Foreword

THE SCIENCE OF HEATING is the art of supplying heat to a building at the rate at which heat is being given up by that building. It is not generally considered an exact science because of the many uncontrollable variables with which it must contend. In the average mind the very commonplaceness of heating tends to give the science a simplicity which, unfortunately, it cannot claim. This misconception has been the basis of many hit-and-miss methods that have sometimes hit, and oft-times missed, to the joy or the discomfort of the owner.

Any building, during the heating season, regardless of size, shape or construction, unless the temperature within it is the same as outdoors, gives off heat to the great outdoors just as a stove or a radiator on a smaller scale gives off heat to the room in which it stands. *The amount of heat so lost from the building varies with the outdoor and indoor temperatures, the velocity of the wind, the shape and size of the building itself, the character and materials of its construction, and its position with relation to other buildings or naturally protected or exposed locations.*

When all factors causing heat loss have been considered and the total loss rate determined for coldest weather, a heating system is designed with a capacity equal to this rate of loss and to maintain the building temperature at an even and predetermined temperature.

The better a building is constructed, the less heat will be required, and the lower will be the cost of heating. Obviously it is more profitable to build well, and use the minimum artificial heat and heating plant rather than to install a big heating plant trying to heat "all outdoors."

A heating system should be capable of delivering a quantity of heat sufficient to replace—no more, no less—the heat loss from the building under all changes of weather, with allowances for exposure to winds, air leakage, heat losses of piping, and the initial heating-up of the building. When a system meets this requirement without over-heating or under-heating we say the building is satisfactorily heated.

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The data set out in the following pages have been prepared and assembled in the hope that they will prove of valuable assistance to Engineers, Architects, Contractors and others whose activities lie in the field of Engineering generally, and more particularly in the field of Heating Engineering pertaining to buildings.

While the data have been collected from various reliable sources and authorities and can be recommended on the basis of extensive usage, the C. A. Dunham Company assumes no responsibility for results that may be obtained from their use and applications.

HEATING DESIGN DATA

HEAT LOSS

The design of any heating system begins with the computation of heat losses from a building.

The heat loss from a building is affected by the following factors:

(1) a. Area of glass windows and doors,
 b. Number of layers of glass, i.e., single, double or triple glazing or separate storm sash,
 c. Type of sash.

(2) Thickness and type of construction of exterior walls.

(3) Type of exterior wall surfaces.

(4) Type of interior wall surfaces.

(5) Type of ceiling or roof construction.

(6) Infiltration of air into building through windows, doors and exterior surfaces due to porosity of building materials and relation of infiltration to air volume.

(7) Outside weather conditions, i.e., (a) temperature, (b) sun effect, (c) wind direction and velocity, (d) rain and snow.

(8) Bulding interior conditions, i.e., (a) temperature (b) degree of temperature regulation (c) tendency for air stratification (d) period and nature of occupancy (e) ventilation requirements (f) type of heating system (g) operating conditions, continuous or intermittent.

(9) Temperature difference between various rooms or spaces within the building causing sectional heat loss or gain through interior walls, floors or ceilings.

(10) Thermal capacity of building construction materials.

Table No. 1 shows heat transmission values "U" for various combinations of building construction and are either taken from or based on data given in the A.S.H.V.E. Guide by the courtesy and permission of the American Society of Heating & Ventilating Engineers. For "U" factors for other combinations of building constructions and for the methods of derivation, see current issue of the A.S.H.V.E. Guide.

TABLE NO. 1. HEAT TRANSMISSION COEFFICIENTS "U" FOR BUILDING CONSTRUCTION.

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on a wind velocity of 15 m.p.h.

Where 'lath' is not specifically described as 'metal lath,' it should be taken to mean 'wood lath.' Where plaster thickness is not mentioned, it is intended as ½".

EXPOSED WALL (W)

No.		Construction	"U" Factor
No. 1 —	(a)	FRAME, WOOD SIDING, PAPER, SHEATHING, STUDS, LATH AND PLASTER	.25
	(b)	Same as 1(a) substituting ½" rigid insulation for lath	.19
	(c)	Same as 1(a) with ½" flexible insulation between joists in contact with sheathing	.17
	(d)	Same as 1(a), with 3⅝" rock wool or glass wool between studs	.07
	(e)	Same as 1(a) with ½" plaster on 1" rigid insulation instead of lath and plaster	.15
	(f)	Same as 1(a), with ½" plaster and 1½" of cork board	.11

EXPOSED WALL (W) Cont'd.

No.		Construction	"U" Factor
No. 2 —		CLAPBOARDS OR WOOD SIDING, STUDS, LATH AND PLASTER	.35
No. 3 —	(a)	8" BRICK WALL, PLAIN	.50
	(b)	Same as 3(a) plastered on one side	.46
	(c)	Same as 3(a) plaster and lath on one side furred	.30
	(d)	Same as 3(c) substituting ½" rigid insulation for lath	.22
	(e)	Same as 3(a) with ½" plaster on 1½" cork board	.14
	(f)	Same as 3(a) with ½" plaster on metal lath with 2" furring and 1⅝" rock wool	.12
No. 4 —	(a)	12" BRICK WALL, PLAIN	.36
	(b)	Same as 4(a) plastered on one side	.34
	(c)	Same as 4(a) furred, lath and plaster one side	.24
	(d)	Same as 4(c) substituting ½" rigid insulation for lath	.19
	(e)	Same as 4(a) with ½" plaster on 1½" cork board	.12
	(f)	Same as 4(a) with ½" plaster on metal lath with 2" furring and 1⅝" rock wool	.11
No. 5 —	(a)	4" BRICK VENEER ON 6" HOLLOW TILE, NO PLASTER	.36
	(b)	Same as 5(a) having ½" plaster	.34
	(c)	Same as 5(a) plaster on wood lath, furred	.24
	(d)	Same as 5(a) with ½" plaster on 1½" cork board	.13
	(e)	Same as 5(a) with ½" plaster on metal lath, furred 2" with 1⅝" rock wool	.11
No. 6 —	(a)	4" BRICK VENEER AND 8" HOLLOW TILE, NO PLASTER	.34
	(b)	Same as 6(a) plastered on one side	.33
	(c)	Same as 6(a) furred, lath and plaster	.24
	(d)	Same as 6(c) substituting ½" rigid insulation for lath	.18
	(e)	Same as 6(a) with ½" plaster on 1½" cork board	.12
	(f)	Same as 6(a) with ½" plaster on metal lath with 2" furring and 1⅝" rock wool	.11
No. 7 —	(a)	4" BRICK VENEER AND 10" HOLLOW TILE—NO PLASTER	.34
	(b)	Same as 7(a) with ½" plaster	.32
	(c)	Same as 7(a) plaster on wood lath, furred	.23
	(d)	Same as 7(a) with ½" plaster on 1½" cork board	.12
	(e)	Same as 7(a) with ½" plaster on metal lath, furred 2" with 1⅝" rock wool	.11
No. 8 —	(a)	4" BRICK VENEER—PAPER, WOOD SHEATHING, STUDS, LATH AND PLASTER	.27
	(b)	Same as 8(a) substituting ½" rigid insulation for lath	.20
	(c)	Same as 8(a) with 3⅝" rock wool or equivalent between studs	.07
No. 9 —	(a)	4" BRICK VENEER—6" SOLID CONCRETE	.57
	(b)	Same as 9(a) with ½" plaster	.53
	(c)	Same as 9(a) plaster on wood lath, furred	.33
	(d)	Same as 9(a) with ½" plaster on 1½" cork board	.14
	(e)	Same as 9(a) with ½" plaster on metal lath, furred 2" with 1⅝" rock wool fill	.13

EXPOSED WALLS (W) Cont'd.

No.	Construction	"U" Factor
No. 10—(a)	4" BRICK VENEER—10" CONCRETE	.48
(b)	Same as 10(a) with ½" plaster	.45
(c)	Same as 10(a) with plaster on wood lath, furred	.30
(d)	Same as 10(a) with ½" plaster on 1½" cork board	.14
(e)	Same as 10(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12
No. 11—(a)	4" BRICK VENEER — 8" CINDER BLOCKS	.35
(b)	Same as 11(a) with ½" plaster	.33
(c)	Same as 11(a) with plaster on wood lath, furred	.24
(d)	Same as 11(a) with ½" plaster on 1½" cork board	.12
(e)	Same as 11(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 12—(a)	4" BRICK VENEER—8" CONCRETE BLOCKS	.44
(b)	Same as 12(a) with ½" plaster	.42
(c)	Same as 12(a) with plaster on wood lath, furred	.28
(d)	Same as 12(a) with ½" plaster on 1½" cork board	.13
(e)	Same as 12(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12
No. 13—(a)	4" BRICK VENEER — 8" HAYDITE BLOCKS	.31
(b)	Same as 13(a) with ½" plaster	.29
(c)	Same as 13(a) with plaster on wood lath, furred	.23
(d)	Same as 13(a) with ½" plaster on 1½" cork board	.12
(e)	Same as 13(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 14—(a)	4" CUT STONE VENEER—8" HOLLOW TILE	.36
(b)	Same as 14(a) with ½" plaster	.34
(c)	Same as 14(a) with furred wood lath and plaster	.24
(d)	Same as 14(a) with ½" plaster on 1½" cork board	.13
(e)	Same as 14(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 15—(a)	4" CUT STONE VENEER—12" HOLLOW TILE	.28
(b)	Same as 15(a) with ½" plaster	.26
(c)	Same as 15(a) with furred wood lath and plaster	.20
(d)	Same as 15(a) with ½" plaster on 1½" cork board	.11
(e)	Same as 15(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.10
No. 16—(a)	4" CUT STONE VENEER—8" COMMON BRICK	.37
(b)	Same as 16(a) with ½" plaster	.35
(c)	Same as 16(a) with wood lath and plaster, furred	.25
(d)	Same as 16(a) with ½" plaster on 1½" cork board	.13
(e)	Same as 16(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 17—(a)	4" CUT STONE VENEER—12" COMMON BRICK	.28
(b)	Same as 17(a) with ½" plaster	.27
(c)	Same as 17(a) wood lath and plaster, furred	.21
(d)	Same as 17(a) with ½" plaster on 1½" cork board	.12
(e)	Same as 17(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.10

EXPOSED WALLS (W) Cont'd.

