Radiant heating installations in Montana
by Leroy C Horpedahl

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requiremenrs for the degree of Master of Science in Mechanical Engineering
Montana State University
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Abstract:
Radiant heating is not something very new. The Romans used it over 2,000 years ago, but it was not until 1908 that it was put on a commercial basis. There are many methods of supplying this form of heat to a dwelling. It may be done by passing hot air through ducts in floors, walls, or ceilings, or it may be accomplished by means of passing hot water through pipes in the same areas. This thesis concerns only the latter.

Montana State College was granted a sum of $5,000 by the Danforth Foundation to be used toward the erection of a campus chapel. Various departments have volunteered their services, both professional and manual, to help make this chapel a reality at a minimum cost and at a maximum of student interest. My contribution is the complete design of a radiant heating system for the chapel which is included in this thesis.

Radiant floor panels used with hardwood floors have been the desire of many citizens, hence a complete design and cost analysis is given with such a construction. This has been constructed and is in satisfactory operation.

Much can he learned from the mistakes and suggestions of others, hence a survey of radiant heating installations in Montana is included in this thesis. In connection with the survey, several inquiries were made concerning proper floor coverings to use with heated floors, The results of the research conducted on various types of floor coverings are also included in this thesis.

All calculations in this thesis were performed on a slide rule.

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RADIANT HEATING INSTALLATIONS IN MONTANA

by

LEROY C. HORPEDAHL

A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Master of Science in Mechanical Engineering

at

Montana State College

Approved:

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Bozeman, Montana
July, 1950

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ABSTRACT

Radiant heating is not something very new. The Romans used it over 2,000 years ago, but it was not until 1908 that it was put on a commercial basis. There are many methods of supplying this form of heat to a dwelling. It may be done by passing hot air through ducts in floors, walls, or ceilings, or it may be accomplished by means of passing hot water through pipes in the same areas. This thesis concerns only the latter.

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Radiant floor panels used with hardwood floors have been the desire of many citizens, hence a complete design and cost analysis is given with such a construction. This has been constructed and is in satisfactory operation.

Much can be learned from the mistakes and suggestions of others, hence a survey of radiant heating installations in Montana is included in this thesis. In connection with the survey, several inquiries were made concerning proper floor coverings to use with heated floors. The results of the research conducted on various types of floor coverings are also included in this thesis.

All calculations in this thesis were performed on a slide rule.

A RADIANT HEATING SYSTEM FOR A PROPOSED DANFORTH CHAPEL ON THE CAMPUS OF MONTANA STATE COLLEGE

In the design of any building in Montana, careful consideration must be given to the type of heating system used with respect to cost, maintainence, and the ability to heat during extreme weather conditions. In a more specific case, such as the design of a chapel, other conditions must also be included, such as quietness of operation, comfort, and exclusion of elements which would tend to deviate from the modernistic theme of the contemporary chapel. With these restrictions in mind, radiant heating was suggested and the following design is proposed. Two complete systems are shown, one with ½" copper tubing and the other with 3/4" copper tubing. The selection of the ½" tubing system was chosen because of the better heat distribution in the concrete floor with shorter spacing distances. Also, the cost was slightly less.

The first step in any heating design is to calculate the heat loss of the building. In radiant installations, it is necessary to break up the heat losses into each individual room because the amount of panel installed in each room is a function of the heat loss for that particular room. In this particular case, recommendations for insulation and windows were made in conjunction with the heat loss calculations at the request of the architect. Heat loss calculations for both single and double glass windows were made to determine whether single glass would be feasible. As the calculations which

follow show, it would not be practical here in Montana to use the single glass over such a large area. First of all, frost formations would occur on the window with the resulting moisture on the walls and floor below. Secondly, it would be impossible to heat this chapel under extreme conditions with just a floor panel using radiant heat without exceeding an 85°F floor temperature. Wall or ceiling panels were not considered in this design because of the nature of their construction.

The heat loss calculations with the necessary recommendations and assumptions, follow. All heat transfer coefficients (U) and resistances (R) were taken from the ASHVE Guide (1949).

Heat Loss Calculations

A. Sanctuary and entry

1. Ceiling

	R
Inside air film	0.606
Insulating board ½" thick	1.52
3/4" air space	0.91
4" mineral wool insulation	14.80
8" air space	0.91
25/32" fir or yellow pine sheathing	0.98
Built-up roof (assumed 3/8" thick)	0.28
Outside air film	0.167
	R = 20.173

U = 1/20.173 = 0.05 Btu/hr-sq.ft.-°F

Ceiling area =

53 x 22½ - 2 x 6 - 5 x 2⅔ x 2½ = 1149 sq. ft.

Heat loss = 1149 x .05 x 90. = 5160 Btu/hr

2. Walls

	R
Inside air film	0.606
25/32" redwood	1.055
25/32" pine sheathing	0.98
4" mineral wool	14.80
25/32" pine sheathing	0.98
25/32" redwood	1.055
Outside air film	0.167
	R = 19.643

U = 1/19.643 = .051 Btu/hr-sq.ft.-°F

Wall area

$9\frac{1}{2}$ x 33.5 + $9\frac{1}{2}$ x 19 + $9\frac{1}{2}$ x 22.5 = 713 sq. ft.

Heat loss = 713 x .051 x 90 = 3270 Btu/hr

3. Doors (assumed thickness 1 3/4")

U = 0.51 Btu/hr-sq.ft.°F

Door area = 7 x 3 = 21 sq.ft.

Heat loss = 2 x 21 x .51 x 90 = 1928 Btu/hr

4. Stained glass window

U = 1.13 Btu/hr-sq.ft.-°F

Area = $9\frac{1}{2}$ x 6 = 57 sq.ft.

Heat loss = 57 x 1.13 x 90 = 5,800 Btu/hr

5. Skylights

U = .45 Btu/hr-sq.ft.°F

Area = 5 x 2.5 x 2.5 = 31.25 sq.ft.

Heat loss = 31.25 x .45 x 90 = 1,265 Btu/hr

6. Glass wall area

Area = $6\frac{1}{3}$ x 43 + $2\frac{1}{3}$ x 50 = 404 sq. ft.

(Assuming the use of double glass)

U = .45 Btu/hr-sq.ft.-°F

Heat loss = 404 x .45 x 90 = 16,350 Btu/hr

7. Infiltration--crack method

Windows

Factor for average window, non-weather stripped--
39.3 cu. ft./ft. crack/hr

Two.....$2\frac{1}{2}$' x 3' = 22 ft. of crack

One.....$2\frac{1}{2}$' x 5' = 15 ft. of crack

Total.....37 ft.

37 x 39.3 = 1454 cu. ft./hr

Doors

Factor....110.5 cu. ft./ft. crack/hr

Two doors....3' x 7' = 40 ft. of crack

40 x 110.5 = 4,420 cu. ft./hr

Total = 1454 + 4420 = 5,874 cu. ft./hr

Volume of sanctuary and entry

1180 x 10 = 11,800 cu. ft.

This only gives $\frac{1}{2}$ air change per hr., therefore,
assume 1 air change per hr.

Heat loss = 11,800 x .018 x 90 = 19,100 Btu/hr

Where .018 = .24 x .075

and .24 = specific heat of air

.075 = density of air, lbs./cu. ft.

8. Floor (ground loss)

	Heat loss, Btu/hr
Ceiling	5160
Walls	3270
Doors	1928
Stained glass window	5800

Skylights..... 1265
Glass wall.....16350
Infiltration.....19100
Total.....52873 Btu/hr

Assume ground loss 15% of total heat loss:

15% x 52873 = 7930 Btu/hr

Total = 7930 + 52873 = 60,803 Btu/hr

B. Sacristy

1. Ceiling area

Area = 17 x $11\frac{1}{2}$ - 7 x 5 = 160 sq. ft.

U = .05 Btu/hr - sq. ft. - $^{\circ}$F

Heat loss = 160 x .05 x 90 = 720 Btu/hr

2. Wall area

Area = $11\frac{1}{2}$ x $9\frac{1}{2}$ + 6 x $9\frac{1}{2}$ + $10\frac{1}{2}$ x $9\frac{1}{2}$ = 261 sq. ft.

U = .051 Btu/hr - sq. ft. - $^{\circ}$F

Door area = 21 sq. ft.

Window area = 21 sq. ft.

Total area = 261 - 21 - 21 = 219 sq. ft.

Heat loss = 219 x .051 x 90 = 1000 Btu/hr

3. Door area

Area = 21 sq. ft.

U = .51 Btu/hr - sq. ft. - $^{\circ}$F

Heat loss = 21 x .51 x 90 = 964 Btu/hr

4. Window area (assume double glass)

Area = $2\frac{1}{2}$ x $8\frac{1}{2}$ = 21 sq. ft.

U = .45 Btu/hr - sq. ft. - $^{\circ}$F

Heat loss = 21 x .45 x 90 = 850 Btu/hr

5. Infiltration--crack method

Windows

Factor---39.3 cu. ft./ft. crack/hr

One.....$2\frac{1}{4}'$ x $2\frac{1}{3}'$ = 9.5 ft. of crack

39.3 x 9.5 = 373 cu. ft.

Doors

Factor---110.5 cu. ft./ft. crack/hr

One.....3' x 7' = 20 ft. of crack

110.5 x 20 = 2210 cu. ft.

Total = 373 + 2210 = 2583 cu. ft./hr

Volume of sacristy = 160 x 10 = 1600 cu. ft.

Crack method gives approximately two air changes per hr. Use infiltration by crack method for heat loss.

Heat loss = .018 x 2583 x 90 = 4190 Btu/hr

6. Floor (ground loss)

	Heat loss, Btu/hr
Ceiling	720
Walls	1000
Doors	964
Windows	850
Infiltration	4190
Total	7724 Btu/hr

Assume ground loss = 15% of total heat loss

15% x 7724 = 1158 Btu/hr

Total = 7724 + 1158 = 8882 Btu/hr

Total Heat Loss For Chapel

Assumed Use of Double Glass in East Wall

Sanctuary and entrance

1. Ceiling	5160	
2. Walls	3270	
3. Doors	1928	
4. Stained glass window	5800	
5. Skylights	1265	
6. Glass wall	16350	
7. Infiltration	19100	
8. Floor	7930	
Total	60803	Btu/hr

Sacristy

1. Ceiling	720	
2. Walls	1000	
3. Doors	964	
4. Windows	850	
5. Infiltration	4190	
6. Floor	1158	
Total	8882	Btu/hr

Total heat loss..... 69,685 Btu/hr

Total Heat Loss For Chapel

Assumed Use of Single Glass in East Wall

Sanctuary and entrance

1. Ceiling	5160	
2. Doors	1928	
3. Walls	3270	
4. Stained glass window	5800	
5. Skylights	1265	
6. Glass wall	41100	
7. Infiltration	19100	
8. Floors	7930	
Total	85553	Btu/hr

Sacristy

1. Ceiling	720	
2. Walls	1000	
3. Doors	964	
4. Windows	850	
5. Infiltration	4190	
6. Floor	1158	
Total	8882	Btu/hr

Total heat loss..... 94,435 Btu/hr

Design of Floor Panels

Note:

Heat losses based on the use of double glass in all windows except stained glass mural.

Design temperature of water is 130°F with a 20°F temperature drop through the circuit.

Depth of bury is 2 inches.

A. Floor panel - ½" copper tube 9" and 6" O.C.

1. Sanctuary and entry

Heat loss = 60803 Btu/hr

Panel rating used = 50 Btu/hr-sq. ft.

Floor panel area required = 60803 ÷ 50 = 1215 sq. ft.

Actual floor area = 1160 sq. ft.

Use ½" copper tube 9" and 6" O.C.

Length of tube required = 1040 x 1.3 = 1352 ft.
120 x 2.0 = 240 ft.

Total..... 1592 ft.

2. Sacristy

Heat loss = 8882 Btu/hr

Panel rating used = 50 Btu/hr - sq. ft.

Floor panel area required = 8882 ÷ 50 = 177 sq. ft.

Actual floor area = 162 sq. ft.

Use ½" copper tube 9" O.C.

Length of tube required = 162 x 1.3 = 210 ft.

Total length of tube required = 1592 + 210 = 1802 ft.

3. Circuits

Use circuits of approximately 180 feet.

No. of circuits = 1802 ÷ 180 = 10--Approximately

Circuit	#1	184 Ft.
"	#2	186 "
"	#3	173 "
"	#4	181 "
"	#5	170 "
"	#6	186 "
"	#7	185 "
"	#8	191 "
"	#9	182 "
"	#10	166 "
	Total	1804 Ft.

