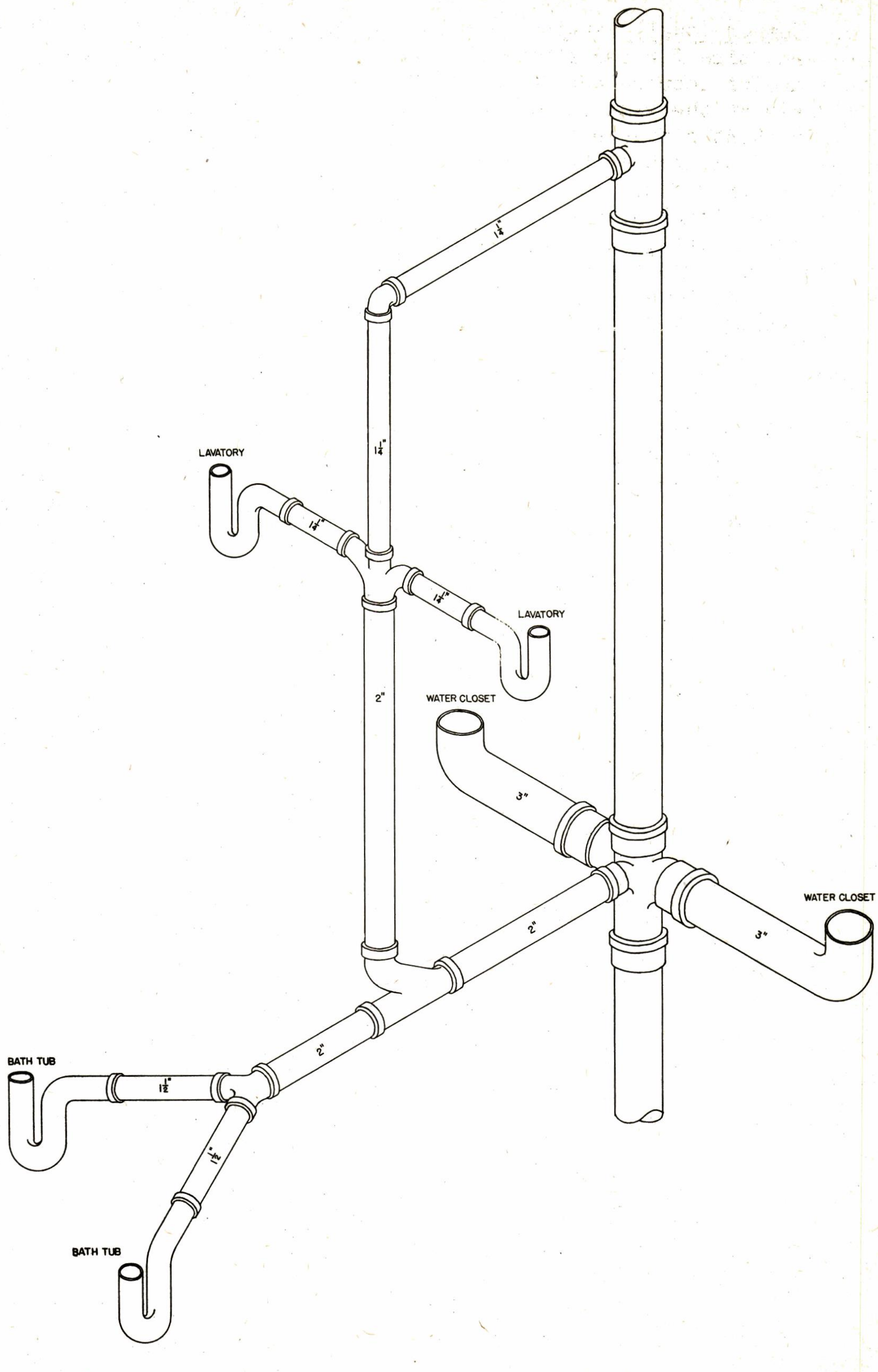

FIGURE 3 WET VENTING OF TWO BATHROOM GROUPS CONNECTED BACK TO BACK

Separate storm drains should not be connected in any way with the sanitary drainage system. Where combined drains are to be used, the connection from the storm drain to the combined drain should be made at the same level through a single wye fitting at least 10 feet downstream from any branch to the sanitary drain or from any soil stack. The size of the combined drain should be based on the combined flow from the storm and sanitary drains. The flow in the sanitary drain should be converted to its equivalent flow from a projected roof area by the use of one of the following criteria, (based on a 4-inch rate of rainfall).

a. When the total load in the sanitary drain is any value less than 325 fixture units, the flow in the sanitary drain should be taken as the equivalent of the flow from 1,000 square feet of projected roof area.

b. When the total load in the sanitary drain exceeds 325 fixture units, the flow due to each fixture unit should be considered the equivalent to the flow from 3.1 square feet of projected roof area.

The sum total of actual projected roof area and projected roof area computed from one of these criteria can then be used in conjunction with Table 6 (after adjusting both areas for actual rate of rainfall) to determine the size of the combined drain. In any case, the combined drain sizes used should not be less than 4 inches, or be smaller than either the separate storm or sanitary drains discharging into the combined drain.

Where there is continuous or intermittent discharge into a drain, as from a pump or similar device, each gallon per minute of such discharge should be considered as being equivalent to the flow from 24 square feet of projected roof area, on the basis of a 4-inch rate of rainfall.

11. FLOOR DRAINS AND AREA DRAINS

Floor drains should be installed in project laundry rooms, boiler rooms, equipment rooms which contain pumps or water storage tanks, and basement spaces into which drainage from underground steam or hot water distribution tunnels or conduits will flow. Area drains should be installed at all exterior ramps or entrances that are below grades. Each drain should be placed at the lowest point of the floor or drainage area, and the entire floor or area should slope uniformly toward this low point. The drains should discharge into the sanitary or storm drainage system, directly or through a sump pump. Venting of the drain trap is unnecessary.

Floor and area drains should be constructed of cast iron and be provided with a hinged grating cover and P-trap. Because of their location, these drains (especially exterior area drains) frequently become filled with sand or debris; therefore, to minimize maintenance costs, drain outlets should be 3 inches in size. In addition, area drains should be provided with removable sediment buckets or pans.

12. SUMP PUMPS

As far as possible, the drainage systems should be designed to provide complete gravity flow from drains to sewer. This is especially true of the sanitary drainage systems, since sewage ejectors are costly, troublesome, and unreliable. If necessary to obtain gravity flow for sanitary drains, it would be advisable to relocate plumbing fixtures, basement rooms, or even entire buildings.

Discharges from floor and area drains located below the level of the building drain can be handled by sump pumps (cellar drainers), when gravity flow is impossible. Since boiler rooms usually require more headroom than the usual basement space, sump pumps, when required, are usually located in such rooms. A boiler room of large dimensions, separated from the remaining buildings of the project and subject to heavy ground water infiltration should have a duplex sump pump installation; a boiler room that is fairly small, integral with a building containing dwellings, and where little ground water infiltration is anticipated, should have a single sump pump. Intermediate conditions should be decided by the engineer.

The size of sump pumps should be based on the area to be drained, the estimated rate of ground water infiltration, the rate at which water would be released from any equipment, and the static head against which the pump must operate. The pump should discharge through a check valve to prevent backflow. Each pump motor should be controlled by an automatic float switch actuated by the water level in the pit. For duplex pumps, an alternator should energize the motors alternately, under normal conditions, or simultaneously when one pump alone cannot handle the load.

A clay or concrete pipe, 3 feet long, makes the simplest sump pit. If pipe of the required size is not available, a concrete or brick manhole should be constructed. The base of the pit should be concrete, 4 inches thick, and the cover should be the steel plate from which the pump installation is suspended. The entire pit should be relatively watertight, and water entering the pit should come only through floor and area drains.

13. TESTING DRAINAGE SYSTEMS.

The entire drainage system including soil, waste and vent stacks, interior leaders, branch wastes and vents, and building sanitary and storm drains should be tested for leaks in the presence of representatives of the Local Authority, before and after the plumbing fixtures have been attached to the system. No portion of the system should be covered before being tested and approved. Tests should be made on an entire system or sections of a system. If necessary, cleanouts should be removed to determine if all parts of the system are under pressure.

Initial tests should be made with water or air. If water is used, all openings in the section to be tested should be tightly closed, except the highest opening, and the system filled with water to the point of overflow. All parts of the system should be under not less than a 10 foot head of water, except the uppermost 10 feet of the piping directly beneath the opening. The water should be kept in the system at least 15 minutes and then all joints should be examined for leaks.

If air is used, an air compressor or testing apparatus should be attached to any suitable opening (usually a cleanout), and all other openings should be tightly closed. Air should be forced into the system until there is a uniform gage pressure of 5 pounds per square inch or 10 inches of mercury. This pressure should remain constant for 15 minutes (without further pumping of air into the system).

The final test should be made with smoke or a peppermint solution after the fixtures have been connected and the fixture traps filled with water.

When smoke is used, a pungent thick smoke produced by smoke machines (not by a chemical mixture) should be introduced through a cleanout opening into the system. As the smoke appears at each roof opening, the opening should be closed and the introduction of the smoke continued until a pressure of 1 inch of water has been built up within the system and maintained for 15 minutes. Under this pressure smoke should not be visible at any joint, connection or fixture.

If peppermint is used, a mixture of two ounces of oil of peppermint and one gallon of hot water should be poured into each roof opening of the system, and should cause no noticeable odor of peppermint within the building. It is essential that the individual who mixes and pours the peppermint solution shall not enter the building until the test inspection has been completed, as the odor of the peppermint clinging to his clothes may cause erroneous test results.

Any defective work that is discovered as a result of tests or inspections should be corrected, and the entire system or section should be retested and reinspected after the corrections have been made. Calking of screwed joints, cracks, or holes should not be permitted; screwed joints should be remade completely, and any portion of the piping with a crack or hole should be removed and replaced with new, undamaged, pipe or fittings.

PLUMBING, HEATING, AND VENTILATION

PART VIII - DRAINAGE SYSTEMS IN BUILDINGS
(Based on the National Plumbing Code 1/

The function of a building drainage system is to carry away from plumbing fixtures and surface drains all water-borne wastes that may reasonably be expected to be deposited in such fixtures or drains. Because of possible presence of disease-producing organisms in these wastes, the method of disposal must be such that there will be no possibility of affecting the health or well-being of the building occupants. In addition, the sewer gas or air within the drainage system must be kept from entering living spaces, as the odor of such gases is not only objectionable but probably has a deleterious effect on health.

The design of effective drainage systems should be based on the results of scientific research and practical experience with due regard for economy. Necessarily, the provisions of the applicable plumbing code will also determine the details of the design. However, because of irregularities and inconsistencies among various local plumbing codes, the data presented herein is, in general, based on the National Plumbing Code 1/. This suggested code is the result of studies of the entire problem of drainage and venting and the conclusions expressed have a rational basis. Where local codes permit, it is hoped that the methods presented will be used as the basis for the design of building drainage systems. These design methods provide the means of reducing construction costs by simplifying and standardizing plumbing installations.

1. GENERAL PRINCIPLES

In almost every instance, the simplest and most direct drainage and venting layout has proved to be the most satisfactory. To secure a simple system the fixtures should be grouped around the stack into which they drain, and the arrangement of the fixtures should be such that the paths of branch wastes and vents through the walls and floor to the stack should be direct, short, and without detriment to structural members. Placing the stack between adjacent bathrooms or kitchens, or locating the bathrooms and kitchens vertically one above the other, are obvious means of simplifying the layouts.

The peak loading of the elements of a drainage system is the result of simultaneous discharges of a member of the fixtures at various locations. The pipe sizes herein recommended are based on mathematical estimates of peak loadings combined with factors of safety and, therefore, it is highly improbable that the indicated capacities will ever be exceeded in any actual installation.

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1/ The American Standard Association's "National Plumbing Code," ASA A40.8 is available from the American Society of Mechanical Engineers, 245 East 47th Street, New York, New York 10017.

NOTE: This is a new Part VIII, Bulletin No. LR-7, Drainage Systems in Buildings, and replaces the previous Part VIII which was obsoleted in October 1963. The material contained in the previous Part VIII has been completely revised.

In recent years detergent foaming at plumbing fixtures in dwelling units located on lower floors of high-rise buildings has been a nuisance problem for many Local Authorities. It is suggested for a corrective method to this problem, to avoid effects of back pressures at base of a stack, that such fixtures as kitchen sinks, or kitchen sink and laundry trays combinations, for the first three floors of buildings 12 stories high and over should be connected to a waste stack(s) that is separate from stack(s) for fixtures located on the upper floors. For buildings under 12 stories high the first floor, or the first and second floor fixtures, depending on building height, should also be connected to separate stack(s). The horizontal branch waste from each lower floor stack should be run at a higher level than the horizontal waste runoff from the upper floor fixtures and should extend approximately 13 feet, or approximately 40 times the stack pipe size, before connection is made to upper floor waste main.

2. FIXTURE UNITS

Most modern plumbing codes have accepted the use of fixture unit loading for determining pipe sizing of the drainage and venting systems. A fixture unit is a design factor for the drainage system, so chosen that the load producing values of plumbing fixtures can be expressed approximately as multiples of that factor. The accepted values for various types of plumbing fixtures or group of fixtures for the required size of traps and fixture drains can be best determined by consulting the fixture unit table listed under the chapter on Drainage System in the National Plumbing Code.

Fixture unit values for continuous or semicontinuous flow into a drainage system, such as from a pump, sump ejector, air-conditioning equipment, or similar device, should be computed on the basis of one fixture unit for each gallon per minute of flow.

3. SIZING OF SOIL AND WASTE PIPING

The size of the drainage piping should be computed on the basis of the maximum fixture unit load for building drain or building sewer and for soil and waste stacks with connected horizontal branch drainage lines from fixtures. Drainage pipe sizes can best be determined by consulting the maximum load tables listed under the chapter on Drainage System in the National Plumbing Code.

No soil or waste stack should be smaller than the largest horizontal branch connected thereto except that a 4-inch water closet bend connected to a 3-inch soil stack should not be considered as a reduction in pipe size. Horizontal drainage piping should be installed in uniform alignment at uniform slopes of not less than 1/4 inch per foot for 3-inch and smaller pipe sizes, not less than 1/8 inch per foot for 4- to 8-inch pipe size, and not less than 1/16 inch per foot for 10-inch pipe size and larger.

To minimize the effects of corrosion, leaks, and injury to the piping, all underground building drains within the building and extending five feet outside the building should be extra-heavy cast-iron soil pipe and fittings. Since

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cast-iron soil pipe is not made smaller than 2 inches, it follows that to ensure the use of underground drainage piping of this material, and to reduce maintenance work, no portion of the drainage system installed underground or below a basement or cellar floor should be less than 2 inches in diameter.

4. SOIL AND WASTE CONNECTIONS

Connections for drainage piping should be made with recessed drainage fittings to provide smooth unobstructed flow. Short pattern sanitary tee fittings can generally be used to connect horizontal branches to vertical drains or stacks. However, when two fixtures, such as lavatories, sinks, or combination fixtures, are installed back to back, the connections to the common vertical drain should be made with long-turn sanitary pattern TYs, to prevent cross-flow from one fixture to the other. Since clogging of a common drain is likely to occur more frequently than with a drain which serves a single fixture, another reason for using the long-turn TY is that it is more easily rodded and cleaned than is the sanitary tee. To further minimize the possibility of stoppages the common drain for two fixtures should be at least 2 inches in size.

The connections from vertical to horizontal piping should be made by long-turn bends, long-turn TYs, or combination Y and eighth bend fittings. Such fittings serve to prevent clogging of the piping which tends to occur because of the decrease in velocity of the discharge at these points.

Branches from kitchen sinks or sink and tray combinations (which usually carry grease and food scraps) should have the shortest possible horizontal runs to prevent depositing of the grease and solids in the branch. Similarly, changes in direction of any drainage piping should be kept to a minimum to prevent the settling of solids. No change of direction greater than 90° should be permitted. In horizontal piping such changes should be made by use of 45° Ys, half Ys, and long sweep quarter, sixth, eighth, or sixteenth bends. Where the piping size changes, standard increasers and reducers should be used.

Obstructions in the horizontal lines, such as house traps or grease traps, decrease the capacity of the drain and increase maintenance problems considerably, yet provide little or no benefit to the drainage systems. It is strongly recommended that all such obstructions be omitted.

No fitting having a hub in the direction opposite to flow, or tee branch, should be used as a drainage fitting. No fitting or connection which has an enlargement chamber or recess with a ledge or shoulder or reduction in pipe area should be used. No drainage or vent piping should be drilled or tapped.

Building drains which cannot be discharged to the sewer by gravity flow should be discharged into a covered and vented sump pit from which the liquid waste should be lifted and discharged into the building gravity drainage system with automatic pumping equipment.

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5. CLEANOUTS

Cleanouts serve two purposes. They provide openings to be used in relieving pipe stoppages and testing the drainage systems. Experience has shown that frequently the installation of cleanouts at favorable points has been completely overlooked, or they have been installed in locations where utilization was impossible or undesirable. To best serve their purpose, cleanouts should be installed in accessible positions at the following locations:

a. At each change of direction of the building drain greater than 45°.

b. At or near the foot of each vertical soil stack, waste stack, or inside leader.

c. Near the point of exit of the building drain from large buildings.

d. Not more than 50 feet apart on horizontal soil lines. (This distance is considered most convenient for use of one man operating a rodding cable.)

Overhead cleanouts should not be placed above any space where food is to be stored, prepared, or consumed, or above domestic hot water storage tanks or heaters, or over surge or suction tanks or similar appurtenances of the potable water distribution systems. Cleanouts at finish floor level in corridors, passageways, boiler rooms, or other spaces where equipment is moved across the floor should be provided with countersunk heads.

Every cleanout should be installed so that the cleanout opens in a direction opposite to the flow on the drainage line or at right angle thereto.

6. VENTS AND VENTING

Various parts of a drainage system are opened to the atmosphere by means of vents for the following purposes:

a. Prevention of back pressures (pressures above atmospheric) that would obstruct the free flow of wastes through the drainage system.

b. Prevention of the loss of a trap seal, due to fluctuations in pressure caused by flow from other fixtures attached to the system.

c. Prevention of self-siphonage of a trap seal, due to flow through the trap.

The location and size of the vents required for a particular drainage system will depend on the laws of flow of air in piping; the type and arrangement of the connections; the size, slope, and development length of the stack and drains; the type and number of fixtures connected; and the size and development length of the vents. (The developed length of vent piping is the length measured along the center line of the pipe and fitting from the connection

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to the drainage system to the terminus of the vent in the open air.) To protect the trap seal, each fixture should have a vent in its drain line not closer than two pipe diameters to the trap weir to prevent fouling of the end of the vent. To prevent self-siphonage of the trap, the distance of the fixture trap from the vent riser is established by the pipe size of the fixture drain and can best be determined by consulting the fixture vent table listed under the chapter on Vents and Venting in the National Plumbing Code.

7. METHODS OF VENTING

Venting can be accomplished by any of the following methods, subject to conditions outlined in the table, that determines the distance of fixture trap from vent, listed under the chapter on Vents and Venting in the National Plumbing Code.

a. Individual (back) venting--piping installed for the purpose of venting a fixture trap by extending a vent line from the fixture drain to the venting system above the fixture. Generally this method can be applied in any installation but it is the most expensive and does not always produce the best protection since the end of the vent pipe where it connects to the drain line may become fouled.

b. Stack venting. The extension of a soil or waste stack through the roof to the open air and the use of this extension as a means of venting a group of fixtures consisting of one bathroom group and a kitchen sink or sink and tray combination fixture. Each fixture drain should connect independently to the stack with the bathtub and water closet drains entering at the same level, below the level of the lavatory and combination fixture connections. However, if such a fixture group is vented in this manner and if the street sewer is so overloaded that it causes frequent submersion of the building sewer, a relief vent (or a back-vented fixture) should be connected to the stack at or below the bathtub and water closet connections. If the combination fixture (or kitchen sink) is omitted from the stack-vented group of fixtures, the relief vent or back-vented fixture is unnecessary. An experimental investigation of stack venting is detailed in National Bureau of Standards report BMS 118 2/.

c. Common (dual venting. An individual vent, installed vertically, may be used as a common vent for two fixture traps when both fixture drains connect with a vertical drain at the same level. A common vent may also be used for two fixtures set on the same floor level but connecting at different levels in the stack, provided the vertical drain is one pipe diameter larger than the upper fixture drain but in no case smaller than the lower fixture drain, whichever is the larger and that both drains should conform to the table "Distance of Fixture Trap from Vent" set forth under the chapter on Vents and Venting in the National Plumbing Code.

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2/ Stack Venting of Plumbing Fixtures, BMS 118. Building Materials and Structures Reports, National Bureau of Standards, 1950. Available from the Superintendent of Documents, Washington, D.C. 20402. Price 15 cents.

d. Wet Venting. A single bathroom group of fixtures may be installed with a drain from a back-vented lavatory, kitchen sink, or combination fixture serving as a wet vent for a bathtub or shower stall and for a water closet, provided that:

(1) Not more than one fixture unit is drained into a 1-1/2 inch diameter wet vent or not more than four fixture units drained into a 2-inch diameter wet vent.

(2) The horizontal branch drain connects to the stack at the same level as the water closet drain or below the water closet drain when installed on the top floor. It may also connect to the water closet bend.

Bathroom groups back-to-back on top floor consisting of two lavatories and two bathtubs or shower stalls may be installed on the same horizontal branch with a common vent for the lavatories and with no back vent for the bathtub or shower stalls and for the water closet, provided that the wet vent is not less than 1-1/2 inches in diameter.

On the lower floors of a multistory building, the waste pipe from one or two lavatories may be used as a wet vent for one or two bathtubs or showers provided that:

(1) The wet vent and its extension to the vent stack is not less than 2 inches in diameter.

(2) Each water closet below the top floor is individually back vented.

(3) The vent stack size can best be determined by consulting the table on "Size and Length of Vents" set forth under the chapter on Vents and Venting in the National Plumbing Code.

e. Multistory and battery venting. special venting layouts to serve multistoried buildings, or batteries of fixtures on the same floor. Such venting methods include circuit, loop, and various forms of relief and wet venting; their conditions of use can best be determined by consulting the chapter on Vents and Venting in the National Plumbing Code.

8. SIZING OF VENT PIPING

Every soil and waste stack should be extended as a stack vent to the open air. The vent stack from the fixtures below the top floor should also terminate in the open air, or be connected to the main stack vent at least 6 inches above the flood level rim of the highest fixture. The size of an individual (back) vent should be not less than 1-1/4 inches, or less than one-half the diameter of the drain to which it is connected. The size of a stack vent should be not less than the size of the soil or waste stack. A vent stack or main vent

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should be at least one-half the diameter of the soil or waste stack, but in no case less than 1-1/2 inches or less than the sizes set forth in table on "Size and Length of Vents" set forth under the chapter on Vents and Venting in the National Plumbing Code.

9. LEADERS, STORM DRAINS, AND ROOF DRAINS

A leader (downspout) is the vertical water conductor that extends from a roof drain to a drain point at the ground or to a point of connection of horizontal storm drain. The size of the vertical leaders, established by the square foot area of the roof, can best be determined by consulting the table on "Size of Vertical Leaders" set forth under the chapter on Storm Drains in the National Plumbing Code.

The size of the building storm drain or any of its horizontal branches having a slope of 1/2 inch or less with a maximum rate of rainfall of 4 inches per hour should be based on the maximum projected roof area to be handled and can best be determined by consulting the table on "Size of Horizontal Storm Drains" set forth under the chapter on Storm Drains in the National Plumbing Code.

Storm drains when connected to a combined sewer should be trapped. No traps will be required for storm-water drains which are connected to a drainage system carrying storm water exclusively. Where combined drains are to be used, the connection from the storm drain to the combined drains should be made at the same level through a single wye fitting preferably outside building and at least no less than 10 feet downstream from any branch to the sanitary drain or from any branch to the sanitary drain or from any soil stack. The size of the combined drain should be based on the combined flow from the storm and sanitary drains. The flow in the sanitary drain should be converted to its equivalent flow from a projected roof area by the use of one of the following criteria, (based on a 4-inch rate of rainfall):

a. When the total load in the sanitary drain is any value less than 256 fixture units, the flow in the sanitary drain should be taken as the equivalent of the flow from 1,000 square feet of projected roof area.

b. When the total load in the sanitary drain exceeds 256 fixture units, the flow due to each fixture unit should be considered the equivalent to the flow from 3.9 square feet of projected roof area.

The sum total of actual projected roof area and projected roof area computed from one of these criteria can then be used in conjunction with table on "Size of Horizontal Storm Drains" under chapter on Storm Drains in the National Plumbing Code (after adjusting both areas for actual rate of rainfall) to determine the size of the combined drain. In any case, the combined drain sizes used should not be less than 4 inches, or be smaller than either the separate storm or sanitary drains discharging into the combined drain.

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Where there is continuous or intermittent discharge into a drain, as from a pump, ejector, air-conditioning plant, or similar device, each gallon per minute of such discharge should be considered as being equivalent to the flow from 24 square feet of projected roof area, on the basis of a 4-inch rate of rainfall.

Roof drains should be cast iron and should have the same outlet size as the leader to which they are connected and should have beehive or dome-shaped strainers. The available inlet area of the strainer above the roof level should be not less than 1-1/2 times the area of leader to which the drain is connected. Roof drain strainers for promenade roofs, sun decks, and similar areas, normally serviced and maintained, should be of the flat surface type with an available inlet area of not less than 2 times the area of the leader to which the drain is connected.

10. FLOOR DRAINS AND AREA DRAINS

Floor drains should be installed in project laundry rooms, boiler rooms, equipment rooms which contain pumps or water storage tanks, and basement spaces into which drainage from underground steam or hot water distribution tunnels or conduits will flow. Floor drains should be located from direct paths of pedestrian traffic. Area drains should be installed at all exterior ramps or entrances that are below grades. Each drain should be placed at the lowest point of the floor or drainage area, and the entire floor or area should slope uniformly toward this low point. The drains should discharge into the sanitary or storm drainage system, directly or through a sump pump. Venting of the drain trap is unnecessary.

Floor and area drains should be constructed of cast iron and be provided with a hinged grating cover and P-trap. Because of their location, these drains (especially exterior area drains) frequently become filled with sand or debris; therefore, to minimize maintenance costs, drain outlets should be 3 inches in size. In addition, area drains should be provided with removable sediment buckets or pans.

11. SUMP PUMPS

As far as possible, the drainage systems should be designed to provide complete gravity flow from drains to sewer. This is especially true of the sanitary drainage systems, since sewage ejectors are costly, troublesome, and unreliable. If necessary to obtain gravity flow for sanitary drains, it would be advisable to relocate plumbing fixtures, basement rooms, or even entire buildings.

Discharges from floor and area drains located below the level of the building drain can be handled by sump pumps (cellar drainers), when gravity flow is impossible. Since boiler rooms usually require more headroom than the usual basement space, sump pumps, when required, are usually located in such rooms.

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A boiler room of large dimensions, separated from the remaining buildings of the project and subject to heavy ground water infiltration, should have a duplex sump pump installation; a boiler room that is fairly small, integral with a building containing dwellings, and where little ground water infiltration is anticipated, should have a single sump pump. Intermediate conditions should be decided by the engineer.

The size of sump pumps should be based on the area to be drained, the estimated rate of ground water infiltration, the rate at which water would be released from any equipment, and the static head against which the pump must operate. The pump should discharge through a check valve to prevent backflow. Each pump motor should be controlled by an automatic float switch actuated by the water level in the pit. For duplex pumps, an alternator should energize the motors alternately, under normal conditions, or simultaneously when one pump alone cannot handle the load.

A clay or concrete pipe, 3 feet long, makes the simplest sump pit. If pipe of the required size is not available, a concrete or brick manhole should be constructed. The base of the pit chould be concrete, 4 inches thick, and the cover should be the steel plate from which the pump installation is suspended. The entire pit should be relatively watertight, and water entering the pit should come only through floor and area drains.

12. TESTING DRAINAGE SYSTEMS

The entire drainage system including soil, waste and vent stacks, interior leaders, branch wastes and vents, and building sanitary and storm drains should be tested for leaks in the presence of representatives of the Local Authority, before and after the plumbing fixtures have been attached to the system. No portion of the system should be covered before being tested and approved. Tests should be made on an entire system or sections of a system. If necessary, cleanouts should be removed to determine if all parts of the system are under pressure.

Initial tests should be made with water or air. If water is used, all openings in the section to be tested should be tightly closed, except the highest opening, and the system filled with water to the point of overflow. All parts of the system shuuld be under not less than a 10-foot head of water, except that uppermost 10 feet of the piping directly beneath the opening. The water should be kept in the system at least 45 minutes and then all joints should be examined for leaks. If air is used, an air compressor or testing apparatus should be attached to any suitable opening (usually a cleanout), and all other openings should be tightly closed. Air should be forced into the system until there is a uniform gage pressure of 5 pounds per square inch above atmospheric pressure or 10 inches of mercury. This pressure should remain constant for 15 minutes (without further pumping of air into the system.)

(Cont'd)

The final test should be made with smoke or a peppermint solution after the fixtures have been connected and the fixture traps filled with water.

When smoke is used, a pungent thick smoke produced by smoke machines (not by a chemical mixture) should be introduced through a cleanout opening into the system. As the smoke appears at each roof opening, the opening should be closed and the introduction of the smoke continued until a pressure of 1 inch of water has been built up within the system and maintained for 15 minutes. Under this pressure smoke should not be visible at any joint, connection, or fixture.

If peppermint is used, a mixture of two ounces of oil of peppermint and one gallon of hot water should be poured into each roof opening of the system, and opening should then be tightly closed. There should be no odor of peppermint within the building or at any joint, connection, or fixture opening as a result of this test having been introduced into the system. It is essential that the individual who mixes and pours the peppermint solution shall not enter the building until the test inspection has been completed, as the odor of the peppermint clinging to his clothes may cause erroneous test results.

Any defective work that is discovered as a result of tests or inspections should be corrected, and the entire system or section should be retested and reinspected after the corrections have been made. Calking of screwed joints, cracks, or holes should not be permitted; screwed joints should be made completely, and any portion of the piping with a crack or hole should be removed and replaced with new, undamaged, pipe or fittings.

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PLUMBING, HEATING AND VENTILATION

PART IX BOILER PLANT INSTRUMENTS

Great importance is properly attached, in the early stages of project design, to the selection of the most economical combination of utilities, including the determination of a heating method and system and the fuel therefor. The significance of such selection will be lost if efficiencies originally anticipated are not obtained as a result of faulty design or lack of complete knowledge as to how the plant is functioning under varying load conditions. One of the greatest industrial losses in the country results from waste that goes up the chimney; low-rent housing can afford this kind of loss much less than industry.

As it is important for the physician to measure the rate of heat generated within the body, resulting from food oxidation (metabolism), to trace the cause of certain illnesses, so it is important for the engineer to measure the useful energy resulting from combustion processes in fuel burning. The engineer must have the scientific approach to fuel savings; he must know and understand the means to obtain the maximum heat energy liberated from the boilers.

Instruments are the tools to guide and direct him in the care and efficient operation of the boiler plant; they are a necessary adjunct to a well-planned heating system. The instruments discussed in this text are limited to plants operated and maintained by project management and relate principally to the boiler itself.

The instruments which are generally essential in this work are a carbon dioxide (CO_2) measuring device, a flue gas temperature measuring device and a draft gauge. There are other useful instruments, such as the steam flow meter, the hot water displacement meter and the smoke indicator. These may not be as important as the carbon dioxide and flue gas temperature measuring devices, or the draft gauge, but are relatively useful because they, too, directly measure or record the available heat energy.

So well recognized are the functions of these instruments, that engineers who design small plants, where the more extensive types of instrumentation may not be warranted can justifiably specify the furnishing of small, inexpensive, portable sets of carbon dioxide indicators, thermometers, and draft gauges.

1. CARBON DIOXIDE AND FLUE GAS MEASUREMENTS

The combustion engineer knows that carbon dioxide is the most significant component of flue gas because it is formed by the burning of the carbon in the fuel. The engineer is aware that a low percentage of CO_2 means too much air is being drawn into the boiler through badly fitted doors and poorly constructed settings or, perhaps, that the firing apparatus has not been regulated to coordinate the air supply with the fuel burning rate. Conversely, a high CO_2 accompanied by dense smoke means incomplete burning, resulting from too little air; with anthracite, unburned gases can be lost without smoke. The flue gas temperature measuring device shows the effectiveness with which the boiler exchange surfaces absorb the heat from hot gases.

There is, for each type and classification of fuel, an "ultimate" value of CO_2 which is the result of supplying and utilizing the required amount of oxygen for the perfect or theoretical combustion of fuel. This value depends upon the original constituents in the fuel such as carbon, hydrogen, components of carbon and hydrogen, nitrogen, sulphur, etc. The degree to which the theoretical figure is approached, together with the temperature measurement of the gas leaving the burner form the basis of determining the "combustion" or "indirect" efficiency.

Curves in the ASHVE Guide have been plotted from application of formulae to show the overall boiler efficiency for various types and classes of fuel, dependent upon the CO_2 and flue gas temperature. When using a good grade of coal or oil, a CO_2 of 10 percent and gas temperature of 800° F., results in an overall efficiency of about 68 to 70 percent. The 800° F. temperature is higher than average, and can indicate a dirty or improperly baffled boiler. If boiler exchange surfaces were kept clean and the boiler properly baffled, flue gas temperatures could be reduced to not over 650° F; under the same combustion conditions, the overall efficiency would then be about 75 percent.

2. DRAFT MEASUREMENT

Draft creates movement of gases through the furnace or boiler and up the stack. Essentially, draft is a pressure which may be positive or negative. It can start and maintain air in motion to support combustion.

Natural draft is the basis of most plant and chimney designs, and is formed by the difference in weight of the colder, heavier air on the outside of a chimney and the hotter, lighter gases within the stack. Forced or induced drafts supplement natural draft, the former being used extensively in stokers and oil burner installations, and to some extent in gas burner installations.

Forced draft is provided by a blower, located at the pit of the boiler which supplies air under pressure through a coal bed or over a burner to aid fuel burning. This pressure is positive at the inception of the burning process and becomes negative in the combustion chamber, at which point, secondary air is drawn into the boiler to complete the final burning. A negative pressure is desirable since it prevents flame and smoke from being blown into the boiler room.

Induced draft is created by a fan, which is generally located between the boiler outlet and the chimney inlet. Draft, whether natural, forced or induced, is measured in "inches of water column", and gives the necessary information to regulate the proper amount of air intake and flow for the respective fuel burning rate. Measuring the resistance offered to the flow

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for the respective fuel burning rate. Measuring the resistance offered to the flow of gases in their travel through the boiler passages should also help locate the area of trouble if any deficiencies develop within the boiler. The two-point, three-point or multi-point draft gauge is arranged in vertical quadrants for typical large size boiler installations. The draft gauge can be useful in determining the draft, with varying loads, which produces the best combustion conditions. The CO_2 and the temperature of the flue gas will have to be measured for each condition.

3. SMOKE INDICATION AND RECORDING

The Need for smoke abatement, and the frequency with which the public has become conscious of its effect upon property values, has been discussed in numerous articles, and does not require repetition here. When smoke is charged with fine particles of carbon, which indicates improper combustion, fuel is being wasted. The smoke indicator or recorder (one form of which operates upon the photo-electric cell principle) shows combustion conditions in the boiler. This instrument is so sensitive in gauging the haze or smoke density, that correct interpretation will tell whether excessive or insufficient air is being drawn through the combustion chamber. The smoke indicator recorder has become a necessity in localities where smoke ordinances are rigidly enforced.

4. STEAM AND WATER MEASUREMENT

The steam recording flow meter, the condensate meter, or the ordinary hot water displacement meter can give an accurate analysis concerning the rate of steam evaporated per unit of fuel burned; this is a check on direct efficiency, or the output of the boiler at its nozzle. To illustrate: an evaporation of about 8.4 lbs. of steam, transposed to standard conditions at atmospheric pressure and 212° F., per lb. of 12,500 Btu coal, would mean an efficiency of about 65 percent; an evaporation of about 9 lbs. of steam under the same circumstances and conditions would mean an efficiency of about 70 percent. The steam flow meter seems to function more accurately in high pressure steam plants because its operation depends upon the pressure drop across an orifice. The drop may be too large to permit effective operation of low pressure steam systems.

The average commercial type of cold water meter will determine the amount of make-up water the plant is using; more than average use of such make-up indicates existence of leaks in the system.

5. NUMBER AND TYPE OF INSTRUMENTS

Instrumentation need not be carried to an extreme, but only to a degree where the reading of each device can be integrated effectively in plant operation. Benefits can be realized only when the significance and correlated value of each instrument is known.

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Since measuring devices are constructed with delicate mechanisms, they must be located where they will be subject to a minimum of dust, shock and vibration. Mounting on instrument panels or boards where they are easily accessible for reading and servicing has been found most feasible; when so mounted a boiler pressure gauge and an electric clock could be included. Water meters installed with a 3-valve by-pass will facilitate meter servicing without interruption of plant operation.

It is best to base the selection of each instrument on the boiler size, which directly reflects the capacity of the system. On such a basis, the instruments referred to below are recommended. Instruments (except a cold water meter) are not listed for boiler sizes less than 1,000 sq. ft. heating surface, but there is no reason why, when boilers of lesser capacity are required, a simple test kit comprising the CO_2, flue gas and draft measuring devices (as discussed hereinbefore) should not be provided and used to advantage.

a. Boiler Size: 1,000-2,500 sq. ft. heating surface
- (1) Instrument: Hot water displacement meter.
- (2) Service: Measuring quantity of steam produced.
- (3) Remarks: Installed on main feed line to boilers and designed for measurement of water to approximately 200° F. Where make-up water is fed directly into boilers, the water meter will measure system returns; where make-up water is fed into condensate receiving tank on the suction side of the boiler feed pumps, the meter will measure the total of the system returns and make-up.

b. Boiler Size: 2,500, and above, sq. ft. heating surface, (high pressure steam only).
- (1) Instrument: Recording and integrating steam flow meter.
- (2) Service: Measuring quantity of steam produced.
- (3) Remarks: Installed on each boiler lead. Flanges in the steam main serving the entire project will be useful if it is decided to install flow meter at a later date.

c. Boiler Size: All boilers where there is underground distribution.
- (1) Instrument: Commercial type of cold water meter.
- (2) Service: Measuring quantity make-up water in steam systems.
- (3) Remarks: Installed on make-up line.

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d.	Boiler Size:	650, and above, sq.ft. heating surface.
	(1) Instrument:	Indicating thermometer (high grade, easily read, steam or dial type).
	(2) Service:	Measuring feed water temperature in steam systems.
	(3) Remarks:	Installed where it will measure feed water temperatures. Where feed water heater is installed, high grade, easily read, stem or dial indicating thermometers should be included to measure temperature of supply to, and discharge from, feed water heater. Where boilers have 2500, and above, sq.ft. of heating surface each, a recording check on temperature of supply to and discharge from feed water heater is advisable, and can be secured with a two pen instrument.
e.	Boiler Size:	1000-2500 sq.ft. heating surface.
	(1) Instruments:	One combination CO_2 and flue gas temperature recorded for plant, or separate indicating instrument for each function.
	(2) Service:	Measuring CO_2 and flue gas temperature.
	(3) Remarks:	Arranged so that CO_2 and temperature of flue gas can be measured selectively from each boiler.
f.	Boiler Size:	2500, and above, sq.ft. heating surface.
	(1) Instruments:	CO_2 recorder and flue gas temperature recorder.
	(2) Service:	Measuring CO_2 and flue gas temperatures.
	(3) Remarks:	Separate instruments for each boiler are desirable.
g.	Boiler Size:	1,000 and above, sq.ft. heating surface.
	(1) Instrument:	Smoke indicator and recorder equipped with signal light or alarm.
	(2) Service:	Measuring smoke density.
	(3) Remarks:	Installed in main breaching in coal or oil-fired plants, only in those localities which have or contemplate smoke ordinances.

h.	Boiler Size:	1000, and above, sq.ft. heating surface.
	(1) Instrument:	Draft gauge suitable for service required.
	(2) Remarks:	Installed for coal-fired installations, to measure draft in wind box, over fire and last pass. Installed for oil and gas-fired installations to measure draft in combustion chamber and last pass.
i.	Boiler Size:	No minimum.
	(1) Instruments:	Indicating thermometers (high grade, easily read, stem or dial type).
	(2) Service:	Measuring water temperature in forced hot water systems.
	(3) Remarks:	Installed on supply to and discharge from boiler or heat exchanger, and at discharge from mixing valve. Where boilers have 2500, and above, sq.ft. heating surface a recording thermometer should be installed to measure water temperature at discharge from mixing valve.
j.	Boiler Size:	No minimum.
	(1) Instruments:	Indicating pressure gauges, in addition to that supplied with boiler.
	(2) Service:	Measuring pressure in forced hot water systems.
	(3) Remarks:	Installed on suction and discharge connections at circulating pumps.

A combined steam flow-air flow meter and pyrometer may be substituted for the separate steam flow meter and the flue gas temperature measuring device (recorder) mentioned herein. In effect the combined device is three instruments in one: (1) recording and integrating the steam flow; (2) recording the relative rate of air flow for combustion; and (3) recording the flue gas temperature. All recordings are on one chart. Here, as for the steam flow meter, operation is most accurate in high pressure systems. Although the combined instrument does not directly measure the CO_2, the combined readings on the chart are informative enough to show whether correct proportions of CO_2 have been released. There may, therefore, be no need for the CO_2 recorder, but in its place the "Orsat" apparatus or other sample test kits could be used to make occasional checks on the flue gas.

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Two of the pens in the instrument, recording steam flow and air flow, operate together when best combustion results are obtained. In one make of instrument, when the air flow pen moves higher on the record chart than the steam flow pen, it shows too much air and too little fuel; conversely the air flow pen moving below the steam flow pen shows too little air or too much fuel. The third pen records the flue gas temperature.

Adjustments are made on the instrument originally by the manufacturer to have the steam and air flow pens move together, after trial and error tests are run on flue gas samples through the range of operating loads.

PLUMBING, HEATING AND VENTILATION

PART IX-BOILER PLANT INSTRUMENTS

Importance is properly attached, in the early stages of project design, to the selection of the most economical combination of utilities, including the heating method and system, and the fuel therefor. The significance of such selection will be lost if operation and maintenance efficiencies originally anticipated are not obtained, resulting from faulty design or from lack of complete knowledge as to how the heating plant is functioning under varying load conditions. One of the great industrial losses in the country results from waste that goes up the chimney; public low-rent housing can ill-afford this kind of loss.

It is important for the plant operator to measure the useful energy resulting from combustion processes in fuel burning. The design engineer must have the scientific approach to fuel savings; he must know and understand the means to obtain the maximum heat energy liberated from the boilers.

Instruments are the tools to guide and direct the operator in the proper care and efficient operation of the heating plant; they are a necessary adjunct to a well-planned heating system. The instruments discussed in this text are limited to plants operated and maintained by project management.

The instruments which are essential in this work are a carbon dioxide (CO_2) measuring device, a flue gas temperature measuring device, a draft gauge, and a cold water meter. There are other useful instruments, such as the steam flow meter, the hot water displacement meter, and the smoke indicator. The latter may not be as important as the carbon dioxide and flue gas temperature measuring devices, or the draft gauge, but are relatively useful because they, too, directly indicate or record data necessary to guide boiler operation.

So well recognized are the functions of instruments, that operators of small plants, where the more extensive types of instrumentation may not be warranted can justifiably purchase inexpensive, portable sets of carbon dioxide indicators, thermometers, and draft gauges.

1. CARBON DIOXIDE AND FLUE-GAS MEASUREMENTS

The design engineer knows that carbon dioxide is the most significant component of flue gas, because it is formed by the complete burning of the carbon in the fuel. For example, the engineer is aware that a low percentage of CO_2 means too much air is being drawn into the boiler through badly fitted doors and poorly constructed settings or, perhaps, that the firing apparatus has not been regulated to coordinate accurately the air supply with the fuel burning rate. The flue gas temperature measuring device shows the effectiveness with which the boiler exchange surfaces absorb the heat from hot gases.

NOTE: This Part supersedes Part IX of Bulletin No. LR-7, dated June 15, 1950. It has been revised throughout.

There is, for each type and classification of fuel, an "ultimate" value of CO_2 which is the result of supplying and utilizing the required amount of oxygen for the perfect combustion of fuel. This value depends upon the original constituents in the fuel. The degree to which the theoretical figure is approached, together with the temperature measurement of the flue gas leaving the boiler, form the basis of determining the "combustion" or "indirect" efficiency.

Curves in the American Society of Heating, Refrigerating and Air-Conditioning Engineers Guide have been plotted to show this indirect boiler efficiency for various types and classes of fuel, dependent upon the CO_2 and flue gas temperature. For example, when using a good grade of coal or oil, a CO_2 of 10 percent and gas temperature of 800°F., result in an indirect efficiency of about 68 to 70 percent. The 800°F. temperature is higher than average, and can indicate a dirty or improperly baffled boiler. If boiler heat-exchange surfaces were kept clean and the boiler properly baffled, flue gas temperatures could be reduced to not over 550°F; under the same combustion conditions, the overall efficiency would then be about 78 percent.

2. DRAFT MEASUREMENT

Draft creates movement of gases through the boiler and up the stack. Essentially, draft is a pressure which may be positive or negative. It can start and maintain air in motion to support combustion.

Natural draft is the basis of most plant and chimney designs, and is formed by the difference in weight of the colder, heavier air on the outside of a chimney and the hotter, lighter gases within the stack. Forced or induced drafts may supplement natural draft. Obviously mechanical draft is necessary when stub pieces project from the boiler smoke up-takes in separate one or two story boiler plants, or where the chimney is reduced from the required natural draft height to maintain the architectural effect of a project.

Forced draft is provided by a blower, located in coal stoker installations at the pit of the boiler which supplies air under pressure through the coal bed. In oil or gas burning installations, the blower is an integral part of the burner equipment. This pressure is positive at the inception of the burning process and may become negative in the combustion chamber, at which point, secondary air is drawn into the boiler to complete the final burning. The advantage in a slight negative pressure of about 0.05 inches water column is that it prevents flame and smoke from being blown into the boiler room, and prevents burner rings in oil-fired installations from becoming damaged.

The disadvantage in low stacks is creation of a smoke and odor nuisance at habitable area levels; caution in their use is therefore advisable.

Induced draft is created by a fan, which is located between the boiler outlet and the chimney inlet. Draft, whether natural, forced, or induced, is measured in "inches of water column," and gives the necessary information to regulate the proper amount of air intake for the respective fuel burning rate. Measuring the resistance offered to the flow of gases by a draft gauge in their travel through the boiler passages should also help locate the area of trouble if any deficiencies develop within the boiler. The two-point, three-point or multipoint draft gauge is generally arranged in vertical quadrants. The gauge is useful in determining the draft, with varying loads to produce the best combustion conditions. The CO_2 and the flue gas temperature should be measured for each condition.

3. SMOKE INDICATION AND RECORDING

The need for smoke abatement, and the frequency with which the public has become conscious of its effect upon health, and property values, has been discussed in numerous articles, and does not require repetition here. When smoke is charged with fine particles of carbon, which indicates improper combustion, fuel is being wasted. The smoke indicator or recorder (one form of which operates upon the photoelectric cell principle) shows combustion conditions in the boiler. This instrument is so sensitive in gauging the smoke density, that correct interpretation will tell whether excessive or insufficient air is being drawn through the combustion chamber. The smoke indicator or recorder has become a necessity in localities where smoke ordinances are rigidly enforced.

4. STEAM AND WATER MEASUREMENT

The steam recording flow meter, the condensate meter, or the ordinary hot water displacement meter shows the rate of steam evaporated per unit of fuel burned; this is a check on direct efficiency, or the output of the boiler at its nozzle. To illustrate: an evaporation of about 8.4 lbs. of steam, transposed to standard conditions at atmospheric pressure and 212° F., per lb. of 12,500 Btu coal, would mean an efficiency of about 65 percent; an evaporation of about 9 lbs. of steam with the same fuel would mean an efficiency of about 70 percent. The steam flow meter functions more accurately in high pressure steam plants because its operation depends upon the pressure drop across an orifice. The drop may be too large to permit effective operation of this instrument in low pressure steam systems.

The average commercial type of cold water meter will determine the amount of makeup water the plant is using; more than average use of such makeup indicates existence of leaks in the system. Indication of corrosion in the pipe lines would necessitate additional chemical treatment of the boiler water.

5. NUMBER AND TYPE OF INSTRUMENTS

Instrumentation need not be carried to an extreme, but only to a degree where the reading of each device can be integrated effectively in plant operation. Benefits can be realized only when the significance and correlated value of each instrument is known.

Since measuring devices are constructed with delicate mechanisms, they must be located where they will be subject to a minimum of dust, shock, and vibration. Mounting on panels where they are easily accessible for reading and servicing has been found most feasible; when so mounted a boiler pressure or temperature gauge (depending whether the heating medium is steam or hot water), and an electric clock could be included. Water meters installed with a 3-valve bypass will facilitate meter servicing without interruption of plant operation.

Selection of instruments should be based on the size of each boiler. On such basis, the instruments referred to below are recommended. Instruments (except thermometers and a cold water meter) are not listed for each boiler size less than 65 boiler horsepower output. However, when boilers of this lesser capacity are required, a simple test kit comprising the CO_2, flue gas and draft measuring devices (as discussed hereinbefore) should be useful, and is definitely recommended.

The figures indicated below under boiler size are boiler horsepower outputs.

a. Boiler Size: 100-250
(1) Instrument: Hot water displacement meter.
(2) Service: Measuring quantity of steam produced.
(3) Remarks: Installed on main return line to boilers, and designed for measurement of water up to approximately 200° F. Where makeup water is fed directly into boilers (bypassing meter), meter will measure system returns; where makeup water is fed into condensate receiving tank on the suction side of the boiler feed pumps, the meter will measure the total of the system returns and makeup.

b. Boiler Size: 250 and above. (high pressure steam only).
(1) Instrument: Recording and integrating steam-flow meter.
(2) Service: Measuring quantity of steam produced.
(3) Remarks: Installed on each boiler supply lead. Flanges in the steam main serving the entire project will be useful if it is decided to install flow meter at a later date. Use condensate meter for low pressure steam systems.

c.	Boiler Size:	No minimum .
	(1) Instrument:	Commercial type of cold water meter.
	(2) Service:	Measuring quantity of makeup water
	(3) Remarks:	Installed on makeup line.
d.	Boiler Size:	65, and above.
	(1) Instrument:	Indicating thermometer (high grade, easily read, stem or dial type).
	(2) Service:	Measuring return water temperature in steam systems.
	(3) Remarks:	Installed on return line at boilers. Where feed water heater is installed, high grade, easily read, stem or dial indicating thermometers should be included to measure temperature of supply to, and discharge from, feed water heater. Where each boiler has 250 and above horsepower output, a recording check on temperature of supply to and discharge from feed water heater is advisable, and should be secured with a two pen recording instrument.
e.	Boiler Size:	100-250.
	(1) Instruments:	One combination CO_2 and flue gas temperature recorder for plant, or separate instrument for each function.
	(2) Service:	Measuring CO_2 and flue gas temperature.
	(3) Remarks:	Arranged so that CO_2 and temperature of flue gas can be measured selectively from each boiler.
f.	Boiler Size:	250, and above.
	(1) Instruments:	CO_2 and flue gas temperature recorder, in combination or separate instruments.
	(2) Service:	Measuring CO_2 and flue gas temperatures.
	(3) Remarks:	Separate recorders for each boiler are desirable.
g.	Boiler Size:	100 and above.
	(1) Instrument:	Smoke indicator and recorder equipped with signal light or alarm (horn or bell).
	(2) Service:	Measuring smoke density.
	(3) Remarks:	Installed in main breaching in coal or oil-fired plants; and for all boiler sizes in those localities which have or contemplate smoke ordinances.

h. Boiler Size 100 and above.
(1) Instrument: Draft gauge suitable for service required.
(2) Remarks: Installed for coal-fired installations, to measure draft in wind box, over fire and last pass. Installed for oil and gas-fired installations to measure draft in combustion chamber and last pass.

i. Boiler Size: No minimum.
(1) Instruments: Indicating thermometers (high grade, easily read, stem or dial type).
(2) Service: Measuring water temperature in forced hot water systems.
(3) Remarks: Installed on supply to and discharge from boiler or heat exchanger, and at discharge from mixing valve. Where each boiler has 250 horsepower, and above a recording thermometer should be installed to measure water temperature at discharge to system.

j. Boiler Size: No minimum.
(1) Instruments: Indicating pressure gauges, in addition to that supplied with boiler.
(2) Service: Measuring pressure in forced hot water systems.
(3) Remarks: Installed on suction and discharge connections at circulating pumps.