No.	Construction	"U" Factor
No. 18—(a)	8" HOLLOW TILE—PLAIN STUCCO EXTERIOR	.40
(b)	Same as 18(a) plastered	.37
(c)	Same as 18(a) lath and plaster, furred	.26
(d)	Same as 18(c) substituting ½" rigid insulation for lath	.20
(e)	Same as 18(a) with ½" plaster on 1½" cork board	.13
(f)	Same as 18(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 19—(a)	12" HOLLOW TILE—PLAIN STUCCO EXTERIOR	.30
(b)	Same as 19(a) plastered	.29
(c)	Same as 19(a) furred, lath and plaster	.22
(d)	Same as 19(c) substituting ½" rigid insulation for lath	.17
(e)	Same as 19(a) with ½" plaster on 1½" cork board	.12
(f)	Same as 19(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.10
No. 20—(a)	8" CINDER BLOCKS, PLAIN	.42
(b)	Same as 20(a) plastered	.39
(c)	Same as 20(a) furred, lath and plaster	.27
(d)	Same as 20(c) substituting ½" rigid insulation for lath	.20
(e)	Same as 20(a) with ½" plaster on 1½" cork board	.13
(f)	Same as 20(a) with ½" plaster on metal lath with 2" furring and 1⅝" rock wool	.12
No. 21—(a)	12" CINDER BLOCKS	.37
(b)	Same as 21(a) with ½" plaster	.35
(c)	Same as 21(a) with plaster on wood lath, furred	.25
(d)	Same as 21(a) with ½" plaster on 1½" cork board	.13
(e)	Same as 21(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 22—(a)	8" HAYDITE BLOCKS	.36
(b)	Same as 22(a) with ½" plaster	.34
(c)	Same as 22(a) with plaster on wood lath, furred	.26
(d)	Same as 22(a) with ½" plaster on 1½" cork board	.13
(e)	Same as 22(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 23—(a)	12" HAYDITE BLOCKS	.34
(b)	Same as 23(a) with ½" plaster	.32
(c)	Same as 23(a) with plaster on wood lath, furred	.25
(d)	Same as 23(a) with ½" plaster on 1½" cork board	.12
(e)	Same as 23(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 24—(a)	8" CONCRETE BLOCKS, PLAIN	.56
(b)	Same as 24(a) plastered	.52
(c)	Same as 24(a) with lath and plaster, furred	.32
(d)	Same as 24(a) furred, with ½" rigid insulation and plaster	.23
(e)	Same as 24(a) with ½" plaster on 1½" cork board	.14
(f)	Same as 24(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12
No. 25—(a)	12" CONCRETE BLOCKS, PLAIN	.49
(b)	Same as 25(a) plastered	.46
(c)	Same as 25(a) furred, lath and plaster	.30
(d)	Same as 25(a) with ½" rigid insulation and plaster, furred	.22
(e)	Same as 25(a) with ½" plaster on 1½" cork board	.14
(f)	Same as 25(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12

EXPOSED WALLS (W) Cont'd.

			"U" Factor
No. 26	(a)	8" SOLID STONE	.71
	(b)	Same as 26(a) with ½" plaster	.64
	(c)	Same as 26(a) with wood lath and plaster, furred	.37
	(d)	Same as 26(a) with ½" plaster on 1½" cork board	.15
	(e)	Same as 26(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.13
No. 27	(a)	12" SOLID STONE	.58
	(b)	Same as 27(a) with ½" plaster	.53
	(c)	Same as 27(a) furred, wood lath and plaster	.33
	(d)	Same as 27(a) with ½" plaster on 1½" cork board	.14
	(e)	Same as 27(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.13
No. 28	(a)	16" SOLID STONE	.49
	(b)	Same as 28(a) with ½" plaster	.45
	(c)	Same as 28(a) with wood lath and plaster, furred	.30
	(d)	Same as 28(a) with ½" plaster on 1½" cork board	.14
	(e)	Same as 28(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12
No. 29	(a)	6" SOLID CONCRETE	.79
	(b)	Same as 29(a) with ½" plaster	.70
	(c)	Same as 29(a) furred, wood lath and plaster	.39
	(d)	Same as 29(a) with ½" plaster on 1½" cork board	.16
	(e)	Same as 29(a) plaster on metal lath, furred 2", with 1⅝" rock wool	.13
No. 30	(a)	10" SOLID CONCRETE	.62
	(b)	Same as 30(a) with ½" plaster	.57
	(c)	Same as 30(a) furred, wood lath and plaster	.34
	(d)	Same as 30(a) with ½" plaster on 1½" cork board	.15
	(e)	Same as 30(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.13
No. 31	(a)	16" SOLID CONCRETE	.48
	(b)	Same as 31(a) with ½" plaster	.44
	(c)	Same as 31(a) with plaster on wood lath, furred	.29
	(d)	Same as 31(a) with ½" plaster on 1½" cork board	.14
	(e)	Same as 31(a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.12
No. 32	(a)	6" SOLID CONCRETE AND 6" HOLLOW TILE	.35
	(b)	Same as 32 (a) with ½" plaster	.34
	(c)	Same as 32 (a) with wood lath and plaster, furred	.31
	(d)	Same as 32 (a) with ½" plaster on 1½" corkboard	.12
	(e)	Same as 32 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 33	(a)	6" SOLID CONCRETE AND 8" HOLLOW TILE	.34
	(b)	Same as 33 (a) with ½" plaster	.33
	(c)	Same as 33 (a) with wood lath and plaster, furred	.30
	(d)	Same as 33 (a) with ½" plaster on 1½" corkboard	.12
	(e)	Same as 33 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.11
No. 34	(a)	6" SOLID CONCRETE AND 12" HOLLOW TILE	.27
	(b)	Same as 34 (a) with ½" plaster	.26
	(c)	Same as 34 (a) with wood lath and plaster, furred	.24
	(d)	Same as 34 (a) with ½" plaster on 1½" corkboard	.11
	(e)	Same as 34 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	.10

EXPOSED WALLS (W) Cont'd.

			"U" Factor
No. 35	(a)	10" SOLID CONCRETE AND 6" HOLLOW TILE	[illegible]
	(b)	Same as 35 (a) with ½" plaster	[illegible]
	(c)	Same as 35 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 35 (a) with ½" plaster on 1½" corkboard	[illegible]
	(e)	Same as 35 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]
No. 36	(a)	10" SOLID CONCRETE AND 8" HOLLOW TILE	[illegible]
	(b)	Same as 36 (a) with ½" plaster	[illegible]
	(c)	Same as 36 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 36 (a) with ½" plaster on 1½" corkboard	[illegible]
	(e)	Same as 36 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]
No. 37	(a)	10" SOLID CONCRETE AND 12" HOLLOW TILE	[illegible]
	(b)	Same as 37 (a) with ½" plaster.	[illegible]
	(c)	Same as 37 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 37 (a) with ½" plaster on 1½" corkboard	.10
	(e)	Same as 37 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]
No. 38	(a)	16" SOLID CONCRETE AND 6" HOLLOW TILE	[illegible]
	(b)	Same as 38 (a) with ½" plaster	[illegible]
	(c)	Same as 38 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 38 (a) with ½" plaster on 1½" corkboard	[illegible]
	(e)	Same as 38 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]
No. 39	(a)	16" SOLID CONCRETE AND 8" HOLLOW TILE	[illegible]
	(b)	Same as 39 (a) with ½" plaster	[illegible]
	(c)	Same as 39 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 39 (a) with ½" plaster on 1½" corkboard	[illegible]
	(e)	Same as 39 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]
No. 40	(a)	16" SOLID CONCRETE AND 12" HOLLOW TILE	[illegible]
	(b)	Same as 40 (a) with ½" plaster	[illegible]
	(c)	Same as 40 (a) with wood lath and plaster, furred	[illegible]
	(d)	Same as 40 (a) with ½" plaster on 1½" corkboard	[illegible]
	(e)	Same as 40 (a) with ½" plaster on metal lath, furred 2", with 1⅝" rock wool	[illegible]

FRAME INTERIOR PARTITIONS

No. 41	(a)	WITH LATH AND PLASTER ONE SIDE ONLY	[illegible]
	(b)	Same as 41 (a) substituting ½" rigid insulation for lath	[illegible]
	(c)	Same as 41 (a) with ½" rigid insulation on other side	[illegible]
No. 42	(a)	WITH LATH AND PLASTER BOTH SIDES	[illegible]
	(b)	Same as 42 (a) substituting ½" rigid insulation for lath	[illegible]
	(c)	Same as 42 (a) with 3⅝" rock wool insulation	[illegible]

FOUNDATION WALLS — BELOW GRADE

No. 43	(a)	12" CONCRETE BLOCK	[illegible]
	(b)	Solid Concrete—8"	[illegible]
	(c)	Solid Concrete—12"	[illegible]
	(d)	Solid Concrete—16"	[illegible]
	(e)	12" Limestone	[illegible]
	(f)	16" Limestone	[illegible]

CEILING BELOW UNHEATED ATTIC (INCLUDING ROOF LOSSES) — Pitch of Roof 1/4 to 1/3

		"U" Factor
No. 44—(a)	WOOD LATH OR PLASTER BOARD AND PLASTER CEILING, NO FLOORING ABOVE, WITH ROOF OF SHEATHING AND COMPOSITION OR WOOD SHINGLES OR TILE WITH ROOFING FELT	.30
(b)	Same as 44 (a) with attic flooring	.18
(c)	Same as 44 (a) with 1/2" fibre board insulation on under side of rafters and between attic ceiling joists—no flooring	.15
(d)	Same as 44 (c) with attic flooring	.11
(e)	Same as 44 (a) with 3 5/8" rock wool between ceiling joists, no flooring	.07
(f)	Same as 44 (e) with attic flooring	.06
(g)	1 1/2" cork board and plaster ceiling, no flooring above, with roof of sheathing and composition or wood shingles, or slate or tile with roofing felt	.12
(h)	Same as 44 (g) with attic flooring	.10
(i)	2" corkboard, otherwise same as 44 (g)	.10
(j)	2" corkboard, otherwise same as 44 (h)	.09
(k)	1/2" insulating board and plaster on ceiling, roof of sheathing and shingles—no other insulation	.21
(l)	Same as 44 (k) with attic flooring	.13
(m)	Same as 44 (k) with 1/2" insulation between roof rafters	.16

