ENGINEERING STANDARD

FOR

BUILDING HEATING SYSTEM

CONTENTS :

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1. SCOPE

This Standard covers the minimum requirements for design of central water and steam heating systems, including calculation of heating load, piping design, type and selection method for heating equipment, etc. (For building air conditioning systems reference is made to E-AR-120).

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Consultant.

ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)

ASME Section VIII "Boiler and Pressure Vessels"

ASHRAE (AMERICAN SOCIETY OF HEATING, REFRIGERATING & AIR CONDITIONING ENGINEERS, INC.)

ASHRAE "1989 Fundamental Volume, Chapters 25 and 33; and
1988 Equipment Volume, Chapters 23 ,27 and 28; and
1988 Systems Volume"

3. DEFINITIONS AND TERMINOLOGY

3.1 Closed System

A heating piping system in which circulating media is completely enclosed, under pressure above atmosphere, and shut off from the atmosphere.

3.2 Convector

A surface designed to transfer heat to a surrounding fluid largely or wholly by convection.

3.3 District Heating

A heating system that serves two or more building with one central heating system.

3.4 Expansion Tank

A partially filled tank at the top of a water heating system that compensates for the thermal expansion and contraction of water.

3.5 Heating Load

The heating rate required to replace heat loss from the space being controlled.

3.6 Heating System

A system that transfers heat from a source, through a distribution network to spaces to be warmed.

3.7 Hydronics

The science of heating and cooling with fluids.

3.8 Infiltration

Air leaking into the building through small cracks around sash and doors.

3.9 One-Pipe System

A piping system in which the condensable vapor or hot water withdrawn from the boiler and returned as condensate or cold water from the farthest unit to the same supply main.

3.10 Pressure Drop

1) Pipe flow loss (as from one end of a line to the other) from friction, heat, etc.
2) Minor pressure losses across elements of piping system such as valves, bends, joints, etc.

3.11 Steam Trap

A device that allows the passage of condensate and prevents the passage of steam, or that which allows the passage of air as well as condensate.

3.12 Two-Pipe System

A piping system in which one pipe is used for supply of the heating medium to the heating unit, and another for the return of the heating medium to the supply main.

3.13 Water Treatment

A process that removes impurities from water.

4. UNITS

This Standard is based on International System of Units (SI) except where otherwise is specified.

PART I
BASIC DESIGN REQUIREMENTS

5. HEAT LOAD CALCULATIONS

Designers shall determine the following requirements for calculation heating loads :

5.1 Building Heat Load

5.1.1 Design conditions

a) Winter climate data for outdoor conditions can be found from records of the weather organization as indicated in Attachment 1.

b) The indoor design temperature shall be selected for each room to be heated during the coldest weather. Optimum dry bulb temperature for comfort at the breathing line (1.5 meter above the floor) can be selected from the recommended figures in Attachment 2.

5.1.2 Heat transfer coefficient

The heat transfer coefficient (U values) for each area, relating to type of construction shall be determined. With attic area above the room, the roof structure and ceiling of the top floor must be taken into consideration and the combined coefficient for the top floor ceiling shall be as follows:

$$U_{cr} = \frac{U_R U_C}{U_R + \frac{U_C}{r}} \qquad \textbf{(Eq. 1)}$$

Where: $r = \frac{A_r}{A_c}$

Where:

U_R = heat transfer coefficient of the roof, w/m^2 °C.
U_c = heat transfer coefficient of the ceiling, w/m^2 °C.
U_{cr} = combined heat transfer coefficient, w/m^2 °C.
r = square meter of roof area in attic (A_r) divided by the square meter of ceiling area on top floor (A_c).

5.1.3 Unheated space temperatures

If the respective surface areas of unheated room adjacent to the heated room and those exposed to the outside are approximately the same, and if coefficient of transmission are approximately equal, the unheated space temperature may be assumed to be the mean of indoor and outdoor design temperature.

If surface areas and coefficients are unequal, the unheated space temperature shall be calculated as follows:

$$t_u = \frac{t_i\,(A_1U_1 + A_2U_2 + A_3U_3 + etc.) + t_o\,(KV_o + A_aU_a + A_bU_b + A_cUc_c + etc.)}{(A_1U_1 + A_2U_2 + A_3U_3 + etc.) + (KV_o + A_aU_a + A_bU_b + A_cU_c + etc.)} \qquad \textbf{(Eq. 2)}$$

Where:

k	= 1200 or 0.018 Btuh/ft^2 °F for standard air.
t_u	= temperature in unheated space, °C (°F).
t_i	= indoor design temperature of heated room, °C (°F).
t_o	= outdoor design temperature,°C (°F).
A_1, A_2, A_3, *etc.*	= areas of unheated space adjacent to heated space, m^2 (ft^2).
A_a, A_b, A_c, *etc.*	= areas of surface of unheated space adjacent to outdoor, m^2 (ft^2).
U_1, U_2, U_3, *etc.*	= heat transfer coefficients of surfaces A_1, A_2, A_3 etc., w/m^2 °C.
U_a, U_b, U_c, *etc.*	= heat transfer coefficients of surfaces of A_a, A_b, A_c, etc., w/m^2 °C.
V_o	= rate of introduction of air into the unheated space by infiltration or ventilation, l/s(cfh).

5.1.4 Transmission heat loss

Where floors are directly on the ground, the ground temperature is assumed 40°C above outside temperature. The heat losses by conduction and convection including heat losses through walls, ceilings, partitions, glass, doors and floor above ground shall be calculated as follows:

$$Q = AU(t_i - t_o) \qquad \textbf{(Eq. 3)}$$

Where:

Q	= heat transfer through the wall, roof, ceiling, floor or glass, watts (Btu/h).
A	= area of wall, glass, roof, ceiling, roof or other exposed area, m^2 (ft^2).
U	= air-to-air heat transfer coefficient, w/m^2 °C (see chapter 25, ASHRAE 1989 Fundamentals volume)
t_i	= inside air temperature near surface involved, °C (°F).
t_o	= outdoor air temperature or temperature of adjacent (partition) unheated space, °C (°F).