A combined steam-flow air-flow meter and pyrometer may be substituted for the separate steam-flow meter and the flue gas temperature measuring device (recorder). The combined device is three instruments in one: (1) recording and integrating the steam flow; (2) recording the relative rate of air flow for combustion; and (3) recording the flue gas temperature. All recordings are on one chart. Here, as for the steam-flow meter, operation is most accurate in high pressure systems. Although the combined instrument does not directly measure the CO_2, the combined readings on the chart are informative enough to show whether correct proportions of CO_2 have been achieved. There may, therefore, be no need for the CO_2 recorder, but in its place the "Orsat" apparatus or other simple test kits could be used to make occasional checks on flue gas.

The design engineer should exercise his judgement as to the prevailing practice, and operating skills available in the community. It is conceivable that the boiler horsepower limitations above may be increased or decreased to effect maximum practical economy consistent with local conditions.

PLUMBING, HEATING, AND VENTILATION

PART X - WATER SUPPLY AND DRAINAGE PIPING MATERIALS

1. GENERAL

Nearly all local plumbing codes permit a choice of water supply piping materials, and most of them allow optional selection of some part of the drainage system. The purpose of these notes is to consider in light of the experience and needs of public low-rent housing, the relative advantages of the various materials used for water supply and drainage piping.

The first objective in the selection should be a probable life expectancy of approximately forty years with a minimum of anticipated repairs or replacements during that period; the second should be to select the lowest cost materials that will meet the foregoing requirement of probable life expectancy. A material that will meet these objectives in one locality will not necessarily do so in another, since differences in water, soil, and other conditions will often favor a material in one locality and not do so elsewhere. Hence, the results of local experiences should be sought from all available sources. When information so obtained is inconclusive or inadequate, or where it is expected that local conditions may be changed, it is strongly advised that a water and soil analysis be made by a competent and disinterested corrosion engineer to aid in making correct selection of the materials, especially of the water-supply piping.

2. UNDERGROUND DRAINAGE PIPING WITHIN BUILDINGS

Such pipe is subject to soil and water corrosion, damage due to backfilling, and leaks caused by settlement and vibration. Since repairs or replacements are costly, this piping should be able to withstand all possible hazards.

The material subject to the fewest risks is extra-heavy cast-iron soil pipe and fittings. The relatively thick and uniform walls of this pipe, together with properly made joints of lead and oakum, offers the best insurance against corrosion and damage. This type of pipe should extend five feet beyond the exterior walls of buildings.

3. ABOVE-GROUND DRAINAGE AND VENT PIPING

Following is a list of the various materials used for these purposes, with comments on their characteristics, advantages, etc:

a. Cast-iron soil pipe and fittings, victory weight (lighter than extra-heavy), available in two inch diameter and larger, is the material most commonly used for this purpose. It is thick enough to resist normal corrosion, well made joints are gas tight and will withstand moderate movements. Joints are easily made, cutting to desired lengths can be done readily, and the pipe sections are light and readily handled.

This weight of pipe is subject to breakage under careless handling, the wall thickness is not always uniform, and sand holes and other defects are not uncommon. The possibility of latent flaws demands careful tests after installation and removal of entire sections that are found defective, since sealing flaws is not permanent and should not be permitted. Horizontal runs of this type of piping should be supported at five-foot intervals which results in more hangers than are required for screwed ferrous piping.

b. Threaded cast-iron pipe, with screwed fittings, is usually of better quality than cast-iron soil pipe and has fewer flaws. Available sizes are 1-1/4 inch diameter and larger. Since the fittings, being without hubs, are smaller than soil pipe fittings, the piping can be worked into tighter spaces. This pipe is more expensive than cast-iron soil pipe and good thread cutting is difficult and expensive, since cast iron is hard and brittle. The pipe will readily fracture under moderately heavy torque when the joints are made up.

c. Galvanized steel pipe of standard weight with screwed fittings is generally used for stacks up to 2 inches, and for branch waste and vents. Relatively low cost for these sizes and ease in cutting, threading, and fitting are the main advantages. Connections from fixtures to a stack are fairly rigid and excessive movements of the building (not a likely hazard if the structure is properly designed and built) may fracture the connection at the stack or at the fixtures.

d. Galvanized wrought-iron pipe of standard weight and with screwed fittings is generally more expensive than galvanized steel. Formerly it was believed to resist corrosion better than steel, but many authorities are now convinced that all ferrous materials corrode about equally under normal conditions, and that it is the thickness of the pipe wall that is the determining factor in the life of the piping. If corrosion of the drainage and vent piping is expected to be severe, it would be advisable to use extra-heavy steel piping rather than standard weight wrought iron.

e. Lead waste pipe of weight D or XL is flexible, can be worked into tight spaces, and is not affected by structural movements. Its use is limited to branch lines between the fixtures and stacks since the pipe requires supports to prevent sagging on horizontal runs and at 4 foot intervals when placed vertically. The cost of these supports and the necessary wiped joints makes lead pipe more expensive than some other materials. Lead pipe can be easily damaged during construction, is subject to corrosive attack when placed in contact with concrete and plaster, and has been known to suffer from attacks by rodents.

f. Brass or copper pipe with screwed brass or bronze fittings is more expensive than other materials and, hence, is seldom used for drainage piping. Joints must be carefully made since the threads are easily damaged after a joint has been made, it cannot be broken and remade with the same threaded ends or fittings.

g. Copper tubing with wrought-copper solder-joint sleeve-type fittings is made in weights K, L, and M. Type K has the thickest wall and is used principally for underground installation; types L and M are for above-ground work. Type M has a thinner wall than type L and should be used only where suitable protection can be provided. Both types K and L are furnished as hard-drawn or annealed tubing, while type M can be had only in hard-drawn form. Generally, hard-drawn tubing is used in new installations, while the annealed type is more suitable for repairs or replacement work.

Copper tubing is light, easily bent to shape, requires few fittings and these can be quickly made up. (Tin-antimony solder for joints is considered better than the tin-lead type; flux should be the non-corrosive type of rosin and mineral grease). Since fittings are the "stream-line" type, the tubing can be worked into tight spaces and may, in some cases, permit thinner partitions than piping of other materials. The drainage passageway is very smooth which reduces the possibility of stoppage, and the material is relatively non-corrosive.

Copper tubing is expensive, in comparison with other materials and is subject to damage during construction, but these disadvantages may be offset by the rapidity and ease of installation.

4. FITTINGS FOR DRAINAGE AND VENT PIPING

Fittings for cast-iron soil piping should be the same weight as the pipe. Ferrous drainage piping, other than soil piping, should have cast-iron recessed drainage fittings. Piping for the vent system should have galvanized cast-iron, or malleable-iron, straight type (steam pattern) fittings. Connections between lead pipe and cast-iron soil piping should be made with a brass calking ferrule wiped to the lead and calked into the hub of the soil pipe fitting; if the lead is connected to other types of drainage piping, it should be wiped to a brass soldering nipple or bushing which is screwed into such piping. Copper tubing branches are screwed to non-copper stacks by means of adapters. Brass or copper tubing or fittings should not be connected to galvanized piping unless an insulating fitting is used.

5. WATER SUPPLY PIPING

Materials available for use in water distribution piping are cast iron, galvanized steel, or wrought iron, lead, brass or copper, and choosing between them the life-expectancy and the economy of each should receive full consideration. The corrosion of water piping is particularly important, since it is usually smaller than drainage or vent piping and the effects of corrosion will tend to make the lines useless by penetrating the pipe wall or by filling the pipe with scale. Even more so than in the case of drainage piping, a soil and water corrosion specialist may be needed to assist in making the final choice. Some general comments regarding various water-piping materials follow.

a. Cast-iron water piping is used almost exclusively for underground piping. The pipe is usually coated with coal-tar pitch and can also be obtained with cement lining so that it will effectively resist both water and soil corrosion. When large size piping is required, this material gives excellent service because of its relatively thick pipe walls. However, the cost of cutting and handling must be considered in evaluating its economy.

b. Galvanized steel water pipe with galvanized malleable-iron screwed fittings has probably the lowest cost of the commonly used pipe materials, but also is most liable to corrosive attack both from the soil and the water. Galvanized wrought-iron has similar characteristics, but costs considerably more.

Steel or wrought-iron pipe can be used only where water and soil conditions are very favorable since, if the water is soft, the effects of corrosion will be to cause penetration of the pipe wall, and if the water is hard the interior will become coated and eventually clogged to such an extent that the flow (especially through the smaller branches) will be seriously retarded. These conditions are particularly prevalent in heated water. There are relatively few places in this country where water conditions are such that these materials will last the required length of time.

c. Cement-lined steel water pipe with cement-lined malleable-iron fittings is suitable for highly corrosive waters. In some localities this is the only piping that can be used with any success; however, the cost is relatively high, and the piping must be carefully handled to prevent fracture or spalling of the cement lining. The pipe and all fittings should be factory-lined, and special jointing compound should be used. Make-shift or on-the-job lining of pipe or fittings should be forbidden, as the lining will not be continuous and corrosive water will attack the exposed metal. When cutting this pipe, a hack saw should be used since an ordinary pipecutter may fracture the lining. Because of the high cost of this material and its installation, it should be used only where none of the other commonly-used materials will withstand the corrosive attacks of the water.

d. Lead water piping is useful for underground piping only because (as noted previously) lead pipe requires more supports than other materials. Some water constituents will combine with lead to form a toxic poison, and it should be definitely determined that such constituents are not present in any water that will be used with lead pipe. Lead is fairly resistant to corrosion, except when in contact with concrete or plaster. Because of its relative softness, care must be taken to prevent damage during installation and backfilling. The cost of the material, handling, and jointing, is fairly high.

e. Brass or copper water pipes with brass or bronze fittings have the same disadvantage as outlined for the use of these materials in drainage and vent piping. In addition, there is a tendency for some corrosive waters and soils to dissolve out the zinc in the brass pipe or fittings, rendering the remainder of the metal porous.

f. Copper water tubing with wrought-copper, solder-joints, sleeve-type fittings (as previously described for drainage and vent work) is generally

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well suited for water supply piping. Its greatest advantage is its resistance to the corrosion of most soils and waters, and the virtual assurance of a practically trouble-free life for forty years or more, except under unusually unfavorable conditions. Its smooth surface, as compared to galvanized steel, reduces the friction factor used in designing pipe sizes, and frequently smaller pipe can be used without reducing flow and pressure under design conditions. Since it has so many advantages, it should be considered as a first choice, even though its cost is somewhat higher than galvanized steel.

6. GAS PIPING

Black steel or black wrought-iron pipe with black malleable-iron fittings are used generally for gas piping, although copper tubing may be used for short branch connections or when connecting liquefied petroleum or butane-air storage tanks to gas appliances. As stated previously, wrought-iron gives about the same service as steel. To minimize damage due to corrosion, methods of protecting the piping (especially underground piping) by coating, wrapping or providing cathodic protection are being increasingly used, and Part V of this Bulletin, "Safety Considerations in the Installation of Gas Piping", discusses these methods of protection.

7. REFERENCE SPECIFICATIONS

The acceptable composition of materials, dimensions, tolerances, and general and detailed descriptions and testing procedures to determine their acceptability, are listed in specifications issued by various interested bodies. The United States Government issues a standard stock catalogue of Federal Specifications on most plumbing materials.

These specifications are intended for the use of governmental agencies in purchasing materials. Since these specifications are detailed, complete, and kept current by continual revisions, and since most plumbing supply firms are familiar with their requirements, they can readily be used as a basic requirement for most plumbing materials. Copies of the various specifications are available from the Superintendent of Documents, Washington 25, D.C., at nominal cost.

Also available from the Superintendent of Documents are copies of Commercial Standards and Simplified Practice Recommendations issued by the National Bureau of Standards, Washington, D.C. Commercial Standards are voluntary standards of the various trades published in booklet form, while Simplified Practice Recommendations are recorded voluntary recommendations to the trade. These standards can be made mandatory when applied to the various materials used in plumbing installations. In general, the details of the various materials specified in these standards are in agreement with the applicable Federal Specifications.

The American Standards Association, 70 East 45th Street, New York 17, New York, an industry-supported association, issues various standards on most plumbing materials for general use by governmental agencies and private industry.

These standards may not include all of the items listed in the Federal Specifications, but for the items included the standards should be equally acceptable.

The American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania, issues various standards and tentative standards for the testing and inspection of many plumbing materials. Their testing methods are widely accepted and when necessary can be used with confidence.

The American Water Works Association, 500 Fifth Avenue, New York 18, New York, issues standards and tentative standards principally on cast-iron water piping and coal-tar enamel used to protect piping. The latter standard should be complied with if this type of protection is to be applied to underground water or gas piping.

PLUMBING, HEATING, AND VENTILATION

PART X - WATER SUPPLY AND DRAINAGE PIPING MATERIALS

1. GENERAL

Nearly all local plumbing codes permit a choice of water supply piping materials, and most of them allow optional selection of some part of the drainage system. The purpose of these notes is to consider in light of the experience and needs of public low-rent housing, the relative advantages of the various materials used for water supply and drainage piping.

The first objective in the selection should be a life expectancy of not less than twenty-five years with a minimum of anticipated repairs or replacements during that period; the second should be to select the lowest cost materials that will meet the foregoing requirement of probable life expectancy. A material that will meet these objectives in one locality will not necessarily do so in another, since differences in water, soil, and other conditions will often favor a material in one locality and not do so elsewhere. Hence, the results of local experiences should be sought from all available sources. When information so obtained is inconclusive or inadequate, or where it is expected that local conditions may be changed, it is strongly advised that a water and soil analysis be made by a competent and disinterested corrosion engineer to aid in making correct selection of the materials, especially of the water-supply piping.

2. UNDERGROUND DRAINAGE PIPING WITHIN BUILDINGS

Such pipe is subject to soil and water corrosion, damage due to backfilling, and leaks caused by settlement and vibration. Since repairs or replacements are costly, this piping should be able to withstand all possible hazards.

The material subject to the fewest risks is extra-heavy cast-iron soil pipe and fittings. The relatively thick and uniform walls of this pipe offer the best insurance against corrosion or damage. Joints should be firmly packed with oakum or hemp and filled with molten lead, or factory made compression type joints may be used. This type of pipe should extend five feet beyond the exterior walls of buildings.

3. ABOVE-GROUND DRAINAGE AND VENT PIPING

Following is a list of the various materials used for these purposes, with comments on their characteristics, advantages, etc:

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NOTE: This Part supersedes Part X of Bulletin No. LR-7 dated 6-29-50. It has been revised to include additional piping material and to update the material and references.

a. Cast-iron soil pipe and fitting, hub and spigot type, or centrifugally cast type with hub and without spigot is available in both five-foot and ten-foot lengths, and in pipe sizes of two-inch diameter and larger is the material most commonly used for this purpose. Most building codes require the use of extra heavy type pipe and fittings for high-rise buildings and will permit the use of service weight pipe and fittings for low-rise buildings.

Hubless type cast-iron pipe and fittings, with joints comprised of neoprene gaskets and fastened in place with stainless steel shields and band clamps, may be used in compact installations, in lieu of the use of hub type pipe, particularly for drainage systems in low-rise buildings.

b. Galvanized steel pipe of standard weight with screwed fittings is generally used for stacks up to 2 inches, and for branch waste and vents. Relatively low cost for these sizes and ease in cutting, threading, and fitting are the main advantages. Connections from fixtures to a stack are fairly rigid and excessive movements of the building (not a likely hazard if the structure is properly designed and built) may fracture the connection at the stack or at the fixtures.

c. Galvanized wrought-iron pipe of standard weight and with screwed fittings is generally more expensive than galvanized steel. Formerly it was believed to resist corrosion better than steel, but many authorities are now convinced that all ferrous materials corrode about equally under normal conditions, and that it is the thickness of the pipe wall that is the determining factor in the life of the piping. If corrosion of the drainage and vent piping is expected to be severe, it would be advisable to use extra-heavy steel piping rather than standard weight wrought iron.

d. Lead waste pipe of weight D or XL is flexible, can be worked into tight spaces, and is not affected by structural movements. Its use is limited to branch lines between the fixtures and stacks since the pipe requires supports to prevent sagging on horizontal runs and at 4 foot intervals when placed vertically. The cost of these supports and the necessary wiped joints makes lead pipe more expensive than some other materials. Lead pipe can be easily damaged during construction, and is subject to corrosive attack when placed in contact with concrete and plaster.

e. Copper tubing with wrought-copper solder-joint sleeve-type fittings is made in weights K, L, M and DWV; types M and DWV are generally used for above ground drainage and vent work. Type DWV has a thinner wall than type M and should be used only where suitable protection can be provided. The interior wall of copper tubing has low frictional resistance to flow and is relatively noncorrosive.

The light weight of the material permits easy handling and with the use of "streamline" type fittings, the tubing can be worked into tight spaces and may, in some cases, permit tubing to be concealed between studs thus reducing furring that may be required for other materials.

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Copper tubing is expensive, in comparison with other materials, but this disadvantage may be offset by the rapidity and ease of installation.

f. Plastic pipe with solvent welded type fittings, a relatively new product that is rapidly gaining favor in use for waste and vents for low-rise buildings. Such piping materials, commercially known as Polyvinyl Chloride (PVC) or Acrylonite-Butadiene-Styrene (ABS), are being used for this purpose. The pipe materials are light in weight, easy to handle and assemble, and have the necessary requirements for good pipe performance, such as toughness, rigidity, and resistance to corrosion. Connections to other types of non-ferrous pipes, where necessary, can be made through the use of adapters.

Plastic pipe will probably gain in popularity in the coming years for use in waste and vent systems within buildings. However, its expanded use for this purpose is subject to acceptance in local building codes.

4. FITTINGS FOR DRAINAGE AND VENT PIPING

Fittings for cast-iron soil piping should be the same weight as the pipe. Ferrous drainage piping, other than soil piping, should have cast-iron recessed drainage fittings. Piping for the vent system should have galvanized cast-iron, or malleable-iron, straight type (steam pattern) fittings. Connections between lead pipe and cast-iron soil piping should be made with a brass calking ferrule wiped to the lead and calked into the hub of the soil pipe fitting; if the lead is connected to other types of drainage piping, it should be wiped to a brass soldering nipple or brushing which is screwed into such piping. Copper tubing branches are screwed to non-copper stacks by means of adapters. Brass or copper tubing or fittings should not be connected to galvanized piping unless an insulating fitting is used. Connections of plastic pipe to cast-iron, steel, or other types of pipe should be made by means of adapters.

5. WATER SUPPLY PIPING

Materials available for use in water distribution piping are cast-iron, copper, galvanized steel or wrought iron, plastic and asbestos cement, and in choosing between them the life expectancy and the economy of each should receive full consideration. Corrosion of ferrous water piping is particularly important since the effects of corrosion tend to make the lines useless by filling the pipe with scale or by penetrating the pipe wall in below ground installations. In certain areas a water corrosion specialist may be needed to assist in making the final choice of type of pipe to be used.

a. Cast-iron water pipe and fittings completely coated inside and out with coal-tar varnish are the type of material generally selected for underground water mains. When large size piping is required this material gives excellent service because of its relatively thick walls.

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Such pipe and fittings can also be obtained with cement lining to meet unusual service conditions.

b. Cement-asbestos pressure type pipe may be used for underground work. The fittings must be cast-iron with all bell connections, or special dimensions as required, or equipped with adapters as necessary for proper joining. This type of inert piping material is light in weight and is easy to handle and is generally used for water mains. The cast-iron fittings required can also be obtained with cement lining to meet unusual service conditions.

c. Galvanized steel water pipe with galvanized malleable-iron has probably the lowest cost of ferrous pipe materials, but also is most liable to corrosive attack both for the soil and the water. Glavanized wrought-iron has similar characteristics, but costs considerably more.

Steel or wrought-iron pipe can be used only where water and soil conditions are very favorable since, if the water is soft, the effects of corrosion will be to cause penetration of the pipe wall, and if the water is hard, the interior will become coated and eventually clogged to such an extent that the flow (especially through the smaller branches) will be seriously retarded. These conditions are particularly prevalent in heated water.

In evaluating the use of this material, with nonferrous materials for underground work, the additional cost of coating and wrapping the steel or wrought-iron piping consistent with PHA requirements must be considered.

d. Copper water tubing with wrought-copper solder-joint sleeve type (as previously described for drainage and vent work) is generally well suited for water supply piping. Type K has the thickest wall and is used principally for underground installation and type L for aboveground work. Both type K and L are furnished as hard-drawn or in annealed form. The greatest advantage to the use of copper tubing is its resistance to the corrosion of most soils and waters, and the virtual assurance of a practically trouble-free life for twenty-five years or more, except under unusually unfavorable conditions. Its smooth surface, as compared to galvanized steel, reduces the friction factor used in designing pipe sizes, and frequently smaller pipe can be used without reducing flow and pressure under design conditions. Since it has so many advantages, it should be considered as a first choice, even though its cost is higher than steel or wrought-iron pipe.

e. Plastic pipe for water distribution, such as (PVC) or (ABS) with solvent welded type fittings (as previously mentioned for drainage vents systems) or the flexible polyethylene type with molded insert type fitting and stainless steel clamps, can be used for underground work outside buildings. However, the availability of plastic materials for water piping systems in building and particularly for domestic hot water is limited. The high cost of such material as polyvinyl dichloride (PVD) suggested as a suitable plastic for hot and cold water pipe and acceptance by local codes will perhaps delay the use of plastic pipe for this purpose for several years.

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6. GAS PIPING

a. Black steel or black wrought-iron pipe with black malleable-iron fittings are used generally for gas piping, although copper tubing may be used for short branch connections or when connecting liquefied petroleum or butane-air storage tanks to gas appliances. As stated previously, wrought-iron gives about the same service as steel. To minimize damage due to corrosion all steel and wrought-iron pipe used in underground work must be coated and wrapped to meet the requirements set forth in PHA Low-Rent Housing Manual Section 207.1. Part V of this Bulletin, "Safety Considerations in the Installation of Gas Piping," discusses methods of protection and other pertinent gas piping installation data.

b. Plastic pipe with solvent welded type fittings is rapidly gaining favor for use in underground gas distribution systems. The American Gas Association Subcommittee on Plastic Pipe Standards lists several types of plastic materials recommended for use in natural gas distribution systems, such as types (ABS) and (PVC). Local Authorities should thoroughly investigate the qualifications of any and all kinds of plastic pipe for a specific application before the use of a specific type. This probably can best be determined at the time that the local utility company is consulted on installation and service requirements.

7. REFERENCE SPECIFICATIONS

The acceptable composition of materials, dimensions, tolerances, and general and detailed descriptions and testing procedures to determine their acceptability are listed in specifications issued by various interested bodies. The United States Government issues a standard stock catalogue of Federal Specifications on most plumbing materials.

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PART XI

PLUMBING, HEATING AND VENTILATION

PART XI - WATER SUPPLY SYSTEMS IN BUILDINGS

CONTENTS

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PLUMBING, HEATING AND VENTILATION

PART XI - WATER SUPPLY SYSTEMS IN BUILDINGS

1. INTRODUCTION

The design of water supply systems for buildings can be considered as the practical solution of three related problems: the choice of materials, the layout of the supply piping, and the sizing of this piping.

The piping material chosen will necessarily affect the pipe sizing, and to a lesser degree the piping layout; the design procedure therefore should begin with a determination of the materials to be used, and then proceed to the layout and sizing.

2. LENGTH OF SERVICE OF WATER PIPING

The separate elements that go to make up a low-rent housing project should reasonably be expected to last as long as the probable life of the project (approximately forty years), unless it is more economical to install and periodically replace elements or materials of shorter life expectancy. Since replacing a water supply system usually involves breaking into and replacement of the finished surfaces of walls, partitions and floors, and, possibly, excavation beneath parts of occupied buildings and finished exterior spaces, it is not likely that it would be economically desirable in any but the most unusual circumstances to install a water supply system with a life expectancy less than that of the project buildings.

The principal factor that determines the life of water piping is corrosion of the interior or exterior of the piping. Corrosion will attack the entire piping system, some portions more severely than others, and it is usually the severity of the attack that is the determining factor in the length of its life.

3. FUNDAMENTALS OF CORROSION

The subject of corrosion is extensive and involved, and it is not intended to present herein more than a few basic facts to aid in understanding its action on water supply piping. Corrosion of all metals is fundamentally similar, although the effects on different metals vary greatly. The basic cause of corrosion is an electrochemical reaction between the metal and its surroundings. The reaction will begin because of the nature of the metal and its environment, but the speed with which it will progress will depend principally on the nature of the products of the initial reactions. The presence of moisture and oxygen is usually essential to a corrosive reaction and, other factors being equal, the rate at which corrosion will proceed depends directly on the concentration of oxygen immediately surrounding the metal. Acid surroundings will induce more rapid corrosive action than neutral surroundings, which in turn are more corrosive than alkaline surroundings.

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Surface films of corroded metal sometimes act as insulation between a metal and its environment, and materially affect the resistance to further corrosive action. If the initial action forms a continuous film, the speed of corrosion will decrease markedly after a short period of time; if the film is not continuous the corrosive action will progress. In some materials the surface film may combine with insoluble compounds from the surroundings and become a thick coating, which may be loose (in which case corrosion is accelerated), or dense and adherent -(retarding the corrosion). The rate of corrosion usually increases with an increase in velocity of water past the metal, since more oxygen comes in contact with the metal and the movement tends to break up the formation of a surface film. However, if a strong surface film does form, the effect of increases in velocity becomes negligible.

Localized corrosion will occur when dissimilar metals contact each other in the presence of some medium (the electrolyte) through which a galvanic current can flow to complete an electrical circuit. The dissimilarity may occur between a metal and its surface film or surface scale, between two pieces of metal of supposedly identical composition but with slight chemical differences, or even between portions of a single piece of metal. However, localized corrosion becomes most significant when two widely differing metallic elements (such as zinc and copper) are in contact. Increased temperatures usually increase the electrical conductivity of the electrolyte and may increase the supply of free oxygen, so that both an increase in the galvanic current and a more rapid oxidizing action speeds up the localized corrosive reactions. The formation of pits in a metal is a form of localized corrosion since the metal in the bottom of the pits becomes dissimilar to the surface metal and reacts with it in such a way as to deepen the pits.

4. CORROSIVITY OF WATERS

Water piping in some localities will last far longer than in others under similar conditions of use. This variation in the life of the piping is principally due to the difference in the protective coatings formed by the corrosive action of the waters in each locality.

Waters not normally containing dissolved solids which precipitate as insoluble compounds (soft waters), or waters from which these solids have been removed by means of special treatments, are usually highly corrosive to piping, since no coating will form on the pipe wall. Hard waters are usually much less corrosive, unless the coating formed by precipitation of the solids is loose or irregular. Non-uniform coatings, covering only part of the piping, may promote localized corrosion between the unprotected and protected portions of the pipe and cause further deterioration. Some types of coatings will eventually completely fill the pipe, or decrease its free opeinings to such an extent that the pipe becomes useless.

5. CORROSIVITY OF SOILS

The action of soil on the exterior of underground piping is similar to the action of the water on the interior, although the effects may differ, since some characteristics of the soil may completely change the nature and the

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progress of the corrosive reaction. Soil corrosion usually results in deep pitting of the piping due to localized factors such as variations in the soil, changing characteristics of soil water, and other factors, some of which are not completely understood. These factors tend to create dissimilar conditions in the areas adjacent to various sections of piping.

6. CHOICE OF WATER PIPING

The preceding statements serve to emphasize the fact that the choice of water piping that will give desirable service for the required number of years is usually not simple. In some locations, differing materials will be required for underground and above-ground use; in other places, hot and cold water lines may require different materials. The characteristics of the water used in a region may be changed radically by the construction of a municipal water softening plant or the introduction of water from new sources. The problem of making a sound choice is not solved merely by using materials which are in common use in the area without an investigation as to how long such materials have actually lasted, and how suited they would be to possible changing conditions. Reliable information may be difficult to obtain, since personal preferences of observers frequently color their view, and some materials in current use have not been available in the past. The best solution is the employment of a competent water and soil corrosion engineer who can collect pertinent information, make and interpret water and soil corrosivity tests and analyses, determine the possible effects of future changes in the water characteristics, and correlate these data to make an intelligent and reliable decision for each project.

7. WATER PIPING LAYOUT

The water piping layout in a building is determined largely by the building design. The architect cannot be expected to shape the building around the plumbing system; it is advisable for the designing engineer to meet with the architect and coordinate the plumbing requirements with the building structure to obtain the most direct, simple, and economical piping system possible.

In addition, the water piping layout should be so designed that the water supply is protected from contamination. No direct cross-connections of any kind to any other piping systems should be permitted, even when one or more valves are used to separate the two systems. Drain valves, sillcocks, or stop and waste valves in the system should not be placed underground or in position where they might be submerged by surface or ground water, since there is always a possibility of backflow through the valves into the water system. Water supply tanks, including building tanks and hot water storage tanks, should always be properly covered or sealed, and should not be located beneath any soil, waste, or storm drainage piping. Underground water piping should not be placed in the same trench with drainage piping unless the drainage piping is extra-heavy cast-iron soil pipe with calked joints and the water piping is at least 12 inches above the top of the drainage line at all points.

When possible, water supply risers should be located in interior partitions or interior pipe spaces. In localities subject to freezing temperatures, piping should not be located in outside walls, attic spaces, or ventilated crawl spaces unless provision has been made to frost-proof the piping by means of suitable piping insulation. Exterior underground piping should be installed below the frost line of the locality or, if it is impossible to place it at such depths, the piping should be insulated and the insulation should be waterproofed. However, since satisfactory waterproofing of insulation is usually difficult and expensive, it is preferable that the layout be revised so that the piping can be lowered below the frost line.

All water piping should be graded toward low points in the system, so that the entire system can be drained completely without water being trapped in pockets or dips of the piping whenever it is necessary to effect repairs and replacements. The minimum grade should be not less than 1 inch in 25 feet, and a drain valve or plug should be provided at each low point to facilitate drainage. In addition, the piping should be pitched up from the mains toward the risers, and the connections to the risers should be taken off the top of the mains, to permit air to rise from the mains to the risers and eventually be released at a fixture outlet. The risers should extend at least 18 inches above the topmost fixture branch and the riser ends should be tightly capped to provide air chambers to help absorb shocks in the system.

8. CONTROL VALVES

To make repairs and maintenance a relatively simple and inexpensive operation, it is essential that suitable control valves be provided throughout a water supply system so that the section of the system on which work is to be done can be isolated. If, for instance, it is necessary to shut off and drain an entire building to make a simple repair at a single fixture, the increase in maintenance cost is out of proportion to the cost of a control valve.

To facilitate maintenance and repair work, control valves should be located as follows:

a. Within each dwelling or at each fixture (whichever is more economical) to control the hot and cold water supply to the fixtures.

b. At the base of each hot and cold water riser that exceeds two stories in height.

c. At the hot and cold water service entrance to each multi-dwelling building.

d. At suitable accessible points in the hot and cold water distribution systems, placed to subdivide the systems into sections serving about 50 dwellings, with not less than two such sections for any one project.

e. In the branches to each outside sillcock or drinking fountain in localities subject to freezing. These valves should be the stop and waste type, located lower than the outlet, to permit draining the branch between the valve and outlet.

Control valves should always be readily accessible. Locations such as crawl spaces should be avoided, since they are usually difficult to enter (especially when there is snow on the ground). Buildings constructed with crawl spaces or directly on ground-supported slabs should have the necessary building control valves in a hallway, bathroom or utility room on the first floor.

9. SILLCOCKS

Where a project consists of row houses, a sillcock should be installed at the front and rear of each pair of dwellings, located close to the party wall between the dwellings. Where multi-dwelling or community facility buildings are constructed, sillcocks should be spaced around the perimeter of the buildings so that about 50 feet of hose will reach all the lawns and walks on the project. Sillcocks should be located on a building wall about 18 inches above grade for convenient use. They should not be placed in lawns or walks since in such locations maintenance cost is high and they may cause accidents.

10. HOT WATER RECIRCULATING SYSTEMS

Where domestic hot water is supplied from a project-operated water heater or storage tank the waste of fuel and water is minimized and tenant convenience is increased when the water in the supply lines is kept hot. This is achieved by recirculating piping extending from the ends of the hot water supply piping back to the water heater or tank.

Where the length of the supply piping from the heater or storage tank to the end of the supply line is less than 100 feet, or the project buildings are less than 6 stories in height, recirculating pipe is usually unnecessary, since the moderate drop in temperature of the water in the supply piping provides reasonably satisfactory conditions. Where the length of supply piping exceeds 100 feet but the buildings are not over 6 stories high, recirculating piping should run from the base of the last riser to the hot water source. Where the buildings are higher, the water should be made to recirculate through the risers. This is accomplished by placing the supply mains in the top floor or in the attic space, and feeding down through the risers to the recirculating main at or below the first floor; or by installing both supply and recirculating mains at or below the first floor with supply and recirculating risers extending up through the building and connecting together at the top floor just below the topmost branch to the fixtures. The first (downfeed) method is usually more economical since only one set of risers are required, but it may be difficult to accommodate the supply main in the attic (or at the top floor). The two methods can be combined by extending a supply riser up to the top floor, running a horizontal main across the top floor or attic space to another riser location, and extending the line down to the recirculating main at or below the first floor. Where the main is placed above the fixtures, the topmost point of the main should be connected directly to a downfeed riser to vent air from the main.

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11. FACTORS AFFECTING PIPE SIZING

Factors that influence the size of water piping are (a) the quantity of water that is to flow through each section of piping (demand load), (b) the available pressure, and (c) the total friction. The quantity of water is estimated by considering the requirements of the individual plumbing fixtures and the summation of the demand from groups of fixtures. The available pressure is the water pressure in the street main less the estimated friction losses in any attached water meters and piping between the street main and the building. The total friction is the estimated loss in head due to the water passing through all the pipes, bends, valves and fittings between the service entrance and the fixture outlet. These factors are discussed in more detail below.

a. Demand Load. The demand load of various plumbing fixtures is best expressed by fixture units. Fixture units are design factors so chosen that the demand producing values of the fixtures can be expressed approximately as multiples of that factor. Various fixture unit valves are listed in Table 1, (corresponding in general to the values specified for fixture drainage loading in Part VIII of this Bulletin except that the means provided to flush a water closet influences the demand value of the water closet).

The estimated flow in gallons per minute through the mains, branches, or risers of a system can be obtained by totaling the fixture unit values of all fixtures served by each part of the system, and then referring to Figure 1 or Figure 2.

If water is supplied continuously to such outlets as lawn sprinklers or fountains, the quantity supplied in gallons per minute should be estimated separately and added to the demand values obtained from Figures 1 or 2.

b. Available Pressure. The minimum daily pressure at the service entrance to each building should be great enough to overcome the static head and the frictional resistance to flow, and should deliver the water to the highest fixture outlet at a pressure sufficient for satisfactory operation of the fixture. The outlet pressure should be a minimum of 8 pounds per square inch for faucets and water closet tanks, and not less than 15 pounds per square inch for flush valves.

Excessive pressures will result in high velocities in the piping, which cause further sharp increases in pressure (water hammer) when the flow is stopped suddenly. Water hammer causes objectionable noise and vibration in the pipes (especially when the piping is improperly secured or supported), leaking joints, and occasionally broken pipes. When the service pressure does not exceed 60 pounds per square inch, the water velocity in the pipes does not exceed 15 feet per second, and the faucets used are the slow-closing (compression) type, water hammers are reduced or eliminated. An air chamber at the top of each riser, or a patented water hammer arrestor at some point in the system is effective as long as the cushion of air is maintained. The available pressure can be stabilized at 60 pounds per square inch by means of a pressure reducing valve.

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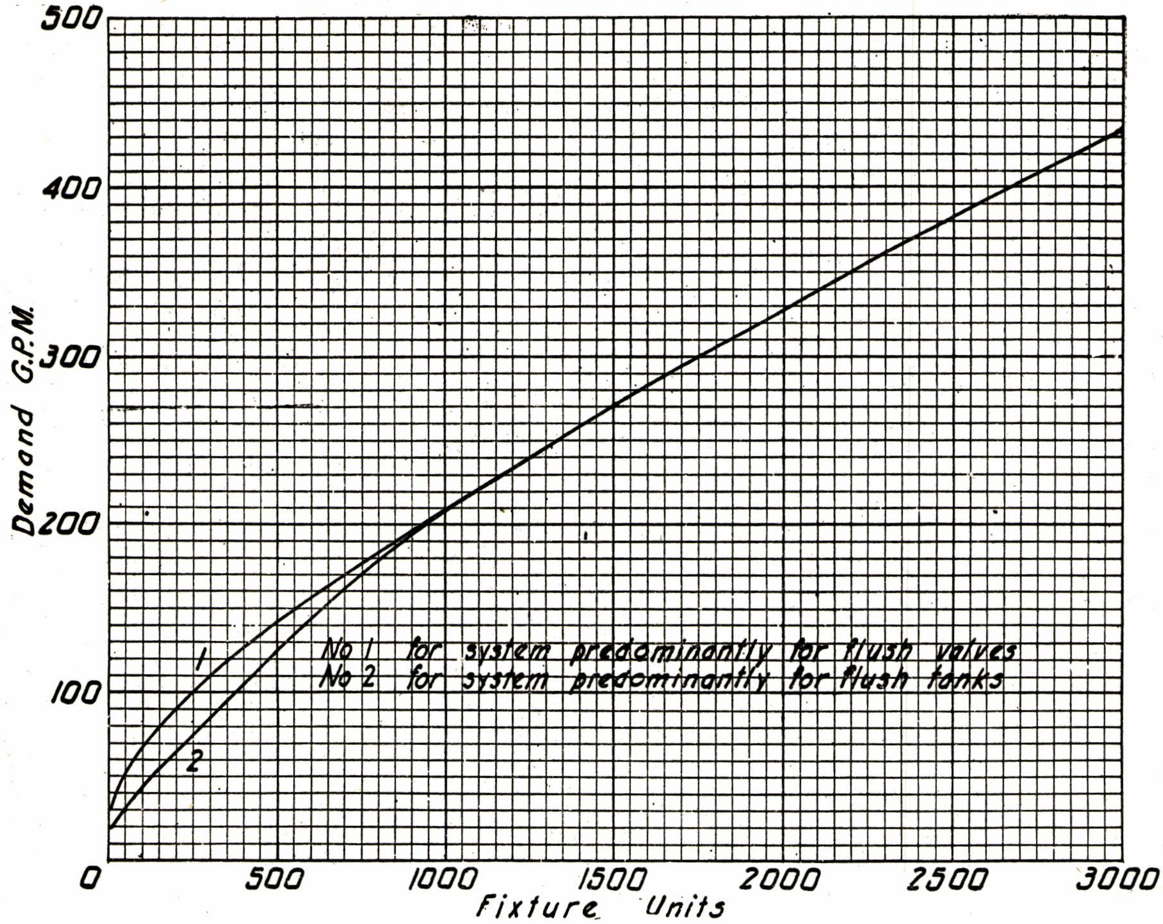

FIGURE 1 ESTIMATE CURVES FOR DEMAND LOAD

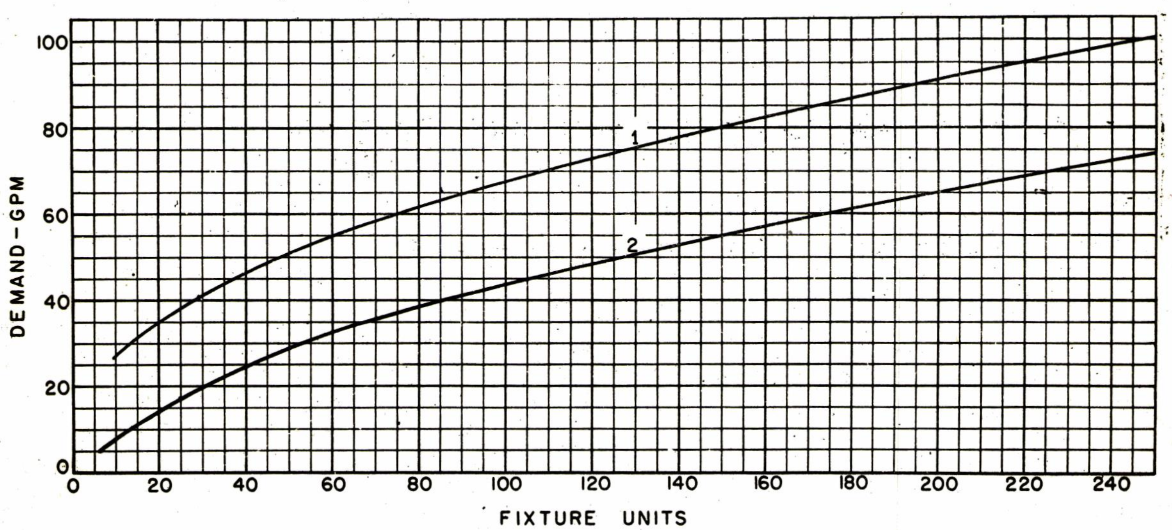

FIGURE 2 SECTION OF FIGURE 1 ON ENLARGED SCALE

Table 1

Fixture Unit Values

Fixture type	No. of fixture units 1/		Minimum size of hot or cold water connection (inches)
One bathroom group consisting of 1 lavatory 1 water closet with flush tank, 1 bathtub or shower stall 2/	6	-------	------------
One bathtub group same as above but with flush valve for water closet 2/	8	-------	------------
Bathtub	2	-------	1/2
Combination sink and tray 3/	3	-------	1/2
Drinking fountain	-------	1/2	3/8
Kitchen sink 3/	2	4	1/2
Lavatory	1	2	3/8
Laundry tray (1 or 2 compartment)	2	4	1/2
Shower, each head	2	4	1/2
Sink, scullery	-------	5	3/4
Sink, service	-------	3	1/2
Urinal, pedestal	-------	10	1
Urinal, wall lip	-------	5	1/2
Urinal, stall	-------	5	3/4
Urinal with flush tank	-------	3	------------
Water closet, flush valve	6	10	1
Water closet, tank	3	5	3/8

1/ These values are the total demand for fixtures with hot and cold water supplies. Values for separate hot and cold water demands may be taken as 3/4 of the listed values.

2/ A shower over a bathtub adds no fixture units to the group.

3/ A garbage grinder attached to a fixture does not change the fixture unit value.

(1) Increasing Available Pressures. Frequently in multi-storied buildings the minimum daily service pressure at certain hours of the day is insufficient to maintain the desired pressure at the highest fixture outlet, especially when the building demand load is high. In such cases, the available pressure must be increased by means of gravity storage tanks, pneumatic tanks, or booster pumps. It is sometimes desirable, especially with tall buildings, to divide the supply system into zones, with the lower zone supplied by water under the normal available pressure, and the upper zone supplied by water under increased pressure.

If it is possible that a pressure of 5 pounds per square inch or less may occur on the suction side of any water supply pump, a low-pressure cut-off switch should be installed to stop the pump and prevent the creation of a vacuum in the water service lines.

(a) Gravity storage tanks are usually cylindrical in shape, constructed of wood planks held together by steel hoops and located on the roof. The capacity of such a tank should equal the maximum deficiency between the accumulated maximum demand and the accumulated minimum inflow, over the period of time during which the demand exceeds the inflow. To this should be added a reserve capacity equal to about 20 minutes of maximum demand. The flow into the tank should be controlled by an automatic valve which is actuated by the water level in the tank.

If the available pressure in a building is insufficient to supply the tank by continuous or accumulated intermittent inflow, or if it is desired to reduce the tank size, pumps can be used to increase the available pressure and step up the inflow into the tank. Two pumps should be provided, so valved and connected that when one pump is being repaired the other can assume the entire load. Each pump should be sized to provide the necessary inflow to the tank against the static head and frictional resistance to flow between the service entrance and the top of the tank. The pump should be controlled by an automatic valve actuated by the water level in the tank. Since the capacity and discharge head of each pump will be high, the use of double-suction, single-stage, centrifugal pumps with bronze impeller and bronze trim is desirable for long life and trouble-free operation.

(b) Pneumatic storage tanks are steel pressure tanks, partially filled with air. The tanks are usually located in the basement and are supplied by a pair of centrifugal pumps, similar to the pumps just described, but operated by a pressure regulating switch in the tank. The pumps force water into the tank and compress the air therein until the necessary pressure is reached. Each pump should be designed to deliver the quantity of water required at maximum demand, as determined in Figures 1 or 2. The tank capacity should be computed on the basis of the following formula:

$$\text{Tank Capacity (gallons)} = Qt\left(1 + \frac{P_2}{P_1 - P_2}\right) + V_R$$

where

Q is the maximum demand equal to the pump capacity in gallons per minute,

t is the rest period of the pump, measured in minutes, between intervals of pump operation at maximum demand,

P_1 is the maximum absolute pressure, in pounds per square inch, permitted in the water supply system,

P_2 is the minimum absolute pressure, in pounds per square inch, necessary to supply all fixtures, and
V_R is the reserve capacity of the tank, in gallons.

The rest period of the pump should be kept low, since its purpose is to ensure that under conditions of maximum demand there will be a short interval between starting and stopping of the pump. Since peak conditions of maximum demand occur very infrequently in a multi-dwelling building due to diversity of use, the time interval could be as low as 1/2 minute, depending on the types of pump, motor, and starter used.

The greater the maximum pressure permitted in the system, the smaller the tank required, but the greater the resulting pulsation at the fixtures and the greater the total power requirements of the pumps. If the variation in tank pressure is large, a pressure regulating valve can be attached to the tank outlet to maintain constant pressure in the supply lines. Usually a system will operate satisfactorily without such a valve when the pressure differential, (P_1-P_2), does not exceed 10 pounds per square inch. A safety valve should be installed on the highest point of the tank to insure that the maximum permissible pressure is not exceeded. The reserve capacity of the tank V_R need not be large but should be sufficient to cover all tank outlets during a time of maximum demand.

A separate manually controlled air compressor, belt-driven by an electric motor, is usually operated once daily to charge the pneumatic tank with air. The required compressor capacity should be based on the following formula:

$$\text{Capacity of the compressor (Cubic feet per minute)} = \frac{V \times P_1^2}{90{,}000 \times T}$$

where

V is the capacity of the pneumatic tank in gallons.
P_1 is the maximum absolute pressure in pounds per square inch, and
T is the time in minutes during which the compressor is to operate.

The cost of a pneumatic tank installation is usually considerably smaller than that of a gravity tank, since the required structural work is greatly reduced. However, the cost of operation and maintenance of the pumps and compressor should be considered, as well as the fact that the water in the pneumatic tank will absorb large quantities of air, which may interfere with the operation of the water heaters unless provision is made for its removal. Also to be considered is the fact that fire department regulations sometimes require a gravity tank as an item of fire protection.

(c) Booster pumps controlled by a pressure switch at the pump outlet and without a storage tank, are sometimes used to provide the needed pressure at times of maximum demand. Such a system produces undesirable pulsations and noises in the water system which are very annoying to the occupants of the building. This type of installation should be used only when the drop in service pressure below the allowable minimum occurs very infrequently, and when the required capacity of the pump is small.

c. Friction Losses

(1) Friction Losses in Pipes. The resistance to the flow of water through the pipe, fittings, valves and bends of a supply system is measured as the loss in head due to friction in the system. This resistance is a function of the flow, the piping material and its condition, the diameter of the piping, the length of the piping, and to a slight extent the physical characteristics of the water. Head loss due to friction is usually expressed as pounds per square inch per 100 feet of length and is obtained from flow charts, as illustrated in Figures 3, 4, 5, and 6, which also show the velocity of flow in the piping. Figure 3 is the flow chart for smooth pipe and is the chart generally used for copper tubing carrying water of normal characteristics; for ferrous piping, a choice among the other flow charts must be made on the basis of the corrosivity characteristics of the water. New ferrous pipe is considered as being in the fairly smooth category, but after a few years of service, even with water having the minimum of corrosive characteristics, the pipe will have changed to the fairly rough type. With more corrosive water the change after a few years of service will be to the rough category. Since corrosion of piping carrying hot water is more pronounced than with cold water, it is sometimes advisable to consider that hot water piping is one category rougher than the corresponding cold water piping as increased caking effects of hot water will further roughen the pipe. The final decision as to which flow chart to use should be based on proper interpretation of the water characteristics analysis.

(2) Friction Losses in Fittings. The resistance to flow through valves and fittings is expressed as the equivalent length of straight pipe that has the same friction loss as the valve or fitting. These equivalent lengths for the various pipe sizes are listed in Table 2.

In any section of a water supply system the developed length of piping will equal the actual length within that section plus the equivalent length of all the valves and fittings in the section. If the required flow through the section is known, reference to the appropriate flow chart will give the friction loss per 100 feet of developed length, which can be converted to the total loss of head due to friction through that particular section of piping.

12. PROCEDURE FOR PIPE SIZING

The sizing of a piping system in a building should proceed as follows: (This method should be applied to all parts of the system, except the fixture supplies which should be not less than the sizes listed in Table 1.)