CEILINGS—PART OF ROOF—NO ATTIC SPACE

No. 45—(a)	LATH AND PLASTER, RAFTER, SHEATHING, SHINGLES	.29
(b)	Same as 45 (a) substituting 1/2" rigid insulation for lath	.21
(c)	Same as 45 (a) with 3 5/8" rock wool between rafters	.06
(d)	Same as 45 (a) with 1" rigid insulation	.16
(e)	Same as 45 (a) with 1 1/2" cork board and plaster	.12
(f)	Same as 45 (a) with 2" cork board and plaster	.10

WOOD FLOORS OVER EXPOSED OR UNHEATED SPACES

No. 46—SINGLE YELLOW PINE FLOOR, 25/32" THICK:

(a)	No ceiling	.46
(b)	Wood lath and plaster	.28
(c)	1/2" rigid insulation and 1/2" plaster	.21
(d)	1" rigid insulation and 1/2" plaster	.16
(e)	3 5/8" rock wool fill — metal lath and plaster	.07
(f)	1 1/2" cork board and 1/2" plaster	.12
(g)	2" cork board and 1/2" plaster	.10

No. 47—MAPLE OR OAK FLOORING (13/16" THICK) ON YELLOW PINE SUB-FLOORING

(a)	No ceiling	.34
(b)	Wood lath and plaster	.24
(c)	1/2" rigid insulation and 1/2" plaster	.18
(d)	1" rigid insulation and 1/2" plaster	.14
(e)	3 5/8" rock wool fill—metal lath and plaster	.07
(f)	1 1/2" cork board and 1/2" plaster	.11
(g)	2" cork board and 1/2" plaster	.09

CONCRETE FLOORS — 4" thick laid on ground

No. 48—(a)	PLAIN OR WITH QUARRY TILE, OR TERRAZZO FINISH	.10*
(b)	Same as 48 (a) yellow pine flooring on sleepers	.10*
(c)	Same as 48 (a) maple or oak on yellow pine sub-flooring on sleepers	.10*

*Recommended by ASHVE Guide, 1943

GLASS BLOCK WALLS

		"U" Factor
No. 49—(a)	2" Thick	.60
(b)	3 5/8" Thick	49

FLAT ROOFS COVERED WITH BUILT-UP ROOFING

No. 50—(a)	1" WOOD—NO CEILING	.49
(b)	Same as 50 (a) with 1/2" rigid insulation	.28
(c)	Same as 50 (a) with 1" rigid insulation	.20
(d)	Same as 50 (a) with 1 1/2" rigid insulation	.15
(e)	Same as 50 (a) with 2" rigid insulation	.12
(f)	Same as 50 (a) with 1" corkboard	.19
(g)	Same as 50 (a) with 1 1/2" corkboard	.14
(h)	Same as 50 (a) with 2" corkboard	.12
No. 51—(a)	1 1/2" WOOD—NO CEILING	.37
(b)	Same as 51 (a) with 1/2" rigid insulation	.24
(c)	Same as 51 (a) with 1" rigid insulation	.17
(d)	Same as 51 (a) with 1 1/2" rigid insulation	.14
(e)	Same as 51 (a) with 2" rigid insulation	.11
(f)	Same as 51 (a) with 1" corkboard	.17
(g)	Same as 51 (a) with 1 1/2" corkboard	.13
(h)	Same as 51 (a) with 2" corkboard	.11
No. 52—(a)	2" WOOD—NO CEILING	.32
(b)	Same as 52 (a) with 1/2" rigid insulation	.22
(c)	Same as 52 (a) with 1" rigid insulation	.16
(d)	Same as 52 (a) with 1 1/2" rigid insulation	.13
(e)	Same as 52 (a) with 2" rigid insulation	.11
(f)	Same as 52 (a) with 1" corkboard	.16
(g)	Same as 52 (a) with 1 1/2" corkboard	.12
(h)	Same as 52 (a) with 2" corkboard	.10
No. 53—(a)	3" WOOD—NO CEILING	.23
(b)	Same as 53 (a) with 1/2" rigid insulation	.17
(c)	Same as 53 (a) with 1" rigid insulation	.14
(d)	Same as 53 (a) with 1 1/2" rigid insulation	.11
(e)	Same as 53 (a) with 2" rigid insulation	.096
(f)	Same as 53 (a) with 1" corkboard	.13
(g)	Same as 53 (a) with 1 1/2" corkboard	.11
(h)	Same as 53 (a) with 2" corkboord	.091
No. 54—(a)	1" WOOD—WITH LATH AND PLASTER CEILING	.31
(b)	Same as 54 (a) with 1/2" rigid insulation	.21
(c)	Same as 54 (a) with 1" rigid insulation	.16
(d)	Same as 54 (a) with 1 1/2" rigid insulation	.13
(e)	Same as 54 (a) with 2" rigid insulation	.11
(f)	Same as 54 (a) with 1" corkboard	.15
(g)	Same as 54 (a) with 1 1/2" corkboard	.12
(h)	Same as 54 (a) with 2" corkboard	.10
No. 55—(a)	1 1/2" WOOD—WITH LATH AND PLASTER CEILING	.26
(b)	Same as 55 (a) with 1/2" rigid insulation	.19
(c)	Same as 55 (a) with 1" rigid insulation	.15
(d)	Same as 55 (a) with 1 1/2" rigid insulation	.12
(e)	Same as 55 (a) with 2" rigid insulation	.10
(f)	Same as 55 (a) with 1" corkboard	.14
(g)	Same as 55 (a) with 1 1/2" corkboard	.11
(h)	Same as 55 (a) with 2" corkboard	.095
No. 56—(a)	2" WOOD—WITH LATH AND PLASTER CEILING	.24
(b)	Same as 56 (a) with 1/2" rigid insulation	.17
(c)	Same as 56 (a) with 1" rigid insulation	.14
(d)	Same as 56 (a) with 1 1/2" rigid insulation	.11
(e)	Same as 56 (a) with 2" rigid insulation	.097
(f)	Same as 56 (a) with 1" corkboard	.13
(g)	Same as 56 (a) with 1 1/2" corkboard	.11
(h)	Same as 56 (a) with 2" corkboard	.092
No. 57—(a)	3" WOOD—WITH LATH AND PLASTER CEILING	.18
(b)	Same as 57 (a) with 1/2" rigid insulation	.14
(c)	Same as 57 (a) with 1" rigid insulation	.12
(d)	Same as 57 (a) with 1 1/2" rigid insulation	.10
(e)	Same as 57 (a) with 2" rigid insulation	.087
(f)	Same as 57 (a) with 1" corkboard	.11
(g)	Same as 57 (a) with 1 1/2" corkboard	.095
(h)	Same as 57 (a) with 2" corkboard	.082

FLAT ROOFS COVERED WITH BUILT-UP ROOFING

	"U" Factor
No. 58—(a) FLAT METAL DECK—NO CEILING	1.06
(b) Same as 58 (a) with ½″ rigid insulation	.39
(c) Same as 58 (a) with 1″ rigid insulation	.24
(d) Same as 58 (a) with 1½″ rigid insulation	.18
(e) Same as 58 (a) with 2″ rigid insulation	.14
(f) Same as 58 (a) with 1″ corkboard	.23
(g) Same as 58 (a) with 1½″ corkboard	.17
(h) Same as 58 (a) with 2″ corkboard	.13
No. 59—(a) FLAT METAL DECK—WITH LATH AND PLASTER CEILING	.46
(b) Same as 59 (a) with ½″ rigid insulation	.27
(c) Same as 59 (a) with 1″ rigid insulation	.19
(d) Same as 59 (a) with 1½″ rigid insulation	.15
(e) Same as 59 (a) with 2″ rigid insulation	.12
(f) Same as 59 (a) with 1″ corkboard	.18
(g) Same as 59 (a) with 1½″ corkboard	.14
(h) Same as 59 (a) with 2″ corkboard	.11
No. 60—(a) 2″ CONCRETE—NO CEILING	.82
(b) Same as 60 (a) with ½″ rigid insulation	.36
(c) Same as 60 (a) with 1″ rigid insulation	.24
(d) Same as 60 (a) with 1½″ rigid insulation	.17
(e) Same as 60 (a) with 2″ rigid insulation	.14
(f) Same as 60 (a) with 1″ corkboard	.22
(g) Same as 60 (a) with 1½″ corkboard	.16
(h) Same as 60 (a) with 2″ corkboard	.13
No. 61—(a) 4″ CONCRETTE—NO CEILING	.72
(b) Same as 61 (a) with ½″ rigid insulation	.34
(c) Same as 61 (a) with 1″ rigid insulation	.23
(d) Same as 61 (a) with 1½″ rigid insulation	.17
(e) Same as 61 (a) with 2″ rigid insulation	.13
(f) Same as 61 (a) with 1″ corkboard	.21
(g) Same as 61 (a) with 1½″ corkboard	.16
(h) Same as 61 (a) with 2″ corkboard	.12
No. 62—(a) 6″ CONCRETE—NO CEILING	.65
(b) Same as 62 (a) with ½″ rigid insulation	.33
(c) Same as 62 (a) with 1″ rigid insulation	.22
(d) Same as 62 (a) with 1½″ rigid insulation	.16
(e) Same as 62 (a) with 2″ rigid insulation	.13
(f) Same as 62 (a) with 1″ corkboard	.21
(g) Same as 62 (a) with 1½″ corkboard	.15
(h) Same as 62 (a) with 2″ corkboard	.12
No. 63—(a) 2″ CONCRETE—WITH LATH AND PLASTER CEILING	.42
(b) Same as 63 (a) with ½″ rigid insulation	.26
(c) Same as 63 (a) with 1″ rigid insulation	.19
(d) Same as 63 (a) with 1½″ rigid insulation	.14
(e) Same as 63 (a) with 2″ rigid insulation	.12
(f) Same as 63 (a) with 1″ corkboard	.18
(g) Same as 63 (a) with 1½″ corkboard	.14
(h) Same as 63 (a) with 2″ corkboard	.11
No. 64—(a) 4″ CONCRETE—WITH LATH AND PLASTER CEILING	.40
(b) Same as 64 (a) with ½″ rigid insulation	.25
(c) Same as 64 (a) with 1″ rigid insulation	.18
(d) Same as 64 (a) with 1½″ rigid insulation	.14
(e) Same as 64 (a) with 2″ rigid insulation	.12
(f) Same as 64 (a) with 1″ corkboard	.17
(g) Same as 64 (a) with 1½″ corkboard	.13
(h) Same as 64 (a) with 2″ corkboard	.11
No. 65—(a) 6″ CONCRETE—WITH LATH AND PLASTER CEILING	.37
(b) Same as 65 (a) with ½″ rigid insulation	.24
(c) Same as 65 (a) with 1″ rigid insulation	.18
(d) Same as 65 (a) with 1½″ rigid insulation	.14
(e) Same as 65 (a) with 2″ rigid insulation	.11
(f) Same as 65 (a) with 1″ corkboard	.17
(g) Same as 65 (a) with 1½″ corkboard	.13
(h) Same as 65 (a) with 2″ corkboard	.11

FLAT ROOFS COVERED WITH BUILT-UP ROOFING Cont'd.