5.1.5 Basement heat loss

In many instances the building heating plant are in the basement. It is fairly common to have the basement space temperature kept at or above 10°C (50 °F).

Heat loss through windows and walls above grade shall be based on outdoor temperature and proper air-to-air transfer coefficients. Heat loss through basement walls below grade line shall be based on the floor and wall coefficients for surfaces in contact with the soil. The heat loss for below grade basement walls and floors are given in Tables 1 and 2.

TABLE 1 - HEAT LOSS BELOW GRADE IN BASEMENT WALLS

Depth ft	Path Length Through Soil, ft	Heat Loss, Btu/h ft °F							
		Uninsulated		R = 4.17		R = 8.34		R = 12.5	
0-1	0.68	0.410		0.152		0.93		0.067	
1-2	2.27	0.222	0.632	0.116	0.286	0.079	0.172	0.059	0.126
2-3	3.88	0.155	0.787	0.094	0.362	0.068	0.240	0.053	0.179
3-4	5.52	0.119	0.906	0.079	0.441	0.060	0.300	0.048	0.227
4-5	7.05	0.096	1.002	0.069	0.510	0.053	0.353	0.044	0.271
5-6	8.65	0.079	1.081	0.060	0.570	0.048	0.401	0.040	0.311
6-7	10.28	0.069	1.150	0.054	0.624	0.044	0.445	0.037	0.348

TABLE 2 - HEAT LOSS THROUGH BASEMENT FLOORS, Btu/h. ft^2. °F

Depth of Foundation Wall Below Grade	Shortest Width of House, ft			
	20	24	28	32
5 ft	0.032	0.029	0.026	0.023
6 ft	0.030	0.027	0.025	0.022
7 ft	0.029	0.026	0.023	0.021

Note:

$\Delta F = (t_a - A)$

5.1.6 Heat loss through floor slabs

Heat transmission from floor slabs can be calculated by the following equation:

$$Q = F_2 P (t_i - t_o) \qquad \textbf{(Eq. 4)}$$

Where:

Q = heat loss through the perimeter of floor, W(Btu/h)

F_2 = heat loss coefficient, of perimeter, w/m^2 °C per m (Btu/h °F per ft) (see chapter 25 Table 5 of ASHRAE 1989 Fundamentals Volume).

P = perimeter or exposed edge of floor, m(ft)

t_i = indoor temperature, °C(°F)

t_o = outdoor temperature, °C (°F)

5.1.7 Heat loss by infiltration

Infiltration heat loss can be calculated by crack method or air change method.

5.1.7.1 In crack method the air leakage heat loss is determined as follows:

$$Q_s = 1200\, BL\, (t_i - t_o) \quad \textbf{OR} \qquad \textbf{(Eq. 5A)}$$

$$Q_s = 0.018\, BL\, (t_i - t_o) \qquad \textbf{(Eq. 5B)}$$

Where:

B	=	air leakage for the wind velocity and type of window or door crack involved, l/s per m of crack (cfh)
L	=	length of window or door crack, m(ft)

Measurement of crack length shall be as follows:

- For double hung windows; 3 times the width plus 2 times the height.
- For wood basement windows; 2 times the width plus 2 times the height.
- For metal pivoted sash-total perimeters of the movable or ventilating sections.

5.1.7.2 To calculate infiltration by the air change method, following formula can be used:

$$Q_s = 1.2 \times n \times v \times (t_i - t_o) \qquad \textbf{(Eq. 6)}$$

Where:

n	=	number of air changes per second.
v	=	volume of room, m^3 (cuft)

The greatest value of Q between equations (5) and (6) shall be selected as the infiltration heat loss.

5.1.8 Total heat load

The calculated heat load through transmission and solar load from walls, ceiling, roof, partition, glass and through infiltration into space (outside air) shall be entered in a heat loss estimating sheet, referenced as a sample in Attachment 3.

Note:

In building with permanent or steady internal heat source of considerable size such as ovens, intensive lighting, etc. an equivalent amount of heat should be reduced from calculated total heating load.

5.2 Domestic Hot Water Load

5.2.1 Domestic water heaters are divided into the two following classes:

1) Those which heat the water by direct application of heat such as gas water heater and small boilers.

2) Those which transfer heat from water or steam in the heating boiler to the domestic water. This is termed as indirect water heating and can be accomplished by any of the following:

a) Double shell storage tank (preferred system). These are suitable for residential and commercial application.

b) Instantaneous storage tank with submerged coil. These are suitable for high demand factor and industrial application.

c) Shell and tube heat exchangers, also called tankless heaters. These are suitable for various application and are generally horizontal in construction.

5.2.2 The heat requirement for the domestic hot water which are in separate circuit from the space heating water shall be evaluated and added to the building heating load. The required heat for consumed hot water may be estimated by the following formula:

$$Q = \frac{4.2\, H\, (t_2 - t_1)}{n} \qquad \textbf{OR} \qquad \textbf{(Eq. 7A)}$$

$$Q = \frac{1\, H\, (t_2 - t_1)}{n} \qquad \textbf{(Eq. 7B)}$$

Where:

Q = required heat load, kW (Btu/h)
H = hot water demand, liters (gallons)
t_2 = hot water temperature, °C (°F)
t_1 = city water temperature, °C (°F)
n = the required time for water heating, (normally between 3-4 hours)

Note:

The demand of domestic hot water can be estimated by using the maximum consumption per occupant.

6. TYPE OF HEATING SYSTEM

6.1 In-Space Heating Equipment

6.1.1 In-space heating equipment contrary to central heating do not need ducts or piping to convey heat from the source to the room that is to be heated. Gravity type models (fossil-fueled) do not require electrical connection, the circulation from the heat source to the room is provided by natural convection.

