T H E S I S

A SYSTEM OF PIPING FOR HEATING THE UNIVERSITY HILL

from a

Central Power Plant

at

Estabrook Hall

under

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by

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The first consideration in the designing of a system of pipes for heating is the determination of the heat losses from the buildings to be heated. These heat losses from a building may occur in three ways- by transmission of heat through the walls and windows, by passage of air up the foul air flues, and by the filtration of air through the walls and air leakage around doors and windows. Experiments have been made which show that the air in an ordinary well constructed building will change about once per hour with all doors and windows closed.

In determining the heat losses from a building all surfaces which have a lower out side temperature than inside temperature must be considered. If the building has an unheated cellar below it, or an unheated attic above, losses through the floor and ceiling must be taken into account. Doors entering into a building lose approximately the same amount of heat per square foot as do windows.

There are several rules by which heat losses may be calculated, but the one which seems best fitted to this particular case is one given by Prof. John R. Allen in his "Notes on Heating and Ventilation". From a table in "Notes on Heating and Ventilation" it will be seen that glass conducts away four times as much heat as a brick wall twenty inches thick. Evidently then, if we divide the number of square feet of brick surface by four and add to this quotient the number of square feet of glass in a building we will obtain the total equivalent glass surface of the building. This sum multiplied by the difference in temperature of the air inside the room and that outside the room will give the B.t.u's lost per hour due to radiation, which is the most important loss. This loss may be multiplied by a certain factor to take care of the loss by filtration of air through the walls and air leakage around doors and windows. This factor varies with the construction and condition of the building. For a well constructed building it will be 1.5, but for an old and poorly constructed building it will be 2.0. As the air in the room changes once per hour 20% of the radiating surface should be added to allow for the heating of the air in the room itself.

The algebraic statement of this rule is as follows:

B.t.u. lost per hour $= (\frac{W}{4} + G)$ d. n.

Where - W. = sq. ft. of brick surface.

G. = sq. ft. of glass surface

d = temperature difference of inside and outside air.

n = Factor which varies from 1.5 to 2.0

d. for this locality is generally taken to be $70^{\circ}F$. d. for unheated attics and cellars as 38°. To change B.t.u. per hour to H.P. divide by 3 4 5 X 970.1.

For the following buildings blue prints were available and measurements were taken from them.

Science Hall

Humes Hall

Barbara Blount Hall

Morrill Hall

Main Building

Estabrook Hall

Gym and Armory

Auditorium & Administration Buildings.

Actual measurements were made on -

Library

South College

Y.M.C.A.

Reese Hall

Old College

Carrick Hall

Horse power required to heat Presidents Residence, Wait House and Turner House was estimated.

The following table shows results of the above calculations for these buildings.

BUILDINGS	B.t.u. per hr.	H.P. per hr.
Library	475,416	14.2
Science Hall	1,096,370	32.7
South College	961,012	29.1
Humes Hall	766,082	27.0
Y.M.C.A.	387,923	11.8
Reese Hall	595,952	17.8
Old College	520,040	15.5
Barbara Blount	930,900	27.8
Carrick Hall	423,404	12.7
Morrill Hall	2,486,840	74.2
President's Residence		8.0
Main Bldg.	2,167,853	64.7
Estabrook Hall	1,292,243	38.5
Wait House		8.0
Turner House		6.0
Gym & Armory	1,044,980	31.2
Two blings. of Main		58.2

Pipe system will be arranged as shown on accompaning blue print cantour map. The main will run straight up the hill from Estabrook Hall to a point opposite the Main Building with a slope always down hill toward Estabrook, so for its entire length return water will flow in that direction .

At points shown on the map, service connections will be made for piping to the various buildings. The branch to Morrill Hall is already established. All branch pipe lines have a sufficient slope to insure the flow of the return water toward the main except those to Science and Humes Halls. A separate return for these runs south east from Humes, east of Science Hall and makes connection with the return immediately south of the President's residence.

High pressure pipes will be put in for the purpose of heating washing and bathing water in -

Humes Hall

Y.M.C.A.

