AN ABSTRACT OF THE THESIS OF

KAMRAN A. OZIPEK for the MS in Mech. Eng.
(Name) (Degree) (Major)

Date Thesis presented March 18, 1948

Title SPECIAL DESIGN FEATURES OF A STEAM HEATING INSTALLATION IN ISTANBUL, TURKEY

Abstract Approved Wallace H. Martin Wallace H. Martin
(Major Professor)

This thesis presents the design of a low pressure two-pipe, overhead steam heating system. It suggests the special design features of this type of heating system which is to be installed in a four story industrial building in the city of Istanbul, Turkey.

The determination of the heat loss for each room, floor and for the entire building was based on the following sources: (1) heat loss through walls; (2) heat loss through windows and doors: (3) heat loss through floors, ceilings and roof; (4) infiltration loss; (5) heat loss due to exposure to south. When necessary allowances which are the arbitrary safety factors were added to the computed heat loss. Fourier's Law of Heat Conduction for the steady state condition was used in the determination of the heat loss. The formula used is as follows:

$$Q - UAdt$$

where,

Q = amount of heat flowing, Btu/hr.
U = overall heat transfer coefficient, Btu/hrFft^2.
A = cross sectional area measured perpendicular to heat flow, ft^2.
dt= temperature difference, ^{o}F

The effect of infiltration loss was determined with the use of the following formula.

$$Q = \frac{Cndt}{55.2}$$

where,

C = cubic contents of the room, ft^3.
n = number of changes per hour.

Radiator sizes were determined after the computation of heat loss for each room (equivalent sq.ft. of radiation surface). The small tube, cast-iron, free standing radiators were used since they are reasonably low in price, desirable and withstand corrosion.

The determination of pipe sizes required the calculation of average pressure drop in the piping system. In order to compute the average pressure drop, first, the longest steam flow path was ascertained and its total equivalent length was determined. Then

5 percent of the total equivalent length was added as an allowance for the fittings since the fittings also offer a resistance to flow of steam. Assuming an initial steam pressure of 2 lb. at the boiler, and also a pressure drop of 0.5 lb. through the system, the average pressure drop was determined, since average pressure drop is equal to the pressure drop through the system divided by the total equivalent length of the longest steam flow path. Then the pipe sizes were selected by the use of chart in Figure 135 in "Heating and Air Conditioning" by Allen, Walker and James, to give as nearly as possible the average pressure drop determined.

For the purpose of efficient operation both the steam piping and the condensate return piping systems were divided into two zones. These zones could be shut down for any reason, such as the failure of apparatus somewhere along its length so that it won't effect the service of the other zone, thus causing the unnecessary shut-down of the whole system. For the conveying of steam and condensate mild-steel "Schedule 40" pipe was used. Wrought-iron pipe was used where the condensate return pipes were buried in soil. Problems of elimination of water hammer and hissing sound were discussed.

Selection of the boiler required the determination of the following design features: (1) design load; (2) maximum load; (3) sq. ft. of heating surface; (4) steam rate; (5) coal consumption; (6) cost of coal. A steel (West Coast), hand fired boiler was selected and its specifications were included in the text of the thesis. Piping connections to and from the boiler were made and the boiler details were studied.

Cast-iron, screwed fittings to be used in the particular design were outlined and their specifications were included. The radiator valves for steam were of the "corner" pattern type having side inlets. They were provided with unions for connecting to the radiators. Their sizes were selected as were the down-risers connecting to the radiators. In order to drain the water from the radiator without allowing steam to escape thermostatic traps of the bellows type were used. In order to promote rapid circulation air vent valves were installed at the ends of mains and the tops of long upfeed risers. The reduction in pipe sizes were made by using eccentric reducers in order to eliminate the possibility of steam pockets that might form at the sections. Proper provision was made for the linear expansion of the steam piping by the use of pipe bends.

Pipe coverings for the steam pipes which are not used to aid in heating rooms and for the buried condensate piping were discussed. Problems of maintenance and 20 requirements for efficient operation and fuel conservation were outlined.

References used in support of this thesis had their sources in: articles; technical journals; bulletins; tables and charts published by American Society of Heating and Ventilating Engineers, and other United States and Turkish publishers.

SPECIAL DESIGN FEATURES OF A STEAM HEATING INSTALLATION IN ISTANBUL, TURKEY

by

KAMRAN ABDURRAHIM OZIPEK

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1948

APPROVED:

Wallace H. Martin

Professor of Mechanical Engineering

In Charge of Major

Head of Department of Mechanical Engineering

Chairman of School Graduate Committee

W Weniger

Dean of Graduate School

ACKNOWLEDGEMENT

The author wishes to express his grateful appreciation for the valuable assistance rendered by the many persons cooperating in this study. He is particularly indebted to W. H. Martin, Professor of Mechanical Engineering, Oregon State College, whose guidance and generous help made this thesis possible; to S. H. Graf, Head of the Department of Mechanical Engineering, Oregon State College; to Professor A. H. Taspinar, Consulting Engineer, Istanbul, Turkey, for their thoughtful criticism and recommendations; and finally, to those men who assisted indirectly through their contributions to technical publications.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

SPECIAL DESIGN FEATURES OF A STEAM HEATING INSTALLATION IN ISTANBUL, TURKEY

INTRODUCTION

This paper presents the design of a low pressure two-pipe, overhead steam heating system. It suggests the special design features of this type of heating system which is to be installed in a four story industrial building in the city of Istanbul, Turkey. This treatise additionally, illustrates that a small sized heating system, operating at a relatively low pressure, deserves the same elements of careful design as a large heating system in the high pressure field.

Availability of materials and equipment, noiseless and efficient operation, maintenance, fuel conservation and workmanship have been the foremost considerations in this design since the author's main purpose is to install this system in a foreign country. A survey of the above items suggested the use of small tube cast-iron -- free standing radiators, and mild steel "Schedule 40" pipe for the conveying of steam and condensate. They are reasonably low in price, desirable and withstand corrosion. The other materials and types of equipment selected will be introduced in the text together with the necessary information and suggestions.

A study of climatic reports in Istanbul, Turkey showed the following temperature conditions.

Small rooms and offices	70 deg.F.
Assembly rooms, laboratories and shops	65 deg.F.
Corridors	50 deg.F.
Outside temperature	40 deg.F.
Ground temperature	35 deg.F.

In computing the heat losses from the entire building, first floor serving as the basement floor is considered to have no heat loss.

References used in support of this design have their source in: articles; technical journals; bulletins; tables and charts published by American Society of Heating and Ventilating Engineers, and other United States and Turkish publishers.

SOURCES OF HEAT LOSS

The determination of the heat loss from each room in the building is of basic importance in heating - system design. The calculated heat loss is used to determine the radiator sizes, which in turn fix the pipe sizes and the size of the boiler.

The loss of heat from a building takes place in several ways. The greatest loss is through the walls and windows. The heat flows through these materials at varying rates depending upon their conductivity and thickness, and is dissipated from the outer surfaces of the building by ways of heat transmission i.e. by convection and by radiation. There is also a large amount of heat lost by the infiltration of air. From the surfaces buried in the ground, heat is lost by conduction to the earth. There are also some minor sources of loss such as exposure to south and others which will be mentioned in the course of the design procedure. The calculation of each of these above mentioned items is made separately and the net heat loss for each room, floor and for the entire building is obtained. The net loss for each room is shown in Table 2. The net heat loss for each floor and for the entire building will be presented at the end of this section after the discussion of the following points.

In order to compute the heat loss through walls, Fourier's Law of Heat Conduction for the steady state condition is used. Fourier's Law for steady state conditon states that the amount of heat "Q" flowing in a unit time from one surface to the other surface of the wall is proportional to the cross sectional area "A", measured perpendicular to the direction of flow, to the temperature difference "dt", and inversely proportional to the thickness "x". This may be expressed as:

$$Q = k\frac{Adt}{x} \qquad (1)$$

where "k" is an experimentally determined proportional constant, called the thermal conductivity.

Suppose the thickness "x" of the wall be composed of a series of sections of varying thicknesses x_1, x_2, x_3,....x_n and different materials of which the conductivities are k_1, k_2, k_3, ... k_n.

Equation (1) may be written as: (2)

$$Q = \frac{k_1(t_1-t_2)}{x_1} A = \frac{k_2(t_2-t_3)}{x_2} A = \frac{k_n(t_{n-1}-t_n)}{x_n} A$$

since for the steady state condition the flow of heat is constant through the wall.

Dividing each equation in (2) by the respective quantity $\frac{kA}{x}$ yields:

$$\frac{Q}{A}\ \frac{x_1}{k_1} = t_1 - t_2$$

$$\frac{Q}{A}\ \frac{x_2}{k_2} = t_2 - t_3$$

$$\vdots \qquad\qquad \vdots$$

$$\frac{Q}{A}\ \frac{x_n}{k_n} = t_{n-1} - t_n$$

adding

$$\frac{Q}{A}\left(\frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots\ldots \frac{x_n}{k_n}\right) = t_1 - t_n \tag{3}$$

Rearranging terms in (3) and solving for the rate of heat flow "Q".

$$Q = \frac{(t_1 - t_n)}{\frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots\ldots \frac{x_n}{k_n}}\ A$$

or

$$Q = UAdt \tag{4}$$

where

dt = difference of temperature between the two surfaces of the wall.

and

$$U = \frac{1}{\frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots \frac{x_n}{k_n}}$$

is the overall transfer coefficient.

The heat loss through walls is computed with the use of equation (4). The value of the overall transfer coefficient "U" for each type of wall have been determined and is included in the design. The heat loss through windows, doors, floors, ceilings and roof is calculated by applying their respective overall transfer coefficients into the equation (4). When necessary, other special factors in connection with the above mentioned computations will be added and illustrated in the course of the design.

One method of computing the effect of infiltration is to figure the heat loss on the basis of a certain number of air changes per hour. The loss from this source may be expected as follows:

$$Q = \frac{Cndt}{55.2}$$

where

Q = heat required per hour to supply loss due to infiltration.

C = cubic contents of the room.

n = number of changes per hour.

dt = difference of temperature between the temperature of the room and the temperature of the outside air.

The factor 55.2 is equal to 1/(0.2415 x 0.0749) and is the number of cubic feet of air that 1 Btu will raise 1 degree F, where 0.2415 is the specific heat of air at constant pressure, and 0.0749 is the weight of 1 cu. ft. of dry air at 70 degrees F.

Exposure allowances are arbitrary safety factors. They were more necessary in former years than they are today when methods of calculation are more exact. However for the purpose of safety in this design, the heat loss due to exposure to south is taken as 15 percent of the total loss through the exposing surfaces.

Another correction factor required is to provide for warming up the building quickly after it has been allowed to cool down. In the determination of the size of the boiler for the system this factor will be included later as a certain percentage of the heating load. Additionally an allowance should be added to the computed heat loss through walls, windows, doors, and roof for the entire building. This allowance is taken as 10 percent of the above mentioned load.

In the following pages for the purpose of illustration the computation of net heat loss for rooms number 1, 4, 7, 10 and 13 are shown. The main reason for taking these rooms as illustrations lies in the fact that they have characteristics of the above mentioned sources of heat loss.

As was mentioned before the net heat loss for each room is shown in Table 2, second column. The net heat loss for each floor and for the entire building is included in the following table.

HEAT LOSSES

Floor	Net Heat Loss Btu per hr.
First	None
Second	102,888
Third	152,934
Fourth	205,714

Total heat loss for the Building:[1]

508,000 Btu/hr

1 This result includes the safety allowance of 10 percent

OVERALL COEFFICIENTS OF HEAT TRANSFER, "U"

Outside Walls:(2)

$$U^1 = \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{f_o}}$$

where:

f_i = surface resistance for air in contact with the inside walls Btu/hr F ft^2 per in. (based on still air).

x_1 = thickness of plaster, in.

k_1 = conductivity of plaster (gypsum), Btu/hr F ft^2 per in.

x_2 = thickness of brick, in.

k_2 = conductivity of brick (common), Btu/hr F ft^2 per in.

x_3 = thickness of granite, in.

k_3 = conductivity of granite, Btu/hr F ft^2 per in.

f_o = surface resistance for air in contact with the outside walls, Btu/hr F ft per in. (based on an outside wind velocity of 15 mph)

$$U = \frac{1}{\frac{1}{1.65} + \frac{1}{3.3} + \frac{10.5}{5.0} + \frac{10.5}{14.0} + \frac{1}{6.0}}$$

$U = 0.255$ Btu/hr F ft^2

1 See Figure 1. Same nomenclature will be used in the determination of overall coefficients on the following pages, unless otherwise indicated

Inside Walls:[2]

Type "a".

$$U^1 = \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{1}{f_i}}$$

$$= \frac{1}{\frac{1}{1.65} + \frac{1}{3.3} + \frac{5.0}{5.0} + \frac{1}{1.65}}$$

$U = 0.355$ Btu/hr F ft^2

Type "b".

$$U^2 = \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{f_i} + \frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{f_i}}$$

$$= \frac{1}{\frac{1}{1.65} + \frac{1}{3.3} + \frac{1}{1.65} + \frac{1}{1.65} + \frac{1}{3.3} + \frac{1}{1.65}}$$

$U = 0.330$ Btu/hr Ft^2

Floors and Ceilings:[1]

Type of flooring:

1. Parquet flooring in mastic or concrete.
2. 1/2 in. plaster applied to under side of concrete.
3. Thickness of concrete - 8 in.

$U = 0.37$ Btu/hr F ft^2

1 See Figure 2
2 See Figure 3

This coefficient is based on still air - no wind - conditions on both sides of floors and ceilings.