6.1.2 In-space heating equipment can be classified as follows:

a) Gas in-space heaters including room heaters, wall furnaces, floor furnaces.

b) Oil in-space convective heaters including vaporizing pot-type heaters, powered atomizing type and portable-type kerosene heaters.

c) Electrical in-space heaters including wall and floor heaters, baseboard heaters, radiant convector wall panel, embedded cable heat and portable electric heaters.

d) Solid fuel in-space heaters.

Note:

For safety and control considerations, reference is made to ASHRAE 1988 Equipment volume.

6.2 Central Heating System

6.2.1 Water heating system

Water systems use hot water to convey heat through piping connection from boiler or water heater to suitable terminal units. Water systems can be classified by temperature, flow generation, pressurization, piping arrangement and pumping arrangement.

6.2.1.1 Types

There are two types of hot water heating system classified by flow generation:

a) Gravity flow system, which uses difference in weight between the supply and return water to circulate water to the heating terminals. Water heated in the boiler increases in volume and rises, simultaneously with a downward movement of the cooler heavier water in the return main; thus setting up the circulation.

b) Forced circulation system, in which an electric pump is employed to provide movement of the water. This system is the preferred type as circulation to the heating terminals are speeded and can almost be instantly supplied with hot water or maintain a constant temperature in the system to offset outside weather conditions.

6.2.1.2 Piping arrangement

According to piping arrangement the water heating system is divided into:

a) One-pipe system or monoflow single loop main are system with a supply and a return tee installed on the main. One-pipe circuits allow manual or automatic control of flow to individual connected heating units. The length and load (temperature variation) imposed on a one-pipe circuit are usually small because of the limitations.

b) Two-pipe circuits which can be direct-return or reverse-return:

i) In direct-return circuits, the return main flow direction is opposite the supply main flow, and the return water from each unit takes the shortest path back to the boiler. The direct-return system usually requires circuit balancing of flow control valves on unit or sub-circuits.

ii) In reverse-return circuits the return main flows in the same direction as the supply main flow, and the return main returns all water to the boiler after the last unit is fed. Reverse-return system seldom need balancing valves, as the water flow distance to and from boiler is the same through any unit.

c) Series loop arrangement which is a continuous run of pipe or tube from a supply connection to a return connection. Terminal units are a part of the loop. One or many series loops can be used in a complete system. The length of loop can be increased by increasing operating temperature drop and decreasing flow rate. The series loop can be used as a part of two-pipe direct-return system.

6.2.1.3 Temperature classifications

Water system in term of temperature is divided as follows:

a) Low temperature water system (LTW). The maximum allowable working pressure shall be up to 1102 kPa (160 Psi) with a maximum temperature limitation of 121.1°C (250°F).

b) Medium temperature water system (MTW). This system operates at temperature of 176.7°C (350°F) or less, with pressure not exceeding 1034 KPa (150 Psi).

c) High temperature water system (HTW). A hot water heating system operates at temperature over 176.7°C (350°F) and pressure of about 2068 kPa (300 Psi). The maximum design supply water temperature is from 204.6°C to 232.2°C (400 to 450°F).

6.2.1.4 Water system equipment

Central plant for water heating system shall consist the minimum requirements of following equipment:

a) Boiler (cast iron or steel).
b) Automatic fuel burner which may be gas burner, fuel oil burner or dual fuel burner.
c) Circulating pump.
d) Pipe headers.
e) Distribution piping, fittings, valves, strainers, expansion joints and supports.
f) Expansion tank (closed or open).
g) Terminal units and heat exchanger.
h) Breeching and chimney.
i) Water treatment equipment and facilities (where required).
j) Main electrical panel and electric wirings with interlocks.
k) Insulation materials.
l) Automatic controls.

Note:

For a typical boiler room piping layout, reference is made to Attachment 4.

6.2.2 Steam heating system

According to the piping arrangement that supply steam to and returns condensate from the terminal equipment, the steam heating systems can be classified as one-pipe or two-pipe system.

These systems can be sub-divided into:

a) By the method of condensate return (gravity flow or mechanical flow by means of condensate pump or vacuum pump).

b) By the piping arrangement (up-feed or down-feed and parallel or counter flow for one-pipe systems). Steam heating system may be classified into:

i) High pressure (operating pressure above 103 kPa or 15 Psi), low pressure (pressure less than 103 kPa or 15 Psi).

ii) Vacuum or vapor system (when under vacuum and low pressure condition, use of vacuum pump is needed).

6.2.2.1 Steam heating system equipment

Water system equipment as mentioned in clause 6.2.1.4 shall apply, but with addition of necessary steam trap, steam control valves, condensate tank, including necessary steam line accessories and controls.

7. PIPE SIZING

7.1 Hot Water Pipe Sizing

7.1.1 To properly design a water piping system, the designer shall evaluate pressure drop due to pipe friction loss and pressure loss through valves, fittings and other elements. The general range of pipe friction loss used for design of hydronic systems shall be between 100 and 400 Pa/m (4 ft/100 ft). A value of 250 Pa/m (2.5 ft/100 ft) represents the mean to which most systems are designed.

7.1.2 Closed loop systems shall be sized below certain upper limits for velocity, such as a velocity limit of 1.2 m/s (240 fpm) for 50 mm pipe and under. Velocity in excess of 1.2 m/s can be used in piping of larger sizes.

7.1.3 The rate of water flow in a system can be determined by the heat carrying capacity in any particular section of piping. This carrying load depends on the type of piping system. The following equation shall be used to describe rate of water flow for each section:

$$G = \frac{H}{4.18\ w.c\ (t_1 - t_2)} \qquad \text{(Eq. 8)}$$

Where:

G = water flow rate, l/s (gpm).
H = heat carrying capacity, kJ/hr (Btu/h)
W = density of water.
C = specific heat of water, kJ/kg°C (Btu/lb°F)
t_1, t_2 = temperature of water entering and leaving the heating unit, °C (°F).