Barbara Blount

Main Bldg.

President's Residence

Estabrook Hall.

Pressure in these pipes will be about 30 pounds per square inch.

After the B.t.u. loss per hour is known the pipe sizes may be calculated. In a low pressure heating system as this is to be, the pressure between the two ends of the pipe is about 10 pounds and the allowable pressure drop seldom exceeds 2 pounds. The following formula is for a low pressure pipe system.

$$p = \frac{1}{20.663}\left(1 + \frac{3.6}{d}\right) \quad \frac{W^2 l \quad .0027}{d^5 \quad\quad D}$$

Where - d = dia. of pipe in inches

D = wt. per cu. ft. - .02602

p = diff. in pressure

l = length of pipe in ft.

$w = \dfrac{\text{B.t.u. per second}}{\text{latent heat of liquid}}$

Sizes of pipes as calculated from above formula are as follows. In low pressure gravity return systems the return is usually taken as half the size of the steam main up to 10 inches.

PIPE	Size (L.P)	Leng.	Size (H.P)	Leng. (H.P)	Size (return)	Leng. (return)
S Main 480'	10"	480'	3½"	480'	4"	480'
S Main 415'	8"	415'	3 "	415'	3"	415'
Carrick, Pres. Residenc	3"	335'	1½"	335'	2½"	335'
Humes Hall	2½"	147'	2"	147'	2"	754½'
Science Hall	3½"	90'			2"	120'
Old College	2½"	135'			2"	135'
Y.M.C.A.Reese, Library	5"	867'	2"	306'	2½"	867'
Main Bldg.	5"	318'	1½"	318'	2 "	318'
Barbara B.	3"	55'	2 "	55'	2 "	55'
So. College	3½"	8'			2 "	8'
Estabrook H.	4 "	24'	1½"	24'	2 "	24'
Conservatory	2½"	22'			2 "	22'
Carrick Hall	2½"	43'			2 "	43'
Pres. Res.	2½"	20'	1½"	20'	2 "	20'
Y.M.C.A.	2½"	10'	2 "	10'	2"	10'
Reese Hall	2½"	30'			2 "	30'

On account of difficulty of access, the pipe of longest life should be chosen for this system. Of those in use, wrought iron will give by far the best service and at the same time a very great strength, its average tensile strength being 50,000 pounds per square inch. The pressures being low, ordinary screwed flange fittings will be of sufficient strength. Flanges are used because in case of the failure of a section of pipe that section can be removed without disturbing the whole system.

Low pressure flanged fittings as given by Crane Company will be used.

The following is the list needed.

No.	Size	Price (faced&drilled)
2	10 x 10 x 3	$50.40
1	10 x 8 x 6	25.20
1	8 x 5 x 5	16.20
2	3 x 3 x 2½	9.98
2	5 x 5 x 2½	17.28
1	10 x 4 x 10	25.20
1	3½ x 3½ x 2	5.76
1	1½ x 1½ x 1½	3.34
1	3½ x 3 x 2	5.76
1	3½ x 3½ x 2	5.76
1	3 x 2 x 1½	4.94
1	3½ x 2 x 3½	5.76
1	4 x 4 x 2½	6.48
1	4 x 4 x 2	6.48
1	4 x 3 x 2½	6.48
1	3 x 3 x 2	5.13

No.	Size	Price
1	2 x 2 x 2	$4.25
1	$2\frac{1}{2}$ x 2 x 2	3.43
3	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 2	10.29
1	4 x 2 x 4	6.48
	CROSSES	
1	8 x 8 x 4 x 4	38.53
	Y - Bends	
1	10x 10 x 2	38.53
1	3 x 3 x $2\frac{1}{2}$	16.45
2	$2\frac{1}{2}$ x $2\frac{1}{2}$ x 2	14.72
1	10 x 10 x 3	38.53
	BENT PIPES	
1	8" 137.5°	16.13
1	2" 114.0°	4.72
1	5" 139.°	8.64
1	5" 119.°	8.64
1	$2\frac{1}{2}$" 139°	4.92
1	$2\frac{1}{2}$" 119°	4.92
1	8" 137.5°	16.13
1	2" 137.5°	4.25
1	3" 90°	4.94
2	2" 90°	4.25
	REDUCERS	
1	6 x $5\frac{1}{2}$	4.72
1	5 x $2\frac{1}{2}$	9.72
1	2 x $1\frac{1}{2}$	5.48
2	4 x $3\frac{1}{2}$	15.60