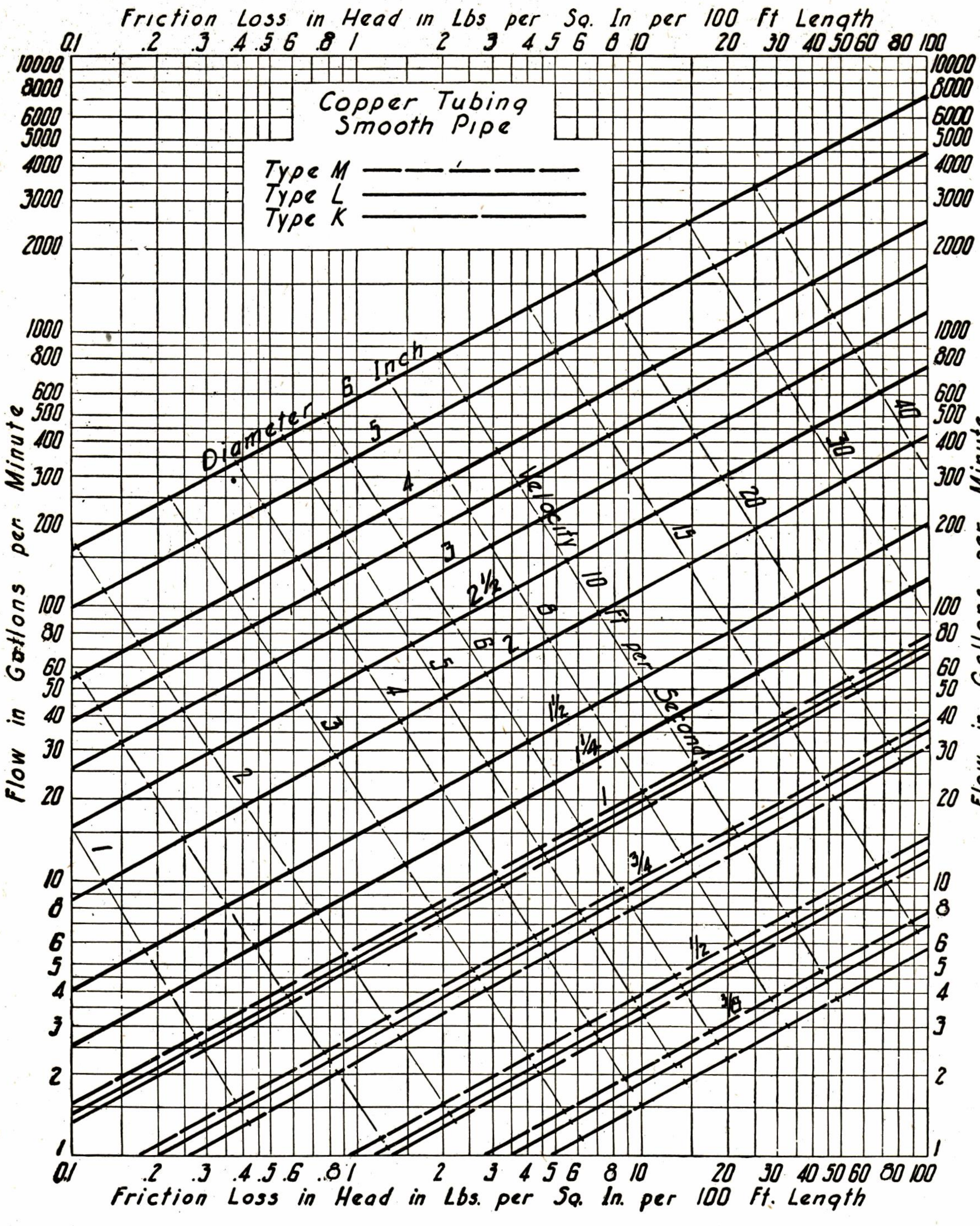

FIGURE 3 FLOW CHART FOR SMOOTH PIPE

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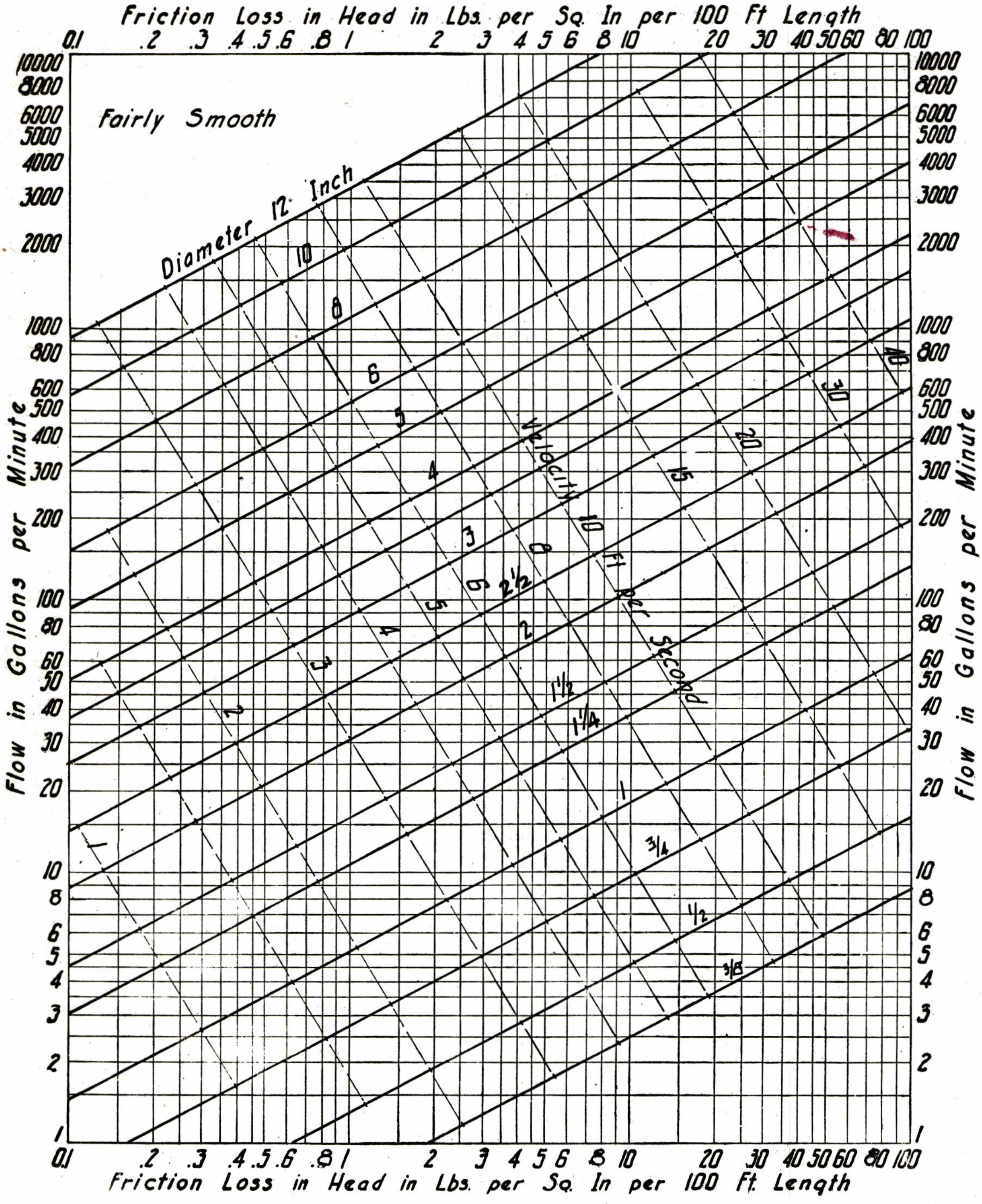

FIGURE 4 FLOW CHART FOR FAIRLY SMOOTH PIPE

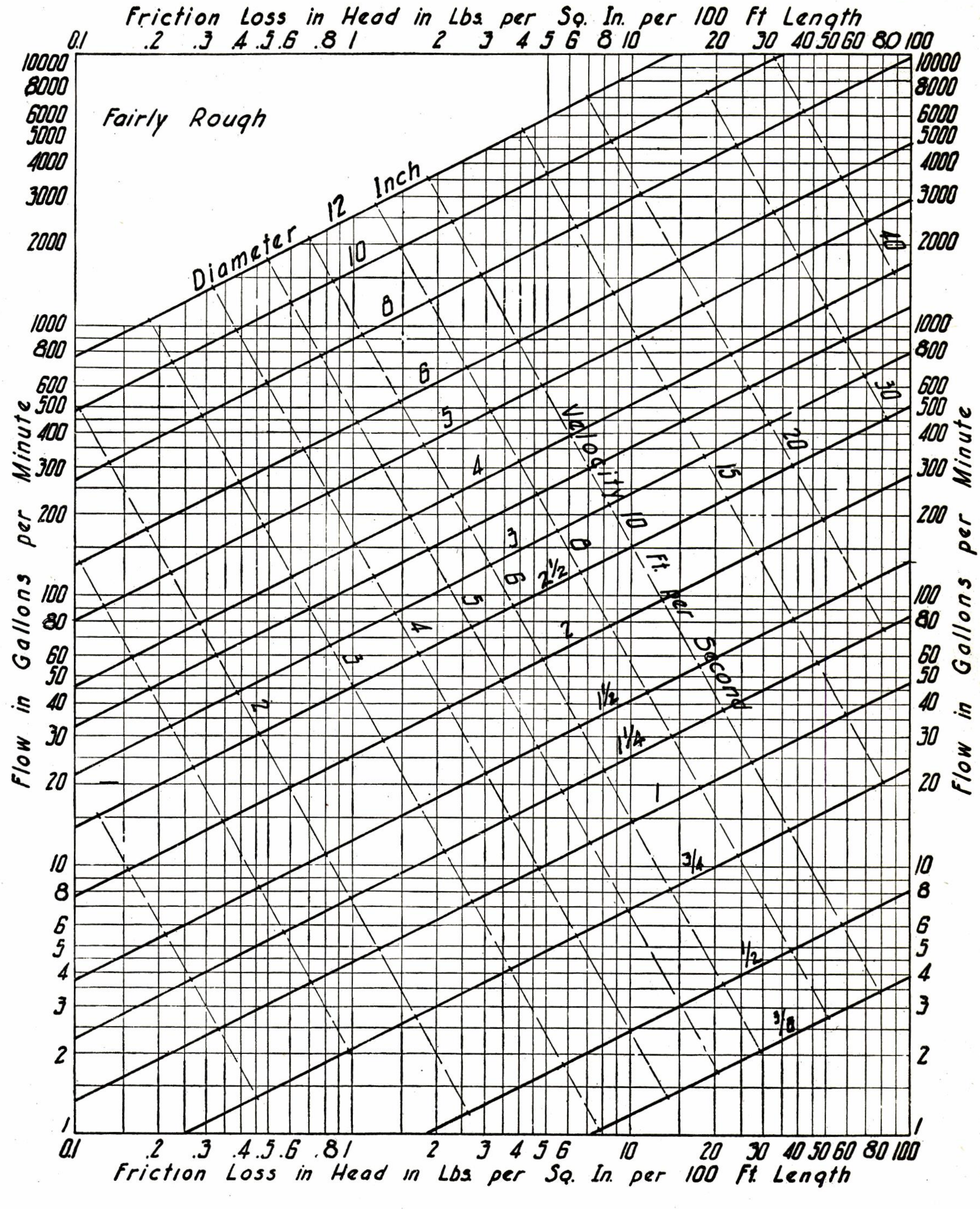

FIGURE 5 FLOW CHART FOR FAIRLY ROUGH PIPE

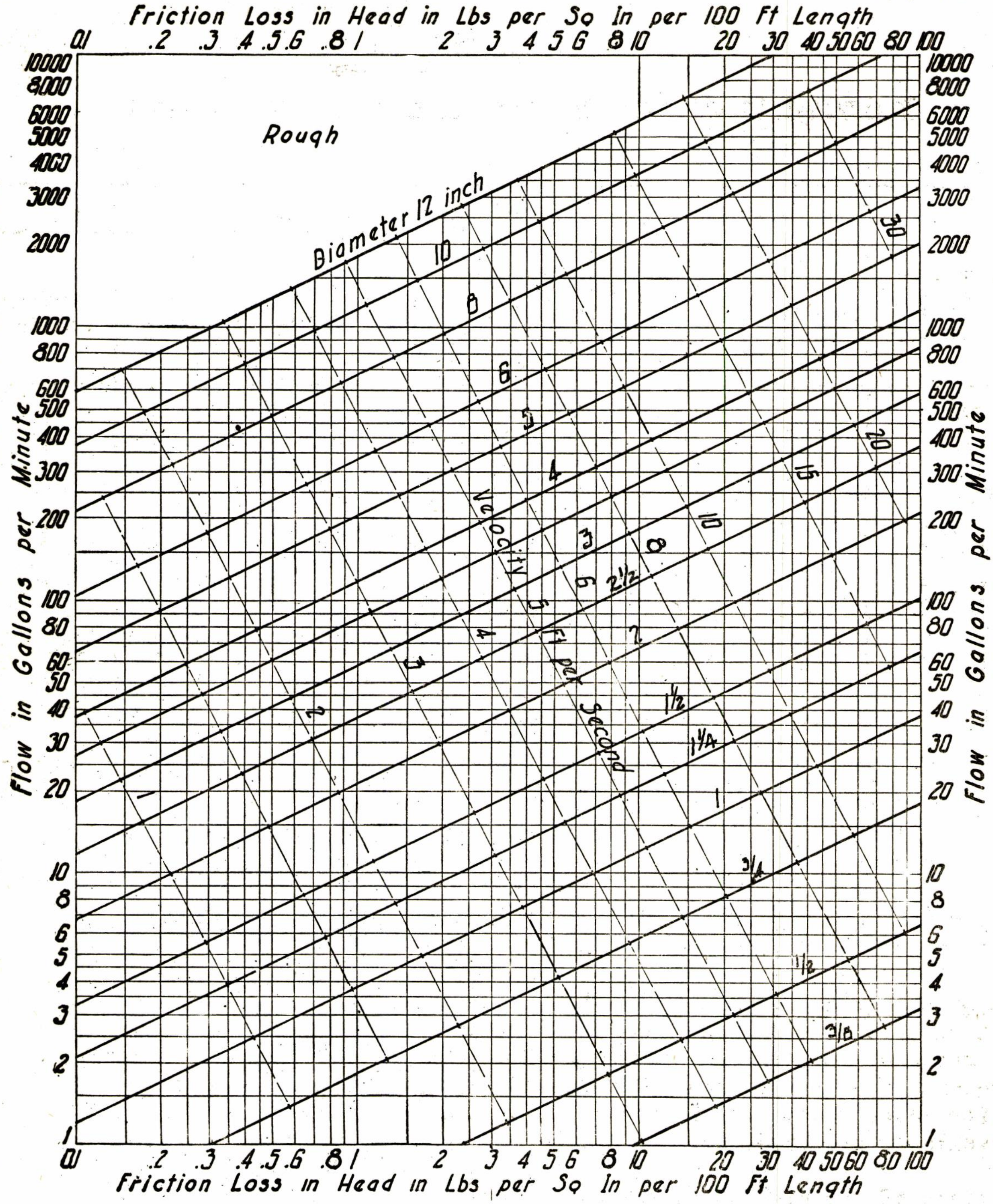

FIGURE 6 FLOW CHART FOR ROUGH PIPE

Table 2

Equivalent Length of Pipe in Feet, for Valves and Fittings

Size of valve or fittings (inches)	Type of Valve or Fitting						
	90° Standard elbow	45° Standard elbow	90° Standard tee	Coupling or Straight run of tee	Gate valve	Globe valve	Angle valve
3/8	1	0.6	1.5	0.3	0.2	8	4
1/2	2	1.2	3	.6	.4	15	8
3/4	2.5	1.5	4	.8	.5	20	12
1	3	1.8	5	.9	.6	25	15
1-1/4	4	2.4	6	1.2	.8	35	18
1-1/2	5	3	7	1.5	1.0	45	22
2	7	4	10	2.0	1.3	55	28
2-1/2	8	5	12	2.5	1.6	65	34
3	10	6	15	3	2.0	80	40
4	14	8	21	4	2.7	125	55
5	17	10	25	5	3.3	140	70
6	20	12	30	6	4.0	165	80

The total fixture unit demand load on each branch of piping should be determined by the use of Table 1.

The flow through each branch of piping, corresponding to the fixture unit values, should be determined by the use of Figures 1 or 2.

The minimum available pressure at the starting point of the building piping should be ascertained from the site engineer or other available source. From this pressure, the desired pressure at the fixture outlet (at least 8 pounds per square inch for faucets and water closet tanks or 15 pounds per square inch for water closet flush valves) should be deducted. The remainder is the net available pressure.

The height of the highest fixture in a section of piping (measured from the starting point of the building piping) should be determined and converted from feet of height to pounds per square inch of static head (by multiplying the height by 0.434). This static head should then be deducted from the net available pressure and the remainder will be the pressure that must overcome the frictional resistance to flow.

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The developed length of the piping should be determined by measuring the actual run of the piping directly to the highest fixture and adding the values of the equivalent length of fittings, as listed in Table 2, for assumed pipe sizes.

The available friction loss in head per 100 feet of length should be obtained by dividing the pressure that must overcome frictional resistance to flow by one hundreth of the developed length. With this value and the flow, the correct flow chart (Figures 3, 4, 5, or 6) can be utilized to indicate the pipe size for each separate run of pipe in the section being considered.

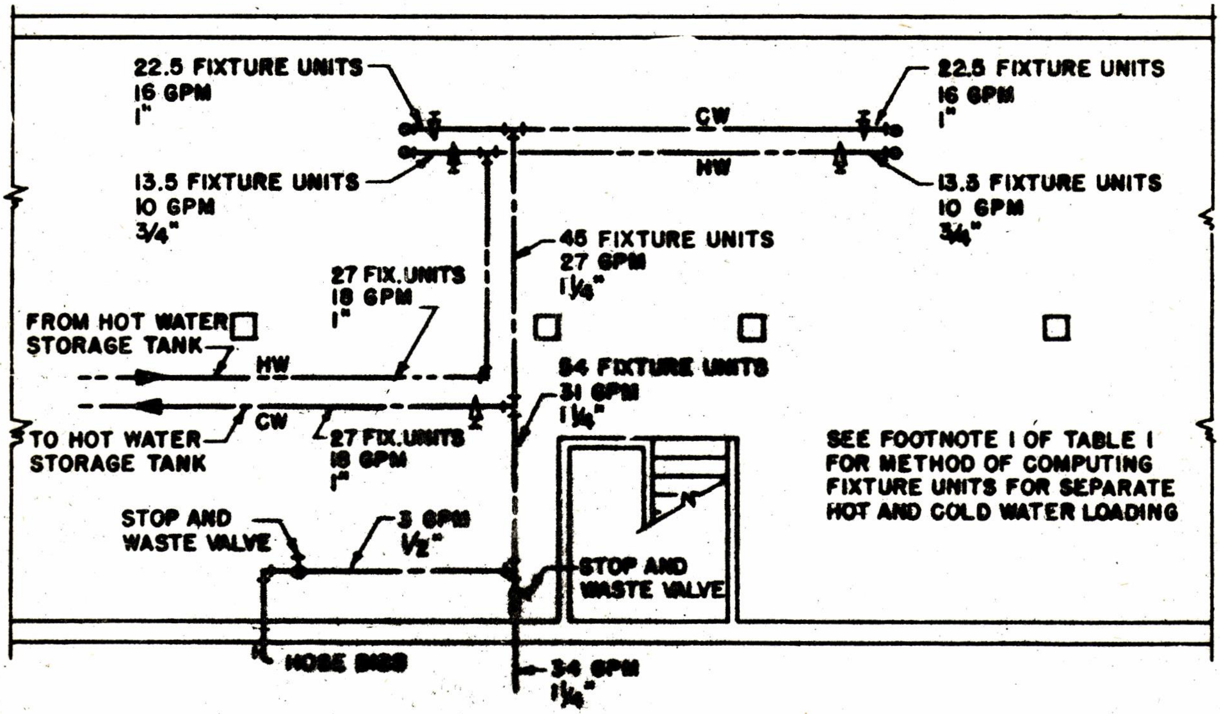
The foregoing data provides a rational basis for pipe size design. However, in using any method it is poor economy to keep pipe sizes down to the absolute minimum, especially for the smaller pipe sizes. Deposits of lime and scale will tend to clog such pipes, especially when the water is hot and is forced to flow at high velocities under high pressures. In addition, pipes that are so small that water velocities in the pipe exceed 15 feet per second should not be used, since objectionable whistling noises and water hammers may occur.

a. Example of Pipe Sizing Procedure. To demonstrate this pipe sizing procedure, Figure 7 illustrates a three-story building consisting of six dwelling units. Each dwelling would contain a bathroom group (with flush tank water closets) and a sink and tray combination fixture; and the building would have a hose bibb connection on the outside wall. Reference to Table 1 indicates a demand load of 9 fixture units per dwelling, or a total of 54 fixture units for the building. The estimated demand for the building would then be 31 gpm (from Figure 2) for the fixtures plus 3 gpm for the hose bibb, or a total of 34 gpm.

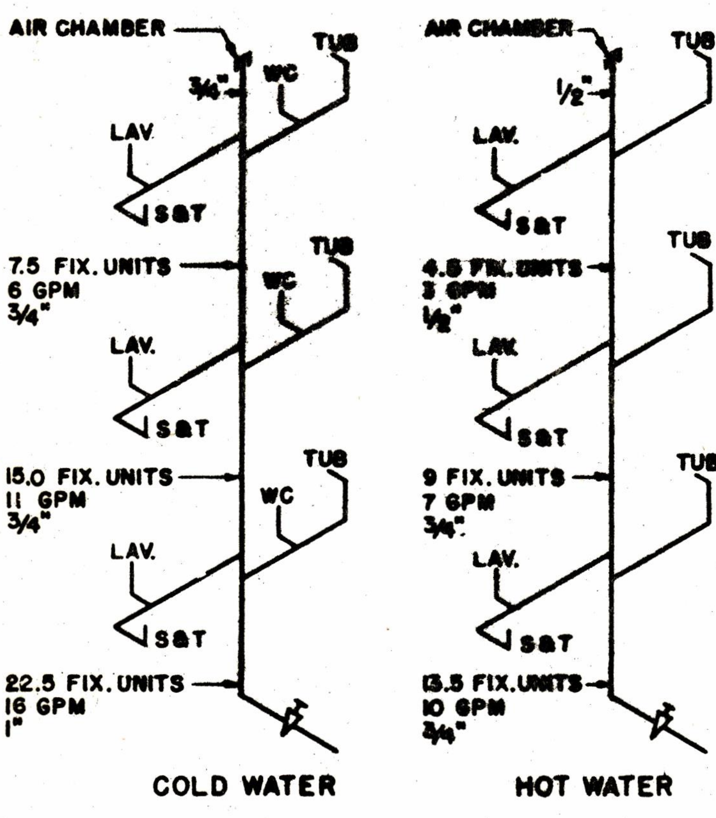
The branch extending to the domestic hot water storage tank would have a load of 27 fixture units (3/4 of 6 fixture units per dwelling), and the branch carrying the building cold water requirements would have a load of 45 fixture units (3/4 of 9 fixture units per dwelling plus 3 fixture units for the water closet in each dwelling). The fixture unit load on the other branches, the risers, and the runouts, are noted on Figure 7, as are the demands in gallons per minute corresponding to the fixture unit loadings.

The elevation of the highest fixture outlet in a three-story building above the basement service entrance of the water piping would be about 30 feet. The loss in static pressure due to this difference in elevation is 30 x 0.434 = 13 pounds per square inch. If the available water pressure at the service entrance is 45 pounds per square inch, and it is desired to have a pressure of 10 pounds per square inch at the highest fixture outlet, the allowable friction loss would be 45-13-10 = 22 pounds per square inch.

The developed length from the service entrance to the highest fixture outlet would be the actual length of piping, 130 feet, plus the equivalent length of 4 gate valves, 1 globe valve, 12 tees, and 9 elbows. It can be assumed



PART BASEMENT PLAN OF TYPICAL BUILDING



AVAILABLE PRESSURE AT THE SERVICE ENTRANCE 45 POUNDS PER SQUARE INCH.
DESIRED PRESSURE AT HIGHEST FIXTURE OUTLET 10 POUNDS PER SQUARE INCH.
HEIGHT OF HIGHEST FIXTURE OUTLET ABOVE SERVICE ENTRANCE 30 FEET.
TOTAL DEVELOPED LENGTH FROM SERVICE ENTRANCE TO TOPMOST FIXTURE 239 FEET.
ALLOWABLE FRICTION LOSS (45-10-30 X .434) ÷ 2.39 = 9.2 POUNDS PER SQUARE INCH PER 100 FEET OF DEVELOPED LENGTH.

ALL BRANCH LINES 1/2" UNLESS OTHERWISE MARKED

TYPICAL RISER DIAGRAM

FIGURE 7 SIZING WATER PIPING IN A TYPICAL 3 STORY BUILDING that 1 gate valve, 2 tees, and 2 elbows are 1-1/2 inch size; 2 gate valves, 4 tees, and 2 elbows are 1-1/4 inch size; 1 gate valve, 2 tees, and 1 elbow are 1 inch size; 2 tees are 3/4 inch size; and 1 globe valve, 2 tees, and 4 elbows are 1/2 inch size. The equivalent length (from Table 2) would then be 1x1.0 + 2x0.8 + 1x0.6 = 3.2 feet for the gate valves; 15 feet for the globe valve; 2x7 + 4x6 + 2x5 + 2x4 + 2x3 = 62 feet for the tees; and 2x5 + 2x4 + 1x3 + 4x2 = 29 feet for the elbows. The total developed length is then 130 + 3 + 15 + 62 + 29 = 239 feet.

The allowable friction loss per 100 feet is then 100 x 22 ÷ 239 = 9.2 pounds per square inch. For Type L copper tubing carrying water which is expected to be fairly non-corrosive the flow chart for smooth pipe (see Figure 3) is applicable. For a flow of 34 gpm and this allowable friction loss the required pipe size is just slightly over 1-1/4 inch, and for practical purposes that should be the size used. Using this allowable friction loss and the flow through the various branches, risers, and runouts, the size of these pipes may also be obtained from Figure 3, except for the sizes of the supply pipes that connect directly to the fixtures, which are each 1/2 inch in size. The valve and fitting sizes assumed previously are not strictly accurate, but any adjustments to the calculations are usually unwarranted if the assumptions are made on a reasonable basis.

13. SIZING THE RECIRCULATING SYSTEM

Since the function of hot water circulating piping is to keep the water in the hot water supply piping warm, (not to supply water to the fixture outlets), the method of sizing this piping differs from the method outlined for supply piping. The recirculating system (together with the hot water supply system) forms a closed circuit which operates only when the hot water faucets are closed, so that the available pressure has no effect on the flow through this circuit.

a. The required flow through the recirculating system is dependent only on the total heat loss from the supply and recirculating piping. This heat loss should be estimated by assuming reasonable sizes for the recirculating piping, obtaining the unit heat loss per linear foot from Table 3 for the various sizes of supply and recirculating piping, multiplying the unit heat loss by the total length of pipe for each size and by the difference in temperature between the pipe and its surroundings; and then summing up the heat losses for the separate pipe sizes in the system.

The required quantity of flow through the system can then be expressed by the formula:

$$\text{Required flow in gallons per minute} = \frac{\text{Total Hourly Heat Loss}}{490 \times T_d}$$

where T_d is the allowable drop in temperature through the hot water piping circuit. This drop should be taken as about 20°F. when the initial hot water temperature is 140°F.

Table 3

Heat Loss From Pipes and Tubing Per °F. Temperature Difference 1/
In Btu per hour per linear foot

Size of pipe or tubing (inches)	Bare pipe or tubing		Insulated pipe or tubing. Asbestos air-cell covering, plies 1/4 inch thick	
	Steel	Copper	3 Ply	4 Ply
1/2	0.57	0.34	0.22	0.19
3/4	.68	.41	.25	.22
1	.82	.49	.29	.25
1-1/4	1.02	.61	.34	.29
1-1/2	1.15	.69	.36	.32
2	1.40	.84	.42	.37
2-1/2	1.65	.99	.48	.42
3	1.96	1.08	.55	.49
4	2.46	1.48	.66	.58
5	3.00	1.80	.78	.69
6	3.54	2.12	.89	.81

1/ These values were determined for horizontal piping at a temperature at 140°F surrounded by still air at 70° F. However, they can be used for hot water systems, regardless of the pipe position or temperature, with a fairly high degree of accuracy.

b. The friction loss through a recirculating system is obtained from Figures 3, 4, 5, or 6. By using the proper chart the friction loss per 100 feet of developed length can be obtained for each assumed pipe size and, if the friction loss or the velocity of flow through the recirculating piping is either excessively large or uneconomically small, the assumed pipe sizes should be corrected. The total friction loss through the circuit should then be obtained from each developed length and its corresponding friction loss per 100 feet. When recirculating flow alone is passing through the water supply piping, the friction loss in that piping is usually so small that it can be neglected.

c. Gravity Head. The total resistance to flow must be overcome by the gravity head on the system or by a recirculating pump. Gravity head results from the decrease in the unit weight of water when the temperature of the water is increased, but since this decrease is small over a range of temperatures used, gravity head is effective only when the difference in elevation between the heat source and the highest point of the circuit is appreciable. In practice, this usually means that gravity circulation is feasible only in multi-storied buildings.

The available head in a circuit is due to the differences in the weight of water in the supply and recirculating risers and it can be computed by means of Table 4, which lists the weight, at various temperatures, of a column of water one square inch in cross-sectional area and one foot high.

Table 4

Weight of a Column of Water One Foot in Height

Temperature of the water °F.	Pounds per square inch of cross-sectional area
100	0.4303
105	.4299
110	.4294
115	.4289
120	.4283
125	.4278
130	.4272
135	.4266
140	.4260
145	.4254
150	.4247
155	.4241
160	.4234

The difference in weight of water in supply and recirculating risers, due to the differing temperatures in those risers, is the gravity head available per foot of difference of elevation. The total available gravity head for the total difference of elevation between the heat source and the top of the recirculating riser is the product of the unit difference in weight by the total difference in elevation and must be equal to or greater than the total friction head in the circuit, for adequate circulation to occur. To decrease this friction, it is frequently necessary to increase the size of the recirculating piping.

d. Recirculating pumps provide much more positive circulation than is possible with gravity head, and usually permit smaller recirculating piping. Pumps should be sized to have a capacity equal to the required flow, at a discharge head necessary to overcome the total frictional resistance of the circuit, neglecting any gravity effects. Since such pumps are small, an electric motor-driven end suction or side suction centrifugal type with bronze impeller and bronze trim is usually satisfactory and economical.

When the entire circuit is at the desired temperature, operation of the recirculating pump is unnecessary, and an immersion aquastat should be provided in the recirculating line to stop the pump motor when such a condition is reached. The most convenient and economical location is about 25 feet from the recirculating pump in a space not affected by heating equipment.

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14. PIPE INSULATION

Water piping is insulated for the following reasons:

a. To prevent excessive heat losses.
b. To prevent freezing of the water in the pipe.
c. To prevent condensation on the exterior of the cold water piping.

In general, extensive systems of large sized hot water supply piping should be insulated to prevent excessive heat losses, while for short runs insulation is usually unnecessary. Where there is doubt as to the value of the insulation, an estimate of the total heat saved by the use of insulation can be determined by the use of Table 3, and the value of the savings compared to the cost of the insulation. Insulation should be omitted on hot water pipe located within interior partitions, because of space limitations. When recirculating systems depend on gravity head for circulation, the recirculation piping is usually left bare, to decrease the temperature in the recirculating lines and increase the available gravity head. Where a recirculating pump is installed, recirculation lines should be insulated on the same basis as supply piping.

Frost-proofing of all water piping (cold, hot, and recirculating) should be done in cold climates when the piping is installed in exterior walls, crawl spaces, attics, and where the piping may be exposed to the weather.

Moisture from the atmosphere will condense on cold water piping located in basements, boiler rooms, crawl spaces, and other places where dampness exists. Condensed moisture will drip off the pipe and damage equipment, tenant belongings or plastered surfaces located beneath the piping. In addition, such condensation will increase the corrosion of the exterior of the pipe, especially at exposed threads. It is advisable, therefore, to insulate all cold water piping where condensation might cause damage.

The most economical insulation for use on hot water pipe is 3 ply pre-shrunk asbestos air-cell covering. Cold water pipe requires an insulation that is more resistant to vapor penetration, such as 3/4 inch pre-shrunk wool-felt covering with an asphalt-saturated felt liner. Both types should have a cotton sheeting jacket which is pasted in place and provided with non-corrosive metal bands to hold the covering. Bands should be spaced 18 inches on centers, and be placed at all fittings. Fittings should be covered with asbestos cement to the same thickness as the pipe covering, and jacketed with cotton sheeting.

15. UNDERGROUND DISTRIBUTION PIPING

Hot water supply and recirculating piping between buildings should be installed in underground tunnels or conduits used for the heat distribution system, and should be insulated in the manner specified for such underground heat piping. Any underground system that is to be used only for water piping should conform to the type of systems specified for the heating system. A subsequent part of this Bulletin will discuss these underground distribution systems in detail.

PLUMBING, HEATING AND VENTILATION

PART XI - WATER SUPPLY SYSTEMS IN BUILDINGS

CONTENTS

NOTE: This Part XI supersedes Part XI of Bulletin No. LR-7 dated 8-25-50. It has been revised throughout to bring the material up to date.

PLUMBING, HEATING AND VENTILATION

PART XI - WATER SUPPLY SYSTEMS IN BUILDINGS

1. INTRODUCTION

The proper design of domestic water supply systems in buildings is necessary for the proper functioning of the various plumbing fixtures. The amount of either hot or cold water used in any building is variable, depending on the type of structure, usage, occupancy, and the time of day. It is essential to provide adequate piping, water heating, and storage facilities of sufficient capacity to meet the peak demand in either piping or equivalent cost without wasteful excess.

One of the difficult problems generally encountered in the economical design of water supply systems in buildings is the selection of pipe sizes for various parts of the systems, particularly for the smaller sizes of pipes, that will assure an adequate supply of water at all outlets under specific service conditions, such as the available service pressure and the difference in elevation between the source of supply of the water and the fixtures. It must be remembered that it is not sufficient to provide for an adequate supply when pipes are new, but that a suitable allowance must be made for decrease in capacity caused by the deterioration of the interior surface of the pipes with age. This involves the choice of piping materials which will be best adapted to the characteristics of the particular water that will be used.

2. LENGTH OF SERVICE OF WATER PIPING

The separate elements that go to make up a low-rent housing project should reasonably be expected to last as long as the probable life of the project, unless it is more economical to install and periodically replace elements or materials of shorter life expectancy. Since replacing a water supply system usually involves breaking into and replacement of the finished surfaces of walls, partitions and floors, and, possibly, excavation beneath parts of occupied buildings and finished exterior spaces, it is not likely that it would be economically desirable in any but the most unusual circumstances to install a water supply system with a life expectancy less than that of the project buildings. The life service of the piping material should be consistent with the findings of the Utility Analysis (see PHA Low-Rent Housing Bulletin No. LR-11, "Selection of Utilities").

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The principal factor that determines the life of water piping is corrosion of the interior or exterior of the piping. Corrosion will attack the entire piping system, some portions more severely than others, and it is usually the severity of the attack that is the determining factor in the length of its life.

3. CORROSION

The definition of corrosion, its forces, and the mechanics of its control have been comprehensively identified in the Local Housing Authority Handbook, Part V, Section 7, "Maintenance of Underground Utilities," prepared by the Maintenance Engineering Branch of PHA. Reference should be made to this Handbook Section. For the purpose of identification here, mechanical protection of underground ferrous piping (except cast-iron) means coating and wrapping of both pipe and fittings; electrical or cathodic protection of underground ferrous piping means protection by sacrificial anode method or the rectifier method. All of the above is explained in the Handbook Section.

Local utilities have devised various ways of protecting their distribution lines mechanically. They should be prepared to advise local engineers or Local Authorities on the efficacy of one protective method over another, and to offer the benefits of their experience on corrosive actions on metal pipe buried in the soil. Types of coatings and wrappings have been used successfully in varying degrees and are described in the above-mentioned Handbook Section, and in Low-Rent Manual Section 207.1.

Other information pertinent to the subject of corrosion of ferrous materials is set forth in Part V of this Bulletin.

4. CORROSIVITY OF WATERS

Water piping in some localities will last far longer than in others under similar conditions of use. This variation in the life of the piping is principally due to the difference in the protective coatings formed by the corrosive action of the waters in each locality.

Waters not normally containing dissolved solids which precipitate as insoluble compounds (soft waters), or waters from which these solids have been removed by means of special treatments, are usually highly corrosive to piping, since no coating will form on the pipe wall. Hard waters are usually much less corrosive, unless the coating formed by precipitation of the solids is loose or irregular. Non-uniform coatings, covering only part of the piping, may promote localized corrosion between the unprotected and protected portions of the pipe and cause further deterioration. Some types of coatings will eventually completely fill the pipe, or decrease its free openings to

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such an extent that the pipe becomes useless. Additional reference information relative to corrosivity of waters is set forth in the chapter on Corrosion and Deposits contained in the American Society of Heating, Refrigerating and Air Conditioning Guide and Data Book1/.

Other reference information pertinent to the corrosivity of waters is comprehensively set forth in a Technical Studies Publication FHA No. 592, titled The Galvanic Corrosion Of Piping Used In Residences2/.

5. CHOICE OF WATER PIPING

The characteristics of the water used in a region may be changed radically by the construction of a municipal water softening plant or the introduction of water from new sources. The problem of making a sound choice is not solved merely by using materials which are in common use in the area without an investigation as to how long such materials have actually lasted, and how suited they would be to possible changing conditions. Reliable information may be difficult to obtain, since personal preferences of observers frequently color their view, and some materials in current use have not been available in the past. In certain areas a corrosion specialist may be needed to assist in making the final choice of the pipe to be used.

The types of piping materials that may be used for water distribution systems and the relative advantages of the various materials used for this purpose are set forth in Part X of this Bulletin.

6. WATER PIPING LAYOUT

The water piping layout in a building is determined largely by the building design. The architect cannot be expected to shape the building around the plumbing system; it is advisable for the designing engineer to meet with the architect and coordinate the plumbing requirements with the building structure to obtain the most direct, simple, and economical piping system possible.

In addition, the water piping layout should be so designed that the water supply is protected from contamination. No direct cross-connections of any kind to any other piping systems should be permitted, even when one or more valves are used to separate the two systems. Drain valves, sillcocks, or stop and waste valves in the system should not be placed underground or in position where they might be submerged by surface or ground water, since there is always a possibility of backflow through the valves into the water system. Water supply tanks, including building tanks and hot water storage

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1/ Available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

2/ Available from the Federal Housing Administration, Washington, D.C. 20411.

tanks, should always be properly covered or sealed, and should not be located beneath any soil, waste, or storm drainage piping. Underground water piping and the building sewer drain piping should be installed not less than 10 feet apart horizontally and should be separated by undisturbed or compacted earth. When it is found necessary to install both water and sewer piping in the same trench area, the water service piping should be placed on a solid shelf excavated at the side of the common trench and the bottom of the water pipe must be at least 12 inches above the top of the sewer line at its highest point.

When possible, water supply risers should be located in interior partitions or interior pipe spaces. In localities subject to freezing temperatures, piping should not be located in outside walls, attic spaces, or ventilated crawl spaces. Operating experience indicates high cost for maintenance and replacement for piping installed in outside walls and in attic spaces, even though the piping was supposedly protected from freezing with a suitable type piping insulation.

All water piping should be graded toward low points in the system, so that the entire system can be drained completely without water being trapped in pockets or dips of the piping whenever it is necessary to effect repairs and replacements. The minimum grade should be not less than 1 inch in 25 feet, and a drain valve or plug should be provided at each low point to facilitate drainage. In addition, the piping should be pitched up from the mains toward the risers, and the connections to the risers should be taken off the top of the mains, to permit air to rise from the mains to the risers and eventually be released at a fixture outlet. The risers should extend at least 18 inches above the topmost fixture branch and the riser ends should be tightly capped to provide air chambers to help absorb shocks in the system. When building design is slab-on-grade type construction it is not considered good design practice to bury water piping below the first floor slab. Leaks developing in piping, installed in this manner, may go undetected for years with the loss of great quantity of water and damage to building foundations. The only way to repair or replace such piping would require tearing up the concrete slab and floor covering, or abandon the piping under the floor and run new piping exposed in the dwellings.

7. CONTROL VALVES

To make repairs and maintenance a relatively simple and inexpensive operation, it is essential that suitable control valves be provided throughout a water supply system so that the section of the system on which work is to be done can be isolated. If, for instance, it is necessary to shut off and drain an entire building to make a simple repair at a single fixture, the increase in maintenance cost is out of proportion to the cost of a control valve.

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To facilitate maintenance and repair work, control valves should be located as follows:

a. Within each dwelling or at each fixture (whichever is more economical) to control the hot and cold water supply to the fixtures.

b. At the base of each hot and cold water riser that exceeds two stories in height.

c. At the hot and cold water service entrance to each multidwelling building.

d. At suitable accessible points in the hot and cold water distribution systems, placed to subdivide the systems into sections serving about 50 dwellings, with not less than two such sections for any one project.

e. In the branches to each outside sillcock or drinking fountain in localities subject to freezing. These valves should be the stop and waste type, located lower than the outlet, to permit draining the branch between the valve and outlet.

Control valves should always be readily accessible. Locations such as crawl spaces should be avoided, since they are usually difficult to enter (especially when there is snow on the ground). Buildings constructed with crawl spaces or directly on ground-supported slabs should have the necessary building control valves in a hallway, bathroom, or utility room on the first floor. In high-rise buildings control valves should be provided with identification tags. Where valves occur above suspended ceilings or in furred spaces, screw duplicate number tags to the face or access panels.

8. SILLCOCKS

Where a project consists of row houses, a sillcock should be installed at the front and rear of each pair of dwellings, located close to the party wall between the dwellings. Where multidwelling or community facility buildings are constructed, sillcocks should be spaced around the perimeter of the buildings so that about 50 feet of hose will reach all the lawns and walks on the project. Sillcocks should be located on a building wall about 18 inches above grade for convenient use.

9. HOT WATER RECIRCULATING SYSTEMS

Where domestic hot water is supplied from a project-operated water heater or storage tank the waste of fuel and water is minimized and tenant convenience is increased when the water in the supply lines is kept hot. This is achieved by recirculating piping extending from the ends of the hot water supply piping back to the water heater or tank.

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Two methods of arranging circulating lines that may be used in multidwelling buildings are: (1) extending a riser to a supply main at the top floor, and feeding down through risers to the recirculating main at basement or ground floor ceiling; (2) by installing both supply and recirculating mains at basement or ground floor ceiling with supply and recirculating risers extending up through the building and connecting together just below the topmost branch supply to fixtures. The first (downfeed) is considered more economical since only one set of risers are required, but it may be difficult to accommodate the supply main at the top floor. The two methods can be combined by extending a supply riser up to the top floor, running a horizontal main across the top floor to another riser location, and extending the line down to the recirculating main at or below the first floor. Where the main is placed above the fixtures, the topmost point of the main should be connected directly to a downfeed riser to vent air from the main. Where the buildings are not over four stories high, recirculating piping should run parallel to the supply main from the base of the last supply riser to the hot water source.

10. FACTORS AFFECTING PIPE SIZING

Factors that influence the size of water piping are (a) the quantity of water that is to flow through each section of piping (demand load), (b) the available pressure, and (c) the total friction. The quantity of water is estimated by considering the requirements of the individual plumbing fixtures and the summation of the demand from groups of fixtures. The available pressure is the water pressure in the street main less the estimated friction losses in any attached water meters and piping between the street main and the building. The total friction is the estimated loss in head due to the water passing through all the pipes, bends, valves, and fittings between the service entrance and the fixture outlet. These factors are discussed in more detail below.

a. Demand Load. The demand load of various plumbing fixtures is best expressed by fixture units. Fixture units are design factors so chosen that the demand producing values of the fixtures can be expressed approximately as multiples of that factor.

The estimated flow in gallons per minute through the mains, branches, or risers of a system can be obtained by totaling the fixture unit values of all fixtures served by each part of the system.

The fixture unit values and the estimated demand in gallons per minute can best be determined by consulting the charts and tables pertaining thereto in the chapter on Water Services contained in the ASHRAE Guide and Data Book.

The demands for outlets (such as lawn sprinklers, air conditioning equipment, etc.) which are likely to impose heavy demands during times of heavy use of the fixtures, should be estimated separately and added to the computed demand for the fixtures, in order to estimate the total demand.

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b. Available Pressure. The minimum daily pressure at the service entrance to each building should be great enough to overcome the static head and the frictional resistance to flow, and should deliver the water to the highest fixture outlet at a pressure sufficient for satisfactory operation of the fixture. The outlet pressure should be a minimum of 8 pounds per square inch for faucets and water closet tanks, and not less than 15 pounds per square inch for flush valves.

Excessive pressures will result in high velocities in the piping, which cause further sharp increases in pressure (water hammer) when the flow is stopped suddenly. Water hammer causes objectionable noise and vibration in the pipes (especially when the piping is improperly secured or supported), leaking joints, and occasionally broken pipes. When the service pressure does not exceed 55 pounds per square inch, the water velocity in the pipes does not exceed 15 feet per second, and the faucets used are the slow-closing (compression) type, water hammers are reduced or eliminated. An air chamber at the top of each riser, or a patented water hammer arrestor at some point in the system, is effective as long as the cushion of air is maintained. The available pressure can be stabilized at 55 pounds per square inch by means of a pressure reducing valve.

Where a project is being served by a street main with excessive water pressure, the project water distribution system should be developed to use a minimum of pressure reducing valve stations. A single PRV located in the main serving the water distribution system to a project would be the most satisfactory arrangement, both from the standpoint of initial cost and maintenance.

(1) Increasing Available Pressures. Frequently in multistoried buildings the minimum daily service pressure at certain hours of the day is insufficient to maintain the desired pressure at the highest fixture outlet, especially when the building demand load is high. In such cases, the available pressure must be increased by means of gravity storage tanks, pneumatic tanks, or booster pumps. It is sometimes desirable, especially with tall buildings, to divide the supply system into zones, with the lower zone supplied by water under the normal available pressure, and the upper zone supplied by water under increased pressure.

If it is possible that a pressure of 5 pounds per square inch or less may occur on the suction side of any water supply pump, a low-pressure cut-off switch should be installed to stop the pump and prevent the creation of a vacuum in the water service lines.

(a) Gravity storage tanks are usually cylindrical in shape, constructed of wood planks held together by steel hoops and located on the roof. The capacity of such a tank should equal the maximum deficiency between the accumulated maximum demand and the accumulated minimum inflow, over the period of time during which the demand exceeds the inflow. To this should be added a reserve capacity equal to about 20 minutes of maximum

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demand. The flow into the tank should be controlled by an automatic valve which is actuated by the water level in the tank.

If the available pressure in a building is insufficient to supply the tank by continuous or accumulated intermittent inflow, or if it is desired to reduce the tank size, pumps can be used to increase the available pressure and step up the inflow into the tank. Two pumps should be provided, so valved and connected that when one pump is being repaired the other can assume the entire load. Each pump should be sized to provide the necessary inflow to the tank against the static head and frictional resistance to flow between the service entrance and the top of the tank. The pump should be controlled by an automatic valve actuated by the water level in the tank. Since the capacity and discharge head of each pump will be high, the use of double-suction, single-stage, centrifugal pumps with bronze impeller and bronze trim is desirable for long life and trouble-free operation.

(b) Pneumatic storage tanks are steel pressure tanks, partially filled with air. The tanks are usually located in the basement and are supplied by a pair of centrifugal pumps, similar to the pumps just described, but operated by a pressure regulating switch in the tank. The pumps force water into the tank and compress the air therein until the necessary pressure is reached. Each pump should be designed to deliver the quantity of water required at maximum demand that may be determined by consulting the chart titled "Estimated Curves for Demand Load" set forth in the chapter on Water Services, contained in the ASHRAE Guide and Data Book. The tank capacity should be computed on the basis of the following formula:

$$\text{Tank Capacity (gallons)} = Qt\left(1 + \frac{P_2}{P_1 - P_2}\right) + V_R$$

where

- Q is the maximum demand equal to the pump capacity in gallons per minute,
- t is the rest period of the pump, measured in minutes, between intervals of pump operation at maximum demand,
- P_1 is the maximum absolute pressure, in pounds per square inch, permitted in the water supply system,
- P_2 is the minimum absolute pressure, in pounds per square inch, necessary to supply all fixtures, and
- V_R is the reserve capacity of the tank, in gallons.

The rest period of the pump should be kept low, since its purpose is to ensure that under conditions of maximum demand there will be a short interval between starting and stopping of the pump. Since peak conditions of maximum demand occur very infrequently in a multidwelling building due to

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diversity of use, the time interval could be as low as 1/2 minute, depending on the types of pump, motor, and starter used.

The greater the maximum pressure permitted in the system, the smaller the tank required, but the greater the resulting pulsation at the fixtures and the greater the total power requirements of the pumps. If the variation in tank pressure is large, a pressure regulating valve can be attached to the tank outlet to maintain constant pressure in the supply lines. Usually a system will operate satisfactorily without such a valve when the pressure differential, (P_1-P_2), does not exceed 10 pounds per square inch. A safety valve should be installed on the highest point of the tank to insure that the maximum permissible pressure is not exceeded. The reserve capacity of the tank V_R need not be large but should be sufficient to cover all tank outlets during a time of maximum demand.

A separate manually controlled air compressor, belt-driven by an electric motor, is usually operated once daily to charge the pneumatic tank with air. The required compressor capacity should be based on the following formula:

$$\text{Capacity of the compressor (Cubic feet per minute)} = \frac{V \times P_1^2}{90{,}000 \times T}$$

where

V is the capacity of the pneumatic tank in gallons,
P_1 is the maximum absolute pressure in pounds per square inch, and
T is the time in minutes during which the compressor is to operate.

The cost of a pneumatic tank installation is usually considerably smaller than that of a gravity tank, since the required structural work is greatly reduced. However, the cost of operation and maintenance of the pumps and compressor should be considered, as well as the fact that the water in the pneumatic tank will absorb large quantities of air, which may interfere with the operation of the water heaters unless provision is made for its removal. Also to be considered is the fact that, in certain areas of the country, fire department regulations require a gravity tank as an item of fire protection.

(c) Constant pressure pumping systems which eliminate pressure and storage tanks, special valves and certain unnecessary piping have gained in popularity, in recent years, as a means to maintain a constant pressure for water service in high-rise buildings. Such systems are available as packaged units, complete with pumps, motors, and automatic controls. The cost is considered less expensive than that of a pneumatic tank installation.

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c. Friction Losses

(1) Friction Losses in Pipes. The resistance to the flow of water through the pipe, fittings, valves, and bends of a supply system is measured as the loss in head due to friction in the system. This resistance is a function of the flow, the piping material and its condition, the diameter of the piping, the length of the piping, and to a slight extent the physical characteristics of the water. Head loss due to friction is usually expressed as pounds per square inch per 100 feet of length and can best be obtained by consulting the flow charts, as illustrated in the chapter on Water Services contained in the American Society of Heating Refrigerating and Air Conditioning Guide and Data Book. The flow charts also show the velocity of flow in the piping. The flow chart illustrated for smooth pipe is generally used for copper tubing carrying water of normal characteristics; for ferrous piping, a choice of the other flow charts must be made on the basis of the corrosivity characteristics of the water.

(2) Friction Losses in Fittings. The resistance to flow through valves and fittings is expressed as the equivalent length of straight pipe that has the same friction loss as the valve or fitting. These equivalent lengths for the various pipe sizes can best be obtained by consulting the table "Equivalent Length of Pipe for Various Fittings" set forth in the chapter on Water Services contained in the ASHRAE Guide and Data Book.

In any section of a water supply system the developed length of piping will equal the actual length within that section plus the equivalent length of all the valves and fittings in the section. If the required flow through the section is known, reference to the appropriate flow chart will give the friction loss per 100 feet of developed length, which can be converted to the total loss of head due to friction through that particular section of piping.

11. PROCEDURE FOR PIPE SIZING

The primary purpose in establishing pipe sizes is to provide an adequate and satisfactory amount of water to the fixtures at all times. One of the important items that must be determined before any part of the water piping system can be sized, is the probable rate of flow in any particular section of the piping system. The rate of flow in the service lines, risers and main branches, however, will rarely be equal to the sum of the rates of flow of all connected fixtures. In fact, the probability that every fixture will be used at the same time is so remote that it would be very poor engineering practice to design the piping system to take care of such simultaneous flow.

The demand load for water supply systems in buildings cannot be determined exactly and is not readily standardized. The two main problems to be considered are: (1) the satisfactory supply of water for a given fixture; and (2) the number of fixtures which may be assumed to be in use at the same time.

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Establishing the correct pipe sizes for water supply systems in building can best be determined by consulting the charts, tables, and other pertinent reference information set forth in the chapter on Water Services contained in the ASHRAE Guide and Data Book.

12. SIZING THE RECIRCULATING SYSTEM

Since the function of hot water circulating piping is to keep the water in the hot water supply piping warm (not to supply water to the fixture outlets), the method of sizing this piping differs from the method outlined for supply piping. The recirculating system (together with the hot water supply system) forms a closed circuit which operates only when the hot water faucets are closed so that the available pressure has no effect on the flow through this circuit.

a. The required flow through the recirculating system is dependent only on the total heat loss from the supply and recirculating piping. This heat loss should be estimated by assuming reasonable sizes for the recirculating piping, obtaining the unit heat loss per linear foot for the various sizes of supply and recirculating piping, multiplying the unit loss by the total length of pipe for each pipe size and the difference in temperature between the pipe and its surroundings; and then summing up the heat losses for the separate pipe sizes in the system. Heat losses for steel pipe and copper tube and the conductivities of various insulating materials can be obtained by consulting the appropriate tables set forth in the chapter on Design Heat Transmission Coefficients contained in the ASHRAE Guide and Data Book. This chapter may also be consulted for the equation to calculate the heat flow through a system.

b. The friction loss through a recirculating system can be obtained by consulting the flow charts as illustrated in the chapter on Water Services contained in the ASHRAE Guide and Data Book. By using the proper chart the friction loss per 100 feet of developed length can be obtained for each assumed pipe size and, if the friction loss or the velocity of flow through the recirculating piping is either excessively large or uneconomically small, the assumed pipe sizes should be corrected. The total friction loss through the circuit should then be obtained from each developed length and its corresponding friction loss per 100 feet. When recirculating flow alone is passing through the water supply piping, the friction loss in that piping is usually so small that it can be neglected.

c. Recirculating pumps should be sized to have a capacity equal to the required flow, at a discharge head necessary to overcome the total frictional resistance of the circuit, neglecting any gravity effects. Since such pumps are small, an electric motor-driven end suction or side suction centrifugal type with bronze impeller and bronze trim is usually satisfactory and economical.

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When the entire circuit is at the desired temperature, operation of the recirculating pump is unnecessary, and an immersion aquastat should be provided in the recirculating line to stop the pump motor when such a condition is reached. The most convenient and economical location is about 25 feet from the recirculating pump in a space not affected by heating equipment.

13. PIPE INSULATION

Water piping is insulated for the following reasons:

a. To prevent excessive heat losses.
b. To prevent freezing of the water in the pipe.
c. To prevent condensation on the exterior of the cold water piping.

In general, hot water supply of recirculating piping should be insulated to prevent excessive heat losses. For installations requiring only short runs of hot water supply piping, insulation is usually unnecessary. Where there is doubt as to the value of the pipe insulation, an estimate of the total heat saved by the use of insulation should be determined, and the value of savings compared to the cost of the insulation. For hot water pipe located within interior partitions, insulation may be omitted where space is limited.