A 11°C (20°F) temperature drop between heating unit inlet and outlet is extensively used. At this temperature drop, 1 gpm will release (10,000 Btu per hour). So the flow rate for each section can be determined as follows:

in I-P unit : $$G = \frac{H}{10,000} \quad \textbf{(Eq. 9A)}$$

In SI unit : $$G = \frac{H}{42} \quad \textbf{(Eq. 9B)}$$

Where:

H	=	heat carrying capacity, kW (Btu/hr)
G	=	water flow rate, l/s (gpm)

7.1.4 The pipe size for each section can be determined from the volume flow rate and pressure drop.

7.1.5 Designer shall calculate the straight lengths of pipe and additional equivalent length due to fittings,valves and other elements. The straight pipe length shall be measured to the centerline of all fittings and valves.

7.2 Steam Pipe Sizing

Designer shall consider the following principle factors for determining pipe sizes for a given load in steam heating system:

a) The initial operating pressure and the allowable pressure drop through the system.
b) The total equivalent length of pipe in the longest run.
c) The maximum velocity of steam.

Note:

For determining the pressure drop and flow rate in steam pipe sizing reference is made to ASHRAE 1989 Fundamentals volume, chapter 33.

7.3 Gas Pipe Sizing

7.3.1 Piping for natural gas appliances shall be of adequate size and installed so that it provides a supply of gas sufficient to meet the maximum demand without undue loss of pressure between the point of supply and appliance. The size of gas pipe required depends on:

a) Maximum gas consumption to be provided.
b) Length of pipe and number of fittings.
c) Allowable loss in pressure from the outlet of the supply to the appliance.
d) Density (specific gravity) of the gas.

7.3.2 The pipe sizing for gas lines shall be based on the latest publication and edition of the N.I.G.C. Standards.

7.3.3 The maximum pressure drop in gas piping system at low pressure ranges (up to 1.5 kPa), shall be 10% of the initial pressure. Pipe size can be determined by knowing the pressure drop, length of pipe and gas flow rate.

7.3.4 Gas consumption in m^3/h is obtained by dividing the kilocalorie input rate per hour at which the appliance (boiler or furnace) will be operated by the average Kilocalorie heating value per cubic meter of gas.

7.4 Fuel Oil Pipe Sizing

7.4.1 Pipe size must be large enough to maintain low pump suction head and, in the case of circulating loop systems, to prevent over pressure at the burner oil pump inlet. Tables in Attachment 7A give recommended pipe oil pump suction sizes for handling No. 5 and No. 6 oils (residual grades) and No. 1 and No. 2 oils (distillate grades).

7.4.2 Pipe materials must be compatible with fuel used and carefully assembled to eliminate leaks.

PART II
APPLIED EQUIPMENT

8. BOILER SELECTION

8.1 General

8.1.1 Designer shall evaluate boiler gross output, which is equal to sum of total heat load of building, heat loss through piping and tanks and warming-up heat loss of boiler.

8.1.2 In average building heating systems, it is common practice to consider 20% of the heat load to the heat loss through pipes and hot water tank and 10% of the heat load to heat loss through radiation of boilers. Therefore a total of 30% shall be added to the calculated total heat load which shall be considered as net output of the selected boiler.

8.2 Selection Parameter

8.2.1 Selection for all kind of boilers shall be based on a component review of the following parameters:

a) ASME or authoritative international standards code section, under which the boiler is constructed and tested.
b) Net boiler output capacity, in kW (Btu/h).
c) Total heat-transfer surface, m^2 (ft^2).
d) Water content, lb (kg).
e) Auxiliary power requirements, Mj (kwh).
f) Internal water-flow patterns.
g) Cleaning provisions for all heat-transfer surfaces.
h) Operational efficiency.
i) Space requirements and piping arrangement.
j) Water treatment requirements.

8.2.2 For fuel fired boilers the following additional component review shall be considered:

a) Combustion space (furnace volume), m^3 (ft^3)
b) Internal flow patterns of combustion products.
c) Combustion air and venting requirements.

8.2.3 For steam boilers the following additional component review shall be considered:

a) Steam space, m^3 (ft^3)
b) Steam disengaging area, m^2 (ft^2)

9. BURNER SELECTION

9.1 Designer shall select burner suitable with the boiler. Rate of fuel L/h, kg/h or m^3/h (Gal/h) can be calculated from the following equation:

$$G = \frac{H_B}{H_o Z} \qquad \textbf{(Eq. 10)}$$

Where :

G = burner firing rate L/h, kg/h, m^3/h, gal/h or lb/h
H_B = boiler capacity, MJ/hr or Btu/h.
H_o = heating value of fuel, MJ/kg, MJ/m^3 or MJ/l (Btu/gal, Btu/lb).
Z = burner efficiency (0.6 - 0.85).

9.2 Heating calorific values for some typical fuels are as follows:

Natural gas:	H_o	=	**37.26 MJ/m^3 (1000 Btu/ft^3).**
No. 2 oil :	H_o	=	**41.8 MJ/kg (140,000 Btu/gal).**
Nos. 4, 5 and 6 oil :	H_o	=	**47.2 MJ/kg (150,000 Btu/gal).**

9.3 The recommended ventilation requirement suitable for burner combustion air should be based on Attachment 6.

10. FUEL OIL STORAGE TANK

10.1 Capacity of the fuel oil storage tank (F.O.T) can be evaluated by using the degree day method. Degree-days for the building specified region is obtained as follows:

Degree-days = (number of days during heating season) × (18.3°C- outside mean temperature °C)

10.2 The capacity of fuel oil tank for seasonal fuel consumption can be obtained directly from the following:

F.O.T. Capacity = Burner GPH × 4 L/gph × 10 hrs/day × 22 days/month

11. EXPANSION TANK

Expansion tank is the primary device in hot water systems used to accomplish system pressure control (when pressurizing equipment are not applied). These systems are designated as open or closed tank.

11.1 Open Expansion Tank

This system is vented to the atmosphere and limited to installations having operating temperature less than 82°C (180°F). The tank should be at least 0.9 m (3ft) above the highest point of the system and be preferably connected to the suction side of the pump. The minimum tank volume should not be less than or equal to 6% of the total system water volume.

$$V_t = (E_w - E_p) \times V_s \qquad \textbf{(Eq. 12A)}$$

Where:

V_t = volume of expansion tank in gallons

V_s = volume of water in system in gallons

$E_w - E_p$ = unit expansion of the water minus the unit expansion of pipe radiation, boilers, etc.