Roof:[1]

Type of roofing:

1. Insulation on top of deck.
2. 1 in. insulating board covered with built-up roofing.
3. Thickness of roof deck - 6 in.
4. Flat roof.
5. No ceiling - underside of roof exposed.

$U = 0.22$ Btu/hr F ft^2

This coefficient is based on an outside wind velocity of 15 M.P.H.

Windows, Skylights and Outside Doors:[1]

Coefficient of transmission, $U = 1.13$ Btu/hr F ft^2

This coefficient is based on a wind velocity of 15 m.p.h.

Inside Doors:[1]

Type:

1. Nominal thickness = 1 in.
2. Actual thickness = 25/32 in.
3. Solid wood doors.

Coefficient of transmission, $U = 0.69$ Btu/hr F ft^2

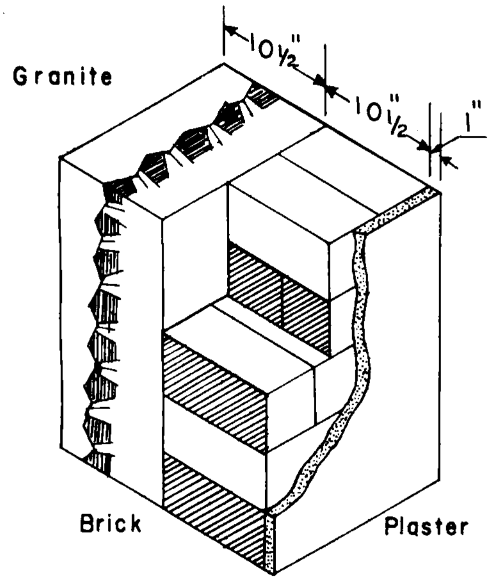


FIG. 1— OUTSIDE WALLS

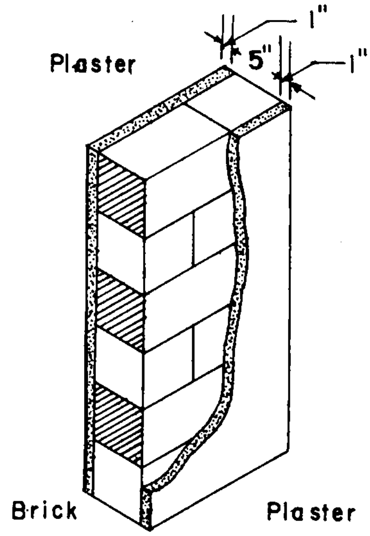


FIG. 2— INSIDE WALLS

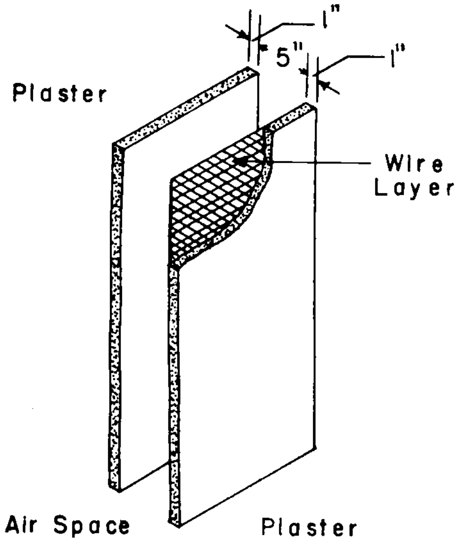


FIG. 3— INSIDE WALLS

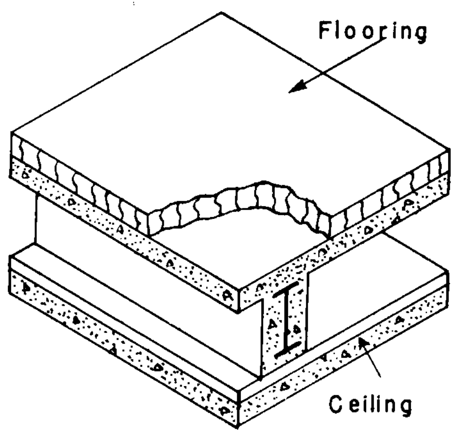


FIG. 4— FLOORS & CEILINGS

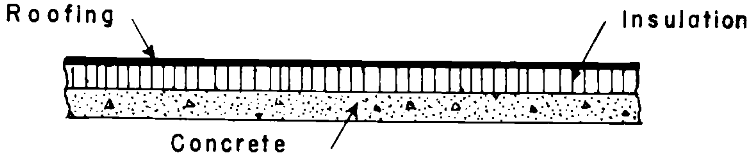


FIG. 5— ROOF

PLATE No.1

TABLE 1 - SIZES OF WINDOWS AND DOORS

Windows			Doors		
Type	Length ft.	Height ft.	Type[1]	Length	Height
B	4.9	3.3	A	4.6	9.1
D	6.9	7.7	C	6.6	8.0
F	2.8	7.7	D	6.9	7.7
G	7.0	4.0	E	8.7	11.3
H	7.2	9.2	J&K	3.0	7.6
I	7.2	12.1	L	10.2	11.7
M	16.7	9.2	O	6.9	12.1
N	10.7	9.2	P	3.0	6.9
R	5.8	2.7	Q	6.3	7.2
S	6.9	6.3	V	5.3	7.3
T	16.8	7.5	X	2.0	7.6
U	10.3	6.5	Y	6.0	9.5
W	3.0	2.7	Z	5.9	10.0
			z	7.2	7.6

1 Sizes of doors J&K are the same although they have variations in their shapes

DETERMINATION OF HEAT LOSSES

Second Floor

Room #1

I. Heat loss through walls of Room #1

1. Towards South-East:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 15.4 \times 13.1 - 7.2 \times 9.2 = 135.7$ ft^2

$= 0.255 \times 30 \times 135.7$

$Q = 1039$ Btu/hr

2. Towards Corridor:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 70 - 50 = 20$ F

$A = 34.8 \times 13.1 - 2 \times 3.0 \times 7.6 = 410.4$ ft^2

$= 0.355 \times 20 \times 410.4$

$Q = 2915$ Btu/hr

3. Towards WC:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 70 - 50 = 20$ F

$A = 15.4 \times 13.1 = 201.5$ ft^2

$= 0.355 \times 20 \times 201.5$

$Q = 1432$ Btu/hr

4. Towards North-East, to the ground:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 70 - 35 = 35$ F

$A = 34.8 \times 13.1 = 456$ ft^2

$= 0.255 \times 35 \times 456$

$Q = 4065$ Btu/hr

II. Heat loss through windows and doors of room #1

A. Loss through windows:

1. "H"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 7.2 \times 9.2 = 66.24$ ft^2

$= 1.13 \times 30 \times 66.24$

$Q = 2247$ Btu/hr

B. Loss through doors:

1. "J"

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 70 - 50 = 20$ F

$A = 2 \times 3.0 \times 7.6 = 45.6$ ft^2

$= 0.69 \times 20 \times 45.6$

$Q = 630$ Btu/hr

III. Heat loss through floor and ceiling of Room #1

A. Loss through floor:

1. Loss through floor to the ground: [1]

$Q = UAdt$

$U = 0.37$ Btu/hr F ft^2

$dt = 70 - 35 = 35$ F

$A = 34.8x(70.2-54.1) = 560$ ft^2

$= 0.37 \times 35 \times 560$

$Q = 7250$ Btu/hr

B. Loss through ceiling:

$Q = UAdt$

$U = 0.37$ Btu/hr F ft^2

$dt = 70 - 65 = 5$

$A = 34.8 \times 15.4 = 536$ ft^2

$= 0.37 \times 5 \times 536$

$Q = 990$ Btu/hr

IV. Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$C = 34.8 \times 15.4 \times 13.1 = 7010$ ft^3

$n = 1$ change/hr

$dt = 70 - 50 = 20$ F

$$= \frac{7010 \times 1 \times 20}{55.2}$$

$Q = 2540$ Btu/hr

1 See plan view, plate #6, for dimensions

V. Heat loss due to exposure to south

Loss through walls, S. E. - 1039x1.15 = 1192

Loss through windows, S.E.- 2247x1.15 = 2582

Loss due to exposure to south = 3774 Btu/hr

Total loss from Room #1

Q = 26,882 Btu/hr

Room #4 - WC -

I. Heat loss through walls of Room #4

1. Towards corridor:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 15.4 \times 13.1 - 3.0 \times 7.6 = 178.7$ ft^2

$= 0.355 \times 15 \times 178.7$

$Q = 950$ Btu/hr

2. Towards stairway:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 9.9 \times 13.1 = 129.8$ ft^2

$= 0.355 \times 15 \times 129.8$

$Q = 690$ Btu/hr

3. Towards North-West:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 15.4 \times 13.1 - 10.7 \times 9.2 = 103$ ft^2

$= 0.255 \times 25 \times 103$

$Q = 656$ Btu/hr

4. Towards North-East, to the ground:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 65 - 35 = 30$ F

$A = 9.9 \times 13.1 = 129.8$ ft^2

$= 0.255 \times 30 \times 129.8$

$Q = 991$ Btu/hr

II. Heat loss through windows and doors of Room #4

A. Loss through windows:

1. "N"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 10.7 \times 9.2 = 98.5$ ft^2

$= 1.13 \times 25 \times 98.5$

$Q = 2785$ Btu/hr

B. Loss through doors:

1. "J"

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3.0 \times 7.6 = 22.8$ ft^2

$= 0.69 \times 15 \times 22.8$

$Q = 236$ Btu/hr

III. Heat loss through floor and ceiling of Room #4

A. Loss through floor:

1. Loss through floor to the ground:

$Q = UAdt$

$U = 0.37$ Btu/hr F ft^2

$dt = 65 - 35 = 30$ F

$A = 9.9 \times 16.1 = 159.3$ ft^2

$= 0.37 \times 30 \times 159.3$

$Q = 1768$ Btu/hr

B. Loss through ceiling:

None, since "dt" is zero

IV. Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$C = 15.4 \times 9.9 \times 13.1 = 1996$ ft^3

$n = 3$ change/hr

$dt = 65 - 50 = 15$ F

$$= \frac{1996 \times 3 \times 15}{55.2}$$

$Q = 1628$ Btu/hr

V. Heat loss due to exposure to south

None

Total loss from Room #4

$Q = 9{,}704$ Btu/hr

Third Floor

Room #7

I. Heat loss through walls of Room #7

1. Towards South-East:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 21.3 \times 13.1 - 7.2 \times 9.2 = 212.8$ ft^2

$= 0.255 \times 25 \times 212.8$

$Q = 1359$ Btu/hr

2. Towards South-West:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 34.7\times13.1-7.2\times9.2-16.7\times9.2 = 234.6$ ft^2

$= 0.255 \times 25 \times 234.6$

$Q = 1498$ Btu/hr

3. Towards North-West:

a. To corridor:

$Q = UAdt$

$U = 0.33$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3.0 \times 13.1 - 3.0 \times 6.9 = 18.6$ft^2

$= 0.33 \times 15 \times 18.6$

$Q = 92$ Btu/hr

4. Heat gain from Room #8

$Q = UAdt$

$U = 0.33$ Btu/hr F ft^2

$dt = 70 - 65 = 5$ F

$A = 16.6 \times 13.1 = 217.5$ ft^2

$= 0.33 \times 5 \times 217.5$

$Q = 358$ Btu/hr

5. Towards North-East:

None, since "dt" is zero

II. Heat Loss through windows and doors of Room #7

A. Loss through windows:

1. "H"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 2 \times 7.2 \times 9.2 = 132.5$ ft^2

$= 1.13 \times 25 \times 132.5$

$Q = 3740$ Btu/hr

2. "M"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 16.7 \times 9.2 = 153.6$ ft^2

$= 1.13 \times 25 \times 153.6$

$Q = 4340$ Btu/hr

Total loss through windows

$= 8080$ Btu/hr

B. Loss through doors:

1. "P"

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3.0 \times 6.9 = 20.7$ ft^2

$= 0.69 \times 15 \times 20.7$

$Q = 215$ Btu/hr

III. Heat loss through floor and ceiling of Room #7

A. Loss through floor:

1. None

2. Heat gain through floor from Room #2, 2nd Floor

$Q = 1025$ Btu/hr

B. Loss through ceiling:

None, since "dt" is zero

IV. Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$C = 34.7 \times 21.3 \times 13.1 = 9680$ ft^3

$n = 1\text{-}1/2$ change/hr

$dt = 65 - 40 = 25$ F

$$= \frac{9680 \times 1.5 \times 25}{55.2}$$

$Q = 6575$ Btu/hr

V. Heat loss due to exposure to south

Loss through walls, S. E.= 1359x1.15= 1562

Loss through walls, S. W.= 1498x1.15= 1720

Loss though windows = 8080x1.15= 9292

Loss due to exposure to south

= 12,574 Btu/hr

Net loss from Room #7 = 30393 Btu/hr

Net gain by Room #7 = 1383 Btu/hr

Total loss from Room #7

Q = 29,010 Btu/hr

Corridor

I. Heat loss through walls of corridor

A. Heat loss:

1. Towards North-West:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 50 - 40 = 10$ F

$A = 16.6 \times 13.1 - 10.7 \times 9.2 =$

$= 118.9$ ft^2

$= 0.255 \times 10 \times 118.9$

$Q = 304$ Btu/hr

B. Heat gain: [1]

1. From Room #6:

a. Through South-East

$Q = 2335$ Btu/hr

b. Through North-East

$Q = 1180$ Btu/hr

2. From Room #7:

$Q = 307$ Btu/hr

3. From Room #8:

$Q = 755$ Btu/hr

4. From Room #9:

$Q = 2832$ Btu/hr

1 Gains from rooms include heat loss through walls, windows, and doors facing corridor

II. Heat loss through windows and doors of corridor

A. Loss through windows:

1. "N"

$$Q = UAdt$$

$$U = 1.13 \text{ Btu/hr F ft}^2$$

$$dt = 50 - 40 = 10 \text{ F}$$

$$A = 10.7 \times 9.2 = 98.5 \text{ ft}^2$$

$$= 1.13 \times 10 \times 98.5$$

$$Q = 1113 \text{ Btu/hr}$$

III. Heat loss through floor and ceiling or corridor

A. Loss through floor:

1. Heat loss:

None

2. Heat gain:

Heat gain from Room #3, 2nd floor, through floor is assumed to be none since "dt" nearly equal to zero