	"U" Factor
No. 66—(a) 1¾″ HAYDITE TILE—SERIES "A"—NO CEILING	.44
(b) Same as 66 (a) with ½″ rigid insulation	.27
(c) Same as 66 (a) with 1″ rigid insulation	.19
(d) Same as 66 (a) with 1½″ rigid insulation	.15
(e) Same as 66 (a) with 2″ rigid insulation	.12
(f) Same as 66 (a) with 1″ corkboard	.18
(g) Same as 66 (a) with 1½″ corkboard	.14
(h) Same as 66 (a) with 2″ corkboard	.11
No. 67—(a) 2½″ HAYDITE TILE—SERIES "B"—NO CEILING	.36
(b) Same as 67 (a) with ½″ rigid insulation	.23
(c) Same as 67 (a) with 1″ rigid insulation	.17
(d) Same as 67 (a) with 1½″ rigid insulation	.14
(e) Same as 67 (a) with 2″ rigid insulation	.11
(f) Same as 67 (a) with 1″ corkboard	.16
(g) Same as 67 (a) with 1½″ corkboard	.13
(h) Same as 67 (a) with 2″ corkboard	.11
No. 68—(a) 3″ HAYDITE TILE—SERIES "C"—NO CEILING	.31
(b) Same as 68 (a) with ½″ rigid insulation	.21
(c) Same as 68 (a) with 1″ rigid insulation	.16
(d) Same as 68 (a) with 1½″ rigid insulation	.13
(e) Same as 68 (a) with 2″ rigid insulation	.11
(f) Same as 68 (a) with 1″ corkboard	.15
(g) Same as 68 (a) with 1½″ corkboard	.12
(h) Same as 68 (a) with 2″ corkboard	.10
No. 69—(a) 3¾″ HAYDITE TILE—SERIES "D"—NO CEILING	.27
(b) Same as 69 (a) with ½″ rigid insulation	.19
(c) Same as 69 (a) with 1″ rigid insulation	.15
(d) Same as 69 (a) with 1½″ rigid insulation	.12
(e) Same as 69 (a) with 2″ rigid insulation	.10
(f) Same as 69 (a) with 1″ corkboard	.14
(g) Same as 69 (a) with 1½″ corkboard	.11
(h) Same as 69 (a) with 2″ corkboard	.10
No. 70—(a) 1¾″ HAYDITE TILE—SERIES "A"—WITH LATH AND PLASTER CEILING	.29
(b) Same as 70 (a) with ½″ rigid insulation	.20
(c) Same as 70 (a) with 1″ rigid insulation	.16
(d) Same as 70 (a) with 1½″ rigid insulation	.13
(e) Same as 70 (a) with 2″ rigid insulation	.11
(f) Same as 70 (a) with 1″ corkboard	.15
(g) Same as 70 (a) with 1½″ corkboard	.12
(h) Same as 70 (a) with 2″ corkboard	.10
No. 71—(a) 2½″ HAYDITE TILE—SERIES "B"—WITH LATH AND PLASTER CEILING	.25
(b) Same as 71 (a) with ½″ rigid insulation	.18
(c) Same as 71 (a) with 1″ rigid insulation	.14
(d) Same as 71 (a) with 1½″ rigid insulation	.12
(e) Same as 71 (a) with 2″ rigid insulation	.10
(f) Same as 71 (a) with 1″ corkboard	.14
(g) Same as 71 (a) with 1½″ corkboard	.11
(h) Same as 71 (a) with 2″ corkboard	.09
No. 72—(a) 3″ HAYDITE TILE—SERIES "C"—WITH LATH AND PLASTER CEILING	.23
(b) Same as 72 (a) with ½″ rigid insulation	.17
(c) Same as 72 (a) with 1″ rigid insulation	.14
(d) Same as 72 (a) with 1½″ rigid insulation	.11
(e) Same as 72 (a) with 2″ rigid insulation	.10
(f) Same as 72 (a) with 1″ corkboard	.13
(g) Same as 72 (a) with 1½″ corkboard	.11
(h) Same as 72 (a) with 2″ corkboard	.09
No. 73—(a) 3¾″ HAYDITE TILE—SERIES "D"—WITH LATH AND PLASTER CEILING	.21
(b) Same as 73 (a) with ½″ rigid insulation	.16
(c) Same as 73 (a) with 1″ rigid insulation	.13
(d) Same as 73 (a) with 1½″ rigid insulation	.11
(e) Same as 73 (a) with 2″ rigid insulation	.09
(f) Same as 73 (a) with 1″ corkboard	.12
(g) Same as 73 (a) with 1½″ corkboard	.10
(h) Same as 73 (a) with 2″ corkboard	.09

WINDOWS AND DOORS

Windows, skylights and doors comprise a substantial proportion of the heat-losing surfaces of a building. Table 2 gives "U" factors for these, and a more detailed treatment of transmission coefficients for hollow glass block walls.

TABLE 2. COEFFICIENTS OR TRANSMISSION (U) OF DOORS, WINDOWS, SKYLIGHTS AND GLASS BLOCK WALLS

Coefficients are based on a wind velocity of 15 mph. and are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air inside and outside of the door, window, skylight or wall.

SECTION A. WINDOWS AND SKYLIGHTS

Description	U
Single	1.13*, ‡
Double	0.45*, ‡
Triple	0.281*, ††

SECTION B. SOLID WOOD DOORS†, ‡

Nominal Thickness Inches	Actual Thickness Inches	U Exposed Door	U§ With Glass Storm Door
1	25/32	0.69	0.42
1¼	1 1/16	0.59	0.38
1½	1 5/16	0.52	0.35
1¾	1⅜	0.51	0.35
2	1⅝	0.46	0.32
2½	2⅛	0.38	0.28
3	2⅝	0.33	0.25

SECTION C. HOLLOW GLASS BLOCK WALLS

Description	U Still Air Both Sides	U Still Air Inside, 15 m.p.h. Outside
Smooth surface glass blocks 7¾x7¾x3⅞ in. thick	0.40	0.49
Ribbed surface glass blocks 7¾x7¾x3⅞ in. thick	0.38	0.46

*See Heating, Ventilating and Air Conditioning, by Harding and Willard, revised edition, 1932.

†Computed using C = 1.15 for wood; $f_i = 1.65$ and $f_o = 6.0$.

‡It is sufficiently accurate to use the same coefficient of transmission for doors containing thin wood panels as that of single panes of glass, namely, 1.13 Btu. per hour per square foot per degree difference between inside and outside air temperatures.

§These values may also be used with sufficient accuracy for wood storm doors. Neglect storm doors if loose and use values for exposed doors.

††Air spaces assumed to be ¾ in. or more in width.

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OUTSIDE-INSIDE TEMPERATURE DIFFERENTIALS

Multiplication of the proper "U" Factors by the total areas of each of the various material combinations comprising the exterior construction of a building gives the total loss of heat in Btu's per hour for a 1°F **differential between the inside and outside temperature** (disregarding infiltration and other qualifying conditions which will be treated later).

This total for a 1°F temperature differential must be multiplied by the number of degrees by which the inside temperature is to be maintained above the outside "base" temperature (design temperature). Table No. 3 gives relevant weather data for representative cities in the United States. For localities not shown in Table No. 3, use the values given for the nearest town or city and determine the value for "T" (temperature difference) by subtracting algebraically the base temperature from the desired building temperature.

Building temperatures generally recommended are shown in Table No. 4.