11.2 Closed Expansion Tank

The size of closed expansion tank is determined by the following ASME formula. This formula should be used when system water temperature operates between 71°C (160°F) and 138°C (280°F).

$$V_t = \frac{(0.00078\,t \quad 0.03348)\,V_s}{\frac{P_a}{P_f} \quad \frac{P_a}{P_o}} \qquad \textbf{(Eq. 12B)}$$

Where :

V_t = minimum volume of the expansion tank, m^3 (ft^3).

V_s = system volume, m^3 (ft^3).

t = maximum average operating temperature,°C (°F).

P_a = pressure in the expansion tank when the water first enters, usually atmospheric pressure.

P_f = initial fill or minimum pressure at tank.

P_o = maximum operating pressure at the expansion tank.

A widely used formula recommended for water temperature below 71°C (160°F) is:

$$V_t = \frac{E}{\frac{P_a}{P_f} - \frac{P_a}{P_o}} \qquad \textbf{(Eq. 12C)}$$

Where:

E = net expansion of the water in the system when heated from minimum to maximum temperature.

Note:

The required minimum pressure (P_f) and the maximum pressure in the expansion tank (P_o) may be changed, depending on the effect of relative pump and tank location.

12. TERMINAL UNITS

12.1 Classification

Terminal units are commonly classified as follows:

1) Natural convection units, which include radiators, cabinet convectors, baseboard and finned-tube units.

2) Forced convection units, include unit heaters, unit ventilators, fan coil units, induction units and air handling units and heating coils in central station units. (Fan coils, unit ventilators and central station units can be used for heating, ventilating and cooling).

3) Radiant panel system, which transfer heat through a controlled surface (such as floor, wall, ceiling).

Note:

For additional information on material specification of various terminal units, reference is made to IPS-M-AR-225.

12.2 Types

12.2.1 Radiators

Radiators are generally confined to sectional large-tube or small tube units. For sizing radiator, the room heat load must be divided by rating per section of the radiators with reference to manufacturer's catalog. After the required number of sections are obtained, a comparison may be performed between different models according to economical consideration. Radiator pipe sizing can be performed by knowing the flow rate.

Radiators can be controlled manually by a globe valve or automatically by means of a circuit balancing valve. Radiators shall be placed at the points of greatest heat loss of the space. For example, such units are commonly located under windows, along exposed walls, and at door openings.

12.2.2 Radiant panels

The following steps shall be used in designing a radiant panel heating system:

1) Calculation of room heat loss.

2) The room heat loss except the floor and edge loss is used to determine the panel size. Total heat loss is used in calculating the amount of water which must be circulated.

3) The type and location of the heating coil shall be floor or ceiling panels or a combination of both may be used. Type of coils may be grid or serpentine type.

4) Required space heat per unit area of floor or ceiling shall be calculated. By knowing the heat transfer coefficient of floor or ceiling and reference to manufacturer's catalogs the panel coil's characteristic and water inlet/outlet temperature can be obtained.

5) Amount of water needed to carry the heating load shall be calculated.

6) Distribution piping shall be sized.

12.2.3 Convectors

12.2.3.1 General

Convectors are available in variety of depths, sizes, lengths and in enclosure or cabinet types. The heating elements are available in fabricated ferrous and nonferrous metals. These may be freestanding, wall-hung or recessed type.

12.2.3.2 Characteristics

A typical convector shall posses the following characteristics:

a) Heating element shall be in copper tube and aluminum smooth fins fixed to the copper tube expanding, and hydraulically tested at minimum pressure of 10 kg/sq. cm.

b) Grill for internal air outlet shall be bent with fins directing air stream and manual damper.

c) Steel sheet casing shall be stove enameled and 12/10 mm min. thickness; front panel completely trip removable for access to the internal part, complete also with rear panel for total enclosure of the equipment.

12.2.3.3 Location

The best location for convectors shall be under windows. Two convectors placed under windows are better than one large convector. Where convectors cannot be located under windows, they shall be placed against outside walls with coldest exposure.

12.2.4 Unit heaters

12.2.4.1 Classification

Unit heaters can be classified according to one or more of the following methods:

1) The heating medium: can be steam, hot water, gas indirect-fired, infrared, oil indirect fired and electric.

2) Types of fan: can be either propeller, centrifugal, or remote air mover. Propeller fan units may be horizontal-blow or down blow. Centrifugal fan units may be of the smaller cabinet type or larger industrial type. Units with remote air movers are known as duct air unit heaters.

3) Arrangement of elements: considered either as the draw-through, in which the fan draws air through, or the blow through, in which the fan blows air through heating element.

12.2.4.2 Application

Unit heaters have relatively large heating capacities in compact casings, the ability to project heated air in a controlled manner over a considerable distance, with a relatively low installed cost. They are used to heat garages, factories, warehouses, show rooms, stores, and laboratories. Unit heaters are also used for spot or intermittent heating, such as blanketing outside doors; also used where filtration of heated air is required.

12.2.4.3 Ratings of unit heaters

It is common to rate unit heaters on the amount of heat delivered by the air above an entering air temperature of 16°C (60°F), rated as follows:

a) The steam unit heaters are based upon dry saturated steam at 13.8 kPa (2 psig) pressure at the heater coil, air at 16°C (60°F) and barometric pressure entering heater, and the heater operating free of external resistance to airflow. The capacity of a heater increases by the steam pressure and decreases by increasing inlet air temperature.

b) Rating of hot water unit heaters is usually based on water at 93°C (200°F), water temperature drop of 11°C (20°F) entering air at 16°C (60°F) and barometric pressure.