B. Loss through ceiling:

1. Heat loss:

None

2. Heat gain:

a. Gain from Room #14, 4th floor [1]

1 See plates #4 and 5 for dimensions

$$Q = UAdt$$

$$U = 0.37 \text{ Btu/hr F ft}^2$$

$$dt = 65 - 50 = 15 \text{ F}$$

$$A = 16.6 \times 7.0 = 116.2 \text{ ft}^2$$

$$= 0.37 \times 15 \times 116.2$$

$$Q = 644 \text{ Btu/hr}$$

IV. Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$$C = 16.6 \times 16.9 \times 13.1 + 17.2 \times 7.0 \times 13.1 = 5252 \text{ ft}^3$$

$$n = \text{change/hr}$$

$$dt = 50 - 40 = 10 \text{ F}$$

$$= \frac{5252 \times 1 \times 10}{55.2}$$

$$Q = 952 \text{ Btu/hr}$$

V. Heat loss due to exposure to south

None

Net gain by corridor = 8053 Btu/hr

Net loss from corridor = 2369 Btu/hr

Total gain by corridor

$$Q = 5{,}684 \text{ Btu/hr}$$

Fourth Floor

Room #10

I. Heat loss through walls of Room #10

1. Towards South-East:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 12.1 \times 14.7 - 6.9 \times 6.3 = 134.5$ ft^2

$= 0.255 \times 30 \times 134.5$

$Q = 1030$ Btu/hr

2. Towards Room #11:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 70 - 65 = 5$ F

$A = 31.3 \times 14.7 - 5.75 \times 2.65 - 3.0 \times 7.6 = 422$ ft^2

$= 0.355 \times 5 \times 422$

$Q = 750$ Btu/hr

3. Towards corridor:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 12.1 \times 14.7 - 3.0 \times 7.6 = 155.2$ ft^2

$= 0.355 \times 15 \times 155.2$

$Q = 827$ Btu/hr

4. Towards North-East:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 31.3x14.7-5.9x10.0-6.9x6.3=357.5\ ft^2$

$= 0.255 \times 30 \times 357.5$

$Q = 2735$ Btu/hr

II. Heat loss through windows and doors of Room #10

A. Loss through windows:

1. "S"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 2 \times 6.9 \times 6.3 = 86.9\ ft^2$

$= 1.13 \times 30 \times 86.9$

$Q = 2945$ Btu/hr

2. "R"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 70 - 65 = 5$ F

$A = 5.75 \times 2.65 = 15.2\ ft^2$

$= 1.13 \times 5 \times 15.2$

$Q = 86$ Btu/hr

B. Loss through doors:

1. "J" - to Room #11:

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 70 - 65 = 5$ F

$A = 3.0 \times 7.6 = 22.8$ ft^2

$= 0.69 \times 5 \times 22.8$

$Q = 79$ Btu/hr

2. "J" - to corridor:

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 70 - 50 = 20$ F

$A = 3.0 \times 7.6 = 22.8$ ft^2

$= 0.69 \times 20 \times 22.8$

$Q = 315$ Btu/hr

3. "Z"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 5.9 \times 10.0 = 59$ ft^2

$= 1.13 \times 30 \times 59$

$Q = 2000$ Btu/hr

III. Heat loss through floor of Room #10 and through roof

A. Loss through floor to the ground: [1]

$Q = UAdt$

$U = 0.37$ Btu/hr F ft^2

$dt = 70 - 35 = 35$ F

$A = 31.3 \times 12.1 = 378.7$ ft^2

$= 0.37 \times 35 \times 378.7$

$Q = 4900$ Btu/hr

B. Loss through roof:

$Q = UAdt$

$U = 0.22$ Btu/hr F ft^2

$dt = 70 - 40 = 30$ F

$A = 31.3 \times 12.1 = 378.7$ ft^2

$= 0.22 \times 30 \times 378.7$

$Q = 2500$ Btu/hr

IV, Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$C = 31.3 \times 12.1 \times 14.7 = 5560$ ft^3

$n = 1\text{-}1/2$ change/hr

$dt = 70 - 40 = 30$ F

$$= \frac{5560 \times 1.5 \times 30}{55.2}$$

$Q = 4535$ Btu/hr

1 See plan view for dimensions, plate #6

V. Heat loss due to exposure to south

Loss through walls, S. E. = 1030 x 1.15 = 1183

Loss through windows, S.E. = 1472 x 1.15 = 1692

Loss due to exposure to south

= 2875 Btu/hr

Total loss from Room #10

Q = 25,577 Btu/hr

Room #13

I. Heat loss through walls of Room #13

A. Heat loss:

1. Towards South-East:

$Q = UAdt$

$U = 0.255$ Btu/hr F ft2

$dt = 65 - 40 = 25$ F

$A = 33.2 \times 14.7 - 2 \times 6.9 \times 6.3 =$

$= 401.1$ ft2

$= 0.255 \times 25 \times 401.1$

$Q = 2560$ Btu/hr

2. Towards Room #14:

None, since "dt" is zero

3. Towards corridor:

a. To North-West:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 50.5 \times 14.7 - 3 \times 3.0$

$\times 2.7 - 3.0 \times 7.6 =$

$= 694.9$ ft^2

$= 0.355 \times 15 \times 694.9$

$Q = 3700$ Btu/hr

b. To North-East:

$Q = UAdt$

$U = 0.355$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3.0 \times 14.7 = 44.1$ ft^2

$= 0.355 \times 15 \times 44.1$

$Q = 235$ Btu/hr

4. Towards Room #11:

None, since "dt" is zero

B. Heat gain:

1. From Room #12:

a. To North-West:

$Q = 388$ Btu/hr

b. To South-West:

$Q = 436$ Btu/hr

II. Heat loss through windows and doors of Room #13

A. Loss through windows:

1. "S"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 2 \times 6.9 \times 6.3 = 86.9$ ft^2

$= 1.13 \times 25 \times 86.9$

$Q = 2455$ Btu/hr

2. "W"

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3 \times 3.0 \times 2.7 = 24.3\ ft^2$

$= 1.13 \times 15 \times 24.3$

$Q = 412$ Btu/hr

B. Loss through doors:

1. "J"

$Q = UAdt$

$U = 0.69$ Btu/hr F ft^2

$dt = 65 - 50 = 15$ F

$A = 3.0 \times 7.6 = 22.8\ ft^2$

$= 0.69 \times 15 \times 22.8$

$Q = 236$ Btu/hr

C. Gain through doors:

1. "J" - from Room #12:

$Q = 79$ Btu/hr

III. Heat loss through floor of Room #13 and through roof

A. Loss through floor:

None, since "dt" is zero

B. Loss through roof:

1. Through insulation: [1]

1 See plate #5 for skylight dimensions

$Q = UAdt$

$U = 0.22$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 33.2 \times 16.7 + 50.5 \times 18.1 -$

$42.5 \times 13.1 = 912.5$ ft^2

$= 0.22 \times 25 \times 912.5$

$Q = 5015$ Btu/hr

2. Through skylight:

$Q = UAdt$

$U = 1.13$ Btu/hr F ft^2

$dt = 65 - 40 = 25$ F

$A = 42.5 \times 13.1 = 556.5$ ft^2

$= 1.13 \times 25 \times 556.5$

$Q = 15730$ Btu/hr

IV. Heat loss due to infiltration

$$Q = \frac{Cndt}{55.2}$$

$C = 33.2 \times 16.7 \times 14.7 + 50.5 \times 18.1 \times$

$14.7 = 21580$ ft^3

$n = 2$ change/hr

$dt = 65 - 40 = 25$ F

$$= \frac{21580 \times 2 \times 25}{55.2}$$

$Q = 19535$ Btu/hr

V. Heat loss due to exposure to south

Loss through walls, S. E. = 2560 x 1.15 = 2945

Loss through windows, S.E. = 2455 x 1.15 = 2822

Loss due to exposure to south

= 5767 Btu/hr

Net loss from Room #13 = 55645 Btu/hr

Net gain by Room #13 = 903 Btu/hr

Total loss from Room #13

Q = 54,742 Btu/hr

TABLE 2 -- RADIATOR SIZES, SMALL TUBE CAST-IRON RADIATORS

No. of Floor	No. of Room	Total Loss From Room Btu./hr.	Rating per Section Sq.ft.	No. of Tubes per Section	Height in.	Width in. Min.	Width in. Max.
	R-1	26,882	2.0	4	25	4-7/16	4-13/16
	R-2	33,510	2.0	4	25	4-7/16	4-13/16
2	R-3	39,355	2.0	4	25	4-7/16	4-13/16
	R-4	9,704	2.0	4	25	4-7/16	4-13/16
	Corr.	8,501	2.0	4	25	4-7/16	4-13/16
	R-5	26,518	2.0	4	25	4-7/16	4-13/16
	R-6	80,100	2.4	5	25	5-5/8	6-5/16
3	R-7	29,010	2.0	4	25	4-7/16	4-13/16
	R-8	14,451	2.0	4	25	4-7/16	4-13/16
	R-9	8,539	2.0	4	25	4-7/16	4-13/16
	Corr.	2,369	--	-	--	--	--
	R-10	25,577	2.0	4	25	4-7/16	4-13/16
	R-11	13,453	2.0	4	25	4-7/16	4-13/16
	R-12	12,256	2.0	4	25	4-7/16	4-13/16
	R-13	54,742	3.7	6	32	6-13/16	8
4	R-14	79,874	2.0	4	25	4-7/16	4-13/16
	R-15	7,740	2.0	4	25	4-7/16	4-13/16
	R-16	4,556	1.6	3	25	3-1/4	3-1/2
	R-17	1,348	--	-	--	--	--
	R-18	9,933	2.0	4	25	4-7/16	4-13/16
	Corr.	12,756	2.0	4	25	4-7/16	4-13/16

TABLE 2 -- RADIATOR SIZES, SMALL TUBE CAST-IRON RADIATORS (Concluded)

Spacing in.	Leg Height in.	Direct Steam Radiation Sq.ft.	No.of Sections Needed	No. of Radiators to be Used	No. of Sections of Each Radiator	Length of Each in.
1-3/4	2-1/2	480	56	2	28	49
1-3/4	2-1/2	480	69	3	23	40-1/2
1-3/4	2-1/2	480	84	3	28	49
1-3/4	2-1/2	480	21	1	21	37
1-3/4	2-1/2	480	18	1	18	31-1/2
1-3/4	2-1/2	480	56	2	28	49
1-3/4	2-1/2	576	140	5	28	49
1-3/4	2-1/2	480	60	3	20	35
1-3/4	2-1/2	480	31	2	16	28
1-3/4	2-1/2	480	18	1	18	31-1/2
--	--	--	--	-	--	--
1-3/4	2-1/2	480	54	2	27	47-1/2
1-3/4	2-1/2	480	28	1	28	49
1-3/4	2-1/2	480	26	1	26	45-1/2
1-3/4	2-1/2	888	62	2	31	54-1/2
1-3/4	2-1/2	480	167	7	24	42
1-3/4	2-1/2	480	17	1	17	30
1-3/4	2-1/2	384	12	1	12	21
--	--	--	--	-	--	--
1-3/4	2-1/2	480	21	1	21	37
1-3/4	2-1/2	480	27	1	27	47-1/2

Remarks on Table 2 "Small-Tube Cast-Iron Radiators"

Column #4. The square foot of equivalent direct steam radiation is defined as the ability to emit 240 B.T.U. per hour with steam at 215 F°, in air of 70 F°. These ratings apply only to installed radiators exposed in a normal manner; not to radiators installed behind enclosures, grilles, etc. (See A.S.H. and V.E. Code for Testing Radiators.)

Column #5. Or equal.

Columns #6 and 9. Over-all height and leg height, as produced by some manufacturers, are 1 inch greater than shown in columns #6 and #9. Radiators maybe furnished without legs. Where greater than standard leg heights are required this dimension shall be 4-1/2 inches.

Column #15. Length equals number of sections times 1-3/4 inches.

OVERHEAD SYSTEM (6)

Before the selection of the proper heating system suitable for this particular design, details of all heating systems have been studied in view of economy, fuel consumption and efficient operation. The difficulties encountered in the use of a low pressure steam heating system which would accomplish above mentioned characteristics are numerous. It is therefore difficult to select an ideal low pressure system which could be controlled more efficiently. However due to the following advantages a two-pipe -- overhead system of distribution with a wet return arrangement is selected.

The chief advantage of two-pipe system lies in the fact that a separate system of piping is provided to carry away the condensation. This eliminates the possibility of interference of condensate and steam with each other which usually occurs in a single - pipe system. A two-pipe system with traps, provided that the gadgets all work and that the air in the piping eliminated properly, permits one to adjust the heat output from the radiator by manipulating the steam supply valve. This achieves a remarkably low fuel consumption. There is no difficulty in demonstrating with any single pipe radiator that water hammer (will be discussed later), and serious damage will result eventually if there is any hesitancy or weakness or temporizing about the positive and complete closing and opening of the steam valve.