Small angles maybe made advantageously by the use of Adjustable Annular Wedges. These wedges fit within the bolt circle of flanged fittings and make any angle up to approximately 10° in any direction.

The following number of Adjustable Wedges will be needed.

No.	Size	Price
3	10"	$24.90
3	8"	22.20
12	2"	22.68
3	4"	6.72
9	3"	23.40
3	3½"	8.64
1	1½"	1.89
7	2½"	16.38
2	5 "	8.64

To take care of expansion and contraction in a system of pipes when changes in temperature occur anchors and expansion joints must be placed at intervals from each other, with one expansion joint between every two anchors. Anchors must be placed at all bends and at all service connections in order that expansion and contraction will not give the pipe a sidewise motion. The Standard Flanged Expansion Joint No. 401 as given by the Crane Company will be used. Each expansion joint will be made accessable for repacking by a manhole as in the illustration. Anchors and expansion joints will be placed as shown on accompaning map.

The sizes and number of each size needed are given below.

No.	Size	Price
	MAINS	
5	10"	$630.00
3	8"	237.60
5	4"	108.00
6	3"	80.00
5	$3\frac{1}{2}$"	90.00
	Carrick, Pres. Res.	
2	3"	26.64
2	$1\frac{1}{2}$"	24.30
2	$2\frac{1}{2}$"	23.04
	Humes Return	
4	2"	48.60
1	2" Double Exp.	25.20
	Humes Hall	
1	$2\frac{1}{2}$"	11.52
1	2"	12.15
	MAIN BLDG.	
2	5"	69.12
2	$1\frac{1}{2}$"	24.30
2	2"	24.30
	Y. Reese, Library	
5	5"	172.80
3	2"	36.45
5	$2\frac{1}{2}$"	57.60
2	5" Double Exp	151.20
2	$2\frac{1}{2}$" " "	57.60

OLD COLLEGE

No.	Size	Price
1	$2\frac{1}{2}$"	$11.52
1	2"	12.15

BARBARA BLOUNT

No.	Size	Price
1	3"	13.32
2	2"	24.30

The question of anchors is an important one. An anchor made of concrete in the form of a box is a very satisfactory one. For our main steam line up the hill, the steam main, the high pressure steam main, and the return main will all be made fast to the same anchors. A concrete box 2 feet square and 2 feet deep with a 10 inch wall will give us an anchor of 31 cubic feet, which will be ample for these three pipes. A metal cover will be placed over each anchor. The pipe will be made fast to the anchor by means of metal strips. These strips will be bent in the middle in the form of a half circle to fit the pipe. One will be placed above and bolted to one placed below. One pair of these will be placed on each side of a flange to prevent the pipe slipping between them. For the five inch pipes 15 cu. feet of concrete will be sufficient and the Humes Hall return will be anchored to a block of about 3 cubic feet.

Underground pipes must be covered with an insulating material to prevent the loss of heat. There are several methods of doing this.

Probably the simplest method of insulation and also the cheapest is to enclose the pipes in a pine board case. This method however, is not as desirable as some of the others because its heat insulation is not as satisfactory and the pipes are more difficult to get at for repairs. Its chief asset is that it is cheap.

Undoubtedly the most satisfactory method is to run the pipes through a tunnel swinging them on rollers. In this method they are easily accessible for repairs. The first cost of this installation is prohibitive in most cases, so will not be considered here.