12.2.4.4 Type of unit heaters

a) Propeller fan units shall be selected in free-delivery applications where the heating capacity and distribution requirements can best be met by units of moderate output, used singly or in multiples, and where filtration of the heated air is not required.

b) Designer shall select horizontal-blow units in association with low to moderate ceiling heights. Downblow units shall be selected in high-ceiling spaces and where floor and wall space limitations dictate on remote location for the heating equipment. The downblow units shall be selected with either adjustable or revolving diffusers.

c) Industrial centrifugal fan units shall be selected where heating capacities and space volumes are large or where filtration of the heated air or operation against static resistance are required. Downblow or horizontal-blow units can be selected depending on the requirements.

d) Cabinet unit heaters shall be selected for free delivery or low pressure duct applications, may be equipped with filters.

e) Duct heaters shall be selected in systems where there is an air handling unit remote from the unit heater. These heaters provide economical means of adding heating to cooling or ventilating systems through ductwork.

12.2.4.5 Selection of unit heaters

Factors to be considered in the selection of unit heater shall include.

a) The heating media to be employed.
b) The type of unit.
c) The location of unit for proper heat distribution.
d) The permissible sound level.
e) The need for filteration.
f) The heating capacity.

13. BREECHING AND CHIMNEY

13.1 Factors to be considered when selecting chimney materials include: (1) The temperature of gases; (2) Their composition and propersity to condense (dew point); (3) The presence of sulfur, halogens, and other fuels and air contaminants that lead to corrosion; and (4) The operating cycle of the appliance.

13.2 The chimney system design should balance the flow of hot gases against friction losses. For a specified boiler heat load and chimney height, the cross section of circular or rectangular chimney can be estimated by the following empirical relation:

$$A = \frac{Q + 1000}{H\,(25 + 2\sqrt{Q})} \qquad \textbf{(Eq. 13)}$$

Where:

- A = chimney cross section, cm.
- Q = boiler heat load, kcal/hr.
- H = chimney height, m.

13.3 Breeching and chimney (stack) must be sized so that the pressure at the boiler outlet shall be as close to zero as possible. Deviations are not recommended to exceed ±0.5" of water.

14. HEAT EXCHANGER (CONVERTERS)

14.1 Classification

Heat exchanger or converters can be classified into the following general types:

a) Steam to water.
b) Water to water.
c) Water to steam (calorifier).

14.2 Application

Water to water or steam to water heat exchangers (generally shell and tube units) are horizontal or vertical type used in hot water systems to produce low temperature water for certain zones or in process water or domestic water services.

Note:

For design requirements of steam to water and water to steam refer to ASHRAE applications handbook. Reference is also made to IPS-E-ME-220.

14.3 Water to Water Heat Exchanger

14.3.1 Designer shall consider the following:

a) Computing the load requirements.
b) Establishing the flow rate of water through the heat exchanger from the following formula:

$$M^3/H = kw/(1.163 \times Dt) \text{ (usually 17°C) } \quad OR$$
$$GPM = Btu/hr/(8.33 \times 60 \times Dt) \text{ (usually 30°F)}$$

c) The entering heating water shall be kept at least 11°C (20°F) in temperature less than the desired leaving water temperature of the water to be heated.

14.3.2 The manufacturer's catalog for the water pressure drop through the tubes of the converter shall be consulted.

14.3.3 The velocity of the water through the tubes shall be minimum of 0.305 m/sec (1ft/sec)and a maximum of 1.5 m/sec (5ft/sec).

14.3.4 The converter tubes shall be selected on the basis of maximum fouling factor for closed systems and for domestic heating systems.

14.3.5 Design requirements

14.3.5.1 The heating coil shall be specified to heat the required flow of the domestic hot water recovery. The domestic water shall be heated from 4.4°C to 60°C (40°F to 140°F).

14.3.5.2 The heat required shall be:

M^3/H (recovery) × 1.163 × Dt (usually 55°C)   OR
GPM (recovery) × 8.33 × 60 × Dt (usually 100°F)

14.3.5.3 The heating water shall preferably enter at 93°C (200°F) and leave at 76.6°C (170°F).

14.3.5.4 Converters shall be constructed of black carbon steel sheets for a working pressure of 1102 kPa (160 psi) in the shell, and 1102 kPa (160 psi) in the tubes.

15. CENTRIFUGAL PUMPS

15.1 Applications

Major application for pumps in the central heating system are:

- Heating water circulation pumps.
- In line circulator for the services (plumbing fixtures).
- Condensate pumps.
- Boiler feed pumps.
- Fuel oil pumps.
- Water pumps for terminal units.

Note:

Where the pumps are to handle hot liquids or have light inlet pressure drops, care shall be taken to see that the required net positive suction head (NPSH) does not exceed the NPSH available on the pump.

15.2 Circulating Pump

For these pumps, the flow rate in m^3/h (gpm) shall be computed (refer to Clause 7.1). Friction loss in all piping and elements in heating system shall be defined as a friction head. By refering to manufacturer's performance (head versus flow rate) curve, the appropriate pump can be selected. Motor size shall be based on 20% increase in calculated pump power.

Note:

For additional information on material specification of pumps, reference is made to M-PM-115 and M-AR-225.

16. WATER TREATMENT

16.1 General Consideration

Designer shall consider the following factors:

a) The potential hazards associated with any particular water treatment chemical program shall be handled by qualified and experienced personnel.

b) Suitable safety rules shall be formulated.

c) Appropriate safety equipment shall be supplied.

d) The safety program shall be enforced at all times to avoid injury or equipment damage.

e) Contamination of drinking water by non-potable or untreated waters shall be prevented by eliminating cross-connections between systems, through provisions of necessary backflow preventers.

f) Disposal of water treated with some chemicals into municipal sewers or into streams or lakes can be restricted.

g) Pollution control regulations shall be consulted when selecting water treatment.

16.2 Corrosion Control

16.2.1 Corrosion damage to water systems can be minimized by using corrosion resistant construction materials, providing protective coatings to separate the water from the metal surfaces of the equipment, removing oxygen from the water or altering the water composition by adding corrosion inhibitors and pH control chemicals.