In the overhead system of distribution the main circles attic, and risers extend downward from it to the first floor, supplying the radiators on the successive floors.[1] The steam is carried to the attic main by a main riser from which no radiators are supplied.

The chief advantage of the overhead system of distribution is that the steam in the risers moves downward thus improving flow conditions. The fact that the large piping is in the attic rather than the first floor is also an advantage since the matter of head room and appearance in the first floor is a consideration.

In the "wet-return" system the return main is below the water line of the boiler, and its main advantage is that it will operate with less noise than a "dry-return" system.

For the purpose of efficient operation the whole heating system under consideration is divided into two zones. These zones can be shut down for any reason, such as the failure of apparatus somewhere along its length so that it won't effect the service of the other zone, thus causing the unnecessary shut-down of the whole system. These zones will be mentioned later in connection with the design of the piping system.

1 In this particular design, boiler is placed in the first floor, see Plate #6

TABLE 3 -- RADIATOR HEATING SURFACES, SQUARE FOOT

No. of Radi.	Heating Surface	No. of Radi.	Heating Surface	No. of Radi.	Heating Surface
31	56	18	32	1	48
32	42	19	36	2	48
33	56	20	68	3	34
34	56	21	56	4	20
35	36	22	56	5	42
36	46	23	68	6	54
37	46	24	68	7	54
38	46	25	68	8	54
39	56	26	68	9	56
40	56	27	40	10	52
Second Floor		28	40	11	115
		29	40	12	115
		30	32	13	48
Third Floor				14	48
				15	48
				16	48
Fourth Floor				17	48

PIPING SYSTEM

The successful and economical operation of the heating system depends to a large degree upon a good piping system. Often, the piping is relegated to a subordinate place in planning or design and is treated as an afterthought.

The piping system is analogous to other forms of transportation systems which require a control on the whole line for efficient operation. Therefore in the following design attention will be focussed not on main riser and steam main alone, but on the whole piping system.

The method used in the determination of pipe sizes on the following pages suggests the use of the chart in Figure 135 in "Heating and Air Conditioning" by Allen and Walker.[1] However for practical purposes tables are available and are suitable for the pipe sizing in heating systems. These tables could be obtained easily and one of them is included in the bibliography as a reference.[9]

DETERMINATION OF PIPE SIZES

Equivalent Resistance of Pipes and Fittings

After ascertaining the longest steam flow path which is from the boiler, A, up the main riser, and down rise L-Lc, we can determine the total equivalent length of the path. Arranging the sections along the path between A and L-Lc in

TABLE 4 -- LENGTHS OF SECTIONS ALONG THE LONGEST STEAM FLOW PATH

Section	Length ft.
A-B	77
B-C	4
C-D	17
D-E	18
E-F	18
F-G	18
G-H	6
H-I	37
I-J	31
J-K	17
K-L	19
L-La	14
La-Lb	14
Lb-Lc	14

Table 5, we find that the total equivalent length of the path is 304 feet.

Obviously, since the pipe sizes are not yet known, it will be necessary to assume them in order to compute the allowance for the fittings. For practical purposes it is close enough to assume the allowance for the fittings as 5% of the total equivalent length. That is: 304 x 0.05 = 15 ft.

Assuming an initial pressure of 2 lb. at the boiler, and also a pressure drop of 0.5 lb. through the system, we can determine the average pressure drop. The total length of the path being 320 ft., the average pressure drop may be taken as 0.5 ÷ 32.0 = 0.0156 lb. per 10 ft. of pipe.

The pipe sizes are selected by the use of Figure 135,[1] to give as nearly as possible the average pressure drop determined above. The pipe sizes are included in Tables 5 and 6 as follows.

TABLE 5 - RADIATION SUPPLIED AND PIPE SIZES FOR MAIN AND DOWN RISERS

Section[1]	Equivalent Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
A - B	77	2244	3-1/2
B - C	4	1170	2-1/2
C - Ca	13	219	1-1/4
Ca - Cb	15	104	1
Cb - Cc	14	36	3/4
C - D	17	951	2-1/2
D - Da	13	295	1-1/2
Da - Db	15	180	1-1/4
Db - Dc	2	112	1
Dc - Dd	11	56	3/4
D - E	18	656	2
E - Ea	14	120	1
Ea - Eb	14	68	1
E - F	18	536	2
F - Fa	14	112	1
Fa - Fb	14	56	3/4
F - G	18	424	2
G - Ga	14	54	3/4
G - H	6	370	1-1/2
H - Ha	14	54	3/4
H - I	37	316	1-1/2
I - Ia	14	54	3/4
I - J	31	262	1-1/2
J - Ja	14	98	1
Ja - Jb	14	56	3/4
J - K	17	164	1-1/4
K - Ka	14	20	3/4
K - L	19	144	1-1/4
L - La	14	144	1-1/4
La - Lb	14	110	1
Lb - Lc	14	42	3/4

1 See plate #6

TABLE 5 - RADIATION SUPPLIED AND PIPE SIZES FOR MAIN AND DOWN RISERS (Concluded)

Section	Equivalent Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
B - M	13	1074	2-1/2
M - Ma	14	162	1-1/4
Ma - Mb	14	114	1
Mb - Mc	14	46	3/4
M - N	18	912	2-1/2
N - Na	14	134	1-1/4
Na - Nb	14	86	1
Nb - Nc	14	46	3/4
N - O	20	778	2-1/2
O - Oa	14	134	1-1/4
Oa - Ob	14	86	1
Ob - Oc	14	46	3/4
O - P	23	644	2
P - Pa	14	144	1-1/4
Pa - Pb	14	96	1
Pb - Pc	14	56	3/4
P - Q	14	500	2
Q - Qa	14	136	1-1/4
Qa - Qb	14	88	1
Qb - Qc	14	56	3/4
Q - R	12	364	1-1/2
R - Ra	14	136	1-1/4
Ra - Rb	14	88	1
Rb - Rc	14	56	3/4
R - S	19	228	1-1/4
S - Sa	14	84	1
Sa - Sb	14	36	3/4
S - L	34	144	1-1/4

TABLE 6 - LENGTHS AND SIZES FOR CONNECTING PIPES[1]

Section	Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
Ca - 12	2	115	1
Cb - 25	2-1/4	68	1
Cc - 35	2-1/2	36	3/4
Da - 11	2	115	1
Db - 24	2-1/4	68	1
Dd - 34	2-1/4	56	3/4
Dc - Z	14	56	3/4
Z - Za	22	56	3/4
Za - 33	11	56	3/4
Ea - 10	2	52	3/4
Eb - 23	2-1/4	68	1
Fa - 9	2	56	3/4
Fb - 22	2-1/4	56	3/4
Ga - 8	2	54	3/4
Ha - 7	2	54	3/4
Ia - 6	2-1/4	54	3/4
Ja - 5	5-1/2	42	3/4
Jb - 21	5	56	3/4
Ka - 4	7	20	3/4
La - 3	5-1/4	34	3/4
Lb - 20	5	68	1
Lc - 32	5-1/4	42	3/4

1 Connecting pipes are between the down risers and the respective radiators on each floor. See plate #6

TABLE 6 - LENGTHS AND SIZES FOR CONNECTING PIPES
(Concluded)

Section	Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
Ma - 13	3	48	3/4
Mb - 26	2-1/4	68	1
Mc - 36	2-1/2	46	3/4
Na - 14	3	48	3/4
Nb - 27	3-1/4	40	3/4
Nc - 37	2-1/2	46	3/4
Oa - 15	3	48	3/4
Ob - 28	3-1/4	40	3/4
Oc - 38	3-1/4	46	3/4
Pa - 16	7-1/2	48	3/4
Pb - 29	7-1/2	40	3/4
Pc - 39	7-1/4	56	3/4
Qa - 17	3	48	3/4
Qb - 30	2-1/2	32	3/4
Qc - 40	3-1/2	56	3/4
Ra - 1	3	48	3/4
Rb - 18	2-1/2	32	3/4
Rc - 31	3-1/2	56	3/4
Sa - 2	5	48	3/4
Sb - 19	5-1/2	36	3/4

RETURN PIPING

Following are the suggestions to be used in connection with the design of the return piping. These suggestions have been followed closely in designing the return pipes of the system under consideration.

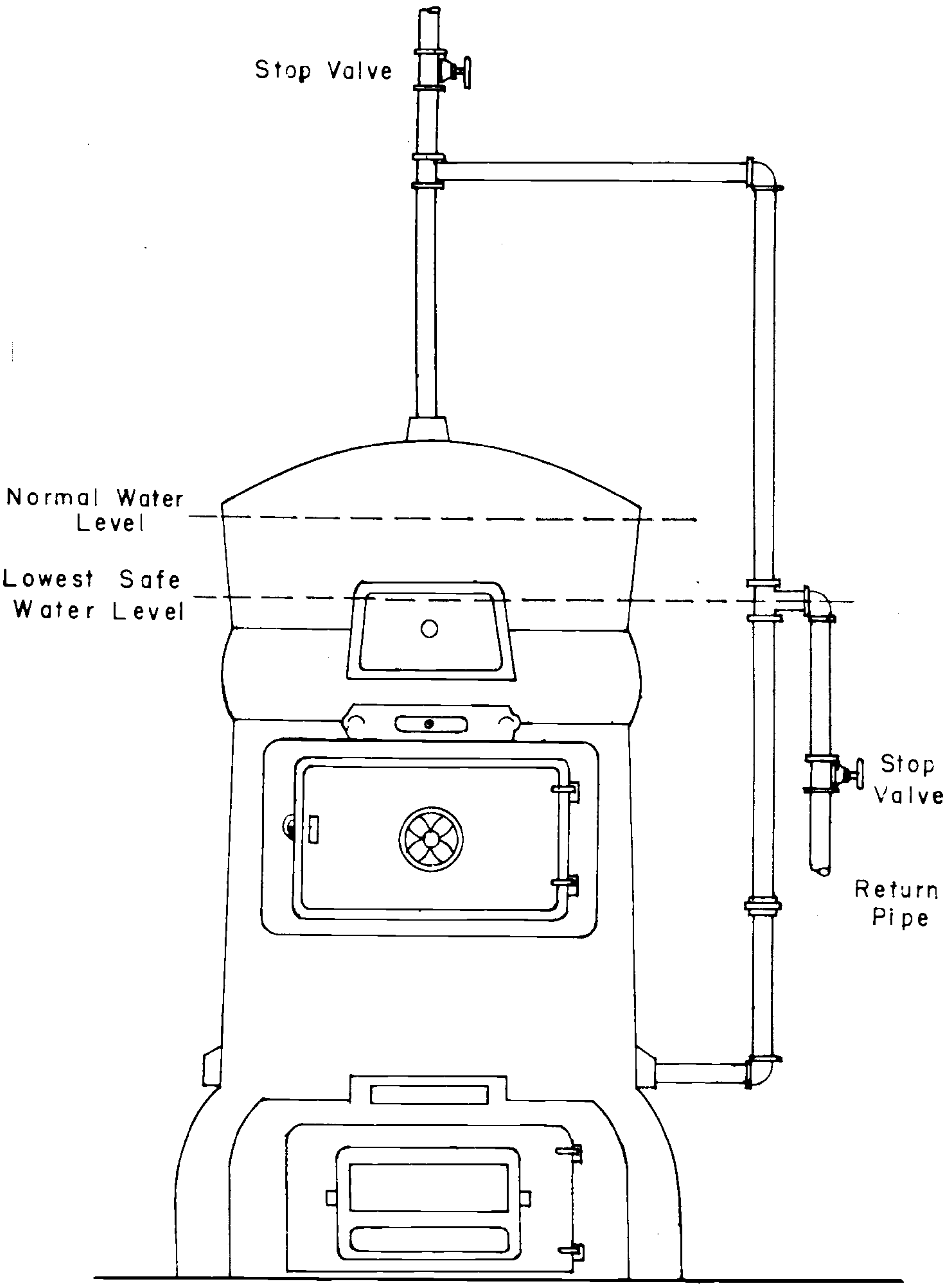
In the design of the return pipes ample provision should be given for expansion, and the wet return main should be pitched toward the boiler so that it may be entirely drained when necessary.

The ideal location of the return main in the first floor is at a point near the floor where it will be readily accessible. The maximum height, preferably, should be one which puts all of the main valves within reach for comfortable operation from the floor. This could be easily justified since there is no exceptional structural reason to prevent it in this design. It is a common practice to run the return main across the top of the boiler which requires the operators to climb ladders, or cope with other handicaps to operate valves at the main. There is no sense of doing this unless otherwise, as mentioned above, some exceptional structural handicaps prevent the location at a point near the floor. The connection of the return main to the boiler is illustrated in Plate No.7. The return main is brought up to the water level of the boiler and connected into a vertical balance connection, which ties into both the steam-outlet pipe and the return opening. This connection will prevent an unbalanced condition which otherwise will cause the water to be forced out of the boiler and back into the return main, with consequent damage to the boiler through overheating.

In order to provide flexibility in the operation of the piping lines the return main should obtain enough branch connections. Plate No.6 will show that there are mainly two branch connections to the return main at "bb". One of the branches starts at "ia" and collecting all the condensate from the individual condensate down risers joins the return main at "bb". The other branch starts at "ja" and collecting all the condensate from this section joins the return main at "bb". The purpose of sectionalizing through a system of two branch condensate return lines permits the ready isolation of any one line without interfering with the continuing operation of the other in case if the line needs to be shut down for any reason.