Frost-proofing of all water piping (cold, hot, and recirculating) should be done in cold climates when the piping is installed in exterior walls, crawl spaces, attics, and where the piping may be exposed to the weather.

Moisture from the atmosphere will condense on cold water piping located in boiler rooms, work rooms, laundry and drying rooms, exterior walls, furred spaces and pipe shafts, finished spaces, crawl spaces, and other space where condensation is likely to occur. Condensed moisture will drip off pipe and damage equipment, household furnishings, plastered surfaces, etc., located beneath or adjacent to the piping. It is advisable, therefore, to insulate all cold water piping where condensation might cause damage.

Insulation for cold, hot, and recirculating piping should be jacketed with cotton sheeting and provided with metal bands to hold the covering in place. Jacket for cold water piping should be the vapor barrier type to prevent sweating. Insulating materials frequently used are: magnesia or calcium silicate or mineral fiber molded pipe covering or flexible unicellular thermal pipe covering. The metal bands should be spaced about 18 inches on centers and be placed at all fittings. Fittings and valve bodies should be covered with insulating and finishing cement to the same thickness as the pipe covering, and jacketed with cotton sheeting.

14. UNDERGROUND DISTRIBUTION PIPING

Hot water supply and recirculating piping between buildings should be installed in underground tunnels or conduits used for the heat distribution

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system, and should be insulated in the manner specified for such underground heat piping. Any underground system that is to be used only for water piping should conform to the type of system specified for the heating system. Part XIV of this Bulletin offers detailed information on underground distribution systems.

PLUMBING, HEATING AND VENTILATION

PART XII - PROJECT-OPERATED HEATING PLANTS
CENTRAL, GROUP, AND BUILDING SYSTEMS

1. GENERAL

The application of project-operated heating plants to housing (other than housing of the apartment type) is relatively new and is in a stage of advance and improvement. The basic principles and details are, however, well understood by qualified heating engineers, hence there would be little occasion for this bulletin except for the fact that this type of heating, when applied to public, low-rent housing must recognize certain peculiarities and conditions not necessarily pertinent to private housing operated on an economic basis. While the differences are not extreme, public housing experience has demonstrated that they are of enough significance to warrant special consideration in the design of project-operated heating plants of any nature.

This bulletin points up the special problems of heating in low-rent housing and offers general suggestions for meeting them. This involves discussion of the factors which may lead to the selection of project-operated rather than tenant-operated heating systems and the further considerations leading to a choice between central, group, or building plants. Finally this discussion deals briefly with the relative advantages and disadvantages of the several systems of heat distribution applicable to project-operated plants - steam, hot water, and warm air.

As used herein the term "Central Plant" means one plant serving all of the buildings in a project; "Group Plants" means two or more plants serving the entire project; and "Building Plant" means a plant within a building and serving all dwellings in the building only.

The designer's attention is directed to other related parts of this bulletin, particularly "Thermal Environment and Comfort", "Boilers, Accessories and Fuel Handling", "Boiler Plant Instruments", and "Underground Distribution".

2. OBJECTIVES AND SPECIAL PROBLEMS

The objectives and problems encountered in the design of heating systems for low-rent public housing will be similar, in all general respects, to those of private housing projects. The system for each should maintain adequate and proper heat for health and comfort within the dwelling areas; the requirements for a healthful degree of heat do not vary because of the economic status of tenants. However, low cost, especially operating cost, is more important for public low-rent housing than for private housing.

The problem involves scaling the heating design down to a point where it provides all that is essential, but nothing more, and this should be borne in mind by the designing engineer. Illustrative of some of the obvious points where savings can be made, it is noted that private housing generally includes refinements not essential in low-rent projects, such as concealed risers, recessed or concealed radiators, radiators in bathrooms and kitchens (instead of exposed heating risers), individual thermostatic temperature control for each dwelling, and in some private housing projects the system will include outside air, heated for ventilation.

3. UTILITY ANALYSIS

The utility analysis required by PHA procedure to determine the lowest economic cost of utilities, including heating (see Bulletin No. LR-11), is predicated on a tentative but normally firm premise as to the dwelling types that will be used in a specific project. Depending upon the nature of these types, whether they are to be three-story or multi-story apartments, flats, or row-houses, or are to be a combination of several of these types, the decision to use tenant or project-operated plants will generally, (but not always) be a foregone conclusion.

For example: if a project is to consist entirely of apartments, the selection of project-operated plants is a certainty and there might be a valid presumption to that effect if the project is to consist largely of apartments but with some row-houses, or an analysis might indicate that a project consisting entirely of row-houses, which normally are heated by individual tenant-operated plants, would operate more economically if project-operated plants are used.

The utility analysis, having, in a given case, pointed to the justification of a project-operated plant, may also have a material bearing upon the decision to use central, group, or building plants, chiefly because of such factors as variations in plant labor cost, fuel, and delivery costs, etc.

There are other factors not susceptible to monetary evaluation in a utility analysis which will influence the decision to select either central, group or building plants systems. Some of these factors are discussed under the following heading.

4. CENTRAL VS. GROUP VS. BUILDING PLANTS

Assuming that the annual operating expense of the several utility combinations considered in the analysis are comparable, or approximately so, the decision to use central, group, or building plants, may depend on considerations such as the topography of the site, its proposed dwelling density; the character of the surrounding areas, and the extent and nature of the roads and dedicated streets contemplated within the project boundaries, thus:

a. A compact site with high density would normally tend to favor a central plant, especially if multi-story buildings are used.

b. A long narrow site with low density would tend to favor either group or building plants since a central plant would require a long distribution system; and good temperature control, by zones, would be difficult and expensive to obtain.

c. A central plant with a tall chimney might be considered incongruous on a site with row-houses in a residential neighborhood, while this might not be true if the site is adjacent to a commercial or industrial area.

d. Group or building plants are usually more readily adaptable to sites with pronounced drainage areas or undulating terrain, since a central plant would require excessive excavation and pumping equipment.

e. A site bisected by dedicated streets may restrict the use of a central plant if, (as is sometimes the case) local ordinances forbid installing heating mains under the streets.

f. Access roads for delivery of fuel oil or coal (and ash removal if required) may tend to favor or handicap either central, group or building plants, depending on the grades and other design features of the project road system.

g. Boiler plants for project-operated heating systems, on either private or public housing projects, present problems of noise, dirt, and hazardous trucking due to fuel delivery (and ash removal if required), and equipment noise and excessive heat within the boiler plant. On existing public housing projects boiler plants have been constructed as separate structures; as part of the management and community buildings; or as a part of a dwelling structure. Because of these facts, a project-operated heating plant within a dwelling structure is the least desirable because of hazard to the tenants and the extra insulation and soundproofing required in such cases.

h. A boiler plant located near the center of the heating load will provide a more equalized distribution system, better temperature control, and simplify operation and maintenance. However, there may be many reasons where such a location would be inexpedient due to grade conditions, site planning, or pronounced drainage areas.

5. SELECTION OF SYSTEM

Having determined upon a central, group, or building plant, the next problem is to decide whether steam, forced hot water or forced warm air should be used. A steam or forced hot water system with radiators, piping, controls, etc., will probably be about the same as to initial cost and operating expense. A forced warm air system with a heat exchanger (connected to a steam or forced hot water system) with duct work, registers, grilles and controls will probably prove more expensive in both initial and operating expense than a steam or forced hot water system.

The system selected, after all other factors are considered, should be readily adaptable to the site and the buildings as contemplated without requiring major changes in the concept of structural or architectural design. Some of the factors that should be considered before the system is selected are:

a. A level site is suitable for a steam or hot water system.

b. A rolling site should be more suitable for forced hot water since the mains can follow the ground contours with consequent lesser amount of excavation than for steam which should pitch uniformly in the direction of steam flow.

c. A site where some buildings are below the boiler room level should be more suitable for forced hot water than steam, since extra pumping will not be required for hot water.

d. Steam or hot water is suitable for standard dwelling units; however, if a forced warm air system is used, additional space must be provided for the heat exchanger and the required ducts to each room.

Comparable results will be obtained from properly designed steam, hot water, or warm air systems. The minimum requirements of the American Society of Heating and Ventilating Engineers are recommended as the basis of design. In the interest of economy, design, and installation, the suggestions under the following headings are offered for consideration.

6. STEAM SYSTEMS

a. Recommendations

(1) Radiators, standing cast-iron or convectors, under windows.

(2) Standard weight black steel piping above ground; extra heavy black steel or wrought-iron in conduits below grade, with standard weight cast-iron fittings.

(3) All risers exposed; valves on supply and return mains in each building; valves on risers in buildings over six stories high.

(4) Heat bathrooms with exposed risers, which should be used to supply radiators in adjacent rooms.

(5) Install radiators on first floors only in public stair halls.

(6) Install sleeves for all piping passing through floors, walls, and partitions; sleeves to be at least 1/2 inch larger than the pipe and extend 1/2 inch above floor; sleeves in masonry or concrete to be steel pipe, and sheet metal in wood construction.

(7) Grade steam mains to low points and drip; return mains to grade back to pumping equipment without lifts; drip traps to be float and thermostatic with strainers on inlet of each trap; radiator traps to be thermostatic type.

(8) Insulate pipe and fittings below the first floor with moulded sectional covering; plastic asbestos cement on fitting; insulation in conduits underground to be protected with waterproofed paper and mastic.

(9) Provide hand valves on each radiator for tenant control.

(10) Use single or duplex, vacuum or condensate pumps on return systems.

b. Advantages. No danger of freezing; floor to each radiator can be balanced with proper orifices; quick heating up; repairs can be made without extensive drainage; radiators do not require manual venting.

c. Disadvantages. Radiators occupy floor space; interfere with furniture; discolor walls and window decorations and present a hazard to children; possibility of noise due to water hammer; drip and radiator traps require cleaning and periodic replacement; require basement or crawl space for installation of mains; pressure reducing valves on high pressure systems are noisy and require frequent adjustment, cleaning, and replacement.

7. FORCED HOT WATER SYSTEMS

a. Recommendations

(1) Material, equipment, and installation generally are similar to steam systems except as noted.

(2) Piping exposed to freezing temperatures should be frostproofed.

(3) Strainers, drip and radiator traps are not required.

(4) Radiator valves to be of the forced hot water type; balancing fittings properly adjusted on each radiator; lock-shield balancing valves on each section of mains; hand-operated valves on each section of mains with drains at low points.

(5) Provide thermometers on supply and return mains at each section.

(6) Use automatic air vents properly valved at all high points.

(7) Provide key or slotted vent valves on each radiator located above the distributing mains.

b. Advantages. Mains may be installed in attic, basement, or crawl space; drip and thermostatic traps are not required, thereby reducing maintenance, repair, and replacement; no danger of water hammer; quick heating up; heating controls are simple in design and operation, ruggedly constructed, lower in first cost and less expensive to maintain; water temperature can be varied to accurately maintain comfortable room conditions especially during mild outside temperatures; line losses will be less than with a steam system because of the lower temperature of the distributing system.

c. Disadvantages. Possibility of freezing if system or radiators are shut down and windows are open; system must be drained for repairs; radiators require manual venting, occupy floor space, interfere with furniture, discolor walls and window decorations and present a hazard to children.

8. FORCED WARM AIR SYSTEMS

a. Recommendations

(1) Heater exchanger with blower motor unit arranged for manual operation; manual starter and electric protective devices; heating coil; removable filters, and metal casing. No fresh air connection should be provided.

(2) Sheet steel or aluminum ducts with adjustable dampers at each supply opening; and flexible connection between ducts and heat exchanger.

(3) Registers and grilles at each duct opening.

b. Advantages. Possibility of leakage or freezing reduced because of fewer piping connections and their location near the center of dwellings; properly located registers and grilles will not interfere with furniture or window decoration and present no hazard to children.

c. Disadvantages. Space requirement for heat exchanger; higher maintenance and operating expense due to blower-motor; high power consumption especially if tenant uses blower for summer cooling; space and furring required for ducts; filters require cleaning or replacement.

9. MANAGEMENT AND COMMUNITY FACILITIES BUILDINGS

These should have the same type of heating system as the dwellings, but with separate mains from the boiler plant if practicable, and should be valved to permit heat in these spaces when the balance of system is closed down.

10. CONTROLS

Project-operated heating systems must be designed to maintain a comfortable temperature within the dwellings during very low outside temperatures which seldom occur during the regular heating season. Hence, unless some type of control system is included, over-heating will take place resulting in waste of fuel. Normally, of course, this is accomplished with individual manual controls, but experience in low-rent housing indicates that automatic zone temperature controls, although higher in first cost than manual controls, should result in lower operating expense. It is imperative, however, that the control system be coordinated with the heating system to provide comfort within the dwelling with a minimum of maintenance and repair.

The number of zones for a project should be based on the number of dwellings, the site density, and the length of the distribution system. The zones should be synchronized so that the load on the boilers will not vary more than ten percent above or below the average demand during an interval of twenty minutes.

Temperature control systems for the various type of project-operated heating installation should be as follows:

a. Steam systems may be either of the "Continuous Flow" or the "On and Off" type with an outside device or a combination of outside and inside devices that will vary either the quantity or the temperature of steam to each zone; the

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flow to each radiator should be equalized by means of accurately sized orifices; vacuum pumps are generally required with the "On and Off" type control while either vacuum or condensate pumps may be used with the "Continuous Flow" systems.

b. Hot water systems - regulated by varying the water temperature by means of an automatic valve controlled by outside temperature.

c. Forced warm air systems - regulated by a self-contained valve installed on the supply connection to the coil in the heat exchanger that will vary the discharge air temperature in accordance with the return air temperature; or the control system may function on the steam or forced hot water system as mentioned in "a" or "b" above.

PLUMBING, HEATING AND VENTILATION

PART XII - PROJECT-OPERATED HEATING PLANTS
CENTRAL, GROUP, AND BUILDING.

1. GENERAL

This Bulletin discusses the factors which lead to the selection of project-operated heating plants, and outlines considerations leading to a choice between central, group, or building plants. Finally this discussion deals with the relative advantages and disadvantages of the several heat distribution media--steam, hot water, and warm air.

The term "central plant" means one plant serving the entire project; "group plants" means two or more plants serving the entire project; and "building plant" means a plant within a building serving the dwellings in the building.

Attention is directed to other related parts of this Bulletin, particularly "THERMAL ENVIRONMENT AND COMFORT," "BOILERS, FUEL HANDLING AND STORAGE, ACCESSORIES," "BOILER PLANT INSTRUMENTS," and "UNDERGROUND HEAT DISTRIBUTION,"

2. OBJECTIVES AND SPECIAL PROBLEMS

The objectives to be achieved in the design of heating systems for low-rent public housing will be similar to those in private housing projects. The comfort requirements do not vary because of the economic status of tenants. However, operating cost is more important for public low-rent housing than for private housing. The problem involves scaling down the heating design to a point where it provides all that is essential, but nothing more. Illustrative of some of the points where savings can be made, private housing may include refinements not essential in low-rent projects, such as concealed risers, recessed or concealed radiators, temperature control for each dwelling, or multiple heat control zones for each building.

3. UTILITY ANALYSIS

The utility analysis required by PHA procedure to determine the lowest economic cost of utilities, including heating (see Bulletin No. LR-11), is predicated on a tentative but normally firm premise as to the dwelling types proposed for a specific project. Depending upon the nature of these types, whether they are to be row-houses, flats, three-story, or hi-rise buildings, or are to be a combination of several of these types, the decision to use tenant or project-operated plants may generally (but not always) be a foregone conclusion.

Note: This Part supersedes Part XII of Bulletin No.LR-7 dated 8-2-50. It has been revised throughout.

For example: if a project is to consist entirely of hi-rise buildings, the selection of project-operated plants can be a certainty, or, an analysis might indicate that a project consisting entirely of row-houses, which normally are heated by individual tenant-operated plants, may operate more economically if project-operated plants are used. The cost of the fuel will largely be the determining factor in the latter instance.

The utility analysis, having, in a given case, pointed to the justification of a project-operated plant, may also point to the use of central, group, or building plants, chiefly because of such factors as operating and maintenance costs. There are other factors in a utility analysis which will influence the decision to select either central, group, or building plants. Some of these factors are discussed under the following section.

4. CENTRAL VS. GROUP VS. BUILDING PLANTS

Assuming that the annual operating and maintenance costs of the several utility combinations considered in the analysis are comparable, the decision to use central, group, or building plants, may depend on the topography of the site and its dwelling density, the character of the surrounding areas, and the extent and nature of the roads and dedicated streets contemplated within the project boundaries, thus:

a. A compact site with high density would favor a central plant, especially if hi-rise buildings are used.

b. A long narrow site with low density would tend to favor either group or building plants since a central plant would require a long distribution system; and good zone heat control in a central plant of this type could be difficult and expensive to obtain. Building plants in row-house sites tend to be feasible where gas or oil are the most economic fuels; here the plants can be fully automatic with low operating labor costs.

c. A central plant with a tall chimney might be considered incongruous on a site with row-houses in a residential neighborhood, while this might not be true if the site is adjacent to a commercial or industrial area.

d. Group or building plants are usually more readily adaptable to sites with pronounced drainage areas or rolling terrain, since a central plant would require excessive excavation and pumping equipment.

e. A site bisected by dedicated streets may restrict the use of a central plant if, (as is sometimes the case) local ordinances forbid installing heating mains under the streets.

f. Access roads for delivery of fuel oil or coal (and ash removal) may tend to favor or handicap either central, group, or building plants, depending on the grades and other design features of the project road system.

g. Boiler plants present problems of noise and dirt from operating equipment, and trucking due to fuel delivery (and ash removal). Boiler plants have been constructed as separate structures; as part of the management and community buildings; or as a part of a dwelling structure. A plant within a dwelling structure is the least desirable because of building insulation and soundproofing required in such cases to lessen the tenants' discomfort.

h. A boiler plant located near the center of the heating load will provide a more equalized piping distribution system and better heat control; the initial, and operating and maintenance costs should be less. However, there may be many reasons where such a location would be inexpedient due to grade conditions, site planning, or pronounced drainage areas.

5. SELECTION OF SYSTEM

Having determined upon a central, group, or building plant, the next problem is to decide whether steam, forced hot water, or forced warm air should be used. A steam or forced hot water system with radiation, piping, and controls, will probably be about the same for initial and annual costs. The extra pumping cost in the forced hot water system is offset by: (1) steam trap maintenance cost; (2) cold water make-up cost; (3) the chemical treatment of boiler water in the steam system. A forced warm air system with a heat exchanger in each dwelling unit (connected to a steam or forced hot water system) with duct work, registers, grilles, and controls will prove more expensive in both initial and operating costs than a steam or forced hot water system with direct radiators. The use of this warm air system in public housing is practically nil.

The system selected, after all other factors are considered, should be readily adaptable to the site and the buildings without requiring major changes in the concept of structural or architectural design. Some of the factors that should be considered before the system is selected are:

a. A level site is suitable for a steam or hot water system.

b. A rolling site should be more suitable for forced hot water since the mains can follow the ground contours with consequent lesser amount of excavation than for steam where the lines should pitch uniformly in the direction of flow.

c. A site where some buildings are below the boiler room level should be more suitable for forced hot water than for steam, since extra pumping will not be required for hot water.

d. Steam or hot water is suitable for standard type dwelling units; however, if a forced warm air system is used, additional space must be provided for the heat exchanger.

The minimum requirements of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers are recommended as the basis of design. In the interest of economical design the following suggestions are offered for consideration.

6. STEAM SYSTEMS

a. Recommendations

(1) Radiators, standing cast-iron or convectors, under windows.

(2) Standard weight black steel piping.

(3) All risers exposed; valves on supply and return mains in each building; valves at base of risers in hi-rise buildings.

(4) Install radiators on first floors only in public stair halls.

(5) Pitch steam mains to low points and drip; pitch return mains to pumping equipment without lifts; drip traps to be generally float and thermostatic with strainers on inlet of each trap; radiator traps to be thermostatic type.

(6) Provide hand valves on each radiator for tenant control.

b. Advantages. No danger of freezing; flow to each radiator can be balanced with orifices; quick heating-up; repairs can be made without extensive drainage; radiators do not require manual venting.

c. Disadvantages. Steam traps require periodic maintenance; leaking traps result in cold water make-up to the boilers necessitating additional boiler water treatment. Gases collecting in the condensate lines require treatment for neutralization to reduce corrosion and increase pipe life. Pressure reducing valves on high pressure steam systems require frequent adjustment and maintenance. Controls do not always produce the same degree of sensitivity and finesse at the radiator, as do controls in forced hot water systems. Further, steam controls capable of producing a comparable degree of comfort and economy as with hot water are usually more expensive in initial and maintenance costs.

7. FORCED HOT WATER SYSTEMS

a. Recommendations

Material, equipment, and installation generally are similar to that in steam systems except for the following:

(1) Piping exposed to freezing temperatures should be frostproofed.

(2) Supply valves on radiators to be of the forced hot water type; return els on radiators to be balancing type; lock-shield balancing valves on each section of return mains; hand-operated valves on each section of supply mains; drains at low points; globe valve on discharge side of pump for hand regulation of head pressure.

(3) Provide thermometers on supply and return mains at each section.

(4) Use automatic air vents at all high points.

(5) Provide key or slotted vent valves on each radiator located above the distributing mains.

b. Advantages. Drip and thermostatic traps are not required, thereby reducing maintenance, repair, and replacement; heating controls are simple in design and operation, lower in first cost and less expensive to maintain; water temperature can be varied to maintain comfortable room conditions especially during any outside temperature; line losses will be less than with a steam system because of the lower temperature of the distributing system. Insignificant amount of cold water make-up water required. Chemical water treatment is no problem.

c. Disadvantages. Possibility of freezing if system or radiators are shut down and windows are open; system must be drained for repairs; radiators require manual venting. Possibility of thermal shock in boilers, causing leaks.

8. FORCED WARM AIR SYSTEMS

a. Recommendations

(1) Heat exchanger, steam or hot-water coil, with blower motor unit arranged for automatic and manual operation; manual starter and electric protective devices; heating coil; removable filters, and metal casing.

(2) Sheet steel or aluminum ducts with adjustable dampers at each branch take-off; and flexible connection between ducts and heat exchanger.

(3) Registers at supply openings and grilles at return openings.

b. Advantages. Quick heating-up, and very responsive to outside weather changes. Possibility of leakage or freezing reduced because of fewer piping connections and their location at exchanger near the center of dwellings.

c. Disadvantages. Space requirement for heat exchanger; higher maintenance and operating expense due to blower-motor; high power consumption especially if tenant uses blower for summer ventilation; heating coil and filter cleaning; filters also require replacement.

9. MANAGEMENT AND COMMUNITY FACILITIES BUILDINGS

Except where the dwelling units are individual tenant-operated, these buildings should have the same type of heating system as the dwellings. The piping should be so valved to permit heat in these spaces when the remainder of the system is shut down.

10. CONTROLS

Systems should be designed to maintain a 70° F. temperature (75° F. for the elderly) within the dwellings during all weather conditions. Hence, unless some type of control system is included, over-heating will take place, resulting in waste of fuel. Normally, experience in low-rent housing indicates that automatic zone heat controls, although higher in first cost than manual controls, should result in lower fuel costs.

The number of zones for a project should be based on the number of dwellings, the site density, and the length of the distribution system. Temperature control systems may be as follows:

a. Steam system controls may be either of the "continuous flow" or the "on-and-off" type, with an outside device or a combination of outside and inside devices, that will vary either the quantity or the temperature of steam to each zone; the flow to each radiator should be equalized by means of accurately sized orifices; vacuum pumps are generally required with the "on-and-off" type control, while either vacuum or condensate pumps may be used with the "continuous flow" type. In the on-and-off system of controls, difficulty of unusual load fluctuations on the boiler have been experienced; to avoid this condition, a minimum of five zone valves, operating in sequence, should be so programmed as not to vary the load on the boilers more than ten percent plus or minus in an interval of twenty minutes.

b. Hot water systems - generally regulated by varying the water temperature by means of a three-way mixing valve controlled by outside temperature. The mixing valve should be so operated as to eliminate thermal shock on the boilers.

c. Forced warm air systems - regulated by a self-contained valve installed on the supply connection to the coil in the heat exchanger; this control should vary the discharge air temperature to maintain a predetermined room temperature; the main distribution heat control should function on the steam or forced hot water systems as mentioned in "a" or "b" above.

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PLUMBING, HEATING AND VENTILATION

PART XIII PROJECT-OPERATED SYSTEMS

BOILERS, ACCESSORIES, FUEL HANDLING AND STORAGE

1. INTRODUCTION

Considering the number, size and variety of project-operated heating plants, constructed for low-rent housing projects in the past, the operating results have generally been satisfactory. However, on several projects, special problems have arisen which required extensive alterations, repair or replacements to maintain satisfactory and economical service. This bulletin points out some of these special problems and offers suggestions for meeting or avoiding them on future projects. The equipment considered in this release is confined largely to boilers, stokers, oil and gas burners, fuel storage and handling facilities, pumps, hot water generators and heat exchangers, pipe, fittings etc. Certain of these items will be required on all projects, while other projects will need only a few of them.

Carefully selected and properly installed equipment will provide useful and economic service which will contribute much to the health and comfort of the tenants.

The failure of any piece of equipment may impair the operation of the system and result in expensive repairs, possible replacement, or excessive operating labor.

The structural design of the boiler plant should include openings of sufficient size for the removal and replacement of the largest piece of equipment. Such openings may be a removable window, door or slab in the roof. A screened opening with fixed louvers, having a free area equal to the chimney size, is required to supply air for combustion to the boiler room. The mechanical engineer should assure himself that the building as designed will support all of the equipment under full operating conditions, and with an ample factor of safety. An adequate clearance should be provided around all equipment for proper access, operation and maintenance.

Boiler and equipment rooms located within a dwelling structure should have an insulated hung ceiling and/or insulated walls to prevent over heating in the adjacent living quarters. Hung ceilings should have ventilating outlets (preferably to the outside), to provide air movement in the ceiling space.

The chimney size and height should be based on natural draft, and possible conversion to any other fuel or firing method. The chimney should be located to provide proper clearance from nearby structures, trees and hills. The minimum requirements of the American Society of Heating and Ventilating Engineers should be used as the basis of design. The equipment specified, and the installation, should conform to applicable requirements of local codes and regulations and of the National Board of Fire Underwriters. The designer's attention is directed to other parts of this bulletin particularly "Boiler Plant Instruments", "Underground Distribution", which offers suggestions for locating the boiler plant.

2. BOILERS

Cast-iron boilers and steel boilers each have their proper place in heating plants and under some conditions, price considerations being more or less equal, either type of boiler can be made to serve its proper function. However, under conditions of relatively heavy load, because cast-iron boilers are not made in capacities as large as steel boilers, the multiple use of cast-iron boilers becomes, beyond a certain point, uneconomical, as to initial cost (the boilers themselves and space required) and more expensive as to operation and upkeep. Thus this question should be very carefully considered in every case. (This point is made not on the basis of theoretical possibility, but because there have been actual instances in Public Housing where cast-iron boilers were used on an uneconomical basis.)

To assist the designing engineer in selecting boilers to meet the various operating conditions, many of which are peculiar to public low-rent housing projects, the following comments and suggestions are pertinent:

a. In the interest of operating economy, public housing project-operated heating plants normally are shut down from late evening to early morning. This shut down will average approximately four to eight hours depending on outside temperature. Approximately twenty-five per cent should be added to the requirements for space and domestic water heating, to compensate for the morning pickup and normal line losses.

b. When the total boiler horsepower requirements are two hundred and fifty or over, it is recommended that three equally sized boilers be used. As the domestic water heating averages between twenty-five to forty per cent of the total boiler capacity, this will allow any one boiler to be used for the domestic hot water requirements. With firing equipment, sized for not less than twenty-five per cent in excess of the maximum boiler demand, two boilers will handle the project, except in extremely low temperatures. To provide greater flexibility in large projects, the normal rating of a single boiler should not exceed five hundred horsepower regardless of the total boiler requirements.

c. When the total boiler horsepower requirements are less than two hundred and fifty, two boilers will be satisfactory. Each boiler should be sized for approximately sixty-five per cent of the total requirements. One boiler, operated in excess of its nominal rating, will provide space and water heating, except during periods of extremely low temperatures.

d. Building plants which provide space heating and domestic hot water for up to twenty dwellings need have only one boiler.

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e. Boilers and equipment in adjacent group or building plants should be inter-connected so that one plant may provide domestic hot water during the "off" heating season, and partial service when one plant is out of service.

f. Boilers and firing equipment should be specified to operate at least one hundred twenty-five per cent of nominal rating in order to eliminate the necessity for a spare boiler on the rare occasions when a boiler fails during peak demand.

g. Smoke breeching should be designed for natural draft. Manually operated adjustable dampers should be installed in the breeching connection for coal-fired boilers only. A main damper, installed in the breeching near the chimney, should be specified for multi-boiler installations. This damper may be manually operated or automatically controlled by the firing equipment. Combustion control dampers should be specified for oil and coal fired boilers and should have the same area as the breeching. A barometric draft regulator will maintain a uniform rate of over draft, balancing out fluctuations caused by varying atmospheric conditions.

3. COMBUSTION CHAMBERS, BOILER WALLS AND SETTINGS

The firing equipment on a number of projects has been replaced to allow the use of another fuel because of an increase in cost of the fuel originally selected. In several instances, this conversion required expensive alteration in the boiler setting and piping connections. It is strongly recommended that the boiler setting provide ample space for conversion to any other fuel without requiring changes in the setting or piping.

Probably in the interest of initial savings, and without proper consideration for operating and replacement expense, the boiler setting and combustion chambers on some projects were so specified and constructed as to require complete replacement or expensive repairs within a few years after completion. This was particularly true on projects with large multi-boiler installations. To avoid similar breakdown it is recommended that:

a. Steel boilers (other than the portable fire box type) should be supported by steel columns and beams (not by the brick settings.)

b. A completely independent brick setting should be provided for each boiler with ample maintenance space between each boiler.

c. Boiler of three hundred horsepower and over should have water or air cooled walls. The walls should be sectionally supported and not load bearing. This will allow the boiler to operate up to two hundred per cent of rating, during an emergency, without damage to the settings or combustion chamber. The preheated air circulated through the air-cooled walls should be used for combustion purposes wherever practicable.

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d. Combustion chambers should be constructed of first-class fire brick complying with Federal Specifications HH-B-671C "high heat" with a pyrometric cone equivalent of 32. Refractory lining should extend approximately six inches above the water leg of fire-boilers.

4. FIRING EQUIPMENT

The firing equipment should always be sized to operate its boiler at least one hundred twenty-five per cent of its nominal rating. A single automatic temperature or pressure control device should be located on each boiler to operate the firing device. A single control device installed on the piping to control all of the firing equipment simultaneously has proven unsatisfactory because the fluctuations in the pressure or temperature will start and stop the firing device intermittently instead of maintaining steady operation.

In general, stokers, oil and gas burners, and their controls have given satisfactory service. However, on some projects faulty design and installation and acceptance of experimental equipment has resulted in excessive operating labor, expensive alterations, replacement and fuel wastage. The following suggestions are offered to assist the designing engineer in selecting equipment, and specifying its installation, to provide economical and satisfactory service for the life of the project:

a. Hand fired boilers are seldon justified on project-operated plants due to the additional operating labor required and to the difficulty in coordinating the firing rate with the space and domestic hot water requirements. However, should this type of boiler be used, the automatic controls should be arranged to close the draft damper and open the check draft, in the event of electrical power failure.

b. Stokers should be selected for the type and grade of coal that will be used on the project. They should be of a make that has given satisfactory service, in similar installations, for a period of at least two years; experimental models should not be specified. Space should be provided in the ash pit for at least eight hours accumulation of ash. When dumping grates are used particular attention should be given to the height of the pit, so that large sized clinkers will not prevent the grates from returning to their normal position.

Improper distribution of air under the fire has resulted in burning out grates, improper combustion, and excessive clinkers. To correct this condition it is suggested that sectional baffles be installed to distribute the air evenly across the underside of the grates.

Cleanout doors should be provided in the wind box for removal of fly ash. Side dumper stokers should have provision for burning down the fire prior to dumping.

Any part of the stoker subject to rapid wear or breakage should be designed for easy removal.

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c. Oil burners should be of the modulating type rather than "off" and "on" Secondary air should be automatically regulated.

Where the oil pressure in the heater is greater than the operating pressure of the boiler, and a leak occurs in the heating coil, considerable trouble has been experienced by oil getting into the boiler. It is recommended that wherever possible the oil pressure be kept lower than the operating pressure.

Auxiliary electric heaters should be of ample size to heat the oil consumed by the burner as well as the oil that is recirculated. This heater should be thermostatically controlled and have a signal device which will indicate when the heater is "on" or "off".

d. Gas burners should be of the up-shot type. Where ignition takes place at only one point it is possible for the combustion chamber to fill with an explosive mixture before the entire burner is ignited. This is dangerous and it is recommended that ignition take place at not less than four points of the burner. The safety pilot should shut down the burner in the event of ignition failure. The burners and controls should be approved by the American Gas Association and bear their label, and have the approval of the local utility.

5. FUEL AND ASH HANDLING AND STORAGE

Coal and ash handling and storage on certain projects have been a source of constant trouble, until expensive corrective measures were authorized. To a lesser degree, oil storage has also presented certain problems. The following suggestions are offered for inclusion in the design of projects using either coal or oil:

a. Oil storage tanks and their location should meet the requirement of all local codes and ordinances, and the National Board of Fire Underwriters. Tanks should be set on a solid foundation and strapped down to prevent movement in any direction. The tanks should be sized to hold at least a ten days' supply based on maximum use. Two tanks should be specified, with the piping arranged and valved to allow one tank to be shut down and cleaned periodically. Each tank should hold at least a full tank truck of oil. Consideration should be given to the installation of storage tanks that will hold a full railroad tank car of oil if lower prices are obtainable by this method of purchase.

b. Considerable trouble has been experienced with the provisions for storing and handling of coal and ashes; they have often resulted in expensive repairs, alterations, replacements or excessive operating labor. Following are points derived from experience on existing installations, and suggestions to assist in keeping operating labor to a minimum:

(1) Where a sloping terrain is available adjacent to the boiler room location, the coal storage should be located above the stoker so that coal may be fed by gravity into the stoker hopper.

(2) Manholes for coal delivery should be set at least three inches above the surrounding grade to prevent surface water from draining into the coal storage.

(3) Where coal storage and boilers are at the same elevation and when approximately eight tons or less are required per eight hour shift, a monorail and drop-bottom bucket should be provided: and when more than twelve tons are required per eight hour shift, overhead storage with elevators, conveyors and a weight larry should be provided.

(4) Overhead coal or ash storage chambers should be constructed of concrete, but if constructed of steel, should be lined with concrete or masonry. Overhead bunkers should have sharply sloping sides and bottom for coal or ash removal without need for hand trimming.

(5) If overhead storage is provided, precautions should be taken to prevent freezing of wet ashes.

6. MATERIALS

a. Standard weight black steel pipe will be satisfactory for all services, except that extra heavy should be used for blow offs. Joints should be either flanged welded, or screwed. Piping should be supported to prevent vibration in adjacent dwelling units.

b. Valves and unions should be installed at each piece of equipment to allow for repairs and maintenance.

c. Insulation should be specified for boilers, piping, breeching, hot water generators and heat exchangers.

7. ACCESSORIES

The accessories required for the successful operation of a project-operated heating system may range from a pump in a building or small group plant to a very complex arrangement in a large high pressure central plant. This will discuss a number of items that will be required for any boiler, regardless of size.

a. Pumps will depend on the type of service for which they will be used. They may be condensate or vacuum heating pumps for low pressure systems, circulating pumps for forced hot water, and boiler feed pumps for certain projects depending on the type of boilers and the development of the site.

(1) Low pressure heating service pumps should be condensate or vacuum duplex type, centrifugal design, electric motor driven, equipped with receiving tank and necessary operating automatic controls. Whether a condensate or vacuum pump is used will depend on the type of heating controls specified. Certain types of continuous flow and all "on and off" control systems will require vacuum pumps.

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Low density projects with 175 dwellings and over, having pumps located away from the boiler room should have duplex boiler feed pumps and condensate receiver in the boiler room (Note: The number of dwelling units may be increased by twenty-five per cent for high density projects in multi-story buildings). The receiver should have: (a) minimum storage capacity of thirty minutes of maximum requirements; (b) a cold water make-up connection with float valve in the lower section, and (c) receive condensate from all heating pumps. Condensate receivers should be located above the pump suction. The boiler feed pumps should be automatically operated from the boiler water line. When the heating pumps are located in the boiler room they should discharge directly to the boiler. All pump discharges should be connected to the boiler through a standard "Hartford Loop" as shown in the ASHVE Guide.

In small group or building plants, single unit condensate pumps will be satisfactory, discharging direct to the boilers. (An open drain to the sewer will allow the condensate to be wasted temporarily when repairs or replacements are necessary).

Vacuum pumps will be required in group or central plants having extensive distribution systems.

Pumps located in isolated buildings due to topography of the site should be of the condensate type, discharging into the receiving tank of pumps located in the boiler room.

(2) Forced hot water pumps should be of the centrifugal circulating motor driven type and designed to deliver the gallonage of water required, based on the friction in the system. In systems with a high static head, the suction side of pumps should be connected to the boiler or heat exchanger. Pumps may be manually operated or arranged to operate in conjunction with the temperature control system. Pumps should be set on an isolated slab with flexible connections on the inlet and outlet of each pump. In small group or building plants a single pump will be satisfactory, with the connections arranged and valved to allow for the insertion of a substitute pump in the event of a breakdown. On large central or group installations two pumps should be considered for each plant, and each pump should be sized for the full load on the system.

(3) Duplex sump pits and pumps should be provided for boiler and machine room located below the sewer elevation.

b. Soot blowers should be considered for boilers with a rating of 100 horsepower and over, particularly where heavy oil (No. 6) or bituminous coal is used. Soot blowers for low pressure boilers should be operated by compressed air, while those on high pressure boilers by steam. Air operated soot blowers should be of the type which blows all of the air into the tubes, rather than the type which blows against the tube sheet. Soot blowers for horizontally baffled boilers should be arranged to remove all of the fly ash.

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c. Feed water heaters should be used only in high pressure plants and be of the deaerating type of sufficient capacity to heat water to approximately 210° F. Heater should deaerate the total amount of water per hour delivered to the boilers. Approximately 85 per cent of the water will be condensate return and the balance cold water make-up. Heater should be equipped with oil separater, float valve, vent line, back pressure valve, exhaust and all necessary equipment and controls. Thermometers should be installed on condensate return and pump discharge lines. The water storage compartment should be designed for a minimum of thirty minutes storage to allow for pickup after night shut down, during coldest periods. Make-up cold water connection should be at the lower third of the tank.

d. Pressure reducing valves will be required only for high pressure systems. The valves should reduce the boiler pressure in two steps; the first step should reduce the pressure to between 30 to 40 P.S.I. for distribution to machine rooms located in the basement of various buildings;the second step should reduce the pressure to between 2 and 5 P.S.I. for distribution to the radiators. The primary valves should be located in the boiler room, with two valves connected in parallel, and with a common by-pass. One valve should be sized to handle the domestic hot water load and the other valve sized to take care of the varying heating load. Maximum capacities should be predicated on wide open valves. Valves should be equipped with strainers, gate valves on the inlet and outlet, pilot piping, gages and a relief valve sized to prevent excess building up on the outlet side of the valve.

e. Heat exchangers or convertors will be required only when steam boilers are specified and a forced hot water heating system is used. Capacity should be based on not less than the maximum load requirements plus 25 per cent. Exchangers should be supported on pipe or structural frame and furnished with necessary controls, and relief valves as required. Thermometers should be installed on supply and return connections to the heating system.

f. Expansion tanks should be sized for the requirements of the system and should be provided with a tank drain relief valve.

g. Metal ladders and walks should be provided only where it would otherwise be difficult to operate and maintain valves and equipment set at excessive heights above the boiler room floor.

PLUMBING, HEATING AND VENTILATION

PART XIII - PROJECT-OPERATED PLANTS

BOILERS, FUEL HANDLING AND STORAGE, ACCESSORIES

1. INTRODUCTION

Considering the number, size, and variety of project-operated heating plants in low-rent housing projects, the operating results have been satisfactory. However, problems have arisen which required alterations, repairs, or replacements, to maintain satisfactory and economical service. This Bulletin offers suggestions for avoiding such problems. The equipment considered in this release is confined to boiler plant structures and chimneys, boilers, firing equipment, boiler plant accessories, and materials. The designer's attention is directed to other parts of this Bulletin, particularly "BOILER PLANT INSTRUMENTS" and "UNDERGROUND HEAT DISTRIBUTION."

The structural design of the boiler plant should include openings of sufficient size for the removal and replacement of the largest piece of equipment. The design engineer should assure himself that the building will support all of the equipment with an ample factor of safety. Clearance should be provided around all equipment for proper access, operation, and maintenance.

a. A continuous source of fresh air is important for support in proper and efficient combustion of fuel. This can be economically attained with screened fixed louvers having a free (daylight) opening equivalent to a minimum of 15 square inches per 140,000 Btu per hour of fuel input.

Boiler rooms, and rooms housing heat-exchanger equipment, located within a dwelling structure should have an insulated hung ceiling and/or insulated walls, to prevent overheating in the adjacent living quarters. Hung ceilings should have ventilating outlets (preferably to the outside), to provide air movement in the ceiling space. The ventilation should be divorced from the boiler rooms, so as not to "rob" air needed for combustion. Motor (other than fractional horsepower)-equipment rooms contiguous to dwelling units should have sound-absorption, to prevent transmission of vibration noise to units.

The chimney size should be based on natural draft, except where forced- or induced- draft fans supplemental to the fuel-firing equipment are furnished. It should be remembered that such fans, although they serve a useful purpose, present a maintenance problem. Their use is recommended primarily with the "package type" boiler, where boiler, firing equipment, and fan are assembled

NOTE: This Part supersedes Part XIII of Bulletin No. LR-7 dated 8-25-50. It has been revised throughout to reflect additional experience gained in the operation of project plants.

as an integral unit at the boiler factory. The chimney should be located, and its height extended if necessary, to obviate downdrafts caused by proximate structures, trees, and hills. Careful attention in chimney design and construction should be paid to requirements of local codes and of the National Board of Fire Underwriters. Low stacks usually create a nuisance.

2. BOILERS

Cast-iron boilers and steel boilers each have their proper place. Price considerations being more or less equal, either type of boiler can serve effectively. However, under conditions of relatively heavy load, because cast-iron boilers are not made in capacities as large as steel boilers, the multiple use of cast-iron boilers in a plant becomes, beyond a certain point, uneconomical, because of initial cost (the boilers themselves and space required). Thus, this question should be carefully considered.

a. In the interest of operating economy, heating plants normally are shut down from late evening to early morning. This shutdown will average approximately four to eight hours, depending on outside temperature. Approximately twenty-five percent should be added to the requirements for space and domestic water heating, to compensate for line losses and the morning pickup.

b. When the total boiler horsepower requirements (total demand load), which include morning pickup and line losses, are two hundred and over, at least three equal-sized boilers should be used. As the domestic water heating averages between twenty and thirty percent of the total boiler capacity, this may allow any one boiler to be used for the domestic hot water requirements. With firing equipment sized for not less than twenty-five per cent in excess of the total demand load, two boilers will handle the project, except in low temperatures. To provide greater flexibility in large projects, the capacity rating of a single boiler should not exceed five hundred horsepower regardless of the total boiler requirements.

c. When the total boiler horsepower requirements are less than two hundred, two boilers will be satisfactory. Each boiler should be sized for approximately sixty-five percent of the total demand load. One boiler will furnish the needed requirements, except during periods of low temperatures.

d. Building plants which provide space heating and domestic hot water for up to twenty dwelling units need have only one boiler.

e. Boilers and equipment in adjacent group or building plants, interconnected, will provide domestic hot water during the "off" heating season, and partial space and domestic water heating requirements when one plant is out of service.

f. Boilers with properly designed and constructed settings can operate continuously in excess of capacity ratings without damage for short periods (up to three hours). Spare boiler capacity therefore is not essential merely to suit the rare occasions of a boiler failure during peak demand.

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g. Boiler dampers automatically operated through combustion-regulating equipment are warranted in the larger-sized boilers; two-hundred-horsepower boilers would appear to be a reasonable minimum limiting size. Well-selected combustion-regulating equipment contributes to fuel-saving. A barometric draft damper of the industrial type will help maintain a uniform draft, balancing out fluctuations caused by varying atmospheric conditions.

3. BOILER SETTINGS

The boiler equipment on a number of projects has been replaced to use another fuel, because of an increase in cost of the fuel originally selected, and because a national emergency dictated a change to divert the original fuel to more important channels. In several instances, this conversion required extensive alterations to the boiler settings. Therefore, original settings should provide space for conversion to another fuel without requiring major changes.

a. Factory erected steel boilers, except the "package type," should be supported by structural steel members independent of brick settings; these members are not particularly important where the boilers are less than 200 horsepower. In the smaller sizes, steel mounting angles welded to the sides of the boiler should rest on the settings.

b. Independent settings should be provided for each boiler, with ample maintenance space between each boiler.

c. Field-erected boilers of three hundred horsepower and over should have air-cooled or water-cooled walls in the combustion chambers, allowing boiler to operate up to 150 percent of nominal rating (10 square feet of heating surface per boiler horsepower) for air-cooled walls, and up to 200 percent of nominal rating for the water-cooled walls, continuously, without damage to the boiler parts or settings. The air-cooled walls can also be used to preheat combustion air. Walls, whether solid, air-cooled, or water-cooled, should be sectionally supported and not load-bearing. Support for boilers should be by structural steel members.

4. FIRING EQUIPMENT

The firing equipment should always be sized to operate its boiler at at least 125 percent of its specified capacity rating. A single automatic-control device should be located on each boiler, to operate the firing equipment. A single control device installed in the piping to control all of the firing equipment simultaneously has proven unsatisfactory, because the fluctuations in the pressure or temperature will start and stop the firing equipment for each boiler at one time, instead of maintaining steady operation, when the separate controls are wired for sequence operation.

a. Hand-fired boilers are seldom justified on project-operated plants, due to the additional operating labor required and to the difficulty in coordinating the firing rate with the load demand.

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b. Stokers should be selected for the type and grade of coal. Space should be provided in the ash pit for at least eight hours' accumulation of ash. When dumping grates are used, particular attention should be given to the height of the pit, so that large-sized clinkers will not prevent the grates from returning to their normal position. Dust collectors of the high-resistance type, and supplemented with an induced-draft fan, preferably one of each for each boiler, are necessary when spreader stokers are used. For other type stokers, a low-draft-loss cinder trap is adequate. In any event, local municipal regulations should be followed.

Inequitable distribution of air under the fire can result in burning out of grates, improper combustion, and excessive clinkers. This condition is corrected with sectional baffles installed to divert the air evenly across the underside of the grates.

Cleanout doors are necessary in the wind box, for removal of coal siftings. Stokers with side dump plates should have provision for burning down the fire prior to dumping. Any part of the stoker subject to wear or breakage should be designed for easy removal.

c. Oil burners should have their controls modulate the supply of oil from low to high fire, consistent with the load demand, on boilers 100 horsepower and over; for the smaller boilers, burners need operate only on-and-off.

Burning No. 6 (Bunker C) oil should not be attempted where requirements are less than about 15 gallons per hour; combustion chambers in the smaller boilers are inadequate to burn the heavy oil efficiently. Most No. 5 oils throughout the country require preheating; so there is no advantage in burning this oil. No. 4 oils can be burned efficiently without preheating, except perhaps on cold-starting, electrically. This grade oil, therefore, should be burned in the smaller boilers; also, this grade of oil should be considered in combination oil-gas burners, thus avoiding the costly operating need for keeping the heavier oils preheated when not in use.

Oil heaters (electric, steam, hot water) should be capable of heating the heavy oils to at least 180° F. before oil is admitted to the burner nozzle, for proper atomization. Special designs should be provided to keep oil lines hot to burners when boilers are down. Separate duplex pumps with oil lines looped at burners are usually required. Steam or hot water heaters can be furnished with double coils (one coil set within the other concentrically); in the event of inner-coil failure, the oil will circulate through the outer coil, preventing oil getting into the boiler.

d. Gas burners are of three types:

(1) Atmospheric, which employs the kinetic energy of the gas to inspirate and mix the primary air with the gas; the mixture burns at the ports or jets, with the addition of secondary air. The burners can be of the up-shot or in-shot type; if necessary, for even gas distribution in the larger boilers, ignition should take place at more than one point.

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(2) Fan-assisted, so arranged that all the required air for combustion is supplied by a fan sufficient only to overcome resistance of air flow through the burner.

(3) Premix, so arranged as to produce a completely combustible mixture without the need for additional air.

5. FUEL AND ASH HANDLING AND STORAGE

Fuel handling and storage can be a source of constant trouble, without proper facilities.

a. Oil storage tanks and their location should meet the requirements of all local codes and ordinances and of the National Board of Fire Underwriters. Tanks should be set on a solid foundation and strapped down to prevent movement in any direction. The tanks should be sized to hold at least a two-weeks' supply in coldest weather. Two tanks should be specified, with the piping arranged and valved to allow one tank to be shut down and cleaned periodically, where requirements are in excess of 15,000 gallons storage.

b. Coal-burning plants should be planned for a minimum of coal- and ash-handling facilities, consistent with the tonnage required. A two weeks' coal supply in coldest weather should be available.

(1) Advantage should be taken of site topography in locating the plant; for example, with the plant located at the lowest end of the site, the coal storage may be arranged so that trucks can drive atop the storage to dump the coal through a series of manholes strategically placed for even coal distribution, thus avoiding elevators and coal-spreading machinery.

(2) Manholes for coal delivery to underground storage should be set at least four inches above the surrounding grade, to prevent surface water from draining into the coal storage.

(3) Where coal storage and boilers are at the same elevation, and when approximately eight tons or less are required per eight-hour shift, a monorail and drop-bottom bucket should be adequate. When more than twelve tons are required per eight-hour shift, overhead storage with elevators (where the terrain requires elevators), flight conveyers, and a weigh larry would be an effective equipment assembly.

(4) Overhead coal or ash storage chambers should be constructed of concrete, but if constructed of steel should be lined with concrete or masonry or other approved materials resistant to the corrosive action of the coal or ash. Overhead bunkers should have sharply sloping sides, to obviate the need for hand trimming and to assist in removal of the coal or ash.

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(5) If overhead ash storage is provided, precautions should be taken to prevent freezing of wet ashes. With such overhead storage, ashes should be conveyed through cast-iron pipes horizontally in boiler-room floor trench, then vertically to ash bunker, powered by steam jet (possible only with high-pressure steam). Otherwise, other methods of ash conveyance should be investigated.

6. MATERIALS

a. Standard-weight black steel pipe will be satisfactory for all services, except that extra-heavy should be used for blow-offs.

b. Gate valves and unions should be installed at each piece of equipment, to allow for repairs and maintenance. There should be a globe valve by-pass at each temperature-regulating valve.

c. Insulation should be specified for boilers, piping, breeching, hot water generators, and other type heat exchangers. Exposed-to-view piping in dwelling units need not be insulated; the heating surface of such uninsulated piping should be considered when calculating requirements.

7. ACCESSORIES

The accessories required may range from a pump in a building plant or small group plant to a complex arrangement in a high-pressure central plant.

a. Pumps will depend on the type of service for which they will be used. They will be condensate or vacuum heating pumps for low-pressure steam systems, and circulating pumps for forced hot water. In steam-system central or group plants where pumps in outlying buildings discharge condensate to a central tank in the boiler house, boiler feed pumps pick up this condensate for delivery to the boilers.

(1) The use of condensate or vacuum pump will depend on the type of heating controls specified. On-and-off control systems will require vacuum pumps; also certain types of continuous-flow control systems, such as the subatmospheric type, will require vacuum pumps.

b. Central condensate receiving tank in boiler house should have: (a) minimum storage capacity of thirty minutes (from tank bottom to overflow connection) at total demand load; and (b) cold water make-up connection, with float valve in the lower third section. Condensate receiver pumps should be automatically operated from the boiler water line. When the condensate or vacuum pumps are located in the boiler room they should discharge directly to the boiler, where there are no separate boiler feed pumps. Cold water make-up should be metered. All pump discharges should be connected to the boiler through a standard "Hartford Loop."