16.2.2 The minimum concentration required can be from 200 (as sodium chromate) to 2000 mg/l (ppm).

Note:

Heating systems do not generally suffer from the effects of biological growths, because their operating temperatures are sufficient to kill the organisms involved.

16.3 Selection of Water Treatment

Designer shall consider the following factors for selection of water treatment:

a) The chemical analysis of water.
b) Economic parameter.
c) Other non-chemical influences such as the design of individual major system components, equipment operation and human factors (the quantity and quality of operating personnel available).

Note:

For additional information on water treatment, reference is made to IPS-E-CE-350 and ASHRAE 1991 Application volume, chapter 43.

PART III

ATTACHMENTS

(The Attachments are for information purposes and do not form part of this Standard)

ATTACHMENT 1
OUTDOOR DESIGN WINTER TEMPERATURES

CITY NAME	MINIMUM TEMP. °C	(°F)	AVERAGE WIND VELOCITY M/S
AGAJARI	4.4	(40)	4.5
AHWAZ	1.3	(34)	2.1
ARAK	- 17.3	(1)	4.6
AROOMIEH	- 15.8	(3.2)	3.7
BANDAR ABBAS	8.6	(48)	3
BAKHTARAN	- 12.3	(10.5)	4.4
ESFAHAN	- 8.7	(16.5)	3.8
GACHSARAN	- 1.1	(30)	4.5
HAMEDAN	- 21.6	(-6)	4.9
ILAM	- 6.4	(20)	8.1
KERMAN	- 8.5	(16.5)	5.2
KHARGH	11	(52)	3.0
KHORRAM ABAD	- 4.8	(23)	2.1
MASHHAD	- 13.4	(8)	4
MASJID SOLEIMAN	1.7	(35)	4.8
NOWSHAHR	- 5.9	(21)	3.6
RASHT	- 6.3	(21.2)	2.8
SHIRAZ	- 5.1	(23)	2.8
SHAHRE KORD	- 20.1	(-4)	4.1
SEMNAN	- 8.2	(17)	5
SARI	- 5	(23)	7
SANANDAJ	- 18.3	(-1)	3
TEHRAN	- 9.5	(15)	6
TABRIZ	- 15.9	(3.5)	2.9
YAZD	- 8	(17.6)	3
ZAHEDAN	- 6.1	(21)	4
ZANDJAN	- 19.5	(-3)	3.5

ATTACHMENT 2
RECOMMENDED INDOOR DESIGN DRY-BULB TEMPERATURES

Winter Indoor Dry-Bulb Temperatures Usually Specified*

Type of building	°F
SCHOOLS—	
Classrooms	72–74
Assembly rooms	68–72
Gymnasiums	55–65
Toilets and baths	70
Wardrobe and locker rooms	65–68
Kitchens	66
Dining and lunch rooms	65–70
Playrooms	60–65
Natatoriums	75
HOSPITALS—	
Private rooms	72–74
Private rooms (surgical)	70–80
Operating rooms	70–95
Wards	72–74
Kitchens and laundries	66
Toilets	68
Bathrooms	70–80
THEATERS—	
Seating space	68–72
Lounge rooms	66–72
Toilets	68
HOTELS—	
Bedrooms and baths	75
Dining rooms	72
Kitchens and laundries	66
Ballrooms	65–68
Toilets and service rooms	68
HOMES	73–75
STORES	65–68
PUBLIC BUILDINGS	72–74
WARM AIR BATHS	120
STEAM BATHS	110
FACTORIES AND MACHINE SHOPS	60–65
FOUNDRIES AND BOILER SHOPS	50–60
PAINT SHOPS	80

ATTACHMENT 3
HEATING LOAD ESTIMATE SHEET

HEATING CONDITIONS	TEMPERATURE OF AIR ENTERING UNIT
ROOM ______ D.B. ______ W.B. ______ % R.H. ______ GR/LB	______ % OUTSIDE AIR X ______ °F = ______ °F
OUTSIDE ______ D.B. ______ W.B. ______ % R.H. ______ GR/LB	______ % RECIRCULATED AIR X ______ °F* = ______ °F
DIFF. ______ °F DIFF. ______ GR/LB	TOTAL (AVERAGE ENTERING AIR TEMP.) = ______ °F
	*ROOM TEMP. PLUS TEMP. CORRECTION FOR HT. OF UNIT

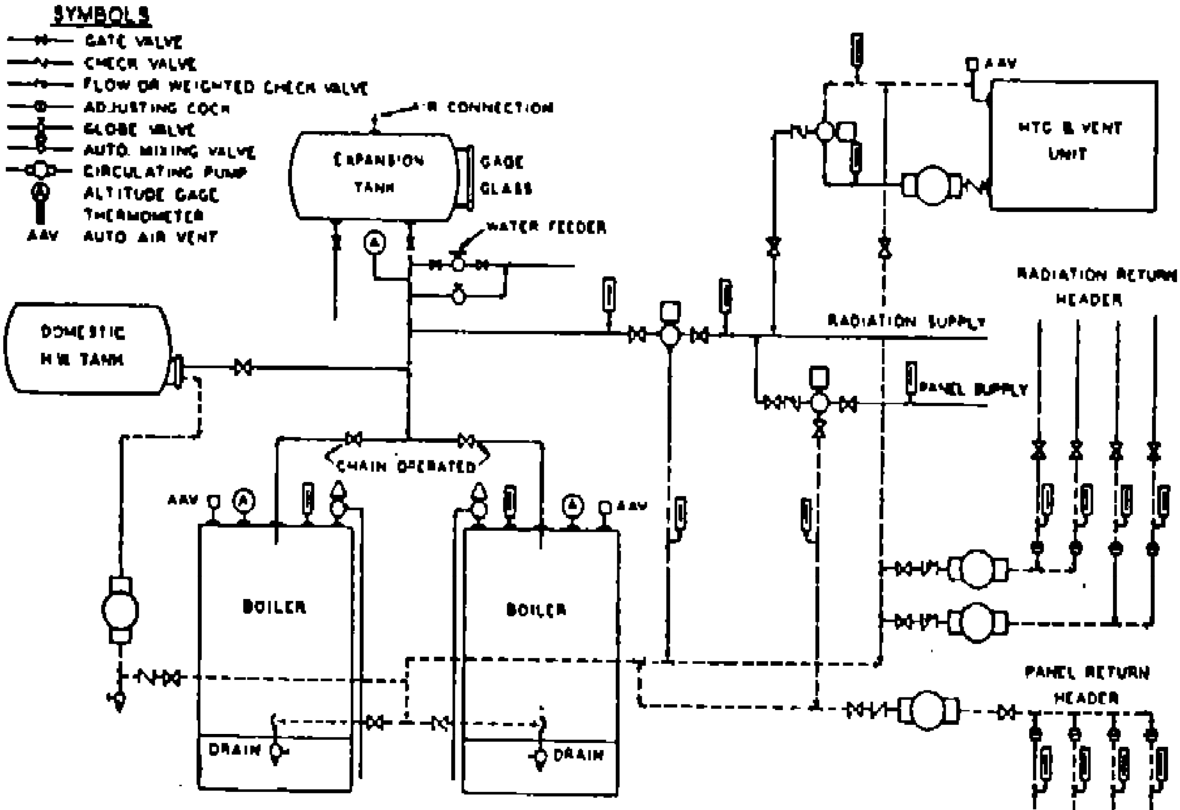
SURFACE	SQ FT	TRANS. FACT.	BTU PER HR PER °F DIFF.	TOTAL BTU PER HR °F DIFF.	TEMP. DIFF.	TOTAL BTU PER HOUR