In connection with the branch system of sectionalizing it will be useful to suggest the use of a separate branch for supplying steam to the hot water storage heater, as water can be heated at a time when the process lines are not in service. Each branch connection should be provided with a valve at the connection to achieve the maximum operating flexibility.

When the return main is near the floor as suggested,



BOILER AND ITS CONNECTIONS

PLATE No. 7

it is ideally situated for the drainage of condensate, being at the low point of the system. The return main should at least be provided with one drip pocket consisting of a short capped pipe. The drip pocket should be equipped with a thermostatic steam trap for the automatic drainage of the condensate. Steam flow conditions often will produce enough difference in pressure drop in even a short distance.

Wrought-iron pipe should be used where the condensate return pipes must be buried in soil, owing to wrought-iron's abaility to withstand corrosion. When buried in soil, return pipes should be insulated. The best plan to conceal them is to arrange them in trenches with removable cover plates.

The improper design of return piping in a steam heating system results in the more common and the more objectionable water hammer as was mentioned earlier. It is caused by improper drainage of the condensation, which in turn is a result of failure of the drainage trap to function. The result of water hammer, tapping or pounding noise in the pipes is caused by slugs or pistons of water being driven against a dead end or sharp turn in the pipe.

The precautions to prevent water hammer are:

1. Proper pitching of pipe lines which would otherwise form water pockets.
2. Avoidance of undrained pockets.

3. Use of eccentric reducers and such fittings.
4. Proper pipe sizes so as to avoid high steam velocities.
5. Avoiding sharp turns.

The other type of noise is a hissing sound due to high steam velocities.

To prevent hissing sound, the following should be provided:

1. Proper regulation of the flow of condensate.
2. Proper pitching of pipes.
3. Use of proper radiator orifices.
4. Proper pipe sizes to avoid high steam velocities.
5. Proper pressure drops.
6. Use of coverings over the hissing surfaces, such as felt or another soft material.
7. Avoiding leaking of steam through the traps- this is the chief objection to float traps since they sometime leak steam and are noisy in operation.

The above mentioned objectionable factors which are the sources of annoyance to the occupants of the building have been eliminated as much as possible in the design under consideration.

TABLE 7 - RADIATION SUPPLIED AND PIPE SIZES FOR CONDENSATE RETURN PATHS

Section[1]	Equivalent Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
aa - bb	33	2100	3
ma - mb	14	48	3/4
mb - mc	14	116	1
mc - m	1-1/2	162	1-1/4
m - bb	12	1070	2-1/2
ca - cb	14	115	1
cb - cc	14	183	1-1/4
cc - c	1-1/2	219	1-1/4
c - m	18	908	2-1/2
da - db	14	115	1
db - dc	14	183	1-1/4
dc - d	1-1/2	239	1-1/4
d - c	18	689	2
za - zb	18	56	3/4
zb - d	4	450	2
ea - eb	14	52	3/4
eb - e	1-1/2	120	1
e - zb	25	394	1-1/2
fa - fc	1	56	3/4
fc - fb	13	218	1-1/4
fb - e	18	274	1-1/2
8 - ga	1/2	54	3/4
ga - g	1-1/2	54	3/4
g - fc	17	162	1-1/4
7 - ha	1/2	54	3/4
ha - h	1-1/2	54	3/4
h - g	16	108	1
6 - ia	1/2	54	3/4
ia - h	38	54	3/4

1 See plate #6

TABLE 7 - RADIATION SUPPLIED AND PIPE SIZES FOR CONDENSATE RETURN PATHS (Concluded)

Section	Equivalent Length ft.	Radiation Supplied sq.ft.	Pipe Size in.
na - nb	14	48	3/4
nb - nc	14	88	1
nc - n	1-1/2	134	1-1/4
n - bb	5	1030	2-1/2
oa - ob	14	48	3/4
ob - oc	14	88	1
oc - o	1-1/2	134	1-1/4
o - n	20	836	2-1/2
pa - pb	14	48	3/4
pb - pc	14	88	1
pc - p	1-1/2	144	1-1/4
p - o	14	762	2
qa - qb	14	48	3/4
qb - qc	14	80	1
qc - q	1-1/2	136	1-1/4
q - p	23	618	2
ra - rb	14	48	3/4
rb - rc	14	80	1
rc - r	1-1/2	136	1-1/4
r - q	19	482	2
sa - sb	14	48	3/4
sb - sc	15	84	1
sc - r	18	346	1-1/2
la - lb	14	34	3/4
lb - ld	1	102	1
ld - lc	13	220	1-1/4
lc - sc	36	262	1-1/2
ka - kb	15	20	3/4
kb - ld	16	118	1
ja - jb	14	42	3/4
jb - kb	19	98	1

TOTAL LENGTH OF PIPING

In the following table the total length of pipes of different diameters used in the system will be outlined. See second and fourth columns of Tables 5, 6, and 7.

TABLE 8 -- TOTAL LENGTHS OF PIPES

Pipe Diameter in.	Total Length[1] ft.
3/4	605
1	380
1-1/4	300
1-1/2	196
2	91
2-1/2	127
3	33
3-1/2	77

1 Including the allowance for proper pitch toward the boiler

DESIGN FEATURES IN THE DETERMINATION OF THE PROPER SIZE OF BOILER

For the better understanding of the selection of the proper size of boiler the following paragraphs should be reviewed.

A. Design Load:

The design load consists of the following items:

1. Heat required by all heat-emitting units with normal room temperatures and with the minimum outdoor temperature.
2. Heat emitted from all covered and uncovered steam piping.
3. Heat required by attached water heaters or other devices.

This is the load that must be provided for during the coldest weather after the building has been brought up to temperature.

Total heat loss of the building as calculated earlier is 2244 sq. ft., and is the equivalent radiator surface.

The heat emitted from the piping, both bare and covered, is included in the boiler load, and is an important part of the load. It is customary to treat pipes covered with insulation less than 3/4 in. thick as bare pipes. The heat emission from bare pipes is taken as 2 Btu. per hr. per sq. ft. of pipe surface per degree difference between the steam and the surrounding air. When pipe covering 3/4 in. or more in thickness is used, the heat emission is taken as 25 per cent of the amount given above for bare pipes.

In this design a hot water tank having a capacity of 260 gallons is also to be used. In this case in order to convert the heat required to equivalent sq. ft. of radiation it is suggested that the storage-tank capacity in gallons be multiplied by 2.

In determining the design load it has been considered that one square foot of steam radiator surface to have an emission of 240 Btu. per hr. This is the usual standard rating.

Above mentioned temperature difference between the steam, in the main and the down risers, and the surrounding air is:

$$dt = 218 - 65 = 153 \text{ F}$$

where,

steam temperature at 16.696 psi = 218 F

average temperature of the surrounding air = 65 F

B. Maximum Load:

The maximum or gross load consists of the design load plus the "starting load", which includes:

1. The additional heat emission of the radiators and piping, caused by the lower room temperatures existing during the warming-up period.

2. The heat required to raise the metal in the

radiators and piping to the working temperature.

The maximum load is usually calculated by adding a percentage allowance to the design load to cover above mentioned items. In this design 50 percent allowance is used as suggested by the A.S.H. & V.E. Code[1] for the design load under consideration.

C. Sq. ft. of Heating Surface:

The type of boiler to be used in this design being steel and using hand fired solid fuel the required heating surface is determined as recommended by the Steel Boiler Institute. That is, "for boilers in which hand-fired solid fuel is burned, the rating of a steel boiler expressed in square feet of steam radiator surface is 14 times the heating surface of the boiler in square feet."

The rating corresponds with the estimated design load (direct radiation plus hot water load plus heat loss from piping).

Heating surface is considered as including all surfaces that are exposed to the products of combustion on one side and water on the other side. The outer surface of tubes is used.

The furnace volume will be considered as the cubical content of the space between the bottom of the fuel bed and the first plane of entry into or between the tubes.

D. Steam Rate:

In determining the steam rate the temperature of the condensate will be assumed to be 140 F which is quite a reasonable temperature for condensate. In this case the heat content (enthalpy) of steam in Btu. per lb. will be the difference between the outgoing and incoming steam. Namely the heat content of steam in vapor state at 16.696 psi is 1152.8 Btu. per lb. and that in liquid state at 140 F is 108.0 Btu. per lb.(3)

The combined efficiency of boiler and grate is assumed to be 70 percent, and it closely checks the manufacturers' Rating Codes.

E. Coal Consumption:

Under the circumstances the available and most economical solid fuel to be used is "Low Volatile Bituminous coal". Most bituminous coals when heated at uniformly increasing temperature, in the absence or partial absence of air, fuse and become plastic. Such coals are designated "caking" coals; bituminous coals possess this caking property in varying degree. Caking is an important factor in the burning of coal. In the low volatile bituminous coal the limits of fixed carbon, mineral-matter-free basis are as follows.

Dry fixed carbon, 86 - 92 percent.

Dry volatile matter, 14 - 8 percent.

The heat value of the coal to be used could freely be assumed as 12,500 Btu. per lb. basing our assumption on the above given classification. However it is suggested firmly that the heating value of the coal to be used be tested thoroughly before use.

There will not be much trouble in obtaining the low volatile bituminous coal tobe used in connection with this design from the rich sources in Turkey. The use of this kind of coal provides safety, reduction of cost and will fascilitate purchase and transportation.

F. Cost of Coal:

As is already mentioned in part E, under the present day conditions the cost of low volatile bituminous coal runs around 105 Ltq. per ton. The present Turkish Lira (Ltq.) and the American dollar exchange rate is 2.83 Ltq. equal one dollar.

DETERMINATION OF THE SIZE OF BOILER

A. Design Load:

Equivalent radiator surface	= 2244 Sq. ft.
Well - insulated pipe surface	= 49 Sq. ft.
Bare pipe surface	= 572 Sq. ft.
Hot water tank surface [1]	= 520 Sq. ft.

Design load =

$$2244 + \left(\frac{49}{4} + 572\right) \times (218 - 65)$$

$$\times \frac{2}{240} + 520$$

$$= 3494 \text{ Sq. ft.}$$

or 838,560 Btu/hr

B. Maximum Load:

Percentage to be added for starting load = 50%

Maximum load = 838,560 x 1.50

= 1,257,840 Btu/hr

or 5,241 Sq. ft.

C. Sq. ft. of Heating Surface:

$$s = \frac{\text{Design Load}}{14}$$

where:

s = heating surface, sq. ft.

$$s = \frac{3494}{14}$$

Required Heating Surface = 250 sq. ft.

1 Capacity of water tank 260 gallons

D. Steam Rate:

$$s.r. = \frac{Q}{h \cdot E}$$

where:

Q = boiler output, Btu per hr

s.r. = steam rate, lb. per hr

h = heat content of steam, Btu per lb

E = combined efficiency of boiler and grate

$$s.r. = \frac{1,257,840}{(1152.8-108) \times 0.70}$$

Steam rate = 1718 lb/hr

E. Coal Consumption:

$$c.c. = \frac{Q}{H \cdot E}$$

where:

c.c. = coal consumption, lb. per hr

H = calorific value of fuel, Btu per lb

$$= \frac{1,257,840}{12500 \times 0.70}$$

Coal consumption = 144 lb/hr

F. Cost of Coal:

$$c = \frac{c.c. \times P}{2200}$$

where:

c = cost of coal, Ltg. per hr

P = purchase and transportation price, Ltg. per ton

$$c = \frac{144 \times 105}{2200}$$

Cost of coal = 6.87 Ltg/hr

G. Selection of the Boiler:

As recommended by the Steel Boiler Institute, having determined the required heating surface we have selected the boiler from the Catalogue.[4] The following are the specifications of the boiler selected as given by the Manufacturers'.

Mfg: West Coast, The Steel Tank and Pipe Co.

Type: Steel, hand fired.

Weight: 5600 lbs.

Heating Surface: 260 Sq. ft.

Size of Square Chimney Required: 16 in.

Height of Chimney Required: 45 ft.

Draft: 0.21 in. of water.

FITTINGS AND VALVES

Fittings and valves are quite important in all steam heating systems as well as the piping details. It has long been the practice to let the contractor choose the fittings and valves as he wished. This of course does not apply to designs which require extreme attendance. Depending upon the contractor is usually the case with designs such as the one under consideration. On the other hand in this design special features have been studied carefully in order not to make the same mistakes which are observed almost every day. One of the best examples is the so called water hammer which is the more common and the more objectionable tapping or pounding in the pipes. Another example of faulty installation is the improper provision for the linear expansion of the pipes. This item will be considered in detail later as will be emphasized. However in order to have a clear understanding of Table 9, and figures from six to nine (included) it is necessary to take up the following illustrations first.

Fittings:

Study of Table 9, will show that the first section on elbows is self explanatory. The sizes of the elbows are designated according to the nominal size of the pipes to which they are going to be fitted. It is sometimes a practice to use a special elbow, called a pitched elbow in heating work.

Pitched elbows are not suggested to be used in this design unless otherwise specified.

In designating reducing tees, the size of the openings opposite each other is given first and last, and the size of the branch opening is given at the middle. Namely, the size given first in Table 9, corresponds to "L" (left) in Figure 6, respectively the size given at the middle corresponds to "M" (down riser), and the size given last corresponds to "R" (right).

All the fittings that are used are made of cast iron.

Where screwed fittings are used, provision should be made, at intervals in the line, for disconnecting the piping for repairs, and inspections. It is especially suggested to use unions for this purpose. For pipe sizes up to 2 inches (nominal size), nut unions, consisting of two pieces screwed to the ends of the pipe and held together by means of a threaded nut, will best serve the above mentioned purpose. Flange unions are suggested to be used with larger sizes of pipe.