A system quite largely used is to enclose the pipes in hollow wooden logs. These log pipes are creosoted and filled with an asphalt paint or some other means of preservation from decay. They are often lined with a tin lining. The pipe is passed through the log and is usually covered with about one inch of some standard form of pipe covering. This furnishes a very satisfactory heat insulation. It is much more durable than the pipe board duct, is easier to install and easier to replace. It has however, the disadvantage of making the pipe quite inaccessible and the whole system must be removed in case repairs are needed. Taken all together this method is very satisfactory for the insulation of a single pipe, but for several pipes, as in our case, another method will be found better.

That method is the split tile method as installed by the Johns-Manville Company. These manufacturers guarantee for their system an efficiency of not less than 90%. This means that 90% of the heat that would be lost if the pipes were uninsulated, is saved by the use of this insulation. The materials which form the protective part of this system are stone and the depreciation of the entire system is so small as to be negligible. While the initial cost of this system of insulation is greater than that of some less efficient methods, the cost per year is far less.

The containing sections are simply split tile of a size sufficient to leave a space of at least 3 inches from the outside of the pipe to the inside of the tile. The supporting sections of the system are sections that completely cover and enclose the roll frame and the concrete base in which the roll frame is enclosed and also acts as a connecting link between the containing sections. The roll frame provides for the support of the pipes and also provides rollers on which the pipes move when they expand or contract. It is anchored in a concrete base, without leaving or causing openings which may admit water. To prevent water from accumulating around the system and in man-holes, and anchor pits an underdrain is provided. This underdrain is of small tile pipe laid with open joints and imbedded in crushed stone. This system consists of -

(a) Roll frames and rolls for the support of piping.

(b) Supporting sections for the enclosure and support of the roll frames.

(c) Straight sections and unions for the connections between supporting sections and between supporting sections and buildings or pits.

(d) Asbestos filling for the insulation of the pipes.

(e) Underdrain for the drainage of the systems

(f) Broken stone or gravel for surrounding lower half of system.

(g) Shutters to seal the ends of the system where it terminates in buildings, manholes or pits.

For insulating the separate return pipe from Humes and Science Halls a Pyro-Bestos covering will be used. Pyro-Bestos is an absolutely water and fire-proof insulating material. Pipe guides are placed every 15' inside the Pyro-Bestos for the pipe to slide on during expansion and contraction. Price per lineal foot for double 1" broken joint construction for a 2" pipe is $1.00

874.5'	@	$1.00	$874.50
58	guides @	.19	11.02
Total			$885.52

For the purpose of calculating costs the total length of different sized pipes were sumarized. Prices are quoted by C. M. McClung Company.

PIPE Size	Length	Price per Hd.	Total Price
10"	472'0"	$168.45	$795.08
8"	408'3"	131.60	536.93
3"	1214'6"	35.18	437.08

Size	Length	Price per Hd.	Total Price
2½ "	1602'6"	$26.18	$429.50
3½ "	574'0"	45.81	262.95
5 "	1175'0"	72.28	819.28
4 "	499'8"	54.27	291.81
1½ "	696'4"	12.64	87.97
2 "	2053'9"	17.00	349.18
		Total	$4,009.78

Total cost of fittings and expansion joints as given on previous pages is $2591.68.

The cost of split tile as given by Chandler & Company will be as follows:

Length	Size	Price per ft.	Cost
480'	21"	$1.50	$720.00
415'	18"	1.02	423.30
1,599'	15"	.75	1199.25
505'	12"	.51	257.55
2,999		Total	$2,600,00

Estimated cost of rollers $1,150

Estimated cost of Sponge asbestos $4,000.

The number and sizes of anchors to be used are as follows:

Number	Cu. ft.	Total Cu. ft.
9	31	279
11	15	165
5	10	50
6	3	18
		512 cu. ft. ± 19 cu.yds

For roller frame anchors about one cubic foot will be required per anchor. Using 150 anchors - 150 cu. ft. = 5.9 cubic yards.

For concrete floors in manholes 4 cubic yards will be needed.

Total concrete = 28.9 cubic yards.