TABLE 3. CLIMATIC CONDITIONS COMPILED FROM WEATHER BUREAU RECORDS*

COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G
State	City	Average Temperature, Oct. 1-May 1	Lowest Temperature Ever Reported	Recommended Design Temperature	Average Wind Velocity Dec., Jan., Feb., Miles per Hour	Direction of Prevailing Wind, Dec., Jan., Feb.
Ala.	Birmingham	53.8	−10	10	8.5	N
	Mobile	58.9	−1	20	10.4	N
Ariz.	Flagstaff	35.8	−25	−10	7.8	SW
	Phoenix	59.5	12	25	6.4	E
Ark.	Fort Smith	50.4	−15	5	8.1	E
	Little Rock	51.6	−12	10	8.7	NW
Calif.	Los Angeles	58.5	28	30	6.3	NE
	San Francisco	54.2	27	30	7.6	N
Colo.	Denver	38.9	−29	−15	7.5	S
	Grand Junction	38.9	−21	−10	5.3	NW
Conn.	New Haven	38.4	−15	0	9.7	N
D. C.	Washington	43.4	−15	0	7.1	NW
Fla.	Jacksonville	62.0	10	25	9.2	NE
Ga.	Atlanta	51.5	−8	10	12.1	NW
	Savannah	58.5	8	15	9.5	NW
Idaho	Lewiston	42.3	−23	−5	5.3	E
	Pocatello	35.7	−28	−10	9.6	SE
Ill.	Chicago	36.4	−23	−10	12.5	W
	Springfield	39.8	−24	−10	10.1	NW
Ind.	Evansville	45.1	−16	0	9.8	S
	Indianapolis	40.3	−25	−10	11.5	SW
Iowa	Dubuque	33.9	−32	−20	7.1	NW
	Sioux City	32.6	−35	−20	11.6	NW
Kans.	Concordia	39.8	−25	−10	8.1	S
	Dodge City	41.4	−26	−10	9.8	NW
Ky.	Louisville	45.3	−20	−5	9.9	SW
La.	New Orleans	61.6	7	20	8.8	N
	Shreveport	56.2	−5	10	8.9	SE
Me.	Eastport	31.5	−23	−10	12.0	W
	Portland	33.8	−21	−10	9.2	NW
Md.	Baltimore	43.8	−7	10	7.8	NW
Mass.	Boston	38.1	−18	0	11.2	W
Mich.	Alpena	29.6	−28	−10	12.4	W
	Detroit	35.8	−24	−10	12.7	SW
	Marquette	28.3	−27	−10	11.1	NW
Minn.	Duluth	24.3	−41	−30	12.6	SW
	Minneapolis	29.4	−33	−20	11.3	NW
Miss.	Vicksburg	56.8	−1	15	8.3	SE
Mo.	St. Joseph	40.7	−24	−10	9.3	NW
	St. Louis	43.6	−22	−5	11.6	S
	Springfield	44.3	−29	−10	10.8	SE
Mont.	Billings	34.0	−49	−30	......	W
	Havre	27.6	−57	−30	9.5	SW
Nebr.	Lincoln	37.0	−29	−15	10.5	S
	North Platte	35.4	−35	−20	8.5	W
Nev.	Tonopah	39.4	−10	5	10.0	SE
	Winnemucca	37.9	−28	−15	8.7	NE
N. H.	Concord	33.3	−35	−20	6.6	NW
N. J.	Atlantic City	41.6	−9	5	15.9	NW
N. Y.	Albany	35.2	−24	−5	8.1	S
	Buffalo	34.8	−20	0	17.2	W
	New York	40.7	−14	0	17.1	NW
N. M.	Santa Fe	38.3	−13	0	7.8	NE
N. C.	Raleigh	50.0	−2	15	8.2	SW
	Wilmington	54.2	5	20	8.5	SW
N. D.	Bismarck	24.6	−45	−30	9.1	NW
	Devils Lake	20.3	−44	−30	10.6	W
Ohio	Cleveland	37.2	−17	−5	13.0	SW
	Columbus	39.9	−20	−10	12.0	SW
Okla.	Oklahoma City	47.9	−17	0	12.0	N
Ore.	Baker	35.2	−24	−15	6.9	SE
	Portland	46.1	−2	10	7.5	S
Pa.	Philadelphia	42.7	−6	0	11.0	NW
	Pittsburgh	41.0	−20	−5	11.7	W
R. I.	Providence	37.2	−17	0	12.8	NW
S. C.	Charleston	57.4	7	15	10.6	SW
	Columbia	54.0	−2	10	8.1	NE
S.D.	Huron	28.2	−43	−25	10.6	NW
	Rapid City	33.4	−34	−20	8.2	W
Tenn.	Knoxville	47.9	−16	0	7.8	SW
	Memphis	51.1	−9	0	9.7	S
Texas	El Paso	53.5	−5	0	10.4	NW
	Ft. Worth	55.2	−8	0	10.4	NW
	San Antonio	60.6	4	10	8.0	NE
Utah	Modena	36.3	−24	−15	8.8	W
	Salt Lake City	40.0	−20	−10	6.7	SE
Vt.	Burlington	31.5	−29	−20	11.8	S
Va.	Lynchburg	46.8	−7	10	7.1	NW
	Norfolk	49.3	2	15	12.5	N
	Richmond	47.0	−3	10	7.9	SW
Wash.	Seattle	44.8	3	15	11.3	SE
	Spokane	37.7	−30	−15	7.1	SW
W. Va.	Elkins	39.4	−28	−10	6.6	W
	Parkersburg	42.6	−27	−10	7.5	SW
Wis.	Green Bay	30.0	−36	−20	10.4	SW
	La Crosse	31.7	−43	−25	7.3	S
	Milwaukee	33.4	−25	−10	11.5	W
Wyo.	Lander	30.0	−40	−25	5.0	SW
	Sheridan	30.7	−41	−25	6.0	NW

TABLE 3. CONTD. CLIMATIC CONDITIONS COMPILED FROM WEATHER BUREAU RECORDS*—(Concluded)

COL. A	COL. B	COL. C	COL. D	COL. E	COL. F	COL. G
State or Province	City	Average Temperature, Oct. 1-May 1	Lowest Temperature Ever Reported	Recommended Design Temperature	Average Wind Velocity Dec., Jan., Feb., Miles per Hour	Direction of Prevailing Wind, Dec., Jan., Feb.
Alta.	Edmonton	23.0	−57	−20	6.5	SW
B. C.	Vancouver	42.0	2	15	4.5	E
	Victoria	43.9	− 1.5	15	12.5	N
Man.	Winnipeg	17.5	−47	−30	10.0	NW
N. B.	Fredericton	27.0	−35	−10	9.6	NW
N. S.	Yarmouth	35.0	−12	0	14.2	NW
Ont.	London	32.6	−27	0	10.3	SW
	Ottawa	26.5	−34	−10	8.4	NW
	Port Arthur	22.4	−37	−15	7.8	NW
	Toronto	32.9	−26.5	− 5	13.0	SW
P. E. I.	Charlottetown	29.0	−27	− 5	9.4	SW
Que.	Montreal	27.8	−29	−10	14.3	SW
	Quebec	24.2	−34	−10	13.6	SW
Sask.	Prince Albert	15.8	−70	−55	5.1	W
Yukon	Dawson	2.1	−68	−50	3.7	S

*United States data from U. S. Weather Bureau.
Canadian data from Meteorological Service of Canada.

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TABLE 4. WINTER INSIDE DRY-BULB TEMPERATURES USUALLY SPECIFIED*

Type of Building	Deg. Fahr.	Type of Building	Deg. Fahr.
Schools—		Theaters—	
Class rooms	70–72	Seating space	68–72
Assembly rooms	68–72	Lounge rooms	68–72
Gymnasiums	55–65	Toilets	68
Toilets and baths	70		
Wardrobe and locker rooms	65–68	Hotels—	
Kitchens	66	Bedrooms and baths	70
Dining and lunch rooms	65–70	Dining rooms	70
Playrooms	60–65	Kitchens and laundries	66
Natatoriums	75	Ballrooms	65–68
		Toilets and service rooms	68
Hospitals—			
Private rooms	70–72	Homes	70–72
Private rooms (surgical)	70–80	Stores	65–68
Operating rooms	70–95	Public buildings	68–72
Wards	68	Warm air baths	120
Kitchens and laundries	66	Steam baths	110
Toilets	68	Factories and machine shops	60–65
Bathrooms	70–80	Foundries and boiler shops	50–60
		Paint shops	80

*The most comfortable dry-bulb temperature to be maintained depends on the relative humidity and air motion. These three factors considered together constitute what is termed the *effective temperature.*

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INFILTRATION

Basic factors affecting heat losses treated thus far make no allowances for air leakage or infiltration and for exposure. The following Tables give necessary data for the determination of the increased heat losses due to these factors.

TABLE 5. INFILTRATION THROUGH WALLS*
Expressed in cubic feet per square foot per hour

Type of Wall		Wind Velocity, Miles per Hour					
		5	10	15	20	25	30
8½ in. Brick Wall	Plain	1.75	4.20	7.85	12.2	18.6	22.9
	Plastered	0.017	0.037	0.066	0.107	0.161	0.236
13 in. Brick Wall	Plain	1.44	3.92	7.48	11.6	16.3	21.2
	Plastered	0.005	0.013	0.025	0.043	0.067	0.097
Frame Wall, with lath and plaster†		0.03	0.07	0.13	0.18	0.23	0.26

*The values given in this table are 20 per cent less than test values to allow for building up of pressure in rooms and are based on test data reported in the papers listed at the end of this chapter.

†Wall construction: Bevel siding painted or cedar shingles, sheathing, building paper, wood lath and 3 coats gypsum plaster.

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TABLE 6. INFILTRATION THROUGH WINDOWS
Expressed in Cubic Feet per Foot of Crack per Hour*

Type of Window	Remarks	Wind Velocity, Miles per Hour					
		5	10	15	20	25	30
Double-Hung Wood Sash Windows (Unlocked)	Around frame in masonry wall—not calked.[b]	3.3	8.2	14.0	20.2	27.2	34.6
	Around frame in masonry wall calked.[b]	0.5	1.5	2.6	3.8	4.8	5.8
	Around frame in wood frame construction.[b]	2.2	6.2	10.8	16.6	23.0	30.3
	Total for average window, non-weather-stripped, 1/16-in. crack and 3/64-in. clearance.[c] Includes wood frame leakage[d]	6.6	21.4	39.3	59.3	80.0	103.7
	Ditto, weatherstripped.[d]	4.3	13.0	23.6	35.5	48.6	63.4
	Total for poorly fitted window, non-weatherstripped, 3/32-in. crack and 3/32-in. clearance.[e] Includes wood frame leakage[d]	26.9	69.0	110.5	153.9	199.2	249.4
	Ditto, weatherstripped.[d]	5.9	18.9	34.1	51.4	70.5	91.5
Double-Hung Metal Windows[f]	Non-weatherstripped, locked	20	45	70	96	125	154
	Non-weatherstripped, unlocked	20	47	74	104	137	170
	Weatherstripped, unlocked	6	19	32	46	60	76
Rolled Section Steel Sash Windows[k]	Industrial pivoted 1/16-in. crack[g]	52	108	176	244	304	372
	Architectural projected, 1/32-in. crack.[h]	15	36	62	86	112	139
	Architectural projected, 3/64-in. crack.[h]	20	52	88	116	152	182
	Residential casement, 1/64-in. crack.[i]	6	18	33	47	60	74
	Residential casement, 1/32-in. crack.[i]	14	32	52	76	100	128
	Heavy casement section, projected, 1/64-in. crack.[j]	3	10	18	26	36	48
	Heavy casement section, projected, 1/32-in. crack.[j]	8	24	38	54	72	92
Hollow Metal, vertically pivoted window[f]		30	88	145	186	221	242

*The values given in this table, with the exception of those for double-hung and hollow metal windows, are 20 per cent less than test values to allow for building up of pressure in rooms.

[b]The values given for frame leakage and per foot of sash perimeter as determined for double-hung wood windows. Some of the frame leakage in masonry walls originates in the brick wall itself and cannot be prevented by calking. For the additional reason that calking is not done perfectly and deteriorates with time, it is considered advisable to choose the masonry frame leakage values for calked frames as the average determined by the calked and not-calked tests.

[c]The fit of the average double-hung wood window was determined as 1/16-in. crack and 3/64-in. clearance by measurements on approximately 600 windows under heating season conditions.