In cases where it is necessary to disconnect the piping between the floors which is namely the disconnection of down risers, an important point is usually overlooked. This trouble is faced even in most of the well planned designs due to the neglect on behalf of the designer or due to the lack of interest of the contractor. This trouble arises when the pipes between the two floors, down riser, are rigidly in touch with the concrete flooring. In cases of disconnection it is essential to dig out the pipe from the concrete flooring which entails extra cost and loss in essential time. The usual practice in such cases is to use a tube which has a diameter large enough so that the riser could pass through freely. The length of this tube should be long enough to provide half an inch margin on both sides of the floor. This short so called, through pipe being in touch with the concrete floor rigidly provides a free movement for the riser which otherwise would result in some preliminary complications. This is an essential factor in heating systems installed after the construction of the building. This fact is usually overlooked due to the first cost but it turns out to be quite a nuisance later when the system needs repairs or inspections. The use of this pipe system is definitely suggested for this design under consideration.

Valves:

Table 9, gives the dimensions and the kinds of representative valves suitable for this steam system. These types represent the valves that are commercially available. Catalogues of manufacturers should be consulted for more detailed information in case of various technical set-ups. They may be of cast iron, malleable iron, steel, non-ferrous metal or preferably entirely of brass. In designating the valves in Table 9, the size of the inlets is given according to the nominal size of the pipes to which they are going to be fitted.

The radiator valve for steam is of the "corner" pattern type having a side inlet and is provided with a union for connecting to the radiator. The valve disk is made of hard rubber and is renewable. This valve is of the packless type, having a flexible bellows that prevents leakage around the stem while permitting free movement of the stem and disk. This valve does not require soft packing around the stem. In case of any difficulty in obtaining the packless type valve it is suggested that the "corner" pattern valve having its stem packed with a soft stranded packing should be used. This type prevents leakage to some degree but resulting leakage, if there is any, is often a considerable annoyance.

In order to drain the water from the radiator without allowing steam to escape thermostatic traps of the bellows type are suggested to be used in connection with this design. It consists of a thin-walled chamber or bellows which contains a volatile liquid such as kerosene or alcohol. The theory behind this type of trap is not going to be taken up further, the catalogues of manufacturers should be consulted for more detailed information. In actual operation the trap remains open sufficiently to allow the air and condensation to pass through it. When steam reaches it and heats the thermostatic element it closes and remains closed until the condensation accumulating in it cools a few degrees, causing it to open again slightly. In case the "corner" pattern radiator valve having its stem packed with a soft stranded packing is used, it is suggested that the float trap should be used instead of the bellows type. The objection to the use of float trap will be mentioned later.

The entire system being divided into two zones necessitates the use of stop valves. The first of the zone extends from "C" to "L" (see Plate No.6) and the other extends from "M" to "L". The main purpose in the use of zones, as was mentioned before, is to economize on fuel in cases when only one part of the building is in use. It is usually a good and a desirable practice to run separate supply and return mains, and the best layout is usually that which uses the least length of pipe. In order to control these zones of heating independently three "cross" pattern stop valves are installed on the main which circles the attic. The location of the first two (2-1/2 - 2-1/2) size valves are on section "B-C", and "B-M" which are the two side outlets of the main riser "A-B". The location of the other (1-1/4 - 1-1/4) size valve is on section "K-L" (see Plate No.6). As far as the control of these valves is concerned it is not necessary to install an automatic control system which would be rather costly and impractical, at least for this type of heating design. The manual operation of these valves is suggested since the cost of labor is cheaper than the installation of an automatic control system.

In order to promote rapid circulation the installation of air vent valves at the ends of mains and the tops of long upfeed risers is desirable. It is suggested that two air vent valves should be installed, one at the top of the main riser at point "B" and the other at the end of main circling the attic at point "L" (see Plate No.6 for the point of location). The reducing crosses are used with the air vents and will be discussed in the following paragraph.

For the purpose of installing air vent valves at the above mentioned locations, cast iron reducing crosses are used. Figure 7 illustrates a typical reducing cross, and the sizes of the crosses to be used are given in the following table.

SIZE OF REDUCING CROSSES

Location[1]	Number to be used	Size[2] in.			
		L	M	R	V
B	1	2-1/2	3-1/2	2-1/2	2
L	1	1-1/4	1-1/4	1-1/4	1

The use of crosses at such locations eliminates the use of tees and provides the rapid circulation of steam with the use of air vent valves as was mentioned above.

1 See Plate No.6
2 See Figure 7

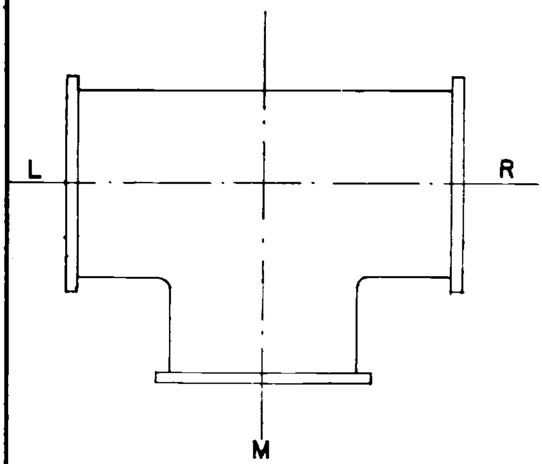


FIG. 6—REDUCING TEE

L = LEFT R = RIGHT
M = DOWN R.

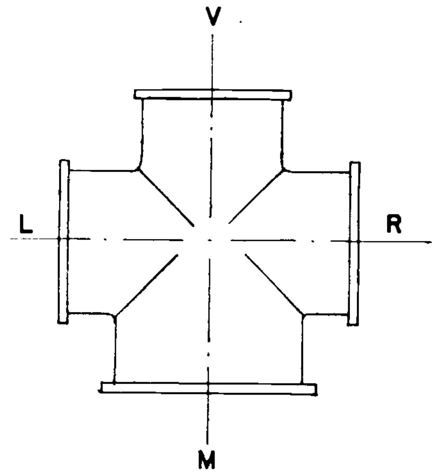


FIG. 7—REDUCING CROSS

V = AIR VENT VALVE
OUTLET

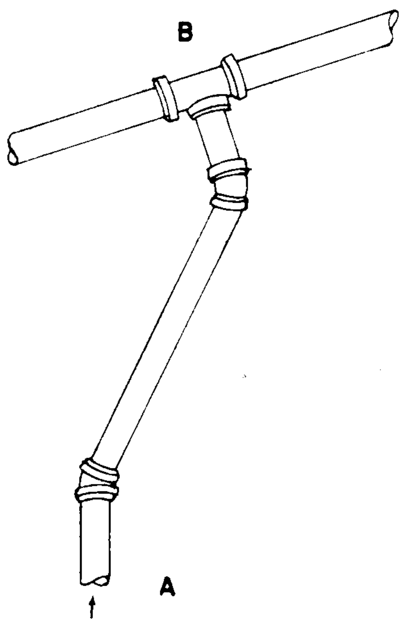


FIG. 8—CONNECTING BRANCH
ON MAIN RISER NEAR "B"

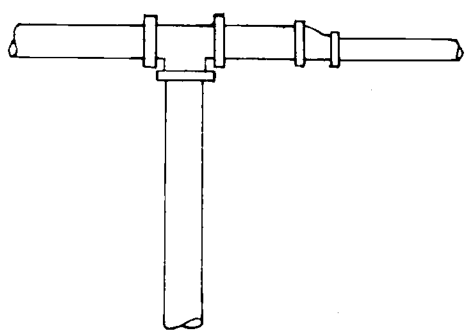


FIG. 9—ECCENTRIC
REDUCER

A common error is the use of fittings that form steam pockets which are usually caused by the reducing tees. This is an observed fact and frequently results in the breaking of cast-iron fittings. The reduction in pipe size should be made by using an eccentric reducer, illustrated in Figure 9.

One of the most important considerations in heating designs is the proper provision for the linear expansion of the pipes. When steam is turned into or shut off from a system of piping, a considerable change of temperature occurs. Provision must be made for allowing the resulting change of length to occur without putting excessive strains on the fittings. There are, in general, three ways in which the expansion in a system of piping may be absorbed: (a) by the turning of some of the threaded joints, (b) by the bending of the pipes, and (c) by the use of special devices designed to absorb the movement. The use of continued twisting of a threaded joint will in time often result in a leak. The threaded joints result in difficulty after corrosion has taken place and do not turn as actually intended. As far as the other methods are concerned the most economical and the most satisfactory method is the use of bends. In the heating system under consideration a considerable expansion of the main riser "A-B" will take place and the method of absorbing this expansion is illustrated in Figure 8. The arrangement of Figure 8 is somewhat better by using 45 degree elbow than using 90 degree elbow, as the

45 degree elbow offers less resistance to the flow of steam. The use of an "expansion loop" on the main riser, anchored near the middle, is not suggested since the resistance offered by the fittings to the steam flow is quite large. Anchoring and the use of "expansion loop" on the main riser should be used in taller buildings when the expansion is too great to be handled by an ordinary branch connection.[1] The anchor gives a true swivel joint in such cases.

1 Data on the design of square-bend expansion loop, could be obtained from (8) in bibliography.

TABLE 9 - FITTINGS AND VALVES TO BE USED

Type of fitting and valve	Number to be used	Size in.
90° Elbow, screwed	3	3-1/2 - 3-1/2
	3	3 - 3
	2	2-1/2 - 2-1/2
	1	2 - 2
	7	1-1/2 - 1-1/2
	5	1 - 1
	37	3/4 - 3/4
45° Elbow, screwed	2	3-1/2 - 3-1/2
Reducing Tee[1]	1	2-1/2 - 3-1/2 - 2-1/2
	1	2-1/2 - 3 - 2-1/2
	1	2-1/2 - 1-1/2 - 2
	5	2-1/2 - 1-1/4 - 2-1/2
	3	2 - 1-1/4 - 2-1/2
	4	2 - 1-1/4 - 2
	2	1-1/2 - 1-1/4 - 2
	1	1-1/4 - 1-1/4 - 1-1/2
	1	1-1/4 - 1-1/4 - 3/4
	2	2 - 1 - 2
	2	1-1/2 - 1 - 1-1/4
	1	1-1/4 - 1 - 1-1/4
	2	1-1/2 - 1 - 1-1/2
	2	1 - 1 - 1-1/4
	2	1 - 1 - 3/4
	2	2 - 3/4 - 1-1/2
	2	1-1/2 - 3/4 - 1-1/2
	1	1-1/4 - 3/4 - 1-1/4
	8	1-1/4 - 3/4 - 1
	10	1 - 3/4 - 3/4
	2	1 - 3/4 - 1

1 See Figure 6

TABLE 9 - FITTINGS AND VALVES TO BE USED
(Concluded)

Type of fitting and valve	Number to be used	Size in.	
"Corner" pattern Radiator valve	7	1	- 1
	33	3/4	- 3/4
Thermostatic trap, bellows type	7	1	- 1
	33	3/4	- 3/4
Stop valve, cross pattern	1	3-1/2	- 3-1/2
	2	2-1/2	- 2-1/2
	1	1-1/4	- 1-1/4
Air vent valve[1]	1		2
	1		1
Reducing cross[2]	2		-
Eccentric reducer[3]	2	2-1/2	- 2
	2	2	- 1-1/2
	2	1-1/2	- 1-1/4

1 To be used with the reducing crosses
2 See Figure 7
3 See Figure 9

PIPE INSULATION

Rising fuel costs make maximum heat savings desirable which is accomplished by proper insulation of steam lines. Thermal insulation, as the term applies, is a substance of pre-determined characteristics which will restrict the flow of heat. It will be noticed that the term "stop the flow of heat" is not used, because while such a material might be highly desirable, it is nevertheless unobtainable.

It is always a good practice to make a more precise determination of the thickness of insulation required for a particular installation. The tables in current use for determining insulation thickness do not take into consideration all the variables involved. These variables are; cost factors, variation of hours of operation, and rate of amortization. The thicknesses of insulation recommended in these tables are based on pipe size and temperature range of operation. In the recent years many methods for the rapid determination of the most economical thickness of pipe insulation have been introduced in many journals.[1] In most installations and especially in this particular design the use of tables is as good as the use of above mentioned methods for the determination of the economical thickness of insulation.

1 See Bibliography (12) and (13)

In this design to determine the thickness of pipe insulation, "Heat Insulation Handbook" is used.(14) This Handbook is published by The Ehret Magnesia Manufacturing Co. and recommends the thickness for Ehret's 85% magnesia pipe coverings.

The following table includes the necessary information on insulation of steam piping in the first floor - part of main supply riser - , and in the attic - attic main, part of main supply riser and the part of down risers.[1] It will not be necessary to provide insulation on the part of main supply riser above the first floor since it will serve as a radiating surface.

DIMENSIONS OF EHRET'S 85% MAGNESIA PIPE COVERINGS

Pipe Size	Pipe Length[2]	Inside Diameter of Cover-ing	Standard Thickness		
			Thickness	Outside Diam.	Canvas Area per Lineal Foot
in.	ft.	in.	in.	in.	sq. ft.
3-1/2	39	4-1/16	1-1/32	6-1/8	1.604
2-1/2	72	2-15/16	1-1/32	5	1.307
2	93	2-7/16	1-1/32	4-1/2	1.177
1-1/2	87	1-15/16	7/8	3-11/16	0.964
1-1/4	93	1-3/4	7/8	3-1/2	0.917
1	3	1-3/8	7/8	3-1/8	0.818
3/4	3	1-1/8	7/8	2-7/8	0.753

1 See Plate #6
2 Ehret's 85% Magnesia pipe coverings are supplied in 3-foot lengths

The structural features of the building required the burial of the return piping in the ground, along lines "ia-d" and "jb-kb".[1] This is not a very good practice, because when buried in soil, return pipes corrode and deteriorate very rapidly. The use of removable cover plates is suggested and that they should be covered with cylindrical tile with cemented joints which keep out the water.