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c. Forced hot water pumps should be sized to circulate the water required, based on the friction in the system and on a 20-degree (F.) temperature drop across the circuit. The suction side of pumps should be connected to the boiler or heat exchanger, to avoid wherever possible the need for higher-pressure equipment. A pressure gauge, thermometer, and valve on each side of the pump, will assist in more accurate surveillance of the system; the gauge should be located between the pump and valve. The valve on the discharge side should preferably be of the globe type, since it is more sensitive than a gate valve to throttling, should throttling become necessary.

d. Pump pit and sump pump should be provided, for boiler and heat exchanger equipment rooms located below the sewer elevation.

e. Soot blowers should be considered for boilers with a capacity rating of 100 horsepower or over, where heavy oil (No. 6) or bituminous coal is used. Soot blowers for low-pressure boilers should be operated by compressed air, and those on high-pressure steam boilers by steam. Air-operated soot blowers for fire-tube boilers should be of the type which blows all of the air into the tubes, rather than the type which blows against the tube sheet during part of the operation. Soot blowers for horizontally baffled boilers should be arranged to permit removal of the fly ash.

f. Feed water heaters should be used only in high pressure steam plants and should be of the deaerating type, of sufficient capacity to heat water to approximately 210° F. Heater should deaerate the total amount of water per hour delivered to the boilers, and it should be equipped with oil separator, float valve, vent line, back pressure valve, exhaust, and all other necessary adjunct equipment and controls. Thermometers should be installed on condensate lines. The water storage compartment should be designed for a minimum of thirty minutes storage (from tank bottom to overflow connection) at total demand load. Make-up cold water connection should be at the lower third of the tank, and be metered.

g. Pressure-reducing valves will be required only for high pressure steam systems, and where steam is purchased from a local utility company. The valves should reduce the line pressure in two steps; the first step should reduce the pressure to between 30 and 40 pounds per square inch gauge for distribution to heat-exchanger equipment rooms located in the basements of the various buildings; the second step should reduce the pressure to between 2 and 5 pounds per square inch gauge for distribution to the radiators, and to heat the domestic water.

(1) Valves should be arranged in parallel. For projects up to about 500 dwelling units, two valves for the primary reduction would seem necessary. One valve could take care of the maximum space heating requirements, and the other the maximum domestic water heating requirements. For projects in excess of 500 dwelling units, a three-valve-in-parallel arrangement would usually be

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more effective. Two valves should handle the maximum space heating demands, in the proportion of 75 percent and 25 percent ; the third valve should handle the maximum domestic water heating load. In either case, valves should be set to close at different downstream pressures, and the valves should be pilot-governed for smoother operation.

(2) For the secondary pressure reduction, the two-valve arrangement would seem satisfactory. One of the valves should be sized to provide for space heating, and the other for the domestic water heating load.

h. Expansion tanks in forced hot water systems should be sized in accordance with the recommendations of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Guide.

i. Metal ladders and metal walkways should be provided only where it would otherwise be difficult to operate and maintain valves and equipment set at unusual heights above the boiler-room floor.

j. Gauges and thermometers should be of a size and type, and should be located, to permit easy reading from boiler-room floor.

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PLUMBING, HEATING AND VENTILATION

PART XIV - UNDERGROUND DISTRIBUTION

1. INTRODUCTION

Underground distribution for housing has been increased extensively with the inception of large scale developments where a number of buildings on one site were supplied with space heating and domestic water heating requirements from a central source. Referred to sometimes as the "yard distribution", the underground system is a vital link between the heat source and piping within the buildings; its use in public housing is justified if the utility analysis (which is discussed at length in another bulletin) establishes as most economical, the project-operated method of supplying space and domestic water heating needs.

Whether the heating medium is piped from a local utility company plant at a considerable distance from the project site, or the piping system originates from a boiler plant on the project site, design techniques are essentially the same, except for the return piping. A local utility generally does not find it economical to pipe returns back to its power plant; under this condition, projects find it practicable and expedient to extract available energy from the returns to preheat domestic water, before the returns are discharged to the local sewer system.

The need for a well-planned system of underground lines is second only in importance, mechanically, to a safe and adequately constructed gas system, and parallels in importance the appropriate selection of piping materials for domestic water services. Without a well-designed and carefully constructed yard distribution, the efficacy of the boiler plant and piping systems in the buildings could well be lowered.

Since an underground distribution system is costly to build, its design lengths should be reduced to a minimum to lower initial costs and to reduce line losses. Principally, line losses become significant when plants are operated under light winter loads or during the summer months when only domestic water is being heated. Line losses mean fuel waste; to the experienced operator, such waste is discouraging because it is not within his ability to control. While corrective measures can, in many cases, be applied to improve operating efficiencies in boiler plants, it is difficult, if not impossible, to cure a badly designed underground distribution system without major revamping or overall replanning.

Excessive economies in design may, however, require operating pressures or temperatures higher than those for which the system was built, resulting in greater frictional resistance to the fluid flow within the piping system. Operating pressures or velocities higher than those originally anticipated may also mean larger line losses.

Extremes in cost can reach from that for the simple conduit to that for the reinforced concrete tunnel. There are times when the latter is not only proper but the most economical method of housing underground lines. A thorough study of all conditions is essential before making final decision on the underground system design.

Soil structure, degree of soil corrosivity, height of water table, building arrangement and site topography are factors which can influence the character and extent of the distribution system. For example, the corrosive action of certain soils is so rapid as to exclude use of metal casing conduits; but it is impractical to determine the measure of corrosivity by usual laboratory methods because of the short time interval between the site selection and design stages. Under the circumstances, favorable soil conditions could be attained by packing gravel around the conduit, proper drainage of the conduit system and other protective devices as illustrated in Figure 1.

Less costly conduit installations are possible by: building rearrangement, if architecturally feasible to permit piping to run from building to building; locating boiler plant centrally in an area or site to equalize design load, to cut down pipe and conduit sizes and to allow multiple pipe installation in one enclosure. Supplying buildings on a hilly site with steam from the low level upward rather than the reverse, permits a more economical conduit installation with the steam and return lines in the same conduit without pumping. Plant location is generally not a relevant factor in forced-water space heating or domestic water heating systems, since multiple pipe installation in one enclosure is possible irrespective of plant location.

Projects may expand after initial development is completed. Consultations with the Local Authority in the early stages of design to determine whether additions to the project are contemplated will avoid placing pipe lines in the way of future buildings. Otherwise, it may be necessary to abandon lines before they reach the limit of usefulness; added costs would then be required to provide new means for distribution. If practicable, contemplated project enlargement should be reflected in pipe sizing.

2. PIPING AND CONDUITS

Factors which influence the selection of piping materials for domestic water services are discussed in Part X of this Bulletin. For space heating services, standard weight, black steel pipe is satisfactory for the supply in steam systems, and for supply and return in water heating systems. While wrought iron supposedly may be preferable for return lines in steam systems, extra heavy black steel pipe should be satisfactory provided condensate is adequately treated.

Concrete trenches, tunnels, and conduits are the methods used for enclosing underground piping, and when correctly constructed should be reasonably watertight and sufficiently strong to withstand ordinary earth loads.

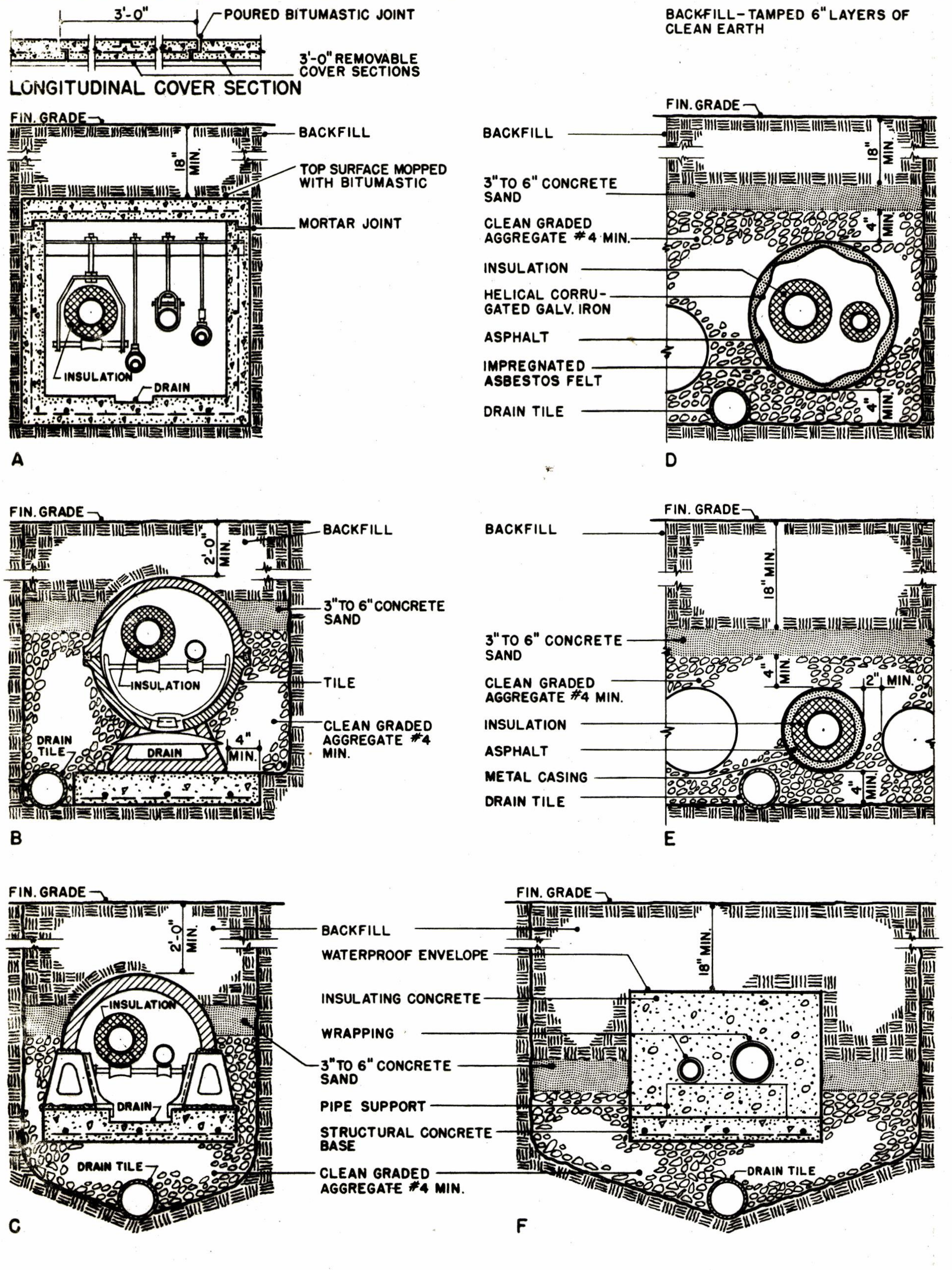

FIGURE I METHODS OF HOUSING UNDERGROUND LINES

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Figure 1 illustrates six methods of housing underground lines. Method A is the trench system; B and C are built-up conduits assembled in the field; D and E are prefabricated or presealed at the factory; F may be classed as presealed, but its complete assembly is carried out in the field.

Method A, the concrete trench, offers the advantage in that it can house a multiple system of piping, including domestic water heating lines. This cannot be done in conduit systems where, in some cases, it is required to pitch one or more of the pipe lines in the opposite direction from which the conduit is pitched. Also, its rugged construction, precluding any possibility of breakage, plus its resistance to attack by surrounding corrosive or water-laden soils, place the concrete trench in a top classification for distribution systems. Another advantage which the trench possesses is its removable precast concrete cover, which permits entrance to the trench for emergency maintenance. Trench floors should have means for carrying away water seepage.

Concrete tunnels, constructed essentially like the concrete trench system, except for their greater depth and width to permit traffic therein, are the most costly method for underground pipe enclosures, and cannot be justified from the mechanical standpoint only. When it is found reasonable to provide tunnels as a passageway between multi-story buildings, the mechanical engineer can avail himself of this feature for the space heating and domestic water heating lines. Pipe is usually laid along the side walls on racks.

Methods B and C, tile conduits, are reasonably satisfactory in average good soils, and when buried not over 6 feet. One type of tile conduit is furnished with, and rests on, a patented tile base drain with loosely fitted joints; all are in turn, supported on a structural concrete base. In another type, the drain is integral with the structural concrete base, on which the tile structure rests. In ground deeper than 6 feet, under streets and roadways or other places where ordinary vehicular traffic is anticipated, extra weight tile is preferable.

Concrete conduit (not insulating), precast or poured in place is another type of built-up conduit competing with tile. The use of cast-iron conduit seems reasonable where added strength is needed to withstand continuous or repeated loads or impacts, such as heavy earth loads, heavy vehicular traffic or street cars.

Method D consists of a galvanized iron conduit, presealed at the factory except for conduit connector sleeves, manufactured from 16 gauge metal formed into a cylinder with helical corrugations over which a coating of high temperature asphalt and a tension-wrapped layer of asbestos felt are applied. More than one pipe can be placed in the same conduit.

Conduit under Method E is presealed at the factory except for the conduit connector sleeves, and is formed by application of a uniformly poured and concentric layer of high melting point asphalt, at least 1 inch thick. The asphalt is formed between the insulated pipe and an outside galvanized iron

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jacket. Each pipe is housed in a separate conduit. Because the melting point of the asphalt is known to be about 235 degrees F, the use of this conduit would seem satisfactory where the heating media temperatures are not high enough to cause the asphalt, eventually, to melt.

Conduit under Method F is sealed in the field. Insulating concrete is poured monolithically around the pipes which rest on insulating concrete blocks, spaced equidistant; the conduit is supported on a structural concrete pad, and is encased in a waterproofing membrane. The insulating concrete serves two purposes: conduit envelopment, and insulation.

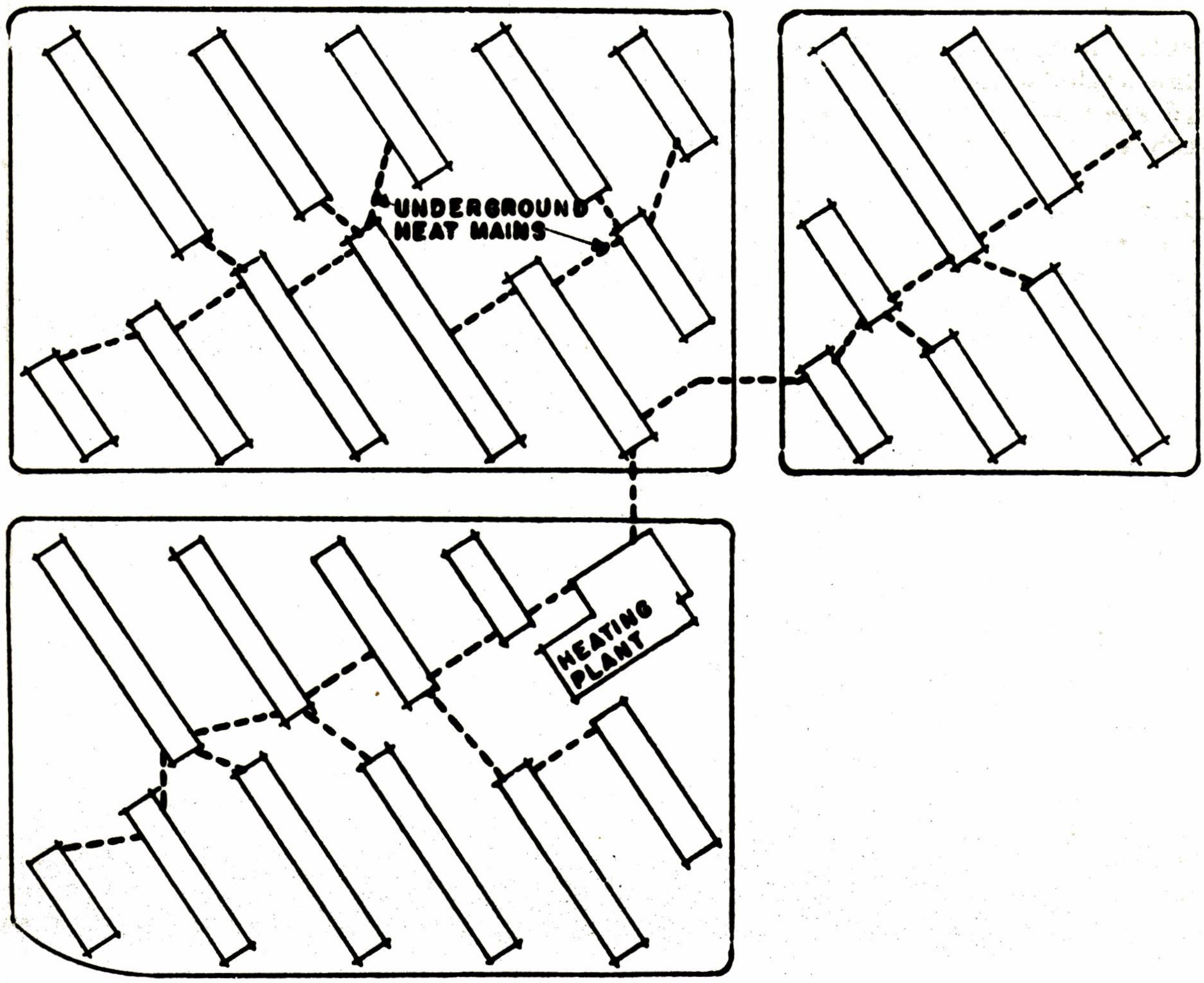
Other types of patented conduits, built-up and presealed may be available and could serve as well as those described herein. Conduit structures should be selected on a basis of anticipated life, equal at least, to the approximate average life of the project, rather than on a strictly competitive basis. However, sound initial economy should be considered along with a reasonable maintenance and replacement expense in making the selection.

Insulation, formed to fit the pipe, is customarily applied to all lines except to gravity or vacuum return lines of steam systems when run together with supply lines in concrete trenches or tunnels, in built-up conduits and in presealed conduits such as that shown in Method D, Figure 1. With an ambient temperature of about 150 degrees F in the enclosure, the heat loss from a bare pipe would not be large enough to warrant the extra cost of return line insulation. Return lines run singly in conduits should, however, be insulated. Loosely packed insulation embedded around the pipes in built-up conduits and in the presealed type, Method D, has been used with some fair degree of success, but a specific disadvantage to this manner of insulation is its greater surface (compared to formed insulation) exposed to the possibilities of water damage. The formed insulation with an asphalt-impregnated paper "half-wrapped" and securely tied over the insulation would seem preferable to the loosely packed type, because the paper offers the added resistance to water penetration.

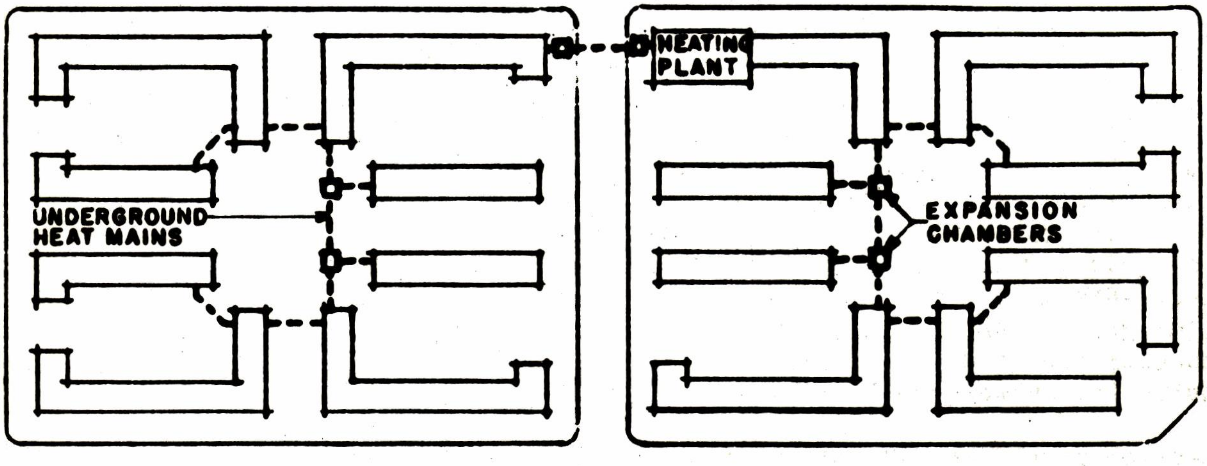
3. DISTRIBUTION AND EXPANSION

An underground distribution system may be elaborate or simple, depending upon the method used in routing the lines. A well-organized site plan will permit direct pipe distribution from building to building, and obviate the need for taking up expansion in costly concrete chambers in the yard. Figure 2 shows two schemes for running a distribution system; layouts are taken from projects, constructed and occupied. Scheme A shows a desirable, inexpensive and practicable method of distribution, since expansion is provided for in the buildings. Scheme B shows a more expensive method of distribution, with expansion provided for in yard chambers. The project with Scheme A was constructed subsequent to that with Scheme B.

Expansion provisions in the yard should be the exception rather than the rule, because usually distances between buildings or between the boiler plant and



A. EXPANSION IN BUILDINGS



B. EXPANSION IN YARD CHAMBERS

FIGURE 2 UNDERGROUND PIPING LAYOUTS

the first building will be less than 100 feet and accordingly require means for about 1 to 1-1/2 inches expansion. Where distances between buildings are less than 200 feet and heating media temperatures are 250 degrees F or less, lines may be anchored in one building and allowed to expand in another. If the distance between buildings is in excess of 200 feet, it is good policy to anchor midway between buildings and provide for expansion in both buildings. Deviations from these design methods may be necessary where pipes are larger than 6 inches and where heating media temperatures are in excess of 250 degrees F (equivalent to about 15 lbs. steam gauge pressure).

The linear expansion of piping will depend upon the type of material, the outside temperature at which the pipe was laid and the operating temperature of the heating medium. If it is anticipated that the pipe will be laid with outside temperatures of 32 degrees F or more, 32 degrees should be used as the base temperature for design. The American Standards Association "Code for Pressure Piping" has set forth in tabular form the rates of expansion in inches per 100 feet, based on incremental temperature increases above 32 degrees, for steel and wrought iron, copper, brass and bronze. Other data have been tabulated to enable the designing engineer to obtain the pipe elongations resulting from any given increase in temperature. The graph in Figure 3 has been plotted from available data and may be used as a guide in designing or selecting the expansion means.

Methods or elements by which elongation of pipe can be taken up are: swing or swivel joints, mechanical expansion joints, and pipe bends, turns or offsets.

Swing or swivel joints can be used in low pressure steam or water systems (space heating or domestic water heating) within buildings. Made up of threaded pipe members with four elbows before the pipe is returned to its original direction, expansion is taken up by the straight members in such offsets and/or in the swivel of the threaded joints. These joints are inexpensive and can be made up easily in the field, but offer disadvantages in leaks and additional resistance to fluid flow. Welded members, in lieu of threaded, would at least, overcome the disadvantage of leaks and could be utilized economically in piping 1-1/2 inches and larger; copper piping would have compression or soldering fittings.

Mechanical joints are factory produced and are generally of the slip and packless types. The slip type operates in the movement of a sleeve within a cylinder, the length of movement being termed the traverse; built of ferrous and/or brass materials, it depends upon packing, and stuffing glands for heating medium tightness. The packless type mechanical joint is built from copper, stainless steel or other corrosive-resistant material such as copper-nickel alloy formed into a series of corrugations or bellows which control the expansion. The slip and the packless joints do not require the space needed for the swing joint or the pipe bend, nor are they subject to the stresses incurred with the use of bends; but, the mechanical joints do involve a maintenance and inspection problem. For this reason, such

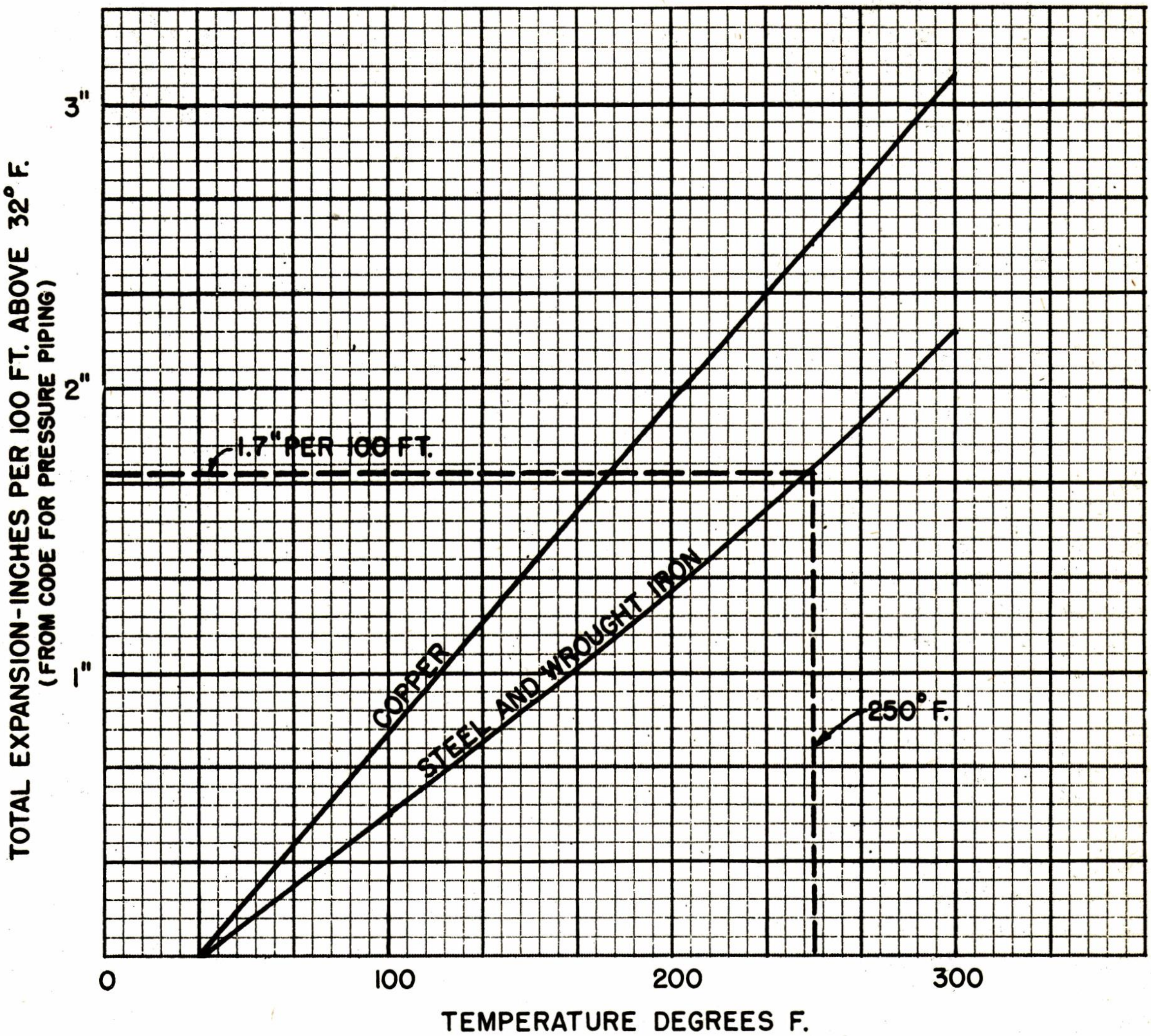


FIGURE 3

joints should be limited to installation in easily accessible places. Experience has indicated the need for two substantially constructed guides on each side of packless joint to ensure pipe alignment, and the need for an internal sleeve to prevent accumulations of sediment, such as scale or core sand, in the corrugations.

Bends commonly used are the double-offset expansion "U" bend, expansion "U" bend and the "hairpin" bend for straight pipe runs, as illustrated in Figure 4, and the 90 or 45 degree bends for directional changes in the piping. The physical properties of the pipe itself give the bend, when accurately designed and fabricated, the necessary flexibility to withstand the forces in pipe movement and to take up expansion. Pipe bends seem the most practicable when it is required to provide for expansion in the yard distribution, because of their flexing properties; the bend involves no maintenance problem, and it can be permanently housed in a concrete chamber where no removable cover or extension manhole is necessary. Guiding on each side of bend is necessary for alignment with pipe movement and to prevent needless increases in thrust.

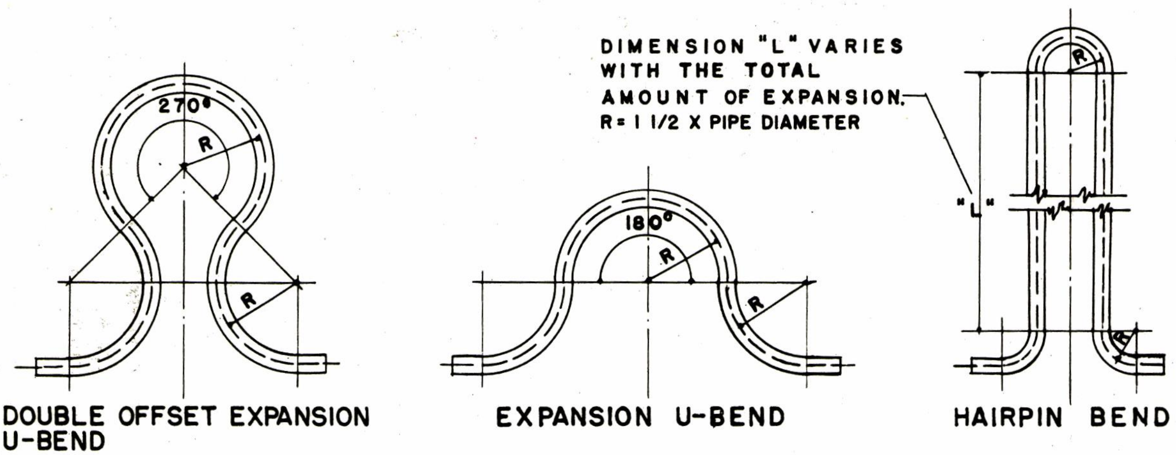


FIGURE 4 EXPANSION BENDS FOR STRAIGHT RUNS

The inherent flexibility of pipe makes possible the spreading or springing of a bend when the pipe is cold. The amount of this spread is termed the "cold spring", and as a general rule, may be made equivalent to 1/2 the total linear movement of the pipe in expansion. The piping to which the bend is connected, is cut short on each side of bend an amount equal to 1/2 of the spring; the bend is then spread into permanent place and welded or bolted to the piping after anchors, guides and supports are definitely set. The "Code for Pressure Piping" has stipulated that, "2/3 of the amount of cold spring may be considered as reducing the total expansion. While piping may be cold sprung more than 1/2 of its computed expansion, the maximum credit allowed shall not exceed 1/3 of the computed total expansion. The full amount of the cold spring shall be taken into account, however, in considering the forces, movements and stresses acting in cold condition". Taking advantage of the flexible properties of the pipe and the expansion credit permitted by the "Code" will reduce the overall cost of concrete chamber and bend.

There are minimum radii to which pipe can be bent for elasticity of movement, or else the piping will buckle when subjected to the stresses incurred by expansion and contraction. If stresses are kept within the limits for which the bend was designed, the bend should resume its original position when normal temperatures are restored. The graphs in Figure 5 show the radius to which a steel or wrought-iron pipe can be curved to the shapes noted for respective pipe sizes and rates of expansion, based upon a fibre stress not exceeding 15,000 lbs per square inch. It should be noted that the minimum radius is equivalent to about 5 pipe diameters.

The hairpin bend, economical to build and adequately suited to conditions under which distribution systems function in housing projects, should be used as a general rule, where required net expansion is less than that shown at origin points of the various pipe size graphs in Figure 5 for the double offset and expansion "U" bends. Figure 6 shows the minimum

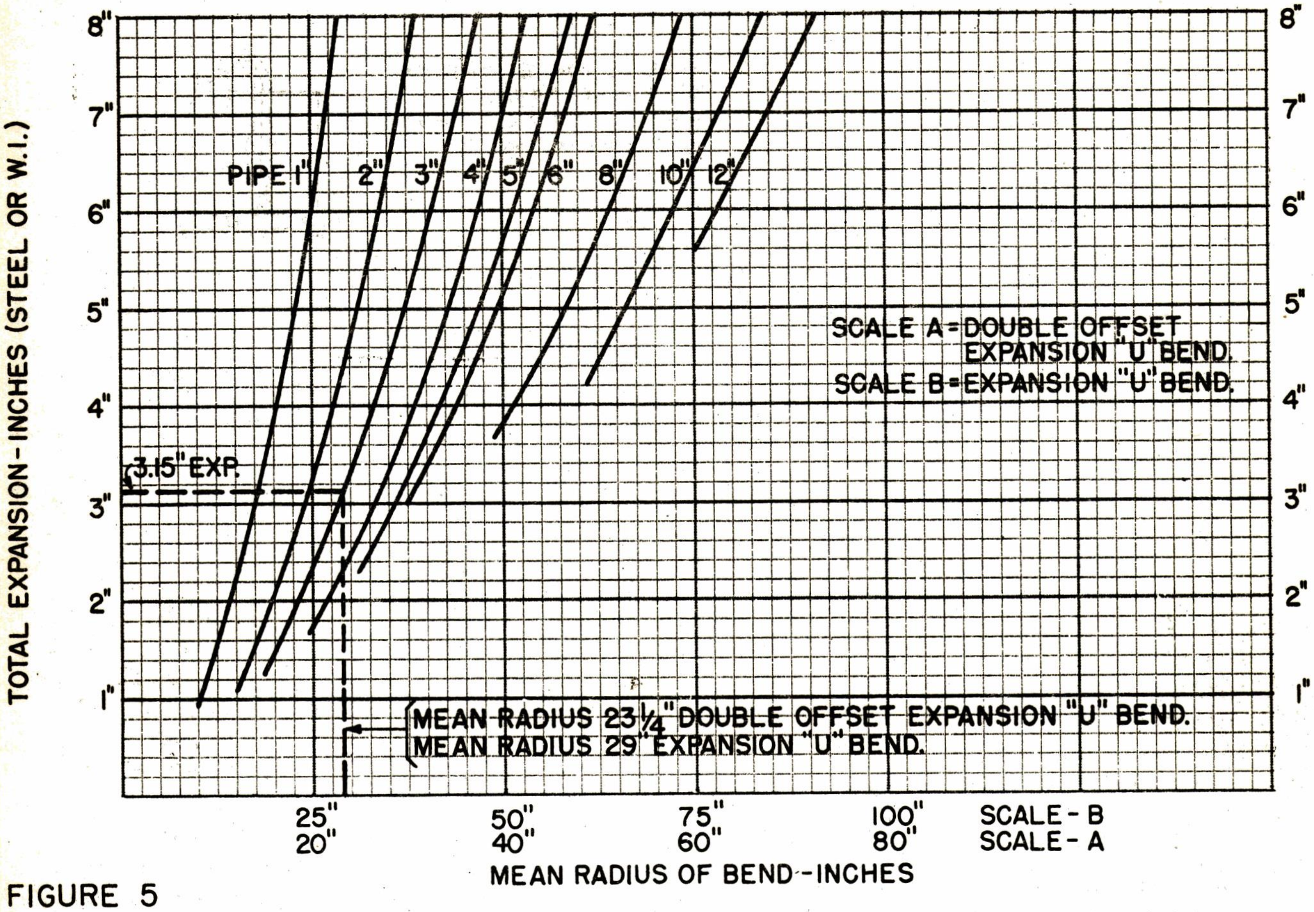
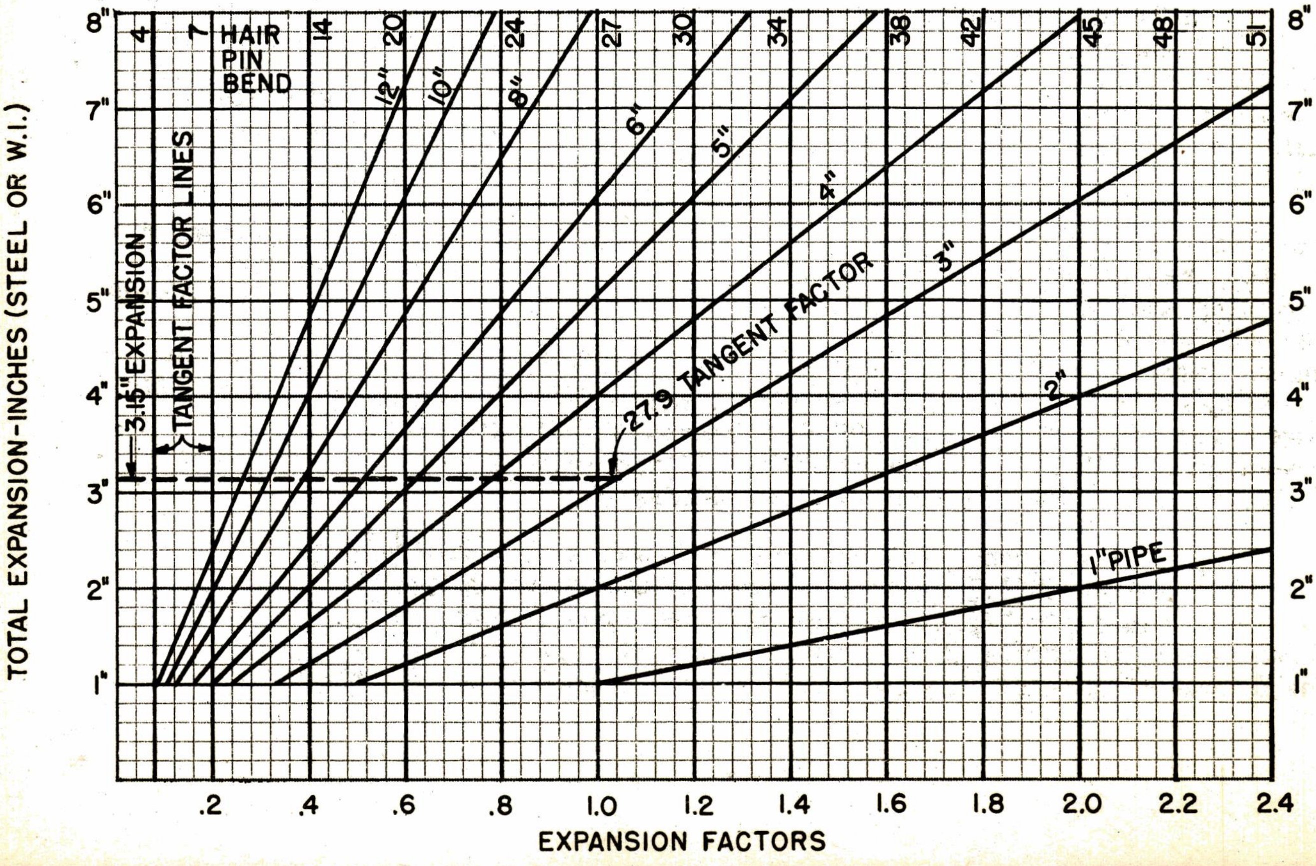

TOTAL EXPANSION-INCHES (STEEL OR W.I.)
PIPE 1" 2" 3" 4" 5" 6" 8" 10" 12"
SCALE A = DOUBLE OFFSET EXPANSION "U" BEND.
SCALE B = EXPANSION "U" BEND.
3.15" EXP.
MEAN RADIUS 23 1/4" DOUBLE OFFSET EXPANSION "U" BEND.
MEAN RADIUS 29" EXPANSION "U" BEND.
25" 20"
50" 40"
75" 60"
100" 80"
SCALE - B
SCALE - A
MEAN RADIUS OF BEND - INCHES

FIGURE 5


TOTAL EXPANSION-INCHES (STEEL OR W.I.)
HAIR PIN BEND
4 7 14 20 24 27 30 34 38 42 45 48 51
TANGENT FACTOR LINES
3.15" EXPANSION
12" 10" 8" 6" 5" 4" 3" 2" 1" PIPE
27.9 TANGENT FACTOR
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4
EXPANSION FACTORS

tangent lengths in the bend composed of two 90 degree and one 180 degree welding elbows; radius of fittings need be only 1-1/2 pipe diameters; the information is for steel and wrought iron pipe.

Expansion for copper tubing in domestic water heating systems will be taken up, in most cases, within buildings. The double offset expansion "U" bend and the expansion "U" bend are satisfactory for the very few instances where expansion will be taken up in the yard. Table 1 shows the suggested mean bend radius of the two types of bends designed to provide for 1-1/4 inches expansion without cold spring. Each bend could withstand a deflection of 1-1/2 x 1-1/4 inches or 1-7/8 inches if the bend were cold sprung a total of 1/2 x 1-7/8 inches or 15/32 inch on each side of bend.

Table 1

Mean Bend Radius for Copper Tubing

Tube Size Inches	Radius - Inches	
	Double Offset Expansion "U" Bend	Expansion "U" Bend
3/4	4-1/2	5-1/2
1	5-1/2	6-3/4
1-1/4	6-1/2	8
1-1/2	7-1/2	9-1/4
2	9-1/2	11-3/4
2-1/2	11-1/2	14-1/4
3	13-1/2	17
3-1/2	15-1/2	19-1/2
4	17-1/2	22

The graphs of the bends in Figures 5 and 6 have been sized on the basis of "effective" expansion, equal to 2/3 of the total calculated expansion, and on the basis that the bend will be "cold sprung" in place an amount equal to 1/2 the total calculated expansion. The following example will illustrate the procedure in selecting the proper bend:

Example: The distance between anchor points of a 3-inch steel steam pipe, sized to carry steam at 15 pounds per square inch gauge (250°F), is 185 feet. Determine:

a. total calculated expansion;
b. effective expansion;
c. amount of cold spring;
d. required mean radius of double offset expansion "U" bend and expansion "U" bend to absorb the required expansion;
e. required tangent lengths of hairpin bend to absorb expansion.

Procedure: Refer to Figure 3. Locate 250° F on the temperature scale, move upward to expansion graph for steel pipe and then horizontally to "expansion" scale, reading 1.7 inches per 100 feet.

a. Total calculated expansion - 1.7 x 185 = 3.15"
b. Effective expansion - 3.15 x 2/3 = 2.10"
c. Cold spring - 3.15 x 1/2 = 1.57"
d. Refer to Figure 5. Locate 3.15" on the "total expansion" scale and move horizontally to the 3" pipe graph, then downward to the "radius of bend" scale, reading 23-1/4" for the radius of a double offset expansion "U" bend and 29" for the radius of an expansion "U" bend.
e. Refer to Figure 5. Locate 3.15" on the "total expansion" scale and move horizontally to the 3" pipe graph; read tangent factor at point of intersection, 27.9. Multiply 27.9 x 3 (the pipe size) which equals 83.7", the required tangent length. The horizontal "expansion factors" scale was used originally to determine the vertical "tangent factor" lines.

4. ANCHORS

Just as it is important to design properly for expansion means, so is it important to establish that pipe movement take place generally between, and by the firm application of two anchors.

To serve their intended purpose, anchors should be secured adequately to the pipe and to a retaining structure such as a gusset plate bolted to the building wall (if anchorage is within building) or to a concrete block or concrete chamber construction (if anchorage is in the yard). If at all practicable, yard anchors should be set at points where branch connections are to be taken from main service lines. Anchors may range from the simple "U" bolt or clamp to the type fabricated from structural channels or angle irons.

5. CHAMBERS AND MANHOLES

Chambers for pipe bends (or pipe bends and anchors) can be economically constructed with reinforced concrete walls suited to meet local conditions, waterproofed and with reinforced slab covering.

A manhole is provided for entrance to the chamber as an integral extension of the chamber. The manhole, like the chamber, should be constructed of reinforced concrete, waterproofed, and should be approximately 25 inches square or, if round, 24 inches in diameter - either type extended to about 4 inches above grade and fitted with cast iron frame and cover; earth backfill should be sloped away in all directions to prevent surface water entering. Manholes are needed where the chamber houses equipment such as mechanical expansion joints, valves, steam drip traps and metering devices, and only when it is not feasible to locate such equipment within buildings. Two entrances to extremely large chambers, where manholes are required, are advisable; the second manhole when opened, will add sufficient ventilation to permit comfortable conditions when making repairs.

The chamber should be designed on the basis of the least physical dimensions to suit the types of expansion device. For example, the area of a chamber required for an expansion "U" bend is greater than that to house a double offset type of bend with the same expansion capacity; the cost of the bend, too, should be weighed in the calculation.

Presealed conduit manufacturers have means of allowing the pipe bend such as the hair pin type to be flexed within its own conduit structure. By this method, the concrete chamber, as such, is not needed.

6. DRAINAGE

The adequacy or inadequacy of a drainage method may well establish the difference between the success and the failure of an otherwise well-proportioned conduit distribution. While extra drains beyond that supplied and erected with the conduit is not necessary in sandy or dense clay soils and of low water table, the use of such devices should be warranted where there is a high water table and where impermeable soils invite excessive ground water. In all conduit installations, ground water should sieve through a layer of clean sand and through the interstices of a bed of crushed rock or gravel. Manufacturers of patented conduit structures are well-intentioned in their attempts to design a reasonably watertight enclosure, but carelessness involved in field assembly plus heavy drainage loads imposed upon the distribution system have often made replacements necessary; public housing can ill afford the high costs incident to such replacements. Figure 1 also shows suggested drainage schemes.

Provision for drainage to the sewer system through a floor drain may be made where drain enters building or yard chamber. Drainage may be continued through a chamber where it is not feasible to provide sewer connections at these points, in which case the conduit should drain at the same level as the chamber floor; otherwise, construction of troughs in the chamber would seem necessary. There are cases where drainage can be emptied into tile pipe surrounding the base of a building, or into a "french drain" proximate to the building wall, if drain loads are not heavy.

7. EXCAVATION AND BACKFILL

Conduit manufacturers' service details indicate the width of trench necessary for particular types of conduit. These details should also show the method of assembly, and should be followed with extreme care; in fact, contract specifications should stipulate that patented conduit systems be installed under direct supervision of the manufacturer's representative. The manufacturer could then assume some measure of responsibility.

Pipe enclosure should rest on firm bearing soil to avoid settlement. In some cases, it may be necessary to include extra supporting methods such as piles.

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Backfill, too, is pertinent to the success of a distribution system; boulders or other extraneous material deposited carelessly can break a tile conduit or otherwise deteriorate a metal conduit subject to corrosive elements present in unclean backfill. Sand and graded crushed rock or gravel should be well distributed wherever it is necessary to direct the flow of ground water for drainage; the gravel is also functional in simulating favorable soil conditions as pointed out hereinbefore.

PLUMBING, HEATING, AND VENTILATION

PART XIV - UNDERGROUND HEAT DISTRIBUTION

1. INTRODUCTION

Underground heat distribution for housing has been increased extensively with large scale developments. Whether the heating medium is piped from a local utility company plant at a considerable distance from the project site, or the piping system originates from a boiler plant on the project site, design techniques are essentially the same, except for the return piping. A local utility does not find it economical to pipe returns back to its power plant; under this condition, projects find it practicable to extract energy from the returns to preheat domestic water, before the returns are discharged to the local sewerage system.

An underground heat distribution system is costly to build. For that reason, design lengths should be reduced to a minimum. Also, extensive systems increase line losses, which become significant when plants are operated under light winter loads, or during the summer months when only domestic water is being heated. Line losses mean fuel waste. While corrective measures can be applied to improve operating efficiencies in boiler plants, it is difficult to cure a badly designed underground system without major revamping or overall replanning.

Extremes in cost can reach from that for the simple conduit to that for the reinforced concrete walk-in tunnel. There are times when the latter is the most economical method of housing underground lines. A thorough study is essential before deciding which method to use.

Soil structure, degree of soil corrosivity, height of water table, building arrangement, and site topography are factors which can influence the character and extent of the distribution system. For example, the corrosive action of certain soils is so rapid as to exclude use of metal casing conduits without cathodic protection.

Less costly conduit installations are possible by: (1) building rearrangement, if architecturally feasible, to permit piping to run from building to building; (2) locating boiler plant centrally, to equalize pipe load and to reduce pipe and conduit sizes. Supplying buildings on a hilly site with steam from the low level upward rather than the reverse, permits a more economical conduit installation with the steam and return lines in the same conduit without pumping. Plant location is generally not a relevant factor in forced hot water heating systems, since multiple pipe installation in one enclosure is possible irrespective of plant location.

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NOTE: This Part supersedes Part XIV of Bulletin No. LR-7 dated 9-13-50. It has been revised throughout to conform with the requirements of revised Section 207.1 of the Low-Rent Housing Manual.

Projects may expand after initial development is completed. Consultations with the Local Authority in the early stages of design to determine whether additions to the project are contemplated will avoid placing pipe lines in the way of future buildings. Otherwise, it may be necessary to abandon lines before they reach the limit of usefulness; added costs would then be required to provide new means for distribution. If practicable, contemplated project enlargement should be reflected in pipe sizing.

2. PIPING AND CONDUITS

Factors which influence the selection of piping materials for domestic water services are discussed in Part X of this Bulletin. For space heating services, standard-weight black steel pipe is satisfactory, although it is important and necessary that the returns in steam systems be chemically treated to neutralize the gases in these lines; such treatment will retard the corrosion and increase an otherwise short life for the piping.

Concrete trenches, tunnels, and conduits are the methods used for enclosing underground piping.

A Federal Construction Council Report No. 30 (1958), titled "Underground Heat Distribution Systems," issued under the Building Research Advisory Board of the National Academy of Sciences and revised as No. 30-R (1959), includes criteria by which an underground conduit system can be selected, applied, installed, and economically maintained for maximum service life. A basic conclusion drawn by the committee (in which the PHA was represented) developing this Report was that systems fail principally as a result of water remaining in the conduit; the potential criterion, therefore, is the control of this water. This Report did not include walk-in tunnel applications, because their design features are significantly different from those applicable to conduit systems and there was no major disadvantage of tunnels other than cost. **All systems must be drainable and dryable in place.**

In basic substance, the Report eliminates mass-poured-insulation conduit systems and divides the acceptable systems into two classifications, namely, "Presealed Systems" and "Built-Up Methods." Grouped in the first classification are the cast-iron and steel conduits (finished with a protective coating or wrapping), which must be used where the ground water table is above the bottom of the conduit at any time; these are designated as Class A systems. Grouped in the second classification are the tile conduit and the concrete trench, which can be used only where the ground water table does not rise above the bottom of the conduit at any time; these are designated as Class B systems.

A soil survey must therefore be made prior to the design of the system, and, whenever practicable, is recommended to be done in coordination with the soil-boring tests. The procedure for the soil survey is outlined in the above Federal Construction Council Report (or its counterpart for private industry in the Building Research Institute Report), which can be obtained from the National Academy of Sciences, Washington 25, D.C. The laboratory tests for watertightness and for air-pressure tightness, as well as tests for pipe insulation, are also outlined in the Report.

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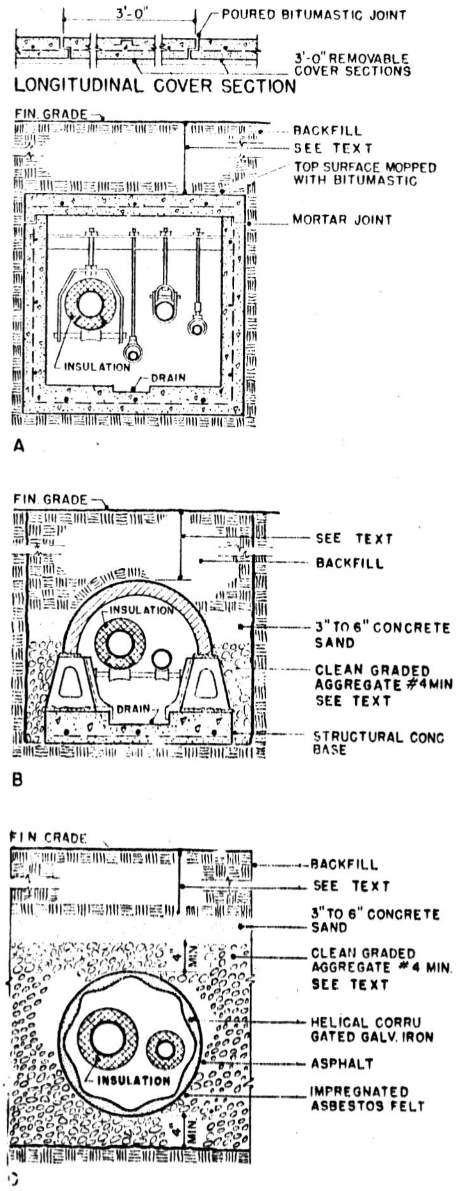

FIGURE 1 METHODS OF HOUSING UNDERGROUND LINES

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Where ferrous casing conduits are to be included in the project specifications, the soil survey should incorporate readings of soil resistivity (see Part V of this Bulletin) in ohms per cubic centimeter after final grading, to determine the need for cathodic protection. Where such survey indicates resistivity below 2,000 ohms per cubic centimeter, then a detailed investigation of cathodic protection should be undertaken.