INFILTRATION				TOTAL TRANSMISSION LOSS	
	CRACK METHOD	AREA METHOD	C F M	X TEMP. GRADIENT FACTOR ______	
WINDOW	______ LIN. FT X ______	______ SQ FT X 0.0		OUTSIDE AIR ______ CFM X ______ °F X 1.08	
SKYLIGHT	______ LIN. FT X ______	______ SQ FT X 0.0		INFILTRATION ______ CFM X ______ °F X 1.08	
DOOR	______ LIN. FT X	______ SQ FT X		SUBTOTAL	
DOOR USAGE	______ SQ. FT X	______ SQ FT X		SAFETY FACTOR ______ %	
		TOTAL		GRAND TOTAL HEAT LOSS	
AIR CHANGE METHOD			C F M	HUMIDIFICATION	WATER EVAPORATED
______ CU FT X { ______ MAX. / ______ MIN. } CHANGES/HR ÷ 60			MAX. ______ MIN. ______	(CFM INFIL. + CFM OA) (GR/LB DIFF.) ÷ 1550	______ LB/H

EQUIPMENT CHOICE

QUAN.	UNIT SIZE	RPM	CFM	FIN. TEMP. F.	BASIC RATING	BTU CONSTANT	INSTALLED CAPACITY	STEAM COND'S. LB/HR	HOT WATER G P M	CU FT GAS/HR

ATTACHMENT 4
TYPICAL BOILER ROOM PIPING



Boiler Piping for Multiple-Zone Multiple-Purpose Heating System

ATTACHMENT 5
FUEL - OIL (PUMP SUCTION) PIPE SIZING

RECOMMENDED SIZES (mm) FOR SUCTION LINES FROM TANK TO PUMP (FOR RESIDUAL GRADES Nos. 5 AND 6)

Pumping Rate, L/h	Maximum Suction Lift = 4.5 m									
	Length of Run, m									
	10	20	30	40	50	60	70	80	90	100
50	40	40	40	50	50	50	65	65	65	80
100	40	40	50	50	65	65	65	65	80	80
200	40	50	50	50	65	65	65	80	80	80
300	50	50	65	65	65	80	80	80	80	80
400	50	50	65	65	80	80	80	80	80	100
500	50	65	65	65	80	80	80	80	100	100
600	65	65	65	80	80	80	100	100	100	100
700	65	65	65	80	80	100	100	100	100	100
800	65	65	80	80	100	100	100	100	100	100

Pipe sizes smaller than 25 mm ISO are not recommended for use with residual grade fuel oils.
Lines conveying fuel oil from pump discharge port to burners and tank return may be reduced by 1 or 2 sizes, depending upon piping length and pressure losses.

RECOMMENDED SIZES (mm) FOR SUCTION LINES FROM TANK TO PUMP (FOR DISTILLATE GRADES Nos. 1 AND 2)

Pumping Rate, L/h	Maximum Suction Lift = 3m									
	Length of Run, m									
	10	20	30	40	50	60	70	80	90	100
50	15	15	15	15	15	20	20	20	25	25
100	15	15	15	15	20	20	20	20	25	25
200	15	20	20	20	20	20	25	25	25	25
300	15	20	20	20	20	25	25	25	25	32
400	20	20	20	20	25	25	25	25	32	32
500	20	25	25	25	25	25	32	32	32	32
600	20	25	25	25	25	32	32	32	32	50
700	20	25	25	25	25	32	32	32	50	50
800	20	25	25	25	32	32	32	32	50	50

ATTACHMENT 6
RECOMMENDED MINIMUM AREA OF BOILERHOUSE OPENINGS FOR VENTILATION

EVAPORATION LBS/hr	MINIMUM AREA SQ FT
2000	1.16
2500	1.45
3000	1.74
3500	2.03
4000	2.32
4500	2.61
5500	3.19
6500	3.77
7500	4.35
8500	4.93
9500	5.51
10500	6.09
11500	6.67
12500	7.25
13500	7.83
14500	8.41
15500	8.99
16500	9.57
17500	10.15
18500	10.73
20000	11.6
22500	13.05
25000	14.50
27500	15.95
30000	17.40
35000	20.30

Notes:

1) Rule of Thumb Method:

To ensure an adequate supply of air for combustion, the room in which the burner is installed shall have permanent ventilation source in order of at least 5.5 cm^2 per kw of Boiler output.

2) Minimum area calculated by formula: $\frac{EVAPORATION \times 2}{3450}$ = Square Feet