[d]The values given are the totals for the window opening per foot of sash perimeter and include frame leakage and so-called elsewhere leakage. The frame leakage values included are for wood frame construction but apply as well to masonry construction assuming a 50 per cent efficiency of frame calking.

[e]A 3/32-in. crack and clearance represents a poorly fitted window, much poorer than average.

[f]Windows tested in place in building.

[g]Industrial pivoted window general used in industrial buildings. Ventilators horizontally pivoted at center or slightly above, lower part swinging out.

[h]Architectural projected made of same sections as industrial pivoted except that outside framing member is heavier and it has refinements in weathering and hardware. Used in semi-monumental buildings such as schools. Ventilators swing in or out and are balanced on side arms. 1/32-in. crack is obtainable in the best practice of manufacture and installation, 3/64-in. crack considered to represent average practice.

[i]Of same design and section shapes as so-called heavy section casement but of lighter weight. 1/64-in. crack is obtainable in the best practice of manufacture and installation. 1/32-in. crack considered to represent average practice.

[j]Made of heavy sections. Ventilators swing in or out and stay set any degree of opening. 1/64-in. crack is obtainable in the best practice of manufacture and installation. 1/32-in. crack considered to represent average practice.

[k]With reasonable care in installation, leakage at contacts where windows are attached to steel framework and to mullions is negligible. With 3/64-in. crack, representing poor installation, leakage at contact with steel framework is about one-third and at mullions about one-sixth of that given for industrial pivoted windows in the table.

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TABLE 7. INFILTRATION THROUGH OUTSIDE DOORS FOR COOLING LOADS*

Expressed in Cubic Feet per Minute per Person in Room

Application	Pair 36 In. Swinging Doors, Single Entrance†	Application	Pair 36 In. Swinging Doors, Single Entrance†
Bank	7.5	Hospital Room	3.5
Barber Shop	4.5	Lunch Room	5.0
Broker's Office	7.0	Men's Shop	3.5
Candy and Soda	6.0	Office	3.0
Cigar Store	25.0	Office Building	2.0
Department Store	8.0	Public Building	2.5
Dress Shop	2.5	Restaurant	2.5
Drug Store	7.0	Shoe Store	3.5
Furrier	2.5		

*For doors located in only one wall or where doors in other walls are of revolving type.

†Vestibules with double pair swinging doors, infiltration may be assumed 75 per cent of swinging door values.

Infiltration for 72 in. revolving doors may be assumed 60 per cent of swinging door values.

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TABLE 8. AIR CHANGES TAKING PLACE UNDER AVERAGE CONDITIONS EXCLUSIVE OF AIR PROVIDED FOR VENTILATION

Kind of Room or Building	Number of Air Changes Taking Place per Hour
Rooms, 1 side exposed	1
Rooms, 2 sides exposed	1½
Rooms, 3 sides exposed	2
Rooms, 4 sides exposed	2
Rooms with no windows or outside doors	½ to ¾
Entrance Halls	2 to 3
Reception Halls	2
Living Rooms	1 to 2
Dining Rooms	1 to 2
Bath Rooms	2
Drug Stores	2 to 3
Clothing Stores	1
Churches, Factories, Lofts, etc.	½ to 3

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TABLE NO. 9—EXPOSURE—FACTOR "E"

The sum of the heat losses by transmission through the outside walls and glass, shall be multiplied by the following factors for exposure noted:

North and North West	1.2
West and North East	1.15
East and South West	1.10
South East	1.05
South	1.00

TABLE 10. LEAKAGE FACTORS "L"

Good construction, moderately tight windows, no weather stripping	1.5
Good construction with weather stripped window	1.3
Loose construction	1.6 or 1.7
Casement or French windows or doors opening outside, no weather stripping	1.6
Casement or French windows or doors opening outside with weather stripping	1.4
Factory Buildings, large amount of glass, using steel window frames	1.7 or 1.8
Corridors and Vestibules	2.0 or 2.5
Corner rooms in Residence and in Apartment Buildings of first class and tight construction, no weather stripping	1.4
Corner rooms in Residence and in Apartment Buildings of first class and tight construction with weather stripping	1.3

CALCULATION OF HEAT LOSSES

The calculation of heat losses in British Thermal Units per hour can be carried out step by step by reference to relevant data given in the preceding tables. Engineering practice varies in the manner of applying the various factors and three of the more commonly used formulae which provide satisfactory results follow.

See equations and examples "A", "B", and "C".

A. The formula following considers the infiltration of air into the building to be a function of the length of the crack around doors and windows and through building construction and is expressed as

$$H = [\,(TGU_G) + (TWU_W) + (T_R RU_R) + (0.018TCV)\,]\,E$$

B. The following formula considers the infiltration of air into building as relative to the air volume of the space to be heated (air change).

$$H = [\,(TGU_G) + (TWU_W) + (TRU_R) + (0.018TAN)\,]\,E$$

C. The following formula considers the heat loss due to infiltration to be an additional percentage of the heat loss from the glass and wall area and is expressed as

$$H = [\,(TGU_G) + (TWU_W) + (TRU_R)\,]\,LE$$

Where H = Total heat loss in Btu.

T = Temperature difference between outside (base temperature) and building temperatures.

T_R = Temperature difference between outside air or attic space and room temperature (for uninsulated ceilings below attic roof assume attic roof temperature to be the mean of the outside plus room temperature. Where insulation is used in ceiling, assume roof temperature to be 10 to 15 degrees higher than outside temperature).

G = Area of glass windows and doors.

U_G = "U" factor for glass—see Table No. 2.

W = Net wall area exposed to outside weather or cooler temperatures.

U_W = "U" factor for wall construction prevailing—see Table No. 1.

R = Roof or ceiling or floor area adjacent to outside weather or cooler temperatures.

U_R = "U" factor for roof, ceiling or floor construction prevailing—see Table No. 1.

C = Length of window or door crack.

V = Volume of air per foot of crack leaking into building—see Table No. 6.

A = Cubical contents of heated space (air change).

N = Number of air changes—see Table No. 8.

E = Exposure factor—See Table No. 9.

L = Leakage factor—see Table No. 10.

0.018 = Btu required to raise one cubic foot of air one degree (approximately).

Examples of the various formulae for estimating heat losses follow. Assume building temperature 70° F.; base temperature outside —10° F.; building walls 4" face brick with 8" concrete blocks. 1" furring, wood, lath and plaster. "U"=.24. Wind velocity 15 miles per hour. Ceiling below attic roof, wood, lath and plaster. No flooring above. Room dimensions 12'x14'. North and west sides exposed. Ceiling height 8'. Two windows on north exposure each 3'x5' single glazed. Window fitting and general construction below average.

HEAT LOSS ESTIMATE BY FORMULA "A"

Building Construction or Items to be Considered	Area of Construction or Length of Window Crack or Volume	Co-efficient or "U" Factor	Temperature Difference	Heat Loss Per Hour BTU	Total Estimate BTU
Glass 3' x 5' x 2	30	1.13	80	2712	....
Wall 8' x (12'+14')					
Less Glass	178	0.24	80	3418	....
Ceiling 12' x 14'	168	0.62	40	4166	....
Infiltration					
15 Mile Wind	38	110.5 x 0.018	80	6080	16376 (1)
Exposure Correction		1.2 x Total (1)			19751 (2)

HEAT LOSS ESTIMATE BY FORMULA "B"

Building Construction or Items to be Considered	Area of Construction or Length of Window Crack or Volume	Co-efficient or "U" Factor	Temperature Difference	Heat Loss Per Hour BTU	Total Estimate BTU
Glass 3' x 5' x 2	30	1.13	80	2712	....
Wall 8' x (12'+14')					
Less Glass	178	0.24	80	3418	....
Ceiling 12' x 14'	168	0.62	40	4166	....
Air Change 1½	1344	1.5 x 0.018	80	2903	13299 (3)
Exposure Correction		1.2 x Total (3)			15959 (4)

HEAT LOSS ESTIMATE BY FORMULA "C"

Building Construction or Items to be Considered	Area of Construction or Length of Window Crack or Volume	Co-efficient or "U" Factor	Temperature Difference	Heat Loss Per Hour BTU	Total Estimate BTU
Glass 3' x 5' x 2	30	1.13	80	2712	....
Wall 8' x (12'+14')					
Less Glass	178	0.24	80	3418	....
Ceiling 12' x 14'	168	0.62	40	4166	10296 (5)
Infiltration					
(Leakage)		1.6 x Total (5)			16473 (6)
Exposure Correction		1.2 x Total (6)			19768 (7)

HIGH CEILINGS

In addition to the heat losses tabulated above, other conditions to be considered are those presented by high ceilings. It is generally conceded that special consideration is not necessary for ceiling heights of 12 ft. or less. However, for ceilings under 20 ft. a sufficiently accurate rule is to assume that air temperature increases 2% for each foot above the breathing line or the 30 in. line as may be determined on. The rule applies more particularly to spaces heated by direct radiation. The mean temperature of the air adjacent to the exterior wall may be determined as

$$T_m = T\left[1 + \left(\frac{0.02H}{2}\right)\right]$$

Where T_m = Mean temperature for estimating heat loss.
T = Temperature at breathing line.
h = Height of breathing line.
H = Height above breathing line.
0.02 = 2% per foot increase in temperature.

To estimate the mean temperature T_m of the air within the space with an 18 ft. ceiling height and temperature at breathing line of 70° F., T_m equals:

$$T_m = 70\left[1 + \left(\frac{0.02 \times 18}{2}\right)\right] = 82.6° \text{ F.}$$

The heat loss would therefore be on the basis of 82.6° instead of 70° F. room temperature.

Since convector units and unit heaters provide a more consistent air movement towards floor, air stratification causing higher temperatures at higher levels is not so prevalent and correction for high ceilings can be reduced, for example, to about one-half the percentage (1%) indicated in previous paragraph.

ATTIC TEMPERATURES

Attic temperatures are generally assumed to be the mean of the inside and outside temperature when no insulation is used. Where insulation is used and applied to ceilings it is usually assumed that roof space temperature is only 10 to 15° F. above the outside temperature. The overall coefficient "U" for combined construction of ceiling, attic space and roofing material per sq. ft. of ceiling area is determined as follows:

$$U = \frac{U_R \times U_{CE}}{U_R + \frac{U_{CE}}{n}}$$

Where U = Combined coefficient to be used with ceiling area.
U_R = Coefficient of transmission for roof construction.
U_{CE} = Coefficient of transmission for ceiling construction.
n = Ratio of area of roof to area of ceiling.