4. Supply and return headers

Use 2" W. I. pipe, 4 ft. long each.

5. Pump

Use 1¼" standard or 1½" high head

6. Water heater

Recommend use of hot water converter similar to no. GC4-4 as supplied by General Fittings Co. and rated at 470 sq. ft. of hot water radiation (5 lb. steam).

7. Valves

Use stop and waste valves on the return header to facilitate removal of air during the filling operation.

Use gate valves on the supply header.

The general specifications, list of materials, and cost follows.

General Specifications:

Heat loss from the chapel is based on the insulation

quantities given below. Any deviation will possibly change the entire set-up, hence strict adherence is advised for satisfactory operation of the heating system.

I. Insulation:

(1) Ceiling....4" rock wool or equivalent

(2) Walls.....4" rock wool or equivalent

(3) Floor.....1" fiber glass insulation at exposed perimeter of slab. Extend 3' inside along the rock wall.

II. Windows:

(1) Sanctuary....double glazing throughout of a "thermopane" nature; three operating sections, one over each door approximately 2' 6" x 3' 0" and one in the end bay approximately 2' 6" x 5' 0".

(2) Skylights....double glass (18" airspace).

(3) Sacristy.....double glazing; one operating section approximately 2' 3" x 2' 6".

III. Doors:

(1) All doors are flush wood doors 1-3/4" thick.

IV. Floors:

(1) The floor is to be constructed of a 4" concrete slab poured on 6" crushed rock or extremely coarse gravel. The floor must be poured separately from the foundation and may have a concrete surface finish, tile, linoleum, or wood nailed to sleepers embedded in the concrete.

V. A 3/4" copper tubing supply and return line shall be imbedded in the concrete from the heating

room to the east wall to be used with radiant baseboards along the east wall of windows should it become necessary.

VI. Construction of the heating system will be done by the students taking the radiant heating course during the fall quarter under the direction of Dr. H. F. Mullikin, if agreeable.

VII. Bill of materials and cost:

1 circulator (1½" std. or 1¼" high head).....	$ 49.00
1 indoor thermostat (Perfex line voltage)...	11.50
1 converter (similar to GC4-4, General Fittings Co.)....	73.20
1 floating thermostatic trap (3/4").....	4.00
1 temperature regulator (no. 928-LC Fulton Sylphon-1½").....	80.00
1 expansion tank (20 gal.).....	16.00
1 automatic air vent.....	4.30
10 shut-off valves (1/2").....	13.50
10 stop and waste valves (1/2").....	15.00
1 supply header (4 ft. of 2" W.I. pipe).....	5.00
1 return header (4 ft. of 2" W.I. pipe).....	5.00
90 ft. of 3/4" copper tubing type L.....	20.00
1 check valve ½".....	6.00
1 reducing valve and 1 relief valve (combined) ½".....	12.00
1 altitude gage (thermometer included).....	7.50
1800 ft. of ½" copper tubing type L.....	282.00

4 shut-off valves 1½"..... 40.00

30 ft. 1½" water pipe @ 42¢ per ft..... 12.60

Miscellanious elbows, tees, etc..... 10.00

Total.....$666.60

VIII. The prices quoted above are subject to educational discounts which can be received if ordered through the Mechanical Engineering Department.

IX. The return header will be located in a pit slightly below the floor level to facilitate draining the system. A sewer outlet will be located in the pit.

X. The headers may be located along the north wall instead of the south wall as shown on the drawing. This will help prevent excessive heat in the utility room.

XI. At each joint in the concrete, wrap each tube with felt or some cloth-like material to prevent the tubes from shearing off due to ground movement.

B. Floor panel--3/4" copper tube 12" and 9" O.C.

1. Sanctuary and entry

Panel rating - 50 Btu/hr

Heat loss and panel area same as with ½" tube.

Length of tube required - 940 x 1 = 940 ft.
200 x 1.3 = 260 ft.
Total.....= 1200 ft.

2. Sacristy

Heat loss and panel area same as with $\frac{1}{2}$" tube

Length of tube required = 162 x 1 = 162 ft.

Total length = 1200 ÷ 162 = 1362 ft.

3. Circuits

Use circuits of approximately 280 ft.

No. of circuits = 1362 ÷ 280 = approximately 5

Circuit	#1	279 ft.
"	#2	290 "
"	#3	281 "
"	#4	270 "
"	#5	273 "
Total		1393 ft.

4. Supply and return headers

Use 2" W. I. pipe, 4 ft. each

5. Pump

Use $1\frac{1}{2}$" standard or $1\frac{1}{2}$" high head

6. Water heater

Recommend use of hot water converter similar to no. GC4-4 as supplied by General Fittings Co. and rated at 470 sq. ft. of hot water radiation (5 lb. steam.

7. Valves

Use stop and waste valves on the return header to facilitate removal of air during the filling operation. Use gate valves on the supply header.

The same general specifications will be used for the 3/4" tubing as for the $\frac{1}{2}$" tubing.

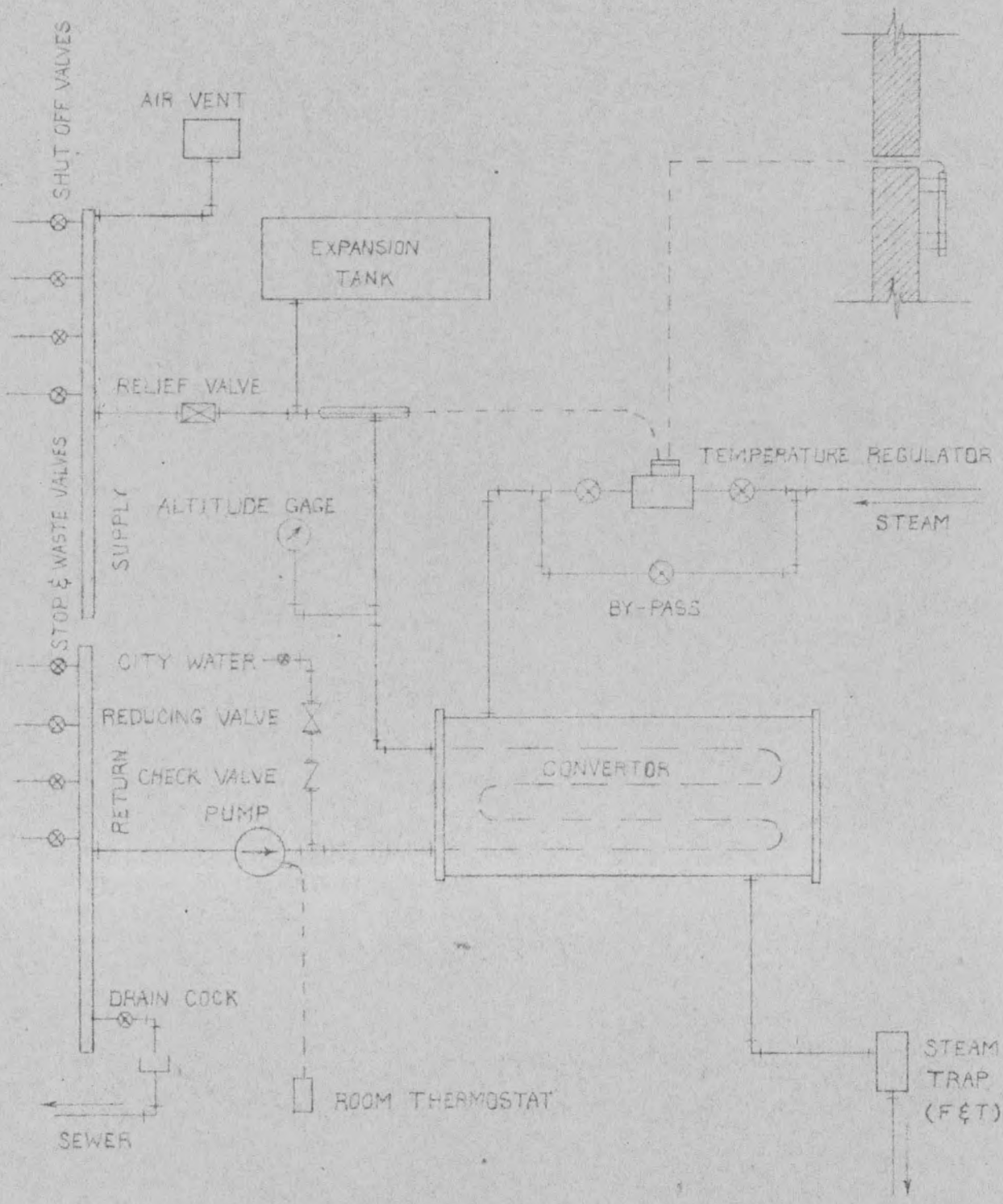
List of materials and cost:

1 circulator (1½" std. or 1¼" high head) B & G.....	$ 49.00
1 indoor thermostat (Perfex line voltage).....	11.50
1 converter (similar to GC4-4, General Fittings Co....	73.20
1 floating thermostatic trap (3/4").....	4.00
1 temperature regulator (no. 928-LC Fulton Sylphon-1½"	80.00
1 expansion tank (20 gal.).....	16.00
1 automatic air vent.....	4.30
6 shut-off valves (3/4").....	11.00
6 stop and waste valves.....	12.00
1 supply header (4 ft. of 2" W. I. pipe).....	5.00
1 return header (4 ft. of 2" W. I. pipe).....	5.00
1490 ft. of 3/4" copper tubing type L.....	332.00
1 check valve (1½").....	6.00
1 reducing valve and relief valve (combined) ½".....	12.00
1 altitude gage (thermometer included).....	7.50
4 gate valves (1½").....	40.00
30 ft. 1½" water pipe @ 42¢ per ft.....	12.60
Miscellaneous tees, elbows, etc.....	10.00
Total.....	$691.10

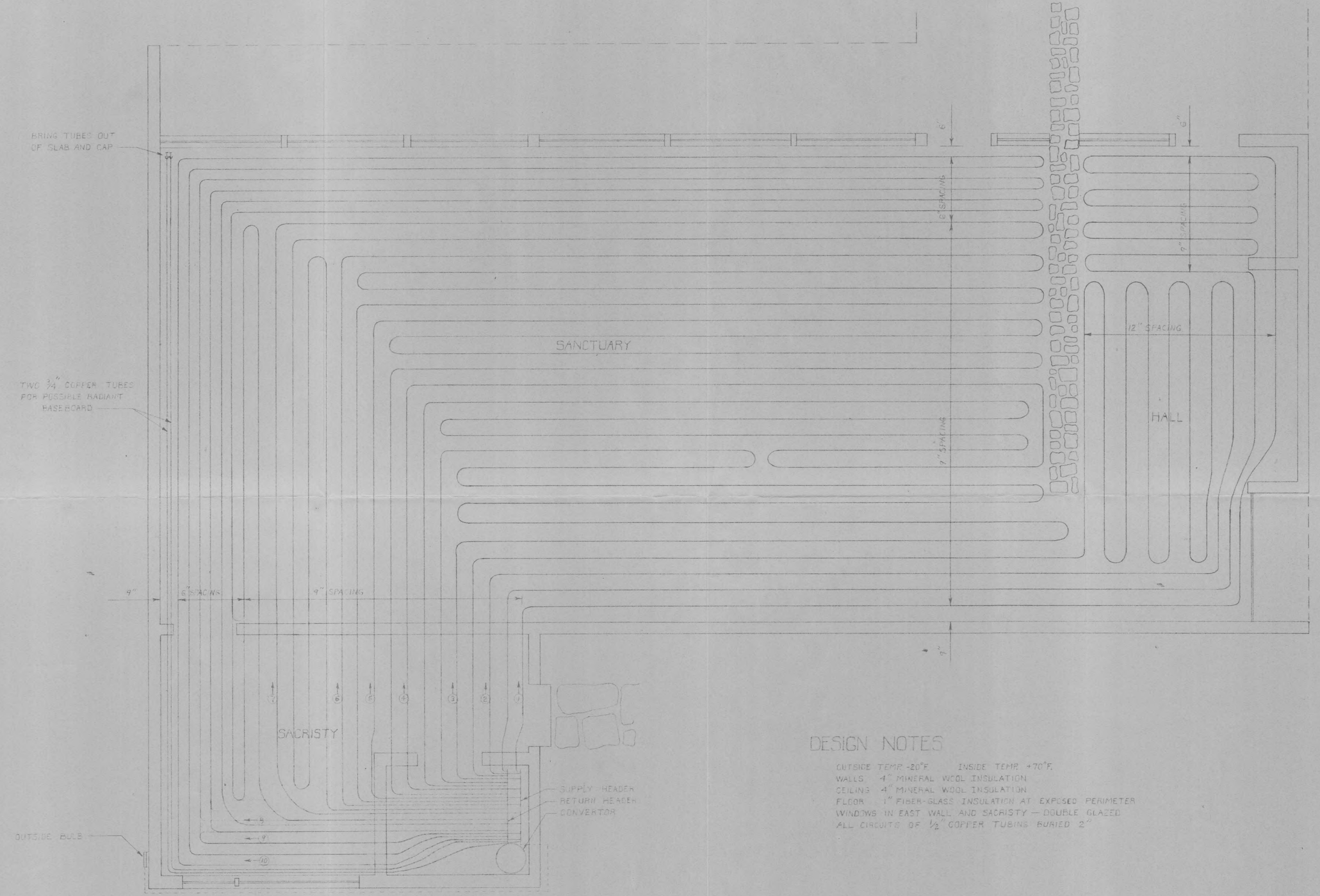
The cost of materials for the two systems is slightly in favor of the ½" system, but the added labor would put both of them about equal. It is recommended that the ½" system be used because the closer spacing will give a more uniform panel

temperature and the smaller tubing gives more turbulent flow and hence better heat transfer.