From the formula $\frac{11}{c + s + g}$ if a 1, 3, 6, mixture is used, 1.1 barrels of cement, .485 cu. yards sand and .97 cubic yards of stone will be used in each cubic yard of concrete.

28.9 x 1.1 =	31.79	bbl. cement.
28.9 x .485 =	14.02	cu. yards sand
28.9 x . 97 =	28.0	cu. yards gravel

31.79 bbl @ $3.60 =	$114.44
14.03 cu. yds. @ $2.00 =	28.06
28.5 cu. yds. @ 1.60	15.60
Total	188.10

Broken stone for packing around insulating system and underdrain -

410 cu. yds @ $1.60 = $656.00

For the underdrain 6" and 4" tile will be used -

Ft.	Size	Price per ft.	Total
2,097	6"	.19½	$408.91
745	4"	.13	96.85
		Total	505.76

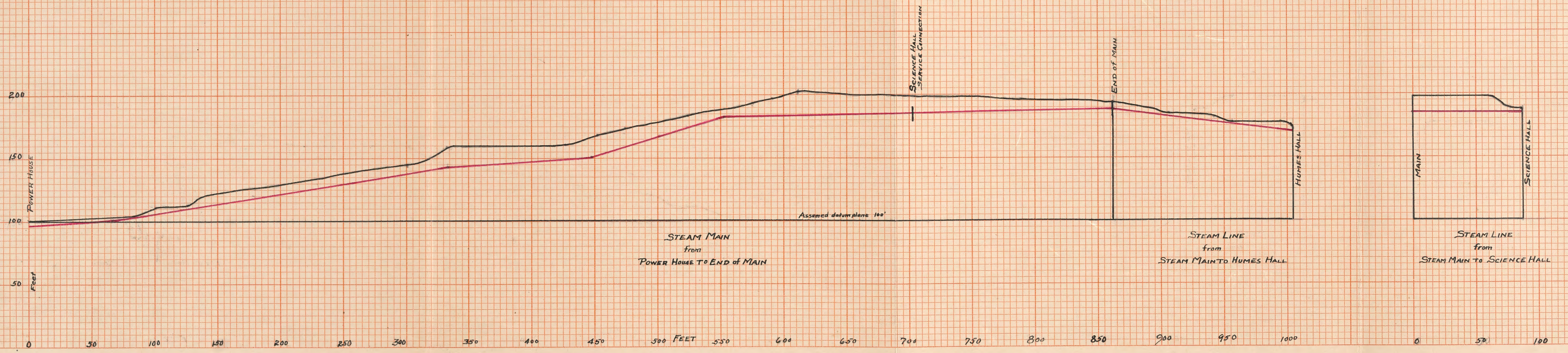
There will be 27 manholes to be made of brick from destroyed buildings. Manhole curbs size #1½ as given by American District Steam Company are $45.00

27 @ $45.00 = $1215.00

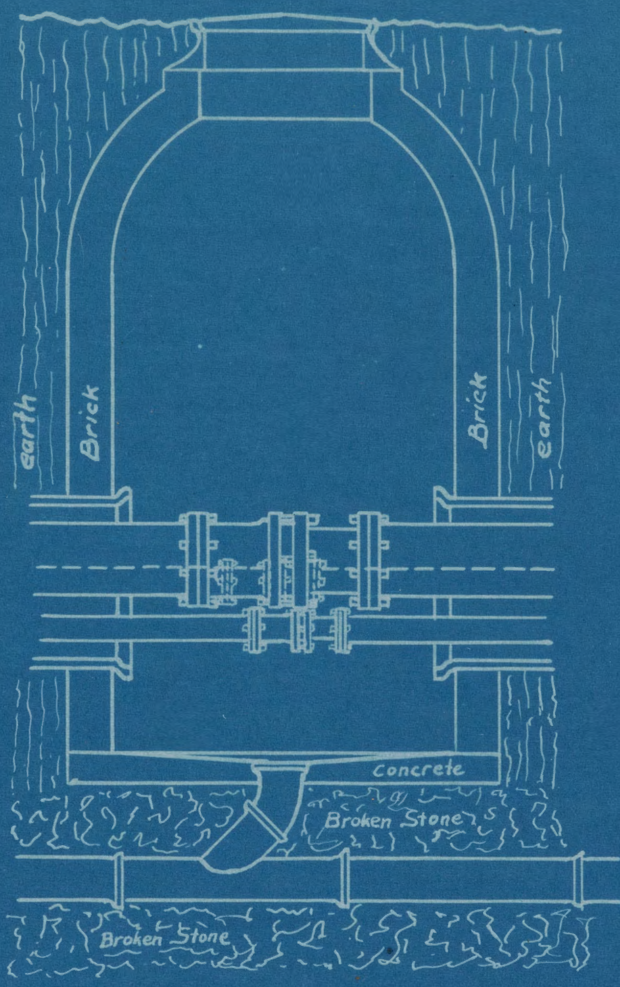
A total excavation of 2,131 cubic yards will be necessary. At $1.00 a yard cost will be $2,131.