The above applies to attic roofs with no windows and unheated. If windows are present in attic roof the approximate value of U_R should be arrived at in relation to the ratio of glass to roof surfaces.

Where attic roofs are ventilated they will likely be at a temperature very near to outside in which case only ceiling coefficient is used.

For more detailed procedure, consult current A.S.H.V.E. Guide.

AUXILIARY HEAT SOURCES

The heat supplied by persons, lights, motors and machines should be ascertained and considered where congregation of persons or process work is of considerable extent. It is generally advisable to provide sufficient heating capacity to bring assembly building temperatures up to 5 to 10° F. below the desired occupancy temperature before audience assembles. In industrial plants, however, sources of heat gain should be considered and compensated for. However, in no case should capacity of the actual heating installation (exclusive of heat gain sources) be below that sufficient to maintain a minimum of 40° F. within the building. See Tables Nos. 11, 12 and 13 for values of heat gain for various sources.

TABLE 11. HEAT GAIN FROM VARIOUS SOURCES

Source	Btu Per Hour		
	Sensible	Latent	Total
ELECTRIC HEATING EQUIPMENT			
Electrical Equipment—Dry Heat—No Evaporated Water	100%	0%	100%
Electric Oven—Baking	80%	20%	100%
Electric Equipment—Heating Water—Stewing, Boiling, etc.	50%	50%	100%
Electric Lights and Appliances per Watt (Dry Heat)	3.4	0	3.4
Electric Lights and Appliances per Kilowatt (Dry Heat)	3413	0	3413
Coffee Urn—Per Gallon Capacity	1025	1025	2050
Electric Range, Household—Small Burner (60% of connected load)	*	*	2050
Electric Range, Household—Large Burner (60% of connected load)	*	*	4505
Electric Range, Household—Oven	8000	2000	10000
Steam Table—Per Square Foot of Top Surface (35% of connected load)	105	300	405
Plate Warmer—Per Cubic Foot Inside Volume (50% of connected load)	615	0	615
Bakers Oven—Per Cubic Foot Inside Volume (60% of connected load)	1300	500	1800
Frying Griddles—Per Square Foot of Top Surface (60% of connected load)	2160	240	2400
Hot Plates—Per Square Foot of Top Surface (60% of connected load)	*	*	6000
Waffle Baker—Per Section (40% of connected load)	*	*	1365
Toaster—Per Slice (50% of connected load)	945	105	1050
Glass Coffee Maker—Per Section	*	*	1365
Sandwich Grille—Per Square Foot of Area (60% of connected load)	*	*	2750
Fry Kettle—Per Pound Fat Capacity (60% of connected load)	*	*	700
Hair Dryer in Beauty Parlor—600 w	2050	0	2050
Permanent Wave Machine in Beauty Parlor—24-25 w Units	2050	0	2050
GAS BURNING EQUIPMENT			
Gas Equipment—Dry Heat—No Water Evaporated	90%	10%	100%
Gas Heated Oven—Baking	67%	33%	100%
Gas Equipment—Heating Water—Stewing, Boiling, etc.	50%	50%	100%
Stove, Domestic Type—No Water Evaporated—Per Medium Size Burner	9000	1000	10000
Gas Heated Oven—Domestic Type	12000	6000	18000
Stove, Domestic Type—Heating Water—Per Medium Size Burner	5000	5000	10000
Residence Gas Range—Giant Burner (About 5½ in. Diameter)	*	*	12000
Residence Gas Range—Medium Burner (About 4 in. Diameter)	*	*	9000
Residence Gas Range—Double Oven (Total Size 18 in. x 18 in. x 22 in. High)	*	*	18000
Residence Gas Range—Pilot	*	*	250
Restaurant Range—4 Burners and Oven	*	*	100000
Cast-Iron Burner—Low Flame—Per Hole	*	*	100
Cast-Iron Burner—High Flame—Per Hole	*	*	250
Simmering Burner	*	*	1800
Coffee Urn—Large, 18 in. Diameter—Single Drum	5000	5000	10000
Coffee Urn—Small, 12 in. Diameter—Single Drum	3000	3000	6000
Coffee Urn—Per Gallon of Rated Capacity	500	500	1000
Egg Boiler—Per Egg Compartment	2500	2500	5000
Steam Table or Serving Table—Per Square Foot of Top Surface	400	900	1300
Dish Warmer—Per Square Foot of Shelf	540	60	600
Cigar Lighter—Continuous Flame Type	2250	250	2500
Curling Iron Heater	2250	250	2500
Bunsen Type Burner—Large—Natural Gas	*	*	5000
Bunsen Type Burner—Large—Artificial Gas	*	*	3000
Bunsen Type Burner—Small—Natural Gas	*	*	3000
Bunsen Type Burner—Small—Artificial Gas	*	*	1800
Welsbach Burner—Natural Gas	*	*	3000
Welsbach Burner—Artificial Gas	*	*	1800
Fish-tail Burner—Natural Gas	*	*	5000
Fish-tail Burner—Artificial Gas	*	*	3000
Lighting Fixture Outlet—Large, 3 Mantle 480 C.P.	4500	500	5000
Lighting Fixture Outlet—Small, 1 Mantle 160 C.P.	2250	250	2500
One Cubic Foot of Natural Gas Generates	900	100	1000
One Cubic Foot of Artificial Gas Generates	500	50	550
One Cubic Foot of Producer Gas Generates	135	15	150
STEAM HEATED EQUIPMENT			
Steam Heated Surface Not Polished—Per Square Foot of Surface	330	0	330
Steam Heated Surface Polished—Per Square Foot of Surface	130	0	130
Insulated Surface, Per Square Foot	80	0	80
Bare Pipes, Not Polished, Per Square Foot of Surface	400	0	400
Bare Pipes, Polished, Per Square Foot of Surface	220	0	220
Insulated Pipes, Per Square Foot	110	0	110
Coffee Urn—Large, 18 in. Diameter—Single Drum	2000	2000	4000
Coffee Urn—Small, 12 in. Diameter—Single Drum	1200	1200	2400
Egg Boiler—Per Egg Compartment	2500	2500	5000
Steam Table—Per Square Foot of Top Surface	300	800	1100
MISCELLANEOUS			
Heat Liberated By Food per person, as in a Restaurant	30	30	60
Heat Liberated from Hot Water used direct and on towels per hour—Barber Shops	100	200	300

*Per cent sensible and latent heat depends upon use of equipment; dry heat, baking or boiling.

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TABLE NO. 12. HEAT GENERATED BY MOTORS AND GIVEN OFF TO SPACE WHERE LOCATED

H.P. of Motors	Condition of Location and Operation or Activity	Heat Given Off Btu per hour
⅛—½	Operating in Room	4250 per h.p.
½—3	Operating in Room	3700 per h.p.
3—20	Operating in Room	2950 per h.p.
⅛—½	Operating machine room, motor outside room	1700 per h.p.
½—3	Operating machine room, motor outside room	1100 per h.p.
3—20	Operating machine room, motor outside room	400 per h.p.

TABLE 13. RELATION BETWEEN METABOLIC RATE AND ACTIVITY*

Activity	Hourly Metabolic Rate for Avg. Person or Total Heat Dissipated, Btu per Hour	Hourly Sensible Heat Dissipated, at 79 F., Btu per Hour	Hourly Latent Heat Dissipated, at 79 F., Btu per Hour	Moisture Dissipated per Hour	
				Grains	Pounds
Basal	291	145	145	978	0.140
Seated at Rest	384	225	159	1072	0.153
Reading Aloud (Seated)	420	225	195	1315	0.188
Standing at Rest	431	225	206	1389	0.198
Hand Sewing (Seated)	441	225	216	1457	0.208
Knitting 23 stitches per minute on Sweater	462	225	237	1598	0.228
Dressing and Undressing	468	225	243	1639	0.234
Tailor	482	225	257	1733	0.248
Singing	486	225	261	1760	0.251
Office Worker Moderately Active	490	225	265	1787	0.255
Light Work, Standing	549	225	324	2185	0.312
Typewriting Rapidly	558	225	333	2246	0.321
Ironing with 5 lb. iron	570	225	345	2326	0.332
Dishwashing—Plates, Bowls, Cups and Saucers	600	225	375	2529	0.361
Clerk Moderately Active Standing at Counter	600	225	375	2529	0.361
Pook Binder	626	225	401	2704	0.386
Shoemaker	661	225	436	2940	0.420
Sweeping Bare Floor 38 Strokes per Minute	672	229	443	2987	0.427
Fool Player	680	230	450	3055	0.434
Walking 2 mph, Light Dancing	761	250	511	3446	0.492
Light Metal Worker (at Bench)	862	277	585	3945	0.564
Painter of Furniture (at Bench)	876	280	596	4019	0.574
Carpenter	954	307	647	4363	0.623
Restaurant Serving	1000	325	675	4552	0.650
Pulling Weight	1041	335	708	4774	0.682
Walking 3 mph	1050	339	711	4795	0.685
Walking 4 mph, Active Dancing, Roller Skating	1390	452	938	6325	0.904
Walking Down Stairs	1444	467	977	6588	0.941
Stone Mason	1490	490	1000	6744	0.963
Bowling	1500	490	1010	6811	0.973
Man Sawing Wood	1800	590	1210	8160	1.166
Swimming	1986				
Running 5.3 mph	2268				
Walking 5 mph	2330				
Walking Very Fast 5.3 mph.	2580				
Walking Up Stairs	4365				
Maximum Exertion Different People	3000-4800				

*These metabolic rates were compiled by the A.S.H.V.E. Research Laboratory from actual tests, from other authoritative sources, and from estimates based upon various considerations.

Division of the total heat dissipation into latent and sensible rates is based on actual test data and on various considerations for metabolic rates up to 1250 Btu per hour, and extrapolated for higher rates. Values for total heat dissipation for a person at rest apply for a dry-bulb temperature range from approximately 60 to 90 F; for other than rest conditions the values apply for a similar but lower temperature range. Below these temperature ranges metabolic rates and total rates of heat dissipation increase, while above these ranges metabolic rates increase slightly and total heat dissipation rates decrease rapidly. Division of total dissipation rates into sensible and latent heat holds only for a dry-bulb temperature of 79 F. For lower temperatures, sensible heat dissipation increases and latent heat decreases, while for higher temperatures the reverse is true.