This chapel has been designed by the students of the Montana State College Department of Architecture. As many departments as possible will contribute toward its construction when sufficient funds are available.



MONTANA STATE COLLEGE BOZEMAN, MONTANA			
CONTROLS FOR DANFORTH CHAPEL HEATING SYSTEM			
DR. BY L. HORPEDAHL	6/20/50	CK. BY	
TR. BY		APP. BY	
	DRAWING NO. ME 319		



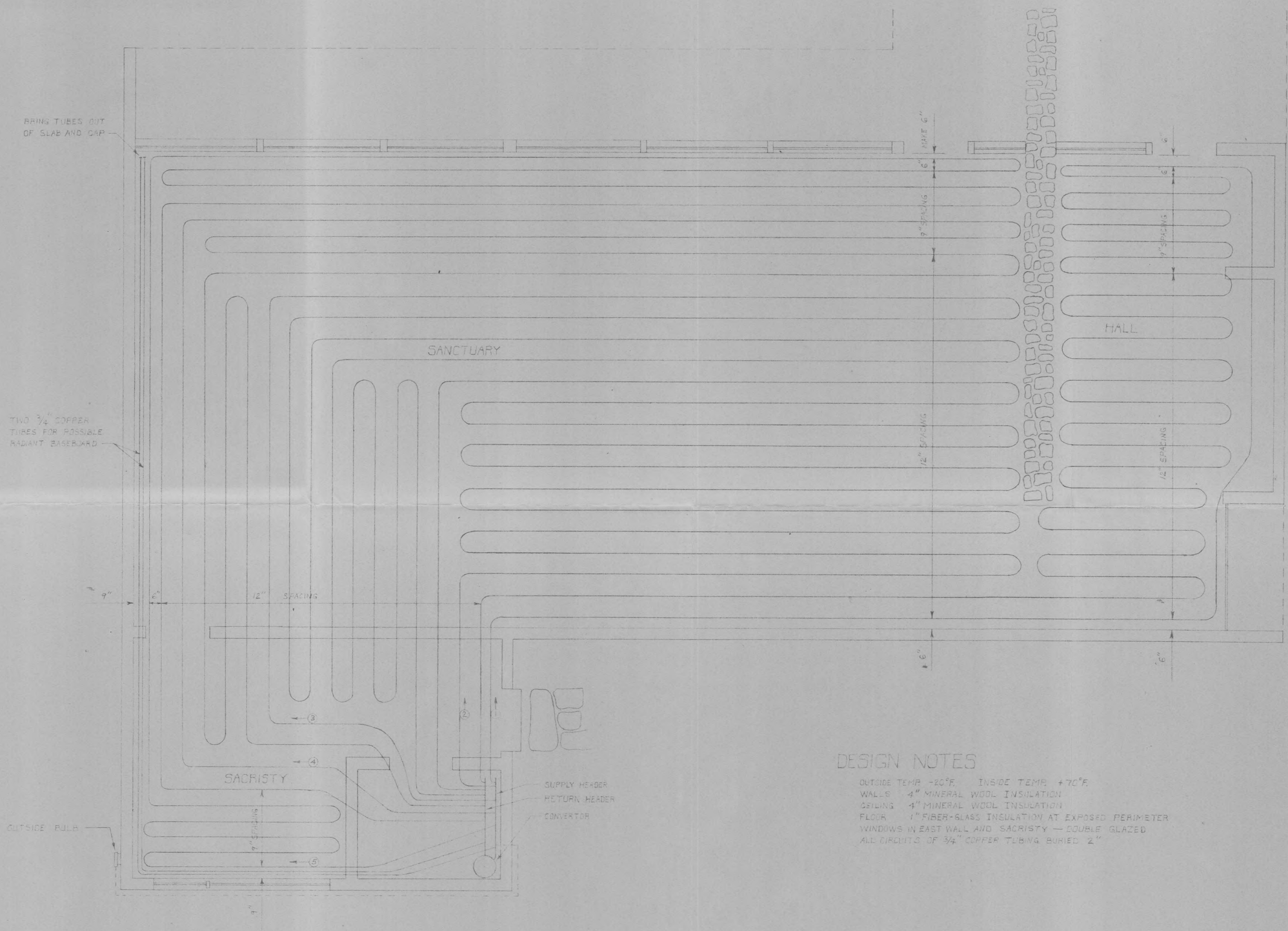
DESIGN NOTES

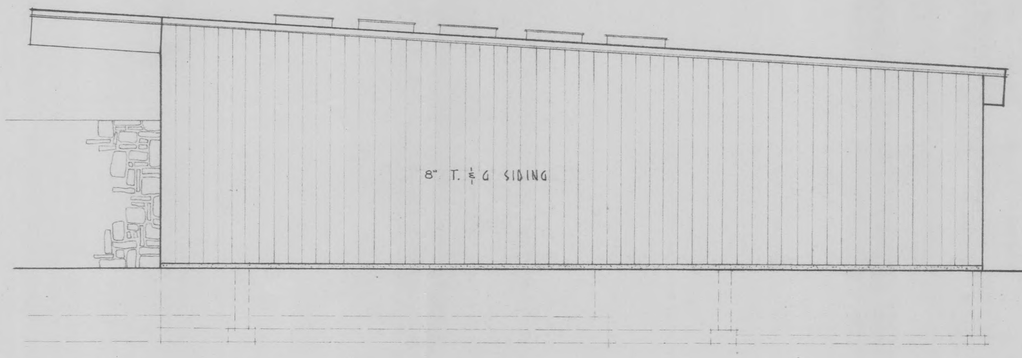
OUTSIDE TEMP -20°F INSIDE TEMP +70°F.
WALLS 4" MINERAL WOOL INSULATION
CEILING 4" MINERAL WOOL INSULATION
FLOOR 1" FIBER-GLASS INSULATION AT EXPOSED PERIMETER
WINDOWS IN EAST WALL AND SACRISTY — DOUBLE GLAZED
ALL CIRCUITS OF ½" COPPER TUBING BURIED 2"

MONTANA STATE COLLEGE
BOZEMAN, MONTANA

RADIANT HEATING FOR PROPOSED DANFORTH CHAPEL

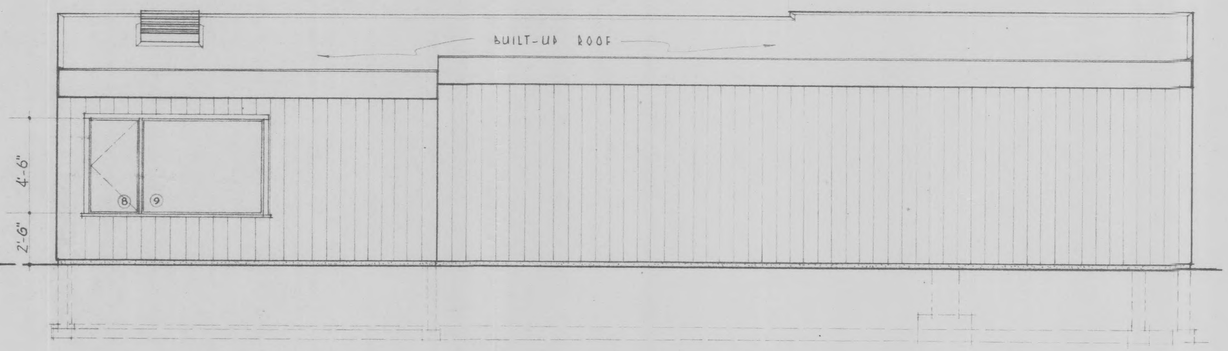
DR. BY L. HOPPEDAHL	6/23/50	CK. BY	
TR. BY		APP. BY	
SCALE: 3/8" = 1 FT.	DRAWING NO. ME 320		


BRING TUBES OUT OF SLAB AND CAP
TWO 3/4" COPPER TUBES FOR POSSIBLE RADIANT BASEBOARD
OUTSIDE BULB
SANCTUARY
HALL
SACRISTY
SUPPLY HEADER
RETURN HEADER
CONVERTOR
9" SPACING
12" SPACING
6" MAKE 6"
9"
6"
12" SPACING
3"
6"
9"
9"
9



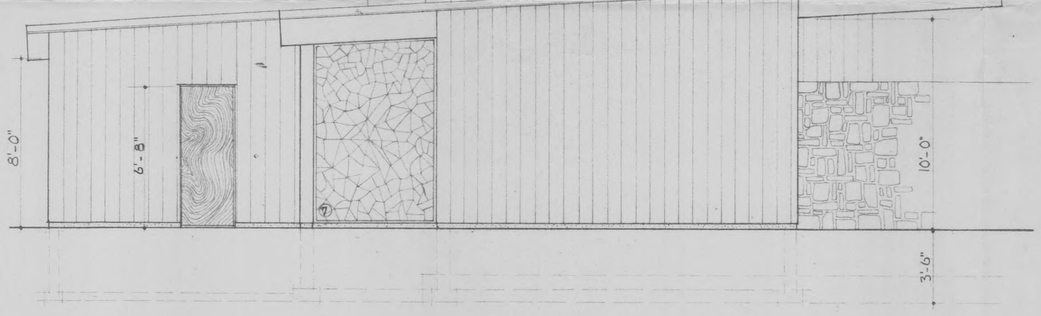
NORTH ELEVATION

SCALE 1/4" = 1'-0"



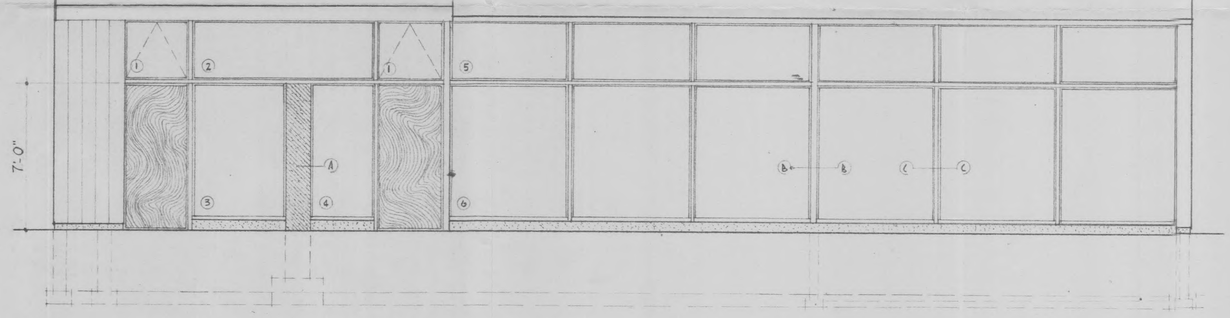
WEST ELEVATION

SCALE 1/4" = 1'-0"



SOUTH ELEVATION

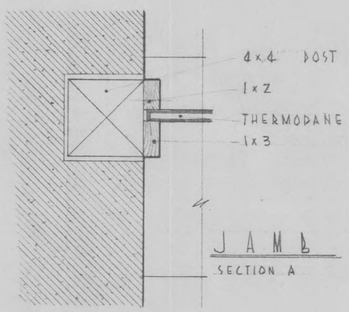
SCALE 1/4" = 1'-0"