Figure 1 illustrates methods of housing underground lines. Method A is the concrete trench system; B is the built-up conduit, assembled in the field; C is the type prefabricated or presealed at the factory.

Method A, the concrete trench, offers the advantage in that it can house a multiple system of piping, including domestic water heating lines. Piping may also be run along the side walls, but never in horizontal rows along the entire width of the trench; the latter arrangement makes repairs to the lower row or rows extremely difficult. Its rugged construction, plus its resistance to attack by surrounding corrosive or water-laden soils, places the concrete trench in a top classification for distribution systems. Another advantage which the trench possesses is its removable precast concrete cover, which permits entrance to the trench for repairs. Trench floors should have means for carrying away water.

Walk-in concrete tunnels, constructed essentially like the concrete trench system, except for their greater depth and width to permit traffic therein, are the most costly method for underground pipe enclosures and cannot be justified from the mechanical standpoint only. When it is found reasonable to provide tunnels as a passageway between multi-story buildings, the mechanical engineer can avail himself of this feature for the space heating and domestic water heating lines. Pipe is usually laid along the side walls on racks.

Method B (tile conduit) is satisfactory when buried not over 6 feet. The drain is integral with the structural concrete base on which the tile structure rests. In ground deeper than 6 feet, under streets and roadways or other places where ordinary vehicular traffic is anticipated, extra-weight tile is preferable. More than one pipe can be placed in the same conduit.

Method C (steel conduit), presealed at the factory except for conduit connector sleeves, which are finished in-place in the field, is formed into a cylinder with helical corrugations over which a coating of bituminous material and a tension-wrapped layer of saturated bituminous felt are applied. Smooth-wall coated cast-iron and steel conduits are also available; so are nonmetallic coated conduits. More than one pipe can be placed in the same conduit, but there must be room for draining and drying the conduit in place.

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Other types of patented conduits, built-up and presealed, may be available and could serve as well as those described herein, provided they are constructed within the scope of Federal Construction Council Reports 30R and 39, and Manual Section 207.1. Conduit structures should be selected on a basis of long life. However, sound initial economy should be considered along with a reasonable maintenance and replacement expense in making the selection.

Insulation, formed to fit the pipe, is applied to all lines except to return lines of steam systems when run together with supply lines in the same enclosure. Return lines run singly in conduits should, however, be insulated.

3. DISTRIBUTION AND EXPANSION

An underground distribution system may be elaborate or simple, depending on the method used in routing the lines. A well-organized site plan will permit direct pipe distribution from building to building, and will obviate the need for taking up expansion in costly concrete chambers in the "yard."

Expansion provisions in the "yard" should be the exception rather than the rule, because usually distances between buildings will be less than 100 feet and accordingly require means for about 1 to 1-1/2 inches expansion. Where distances between buildings are less than 200 feet and heating media temperatures are 250 degrees F. (equivalent to about 15 lbs. steam gauge pressure) or less, lines may be anchored in one building and allowed to expand in another. If the distance between buildings is in excess of 200 feet, it is good policy to anchor midway between buildings and provide for expansion in both buildings. Deviations from these design methods may be necessary where pipes are larger than 6 inches and where heating media temperatures are in excess of 250 degrees F.

The linear expansion of piping will depend upon the type of material, the outside temperature at which the pipe was laid, and the operating temperature of the heating medium. If it is anticipated that the pipe will be laid with outside temperatures of 32 degrees F. or more, 32 degrees should be used as the base temperature for design. The graph in Figure 2 has been plotted from available data and may be used as a guide in designing or selecting the expansion means.

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Swing or swivel joints can be used in space or domestic water heating systems within buildings. Made up of threaded pipe members with four elbows before the pipe is returned to its original direction, expansion is taken up by the straight members in such offsets and/or in the swivel of the threaded joints. These joints are inexpensive and can be made up easily in the field, but offer disadvantages in leaks and additional resistance to fluid flow. Welded members, in lieu of threaded, would at least overcome the disadvantage of leaks and could be utilized economically in piping 1-1/2 inches and larger; copper piping would have compression or soldering fittings.

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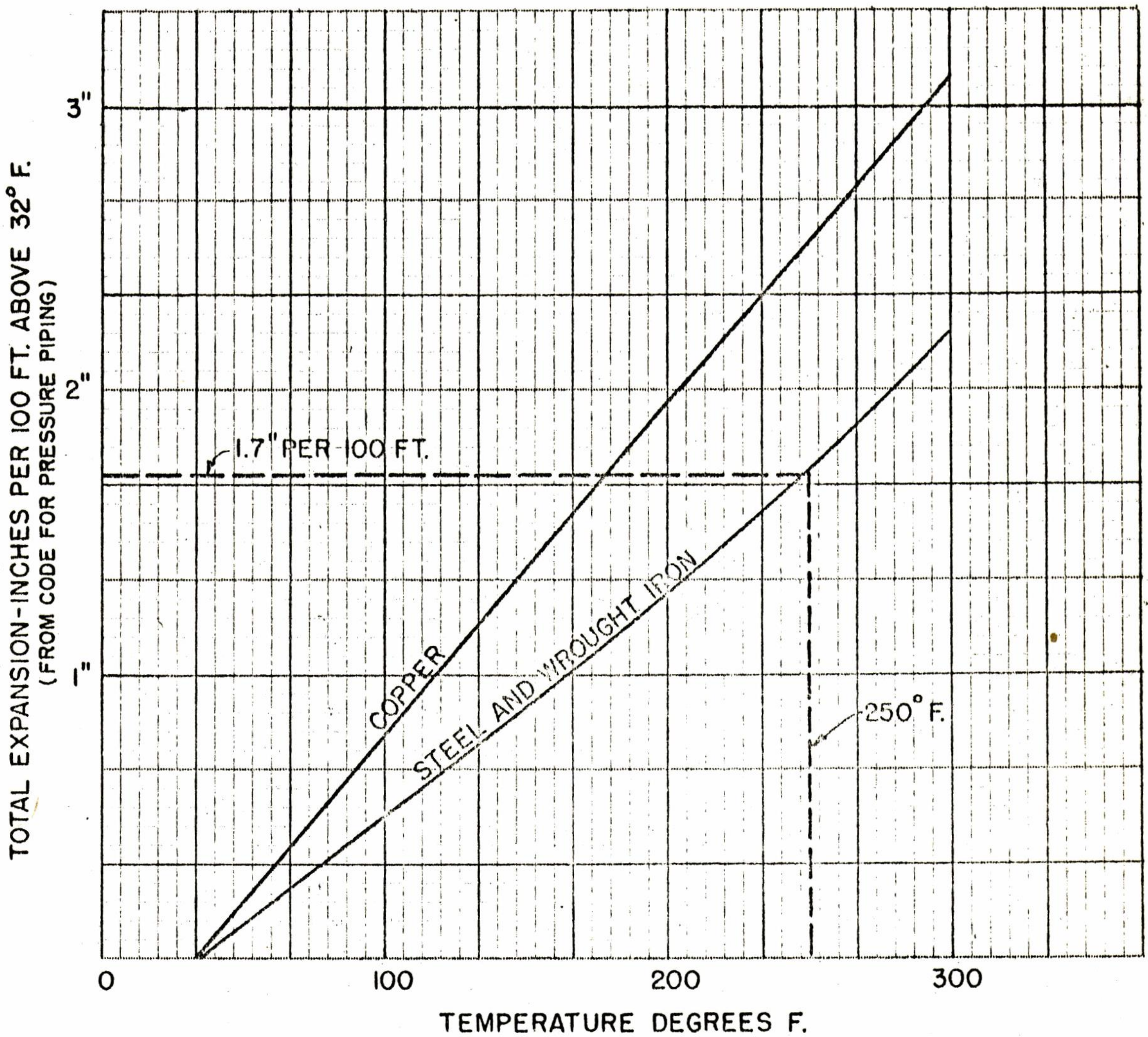

FIGURE 2

Mechanical joints are factory produced and are generally of the slip or packless types, the former type offering greater resistance to more rugged use. The slip type operates in the movement of a sleeve within a cylinder, the length of movement being termed the traverse; built of ferrous and/or brass materials, it depends upon packing, and stuffing glands for heating medium tightness. The packless type is built from copper, stainless steel, or other corrosion-resistant material, such as copper-nickel alloy, formed into a series of corrugations or bellows which control the traverse. The slip and the packless joints do not require the space needed for the swing joint or the pipe bend, but the mechanical joints do involve a maintenance and inspection problem. For this reason, such joints should be limited to installation in easily accessible places. Experience has indicated the need for two substantially constructed guides on each side of the joint to ensure pipe alignment, and the need for an internal sleeve in the packless type to prevent accumulations of sediment in the corrugations.

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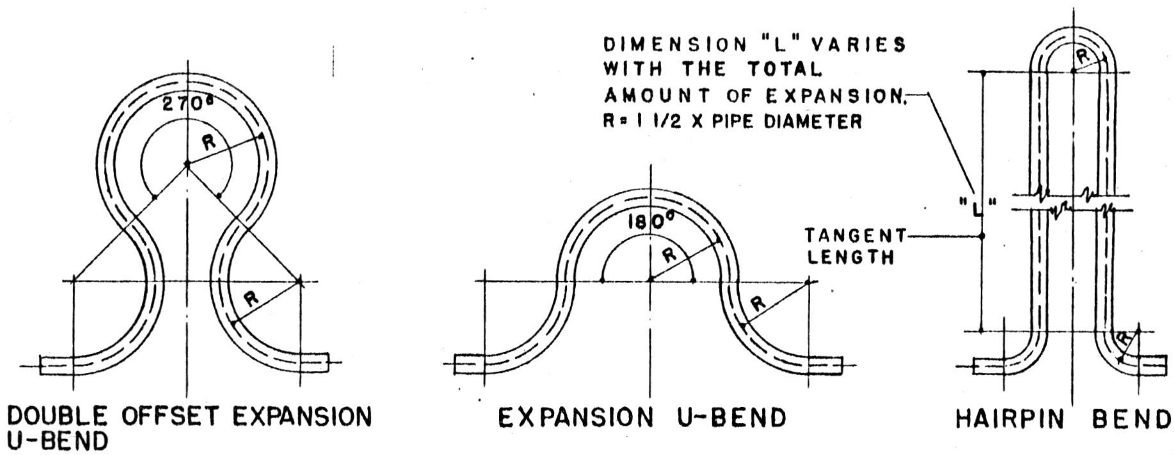

FIGURE 3 EXPANSION BENDS FOR STRAIGHT RUNS

Bends commonly used are the double-offset expansion "U" bend, expansion "U" bend and the "hairpin" bend for straight pipe runs, as illustrated in Figure 3, and the angular bends for directional changes in the piping. The physical properties of the pipe itself give the bend, when accurately designed and fabricated, the necessary flexibility to withstand the forces in pipe movement and to take up expansion. Pipe bends seem the most practicable when it is required to provide for expansion in the "yard" distribution, because of their flexing properties; the bend involves no maintenance problem, and it can be permanently housed in a concrete chamber where no removable cover or extension manhole is essential. Guiding on each side of bend is necessary for alignment with pipe movement and to prevent needless increase in thrust.

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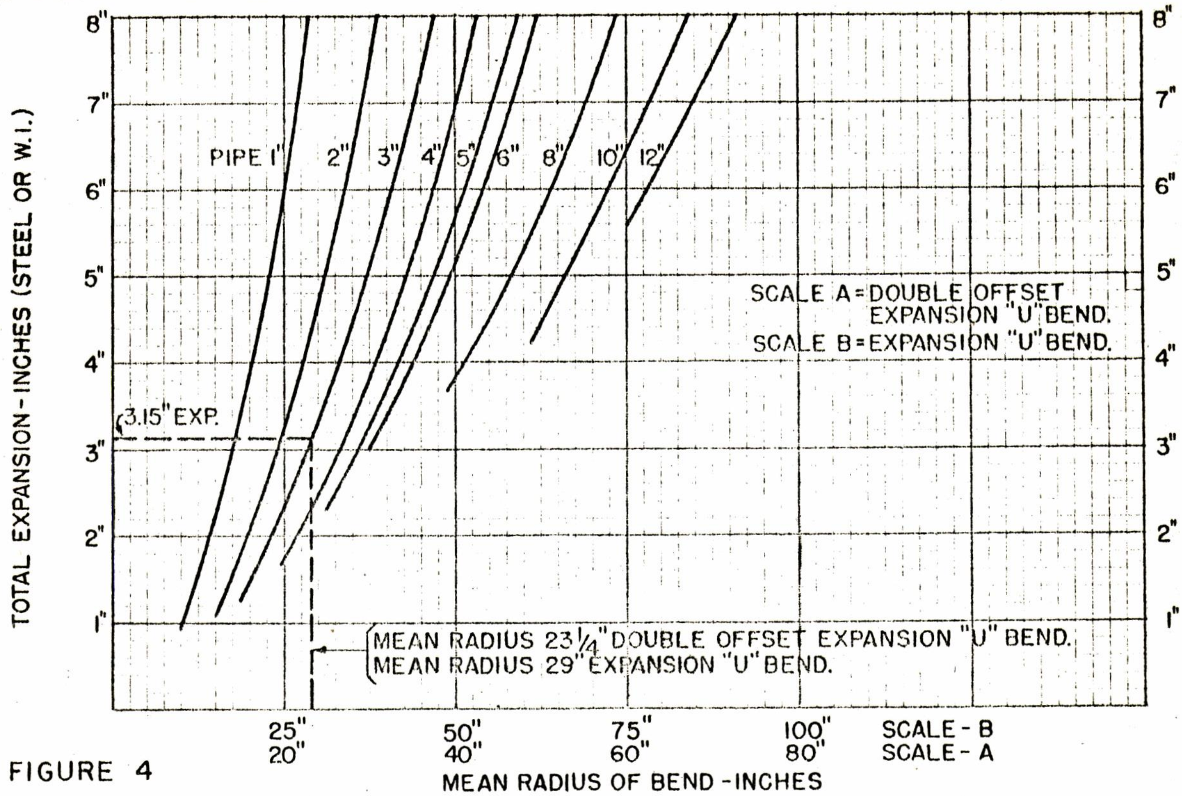

FIGURE 4

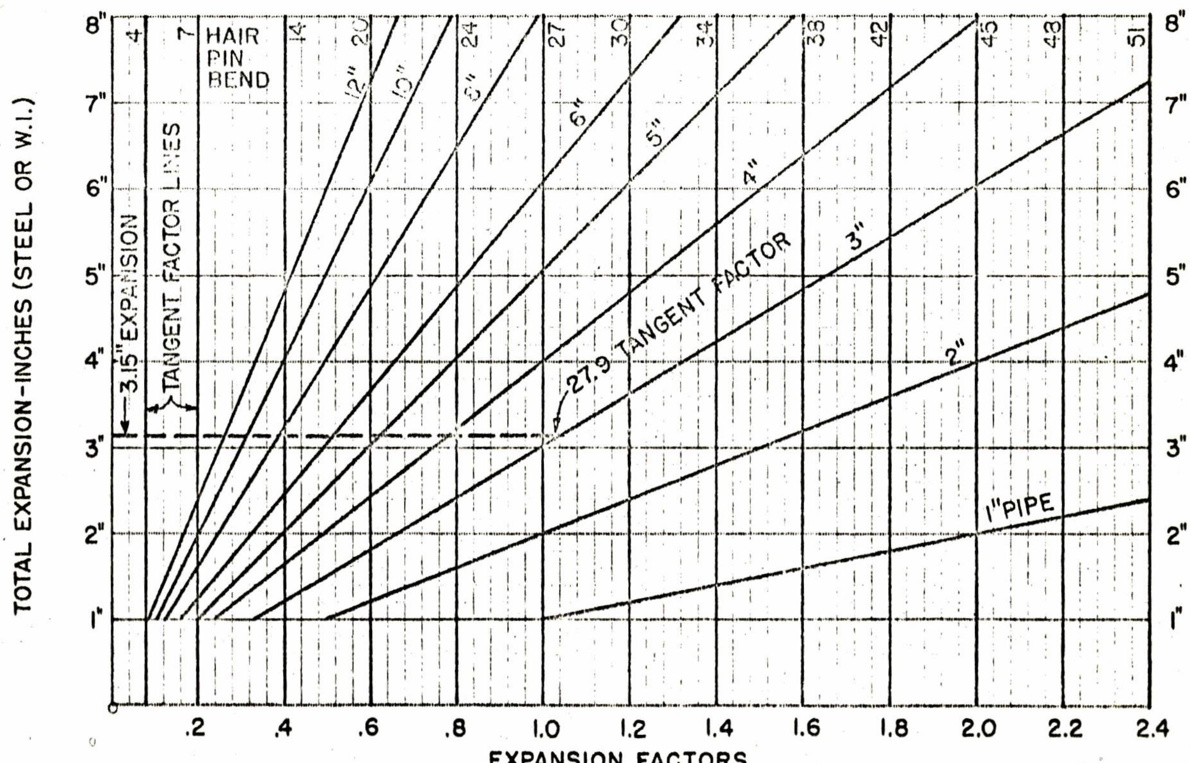

FIGURE 5

(Cont'd)

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The hairpin bend, economical to build and adequately suited to conditions under which distribution systems function in housing projects, should be used, as a general rule, where required net expansion is less than that shown at origin points of the various pipe size graphs in Figure 4 for the double offset and expansion "U" bends. Figure 5 shows the minimum tangent lengths in the bend composed of two 90-degree and one 180-degree welding elbows; radius of fittings need be only 1-1/2 pipe diameters; the information is for steel and wrought-iron pipe.

The graphs of the bends in Figures 4 and 5 have been sized on the basis of "effective" expansion, equal to 2/3 of the total calculated expansion, and on the basis that the bend will be "cold sprung" in place an amount equal to 1/2 the total calculated expansion. The following example will illustrate the procedure in selecting the proper bend:

Example: The distance between anchor points of a 3-inch steel steam pipe, sized to carry steam at 15 pounds per square inch gauge (250° F.), is 185 feet. Determine:

a. Total calculated expansion
b. Cold spring
c. Net expansion
d. Required mean radius of double offset expansion "U" bend, and expansion "U" bend, to absorb expansion
e. Required tangent lengths of hairpin bend to absorb expansion

Procedure: Refer to Figure 2. Locate 250° F. on the temperature scale; move upward to expansion graph for steel pipe and then horizontally to "expansion" scale, reading 1.7 inches per 100 feet.

	a. Total calculated expansion -	1.7 x 1.85 = 3.15"
	b. Cold spring -	1/2 x 3.15 = 1.57"
*	c_1. Allowable expansion reduction -	2/3 x 1.57 = 1.05"
	Net expansion -	3.15" - 1.05" = 2.10"
*	c_2. Maximum expansion credit allowed -	1/3 x 3.15" = 1.05"
	Net expansion -	3.15" - 1.05" = 2.10"

d. Refer to Figure 4. Locate 3.15" on the "total expansion" scale and move horizontally to the 3" pipe graph, then downward to the "radius of bend" scale, reading 23-1/4" for the radius of a double offset expansion "U" bend and 29" for the radius of an expansion "U" bend.

e. Refer to Figure 5. Locate 3.15" on the "total expansion" scale and move horizontally to the 3" pipe graph; read tangent factor at point of intersection, 27.9. Multiply 27.9 x 3 (the pipe size) which equals 83.7", the required tangent length. The horizontal "expansion factors" scale was used originally to determine the vertical "tangent factor" lines.

* c_1 and c_2 are alternate methods for figuring net expansion, which has already been considered in the plotting of the graphs (Figures 4 and 5).

(Cont'd)

4. ANCHORS

Just as it is important to design properly for expansion means, so is it important to establish that pipe movement take place generally between two anchors.

To serve their intended purpose, anchors should be fastened securely to the pipe and to a retaining structure such as a gusset plate bolted to the building wall (if anchorage is within building) or to a concrete block or concrete chamber construction (if anchorage is in the "yard"). If practicable, "yard" anchors should be set at points where branch connections are to be taken from main service lines. Anchors may range from the simple "U" bolt or clamp to the type fabricated from structural channels or angle irons.

5. CHAMBERS AND MANHOLES

Chambers for pipe bends (or pipe bends and anchors) can be economically constructed with reinforced concrete walls suited to meet local conditions, waterproofed and with reinforced slab covering.

A manhole is provided for entrance to the chamber as an integral extension of the chamber. The manhole, like the chamber, should be constructed of reinforced concrete, waterproofed, and should be approximately 25 inches square or, if round, 24 inches in diameter--either type extended to about 4 inches above grade and fitted with cast-iron frame and cover; earth backfill should be sloped away in all directions to prevent surface water entering. Manholes are needed where the chamber houses equipment such as mechanical expansion joints, valves, steam drip traps, and metering devices, and only when it is not feasible to locate such equipment within buildings. Two entrances to chambers, where manholes are required, are advisable; the second manhole, when opened, will add sufficient ventilation to permit comfortable conditions when making repairs.

The chamber should be designed on the basis of the least physical dimensions to suit the types of expansion device. For example, the area of a chamber required for an expansion "U" bend is greater than that to house a double offset type of bend with the same expansion capacity; the cost of the bend too should be weighed in the calculation.

Presealed-conduit manufacturers have means of allowing the pipe bend such as the hairpin type to be flexed within its own conduit structure. By this method, the concrete chamber, as such, is not needed.

6. DRAINAGE

The adequacy or inadequacy of a drainage method may well establish the difference between the success and the failure of an otherwise well-proportioned conduit distribution. While extra drains beyond that supplied and erected with the conduit are not necessary in sandy or dense clay soils,and of low

(Cont'd)

water table, the use of such devices should be warranted where there is a high water table and where impermeable soils invite excessive ground water. While PHA Guide Specifications do not indicate the use of gravel, it is good policy to have the ground water sieve through a layer of clean sand and through the interstices of a bed of gravel.

Provision for drainage to the storm-water system through a floor drain may be made where drain enters building or "yard" chamber. Drainage may be continued through a chamber where it is not feasible to provide sewer connections at these points, in which case the conduit should drain at the same level as the chamber floor. In any event, all low points of the system should be drained to a "positive" drainage source.

7. EXCAVATION AND BACKFILL

Conduit manufacturers' service details indicate the width of trench necessary for particular types of conduit. These details should also show the method of assembly and should be followed with extreme care; in fact, contract specifications should stipulate that patented conduit systems be installed under continuous supervision of the manufacturer's representative. The manufacturer could then assume a definite measure of responsibility.

Pipe enclosure should rest on firm bearing soil to avoid settlement. In some cases it may be necessary to include extra supporting methods such as piles; this is extremely important to prevent settlement, and consequent failure of the system.

Backfill too is pertinent to the success of a distribution system; boulders or other extraneous material deposited carelessly can break a tile conduit or otherwise deteriorate a metal conduit subject to corrosive elements present in unclean backfill. Clean earth, sand, fine gravel, borrow, or excavated material free of large stones, trash, lumber, cinders, or ashes make good backfill material. Amount of cover over the pipe enclosure depends on depth of frost line, site topography, and whether the enclosure is below a roadbed. Refer to the PHA Guide Specifications.

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PLUMBING, HEATING AND VENTILATION

PART XV - SIZING OF GAS PIPING IN BUILDINGS

1. INTRODUCTION

The use of gas-fired equipment and appliances has greatly increased in recent years, and this increase is continuing at an accelerating rate. One principal reason for this trend is the growing availability of gas, due to cross-country natural gas pipe lines serving a greater number of communities.

When gas is selected as a fuel, it is essential that the gas distribution piping leading to the equipment and appliances be properly sized and correctly installed. Excessively large piping unduly increases the initial cost, while undersized piping restricts the selection of the proper equipment and appliances or adversely affects their operation by causing large pressure fluctuations at the appliances under changing load conditions. With modern gas-burning devices, pressure fluctuations in the supply line, which cause variations in the flow of gas, must be kept to a minimum to prevent flame failure of pilot burners and poor service of the main burners. Gas companies have stated that many of the service complaints they receive are caused solely by undersized gas piping.

Correct methods of installation are extremely important to prevent disastrous accidents. Adherence to the installation methods outlined in Part V of this Bulletin, "Safety Considerations in the Installation of Gas Piping," is emphatically recommended.

2. FACTORS AFFECTING GAS PIPE SIZING

The physical laws governing the flow of gas in piping involve the following factors, which influence the determination of correct pipe sizes:

a. The required flow of gas through the piping
b. The specific gravity of the gas
c. The allowable loss in pressure from the service entrance to the equipment or appliance.
d. The developed length of the piping.

The required gas flow is estimated from the maximum Btu demand of the appliances and equipment, the heat content of the gas used, and the diversity factor derived from the number and type of the connected appliances. The specific gravity of the gas will depend on the nature of the gas supplied by the utility. The allowable pressure drop in the system depends on the available gas pressure at the service entrance, the losses or gains in pressure due to differences in elevation between the service entrance and the appliances, and the gas pressure required at the appliances. The developed length of the piping depends on the relative locations of the service entrance and the appliances.

a. Required Gas Flow. The commonly used household appliances have hourly Btu inputs as follows:

Four-burner domestic range	62,500
Refrigerator	
Capacity 4 cubic feet	1,900
6 cubic feet	2,350 to 2,450
8 cubic feet	2,800
Domestic water heater	
Nominal tank size 20 gallon	20,000 minimum
30 gallon	24,000 minimum
40 gallon	30,000 minimum

For exact determination of the Btu inputs of these types of appliances (as well as for space heaters, furnaces, or boilers) reference should be made to the manufacturers' catalogs or to the listings in the "Directory of Approved Gas Appliances and Listed Accessories" 1/ published by the American Gas Association.

The volume of gas that will supply any specified quantity of heat is determined by the heating value of the gas expressed in Btu per cubic foot. The heating value of gases, determined at a standard temperature of 60°F and under a standard pressure of 30 inches of mercury, is between 400 and 600 Btu per cubic foot for manufactured gas; between 900 and 1200 Btu per cubic foot for natural gas; and between 2500 and 3270 Btu per cubic foot for liquefied petroleum gas. The exact heating value for a particular gas being supplied to a locality is obtainable from the gas utility company.

When determining the peak demand for a single gas appliance, it is sufficient to divide the hourly Btu input of the appliance by the heating value of the gas, to get the required flow in cubic feet per hour. However, when more than one household appliance is being served by a gas distribution system, the fact that all the appliances will rarely be operating simultaneously (the diversity factor) influences the determination of the total peak demand of the group of appliances. By means of Figure 1 the peak-hour demand in therms (100,000 Btu) or in thousands of cubic feet can be estimated for groups of dwelling units when such dwellings contain gas ranges, refrigerators, water heaters, or combinations of such appliances.

All tenant-operated space heating equipment (furnaces, boilers, and space heaters) installed in a project will usually operate simultaneously during cold weather; and when only a few such appliances are connected, the total peak demand should be taken as the sum of the inputs to all such equipment. For larger numbers of dwelling units, however, the peak cooking demand would not normally occur simultaneously with the peak space heating demand, so that

1/ Available from the American Gas Association Testing Laboratories, 1032 East 62nd Street, Cleveland 14, Ohio, or 1425 Grande Vista Avenue, Los Angeles 23, California.

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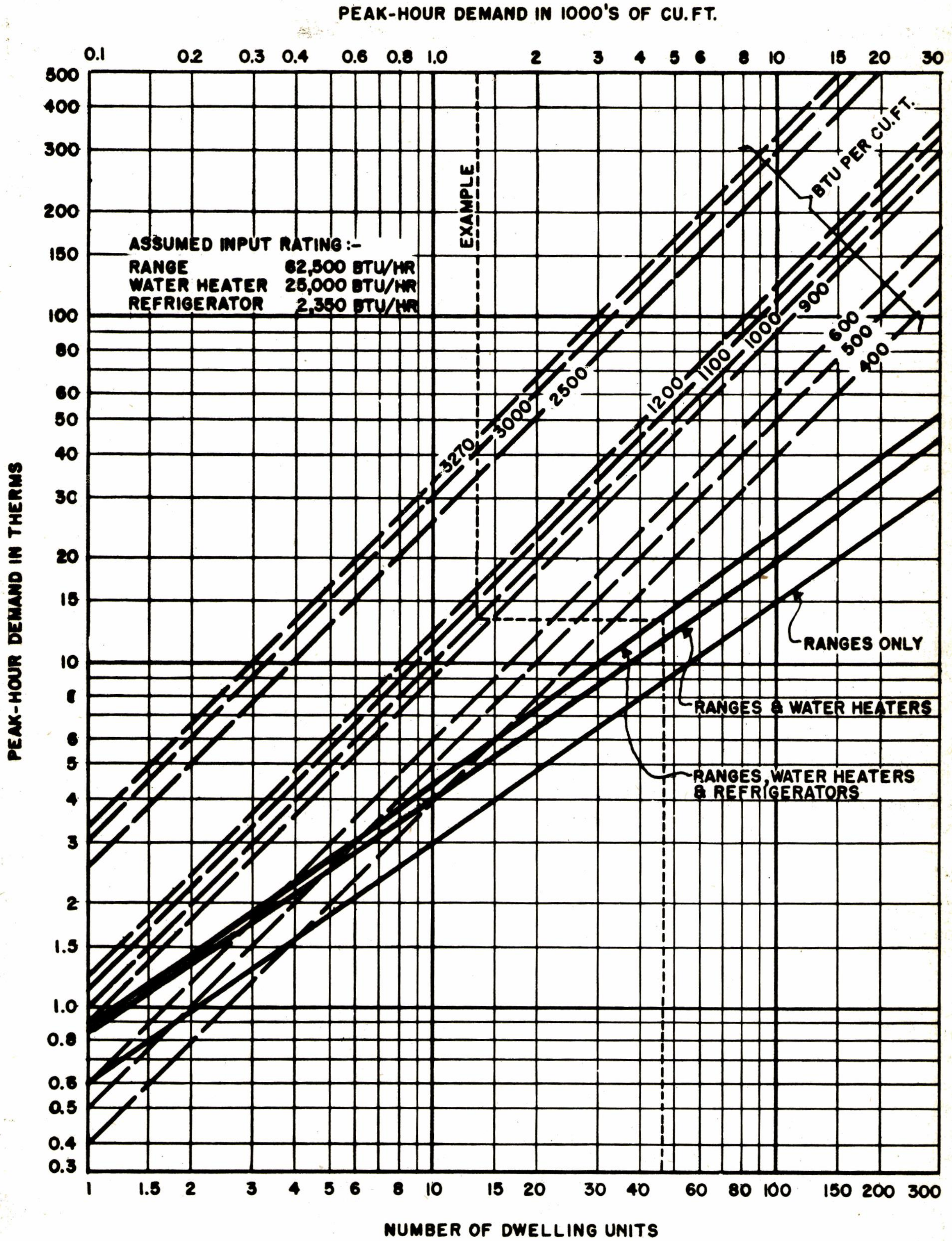

FIGURE 1 PEAK-HOUR GAS DEMAND FOR COOKING, WATER HEATING AND REFRIGERATION

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the combined peak demand for projects with both gas-fired household appliances, and gas-fired space heating equipment should be the values taken from Figure 1, plus the total input ratings of all the connected space heating equipment multiplied by the following factors.

Number of Dwelling Units	Factors for Total Input Ratings of Space Heating Equipment
1	1.00
10	.90
100	.85
1000	.80

Figure 1 shows an example of this procedure for 48 dwelling units using gas-fired ranges, water heaters and refrigerators. The peak-hour demand is shown to be 13 therms, or for gas with a heating value of 1000 Btu per cubic foot, it is 1300 cubic feet. If each dwelling is furnished with a space heater and the total hourly input of all the space heaters is 19.2 therms, the reduction factor should be about .88 and the demand estimate for the space heaters would be 19.2 x .88 = 17 therms. The combined peak hour demand is then 13 + 17 = 30 therms, or 3000 cubic feet of this gas.

b. The specific gravity of gas is the ratio of its weight to the weight of an equal volume of air. Manufactured gas has a specific gravity between 0.40 and 0.70; natural gas between 0.55 and 0.85; liquefied petroleum gas between 1.50 and 2.00. As with the heating value, the specific gravity of the gas to be used in a particular project should be obtained from the local gas supplier.

The flow of gas through piping and gas equipment varies as the square root of the specific gravity of the gas. Capacity ratings of meters, regulators, and similar items are usually based on gas with a specific gravity of 0.60; if the capacity rating at any other specific gravity is desired, the rating at a specific gravity of 0.60 should be multiplied by $\sqrt{\frac{0.60}{\text{Sp.Gr.}}}$ where the denominator of this term is the actual specific gravity of the gas. This factor has been determined in Table 1 for various specific gravity values.

c. The allowable pressure drop is the gas pressure at the service entrance of the building less the minimum pressure required by the gas appliances for their proper operation (2.3 inches of water for appliances using manufactured gas, 4.6 inches of water for natural gas, and 11 inches for liquefied petroleum gas). The service entrance pressure is the street main pressure less the pressure drop through the exterior piping, meters and regulators; its value should be obtainable from the site engineer. From that allowable pressure drop should be deducted the pressure drop through the check meter (about 0.5 inches of water), and the remainder would be the allowable pressure drop through the building piping. Service entrance pressures are usually designed to permit an allowable pressure drop through the building piping of about 0.3 inches of water.

TABLE 1

Specific Gravity Factors
based on a value of 0.60

Specific gravity of the gas	Factor to be applied to capacity ratings
0.40	1.22
0.45	1.15
0.50	1.09
0.55	1.04
0.60	1.00
0.65	0.96
0.70	0.93
0.75	0.90
0.80	0.87
0.85	0.84
1.00	0.78
1.50	0.63
2.00	0.55

When the gas is lighter than air, its pressure will increase when the gas is flowing upward and decrease when the flow is downward; when heavier than air (as is the case with liquefied petroleum gas) the reverse is true. This change in pressure is usually small, but when it is significant it should be added to (or deducted from) the allowable pressure drop through the building piping, and the total value used in the pipe size evaluations.

Table 2, shows an estimation of the change in pressure for gas flowing through vertical piping.

TABLE 2

Change of Gas Pressure with Vertical Distance (at Sea Level)

Specific gravity of the gas	Pressure change in inches of water per 10 feet of vertical distance
0.40	0.089
0.45	0.081
0.50	0.074
0.55	0.066
0.60	0.059
0.65	0.052
0.70	0.044
0.75	0.037
0.80	0.029
0.85	0.022
1.00	0.000
1.50	0.074
2.00	0.149

d. Developed Length of Piping. The sizes of gas piping in the building should be chosen so that the total resistance to flow through the pipe, fittings, and valves in the building is not greater than the allowable pressure drop through the piping. The resistance to flow is a function of the developed length of the piping, that is, the sum of the actual length of the pipe in any particular run plus an allowance for the fittings and valves in that run. The allowance for valves and fittings is expressed as the equivalent length of straight pipe that has the same resistance to flow as the valve or fitting. These equivalent lengths for any particular run of piping could be estimated on a lump sum basis, or can be determined more accurately by means of Table 3.

TABLE 3

Equivalent Length of Pipe in Feet for Valves and Fittings

Size of valve or fitting (inches)	Standard elbow or tee	Globe valve
3/4	1.3	2.0
1	1.7	2.6
1-1/4	2.6	3.9
1-1/2	3.3	5.0
2	5.1	7.7
2-1/2	6.7	10.1
3	9.3	14.0
4	14.0	21.0

3. PROCEDURE FOR PIPE SIZING

The quantity of gas flowing through piping can be computed by means of the Spitzglass formula for "end-to-end" flow. For gage pressures not exceeding 1 pound per square inch the formula is

$$Q = 3550\,K\left(\frac{h}{SL}\right)^{1/2}$$

Where Q is the flow of gas in cubic feet per hour

K is equal to $\left(\dfrac{D^5}{1 + \frac{3.6}{D} + 0.03D}\right)^{1/2}$ where D is the actual pipe diameter in inches

h is the pressure drop in inches of water column
S is the specific gravity of the gas
L is the developed length of the piping in feet

The evaluation of this equation for standard weight steel pipe ranging in size from 3/4 inch to 4 inches is presented in Table 4 for gas with a specific gravity of 0.60. For gas of differing specific gravity the estimated required flow should be divided by the appropriate factor listed in Table 1 and the revised flow used in connection with Table 4. When sizing the pipe for liquefied petroleum gas installations where there is any possibility that natural gas will be substituted for the liquefied petroleum gas during the life of the project, it is advisable to make the initial pipe design on a natural gas basis.

Table 4 should be used in sizing all parts of the piping system except the supply pipes that connect directly to each appliance or piece of equipment. These supplies should be not less than the size of the inlet on the appliance or equipment, usually 3/4 inch for ranges, 1/2 inch for refrigerators, and 1/2 inch for water heaters. The pipe sizing procedure can be summarized as follows:

a. The required gas flow, in cubic feet per hour, in each section of the piping should be determined from Figure 1, taking into consideration the heating value of the gas, the size of the appliances, and whether there is any connected space heating equipment.

b. The specific gravity factor for the gas to be used should be determined from Table 1, and the equivalent flow for a gas with a specific gravity of 0.60 determined by dividing the actual gas flow by the specific gravity factor.

c. The allowable loss in pressure in the piping should be determined by deducting the required outlet pressure and the pressure drop through the check meter from the service entrance pressure, and then adjusting for the total change in elevation between the service entrance and the appliance, using the values given in Table 2.

d. The developed length of the longest run in the piping should be determined by adding to the actual length of the pipe from the service entrance to the farthest appliance the equivalent length of all the fittings and valves, using a lump sum or a computed value derived from Table 3 and based on assumed pipe sizes.

e. Table 4. Enter Table 4 at the left hand column for the Developed Length of Pipe at the value in the table closest to the developed length; follow horizontally to the right till a value of the pressure drop is reached that is just less than the allowable pressure drop; drop vertically to the lower part of the table to the first flow figure that is just larger than the required flow when using 0.60 specific gravity gas; and move horizontally to the left to read the pipe size directly in the lower left hand column.

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TABLE 4

Sizing of Pipe for Gas with 0.60 Specific Gravity

Developed Length of Pipe, Feet	Total Pressure Drop, Inches of Water																
10	—	—	—	—	—	—	—	0.06	0.08	0.10	0.15	0.20	0.30	0.40	0.60	0.80	1.00
15	—	—	—	—	—	—	0.06	0.09	0.12	0.15	0.22	0.30	0.45	0.60	0.90	1.20	1.50
20	—	—	—	—	—	0.06	0.08	0.12	0.16	0.20	0.30	0.40	0.60	0.80	1.20	1.60	2.00
30	—	—	—	—	0.06	0.09	0.12	0.18	0.24	0.30	0.45	0.60	0.90	1.20	1.80	2.40	3.00
40	—	—	—	0.06	0.08	0.12	0.16	0.24	0.32	0.40	0.60	0.80	1.20	1.60	2.40	3.20	
60	—	—	0.06	0.09	0.12	0.18	0.24	0.36	0.48	0.60	0.90	1.20	1.80	2.40	3.60		
80	—	—	0.08	0.12	0.16	0.24	0.32	0.48	0.64	0.80	1.20	1.60	2.40	3.20			
100	0.06	0.08	0.10	0.15	0.20	0.30	0.40	0.60	0.80	1.00	1.50	2.00	3.00				
150	0.09	0.12	0.15	0.22	0.30	0.45	0.60	0.90	1.20	1.50	2.25	3.00					
200	0.12	0.16	0.20	0.30	0.40	0.60	0.80	1.20	1.60	2.00	3.00						
Size of Pipe, Inches	**Flow, Cubic Feet per Hour**																
3/4	33	38	43	53	61	75	86	105	122	136	167	193	236	273	334	386	431
1	67	77	87	106	123	150	173	212	245	274	336	388	475	548	672	776	868
1-1/4	131	152	170	208	240	294	339	415	479	537	657	759	930	1070	1315	1515	1700
1-1/2	204	235	263	322	372	455	526	644	744	832	1020	1175	1440	1660	2040	2350	2630
2	412	475	532	651	752	921	1060	1300	1505	1680	2060	2375	2910	3360	4120	4755	5320
2-1/2	676	780	872	1070	1235	1510	1745	2135	2465	2760	3380	3900	4775	5520	6760	7805	8720
3	1230	1420	1590	1945	2245	2750	3175	3890	4490	5020	6150	7100	8695	10040	12300	14200	15880
4	2570	2970	3320	4065	4695	5750	6640	8130	9390	10500	12860	14850	18190	21000	25700	29700	33200

4. **EXAMPLE OF PIPE SIZING**

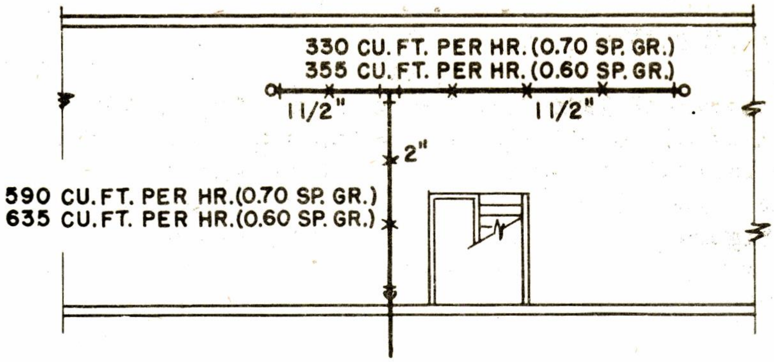
Figure 2 shows a typical layout for sizing the gas pipe in a three-story building containing six dwelling units each supplied with a gas-fired four-burner range, 6 cubic foot refrigerator, 30 gallon water heater and 40,000 Btu space heater. The peak-hour demand for the six dwelling units would be 3 therms (from Figure 1) for the ranges, refrigerators, and water heaters, plus 6 x 40,000 x 0.945 = 226,800 Btu or 2.3 therms for the space heaters, making a total peak-hour demand of 3 + 2.3 = 5.3 therms. If the gas has a heating value of 900 Btu per cubic foot, the required flow at the service entrance is 5.3 x 100,000 ÷ 900 = 590 cubic feet per hour. Similarly the required flow into each riser would be [180,000 + (3 x 40,000 x 0.978)] ÷ 900 = 330 cubic feet per hour, and in the upper sections of each riser it would be the values shown in Figure 2 which are determined in a similar manner.

If the specific gravity of the gas is 0.70, the specific gravity factor (from Table 1) is 0.93. Therefore, the equivalent hourly flow for a gas with a specific gravity of 0.60 would be 590 ÷ 0.93 = 635 cubic feet at the service entrance, 330 ÷ 0.93 = 355 cubic feet at the base of each riser, and similarly for the upper sections of each riser.

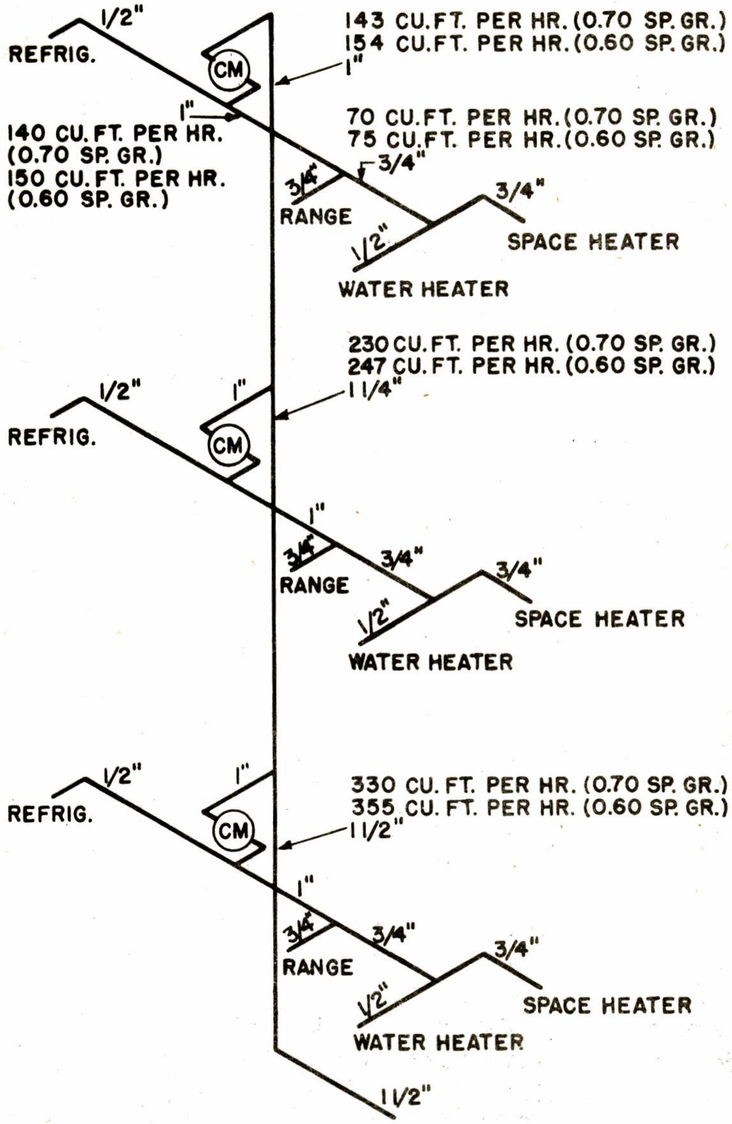
If the gas pressure at the service entrance is given as 5.3 inches of water, the minimum pressure required at the appliances is 4.6 inches, the pressure loss through the check meter is 0.5 inches, and the third floor appliances are 30 feet above the service entrance, then the allowable pressure drop in the piping should be 5.3 - 4.6 - 0.5 + (3 x 0.044) = 0.33 inches where the factor for the last term is taken from Table 2.

The actual length of pipe from the service entrance to the topmost appliance is 60 feet with 14 fittings (tees and elbows) and one shut-off valve in this length. If 3 of the fittings are assumed to be 2 inches in size, 2 fittings are 1-1/2 inch size, 1 fitting is 1-1/4 inch, 5 fittings are 1 inch, and 3 fittings and the shut-off valve are 3/4 inch, the equivalent length of these fittings and valves would be (using Table 3): (3 x 5.1) + (2 x 3.3) + (1 x 2.6) + (5 x 1.7) + (3 x 1.3) + (1 x 2.0) = 38.9 or 39 feet. The developed length to the topmost appliance is 60 + 39 = 99 feet.

Since the developed length to the topmost appliance is 99 feet, the nearest greater length in Table 4 would be 100 feet. Extending horizontally in the table from 100 feet to a value of the pressure drop (0.30 inches) that is the next smallest value to that required (0.33 inches), dropping vertically to an hourly flow value (921 cubic feet) that is the next larger value to the flow required for gas with 0.60 specific gravity (635 cubic feet), and then extending horizontally back to the column on the left gives a required pipe size of 2 inches at the service entrance. Using the same vertical column and the hourly flow in the table (455 cubic feet) that is the next larger flow with 0.60 specific gravity than that required at the base of each riser (355 cubic feet), the pipe size indicated is 1-1/2 inches; and on the same basis the remainder of the riser and the runouts to the appliances are of the sizes shown.



PART BASEMENT PLAN OF TYPICAL BUILDING



TYPICAL RISER DIAGRAM

NOTE :-

IN EACH DWELLING :
- 4-BURNER RANGE
- 6 CU. FT. REFRIGERATOR
- 30 GALLON WATER HEATER
- 40,000 BTU SPACE HEATER

GAS HAS :
- HEATING VALUE OF 900 BTU PER CUBIC FOOT.
- SPECIFIC GRAVITY OF 0.70
- SPECIFIC GRAVITY FACTORS 0.93 FOR CAPACITY, 0.044 FOR HEIGHT

AVAILABLE PRESSURE AT THE BUILDING WALL :
5.3 INCHES OF WATER COLUMN

MINIMUM REQUIRED PRESSURE AT APPLIANCES :
4.6 INCHES OF WATER COLUMN

PRESSURE LOSS THROUGH CHECK METER :
0.5 INCHES OF WATER COLUMN

HEIGHT OF HIGHEST APPLIANCE ABOVE THE SERVICE ENTRANCE:
30 FEET

ALLOWABLE PRESSURE DROP IN PIPE :
5.3 - 4.6 - 0.5 + 0.044 X 3.0 = 0.33 INCHES

DEVELOPED LENGTH FROM SERVICE ENTRANCE TO HIGHEST FIXTURE :
99 FEET

FIGURE 2 SIZING GAS PIPING IN A TYPICAL THREE STORY BUILDING

It should be noted that the assumed pipe sizes used in computing the equivalent length of the valves and fittings are not strictly accurate, but it is obvious that the results of a re-computation of the developed length would not affect the pipe sizes and is, therefore, unnecessary.

PLUMBING, HEATING, AND VENTILATION

PART XV - SIZING OF GAS PIPING IN BUILDINGS

1. INTRODUCTION

When gas fired equipment and appliances are used, it is essential that the gas distribution piping leading to the equipment and appliances be properly sized and correctly installed. Excessively large piping unduly increases the initial cost, while undersized piping restricts the selection of the proper equipment and appliances or adversely affects their operation by causing large pressure fluctuations at the appliances under changing load conditions. With modern gas-burning devices, pressure fluctuations in the supply line, which cause variations in the flow of gas, must be kept to a minimum to prevent flame failure of pilot burners and poor service of the main burners.

The use of gas is so commonplace and the pipe work for this fuel so simple there is some tendency to ignore inherent dangers of leakage and explosions in faulty design and installations. Asphyxiation and disastrous gas explosions frequently are recorded in the press.

Correct methods of installation are extremely important to prevent disastrous accidents. Adherence to the installation methods outlined in Part V of this Bulletin, "Safety Considerations in the Installation of Gas Piping," is emphatically recommended.

2. FACTORS AFFECTING GAS PIPE SIZING

Gas piping should be properly sized and installed as to provide a supply of gas sufficient to meet the maximum demand without undue loss between the meter, or service regulator when a meter is not provided, and the appliances. The size of gas piping depends upon the following factors:

a. Allowable loss in pressure from meter, or service regulator when a meter is not provided, to appliances.

b. Maximum gas consumption to be provided.

c. Length of piping and number of fittings.

d. Specific gravity of the gas.

e. Diversity factor.

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NOTE: This Part supersedes Part XV of Bulletin No. LR-7 dated 9-13-50. It has been revised to bring the material up to date.

The required gas consumption is estimated from the maximum Btu demand of the appliances and equipment, the heat content of the gas used, and the diversity factor derived from the number and type of the connected appliances. The specific gravity of the gas will depend on the nature of the gas supplied by the utility. The allowable pressure drop in the system depends on the available gas pressure at the service entrance, the losses or gains in pressure due to differences in elevation between the services entrance and the appliances, and the gas pressure required at the appliances. The developed length of the piping depends on the relative locations of the service entrance and the appliances.

a. Required Gas Consumption. The commonly used household appliances have hourly Btu inputs as follows:

Four-burner domestic range		65,000
Domestic water heater		
Nominal tank size	30 gallon	24,000 minimum
	40 gallon	33,000 minimum
	50 gallon	35,000 minimum

For exact determination of the Btu inputs of these types of appliances (as well as for space heaters, furnaces, boilers, refrigerators, clothes dryers, high input type water heaters, and other equipment or appliances) reference should be made to the manufacturers' catalogs or to the listings in the "Directory of Approved Gas Appliances and Listed Accessories" 1/, published by the American Gas Association.

The volume of gas that will supply any specified quantity of heat is determined by the heating value of the gas expressed in Btu per cubic foot. The exact heating value for a particular gas being supplied to a locality is obtainable from the gas utility company.

When determining the peak demand for a single gas appliance, it is sufficient to divide the hourly Btu input of the appliance by the heating value of the gas, to get the required flow in cubic feet per hour. However, when more than one household appliance is being served by a gas distribution system, the fact that all appliances will rarely be operating simultaneously (the diversity factor) influences the determination of the total peak demand of the group of

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1/ Available from the American Gas Association, Inc., Laboratories, 1032 East 62nd Street, Cleveland, Ohio 44103, or 1425 Grande Vista Avenue, Los Angeles, California 90023 appliances. The peak-hour demand in therms (100,000 Btu) can be estimated, for groups of dwelling units containing gas ranges and water heaters or combination of both appliances, by consulting the table titled Peak Hour Loads contained in Part II of PHA Bulletin No. LR-11, paragraph 4. - Gas Requirements.