Summary of Cost -

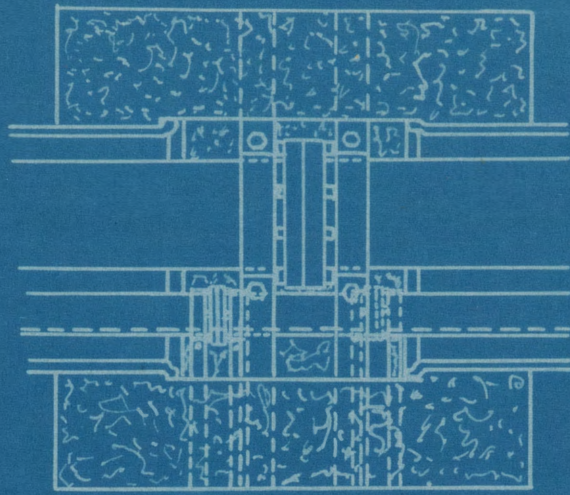
Insulation for Humes Hall Return	$885.52
Pipes	4,009.78
Expansion Joints and Fittings	2,591.68
Split Tile	2,600.10
Rollers	1,150.00
Sponge Asbestos	4,000.00
Concrete	188.10
Broken Stone	656.00
Underdrain Tile	505.76
Manhole Curbs	1,215.00
Excavation	2,131.00
Total cost of Installation	19,932.94



Science Hall
Service Connection
End of Main
200
150
100
50
Power House
Feet
Humes Hall
Main
Science Hall
Assumed datum plane 100'
Steam Main
from
Power House to End of Main
Steam Line
from
Steam Main to Humes Hall
Steam Line
from
Steam Main to Science Hall
0 50 100 150 200 250 300 350 400 450 500 Feet 550 600 650 700 750 800 850 900 950 1000
0 50 100

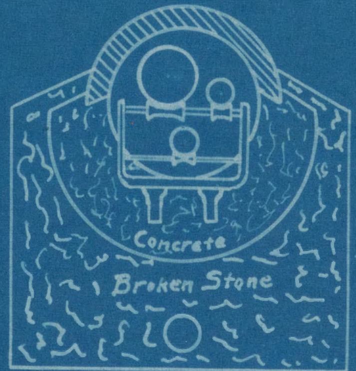


MANHOLE
SHOWING
EXPANSION JOINTS & UNDER DRAIN
Scale – 1" = 2'