EAST ELEVATION

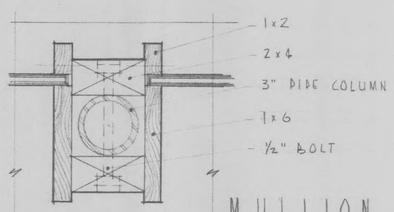
SCALE 1/4" = 1'-0"

WINDOW SCHEDULE		
NO.	GLASS SIZE	TYPE
1	2'-11" x 2'-9"	THERMODANE
2	8'-7" x 2'-9"	"
3	4'-4" x 6'-4"	"
4	2'-11" x 6'-4"	"
5	5'-6" x 2'-9"	"
6	5'-6" x 6'-4	"
7		STAINED GLASS
8	2'-3" x 4'-5"	THERMODANE
9	5'-8" x 4'-5"	"



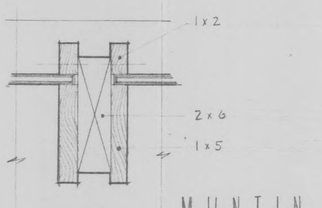
JAMB

SECTION A



MULLION

SECTION B-B



MUNTIN

SECTION C-C

DESIGN BY E. MILSTEIN
DRAWN BY W. J. OTTEM JR.
MONTANA STATE COLLEGE

A CHAPEL FOR
MONTANA STATE COLLEGE

2 JUN 50

ELEVATIONS

SHEET 3 OF 4

RADIANT HEATING FOR A TYPICAL MONTANA LOG BUNGALOW WITH HARDWOOD FLOORS

Most people associate radiant heat with a concrete floor slab. The result is that they don't consider radiant panels with hardwood floors. They forget that wall and ceiling panels even exist! In this particular design, wall and ceiling panels were not feasible due to the particular interior finish of rough logs, hence a floor panel was used.



Fig. 1 - Monte Benson Residence

The nature of construction of this residence was a full basement bungalow of 9" log walls, the logs being sawed on two sides. The cracks were filled with "Hydroseal", an asphalt base sealer, both inside and outside. The basement was finished in the form of bedrooms to be heated from the panel in the floor above.

The first step in the heating design was to compute the heat loss. The computations are as follows.

Coefficients of Heat Transfer (U)

A. Walls

	R
1. Inside air film	0.606
2. 9" log wall (assume 8" average thickness)	10.00
3. Outside air film	.167
	R = 10.773

U = 1/10.773 = .093 Btu/hr - sq. ft. °F

B. Windows

1. Single glazed - U = 1.13 Btu/hr - sq. ft. - °F
2. Thermopane - U = .45 Btu/hr - sq. ft. °F
3. Single glazed (double hung) - U = .45 Btu/hr - sq. ft. °F

C. Ceiling

	R
1. Inside air film	0.606
2. 5/8" fir flooring	0.801
3. 2" rock wool	7.407
4. 2" air space	1.100
5. 1" fir sheathing	1.020
6. Built-up roofing (assumed thickness 3/8")	0.277
7. Outside air film	.167
	R = 11.378

U = 1/11.378 = .09 Btu/hr - sq. ft. °F

Since the 2" air space is used for ventilating purposes, calculate "U" from inside to the air space assuming the air space is at outdoor conditions. Use the higher value of the two.

	R
1. Inside air film	.606
2. 5/8" fir flooring	.801
3. 2" rock wool	7.407
4. Outside air film (still air)	.606
	R = 9.420

U = 1/9.42 = 0.106 Btu/hr - sq. ft. °F

Use U = .10 Btu/hr - sq. ft. °F

D. Doors

(Actual thickness 1 3/8")

U = .51 Btu/hr - sq. ft.°F

E. Bathroom wall

	R
1. Inside air film	0.606
2. 8" logs	10.000
3. 3 5/8" rock wool	13.426
4. Outside air film	.167
	R = 24.199

U = 1/24.2 = .0415 Btu/hr - sq. ft.°F

F. Infiltration

Assume ½ air change per hr. (ground floor)

Assume ½ air change per hr. (basement)

G. Basement walls and floors

U = .1 Btu/hr - sq. ft.°F

Heat Loss Calculations

Inside design temperature	+ 70°F
Outside design temperature	- 20°F
Inside basement design temperature	+ 70°F
Outside basement design temperature	+ 40°F

A. Living Room

1. Walls

Area = 20' x 8' + 14' x 8' - 3 (28" x 46") - 3' x 6'8" - 5' x 4'7" - 5' x 8' = 162 sq. ft.

Heat loss = 162 x .093 x 90 = 1,356 Btu/hr

2. Windows

Area (thermopane) = 5' x 4'7" = 22.9 sq. ft.

Heat loss = 22.9 x .45 x 90 = 929 Btu/hr

Area (single glazed) = (28" x 46") 3 = 26.9 sq. ft.

Heat loss = 26.9 x 1.13 x 90 = 2,740 Btu/hr

3. Door

Area = 3' x 6'8" = 20 sq. ft.

Heat loss = 20 x 90 x .51 = 918 Btu/hr

4. Ceiling

Area = 20 x 14 = 280 sq. ft.

Heat loss = 280 x 90 .1 = 2520 Btu/hr

5. Infiltration

Volume = 20 x 14 x 8 = 2240 cu. ft.

Heat loss = .018 x 1120 x 90 = 1815 Btu/hr

6. Total heat loss = 10,278 Btu/hr

B. Bedroom No. 1

1. Walls

Area = 13 3/4 x 8 + 9 3/4 x 8 - 2 1/3 x 3 5/6 - 2 1/3 x 2 2/3 = 173 sq. ft.

Heat loss = 173 x .093 x 90 = 1,446 Btu/hr

2. Windows

Area = 2 1/3 x 3 5/6 + 2 1/3 x 2 2/3 = 15.2 sq. ft.

Heat loss = 15.2 x 1.13 x 90 = 1,545 Btu/hr

3. Ceiling

Area = 13 3/4 x 9 3/4 = 134 sq. ft.

Heat loss = 134 x 90 x .1 = 1,205 Btu/hr

4. Infiltration

Volume = 13 3/4 x 9 3/4 x 8 = 1070 cu. ft.

Heat loss = .018 x 90/2 x 1070 = .81 x 1070 = 867 Btu/hr

5. Total heat loss = 5063 Btu/hr

C. Bedroom No. 2

1. Walls

Area = 10 x 8 + 12 5/12 x 8 - (2 1/3 x 2 2/3) 2 = 167 sq. ft.

Heat loss = 167 x 90 x .093 = 1400 Btu/hr

2. Windows

Area = 2 (2 1/3 x 2 2/3) = 12.4 sq. ft.

Heat loss = 12.4 x 90 x 1.13 = 1260 Btu/hr

3. Ceiling

Area = 10 x 12 5/12 = 124.2 sq. ft.

Heat loss = 124.2 x 90 x .1 = 1120 Btu/hr

4. Infiltration

Volume = 10 x 12 5/12 x 8 = 995 cu. ft.

Heat loss = .81 x 995 = 806 Btu/hr

5. Total heat loss = 4586 Btu/hr

D. Bathroom

1. Walls

Area = 8 x 5 - 2 x 2 2/3 = 34.7 sq. ft.

Heat loss = 34.7 x 90 x .0415 = 130 Btu/hr

2. Window

Area = 2 x 2 2/3 = 5.3 sq. ft.

Heat loss = 5.3 x 90 x 1.13 = 539 Btu/hr

3. Ceiling

Area = 5 x 7 = 35 sq. ft.

Heat loss = 35 x 90 x .1 = 315 Btu/hr

4. Infiltration

Volume = 5 x 7 x 8 = 280 cu. ft.

Heat loss = .81 x 280 = 227 Btu/hr

5. Total heat loss = 1211 Btu/hr

E. Kitchen

1. Wall

Area = 9½ x 8 - 2 1/3 x 2 2/3 = 70 sq. ft.

Heat loss = 70 x 90 x .093 = 586 Btu/hr

2. Window

Area = 2 1/3 x 2 2/3 = 6.2 sq. ft.

Heat loss = 6.2 x 90 x 1.13 = 630 Btu/hr

3. Ceiling

Area = 9½ x 13.876 = 132 sq. ft.

Heat loss = 132 x 90 x .1 = 1187 Btu/hr

4. Infiltration

Volume = 9½ x 13.876 x 8 = 1055 cu. ft.

Heat loss = 1055 x .81 = 855 Btu/hr

5. Total heat loss = 3458 Btu/hr

F. Dining room

1. Walls

Area = 14½ x 8 + 9 7/12 x 8 - 5 x 4 7/12 - 2 1/3 x 2 2/3 = 163.5 sq. ft.

Heat loss = 163.5 x .093 x 90 = 1370 Btu/hr

2. Windows

Area (thermopano) = 5' x 4'7" = 22.9 sq. ft.

Heat loss = 22.9 x .45 x 90 = 929 Btu/hr

Area (single glazed) = 2 1/3 x 2 2/3 = 6.2 sq. ft.

Heat loss = 6.2 x 1.13 x 90 = 630 Btu/hr

3. Ceiling

Area = 14½ x 9 7/12 = 139 sq. ft.

Heat loss = 139 x 90 x .1 = 1250 Btu/hr

4. Infiltration

Volume = 14½ x 9 7/12 x 8 = 1110 cu. ft.

Heat loss = .81 x 1110 = 900 Btu/hr

5. Total heat loss = 5080 Btu/hr

G. Hall

1. Ceiling

Area = 7 x 5 + 2½ x 1½ = 39 sq. ft.

Heat loss = 39 x 90 x .1 = 351 Btu/hr

2. Total heat loss = 351 Btu/hr

H. Basement entrance

1. Wall

Area = 8 x 3½ - 2 2/3 x 6 2/3 = 10.3 sq. ft.

Heat loss = 10.3 x 90 x .1 = 93 Btu/hr

2. Door

Area = 2 2/3 x 6 2/3 = 17.7 sq. ft.

Heat loss = 17.7 x 90 x .51 = 811 Btu/hr

3. Total heat loss = 904 Btu/hr

I. Basement

1. Walls

Area = 2 (36 x 7½) + 2 (30 x 7) - 10 (1 x 1½) = 912 sq. ft.

Heat loss = (.1) 2 x 30 x 912 = 5472 Btu/hr

2. Floor

Area = 30 x 36 = 1080 sq. ft.

Heat loss = 1080 x .1 x 30 = 3240 Btu/hr

3. Windows

Area = 2 (1 x 1½) 10 = 25 sq. ft.

Heat loss = 90 x 25 x 1.13 = 2540 Btu/hr

4. Infiltration (assume ½ air change/hr)

Heat loss = .81/2 x 7.5 x 1080 = 3275 Btu/hr

Total heat loss (ground floor).....30,767 Btu/hr

Total heat loss (basement).....14,527 Btu/hr

Total heat loss (house).....45,294 Btu/hr

Calculations for Pipe Length

Assume panel output to be 40 Btu/hr - sq. ft. to the ground floor.

To calculate additional panel output necessary to heat the basement, do the following:

Necessary heat/hr - sq. ft. = 14527/1080 = 13.45 Btu/hr - sq. ft. .·. Use 15 Btu/hr - sq. ft.

Total panel output = 40 + 15 = 55 Btu/hr - sq. ft.

A. Living Room (area = 280 sq. ft.)

⅜" tube; 6" O.C.

Ft. of tube = 14478/55 x 2 = 526 ft.

B. Bedroom No. 1 (Area = 134 sq. ft.)

½" tube; 6" O.C.

Ft. of tube = 7073/55 x 2 = 257 ft.

C. Bedroom No. 2 (area = 124 sq. ft.)

½" tube; 6" O.C.

Ft. of tube = 6446/55 x 2 = 234 ft.

D. Bathroom (area = 35 sq. ft.)

½" tube; 6" O.C.

Ft. of tube = 1736/55 x 2 = 63 ft.

E. Kitchen (area = 132 sq. ft.)

½" tube; 8" O.C.

Ft. of tube = 5418/55 x 2 = 197 ft.

F. Dining room (area = 139 sq. ft.)

½" tube; 6" O.C.

Ft. of tube = 7165/55 x 2 = 261 ft.

G. Hall (area = 39 sq. ft.)

½" tube; 12" O.C.

Ft. of tube = 936/55 x 2 = 34 ft.