The following table shows the length and pipe size of the buried return piping.

BURIED RETURN PIPING

Pipe Size in.	Pipe Length ft.
2	16
1-1/2	43
1-1/4	10
1	35
3/4	56

Special care should be given in fitting a section of pipe insulation to resist free turning on the pipe, otherwise it will result in an unsatisfactory fit which will cause a crack at the end of the run.

In order to support the attic main, the use of pipe supports, or hangers is extremely necessary. The kind of

1 See Plate #6

support to be used is up to the contractor and he could obtain the required sizes from the preceding table on insulation dimensions.

MAINTENANCE (10)

Corrosion in the piping systems, though hardly a routine maintenance problem, does have some relation to it.(11) It is suggested that each year steam and condensate piping systems should be examined for corrosion and their condition should be recorded. This record could be compared with the previous years record to determine if any progression of corrosive or galvanic action has taken place. In addition, when possible, it is a good practice to remove some sections of pipe from the system for metallurgical study and report. These tests are made to prolong the life of the system.

During the first two years operation, it is necessary to clean, inspect, repair and test all thermostatic traps at least annually. This is essential because of the large amount of mill scale, and dirt which may not be eliminated despite a thorough flushing of the heating system piping by the contractor. During subsequent seasons, half of the traps may be removed for checking and testing, this is satisfactory for good operation.

The trap manufacturer usually provides gauges for setting the thermostatic elements and a supply of spare parts

1 This test for corrosion, could be done by installing test pieces in the steam and condensate piping systems and then removing for examination

is always available. This care insures tightness and proper operation of traps, with subsequent economy in steam consumption and a minimum of heating troubles. The system should be checked for the leak source at least once a year. Valves are found to be a primary source of trouble at all points of installation so it is necessary to inspect and overhaul a large percentage each year. The importance of above mentioned maintenance schedule is stressed.

In the program of good maintenance and careful operations, cost is one of the most important gauges. Steam consumption is also a factor in determining the operation efficiency and maintenance policy. The study of above factors can best be accomplished by carefully kept records and study to indicate the frequency and necessity of special maintenance work. Consideration should be given to the analysis of life expectancy and vulnerability of each piece of equipment. This analysis determines the total quantity of parts to be inventoried and avoids any future break-down that may occur in the heating system. It is suggested that a fairly complete machine shop should be provided with facilities for the maintenance of the system.

REQUIREMENTS FOR EFFICIENT OPERATION AND FUEL CONSERVATION[1]

1. It is essential that all of the grease and foreign matter be completely eliminated from the boiler so that steam can be generated effectively. This can be done in a new system by using it for ten days to two weeks. The time involved allows the steam to release the oil, compound and other foreign materials which got into the system at the time it was assembled, to return to the boiler. After this period the boiler is skimmed, drained and flushed, then filled to the proper level for operation.

2. The above process of boiler cleaning should be repeated at the start of each heating season.

3. Boiler flues should be cleaned at regular intervals because the products of combustion will deposit themselves in the flues. The greater the thickness of the deposit, the less the amount of heat extracted from the fuel burned which will result in an increase in the amount of fuel consumed.

4. Proper construction of chimney according to the recommended dimensions is necessary for correct combustion of the fuel burned. Properly constructed chimney carries away the non-combustible gases sufficiently fast to aid combustion.

1 See Bibliography: (15) and (16)

5. Piping should be quickly freed of air during operation and completely filled with steam.

6. Steam pipes which are not actually used to aid in heating rooms should be well insulated.

7. Any radiators which are not in use either should be covered or the lines leading to them should be disconnected.

8. Any collection of dirt between the sections of radiators should be removed to obtain maximum radiator efficiency.

9. For maximum efficiency, radiators should not be covered with a coating of bronze or aluminum paint. The radiator efficiency may be improved as much as 10 percent by the application of ordinary oil paints, preferably of a dark color.

10. Some fuel savings may result and some increase in radiator efficiency may be experienced if a surface of high reflectivity is placed behind each radiator. This will prevent heat to be absorbed by the surface of the wall behind the radiator and will aid in reflecting it into the room.

11. All heat supplied to unoccupied spaces should be reduced or turned off completely since there is no danger of damage by freezing. Temperature conditions are above freezing at all times. In the case of radiators in unoccupied spaces, the simplest means of shutting them off is to cover them.

12. Guides should be provided for the operators to

indicate when heat should be turned on or when it should be turned off.

13. Definite heating system pressures should be maintained with relation to the prevailing temperatures.

14. There are several elements - pipe lines, traps, valves, controls -- that can get out of order. The chances are that, when any of them become defective, inefficient operation and waste of heat will follow, for this reason, heating system should be inspected at regular intervals.

15. When steam leaks are found repairs should be made immediately.

16. When traps become worn and defective they should be replaced promptly.

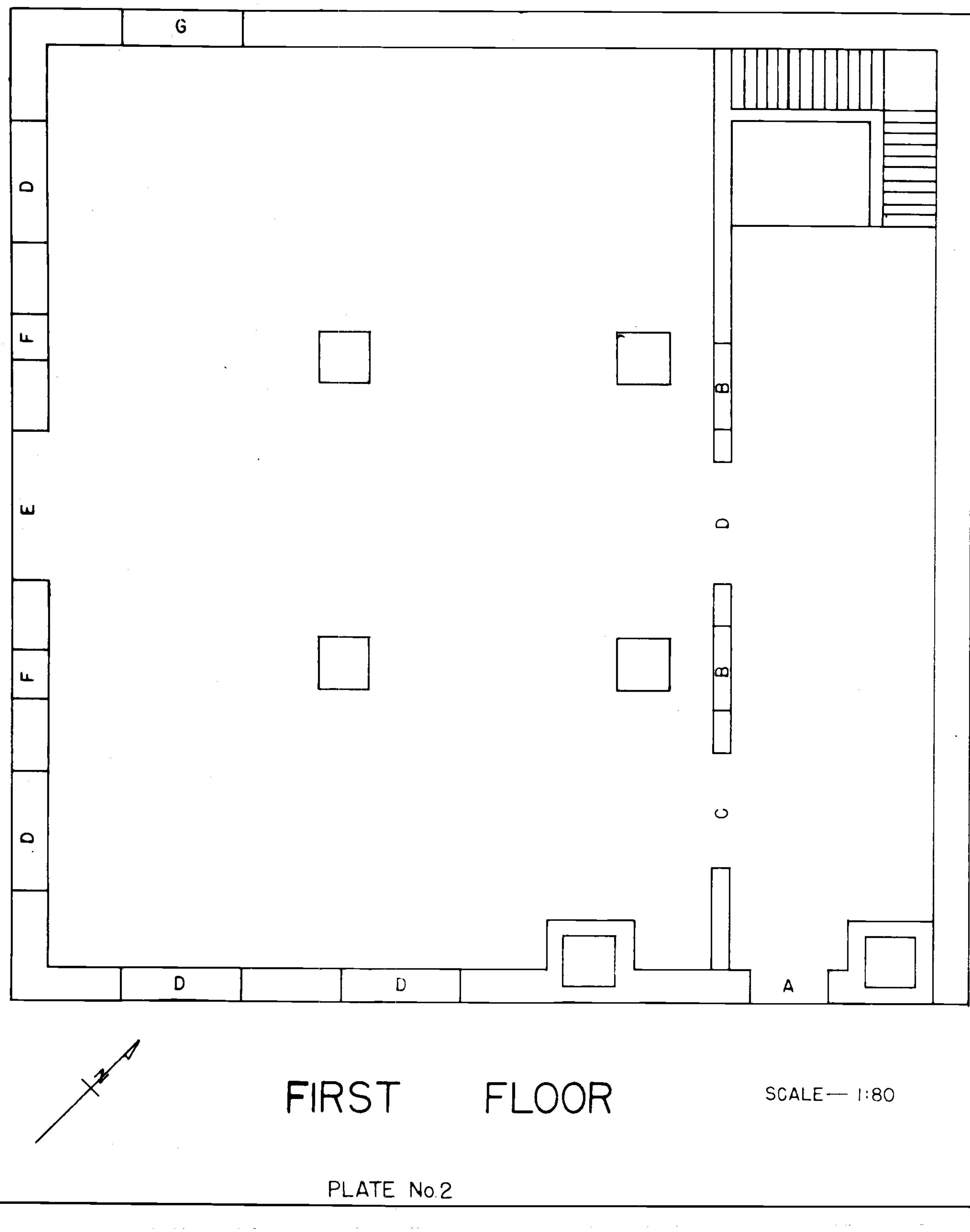
17. Smoke is not the chief source of loss in boiler operation, but black smoke is a nuisance and must be kept to a minimum for social and economic reasons.

18. Need for boiler water treatment is essential.

19. Sifting of coal through the grate should be reduced. This can be done by skillful cleaning of the fire at correct intervals. Grates should be kept in good condition because warped and loose bars may spill good coal into the ash pile, or let too much air through the fire in some spots and too little in others.

20. Any insulation missing from the boiler covering should be replaced to reduce the loss of heat.

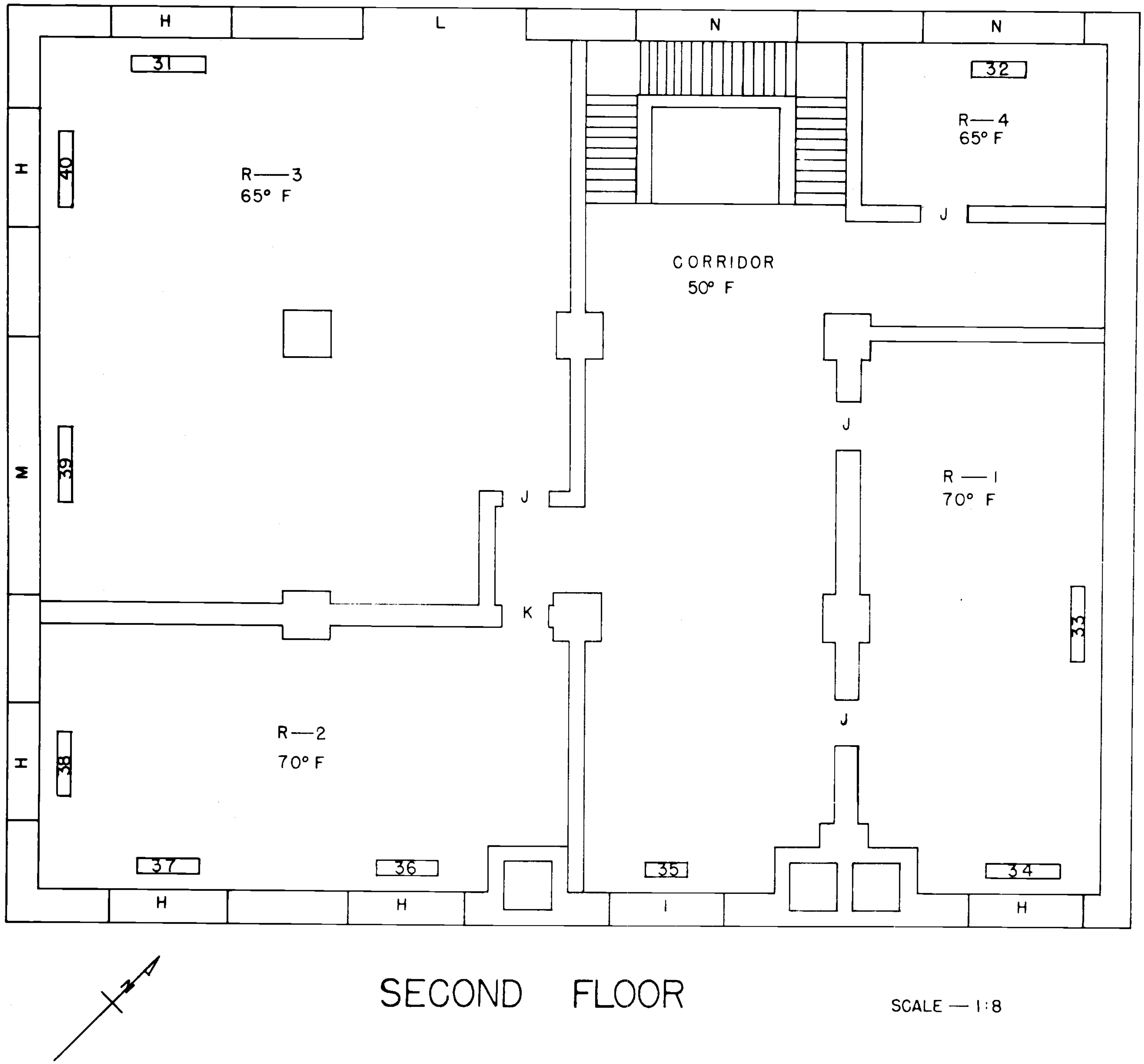
The above listed requirements when properly fulfilled will improve the efficiency of operation and result in fuel conservation.