All tenant-operated space heating equipment (furnaces, boilers, and space heaters) installed in a project will usually operate simultaneously during cold weather; and when only a few such appliances are connected, the total peak demand should be taken as the sum of the inputs to all such equipment. For larger numbers of dwelling units, however, the peak cooking demand would not normally occur simultaneously with the peak space heating demand, so that the combined peak demand for projects with both gas-fired household appliances and gas-fired space heating should be the values of the appliances, referred to in the previous paragraph, plus 90% of the specified input of all connected heating appliances.

3. GAS PIPING SIZING

The size of gas piping in a building can best be determined by consulting the hereinafter mentioned tables that are set forth in Part II of the ASA Handbook Z 21.30 titled "Installation of Gas Appliances and Gas Piping" 1/.

Capacities in cubic feet per hour of 0.60 specific gravity gas for different sizes and lengths are shown in Tables 2A and 2B for iron pipe or equivalent pipe and in Table 2C for semirigid tubing. Tables 2A and 2C are based upon a pressure drop of 0.3 inch water column, whereas Table 2B is based upon a pressure drop of 0.5 inch water column. In using these tables no additional allowance is necessary for an ordinary number of fittings. The serving gas supplier shall designate which table(s) should be used.

Capacities in thousands of Btu per hour of undiluted liquefied petroleum gases based on a pressure drop of 0.5 inch water column for different sizes and lengths are shown in Table 4A for iron pipe of equivalent rigid pipe and in Table 4B for semirigid tubing. In using these tables no additional allowance is necessary for an ordinary number of fittings.

The specific gravity of gas is the ratio of its weight to the weight of an equal volume of air. Manufactured gas has a specific gravity between 0.40 and 0.70; natural gas between 0.55 and 0.85; liquefied petroleum gas between 1.50 and 2.00. As with the heating value, the specific gravity of the gas to be used in a particular project should be obtained from the local gas supplier.

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1/ Available from the American Gas Association, Inc., 605 Third Avenue, New York, N.Y. 10016.

Gas piping systems that are to be supplied with gas of a specific gravity of 0.70 or less can be sized directly from Tables 2A, 2B, and 2C unless the local gas supplier specifies that a gravity factor be applied. When the specific gravity of the gas is greater than 0.70 the gravity factor should be applied. Application of the gravity factor converts the figures given in the above tables to the capacities with another gas of different specific gravity. This is accomplished by multiplying the capacities in the above tables by the multipliers shown in Table 3. If the exact specific gravity does not appear in Table 3, choose the next higher value specific gravity shown.

The procedure to size each section of gas piping in a system within range of the above mentioned Tables 2A, 2B, 2C, 4A, or 4B can be determined by consulting paragraph 2.4.3(d) set forth in Part II of the ASA Handbook Z 21.30.

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PLUMBING, HEATING AND VENTILATION

PART XVI - FLOOR LINE, PERIMETER, AND PANEL HEATING

1. INTRODUCTION

Many new methods of space heating have been advocated and promoted during the past few years, and while not all of them appear to be applicable to low-rent public housing, a few are likely to present such advantages of cost or comfort over the conventional heating systems as to be worthy of consideration in some low-rent housing projects. Two of these methods, floor line heating and panel heating, are now the subject of research investigations under the sponsorship of the Housing and Home Finance Agency, and the resulting information will be issued after the investigations have been completed. The third method, perimeter heating, has been under study by the National Warm Air Heating and Air Conditioning Association, and recommended design and installation practices are contained in their Manual No. 4, "Warm Air Perimeter Heating." 1/ The information presented here relative to these three heating methods is not to be construed as a design procedure or complete coverage of the subject, but is intended only to outline some of the factors that should be taken into account when the possibility of using one of these systems is under consideration.

IMPORTANT NOTE. This discussion recognizes three relatively recent developments in heating systems. It presents their probable advantages and, particularly, their inherent disadvantages, including lack of adequate design data and long-range experience and (usually) unfavorable cost differentials. While it may be that, in certain localities, a favorable combination of cost and climatic conditions may make the use of one or the other of these systems economical and feasible, it is believed that such use, in most cases, will be difficult to justify for low-rent public housing at this time.

2. FLOOR LINE HEATING

A floor line heating system is similar in a broad sense to the conventional steam or forced hot water system, the greatest difference being that instead of radiators of the conventional type, lengths of metal radiator or convector elements are located at the floor line in place of the normal baseboard. Such heating elements, called baseboard units, extend along the exterior walls of each room of the dwelling, and are usually connected in series so that a single pair of risers may serve the entire dwelling. To control the flow of the heating medium through the units, a shut-off valve should be installed in the runout between the supply riser and the first baseboard unit, and a

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1/ Available from the National Warm Air Heating and Air Conditioning Association, 145 Public Square, Cleveland 14, Ohio. Price 60 cents.

balancing device should be placed in an appropriate location to regulate the heating distribution to each dwelling. In addition, a hand-operated damper or bypass valve should be included in the baseboard unit in each room to control the heat output from the unit.

The piping between the separate baseboard units in a dwelling must drop beneath the floor when it crosses doors or similar openings located between the units. If steam is the heating medium, drip traps will be required at such low points, and the expense required for their installation suggests that floor line heating systems are better adapted for use with forced hot water rather than steam; this point, however, should be analyzed if both systems are under consideration.

The advantages of the floor line system over a conventional steam or forced hot water installation are believed to be as follows:

a. Lower piping cost, since only one pair of risers is usually required for each dwelling.

b. Increased comfort, since the temperature gradient between the floor and ceiling should be less than with conventional systems.

c. Improved room appearance, since the baseboard units are not noticeable, and require little, if any, extra room space.

Conversely, the disadvantages of the floor line system would be:

a. Difficulties in bathrooms and kitchens, because the short lengths of unobstructed wall make difficult the insertion of a baseboard unit long enough to heat these rooms adequately.

b. Need for access pits in slab-on-ground construction, where the piping dips to pass beneath doors and other wall openings. Such pits are required for prevention of freezing and to permit drainage of the system.

c. Indefinite output ratings of the baseboard units, since there is no present standard method of testing and rating the units. Manufacturers' catalog ratings for similar baseboard units vary markedly, and give rise to considerable doubt as to what heat outputs can actually be produced by the units.

d. Possibility of freezing, when hot water is the heating medium, when the heat supply to an unoccupied dwelling is shut off. Since the units are adjacent to outside walls, freezing of the water in the units may occur quickly unless the shut-off valve permits a small flow even when completely closed and maintains some heat in the units.

e. Streaking of wall areas above the units due to air currents, which will necessitate more frequent re-decoration.

f. Interference with furniture placement against outside walls, since solid objects placed against the baseboard will interfere with heating the room.

3. PANEL HEATING

A panel heating system differs from conventional heating systems in that a portion of the surface of the floor, wall, or ceiling of each room of the dwelling is heated to a relatively low surface temperature, and the heated surface is utilized to warm the room. The usual method of heating the panels is by circulating heated water through coils embedded within the panel; other (but less used) means are circulating heated air through spaces within the panel, or passing electric currents through conductors that cover the panel surface. Although it may be intended to heat only one surface of a panel, any method that heats one surface will tend to heat the entire panel, including the other surface and the edges. To reduce the heat transmission from this other surface to areas not requiring heat (such as attics and crawl spaces) and from the panel edges to the exterior of the building, insulation should be provided at the panel surface toward such areas, and also at the panel edges. Where a panel is located between two occupied areas (or is part of a slab laid directly on the ground), the effect of heat transmitted from the panel to such occupied spaces (or into the ground) should be considered.

A panel heating installation may require considerable adaptation of the structure, such as thicker plaster to cover heating coils in wall or ceiling panels, waterproofing and edge insulation of ground supported panels, or construction of hollow panels for carrying heated air. In addition, since regulation of the heat output from a panel requires a fine adjustment, balancing devices should be installed to regulate the heat flow to each room.

The advantages of panel heating systems for dwellings are as follows:

a. Increased comfort, since the temperature differential between the floor and the ceiling is very low.

b. Improved room appearance, since no heating elements are visible.

c. Elimination of wall streaking, since convection currents are at a minimum.

The disadvantages of panel heating systems are:

a. Increased installation costs, due to the extra insulation and the required adaptations of the structure.

b. Slow response to changes in the weather, becoming more pronounced with heavier panels.

c. Difficulties with balancing the heat input to each room. Underheated or overheated rooms will usually result if the heat distribution is even slightly maladjusted.

d. Complexity of design over that required for conventional systems is considerable, even with simplified approximate design procedures. In addition, the various design procedures advocated by the various authorities make a definite reliable design solution somewhat uncertain.

e. Difficulty in making alterations, especially in the usual panel heating system where coils are embedded in the panel. Once the coils are installed, it would be prohibitively expensive to add further coil surface, and costly to make repairs or to correct mistakes.

4. PERIMETER HEATING

Perimeter heating systems are designed to utilize forced warm air to heat slab-on-ground dwellings in such manner as to eliminate the cold floors that usually result when conventional forced warm air systems are used. The warm air from the furnace is circulated through perimeter ducts embedded along the outer edges of the concrete slab, and is then discharged into the rooms of the dwelling. Since most of the heat flow in a ground-supported slab is toward the edges of the slab, warming of these edges will reverse the normal heat flow from the center of the slab and tend to raise its temperature. In so doing, however, the heat loss from the ducts through the edges of the slab will be increased and appropriate measures should be taken to construct the slab, and insulate all slab edges to prevent heat losses from becoming excessive.

The advantages of perimeter heating over a conventional forced warm air system are:

a. Increased comfort, since the temperature gradient between the floor and the ceiling is lessened, and the flow of cold air down the outside wall is counteracted.

b. Better slab construction, due to the provisions necessary to keep the buried ducts free from ground moisture.

The disadvantages of perimeter heating are:

a. Increased installation cost due to additional subgrade preparation, concrete, formwork, ductwork, waterproofing, and insulation.

b. Difficulty in making alterations or repairs after installation.

PLUMBING, HEATING, AND VENTILATION

PART XVI - FLOOR LINE, PERIMETER, AND PANEL HEATING

1. INTRODUCTION

Newer methods of space heating have been promoted in recent years, and while not all of them appear to be applicable to low-rent public housing, a few such as those indicated in the title are likely to present such advantages of cost or comfort over the conventional heating systems as to be worthy of consideration. Perimeter heating has been under study by the National Warm Air Heating and Air Conditioning Association, and recommended design and installation practices are contained in their Manual No. 4, "Warm Air Perimeter Heating." 1/ The information presented here relative to these three heating methods is not to be construed as a design procedure or complete coverage of the subject, but is intended only to outline some of the factors that should be taken into account when the possibility of using one of these systems is under consideration.

2. FLOOR LINE HEATING

A floor line heating system is similar in a broad sense to the conventional steam or forced hot water system, the greatest difference being that instead of radiators of the conventional type, lengths of metal radiator or convector elements are located at the floor line in place of the normal baseboard. Such heating elements, called baseboard units, extend along the exterior walls of each room of the dwelling, and are usually connected in series so that a single pair of risers may serve the entire dwelling. To control the flow of the heating medium through the units, a shut-off valve should be installed in the runout between the supply riser and the first baseboard unit, and in addition, a balancing device (if the heating medium is hot water) should be placed in an appropriate location to regulate the heating distribution to each dwelling. In such arrangement, a hand-operated damper should be included in the convector element type baseboard unit in each room to control the heat output from the unit.

The piping between the separate baseboard units in a dwelling must drop beneath the floor when it crosses doors or similar openings located between the units. If steam is the heating medium, drip traps will be required at such low points, and the expense required for their installation suggests that floor line heating systems are better adapted for use with forced hot water rather than with steam; this point, however, should be analyzed if both systems are under consideration.

1/ Available from the National Warm Air Heating and Air Conditioning Association, 640 Engineers Building, Cleveland 14, Ohio.

NOTE: This Part supersedes Part XVI of Bulletin No. LR-7 dated 9-15-50. It has been revised throughout.

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The advantages of the floor line system over a conventional steam or forced hot water installation are believed to be as follows:

a. Lower piping cost, since only one pair of risers is usually required for each dwelling.

b. Increased comfort, since the temperature gradient between the floor and ceiling should be less than with conventional systems.

c. Improved room appearance, since the baseboard units are not too noticeable, and require little, if any, extra room space.

The disadvantages of the floor line system would be:

a. Difficulties in bathrooms and kitchens, because the short lengths of unobstructed wall make difficult the insertion of a baseboard unit long enough to heat these rooms adequately.

b. Need for access pits in slab-on-ground construction, where the piping drops to pass beneath doors and other wall openings. Such pits are required for prevention of freezing and to permit drainage of the system.

c. Possibility of freezing, in hot water systems, when the heat supply to an unoccupied dwelling is shut off. Since the units are adjacent to outside walls, freezing of the water in the units may occur unless the shut-off valve permits a small flow even when completely closed to maintain some heat in the units.

3. PANEL HEATING

A panel heating system differs from conventional heating systems in that a portion of the surface of the floor, wall, or ceiling of each room of the dwelling is heated to a relatively low surface temperature, and the heated surface is utilized to warm the room. The usual method of heating the panels is by circulating heated water through coils embedded within the panel; other (but less used) means are circulating heated air through spaces within the panel, or passing electric currents through conductors that cover the panel surface. Although coils may be embedded in a section of the panel the entire panel will be heated, but unevenly. For this reason, the coil segments should cover the entire panel, equally spaced. Where a panel is located between two occupied areas (or is within a slab laid directly on the ground), the effect of heat transmitted from the panel to such occupied spaces (or into the ground) should require additional insulation.

A panel heating installation may require considerable adaptation of the structure, such as thicker plaster to cover heating coils in wall or ceiling panels, waterproofing and edge insulation of ground supported panels, or construction of hollow panels for carrying heated air. In addition, since regulation of the heat output from a panel requires a fine adjustment, balancing devices should be installed to regulate the heat flow to each room.

The advantages of panel heating systems are as follows:

a. Increased comfort, since the temperature differential between the floor and the ceiling is low.

b. Improved room appearance, since no heating elements are visible.

c. Elimination of wall streaking, since convection currents are at a minimum.

The disadvanatages of panel heating systems are:

a. Increased installation costs, due principally to the extra insulation and the required adaptations of the structure.

b. Slow response to changes in the weather, becoming more pronounced with heavier panels.

c. Difficulties with balancing the heat input to each room. Underheated or overheated rooms will usually result if the heat distribution is even slightly maladjusted.

d. Complexity of design over that required for conventional systems is considerable, even with simplified approximate design procedures. In addition, the various design procedures advocated by the various authorities make a definite reliable design solution somewhat uncertain.

e. Difficulty in making alterations, especially in the usual panel heating system where coils are embedded in the panel. Once the coils are installed, it would be prohibitively expensive to add further coil surface, and costly to make repairs or to correct mistakes.

4. PERIMETER HEATING

Perimeter heating systems are designed to utilize forced warm air to heat slab-on-ground dwellings in such manner as to eliminate the cold floors that usually result when conventional forced warm air systems are used. The warm air from the furnace is circulated through ducts embedded along the edges or other sections of the concrete slab, and is then discharged into the rooms of the dwelling under the windows. Since most of the heat flow in a ground-supported slab is toward the edges of the slab, warming of these edges will reverse the normal heat flow from the center of the slab and tend to raise its temperature. In so doing, however, the heat loss from the ducts through the edges of the slab will be increased and appropriate measures should be taken to construct the slab and insulate all slab edges to prevent heat losses from becoming excessive.

The advantages of perimeter heating over a conventional forced warm air system are:

a. Increased comfort, since the temperature gradient between the floor and the ceiling is lessened, and the flow of cold air down the outside wall is counteracted.

b. Better slab construction, due to the provisions necessary to keep the buried ducts free from ground moisture.

The disadvantages of perimeter heating are:

a. Increased installation cost due to additional subgrade preparation, concrete, formwork, ductwork, waterproofing, and insulation.

b. Difficulty in making alterations or repairs after installation.

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PLUMBING, HEATING AND VENTILATION

PART XVII - PURCHASED STEAM

1. INTRODUCTION

The sale of steam, or "district heating", as a function of utility services, has been a practice for many years. Industrial plants, commercial institutions and apartment developments have found it to their financial advantage to purchase steam in lieu of erecting large boiler plants which are costly to maintain and in which high overall fuel burning efficiencies may be difficult to attain. It is not unusual for the experienced and skillful utility operator to reach an efficiency in his plant of 80-85 percent, but for the average boiler plant operator, such efficiencies are exceptional.

Congested office and apartment building areas provide a wide field for the utility company because the load is concentrated and the quantity of steam supplied per unit of investment is relatively high. Public Low-Rent housing located within the limits of such areas may often benefit thereby since its ratio of average steam load to the maximum load in one day, termed the load factor, is higher than in office buildings. High load factor carries its advantage to the utility company, because comparatively narrow variations in steam requirements required by a housing development result in a more constant load on the company's boilers.

While it is true (as pointed out in Part XII of this Bulletin) that housing project boiler plants present problems of noise, dirt and hazardous trucking due to fuel deliveries and ash removal, economy in construction and operation should be the prime consideration when selecting the method of supplying the heating needs. These intangibles, which "district heating" will eliminate, should not alone influence the decision. There are Low-Rent projects where the "purchased steam" method has been used economically and successfully, and other projects may fall in that classification.

Generally, a utility company is franchised by the municipality to use the city streets for a network of underground distribution mains. The company usually does not find it profitable to pump condensate back to the boilers; the initial cost in laying the returns plus the cost to maintain the lines and the expense to pump the returns exceed the cost of constantly heating fresh water. As noted hereinafter, the purchaser of steam may find beneficial use for this condensate instead of wasting it. Large utility organizations have been successful in "bleeding" multi-stage steam turbines (operating primarily for electric generation) to supply the steam requirements for their customers, and have supplemented such "bleeding" methods with boiler plants intended only to supply steam for sale. The smaller operator uses his plant principally to sell steam.

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2. RATES

Steam is customarily sold on a per thousand pound basis measured, in most cases, as steam passes through a steam-flow meter provided by the utility company. The rate structure of most utility companies (presumably under regulation by the local public service commission) is in block form with different charges for various blocks of usage.

The charge per steam unit in a block becomes progressively lower as consumption is increased; the larger the project, therefore, the lower will be the average rate per steam unit. In addition, some companies impose a demand charge to each customer, which may be dependent upon the customer's maximum rate of use during a given period or on the radiation load. In strictly competitive areas where the economic balance favors the project plant and where proposed additional steam loads taken on by a steam company are incremental and require no further equipment or labor costs, it is probable that the company may find it beneficial, in return for a long term contract, to maintain, in whole or in part, the project underground distribution system. Such opportunities should be explored to their fullest extent; Bulletin LR-11, Selection of Utilities, should be helpful in making the necessary cost analysis for final determination.

3. DISTRIBUTION

Steam at about 100-125 pounds per square inch gauge is brought to a metering point by the local utility company at or within the project boundaries, and terminated with a steam measuring device, furnished and set by the company. Termination may be within a well-ventilated and easily accessible concrete vault or in a basement of a building. The project ties its distribution system in at this point. If it elects, the project may supply its own measuring instrument to keep a close check on consumption.

After metering, steam pressure should be reduced in two stages. The first or "primary" reduction for underground or "yard" distribution to the various "machine rooms" (which house equipment such as hot water generators and pumps) in the buildings should be from the utility company's delivery pressure to whatever pressures are most desirable for the project. Customarily, a range of 30-50 pounds is suitable. The secondary pressure reduction should be down to the operating pressures necessary to supply steam for space heating and domestic water heating services, generally 2 and 5 pounds, respectively. Each "machine room" may be the focal point from which a group of buildings will have their space and domestic water heating needs controlled.

4. PRESSURE REDUCING VALVES

The size and arrangement of the pressure reducing valves, particularly the primary, are extremely important. Correctly sized valves, properly arranged, should admit only the amounts of steam necessary to meet demands. Since each pound of steam is to be measured and paid for, steam consumption for which there is no need becomes as wasteful as burning gas in a range when no cooking is being done.

Selection of the proper sized valve, primary or secondary, should be based on the recommendation of the valve manufacturer, who is most familiar with the valve construction and knows its limitations. The designing engineer should indicate the maximum amount of steam required in pounds per hour and the operating pressures.

Valves should be arranged in parallel. For projects up to about 500 dwelling units, two primary valves would seem necessary. One valve could take care of the maximum space heating requirements, and the other the maximum domestic water heating requirements. For projects in excess of 500 dwelling units, a three valve-in-parallel arrangement would usually be more effective. Two valves should handle the maximum space heating demands in the proportion of 75 percent and 25 percent; the third valve should handle the maximum domestic water heating load. In either case, valves should be set to close at different downstream pressures, and the valves should be pilot-governed for smoother operation.

For the secondary pressure reduction, the two valve arrangement would seem satisfactory since one set could be located in each "machine room". One of the valves should be sized to provide for space heating and the other for the domestic water heating load.

5. PREHEATING DOMESTIC WATER

One important advantage of purchasing steam is utilization of available heat energy from the condensate before it is discharged into the sewerage system. Condensate temperatures may run from about 140° - 170°F.

This condensate should be used very effectively to preheat water, and possibly be carried through two preheating stages before being discharged. The preheated water would then be passed through the steam-coiled hot water generator; the more heat energy extracted from the condensate, the greater will be the operating efficiency.

PLUMBING, HEATING, AND VENTILATION

PART XVII - PURCHASED STEAM

1. INTRODUCTION

The sale of steam by utility companies, or "district heating," has been a practice for many years. Industrial plants, commercial and institutional buildings, and apartment developments have found it to their advantage, financially, to purchase steam in lieu of erecting large boiler plants which are costly to maintain, and in which high overall fuel burning efficiencies may be difficult to attain without skillful operators. It is not unusual for the experienced and skillful utility company operator to reach an efficiency in his plant of 80-85 percent, but for the average boiler plant operator, such efficiencies are exceptional.

Congested commercial and apartment building areas provide a wide field for the utility company because the load is concentrated, and the utility company investment for the quantity of steam supplied is relatively low. Public low-rent housing located within the limits of such areas may often benefit thereby since its ratio of average steam load to the maximum load in one day, termed the "load factor," is higher than in office buildings. High load factor carries its advantage to the utility company, because comparatively narrow variations in steam requirements demanded by a housing development result in a more constant load on the company's boilers.

Economy in operation should be the prime consideration when selecting the method of supplying the heating needs. The intangibles, such as noise and dirt which "district heating" will eliminate, should not alone influence the decision. There are low-rent projects where the "purchased steam" method has been used economically and successfully, and other projects may not fall in that classification. The utility analysis should govern the selection.

Generally, a utility company is franchised by the municipality to use the city streets for a network of underground distribution mains. The company usually does not find it profitable to pump condensate back to the boilers; the initial cost in laying the returns plus the cost to maintain the lines, and the expense to pump the returns, exceed the cost of constantly heating and chemically treating fresh water. Large utility organizations have been successful in "bleeding" multistage steam turbines (operating primarily for electric generation) to supply the steam requirements for their customers, and have supplemented such "bleeding" methods with boiler plants intended only to supply steam for sale.

2. RATES

Steam is customarily sold on a per thousand pound basis, measured, in most cases, as steam passes through a steam-flow meter provided by the utility

NOTE: This Part XVII of Bulletin No. LR-7 supersedes Part XVII dated 10-12-50. It has been revised throughout.

company. The rate structure of most utility companies (presumably under regulation by the local public service commission) is in block form with different charges for various blocks of usage.

The charge per steam unit in a block becomes progressively lower as consumption is increased; the larger the project, therefore, the lower will be the average rate per steam unit. In addition, some companies impose a demand charge to each customer, which may be dependent upon the customer's maximum rate of use during a given period, or on the radiation load. In strictly competitive areas where the economic balance favors the project plant and where proposed additional steam loads taken on by a steam company are incremental and require no further equipment or labor costs, it is probable that the company may find it beneficial, in return for a long term contract, to maintain, in whole or in part, the project underground distribution system. Such opportunities should be explored to their fullest extent; Bulletin LR-11, "SELECTION OF UTILITIES," is helpful in making the necessary cost analysis for final determination.

3. DISTRIBUTION

Steam at about 100-125 pounds per square inch gauge is brought to a metering point by the local utility company at or within the project boundaries, and terminated with a steam measuring device, furnished and set by the company. Termination should be within a well-ventilated and easily accessible concrete vault; or in a basement of a building. The project ties its distribution system in at this point. If it elects, the project may supply its own measuring instrument to keep a close check on consumption.

After metering, steam pressure should be reduced in two stages. The first or "primary" reduction for underground or "yard" distribution to the various "machine rooms" (which house equipment such as hot water generators and pumps) in the buildings should be from the utility company's delivery pressure to whatever pressures are most desirable for the project. Customarily, a range of 30-50 pounds is suitable. The secondary pressure reduction should be down to the operating pressures necessary to supply steam for space heating, and domestic water heating services, generally 2 and 5 pounds, respectively. Each "machine room" may be the focal point from which a group of buildings will have their space and domestic water heating needs controlled. At these secondary stations, steam-to-water heat exchanges could be located if a forced hot water heating system is selected.

4. PRESSURE REDUCING VALVES

The size and arrangement of the pressure reducing valves, particularly the primary, are extremely important. Correctly sized valves, properly arranged, should admit only the amounts of steam necessary to meet demands. Since each pound of steam is to be measured and paid for, steam consumption for which there is no need becomes wasteful.

Selection of the proper sized valve, primary or secondary, should be based on the recommendation of the valve manufacturer, who is most familiar with the valve construction and knows its limitations. The designing engineer should indicate the maximum amount of steam required in pounds per hour and the operating pressures. See Part XIII of this Bulletin, "BOILERS, FUEL HANDLING AND STORAGE, ACCESSORIES," under the section on "Accessories" for recommended methods of installing both primary and secondary pressure reducing valves.

5. PREHEATING DOMESTIC WATER

An important advantage of purchased steam is utilization of available heat energy from the condensate before it is discharged into the sewerage system. Condensate temperatures may run from about 140° - 170° F. This condensate should be used effectively to preheat water, and possibly be carried through two preheating stages before being discharged. The preheated water would then be passed through the steam-coiled hot water generator; the more heat energy extracted from the condensate, the greater will be the operating efficiency.

PLUMBING, HEATING AND VENTILATION

PART XVIII - DOMESTIC WATER HEATING

1. INTRODUCTION

The heating equipment that furnishes hot water for domestic use should be adequate in size, reliable in operation, and consistent with the economy of such equipment from the standpoint of capital cost and the costs of operation, maintenance, and replacement. Any of the commonly-used fuels (coal, oil, or gas), as well as electricity or solar heat, can be utilized as a source of energy, and the heating equipment can be sized to serve individual dwellings, small groups of dwellings, large sections of a project, or an entire project. The fuel and, to a lesser extent, the nature of the equipment should be consistent with the findings of the Utility Analysis. (See PHA Low-Rent Housing Bulletin No. LR-11, "Selection of Utilities").

2. INDIVIDUAL WATER HEATERS

The satisfactory output of hot water from a water heater is dependent on the correct combination of an adequately-sized storage tank and a burner or heating element of sufficient heating capacity (recovery). To some degree these two factors are interdependent so that if the size of the tank is reduced and the recovery is increased proportionately, the hot water output would be satisfactory for normal household use. However, there are limits beyond which it is not advisable to reduce the tank size since if the tank is too small there is insufficient reserve capacity to completely satisfy any of the sustained demands that occur frequently in normal usage. Cold water entering the tank (as the hot water flows out) quickly chills the water remaining in a small tank. A burner of high recovery will reheat the water fairly rapidly, but the resulting intermittent flow of hot water is no substitute for a constant supply. In an effort to obtain this constant supply, tenants will attempt to operate the heaters at water temperatures higher than 140°F; this will not mitigate the unsatisfactory condition to any great extent but will tend to accelerate the corrosion of the tanks, especially ferrous tanks.

As a general rule, individual gas or oil fired water heaters should have tanks of the following sizes:

a. For one-bedroom dwelling units - 20 gallon tanks
b. For two- or three-bedroom units - 30 gallon tanks
c. For four- or five-bedroom units - 40 gallon tanks

The minimum recoveries for the various heaters should be as follows:

a. <u>For Automatic gas-fired units</u>, the hourly AGA input should be not less than -

(1) 20,000 Btu with a 20 gallon tank
(2) 24,000 Btu with a 30 gallon tank
(3) 30,000 Btu with a 40 gallon tank

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b. For automatic gas-fired side-arm heaters, the hourly AGA imput should be not less than -
(1) 20,000 Btu with a 20 gallon tank
(2) 25,000 Btu with a 30 or 40 gallon tank

c. For automatic oil-fired units, the output rating should be not less than 30 gallons of water per hour having a 60°F. temperature rise.

d. For automatic electric water heaters, the rating of the heating elements should be not less than -
(1) Top element 1000 watts, bottom element 600 watts, with a 30 gallon tank.
(2) Top element 1250 watts, bottom element 750 watts, with a 40 gallon tank.

Since the recovery of electric water heaters is so low, and the storage tank of such heaters (with thicker insulating jackets) are relied on to maintain a satisfactory output, it is advisable not to use electric water heaters with tanks smaller than 30 gallons, for one or two bedroom dwellings. A 40 gallon tank should be used for four or five bedroom dwellings.

In the case of coal fired water heaters the storage tank capacity and heater output rating should be sized in combination to prevent overheating of the water in the tank during the night when hot water is not normally used, and also to supply sufficient hot water during the day for normal usage. To prevent overheating, the tank capacity expressed in gallons should be not less than the output rating of the heater expressed in gallons of water raised 100°F in 3 hours. With the tanks sized on this basis, the heater output ratings expressed as noted above should be 30 gallons for a one-bedroom dwelling, 45 gallons for a two- or three-bedroom dwelling, and 60 gallons for a four- or five-bedroom dwelling.

When there is a question of using gas fired heaters having smaller tanks and larger recoveries than the foregoing, the reduction in tank size should be based on increasing the input capacity of the heating element over these minimum values by 1000 Btu per hour for each gallon of reduction in tank size, with a maximum reduction of the 20 gallon tank to 18 gallons, the 30 gallon tank to 25 gallons, and the 40 gallon tank to 35 gallons. When considering tank size reductions, due consideration should be given to the metal used for the tank, since a tank made of corrosion-resisting material can better resist the increased corrosivity caused by high water temperatures.

3. RELIEF VALVES FOR INDIVIDUAL HEATERS

Combined pressure and temperature relief valves should be installed on water heaters as a safety feature, to avoid subjecting the tank to excessive pressures and prevent water in the tank from overheating. Excessive pressures may be due to external causes such as uncontrolled increases of pressure in the street mains or water hammer in the building piping, or may be caused by expansion of water in the tank due to overheating. Overheating occurs when the device controlling the water temperature in the tank fails or is subject to maladjustment. Since the increased pressure due to overheating may be absorbed by backing-up of the water in the cold water line, it is necessary to have a temperature relief as well as a pressure relief valve so that scalding water (which may flash into steam at atmospheric pressure) will not discharge into a plumbing fixture when its faucet is opened.

PHA Low-Rent Housing Bulletin No. LR-10, Part II, "Household Equipment for Cooking, Refrigeration, and Water Heating", discusses individual water heaters, their tanks, water temperature settings, and relief valves in some detail. In addition to the features of combined pressure and temperature relief valves discussed therein, such valves should be constructed of brass or bronze to ensure that corrosion will not affect proper operation, and should be of the type that conforms to the requirements of the American Gas Association as specified in American Standard Z21.22-1935. The rate of discharge from the valve outlet at any heat input should limit the pressure rise to not more than 10 percent above the pressure at which the valve was set to open; and at 210°F. the discharge of hot water should be sufficient to prevent any further temperature rise.

Combined pressure and temperature relief valves should be placed at the top of the tank where the water is normally at its highest temperature. To prevent any possibility of isolating the relief valve from the tank, the valve should be fitted into the tank, or placed as close as possible to the tank, with no valves between them. The relief valve discharge pipe should be at least as large as the valve outlet, and should extend to within 12 inches of the floor. For multi-storied buildings where the heaters are placed above the first story, the discharge pipe should be extended downward to a discharge point on or below the first floor. If the discharge is piped to a point outside the dwelling, a means of indicating that the discharge is occurring (such as a sight gage) should be installed in the discharge line within the dwelling.

Unsuitable discharge points for relief valve outlets would be: the bowls of any plumbing fixtures, exposed openings to the exterior of the dwelling, direct connections to the sanitary or storm drainage system, a floor of a dwelling above the first story, or, in general, any locations where there would be danger of scalding the occupants, polluting the water supply system, freezing the open end of the outlet, or damaging the building. In addition, the discharge from a heater in one dwelling should not be allowed to empty on the floor of the living space of another dwelling.

4. PROJECT-OPERATED SYSTEMS

Water heating systems designed to supply hot water to more than one dwelling unit consist generally of a heating boiler and a separate hot water storage tank. In addition, there are "instantaneous" or tankless methods, whereby the storage tank is omitted and the capacity of the water heater is increased. The objections to tankless systems are: (a) lack of reserve capacity to handle sudden excess demands, (b) extreme fluctuations in water temperature at the fixture outlets especially if the water temperature regulating valve (mixing valve) is not operating satisfactorily, (c) increased corrosion and scaling of the heating element due to its exposure to high temperatures in the boiler, and (d) increased boiler capacity required to supply peak demands. For reliable and consistent service, therefore, a storage tank is essential.

5. STORAGE TANK SIZING

The storage tank capacity that will give satisfactory performance depends on the peak hot water demand and the recovery capacity of the water heater. The peak demand will increase with the number of dwellings, but not in direct proportion to the increased number, due to the diversity of demand. The peak demand for various numbers of dwellings can be estimated from Figure 1, which is based on dwellings containing one bathroom and one kitchen per unit. Each extra bathroom in a dwelling should be considered as adding 1/2 of a unit to the total number, for the purpose of using this curve in estimating peak demand.

Peak demand occurs infrequently, and usually lasts for short periods only. A tank with a capacity equal to the total quantity of water necessary to supply 10 minutes of peak demand, combined with a water heater that is capable of heating an amount of water equal to the tank capacity through the required temperature rise in one hour, should be satisfactory. Storage tanks and heaters selected on this basis will not be excessively large, and will supply adequate quantities of hot water. For example, Figure 1 indicates the peak hot water demand for 120 dwelling units is 115 gallons per minute. The tank capacity should then be 115 x 10 = 1150 gallons and the recovery of the heater should be 1150 gallons per hour when raising the water temperature from 40°F. to 140°F. (assuming 40°F. is the cold water temperature in winter).

6. STORAGE TANK CONSTRUCTION

Since storage tanks must withstand the full pressure required for proper water distribution, they should be constructed for a working pressure of 150 pounds per square inch, in accordance with the American Society of Mechanical Engineers Boiler Construction Code, Section VIII, "Rules for Construction of Unfired Pressure Vessels". 1/ This Code specifies handholes or a manhole in the head of the tank (depending on the tank size), shell thickness, and other details of construction that should ensure satisfactory tank construction.

7. STORAGE TANK MATERIALS

The corrosivity of water is increased when heated, and the heated water tends to attack the container in which the heating action occurs more strongly than

1/ Available from the American Society of Mechanical Engineers, 29 West 39th Street, New York. Price $2.25 for the 1949 edition, and $3.50 for the 1950 edition.

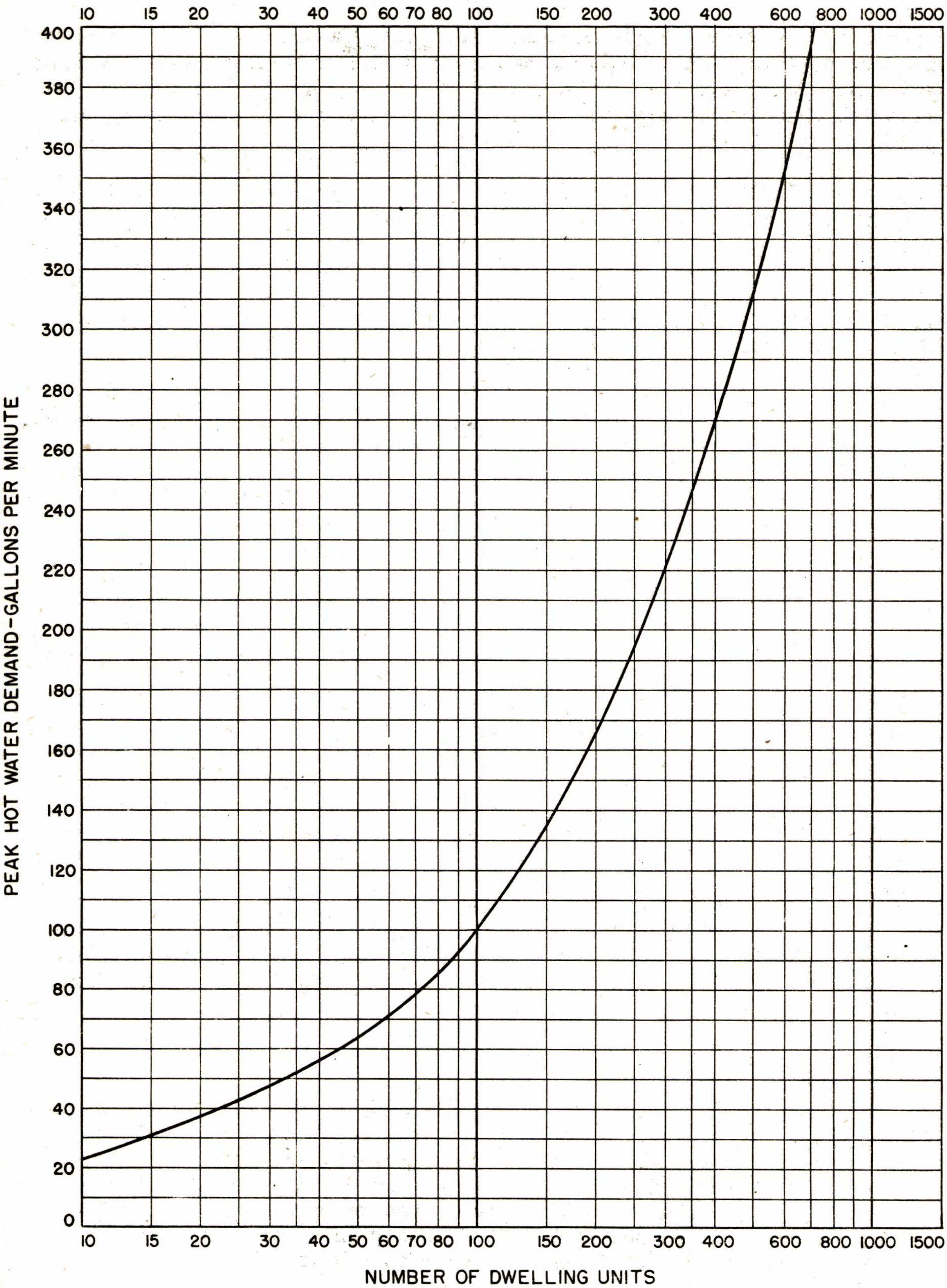

FIGURE 1 ESTIMATED PEAK HOT WATER DEMANDS

other parts of the water supply system. For this reason, the choice of a material for storage tanks should be considered when interpreting the results of a water analysis, and (as in the case of water piping) the choice should be a material that can be expected to last approximately 40 years under normal operating conditions.

The tank material with the lowest initial cost is black steel, which gives satisfactory tank life when the action of the water is to coat the tank interior and protect the metal beneath. However, unless this coating is continuous and durable, the steel shell will corrode continuously, and ultimately require the replacement of the tank. Since such favorable water conditions are rare, there are very few localities where unprotected black steel tanks will give satisfactory service for the required time.

Galvanized steel tanks are subject to the same disadvantage as black steel although they can normally be expected to outlast such tanks by several years. However, unless the water conditions are favorable, the zinc coating over some portions of the interior of the tank will corrode and expose the steel beneath. The time required for corrosion of the zinc is an indication of the increase in the life of galvanized over black steel tanks.

The interior of black steel tanks may be provided with a corrosion-resistant protective lining at an increase in cost. The types of linings available are low-soluble cement applied to the interior surface of the tank, thin copper sheets (forming a tank within a tank), a copper or nickel layer bonded to the interior of the steel shell, or porcelain enamel (glass) fused to the steel shell. The low-soluble cement lining appears to offer the greater advantage for its increased cost over unlined tanks, as the type of cement used can be selected for its special resistance to the water corrosivity encountered, and the cement can be replaced periodically, or an additional coating applied, by project maintenance personnel. The cement should have a uniform thickness of about 5/8 inch, and the entire interior surface, including the exposed surfaces of any tappings, should be covered.

Storage tanks are also made of copper, non-ferrous copper alloys (commercially known by such names as "Herculoy", "Everdur", or "Monel"), or copper-bearing steel alloys. The cost of these tanks is substantially higher than a cement-lined black steel tank, and in normal circumstances it is doubtful whether this increased cost is justifiable.

8. STORAGE TANK ACCESSORIES

Each storage tank should be supported adequately by a concrete pier, a steel pipe frame, or steel saddles. A thermometer and reseating type brass or bronze pressure and temperature relief valves (separate or combined) should be installed in the tank, with the thermometer placed in an easily readable position and so located that it will indicate the water temperature at the tank outlet. Relief valves should be set directly into or close to the highest point of the tank, but in no case more than 3 inches from the tank, and there should be no check valves or shut-off valves between the relief valve and the tank. A discharge pipe with a cross-sectional area equal to the area of the valve outlet should extend from the valve outlet to within 12 inches of the floor. Relief valves for storage tanks should comply with the same reference standards and have the same standard relieving capacity as noted for relief valves used with the tanks of individual water heaters.

9. STORAGE TANK CONNECTIONS

The hot water supply outlet from the tank should pitch up from the tank to the fixtures for proper air relief. The cold water inlet and the hot water outlet should connect at opposite ends of the tank, so that the entering cold water will not chill the hot water leaving the tank. Both hot and cold water connections should preferably be at the top of the tank with the cold water directed to the lower portion of the tank by an inside dip tube to minimize water mixing. If such cold water hook-up is not feasible, the connection should be directly to the bottom of the tank. Hot water recirculating piping should also be connected to the bottom of the tank. If the water piping is a material that is dissimilar to the tank material (for example copper tubing connecting to a steel tank), insulating fittings should be inserted between the tank and the water lines. Shut-off valves and unions should be provided in all the connections, and the tank should have a drain valve, to permit taking the tank out of service for repairs and maintenance. To prevent damage to a dwelling or its furnishing due to hot water faucets being opened and inadvertently left open while the hot water supply is temporarily cut off, a valved by-pass around the tank should be provided to permit cold water to pass through the hot water lines whenever the tank is out of service.

10. HEATING ELEMENTS

Where large numbers of dwellings are served by one storage tank, the water in the tank is usually heated by means of steam or boiler water circulating through a heating element consisting of copper coils submerged in the tank. Tanks heated with boiler water require less fuel during the summer than tanks heated with steam, since the stand-by heat losses are less. Therefore, in systems using low-pressure steam or forced hot water as a heating medium, it is preferable to use boiler water, rather than steam, to heat the water in the storage tanks.

Water heating coils are constructed of seamless copper tubing bent in the form of a nest of U-tubes and extending into the tank for about three-quarters of the tank length. The coils are fitted into tube sheets made of a metal corresponding to the material used for the tank, and the end of the coil that projects into the tank has a floating support to permit expansion and contraction. The element head should be cast-iron with supply and return openings, tappings for an air relief valve and a vacuum breaker (required only when steam is the heating medium). When steam circulates through the element, the flow is controlled by a steam regulating valve which is actuated by an immersion aquastat placed in the tank at mid-height or at the lower third point. If boiler water is the heating medium, the water is made to circulate from boiler to element by gravity, or by means of an electric motor-driven circulator controlled by a similar tank aquastat. When gravity is relied on to promote the flow of boiler water from the heat source to the storage tank, the tank should be placed as high as possible above the heat source and the path to the tank should be as direct and short as possible with a minimum of valves and fittings installed. The piping should be sized to prevent excessive resistance to flow and to permit the required circulation. When a motor-driven circulator is used, its size should be sufficient to deliver the required quantity of boiler water against the total frictional resistance to flow between the element and the tank.

The heating element (instead of being installed in the tank) may be installed within the heating boilers or may be an external type encased in a steel or cast-iron shell. When either of these elements are used, the domestic water, rather than the heating medium, circulates through the coils of the element to the storage tank by gravity or a circulator.

The capacity of a heating element is usually specified by the manufacturer for the conditions of use. These ratings are dependent on the area of coil heating surface, and are usually based on the formula:

$$A = \frac{19.16 \times Q}{U \times (t_2 - t_1)} \times \log \frac{(t_s - t_1)}{(t_s - t_2)}$$

Where A is the area of the coil surface of the heating element in square feet
Q is the quantity of water heated in gallons per hour
t_1 is the cold water outlet temperature in °F.
t_2 is the hot water inlet temperature in °F.
t_s is the average temperature of the heating medium in °F.
U is the coefficient of heat transmission through the coil. in Btu per hour per square foot per °F.

The factor U will vary with the type of heating medium, the velocity of the heating medium through the element, the condition of the coil surface, and the location of the element. Different manufacturers' ratings will be based on different assumptions as to the evaluation of U and, therefore, their published ratings will sometimes vary markedly. The best practice for design purposes is to take the ratings of an established and reliable manufacturer and apply these same ratings on a square foot of coil surface basis to the various heating elements being used under similar conditions.

11. STORAGE TANK INSULATION

All storage tanks should be insulated to save fuel and to increase the heat storage capacity of the tank. Since there are times when there is little or no flow from the tank into the hot water supply system, the amount of heat that will be required to maintain the water in the tank at the desired

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temperature ready for use should be kept to a minimum to operate the system most economically. As an indication of the savings possible with an insulated tank, the heat loss from a bare tank containing 140°F. water and located in a space whose temperature is 60°F. is approximately 164 Btu per square foot of tank surface, while the loss from a tank insulated in the recommended manner under the same temperature conditions is approximately 16 Btu per square foot of tank surface (a reduction of about 90%).

The most widely used storage tank insulation are blocks of 85% magnesia, 1-1/2 inches thick, wired in place with galvanized iron wire over the entire tank surface. Over these blocks a 1/2 inch layer of mortar, consisting of one part portland cement to two parts asbestos cement, should be troweled to a smooth hard finish. One tablespoon of bluestone (copper sulphate) should be added to each gallon of asbestos cement mortar.

12. PROJECT-OPERATED WATER HEATERS

The Utility Analysis for a particular project may indicate that it is most economical to supply the domestic hot water for a group of dwelling units by a separate project-operated water heater. Frequently, a gas utility company will allow lower (dump) rates during the summer season when the demand for gas is low, so that a separate gas water heater can be put in service when these rates are effective, and the heating boilers can be used for space and water heating at other times.

Project-operated water heaters can be coal, oil, or gas fired. The heaters are usually small cast-iron or steel boilers, or copper multi-coil units (gas-fired only). The heaters usually operate on a direct system, where the domestic water is heated in the unit and circulated to the storage tank. For such a hook-up, the heater must be built for a working pressure of 125 pounds per square inch. If the heater is designed for a lower working pressure, an indirect hook-up should be made whereby the water heater acts exactly as does a space heating boiler in supplying steam or boiler water to a separate element which then heats the domestic water. With the indirect hook-up the water heater must be provided with all the safety controls and accessories provided on any heating boiler, including regulating valves, low water cut-outs, safety valves, strainers, and traps when steam is the heating medium; and pressure relief valves, expansion tanks and temperature regulating controls when hot water is the heating medium.

a. Coal-fired water heaters should be tested and rated in accordance with Commercial Standard CS145-47, "Testing and Rating Hand-Fired Hot Water Supply Boilers," issued by the National Bureau of Standards. This standard provides a uniform method of testing and rating this type of heater, and specifies that the unit should be marked with its proven heating capacity. The heater should have grates of the dumping or rocking type, designed for burning coal the size of pea anthracite and larger. The smoke hood should have a choke damper with ample opening, and a draft regulator should be located between the choke damper and the chimney. The draft regulator should be the adjustable type that can be locked at a setting that will provide water at a temperature between 130° and 140°F. A hand shovel, poker, and wire flue brush or scraper with handles should be provided with the heater.

b. Oil-fired water heaters should be provided with an automatic mechanical atomizing type oil burner complying with Commercial Standard CS75-42, "Automatic Mechanical Draft Oil Burners Designed for Domestic Installations", issued by the National Bureau of Standards. Burners so labeled will meet accepted standards that should assure good performance. The combustion chamber should be built in accordance with the recommendations of the oil burner or the heater manufacturer, using a good quality of fire brick. The temperature of the heated water should be regulated by an immersion aquastat which will control the oil burner operation to maintain the water at 140°F. In addition, the heater should be equipped with a high temperature safety control device which will stop the burner operation whenever the temperature of the flue gases becomes excessive or whenever the burner fails to ignite. An adjustable barometric draft regulator should be installed in the smoke pipe of the heater to maintain the constant draft that is necessary for safe and efficient operation, and the area of the opening of this regulator should be equal to the area of the smoke outlet opening of the heater. The installation of the heater, burner, and all accessories should conform to the requirements of the National Board of Fire Underwriters Pamphlet No. 31.

c. Gas-fired heaters should be listed by the American Gas Association. The main burners should be provided with a manually-operated gas valve and an automatic pilot with a manual shut-off. On heaters using natural or manufactured gas the pilot upon flame failure should shut off the gas supply to the main burner; if liquefied petroleum or butane-air gas is used the pilot should shut off the gas supply to both main burner and pilot burner, since those gases are heavier than air and may accumulate in the lower portion of the heater room.

13. SOLAR WATER HEATER SYSTEMS

Utilizing the energy of the sun for heating domestic water is practical and economical in those parts of the country where cloudy days are infrequent. The advantage of a solar water heating system is that although initial cost is higher than that of a conventional system, the cost of operation and maintenance is very low. Where sunshine is not so consistently available, a solar water heater supplemented by an auxiliary water heater may prove economically desirable, when the need for the operation of the auxiliary heater is relatively infrequent.

A solar water heating installation consists of a glass-covered heat absorber connected to a well-insulated hot water storage tank. When the absorber is exposed to the sun's rays (short-wave radiation), they readily penetrate the glass cover and heat the absorber's interior surface. The heated surface will emit long-wave radiation which will not pass through the glass cover, but instead will raise the temperature of the absorber. Water passing through a heating element within the absorber will be heated during the daylight hours, and the hot water can be accumulated in a storage tank for use during the night or at other times when the sun is not shining (the direct system). If it is not desirable to introduce the domestic water directly into the absorber element, a heating medium can be circulated in a continuous circuit from the absorber to a jacket surrounding the tank, or to a coil located within the tank, where it will transfer its heat to the domestic water and then return to the absorber (the indirect system). The heating medium should be a non-freezing mixture in localities subject to low temperatures; in other localities it can be water. An expansion space should be provided to permit increases in the volume of the heating medium as its temperature rises. It has been observed that the effects of corrosion on the storage tanks and the connecting piping have been less with the indirect than with the direct system.

a. Absorber Construction. The absorber usually consists of a flat case, from 3 to 4 inches deep, containing a coil of 3/4 inch copper tubing or galvanized steel piping resting on a lining of sheet metal of the same material as the coil. The lengths of tube or pipe should be soldered to the lining at frequent intervals, or for their full length, and both the coil and the interior of the case should be painted a dull black to increase the heat absorption efficiency. If the absorber coil is copper tubing, the tubes may be flattened to an oval shape before installation in the absorber.

The sides and the bottom of an absorber case should be completely insulated with an insulating material that is not affected by moisture or the weather. The thickness of the insulation should be not less than 1/2 inch, although thicknesses up to 2 inches are more desirable when relatively low air temperatures are to be expected.

The absorber cover usually is made up of sections of single thickness glass window sash, each section being about 14 inches wide and 48 inches long. Two thicknesses of glass, separated by a small air space should be used at low air temperatures to prevent excessive heat losses from the absorber. The joint between the sash and the sides of the case should be air-tight to prevent leakage of heated air from the case, the sash should be removable so that the coil can be serviced,and it should be possible to readily remove and replace broken panes of glass.

b. Absorber and Tank Location. The absorber should be located as far as possible below the storage tank, with the hot outlet of the absorber not higher than the bottom of the storage tank, unless forced circulation is provided. The absorber may be placed on the lower slope of the roof of a building or porch, be installed as an awning over a group of windows, or mounted in a tilted frame on a flat roof. The location should be such that no shadows will fall on the absorber at any time of the day. For maximum heating effect, the absorber should face due south, with the pipes of the coil running east and west, and the north end of the case tilted upward.