H. Total ft. of tube = 1572 ft.

I. No. of circuits = 1572/180 ft./circuit = approx. 9 circuits

Boiler

A used hot water heater using an oil burner was used to save installation cost and await the arrival of the natural gas pipe line to Belgrade. This hot water heater has a

capacity of 60 gallons which is too large but due to its large size, it had a low demand and hence a low price.

Circulator

Use a $1\frac{1}{2}$" std. B. & G.

Headers

Use two W.I. pipes (2")

Of particular importance in this design is the floor construction as shown on the drawing. Notice that a sub-floor is laid over the floor joists followed by a layer of waterproof sisalkraft paper. One-inch by two-inch furring strips were laid on top of the paper on 12" centers with two tubes between each furring strip. After this was accomplished, a layer of a poor grade of concrete was poured and leveled off with the tops of the furring strips. When the concrete was thoroughly dry, the hardwood floor was laid.



Fig. 2 - Furring strips laid on sub-floor



Fig. 3 - Floor ready for layer of concrete

The object of the concrete, which was actually 25/32" thick, was threefold. First, its purpose was to carry the heat away from the tubes by increasing the emissivity factor. A shiny copper tube has an emissivity of about 0.15 as compared to rough concrete of 0.95. Secondly, it removed the air space which is a good insulator. Thirdly, the concrete acted as a grill to spread the heat uniformly over the floor.

This installation was constructed and put into operation in January 1950 and maintained a room temperature of 70°F. while the outdoor temperature was - 35°F. with 120°F. water. At the present time the unit is heated by an oil burning conventional hot water heater until natural gas is piped into Belgrade, Montana, the site of this residence. The owner, Monte Benson, is, in his own mind, convinced that his heating system is cheaper to operate and has a cheaper installation cost than any hot air system he could have installed. In



Fig. 4 - Boiler and nearly completed return header

addition, his heating plant uses a space about 4 feet square in the basement with no duct work to take up space and no convection currents to carry dust and cause objectional drafts throughout the house. "An added feature", says Mr. Benson, "is a warm bed to crawl into every night!"

Since the interior is all finished in natural log, it would be extremely undesireable to have large quantities of dust moving through the air and settling on the logs. Radiant heat cuts convection down to a minimum. Interior decorating

is expensive. With no air ducts to darken the walls with the rising air currents, it is obvious that there would be a saving in interior decorating in any radiantly heated home. Also, there are no radiators or convectors to take up space and interfere with the decorating scheme. In this particular case, they would distract severely from the rustic log cabin theme. With the present system, it appears as if the fireplace is the only source of heat. These are just a few of the many advantages achieved by using radiant panels.



Fig. 5 - Interior of Benson Residence

The materials used and their cost is as follows:

Line voltage room thermostat	$ 11.50
1600 ft. of ½" copper tubing @ 14⅔¢/ft	232.00
Sisalkraft paper	12.00
Hot water heater	150.00
Circulator 1½" B. & G. std	58.00
300 gal. fuel tank with pipe and fittings	46.00

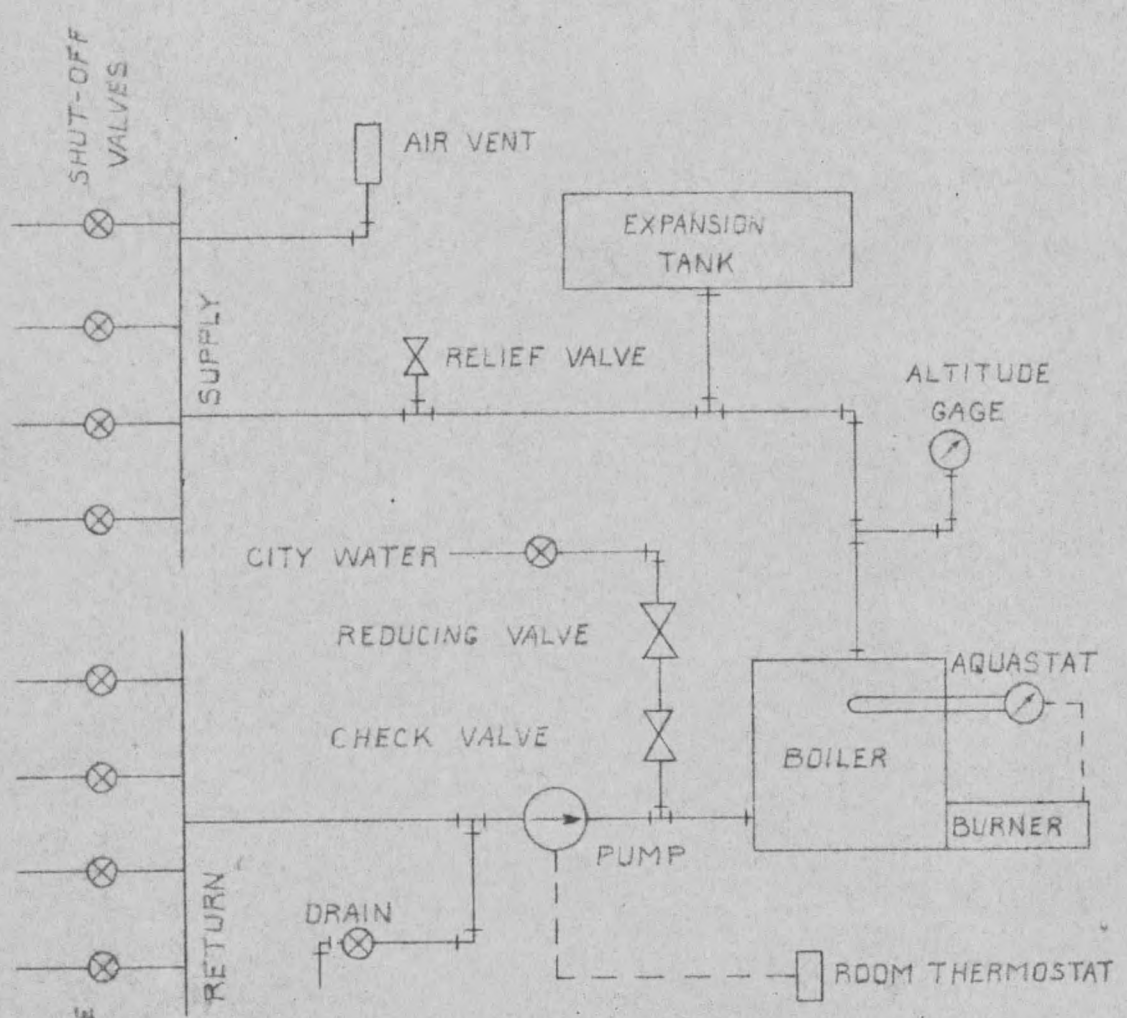
9 stop and waste valves ½"	$ 11.50
9 shut-off valves ½"	12.15
Air vent ½"	5.50
Combination relief and reducing valve	11.75
2 W.I. headers 3 ft. each (2")	3.00
Cement - 4 sacks @ $1.30	5.20
Furring strips	20.00
Sand (1 yard)	3.00
Miscellaneous tees, elbows, etc.	10.00
Total	$593.60

Most of the labor was done by Mr. Benson, hence an exact labor cost analysis was not available. However, assuming that two men could install the system in five eight-hour days at $2.50 per hour, the labor cost would be $200.00, making the total installed cost $793.60. An estimate for a hot air system to heat the same house was given as $900.00 by a local dealer. It, of course, would be accompanied by a large furnace with ducts taking up valuable space and a higher maintainence and operating cost with less comfort and satisfaction.

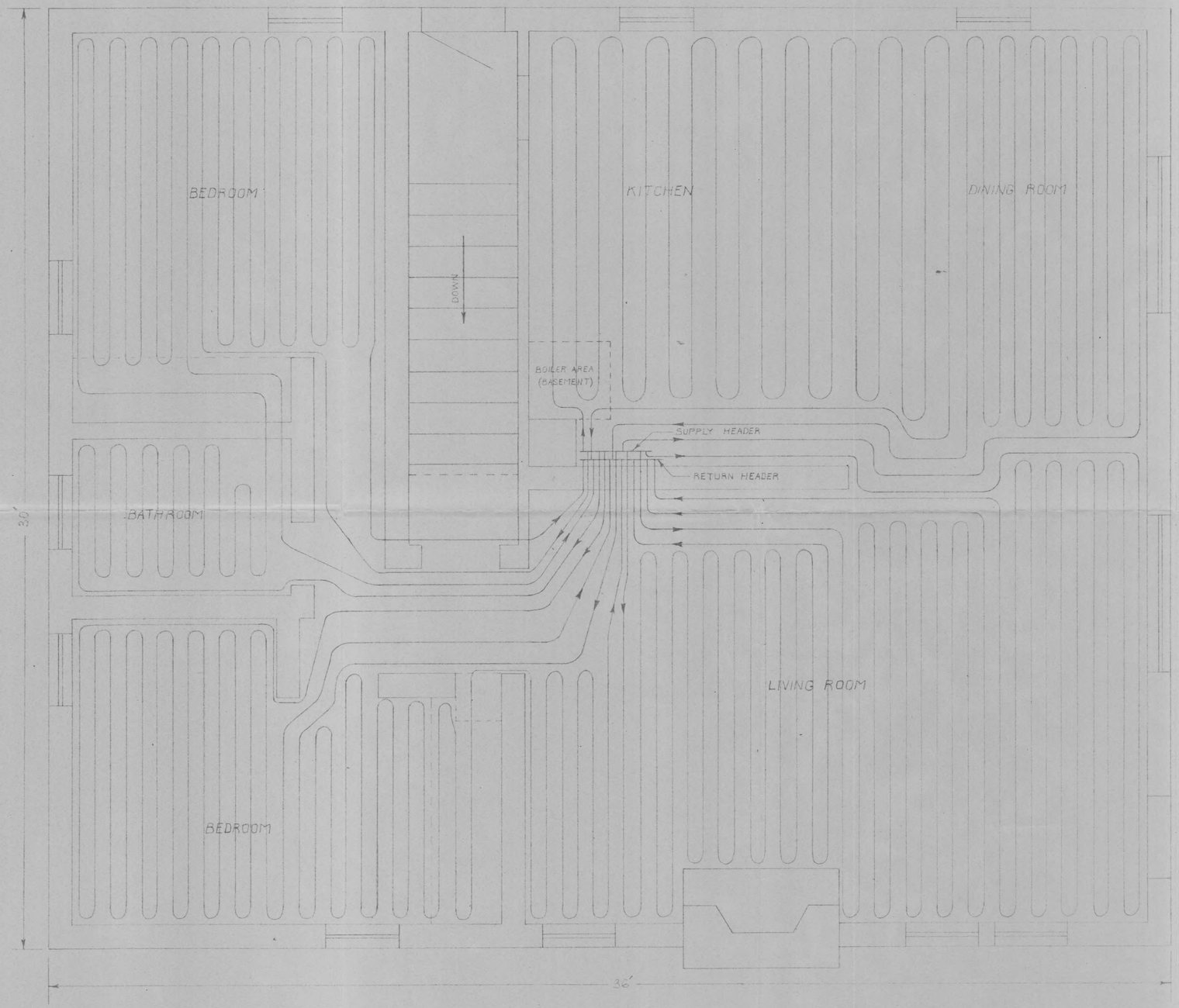
Two different header systems are shown. The short header system was used with all the valves located in the basement. This makes the filling operation and balancing much easier. The "main-type" system locates all the valves on the ground floor where they may be balanced or shut off. They are so arranged that all valves are located in closets or cupboards.

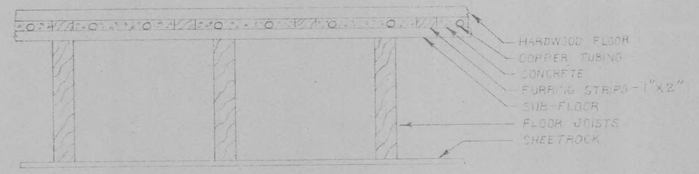
It is necessary with this system to run the headers through the floor joists which is rather undesirable. If the building is quite large, it is necessary to use the "main" system to keep the circuits from getting too long. The short header system was used in the Benson residence. Notice on the drawings that each room has more than one circuit passing through. This gives extra control for obtaining the room temperature desired. In any design, each room should have at least one circuit of its own.

In order to prevent overheating the basement, enough resistance to heat flow was placed between the sub-floor and the basement ceiling to get the correct proportion downward. The drawings follow.