FIRST FLOOR

SCALE— 1:80

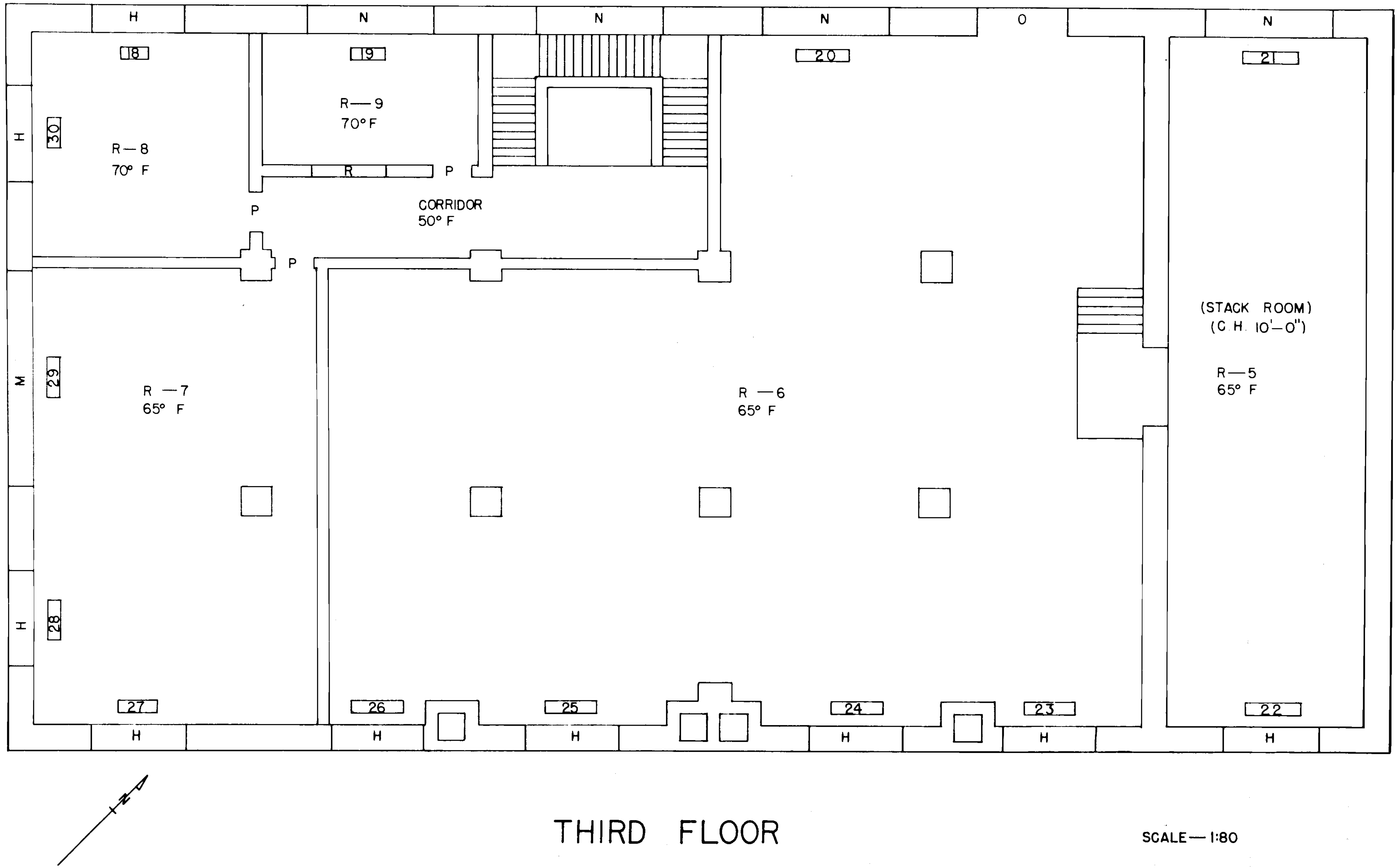
PLATE No.2



SECOND FLOOR

SCALE — 1:8

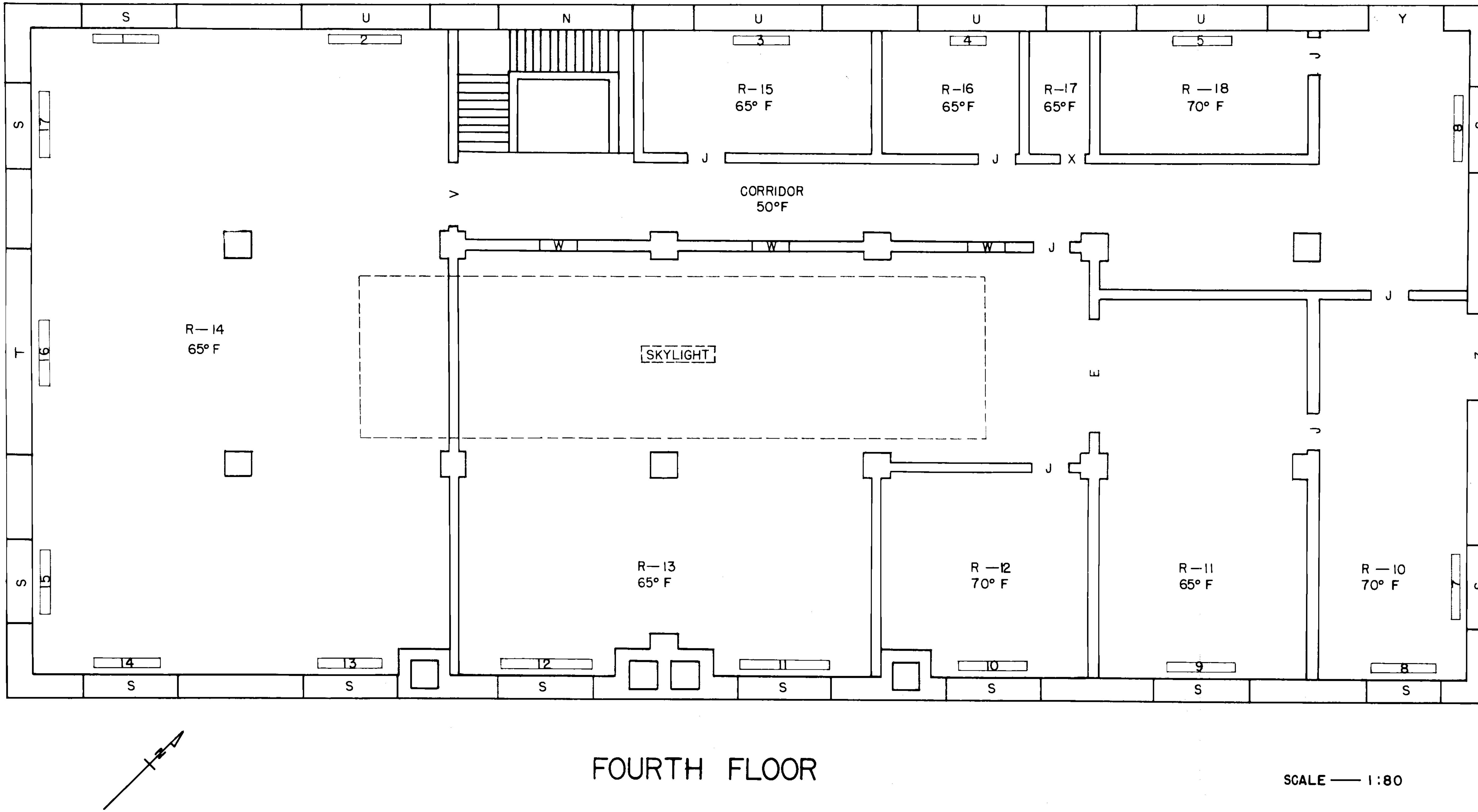
PLATE No. 3



THIRD FLOOR

SCALE—1:80

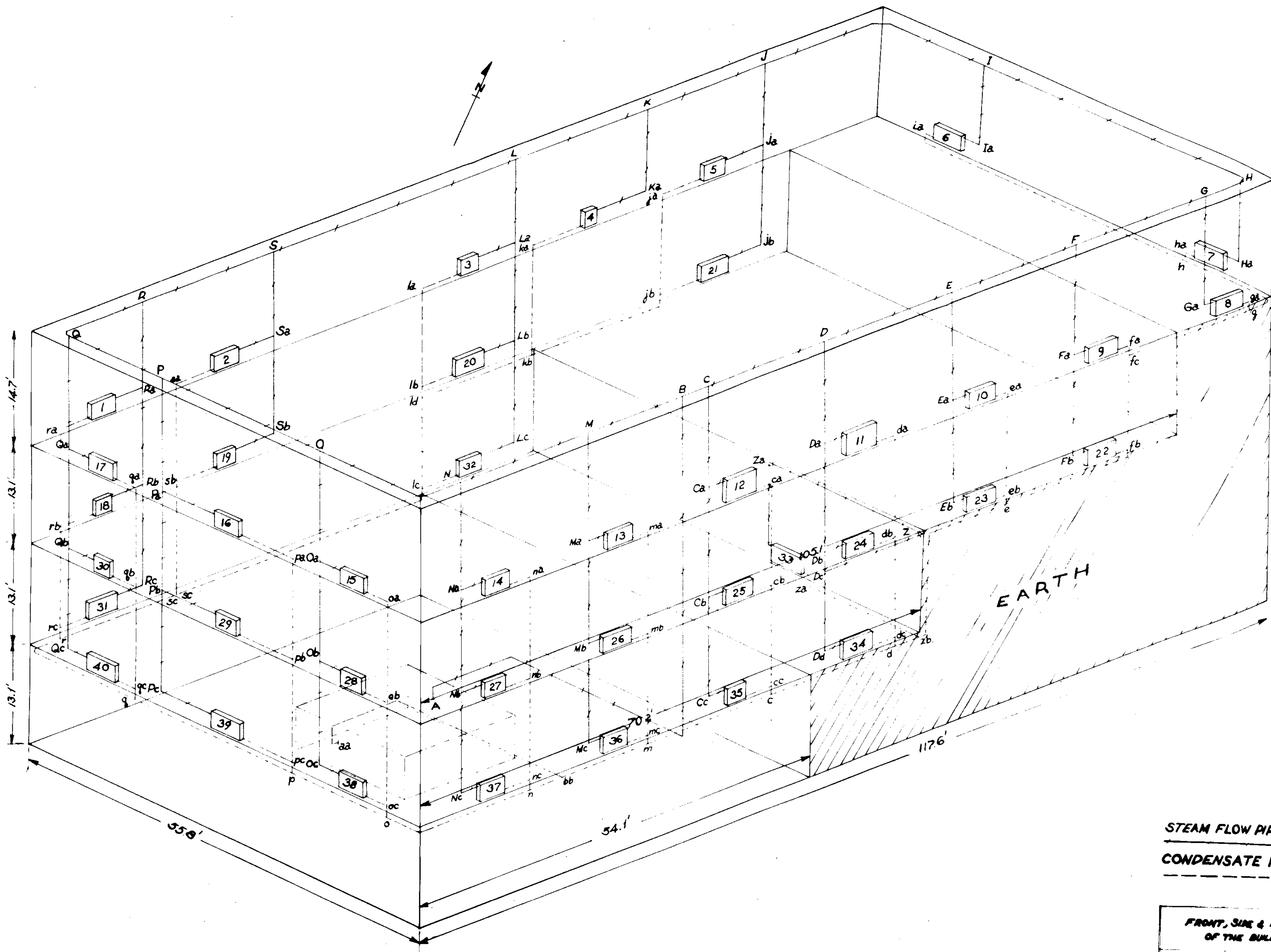
PLATE No. 4



FOURTH FLOOR

SCALE —— 1:80

PLATE No. 5



STEAM FLOW PIPES

CONDENSATE RETURN

PLATE No. 6

FRONT, SIDE & ELEVATION OF THE BUILDING	
DRAWN BY	K. A. ÖZİPEK
CHECKED BY	
SCALE	1:100

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Allen, Walker and James. Heating and air conditioning. 6h ed. New York, McGraw-Hill book co., inc., 1946. 667p.

2. Macintire, H. J. Refrigeration engineering. 5h p. New York, John Wiley and Sons, inc., 1946. 439p.

3. Keenan, Joseph H. and Keyes, Frederic G. Thermodynamic properties of steam. New York, John Wiley and Sons, inc., 1936. 89p.

4. Steel tank and pipe co. West coast steel heating boilers. Portland, The Company, 1930. (Catalog no.15).

5. American society of heating and ventilating engineers. Heating ventilating air conditioning guide 24. New York, The Society, 1946.

6. Lewis, Sam. Is one pipe steam system better than two pipe. Heating piping and air conditioning 19:115-116, Sep.1947.

7. Hauck, G. W. Main steam header-heart of your piping system. Heating piping and air conditioning 16:96-98, Feb. 1944.

8. Horelick, H. Square bend expansion loop. Power 90:561, Aug. 1946.

9. Heating and ventilating. Sizing steam mains. Heating and ventilating 42:74a-74b, Aug. 1945.

10. Dondero, J. A. Maintenance methods at Porkchester. Heating and ventilating 43:53-56, May 1946.

11. Collins, Leo F. Corrosion in condensate piping. Power plant engineering 48:88-89, Mar. 1944.

12. Thomas, Ray. Simplifying pipe insulation dimensions. Heating piping and air conditioning 16:698-701, Dec.1944.

13. Smith, Utley W. Rapid method of determining the economical thickness of pipe insulation. Heating piping and air conditioning 19:118-121, Oct. 1947.

14. Ehret magnesia manufacturing co. Heat insulation handbook. Pennsylvania, The Company, 1942. (Sheet no. HI 105).

15. Rowley, Jordan and Lund. Conservation of fuel. Minnesota, University of Minnesota press, 1943. 61p. (University of Minnesota bulletin no. 20, vol. 46).

16. McGraw-Hill publication. How to get the most out of your coal pile. Factory management and maintenance 101:145-152, Dec. 1943.