The angle of tilt of the case with the horizontal should be not less than the angular value of the latitude of the project, or more than the angular value of the latitude plus 23-1/2°. However, for absorbers mounted on normally sloping roofs, it is probably most practical to place the absorber directly on the sloping roof surface without attempting to gain any extra angle of tilt.

For the solar heating system designed for gravity circulation, the storage tank should be placed in the peak of a sloping roof, or within an enclosure projecting above the roof (which may be made to appear as a chimney or other architectural feature). The tank should be located within 15 feet of the hot outlet of the absorber and the connecting pipes should be as short and direct as possible, pitched uniformly upward toward the tank, and well insulated. The connecting pipes and the absorber case should be flashed at the building surfaces wherever necessary. Figure 2 shows a typical solar heating arrangement.

c. <u>Sizing the Tank and Absorber</u>. Satisfactory operation of a solar heater depends principally on the proper size of the storage tank, since sufficient hot water should be stored in the tank during the hours of sunshine to supply the amount needed during the night-time period and at other times when the sun is not shining. In the various PHA projects using solar water heaters (without auxiliary heaters) satisfactory results have been obtained when the storage capacity provided has been about 66 gallons for each one-bedroom dwelling, 80 gallons for each two-bedroom dwelling, 100 gallons for each three-bedroom dwelling, and 120 gallons for each four-bedroom dwelling. These capacities are adequate whether a separate storage tank is provided for each dwelling or one tank serves a group of dwellings.

The required glass surface area of the absorber depends on the size of the storage tank to which the absorber is connected and the direction in which the glass surface of the absorber is oriented. For absorber units facing due south the glass surface area should be about 40 square feet when connected to a 66 gallon tank, 45 square feet when connected to an 80 gallon tank, 60 square feet when connected to a 100 gallon tank, 75 square feet when connected to a 120 gallon tank, and 90 square feet when connected to a 150 gallon tank. Each square foot of glass surface area should cover about one-half square foot of pipe or tube surface area, that is there should be about 2.2 linear feet of 3/4 inch pipe or tube (nominal size) for each square foot of glass.

When it is not possible to place an absorber with its glass surface facing due south, two separate absorber units both connecting to the one storage tank should be installed, one on the east side of the building and the other on the west side. The total glass area of the two absorber units should exceed the surface area required for an absorber facing due south by an appreciable amount to provide equivalent heating capacity.

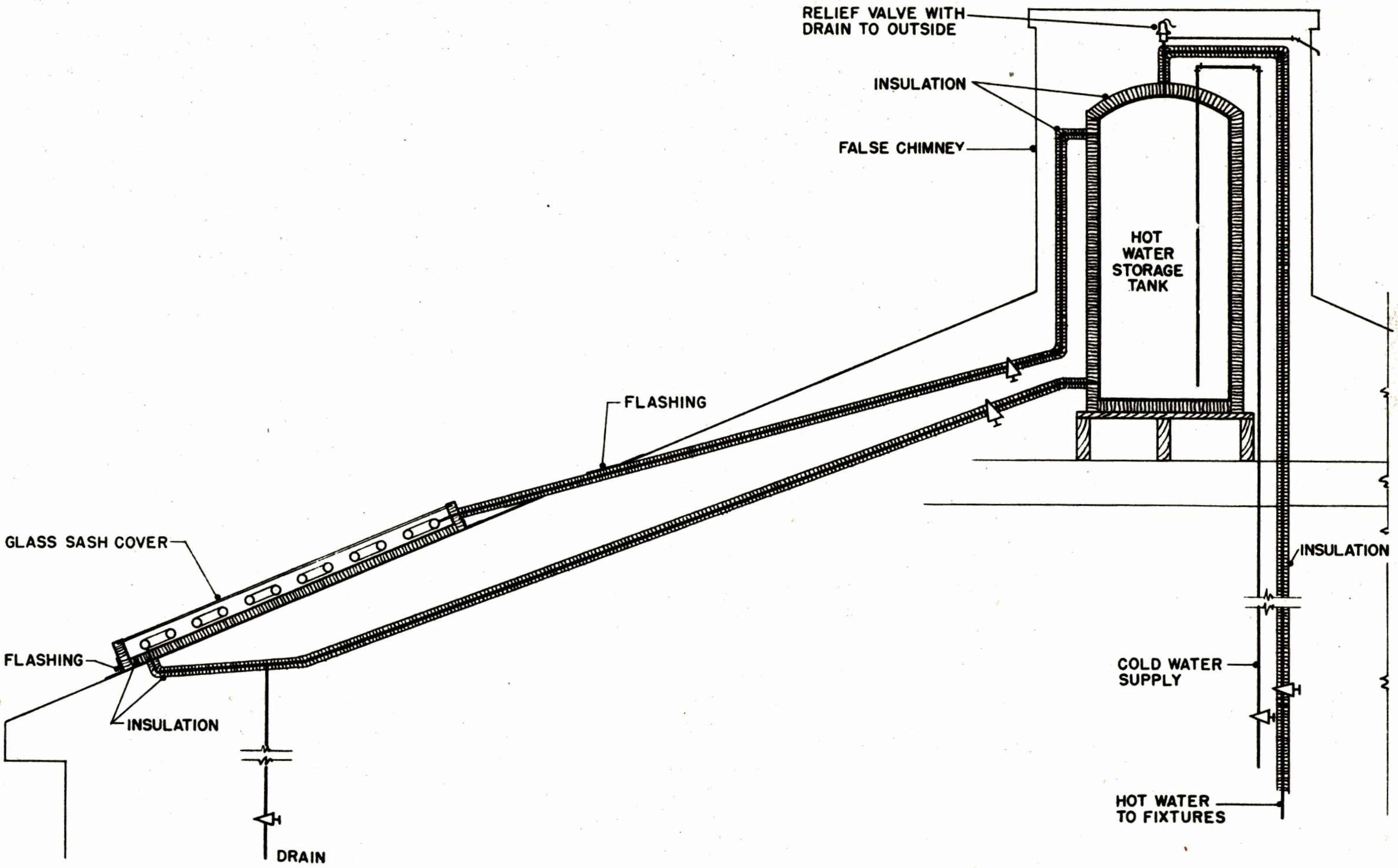

FIGURE 2 HOOK-UP FOR SOLAR WATER HEATER

PLUMBING, HEATING, AND VENTILATION

PART XVIII - DOMESTIC WATER HEATING

1. INTRODUCTION

The heating equipment that furnishes hot water for domestic use should be adequate in size, reliable in operation, and consistent with the economy of such equipment from the standpoint of capital cost and the costs of operation, maintenance, and replacement. The fuel and, to a lesser extent, the nature of the equipment should be consistent with the findings of the Utility Analysis. (See PHA Low-Rent Housing Bulletin No. LR-11, "Selection of Utilities").

2. INDIVIDUAL AUTOMATIC DOMESTIC TYPE WATER HEATERS

Gas-fired water heaters with self-contained storage tanks should comply with the applicable requirements set forth in American Standard ASA Z21.10.1. The heaters should be listed by the American Gas Association and should bear the AGA label. The thermostat, for each heater, should have a temperature adjustment not to exceed 140°F. The storage capacity and hourly AGA input should not be less than the following:

a. For one, two, or three bedroom dwelling units - 30 gallon tank, 28,000 BTU input.
b. For a four bedroom dwelling unit - 40 gallon tank, 33,000 BTU input.
c. For five and six bedroom dwelling units - 50 gallon tank, 35,000 BTU input.

Electric water heaters with self-contained storage tanks should comply with the requirements of Federal Specification W-H-196, except that Type II double heating units should be provided and when such heating units are separately controlled, the thermostats should be interlocked so that any one unit may be operative at any one time. Heaters should be listed by Underwriters' Laboratories, Inc., and should bear their label. The storage capacity and power input should not be less than the following:

a. For efficiencies and one bedroom dwelling units - 40 gallon tank with 1250 watt top element and 750 watt lower element.

b. For two and three bedroom dwelling units - 52 gallon tank with 1500 watt top element and 1000 watt lower element.

c. For a four bedroom dwelling unit - 66 gallon tank with 2,000 watt top element and 1,250 watt lower element.

d. For five and six bedroom dwelling units - 80 gallon tank with 2,500 watt top element and 1,500 watt lower element.

(Cont'd)

NOTE: This is a new Part XVIII, Bulletin No. LR-7, Domestic Water Heaters, and replaces the previous Part XVIII which was obsoleted in October 1963. The material contained in the previous Part XVIII has been completely revised.

3. RELIEF VALVES FOR INDIVIDUAL TYPE WATER HEATER

Relief valves for water heaters should be the combination pressure and temperature reseating type with extension thermal bulb and hand relieving lever and must be installed on water heaters as a safety feature, to avoid subjecting the storage tank to excessive pressures and prevent water in the tank from overheating. Excessive pressures may be due to external causes such as uncontrolled increases of pressure in the street mains or water hammer in the building piping, or may be caused by expansion of water in the tank due to overheating. Overheating occurs when the device controlling the water temperature in the tank fails or is subject to maladjustment. Since the increased pressure due to overheating may be absorbed by backing-up of the water in the cold water line, it is necessary to have a temperature relief as well as a pressure relief valve so that scalding water (which may flash into steam at atmospheric pressure) will not discharge into a plumbing fixture when its faucet is opened.

PHA Low-Rent Housing Bulletin No. LR-10, Part II, "Household Equipment for Cooking, Refrigeration, and Water Heating," discusses individual water heaters, their tanks, water temperature setting, and relief valves in some detail. In addition to the features of combined pressure and temperature relief valves discussed therein, such valves should be constructed of brass or bronze to ensure that corrosion will not affect proper operation, and should be of the type that conforms to the requirements of the American Gas Association as specified in American Standard Z21.22 and should be so labeled. Relief valves when used with water heaters having an input of 15,000 BTU or more should have not less than 3/4-inch inlet and outlet connections and not less than 1/2-inch connections when used with heater having an input of 15,000 BTU or less.

The combined pressure and temperature valve should be located at the highest point of the tank, in the hot water outlet of the tank, or in a tank tapping provided for this purpose. The thermal sensing bulb of the valve must extend into the hottest water at the top of the tank. The length of thermal sensing element stem extending beyond valve inlet opening should be indicated on the body of the valve. There should be no valves of any kind installed between the relief valve and top of the tank. A discharge pipe equal to the size of the relief valve outlet should extend from the valve outlet to within 8 inches of the floor or open drain. If the discharge is piped to a point outside the dwelling, the point of discharge should be visible at the ground level.

Unsuitable discharge points for relief valve outlets would be: the bowls of any plumbing fixtures; exposed openings to the exterior of the dwelling; direct connections to the sanitary or storm drainage system; a floor of a dwelling above the first story; or, in general, any locations where there would be danger of scalding the occupants, polluting the water supply system, freezing the open end of the outlet, or damaging the building. In addition, the discharge

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from a heater in one dwelling should not be allowed to empty on the floor of the living space of another dwelling.

4. STORAGE TANKS FOR INDIVIDUAL DOMESTIC TYPE WATER HEATERS.

The types of tanks commonly used include glass-lined steel, combination type glass-lined and cement-lined, copper silicon alloy, nickel-copper alloy, and cement-lined (stone-lined) steel.

For several years from 1951 through 1959 tests on tank lining of gas water heaters in service in public housing projects were conducted jointly by PHA and Local Authorities. The final test results, published in 1959, established that characteristics of the water were the principal factor in determining how well a particular tank lining would stand up in service. Whereas some linings were little affected by water in one locality, they could be rapidly corroded in another locality, having a different water. It was found that the copper-lined, the stone-lined, and the glass lined tanks performed well in all localities where tests were conducted.

Based on the test data obtained, it is evident that these types of linings would perform equally well in most other locations. The choice between the three types of tank linings for any specific application would have to be made after weighing factors such as initial cost of complete heater, meeting of PHA requirements by the manufacturer, availability of replacement parts, and similar considerations. Since heaters with glass-lined storage tanks are readily available from a large number of heater manufacturers throughout the country, at a much lower initial cost than heaters with other type tanks, consideration should be given to their use, particularly when initial cost is always a pertinent factor. If the water piping is a material that is dissimilar to the tank material (for example copper tubing connections to a steel tank), insulating fittings should be used to make such connections.

5. PROJECT-OPERATED SYSTEMS

Water heating systems designed to supply hot water to a group of dwelling units or buildings consist generally of a heating boiler and a separate storage tank. High-input gas fired type heaters with self contained storage tanks and/or storage tanks that are separate and external from the heaters. In addition, there are "instantaneous" or tankless methods, whereby the storage tank is omitted and the capacity of the water heater is increased. The objections to tankless systems are: (a) lack of reserve capacity to handle sudden excess demands; (b) extreme fluctuations in water temperature at the fixture outlets especially if the water temperature regulating valve (mixing valve) is not operating satisfactorily; (c) increased corrosion and scaling of the heating element due to its exposure to high temperatures in the boiler; and (d) increased boiler capacity required to supply peak demands. For reliable and consistent service, therefore, a storage tank is essential.

6. STORAGE TANK CONSTRUCTION FOR PROJECT-OPERATED SYSTEMS

Since storage tanks must withstand the full pressure required for proper water distribution, they should be constructed for a working pressure of 150 pounds

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per square inch, in accordance with the American Society of Mechanical Engineers Boiler Construction Code, Section VIII, "Rules for Construction of Unfired Pressure Vessels." 1/ This Code specifies handholes or a manhole in the head of the tank (depending on the tank size), shell thickness, and other details of construction that should ensure satisfactory tank construction.

7. STORAGE TANK MATERIALS

The corrosivity of water is increased when heated, and the heated water tends to attack the container in which the heating action occurs more strongly than other parts of the water supply system. For this reason, the choice of a material for storage tanks should be considered when interpreting the results of a water analysis, and (as in the case of water piping) the choice should be a material that can be expected to last approximately 20 years under normal operating conditions.

The tank material with the lowest initial cost is black steel and the useful life varies widely depending principally on the chemical composition and the quantities of the impurities in the water supply. Since favorable water conditions are rare, there are very few localities where unprotected black steel tanks will give satisfactory service for the required life expectancy.

Galvanized steel tanks are subject to the same disadvantage as black steel although they can normally be expected to have a longer life expectancy. However, unless the water conditions are not of a corrosive nature, the interior zinc coating of the tank will corrode and expose the steel beneath. The time required for corrosion of the zinc is an indication of the increase in the life of galvanized black steel tanks.

Tanks are available with corrosion-resistant protective linings at an increase in cost. The types of linings generally used are a low-soluble cement applied to the interior surface of the tank, porcelain enamel (glass lining) fused to interior surface of the tank, copper sheets (forming a tank within a tank), a copper layer bonded to the interior of the steel shell or a tank of copper silicon alloy which contains approximately 95 percent pure copper. Cement-lining of tanks appears to offer the greater advantage, for its increase in cost, over unlined tanks. Cement should be a low-soluble type about 5/8 inch thick that resists the action of corrosive water and with the same coefficient of expansion as the steel.

Storage tanks made of copper silicon alloy (commercially known by such trade names as "Hercloy" or "Everdur"), copper clad steel tanks, or a copper sheet tank within a steel tank are substantially higher in cost than a cement-lined steel tank and in normal circumstances it is doubtful whether this increased cost is justifiable.

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1/ Available from the American Society of Mechanical Engineers, 345 East 47th Street, New York 17, New York.

8. STORAGE TANK ACCESSORIES

Each storage tank should be supported adequately by a concrete pier, a steel pipe frame, or steel saddles. A thermometer should be installed in the tank and placed in an easily readable position and so located that it will indicate the water temperature at the tank outlet. A reseating type pressure and temperature relief valves (separate or combined) must be installed in the tank as a safety feature, to avoid subjecting the storage tank to excessive pressures and to prevent water in the tank from overheating. Valves are to be set directly into the highest point of the tank and there should be no check valves or shut-off valves between the relief valve and the tank. A discharge pipe with a cross-sectional area equal to the area of the valve outlet should extend from the valve outlet to within 8 inches of the floor. Relief valves for storage tanks should comply with the same reference standards and have the same standard relieving capacity as noted for relief valves used with the tanks of individual water heaters. See paragraph 3 for reference standards and other pertinent information.

9. STORAGE TANK SIZING

The storage tank capacity that will give satisfactory performance depends on the peak hot water demand and the recovery capacity of the water heater. The peak demand will increase with the number of dwellings, but not in direct proportion to the increased number, due to the diversity of demand. Estimating hot water storage requirements and tank storage capacities can best be determined by consulting the chapter on Water Services contained in the American Society of Heating, Refrigerating, and Air-Conditioning Engineer's Guide and Data Book. 2/

10. STORAGE TANK CONNECTIONS

The hot water supply outlet from the tank should pitch up from the tank to the fixtures for proper air relief. The cold water inlet and the hot water outlet should connect at opposite ends of the tank, so that the entering cold water will not chill the hot water leaving the tank. Both hot and cold water connections should preferably be at the top of the tank with the cold water directed to the lower portion of the tank by an inside dip tube to minimize water mixing. If such cold water hookup is not feasible, the connection should be directly to the bottom of the tank. Hot water recirculating piping should also be connected to the bottom of the tank. If the water piping is a material that is dissimilar to the tank material (for example copper tubing connecting to a steel tank), insulating fitting should be inserted between the tank and the water lines. Shut-off valves and unions must be provided in all the connections, and the tank should have a drain valve, to permit taking the tank out of service for repairs and maintenance. To prevent damage to a dwelling or its furnishing due to hot water faucets being opened and inadvertently left open while the hot water supply is temporarily cut off, a valved bypass around the tank(s) should be provided to permit cold water to pass through the hot water lines whenever the tank(s) are out of service.

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2/ Available from the ASHRAE, 345 East 47th Street New York 17, New York.

11. HEATING ELEMENTS

Where large numbers of dwellings are served by storage tank(s), the water in the tank(s) is usually heated by means of steam or boiler water circulating through a heating element consisting of copper coils submerged in the tank(s). Tank(s) heated with boiler water require less fuel during the summer than tank(s) heated with steam, since the stand-by heat losses are less. Therefore, in systems using low-pressure steam or forced hot water as a heating medium, it is preferable to use boiler water, rather than steam, to heat the water in the storage tank(s).

The heating element within the hot water storage tank(s) should be U-tube shaped seamless drawn copper tubing. The tube ends should be expanded into tube sheets made of a metal corresponding to the metal used in the tank and the heating element should be installed within the tank with a floating support to permit expansion and contraction. The element head should be equipped with supply and return openings, tappings for an air relief valve and a vacuum breaker (required only when steam is the heating medium). When steam circulates through the element, the flow is controlled by a steam regulating valve which is actuated by an immersion aquastat placed in the tank at mid-height or at the lower third point. If boiler water is the heating medium, the water is made to circulate from boiler to element by gravity or by means of an electric motor-driven circulator controlled by a similar tank aquastat. When gravity is relied on to promote the flow of boiler water from the heat source to the storage tank, the tank should be placed as high as possible above the heat source and the path to the tank should be as direct and short as possible with a minimum of valves and fittings installed. The piping should be sized to prevent excessive resistance to flow and to permit the required circulation. When a motor-driven circulator is used, its size should be sufficient to deliver the required quantity of boiler water against the total frictional resistance to flow between the element and the tank.

The heating element (instead of being installed in the tank) may be installed within a single heating boiler or may be an external type encased in a steel or cast-iron shell. When either of these elements are used, the domestic water, rather than the heating medium, circulates through the coils of the element to the storage tank by gravity or a circulator.

The capacity of a heating element is usually specified by the manufacturer for the conditions of use. These ratings depend on the area of coil heating surface. To check the heating coil ratings under temperatures, other than those stated in the manufacturers' published ratings, can best be determined by consulting the equation set forth in the paragraph titled, Computing Heat-Transfer Surface, listed in the chapter on Water Services contained in the American Society of Heating, Refrigerating, and Air Conditioning Engineers Guide and Data Book.

12. STORAGE TANK INSULATION

All storage tanks should be insulated to save fuel and to increase the heat storage capacity of the tank. Since there are times when there is little or

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no flow from the tank into the hot water supply system the amount of heat that will be required to maintain the water in the tank at the desired temperature ready for use should be kept to a minimum to operate the system most economically. As an indication of the savings possible with an insulated tank, the heat loss from a bare tank containing 140°F. water and located in a space whose temperature is 60°F. is approximately 164 BTU per square foot of tank surface, while the loss from a tank insulated in the recommended manner under the same temperature conditions is approximately 16 BTU per square foot of tank surface (a reduction of about 90%).

Insulating materials for storage tanks may be thermal mineral fiber insulating blankets, or insulating blocks of calcium silicate, or mineral fiber, or magnesia. Storage tanks should be thoroughly cleaned and insulation applied to the entire surface of the tank and secured tightly in place with galvanized chicken wire securely tied together. Over the insulation apply a coat of insulating and finishing cement, troweled to a smooth surface, not less than 1/2 inch overall thickness of two coats.

13. WATER HEATERS FOR PROJECT OPERATED SYSTEMS

The Utility Analysis for a particular project may indicate that it is most economical to supply the domestic hot water for a group of dwelling units by a separate project-operated water heater. Frequently, a gas utility company will allow lower (dump) rates during the summer season when the demand for gas is low, so that a separate gas water heater can be put in service when these rates are effective, and the heating boilers can be used for space and water heating at other times.

Project-operated water heaters can be oil or gas fired. The heaters are usually small cast-iron or steel boilers, or copper multicoil units (gas fired only). The heaters usually operate on a direct system where the domestic water is heated in the unit and circulated to the storage tank. For such a hook-up, the heater must be built for a working pressure of 125 pounds per square inch. If the heater is designed for a lower working pressure, an indirect hook-up should be made whereby the water heater acts exactly as does a space heating boiler in supplying steam or boiler water to a separate element which then heats the domestic water. With the indirect hook-up the water heater must be provided with all the safety controls and accessories provided on any heating boiler, including regulating valves, low water cut-outs, safety valves, strainers, and traps when steam is the heating medium; and pressure relief valves, expansion tanks, and temperature regulating controls when hot water is the heating medium.

In lieu of the use of multicoil gas-fired heater, with separate and external storage tank, a gas fired heater may be used, of a type in which the storage tank and burner are combined as a unit. A reseating type pressure and temperature relief valve must be installed for each heater of this type as a safety feature. See paragraph 3, for reference standards and other information.

a. Gas-fired water heaters should be listed by the American Gas Association and should be the automatically controlled type, with burners adjusted for the type of gas available at the project, and should conform to the applicable

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requirements of American Standard ASA Z21.10.3. Heaters should be installed in accordance with rules and regulations included in American Standard Installation of Gas Appliances and Gas Piping ASAZ21.30, manufacturers' installation instructions and applicable building codes.

b. Oil-fired water heaters should be provided with an automatic mechanical atomizing type oil burner complying with Commercial Standard CS75, "Automatic Mechanical Draft Oil Burners Designed for Domestic Installations", issued by the National Bureau of Standards. Burners so labeled will meet accepted standards that should assure good performance. The combustion chamber should be built in accordance with the recommendations of the oil burner or the heater manufacturer, using a good quality of fire brick. The temperature of the heated water should be regulated by an immersion aquastat which will control the oil burner operation to maintain the water at 140°F. In addition the burner should be equipped with a safety device to stop the burner on system failure. An adjustable barometric draft regulator should be installed in the smoke pipe of the heater to maintain the constant draft that is necessary for safe and efficient operation, and the area of the opening of this regulator should be equal to the area of the smoke outlet opening of the heater. The installation of the heater, burner, and all accessories should conform to the requirements of the National Board of Fire Underwriters Pamphlet No. 31.

14. SOLAR WATER HEATER SYSTEMS

Utilizing the energy of the sun for heating domestic water is practical and economical in those parts of the country where cloudy days are infrequent. The advantage of a solar water heating system is that although initial cost is higher than that of a conventional system, the cost of operation and maintenance is very low. To ensure a continued supply of hot water during cloudy weather, an electric heating element may be installed in the storage tank, to operate generally as does a conventional electric domestic type heater; or where sunshine is not so consistently available, a solar heating system supplemented by an auxiliary water heater may prove economically desirable, when the need for the operation of the auxiliary heater, as a boosting device, is relatively infrequent.

A solar water heating installation consists of a glass-covered heat absorber connected to a well-insulated hot water storage tank. When the absorber is exposed to the sun's rays (short-wave radiation), they readily penetrate the glass cover and heat the absorber's interior surface. The heated surface will emit long-wave radiation which will not pass through the glass cover, but instead will raise the temperature of the absorber. Water passing through a heating element within the absorber will be heated during the daylight hours, and the hot water can be accumulated in a storage tank for use during the night or at other times when the sun is not shining (the direct system). If it is not desirable to introduce the domestic water directly into the absorber element, a heating medium can be circulated in a continuous circuit from the absorber to a coil located within the tank, where it will transfer its heat to the domestic water and then return to the absorber (the indirect system). The heating medium should be a non-freezing fluid in localities subject to

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low temperatures. To provide for the expansion of the nonfreezing fluid a small expansion tank or cylinder with pressure requirements to meet those specified for the storage tank and of a capacity equal to 0.075 of the volume of the total fluid in the closed loop heating system (the indirect system). The 0.075 percentage is based on the formula for expansion tanks set forth in the ASHRAE Guide, and is computed on the temperature of the water in the heating system not exceeding 200°F. and the net expansion of nonfreeze liquid of a permanent type, with Ethylene Glycol base, when mixed with water being relatively the same expansion as water.

a. Absorber Construction. The absorber usually consists of a flat case usually from 3 to 4 inches deep, with length and width developed to accommodate the computed requirement of heating coils. The absorber heating coils may be constructed of 3/4 or 1 inch (Type L) soft copper tubing made in the form of a single continuous coil of the return bend type resting on a plate of sheet copper and solder continuously in intimate contact with the heating coil. The upper side of the copper sheet and coil should be painted with flat black acid resisting paint.

The absorber case (heating tray) should be constructed of 24-gauge galvanized sheet, and insulated with a suitable insulating material that is not affected by moisture of not less than 1/2 inch thick on the bottom and the four sides and should be glazed air tight, except for condensation weep holes drilled in the lower side of the tray.

The absorber cover usually is made up of sections of single thickness glass window sash. Two thicknesses of glass, separated by a small air space should be used at low air temperatures to prevent excessive heat losses from the absorber. The joint between the sash and the sides of the case should be air-tight to prevent leakage of heated air from the case, the sash should be removable so that the coil can be serviced, and it should be possible to readily remove and replace broken panes of glass.

b. Absorber and Tank Location. The absorber should be located as far as possible below the storage tank, with the hot outlet of the absorber not higher than the bottom of the storage tank, unless forced circulation is provided. The absorber may be placed on the lower slope of the roof of a building or porch, or mounted in a tilted frame on a flat roof. The location should be such that no shadows will fall on the absorber at any time of the day. For maximum heating effect, the absorber should face due south, with the pipes of the coil running east and west, and the north end of the case tilted upward.

The angle of the inclination of the absorber case with the horizontal should be not less than the angular value of the latitude plus 23-½°. This will satisfy conditions along the 30°N latitude, which includes the portions of Florida and Southern California where these heaters are most frequently used. The absorber case mounted on a sloping surface with a pitch of 5 inches in 12 inches, or approximately 30° will probably be more practical than attempting to gain any extra angle of tilt. The connecting pipes and the absorber case should be flashed at roof surface wherever necessary.

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Circulating lines between the absorber case and the storage tank should be a minimum of 1 inch copper tubing, and should be well insulated. Cold water line from tank should be connected with heating coil at bottom of the absorber case with a drain valve in the cold water line at this low point. The hot water line from the heating coil at the top of the absorber case should be connected to the storage tank at the upper side tap on the tank.

The storage tank should be placed in the peak of a sloping roof, or within an enclosure projecting above the roof (which may be made to appear as a chimney or other architectural feature). The tank should be located, if possible, within 15 feet of the hot water outlet of the absorber and connecting pipe lines should be as short and direct as possible and pitched uniformly upward from absorber to tank. Control valves should be provided as required.

The storage tank may be constructed of heavy gauge steel, galvanized inside and out or galvanized outside with a low-soluble cement applied to the interior surface of tank and designed for a working pressure of 150 pounds per square inch. Tank should be enclosed with a box type jacket constructed of sheet metal or wood, with removeable top. The space between tank and jacket housing should be insulated on the top and sides with not less than 5 inches of re-granulated type insulation such as cork or mineral wool. The tank should be equipped with a combination reseating type temperature and pressure relief valve.

c. Sizing The Tank. The storage tank should be able to store sufficiently heated water for a night period of about sixteen hours when coil is not functioning, or is operating under poor sun conditions as to make its heating effect negligible. Since the no sun period includes the night period when a minumum of hot water is used, an available storage of 50 per cent of the average daily usage is considered adequate. Since about 25 per cent of stored hot water cannot be drawn out of a storage tank before the incoming cold water reduces the temperature of all water in the tank to an unsatisfactory point for usage, the equation for calculating the storage capacity of the tank becomes:

$$S = \frac{Qd \times 0.50}{0.75} = 0.666\ Qd$$

Where

S=Storage capacity of tank, gallons.
Qd=Average daily usage, gallons.

Thus for a family of four persons (one dwelling unit) or (two one bedroom units) using an average of 40 gallons of hot water per day per person, the size of the tank would be 4 persons x 40 gal. x 0.666 or 106 gal., and the nearest standard size of tank should be used. Tank capacities by number of occupants can be best determined by consulting the chart titled "Suggested Design Data for Solar Heaters" that follows:

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d. Sizing The Absorber. The required glass surface area of the absorber depends on the size of the storage tank to which the absorber is connected and the direction in which the glass surface of the absorber is oriented. For example an absorber unit properly located, facing due south, the glass surface should be about 126 square feet when connected to a 100 gallon tank. Absorber sizes of other related information such as heating coil requirements can best be determined by consulting the chart titled, "Suggested Design Data for Solar Heaters" that follows:

SUGGESTED DESIGN DATA FOR SOLAR HEATERS

DESIGN ITEM	BASED ON RATE OF 40 GAL. PER DAY PER PERSON							
Number of Occupants in Residence	1	2	3	4	5	6	7	8
Hot Water Used at Night, Gal. Per Person	20	20	20	20	20	20	20	20
Hot Water Used at Night, Gal. Total	20	40	60	80	100	120	140	160
Retained in Tank, 25 Percent, Gal.	5	10	15	20	25	30	35	40
Tank Capacity Required, Gal.	25	50	75	100	125	150	175	200
Hot Water Used During Day, Gal.	20	40	60	80	100	120	140	160
Total Water to be Heated:								
Gal. Per 8-Hour Period	45	90	135	180	225	270	315	360
Gal. Per Hour	6	12	17	23	28	34	39	45
Copper Coil Required:								
Surface Area, Square Feet	32	64	96	128	160	192	224	256
Equivalent Length 1-In. Coil, Feet	128	256	384	512	640	768	896	1024
Box Size:								
Area, Sq. Ft.	32	65	96	126	160	198	228	252
Width, Ft.	4	6.5	8	9	10	11	12	12
Length, Ft.	8	10	12	14	16	18	19	21

APARTMENT HOUSE INCINERATORS

(FLUE-FED)

1. INTRODUCTION

The material in this part of the Bulletin is drawn from the technical study on "Apartment House Incinerators (Flue-Fed)" prepared by the Building Research Advisory Board under contract with the Federal Housing Administration. The Public Housing Administration, realizing the need for reliable technical information, initiated the study and contributed financially and provided technical liaison. The study was made by a special committee of prominent engineers from science, industry, and municipal governments, all recognized as national authorities on various technical aspects of the problem. The study is written primarily around the performance levels, although design approaches are definitely identified. The committee concluded that, upon completion of the study, a detailed design analysis could be undertaken, together with a coordinated research effort that could lead to more elaborate design criteria.

The aggravating depth of the air pollution problem, to which the flue-fed incinerators contribute, is well-known; so much so that the President has directed the attention of the Congress to the national need for the control of air pollution in his message on natural beauty of the country. The U.S. Public Health Service has issued a Circular, "Instructions for the Installation of Air and Water Pollution Control and Treatment Systems at New Federal Facilities and Buildings." In this Circular is included an item on incinerators where the multiple-chamber type is recommended, and strict performance levels are indicated. The revised PHA Guide Specification indicates the multiple type also. A flue-fed incinerator is defined as one composed of a single primary chamber, of primary and secondary chambers, with either an integral flue for both refuse delivery and flue-gas exhaust, or a double flue comprising one flue for refuse delivery and the other for flue-gas exhaust. Various municipal codes stipulate and prefer one method over the other; opinions of engineers vary also. However, one large Local Housing Authority on the East Coast and one in the Midwest prefer the integral flue; so does the PHA Central Office because it believes, principally, that less maintenance is involved with good design and with accurate coordination of the various components and specialties.

For a more comprehensive analysis of the subject matter, reference should be made to "Apartment House Incinerators (Flue-Fed)," Publication No. 1280, published by the National Academy of Sciences, Washington, D.C.

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NOTE: This Part of the Bulletin is entirely new.

2. REFUSE

Refuse, as a generic term, refers to solid wastes. For apartment house incinerators of the flue-fed type, refuse can be divided into rubbish and garbage. Rubbish is composed of dry combustible material such as newspapers, magazines, cartons, boxes, plastic containers, and non-combustibles such as metals, tin cans, glass, crockery, and dirt. Garbage is composed of wastes from the preparation and serving of foods. It is largely putrescible organic material with high natural moisture content; removal from the apartment at short intervals is necessary.

The importance in regard to composition is the net heating value per unit weight. Two considerations will affect this value: moisture content, and ratio of combustible to non-combustible materials. It is recommended that, for design consideration, refuse be considered 80% rubbish and 20% garbage, with an average heat content of 4,500-6,000 Btu per pound.

There appears a definite trend to larger amounts of combustible materials such as waxed packages from frozen foods, together with decreasing amounts of garbage. The ratio of rubbish to garbage has risen from the historic 50-50 used in criteria for many years; with the expected continuation of this changing pattern, there will be corresponding increases in the net amount of heat obtained from the refuse. This tendency is strengthened by the increase in canned foods against fresh vegetables; although non-combustible, the cans provide means for a more porous charge in the primary combustion chamber which assists the combustion process and makes for better burn-out.

3. FUNCTIONS AND REQUIREMENTS

Functions of an apartment house flue-fed incinerator are:

a. To offer a convenience to tenants.
b. To provide a more sanitary method of refuse disposal.
b. To serve as a labor-saving device to building owners.
d. To serve as a labor- and cost-saving device to the municipality in reducing the weight and bulk of the refuse which must be hauled from the apartment building to the final disposition point.

The flue-fed incinerator can accomplish the above functions satisfactorily if it:

a. Reduces the refuse to as small a weight and volume as practicable without discharging objectionable air pollutants. Reduction of 70% in weight and 90% in volume, with no more than 10% combustible residue, should be considered acceptable.

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b. Acts as a temporary storage bin for refuse without attracting or harboring rodents or vermin.

c. Remains simple to maintain and operate, with most operations automatically controlled. A steady and strict maintenance program is necessary.

4. PERFORMANCE LEVELS

Primarily, incinerator air pollutants are particulate matter, smoke and noxious gases:

a. Particulate matter includes fly-ash, soot, charred refuse particles, and tar droplets.

(1) Initial tests of a single-chamber incinerator indicated a range of 2.5 - 4.7 pounds of particulate matter per 1,000 pounds of flue-gas, when corrected to 12% CO_2. The use of improved design features, such as multiple chambers, auxiliary gas burners, overfire air, draft control, smoke washers or scrubbers plus proper operational and maintenance practices, makes a liberal goal of 0.85 pounds of particulate matter per 1,000 pounds of flue-gas attainable.

(2) Test procedures to determine the performance level are set forth in the American Society of Mechanical Engineers Power Test Codes 21, "Dust Separating Apparatus," and 27, "Determining Dust Concentration in a Gas Stream."

b. Smoke is actually the sub-micronic particles[1/], which are visible to the naked eye.

(1) Smoke density is the source of many complaints, and is defined on the Ringelmann Chart, Bureau of Mines Circular 7718. The density is compared with lines of various widths on the chart, and a number assigned to which the smoke most closely matches. Besides the density, the other important factor is duration of smoke emission, which should be not over three minutes in any one hour; the allowable density should be not over No. 2, as shown on the Ringelmann Chart.

c. Harmful and odorous compounds, particularly the offensive aldehydes, are also produced. Offensiveness of odor may vary from one incinerator to another, and can produce, if harmful, deleterious effects

1/ Micron is designated by the lower case Greek letter Mu, and is equal to 1/25,000-inch.

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on the human organism. As more is learned of these effects, stricter limitations on this phase of pollutants will be imposed.

(1) The effects of carbon monoxide, CO, a colorless and odorless gas that produces toxic or fatal effects, are well-known; its concentrations must be kept to almost non-measurable amounts; recent work indicates that continuing exposure to even relatively low concentrations is harmful.

(2) Sulphur dioxide, SO_2, is an irritant gas which affects the upper respiratory tract; refuse ordinarily contains at least minute amounts of sulphur-bearing compounds.

d. Evidence is reported that air pollution is connected with respiratory diseases such as chronic bronchitis, pulmonary emphysema, bronchial asthma, and lung cancer.

5. DESIGN APPROACHES TO FLUE-FED INCINERATORS

Technology of incinerator design is undergoing a process of continuing change. With emphasis on air pollution abatement, additional engineering effort has been directed toward the control of this abuse from flue-fed incinerators. Since the incinerator is in itself a combustion device, the design should be the responsibility of the consulting engineer in active collaboration with the architect to preclude deficiencies inherent with poor design or incordinate planning.

The flue-fed incinerator, because of the heterogeneous nature of its charge, its varying rate of combustion, and changing drafts due to operation of hopper doors, plus probable low-quality operation and maintenance, has not been rated as a good performer in the control of air pollution. The problem became critical because in many instances, minimum cost has in the past influenced the design of these units, with little attention paid to the factors fundamental to good combustion. In most cases, the combustion chamber was no more than an enlarged brick chimney with little or no refractory. This circumstance has forced progressive code and air pollution authorities to require specific, detailed design criteria based on the best available information. These criteria have accomplished much to improve the operation of flue-fed units. The U.S. Public Health Service has sponsored extensive research and development in order to produce acceptable systems.

Preference tends toward the performance approach to incinerator design, whereby, through a series of definitive tests and performance levels, assurance can be presented that the device will operate satisfactorily.

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This approach is believed practicable, especially where a series of the same incinerator design are to be used and extensive prototype testing can be conducted. However, it is realized that, in many cases, definitive design criteria should be utilized.

Complete combustion of waste materials can be achieved, but it is difficult to achieve this in a single combustion chamber, primarily because of inability to maintain a high and uniform temperature in the combustion chamber, inadequate or incomplete mixing of the volatized gases with combustion air, relatively short retention time for the gases in the combustion area, and the heterogeneous nature of the fuel. The singlechamber design is, consequently, considered inefficient for new construction for air pollution control. Where existing integral flue incinerators are to be retained, certain modifications can be made to attain optimum performance; these are discussed in the "Operation and Maintenance" section hereinafter.

The preferred design is the multiple-chamber incinerator, (see paragraph n(3) below), with the primary chamber acting as a storage container and as an ignition and combustion chamber, while the subsequent chambers permit the completion of combustion as necessary, and act as fly-ash separators. Calculation for volume and burning-area requirements are, at best, based on empirical values; those included herein are in common use. Values are based on 1.44 pounds of refuse per person per day, with a refuse weight of 4.1 pounds per cubic foot, and a burning period of 10 hours out of every 24. Refuse may run up to 2.0 pounds of refuse per person per day with a weight of about five pounds per cubic foot, in which case the design values should be increased proportionately, in the same ratio as 1.44 - 2.0. Heat content will vary from 4,500 - 6,000 Btu per pound.

a. Volume of primary combustion chamber should be calculated on basis of 0.375 cubic feet per person. Heat release should not exceed 18,000 Btu per cubic foot; this considers leaving adequate combustion space above the charge. Manufacturers should be consulted for secondary chamber measurements and baffling.

b. Combined burning hearth and grate area should be calculated on basis of not less than 0.075 square feet per person; projected grate area should be at least one-half the combined burning area. Grates should be the rocking or stationary type. Hearth beneath the charging chute should be pitched at a 60 degree angle from the horizontal.

c. All interior surfaces of primary combustion chamber should withstand temperature of about 1,600°F without damage.

d. Length to width ratio of primary chamber should vary between 2 - 1, and 1 - 1.

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e. Controlled refuse charging through the use of hopper door locks and/or main flue gates should preferably be employed.

f. Where intermittent charging is utilized, it may be assumed that 60% of the total refuse will be delivered between the hours of 5 p.m. and 7 a.m., and consumed during the first burning of the day. For an integral flue, the following design features are relevant:

g. Charging chute should be directly connected to the primary chamber with no changes in direction or offset, and should be so located as to provide good refuse distribution over the hearth and grate. The chute or flue should be smooth, with no protrusions which could cause bridging or blockage. Access provision should be made for cleaning.

h. Flues, except for those in double flue incinerators, should not be less than 27 by 27 inches; optimum flue size is 30 by 30 inches.

i. When a flue gate at the base of the charging chute is used in conjunction with an integral incinerator, a by-pass flue should be provided, which reconnects with the main flue between the first- and second-floor hoppers; it should be equipped with deflection rods at junction to guard against the entry of refuse. An advantage of this type of design is that the dust-bearing particles must pass through separation chambers where some fly-ash may be trapped, and high-temperature retention time is increased. The by-pass flue should be sized on the basis of 30 feet per second maximum gas velocity, with 200% excess air.

j. Hopper doors should be not less than 10 by 12 inches nor larger than 160 square inches. Hopper door locks should be of simple and rugged construction utilizing a tapered bolt, preferably pneumatic in operation.

k. For fire prevention purposes, the flue-gas exhaust flue should be topped with a stainless steel spark arrester, at least 2'6" high, which should be progressively increased to five feet, as the building stories increase from six to thirteen or more floors.

l. Flue should be higher than any structure within 100 feet, at least four feet above a penthouse, or two feet above a water tower, but in no case less than ten feet above the roof.

m. For double flue incinerators:

(1) Sound insulation should be considered for the charging chute if of metal construction. Size the chute as cited

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above for the flue in integral flue incinerators. The chute may connect directly to the incinerator chamber, or to a platform thence to the incinerator chamber, or discharge directly on the basement floor proximate to the incinerator, in which last case it is necessary to hoe or cart the refuse to the incinerator. Sprinkler heads may be required in chute to quench flash fires.

(2) The exhaust gas flue should be sized to conform to practice for masonry chimneys, but in no case with gas velocities in excess of 35 feet per second or demensions less than 8 by 8 inches, based 200% excess air.

n. Auxiliary gas burner should be provided to ensure temperatures adequate to achieve complete combustion, and maintain high temperatures, 1,400 - 1,600°F. This burner can be thermostatically controlled.

(1) Several locations for the burner have been tried with some success. The best location appears to be above the grate area so that the flame envelope radiates to the burning bed and adds heat to the combustion gases. Limited success has been achieved with the burner located at or beyond the flame port in single-chamber units.

(2) Burners have also been located with questionable success within roof settling chambers, but the cost of reheating the flue gases is considered excessive.

(3) In multiple-chamber incinerators, a relatively new design concept utilized two auxiliary burners--one in the combustion chamber, which assists in igniting and burning the waste; the other at or beyond the flame port, which incinerates the volatized gases and carbonaceous solids.

(4) Burner should produce a long luminous flame, and be fan-assisted type, so constructed that air required for combustion is supplied by the fan sufficient only to overcome the resistance of the air flow through the burner. There should be a safety pilot control, with feature to sense the presence of a pilot flame before gas is admitted to main burner. Pilot burning, electric spark ignited, should be intermittent, proving itself only for each firing cycle; continuous burning pilots have caused nuisance shutdowns due to flame blowouts, prompted to some extent from variable draft conditions.

o. With the design approach to supply most of the combustion air overfire, there has been marked increase in combustion efficiency and

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reduction of effluents. A suggested optimum ratio of overfire to underfire air appears to be approximately 80% to 20%, but provisions for adjustments should be made.

(1) Draft can be regulated through the barometric and turn dampers, or an overfire draft control in conjunction with the turn damper.

(2) Distribution of air overfire with a moderate turbulence can be accomplished by an electric motor blower unit supplying air through a series of jets drilled 40 degrees from the vertical in two parallel rows in a steel header, connected directly to the blower discharge through a volume damper regulating the air flow.

p. Effluent control should also be concentrated on the combustion chamber, where baffled secondary or separation chambers are provided to prevent passage of large particulate matter.

(1) Roof settling chambers have been partially successful in removing the heavier particulates from the gas stream, but they apparently suffer from major disadvantages in the greatly increased pressure drop which can cause smoke-outs through hopper doors at upper floors, and may be responsible for concentration of explosive gases.

(2) Smoke washing equipment, scrubbers, are sometimes used to ensure meeting the more restrictive particulate performance criteria; in fact, some Local Housing Authorities specify this equipment as part of their design and installation standards. An apparent successful type seems to be the intimate contact, impingement type, wherein the effluents pass through a flooded plate so that all of the gas stream makes contact with the water. Installation may be in the penthouse or in the basement proximate to the incinerator, in which case, if a primary and three secondary chambers were originally intended, the last two chambers may be omitted, and connection to the scrubber should be from the remaining secondary chamber. Basement-located scrubbers cool the flue gases and reduce the amount of natural draft available. Also, water vapor may condense on the inside of the flue, and, in combination with gaseous effluents, cause corrosion. However, the advantage of a basement location is that, it is likely to receive better maintenance as a result of more frequent visits from the operator; this is a serious consideration in view of the finding that lack of adequate maintenance is the principal problem with all dust control equipment. This piece of equipment has been

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used in conjunction with the gas burner and overfire air jets.

(3) Proprietary electronic precipator as an adjunct to a smoke washer has been studied and investigated for application to the flue-fed incinerator. A test installation provided on the roof of an East coast housing project, under the inventor's and manufacturer's supervision, without benefit of gas burner and overfire air jets, has reduced the smoke emission considerably.

6. VENTILATION

Emission of odorous gases through hopper doors open to interior corridors, and known as smoke-outs, can be a distressing problem. Emission is caused primarily when lower pressure exists within the structure rather than within the flue. This condition may be aggravated by a negative pressure in the corridors due to exhaust ventilation, restrictions in the flue, smoke washers in the basement, roof settling chambers, accelerated burning rates, or wind conditions. Due consideration should be given to all the above conditions.

a. Possible solutions are to maintain a balanced pressure in the interior corridors by adding forced ventilation, preheating the air if necessary. If only exhaust from the corridors is provided, and if permitted by local code, the exhaust fans can be interlocked with the incinerator, so that fans do not run when incinerator is burning. It would seem though, that the balanced pressure scheme is the firmer, because there are also possibilities of smoke-outs with smoldering fires within the combustion chamber after initial burn-outs.

b. Combustion air to the incinerator room should be supplied through a fixed dependable outside air source. With a long system of ductwork, and with such other items as bird screens and insect screens, a forced-draft fan may be required. If a direct wall louvre or grille is used, air velocities should not exceed 500 fpm through the free area.

7. SUMMARY OF DESIGN CRITERIA

Efforts toward improving design for higher performance levels should primarily be:

a. To improve the firing process, to consume refuse more completely and so to reduce to a minimum, the generation of air pollutants.

b. To locate the discharge point in such fashion that residual pollution would cause the least damage and discomfort.

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The first goal may best be achieved through provision of an adequately and properly designed system, including automatic combustion controls, such as clock control, auxiliary burners, and overfire air system. Dust and fly-ash control may be provided through the use of secondary chambers, or smoke washers.

Finally, the discharge flue should terminate at a point high enough and far enough to avoid nuisance. The flue should terminate with an approved spark arrester.

With the increased emphasis on air pollution and smoke control, not only by localities or by the Federal Government, it is of utmost importance that due consideration be given to any requirement resulting from these programs. In many instances code requirements have not kept pace with civic and Federal programs. Consequently, it is important that all requirements covering the incinerator room, all components of the incinerator and all other details be carefully investigated to ensure compliance with local health and building regulations, applicable requirements of the National Board of Fire Underwriters and the requirements of local and national pollution programs.

8. OPERATION AND MAINTENANCE

The old flue-fed incinerator consisting of a single combustion chamber and an integral flue required little or no maintenance. The operator simply lit the fire and periodically agitated the burning bed. These operational conditions resulted in maximum production of air pollutants.

Modifying the simple flue-fed incinerator to provide some measure of automatic operation will still require careful operator attendance if pollutant emissions are to be reduced. The addition of an auxiliary burner will improve combustion characteristics. In most cases where a gas burner is used, manual, semi-automatic, or automatic operation is possible.

Manual operation requires that the operator light and prove a safety pilot, and operate the main burner. If an overfire air system is installed, as is usual, it must also be energized. Although these operations are not difficult, an untrained operator can negate the advantages by adjusting the burner to produce a short flame rather than a luminous bushy flame; or he can fail to energize the overfire air system, so that improper combustion occurs.

Semi-automatic operation entails use of a main gas burner, electric-ignition safety pilot, overfire air, and time-clock firing control. The operator normally energized the safety and main burners, which automatically

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energize the overfire air system. The time clock automatically turns on the burner assembly to fire for a predetermined period.

Automatic operation involves a main burner, electric-ignition safety pilot, overfire air system, temperature-sensing device, clock control, automatically operated main flue gate. In this procedure, loading of the incinerator by the tenants is controlled by hopper door locks which prevent opening of the doors during the firing cycle. At the predetermined time, the locks are closed, the safety and main burner are energized, the flue gate, if installed, is shut, the overfire air system is energized, the by-pass flue, if installed, is opened, and the incinerator charge is burned. This system requires a minimum of operator assistance as far as combustion control is concerned.

Specific set of operating instructions, framed under glass, should be posted in the incinerator room.

Charging method in both the single- and multiple-chamber flue-fed incinerators will materially affect sizing and the ability to control air pollution emissions. The common practice for many years has been to allow the refuse to be charged during the entire day and then consumed in a single burning. This practice is bound to result in poor combustion and severe air pollution, since: (1) In spite of the great mass of insulating refractory, the combustion walls cool between charges; (2) additional charging during operation may smother the flames so that the volatized gases are not completely burned; (3) an adequate air-fuel ratio cannot be maintained; and (4) the agitation created results in heavy particle generation.

Within the last few years, air pollution authorities have recognized this problem and have been enforcing regulations which control the times at which firing is permitted. In general, the rules permit incinerator operation during the daylight hours so that visual emission checks can be used for enforcement.

a. The major drawback is that tenants, not used to the inconvenience of waiting for the hopper doors to be operational, will block doors open, break the locks, or in some manner make the hopper door lock system inoperable. Since the whole operation is based on a series checking circuit, wherein any one malfunctioning part will present burner start-up, it becomes necessary for the operator to go through the building to determine the status of the door locks. A detailed explanation and educational campaign for the tenants is therefore required to mitigate nuisance shutdowns. An effective dust control system, continuously operated, could mitigate the need for a hopper door lock system.

b. The success of automatic operation is recognized by most code authorities in the fact that extended hours of operation are permitted--

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so that, in effect, a smaller-size incinerator can be utilized.

Dust control devices, such as settling chambers and smoke washers, depend upon a strict policy of maintenance for successful operation.

a. Settling chambers utilizing the principle of gravity deposition, must not be allowed to accumulate the collected fly-ash; accumulation will begin to reduce the cross sectional area of the chamber, increase gas velocity, and reduce chamber effectiveness. Chambers should be cleaned at least once per week. Roof separation (settling) chambers present a problem in the disposal of the collected fly-ash.

b. Smoke washers of the intimate-contact type require careful maintenance. The perforated pan should be carefully watched to prevent clogging of the perforations, the strainer material above the pan must be cleared, and the sludge tank should be scrubbed down to prevent accumulation and blockage. This procedure should be carried out at least once per week. It has been found that continuous operation of scrubbers gives the most satisfactory means of controlling emissions when active burning is completed but smoldering continues.