MONTANA STATE COLLEGE BOZEMAN, MONTANA			
CONTROLS FOR BENSON RESIDENCE HEATING SYSTEM			
DR. BY L. HORPEDAHL	12/8/49	CK. BY	
TR. BY		APP. BY	
	DRAWING NO. ME 324		





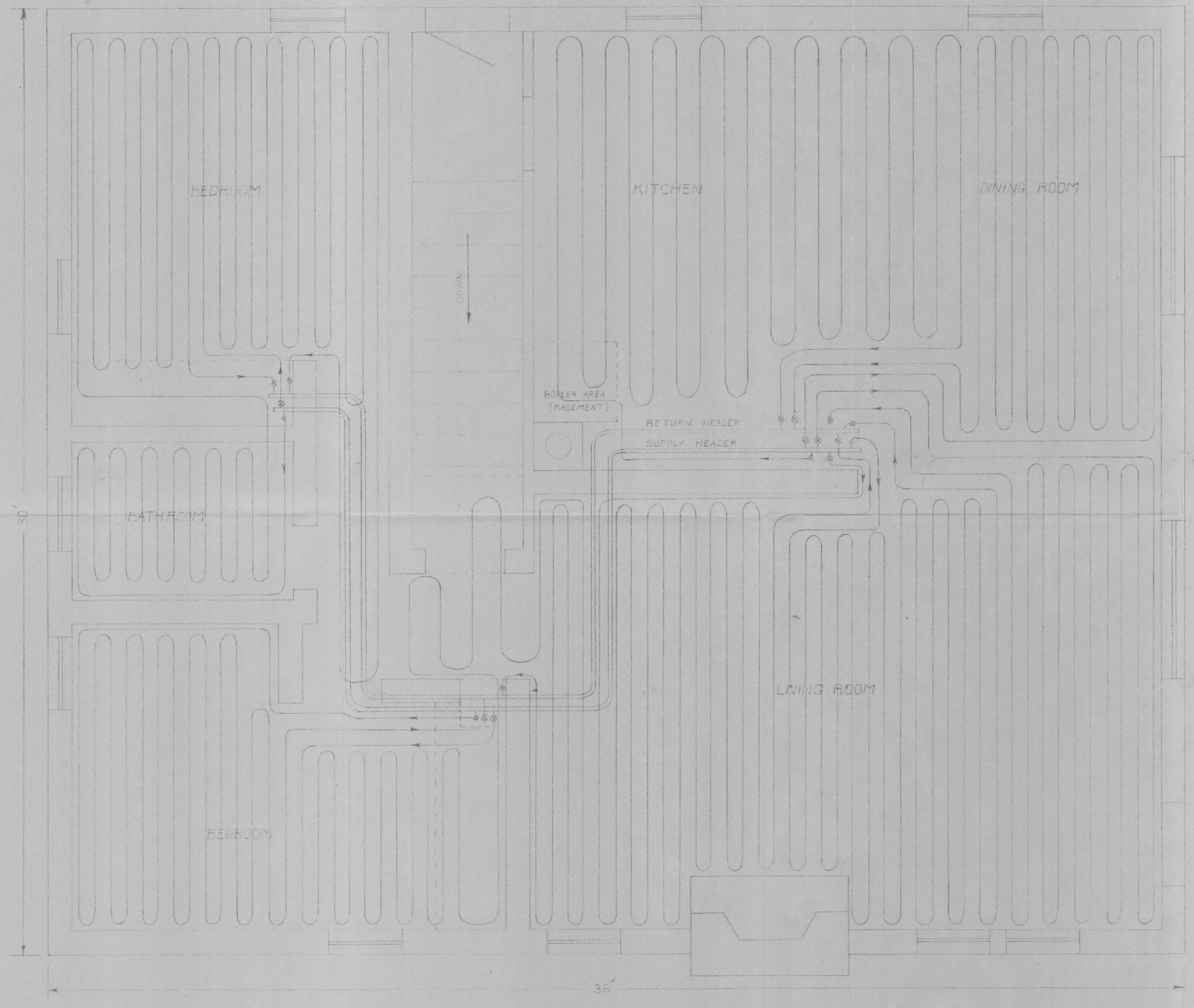
TYPICAL FLOOR CONSTRUCTION

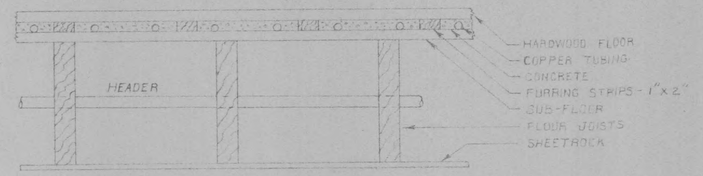
DESIGN NOTES

OUTSIDE TEMP. -20°F. INSIDE TEMP. +70°F.
WALLS 9" LOGS SAWED ON TWO SIDES
ALL WINDOWS EXCEPT ON EAST – DOUBLE HUNG
WINDOWS ON EAST – THERMOPANE
ALL CIRCUITS OF 1/2" COPPER TUBING
SHUT-OFF VALVE ON SUPPLY END OF EACH CIRCUIT
STOP AND WASTE VALVE ON RETURN END OF EACH CIRCUIT
VALVES, HEADERS AND BOILER LOCATED IN BASEMENT
ALL TUBING ON 6" CENTERS EXCEPT KITCHEN ON 8" AND HALL ON 12" CENTERS
LAYER OF SISALKRAFT PAPER ABOVE SUBFLOOR

N

MONTANA STATE COLLEGE BOZEMAN, MONTANA		
RADIANT HEATING FOR MONTE BENSON RESIDENCE, BELGRADE, MONTANA		
DR. BY L. HORPEDAHL	12/10/49	CK. BY
TR. BY		APP. BY
SCALE: 1/2" = 1 FT.	DRAWING NO. ME 323	





TYPICAL FLOOR CONSTRUCTION

DESIGN NOTES

OUTSIDE TEMP. -20°F. INSIDE TEMP. +70°F.
WALLS 9" LOGS SAWED ON TWO SIDES
ALL WINDOWS EXCEPT ON EAST — DOUBLE HUNG
WINDOWS ON EAST WALL — THERMOPANE
ALL CIRCUITS OF 1/2" COPPER TUBING
VALVES LOCATED IN CLOSETS OR CUPBOARDS
1" HEADERS CUT THROUGH JOISTS AT CENTER
BOILER LOCATED IN BASEMENT
ALL TUBING ON 8" CENTERS EXCEPT KITCHEN ON 4" CENTERS
LAYER OF SISALKRAFT PAPER ABOVE SUB-FLOOR

N

MONTANA STATE COLLEGE
BOZEMAN, MONTANA

RADIANT HEATING FOR MONTE BENSON RESIDENCE, BELGRADE, MONTANA

DR. BY L. HORPEDAHL	12/15/47	CK. BY
TR. BY		APP. BY
SCALE: 1/2" = 1 FT.	DRAWING NO. ME 322	

A SURVEY OF SOME TYPICAL MONTANA RADIANT HEATING INSTALLATIONS

Since radiant panel heating is comparatively new, it seemed very worthwhile to make at least a partial survey of such installations in Montana to get personal reactions as well as technical and practical information concerning them. Much was learned from mistakes made and suggestions given by very cooperative and friendly citizens.

The following is a group of brief discussions concerning each installation visited. Several others were surveyed but were identical to some already visited, hence left out of this discussion. Plumbers and architects were also contacted, whenever possible, for their views on the subject of radiant heat.

Several types of construction seem adaptable to radiant heat. The residence of Professor L. O. Brockman, Bozeman, is a two story duplex using walls of 16" of rammed earth. The lower story is half below and half above the ground, taking advantage of a hillside beautifully. The concrete basement floor area covers 1450 sq. ft. and uses 6 floor circuits of ½" copper tubing with its own circulating pump controlled by a room thermostat. The second story of the duplex was heated by ½" copper tubing ceiling circuits covering the same area. The tubes were on 8½" centers and were supplemented by radiant baseboards under the windows on the south wall. These windows extended the entire length of the wall. The ceiling circuits had their

own pump which was controlled by a room thermostat. The system was fired by a natural gas 216,000 Btu input boiler located in the basement. The calculated heat loss of the house was 75,000 Btu/hr. Total installed cost of the heating system was about 12% of the cost of the house. Comments by the Brockmans indicated they would possibly like to install an outdoor thermostat. Also, they had a problem of solar radiation due to the many windows on the south. A great deal of natural circulation was noticed which caused excessive heating. A flow check valve would have prevented that. The fuel bill for this house was $141.00 during the winter of 1949-50.

Another radiantly heated Bozeman residence is that of the Karl Swingles on Huffine Lane. This is a one story, flat roofed log home covering an area of 2550 sq. ft. and no limit on "picture" windows. At a cost of 10% of the cost of the home, radiant heat was installed using 1" copper tubing on 12" centers except in the living room where it was put on 6" centers. All circuits are in the 4" concrete slab floor poured on 8" of crushed rock. The outside perimeter of the slab is insulated with 1" of asphalted felt. The pumice block foundation is filled with zonolite. Each circuit is fed by a supply and return main header system and equipped with a balancing valve. The control system employs a room thermostat to operate the pump intermittently while the aquastat governs the flow of natural gas to the 250,000 Btu input boiler. Calculated heat loss of the

house was 120,000 Btu/hr.

Sourdough Creek, south of Bozeman is the site of a radiantly heated log cabin owned by the Nicholas Helburns. Two floor panels were used involving 1" W.I. pipe on 9" centers buried in a 4" concrete slab. The floor slab was poured over a sub-floor of 4" concrete using 6 parts zonolite and 4 parts cement. No insulation was put between the floor and the foundation, hence an early crop of daffodils occurs each spring! An aquastat sets the oil-fired boiler temperature while the room thermostat turns the burner on and off. The circulator runs constantly. Cost for heating this 575 sq. ft. cabin, runs about $150.00 per year. As for comments, they were sold on floor heating, especially with children. Improvements suggested were the use of one-half as much piping under beds and run circuits under cupboards and closets too. They mentioned that certain waxes failed to harden on the linoleum due to its heated condition. Installation cost ran about one-eighth of the cost of the house.

Another residence using log construction is that of Professor Roy Wiegand, Huffine Lane, Bozeman. Ratio of the cost of heating system to cost of the house ran about 1 to 10. This 1900 sq. ft., one-story home has 10 floor panels which heat it and its basement. The basement, which covers half the floor area, houses the 100,000 Btu input gas-fired boiler and auxilliary equipment. Hardwood floors are used throughout the house

with ½" copper tubing placed on 8¼" centers between the subfloor and the hardwood floor. Furring strips are placed between the floors to support the finished floor. At the time of construction, the tubes were left in air spaces between the floors but due to the low emissivity factor of the shiny copper tubes and the insulating quality of the air space, the house could not be heated although the water temperature was up to 210°F. The water returned from the circuits at practically the same temperature at which it entered. The only solution was to either tear up the hardwood floor and pour concrete or some similar material around the tubes, or take up boards and force the concrete under with a caulking gun. The latter method was used with excellent results. Of course the moisture caused the floors to bulge and warp but the heat brought everything back to normal. A room thermostat controlling the circulator and an aquastat to govern the water temperature completes the control system. Despite the misfortune of not putting concrete around the circuits during construction, the Wiegands are sold 100% on radiant heating. The average years fuel bill runs about $120.00.

The summer of 1948 found Dr. H. F. Mullikin installing radiant heat in his new one-story Bozeman home. Several sources had released information stating that Montana homes could not be heated radiantly by floor panels alone, hence this residence has ceiling panels to furnish the heat and floor panels to keep

the concrete slab floor warm. Fourteen ceiling circuits of ½" copper tubing were used together with 6 floor circuits of the same size. Each circuit was approximately 140 ft. long and was valved at each end to short headers located in the boiler room. This method allows all balancing to be done at one location and all valves are out of the way from possible tampering by children. An indoor-outdoor control system is used employing a three-way mixing valve allowing the water to bypass the boiler when equilibrium conditions occur. An indoor thermostat operates the circulator intermittently. A day-night clock thermostat, to cut down the temperature at night, doesn't seem to perform properly, probably due to the heat lag. Domestic hot water is heated by the same gas-fired 210,000 Btu boiler by means of a tankless heater furnishing an unlimited supply of hot water. Comments by Dr. Mullikin indicated he would just as soon have all the heat in the floor to cut down installation costs. Aside from installation cost, the Mullikins are well satisfied with radiant heating.