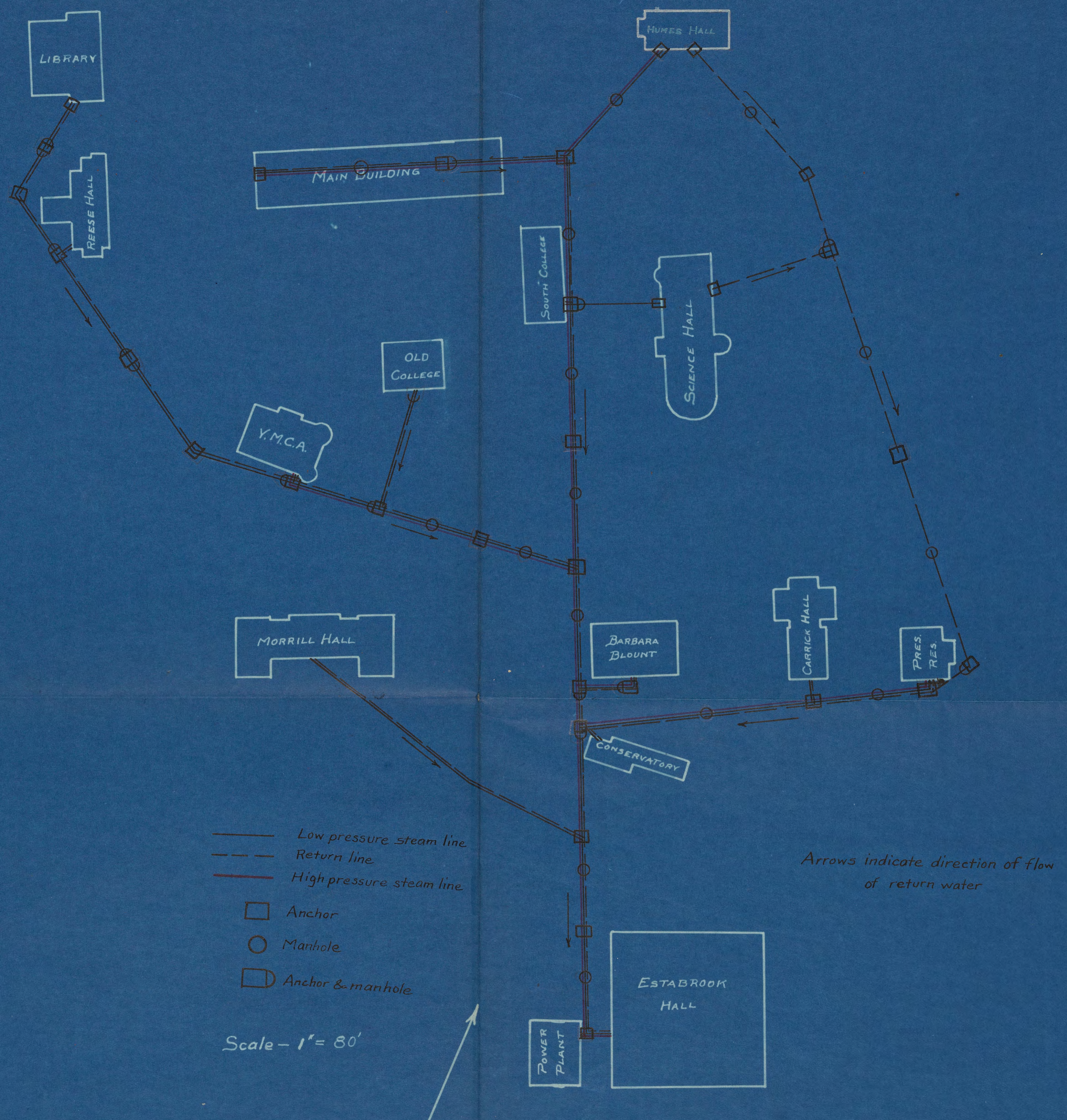


ANCHOR PIT

Scale—$\frac{3}{4}$" = 1'



VIEW THROUGH SUPPORTING SECTION



LIBRARY
REESE HALL
MAIN BUILDING
HUMES HALL
SOUTH COLLEGE
SCIENCE HALL
OLD COLLEGE
Y.M.C.A.
MORRILL HALL
BARBARA BLOUNT
CARRICK HALL
PRES. RES.
CONSERVATORY
ESTABROOK HALL
POWER PLANT
Low pressure steam line
Return line
High pressure steam line
Anchor
Manhole
Anchor & manhole
Scale - 1" = 80'
Arrows indicate direction of flow of return water