Probably the most unique installation in Montana is that of Hiram Dotson, Rimini Route, Helena. His system requires no boiler because water from a natural hot spring is used, hence the only operating cost is the power to operate the pumps and controls. This one story residence is 110 x 47 ft. or 5170 sq. ft. with an outdoor swimming pool which is heated by the dis-



Fig. 6 - Natural hot water radiantly heated residence

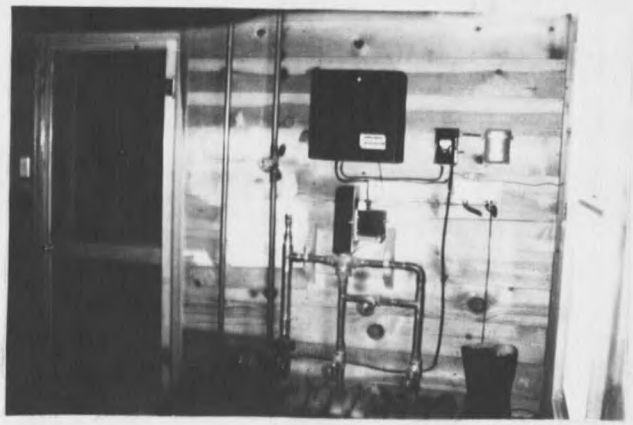


Fig. 7 - "Boiler room" for the above residence

charge from the heating system. This eight room home, Fig. 6, with three baths employs nine circuits embedded in a concrete slab floor. The spacing and pipe sizes vary with the room and floor covering. The bedrooms, living, and dining rooms, all heavily carpeted, use 1½" copper tubing on 15" centers. This set of circuits has its own circulating pump and Minneqpolis-Honeywell Modutrol Regulator which employs an outdoor bulb and a three-way mixing valve. The kitchen, utility room and bathrooms, combined, have a similar set of controls since they all have linoleum covered floors. The circuits use 3/4" copper tubing on 12" centers in these rooms and have their own circulator. The circulators operate intermittently from room thermostats. In addition to the circulators, there is a lift pump which pumps the water from the spring to the house. The Dotsons are extremely satisfied with their heating system although it cost $7,800.00 or 14% of the cost of their house.

An example of an industrial application is the LMH Co., Great Falls, manufacturers of drapes and curtains. Three floor panels of 1½" W.I. pipe on 12" centers are laid in a concrete slab 5" thick. A 3" main feeds the grid system of pipe layout with balancing valves in each circuit. The single-story building consists of a showroom, a workroom and an apartment, each with its own circuit. Cost of the gas to fire the 350,000 Btu boiler runs between $18.00 and $14.00 per month. This cost includes the cooking and domestic hot water for the apartment.

The building has 3110 sq. ft. of floor space with a 10 ft. ceiling. The control system is a room thermostat operating the circulator intermittently. Comments from one of the upholsterers indicated he had been a previous sufferer of rheumatism but since working on a heated floor, it had left him completely. The cost of this installation was $1600.00.

Another Great Falls industrial application is that of Pinski Bros. Plumbers who have 10,000 sq. ft. radiantly heated. Their system cost $5,000, or about one-tenth of the building cost. The showroom, covering 5,000 sq. ft. employs 6 circuits of 1¼" steel pipe on 18" centers with a 2" circulator, 3" overhead supply main and a 2½" overhead return main. It operates on 120°F boiler water with a room thermostat to control the circulator. The workshop comprises the remaining 5,000 sq. ft. and has its own thermostat and circulator because a lower temperature is desired for manual working conditions. Nine circuits on 16" centers are used throughout the workshop except for a small section on 12" centers. Each circuit has a balancing valve. During the month of February 1950, the gas bill to heat the building was $15.80. The boiler is rated at 910,000 Btu (steam) input or 4850 sq. ft. of water. The workmen as well as office girls were very pleased with the heating system.

A third industrial application visited in Great Falls was the Rice Transport, a garage involving huge doors to let trucks in and out for repairs. This seems to be an ideal application

for floor panels because the minute the doors are closed, the mechanics lying on the floor are comfortable. Instead of forcing all the hot air to the ceiling, the source of heat is right where it is needed. Garage mechanics don't mind getting to work on cold mornings with radiant panels in the floor. Fifteen panels using 1¼" steel pipe on 16" centers are buried in the 6" concrete floor. Each circuit has a balancing valve. A room thermostat controls the 3" circulator. A new addition has been built since the first part in 1945. The new section has its own 2½" circulator with its own thermostat. Minimum cost for heating this building with gas is $450.00 per year. Only the most favorable comments were received from mechanics as well as office employees. Unit heaters designed and installed in 1945 to supplement the system have never been used except to blow foul gases out of the garage. Installation cost was 9% of the building cost.

A Great Falls real estate dealer, R. V. Bowker, believes radiant heat is ideal for his offices. His one-story building with four rooms uses 1" W.I. pipe on 9" centers in a concrete slab. A room thermostat controls the pump while the aquastat maintains the boiler temperature at 140°F. Cost of heating the 1125 sq. ft. of office space ran about $7.00 during February 1950. Cost of installation ran about $1.00 per sq. ft. of floor space.

Archie Parks, near Vaughn, Montana, is rather disappointed

with his installation. Two copper tubes were placed between each floor joist under hardwood floors in an air space. Insulation was literally forced underneath to apparently bring the heat to the floor but to no avail. The shiny copper would not emit its heat. Not knowing the cause of the trouble, his contractor finally put in radiant baseboards to supplement the over-abundance of insulation and tubing below the floor which, of course, couldn't function properly. Mr. Parks warns against the use of aluminum casements in windows in Montana. His experience indicates that they frost and then flood the window sills with water when a Chinook wind appears. The control system used was a room thermostat on the circulator. Previous to the installation of radiant baseboards, the boiler temperature was 200°F without attaining comfort conditions. Now, the boiler is set at 145°F. Thus far the operating cost of this oil fired system has been very excessive and installation costs exceeded 10% of the building cost of this one-story, basementless residence.

The use of zonolite plaster around ceiling imbedded circuits caused much difficulty in the Herbert Anderson residence of Great Falls. Since zonolite is an insulator, the heat did not conduct properly over the area and heating was difficult except in the basement where the circuits were buried in concrete. Two circulators operate the ceiling and floor circuits respectively. Ratio of the cost of the heating system to the

cost of the house was about 1/10. Operation costs are about 1/3 less than any system used previously.

Lack of insulation around the concrete floor slab is probably the main cause of excessive fuel bills in the case of the Lee Amundson residence near Lewistown. Lack of insulation throughout the house is another big reason. One-half inch copper tubing on 14" centers is buried in the concrete floor slab. The circulator is controlled by a room thermostat. Despite fuel bills of from $28.00 to $55.00 per month, it is difficult to maintain a comfortable room temperature. No design procedure was used in installing the system.

Lewistown has several very satisfactory radiantly heated homes that have been installed by Maynard Stapleton, a local plumber. Most of his jobs have been wall and ceiling installations. One such system is that owned by Joe Matulys who built his home in 1947. The heating plant ran about $1,000.00 or 1/16 of the total cost of the house. It is a 5 room, one story building with wood floors. There are two inside wall circuits of 3/8" copper tubing on 10" centers and 14 outside wall panels of 3/8" tubing on 10" centers. The outside walls are insulated with 4" rock wool and a double thickness of paper while the ceiling insulation consists of 3" zonolite and 3" rock wool. The boiler temperature setting is 120°F while maintaining a room temperature of 73°F. The average cost of fuel oil has been $63.00 per year despite several 6' x 10' double glass

windows. The floor area covers 1500 sq. ft. Mr. Matulys states that there is no lag problem with his system and that the humidity is much higher in his house than in one using a conventional heating system.

In summing up the survey, it was found that the majority of the installations were of the concrete slab floor type with embedded tubes and that Montana homes can, and are being, heated by floor panels very effectively and efficiently when installed properly. It is very evident that many residents suffered financially and physically due to guessing at tube sizes, spacing, and most of all, lack of, or insufficient, insulation. The proper use of insulation as to location and quantity cannot be overemphasized in Montana regardless of the type of heating system used. An extra layer may easily pay for itself in less than a year. The use of double glass in windows cuts down widnow heat loss more than half, so, with wise selection of insulation and windows, fuel bills can become a minor rather than a major bill. As was pointed out in the survey, metal window casements are not practical in Montana because of the rapid heat conduction through them and the frost formations with eventual flooded sills.

Cost of installation varied from about one-eighth to one-sixteenth of the total building cost. Performance was not always a function of the cost.

The controls used, as a rule, were very simple and inex-



Fig. 8 - Ceiling circuits using 3/8" copper tubing



Fig. 9 - Bathroom heated with both wall and ceiling circuits of 3/8" copper tubing

pensive although some extremes were prevalent. A room thermostat to control the circulator and an aquastat to govern the boiler water temperature was the system most used. Outdoor controls have been shied away from due to their cost, and, probably even more because of lack of understanding by the plumbers.

Fuel bills varied considerably. In some cases they were a minor bill but in several cases quite outrageous. In every case the higher fuel costs could easily be traced to lack of insulation or improper installation or both. In no case could the lack of heat or excessive fuel bill be blamed on the mere fact that radiant heat was used. Such errors as the use of zonolite plaster with buried tubing and the use of shiny copper tubing in an air space are sometimes costly, but often time it could be prevented if a reliable heating engineer were consulted.

There are obviously many applications for radiant heating in Montana. Probably one of interest to chicken ranchers is the application of radiantly heated brooder houses. With this set-up, the chicks are always on a warm surface. The heated floor keeps the litter dry and dries out the droppings. Young chicks are very sensitive to dampness, hence floor panels would be ideal for this purpose. This is just one of the many other possible applications of radiant heat.

INDENTATION CHARACTERISTICS OF FLOOR COVERINGS USED OVER RADIANT FLOOR PANELS

Since several inquiries were made concerning the type of floor covering to use with radiant panels in the floors, it was deemed advisable to set up a test panel to see what the indentation characteristics were in some of the typical floor coverings. A test panel was constructed such that the temperature could be set at any desired value and maintained constant for any desired length of time. A platform with four legs under it was constructed to simulate a chair. A metal glider was put under each leg and the platform loaded with a 200 pound weight. This made the weight on each glider 50 pounds. Different sized gliders were used to see what its effect would be on indentation. The results of the test are shown in Table I.

Although the table tells the complete story of the test, it is interesting to point out a few highlights. First of all, indentation need not be a problem if the proper size and shape gliders are used under furniture. A good example of this is the case of grease-proof asphalt tile which is exceptionally soft under heated conditions. The indentation changed from .016" to .006" by just changing the glider size from ½" to 7/8". The smaller glider was of the 3-prong variety with a more or less hemispherical shape, while the large one was flat with a nail protruding into the platform leg. It is obvious then, that careful consideration should be given to the selection of

gliders for use under furniture on radiant paneled floors. A few cents extra for proper sized gliders may save hundreds of dollars on floor covering.

Secondly, by use of the table, one notices that one must be more careful with glider sizes with some materials. Grease-proof asphalt tile and extremely dark colored asphalt tile are very subject to indentation whereas rubber tile has extremely small indentation properties. The composition of grease-proof and dark colored asphalt tile can probably be blamed for this undesireable trait. It is possible that the darker color has a slightly higher surface temperature. Since no accurate surface temperature recorder was available, this is merely an assumption. Inlaid linoleum seems quite adaptable to heated floors. As shown in Table I, there was very little indentation at a temperature of 103°F. Since floor panel surface temperatures should never run over 85°F, it is obvious that the danger of indentation with inlaid linoleum is negligible---with proper sized gliders. The new vinyl plastic coated linoleum also seemed to hold up quite well as far as indentation was concerned.

In conclusion, it may be stated that floor covering indentation has possibly been over-emphasized. The table shows that indentations are very small at a floor temperature of 89°F. No radiant paneled floor should exceed a surface temperature of 85°F. The sun shining through a window may easily raise a floor

temperature well over 100°F. This shows that despite the type of heating system used, due consideration should be given to selection of floor coverings and appropriate gliders used under all furniture. Floor coverings are not always uniformly constructed as is indicated by sample number 8 in Table I. One spot on the 9" x 9" tile gave an indentation of .023" while another point did not show any mark at all.

TABLE I - INDENTATION OF FLOOR COVERINGS ON HEATED FLOORS

SAMPLE NUMBER	FLOOR COVERING	GLIDER SIZE — 1/2"			GLIDER SIZE — 7/8"		
	TYPE AND DESCRIPTION	TIME, HOURS	DEPTH, INCH	TEMP., °F.	TIME, HOURS	DEPTH, INCH	TEMP., °F.
1	ASPHALT TILE; GREASE-PROOF, DARK GREEN	48 26	.017 .016	103 103	20 50	.006 .003	103 89
2	ASPHALT TILE; GREEN	48	.012	103	46	.003	104
2-A	ASPHALT TILE; GREASE-PROOF, DARK GREEN	26	.010	103	20 27	.005 .002	103 89
3	RUBBER TILE; CREAM	48 22	.004 .004	103 104	24 22	.002 0	102 89
3-A	ASPHALT TILE; GREASE-PROOF, DARK GREEN	26	.030	103	20 50	.010 .007	103 89
4	ASPHALT TILE; MAROON	48	.008	103	27	.003	101
4-A	ASPHALT TILE; GREASE-PROOF, DARK GREEN	26	.019	103	20 50	.007 .003	103 89
4-B	RUBBER TILE; CREAM	22	.002	104	24 22	.002 0	103 89
5	RUBBER TILE; CREAM	22	.005	104	24 22	.002 .0	103 89
6	RUBBER TILE; CREAM	22	.004	104	24 22	.002	103 89
7	ASPHALT TILE; MAROON	26 22	.015 .013	101 102	46 23	.005 .002	104 88
8	ASPHALT TILE; BRIGHT BLUE	26 22	.023 0	101 100	46 23	.010 0	104 88
9	ASPHALT TILE; GRAY	26 22	035 015	101 102	46 47	.010 .010	104 89
10	ASPHALT TILE; BROWN	26 22	.017 .030	101 102	26 23 47	.006 .004 .007	101 88 89
11	LINOLEUM; VINYL PLASTIC COATED, ASPHALT BASE	25 25	.008 .008	103 103			
12	LINOLEUM; INLAID, RED	25 25	.011 .010	103 103	23	0	105
13	ASPHALT TILE; YELLOW	25 25	.018 .012	103 103	27 47	.005 0	101 89
14	ASPHALT TILE; DARK BLUE	25 25	.030 .030	103 103	27 23 47	.020 .004 .015	101 88 89
15	LINOLEUM; INLAID, PRINT	21 21	.006 .003	101 101	24 24	.004 .004	103 103
16	LINOLEUM; INLAID, GRAY	21 21	.006 .015	101 101	24 24	.002 .002	103 103
17	LINOLEUM; BROWN, TILE PATTERN				23 23	.003 .004	105 105

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RADIANT HEATING INSTALLATIONS IN MONTANA

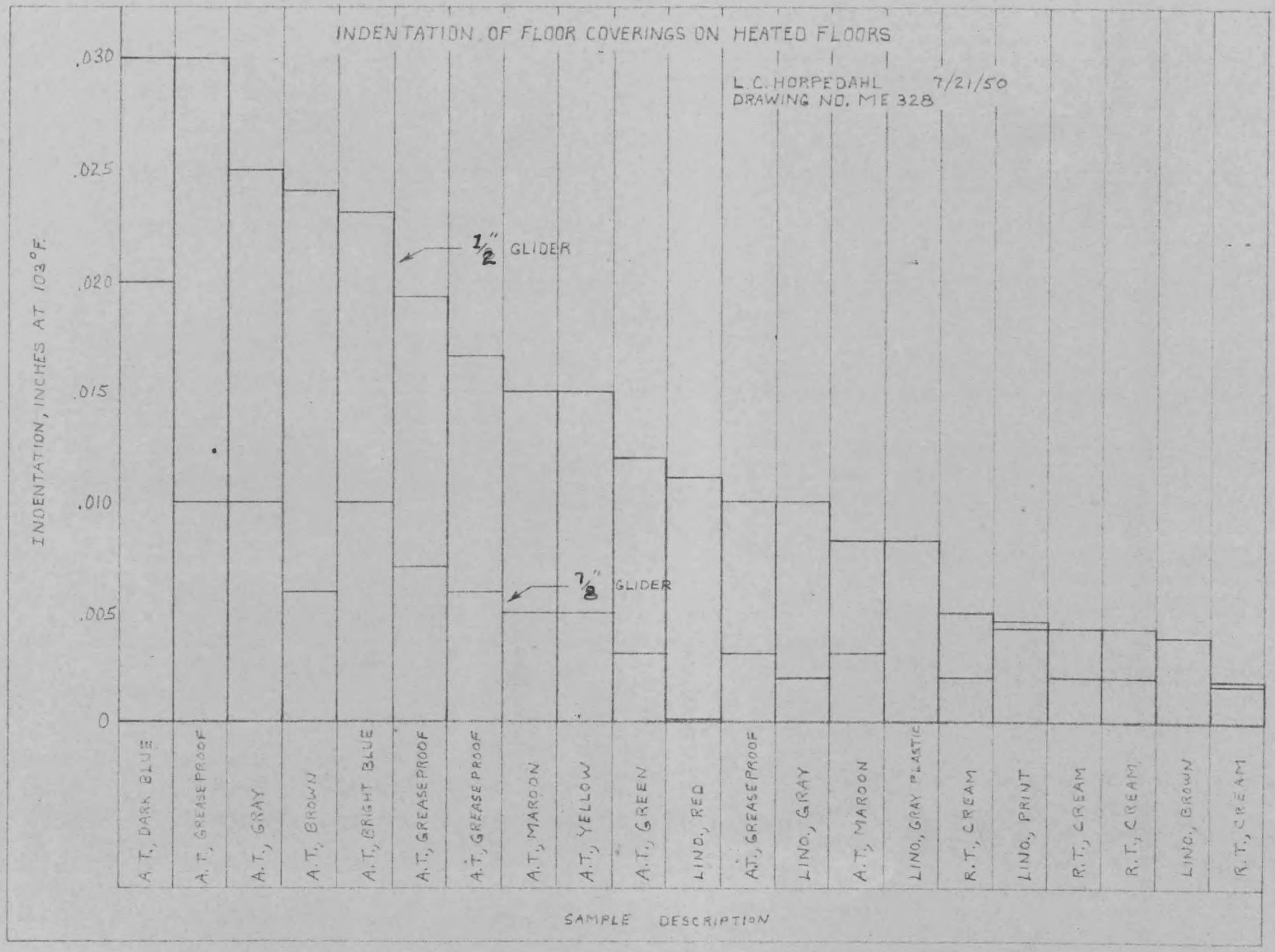
LOCATION	OWNER	TYPE OF STRUCTURE	TYPE OF PANEL	TOTAL HEAT LOSS, BTU/HR.	FUEL USED
BOZEMAN	L.O. BROCKMAN	EARTH-2 STORY	FLOOR & CEILING	75,000	GAS
BOZEMAN	KARL SWINGLE	LOG BUNGALOW	CONCRETE FLOOR	120,000	GAS
BOZEMAN	N. HELBURN	LOG BUNGALOW	CONCRETE FLOOR		OIL
BOZEMAN	R. WIEGAND	LOG BUNGALOW	WOOD ON CONCRETE		GAS
BOZEMAN	H.F. MULLIKIN	WOOD BUNGALOW	FLOOR & CEILING	63,600	GAS
HELENA	H.S. DOTSON	WOOD BUNGALOW	CONCRETE FLOOR		NONE
GREAT FALLS	LMH CO.	CONCRETE BLOCK	CONCRETE FLOOR		GAS
GREAT FALLS	PINSKI BROS.	CONCRETE BLOCK	CONCRETE FLOOR		GAS
GREAT FALLS	RICE TRANSPORT	BRICK & TILE	CONCRETE FLOOR		GAS
GREAT FALLS	R.W. BOWKER	BRICK & TILE	CONCRETE FLOOR		GAS
GREAT FALLS	H. ANDERSON	WOOD BUNGALOW	CEILING		GAS
VAUGHN	A. PARKS	WOOD BUNGALOW	WOOD FLOORS		OIL
LEWISTOWN	L. AMUNDSON	TILE BUNGALOW	CONCRETE FLOOR		OIL
LEWISTOWN	J. MATULYS	WOOD BUNGALOW	PLASTER WALLS		OIL
BELGRADE	M. BENSON	LOG BUNGALOW	WOOD ON CONCRETE	45,300	OIL

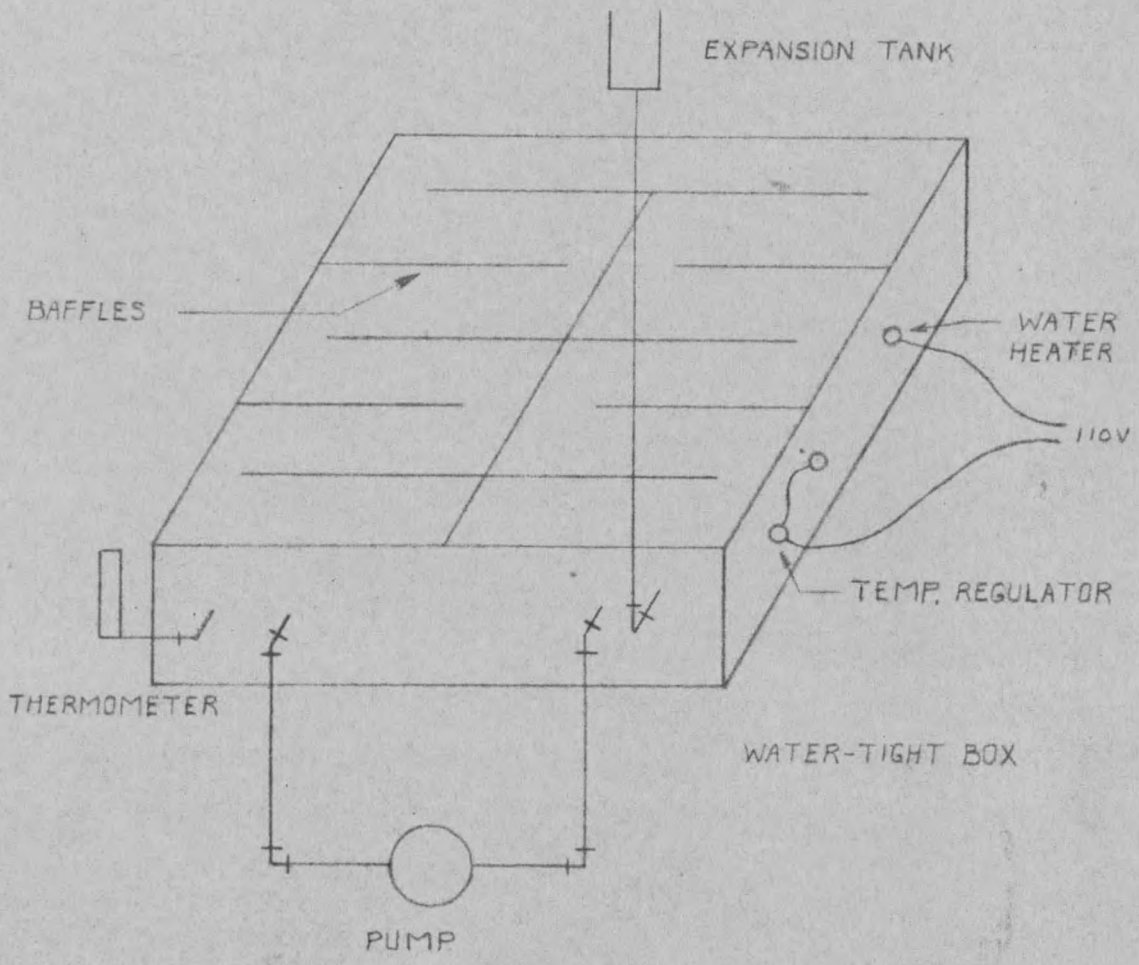
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INDENTATION OF FLOOR COVERINGS ON HEATED FLOORS

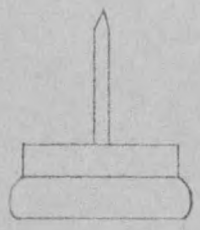
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NOTE: THE FLOOR COVERING WAS PLACED ON A 1/4" STEEL PLATE, FASTENED TO THE TOP OF THE BOX AND IN CONTACT WITH THE WATER.

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SKETCH OF EQUIPMENT USED FOR INDENTATION TESTS			
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7/8" GLIDER



3-PRONG GLIDER 1/2"

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GLIDERS USED IN INDENTATION TESTS			
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