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STACK OR CHIMNEY EFFECT

Infiltration of multi-story buildings. Infiltration of air into various floors of multi-story buildings is influenced by the height of the building, its height above surrounding buildings and the chimney or stack effect prevailing, causing, usually, a greater infiltration of air into lower floors with rate of infiltration diminishing as height above grade increases. On the other hand, wind velocity may decrease at lower floors in buildings closely surrounded by other buildings which may cause a reduction of pressure because of the stack effect created outside of building. The closing of stair wells and elevator halls help to prevent the free upward movement of air to its maximum extent.

Assuming that the neutral zone of wind pressure is at mid height of building and the temperature difference is 70° F., the following formulae may be used in conjunction with Tables Nos. 5 and 6 to determine the equivalent wind velocity at each floor or vertical zone of the building and will allow for both wind velocity and temperature difference.

$$Me = \sqrt{M^2 - 1.75a} \qquad Me = \sqrt{M^2 + 1.75b}$$

Where Me = Equivalent wind velocity to be used in conjunction with Tables 5 and 6.

M = Wind velocity upon which infiltration would be determined if temperature difference was disregarded.

a = Distance of window centres above mid height of building.

b = Distance of window centres below mid height of building.

Where stairways, elevator halls, etc., are effectively sealed off between floors, no allowance need be made for stack or chimney effect. Rather, radiation should be increased for floors above surrounding buildings by from 5 to 20% as between the lower and upper floors above the surrounding buildings. This extra radiation is required only on the windward side of buildings and on windy days. Therefore, automatic temperature regulation should be considered for these installations.

INTERMITTENT HEATING

Intermittently heated buildings require additional heat for raising the temperature of the air, the materials of the structure, and the materials of the contents to the specified inside temperature. The rate of supply of this additional heat depends upon the heat capacity of the building and the material contents and upon the time desired in which specified building temperatures are to be reached.

Some authorities allow 15% additional radiation to take care of conditions where the heating system is operated intermittently such as churches, schools, etc. It is doubtful if this is altogether necessary except in extremely cold climates. Present practice in estimating radiation for base temperatures of 15 to 20° F. above lowest temperatures recorded provide approximately 100% excess radiation for normal heating system operations and buildings can generally be heated to desired temperatures even after a prolonged shutdown in a period of a few hours. NOTE: It is a good plan to increase boiler capacity for intermittent heat requirements to take care of added heating up load because of radiators operating in lower than normal surrounding temperatures when starting up heating system.

SELECTION OF RADIATION

The next step in designing a heating system is to select the heat transmitting unit, either radiation (free standing), convectors (concealed), or unit heaters, for the particular type of system, hot water or steam. The heating capacity of the heat transmitting unit is designated usually in EDR (Equivalent direct radiation). One EDR output equals 150 Btu for an average water temperature of 170° F. within the heat transmitting unit, radiator or convector or unit heater on hot water systems, and 240 Btu with steam temperature in heat transmitting unit of 215° F. for steam systems. The surrounding air temperature for radiators being 70° F. and the inlet air temperature for convectors is assumed at 65° F. and the inlet temperature for unit heaters at 60° F. with a steam pressure in unit heaters at 2 lbs. gauge or 218° F. The size of the radiator, convector or unit heater required is obtained by dividing the estimated Btu loss by Btu transmitted per EDR by the unit selected and for the system condition used.

Table No. 16 (page 11) shows correction factors for radiators and convector output capacity for various heating mediums and air temperatures. The factors should be used when either water, steam or air temperatures differ from those noted in previous paragraphs.

The size (EDR) of radiation having been determined, selection should be made from the catalogues put out by the various manufacturers and should be selected as to dimensions to suit space available for their installation. Tables 14 and 15 show dimension data for radiators of present day manufacture. The maximum assembly is indicated to be 60 sections in length. It is recommended that 30 to 35 sections be used as a maximum to avoid expansion and contraction difficulties.

TABLE 14—SIZES—LARGE-TUBE CAST-IRON RADIATORS

Sectional, cast-iron, tubular-type radiators of the large-tube pattern, that is, having tubes approximately 1⅜ in. in diameter.

Number of Tubes per Section	Catalog Rating per Section■	Section Dimensions▲				
		A Height	B Width Minimum	B Width Maximum	C Spacing ‡	D Leg Height I
	Sq. Ft.	In.	In.	In.	In.	In.
4	2½ 2¾ 3½ 4¼	23 26 32* 38†	6¼ 6¼ 6¼ 6¼	6 13/16 6 13/16 6 13/16 6 13/16	2½ 2½ 2½ 2½	4½ 4½ 4½ 4½
5	2⅔ 3 3½ 4⅓ 5	20 23 26 32* 38†	8 8 8 8 8	8 9/16 8 9/16 8 9/16 8 9/16 8 9/16	2½§ 2½§ 2½§ 2½§ 2½§	4½ 4½ 4½ 4½ 4¼
6	4 6	26 38†	9 9	10⅜ 10⅜	2½ 2½	4½ 4½
7	2½ 3⅔	14‡ 20	11⅜ 11⅜	12 3/16 12 3/16	2½ 2½	3 3 or 4½

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

■See Fig. 1.

IWhere greater than standard leg heights are required, this dimension shall be 6 in., except for 7-tube sections, in heights from 13 to 20 in., incl. for which this dimension shall be 4½ in. Radiators may be furnished without legs.

▲Maximum assembly 60 sections.

*Alternate height by 1 producer is 30 in.

†Alternate height by 2 producers is 36 in., by another, 37 in.

‡Alternate height by 1 producer is 13 in., by 2 producers 13½ in.; by another, 15 in.

§For 5-tube hospital-type radiation, this dimension is 3 in.

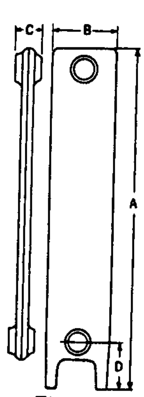

Fig. 1

Fig. 1. Types and Dimensions of Large-Tube Cast-Iron Radiators.

TABLE 15. SIZES—SMALL-TUBE CAST-IRON RADIATORS

Number of Tubes per Section	Catalog Rating per Section■	Section Dimensions▲				
		A Height	B Width Minimum	B Width Maximum	C Spacing ‡	D Leg Height I
	Sq. Ft.	In.	In.	In.	In.	In.
3*	1.6	25	3¼	3½	1¾	2½
4*	1.6 1.8 2.0	19 22 25	4 7/16 4 7/16 4 7/16	4 13/16 4 13/16 4 13/16	1¾ 1¾ 1¾	2½ 2½ 2½
5*	2.1 2.4 3.0	22 25 32	5⅝ 5⅝ 5⅝	6 5/16 6 5/16 6 5/16	1¾ 1¾ 1¾	2½ 2½ 2½
6*	1.6 2.3 3.0 3.7	14 19 25 32	6 13/16 6 13/16 6 13/16 6 13/16	8 8 8 8	1¾ 1¾ 1¾ 1¾	2½ 2½ 2½ 2½

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

■See Fig. 2.

IOverall height and leg height, as produced by some manufacturers is one inch (1 in.) greater than shown in columns A and D. Radiators may be furnished without legs.

▲Even number of sections. Maximum assembly 60 sections.

*Or equal.

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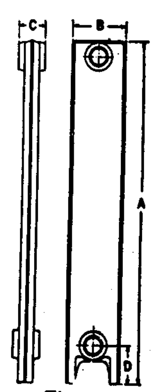

Fig. 2

Fig. 2. Types and Dimensions of Small-Tube Cast-Iron Radiators.

PROPORTIONING RADIATION

Radiation should be proportioned to provide equal distribution about the space to be heated to eliminate localized cold and hot spots. Radiation should be located wherever possible under windows and in relation to the needs of the particular exposure, for instance, larger radiators should be placed on north and west walls usually than on east and south walls for similar glass and wall areas.

In stair wells it is advisable to increase the radiation at lower levels and to decrease it at the upper levels to prevent undue stratification of warm air to the top of the stair well. The amount of increase for lower levels depends on the total height of the stair well. It is suggested that the lower half of stair wells have 50% more radiation than the upper half. That is, 3/5 of the total radiation be installed in the lower 50% of the height of the stair well and 2/5 for the upper 50% of the height of the stair well.

TABLE 16. CORRECTION FACTORS FOR DIRECT CAST-IRON RADIATORS AND CONVECTORS*

Steam Pressure Approximate		Heating Medium Temp. F. Steam or Water	Factors for Direct Cast-Iron Radiators — Room Temperature F.							Factors for Convectors — Inlet Air Temperature F.						
Gage Vacuum In. Hg.	Abs. Lb. per Sq. In.		80	75	70	65	60	55	50	80	75	70	65	60	55	50
22.4	3.7	150	2.58	2.36	2.17	2.00	1.86	1.73	1.62	3.14	2.83	2.57	2.35	2.15	1.98	1.84
20.3	4.7	160	2.17	2.00	1.86	1.73	1.62	1.52	1.44	2.57	2.35	2.15	1.98	1.84	1.71	1.59
17.7	6.0	170	1.86	1.73	1.62	1.52	1.44	1.35	1.28	2.15	1.98	1.84	1.71	1.59	1.49	1.40
14.6	7.5	180	1.62	1.52	1.44	1.35	1.28	1.21	1.15	1.84	1.71	1.59	1.49	1.40	1.32	1.24
10.9	9.3	190	1.44	1.35	1.28	1.21	1.15	1.10	1.05	1.59	1.49	1.40	1.32	1.24	1.17	1.11
6.5	11.5	200	1.28	1.21	1.15	1.10	1.05	1.00	0.96	1.40	1.32	1.24	1.17	1.11	1.05	1.00
Lb. per Sq. In.																
1	15.6	215	1.10	1.05	1.00	0.96	0.92	0.88	0.85	1.17	1.11	1.05	1.00	0.95	0.91	0.87
6	21	230	0.96	0.92	0.88	0.85	0.81	0.78	0.76	1.00	0.95	0.91	0.87	0.83	0.79	0.76
15	30	250	0.81	0.78	0.76	0.73	0.70	0.68	0.66	0.83	0.79	0.76	0.73	0.70	0.68	0.65
27	42	270	0.70	0.68	0.66	0.64	0.62	0.60	0.58	0.70	0.68	0.65	0.63	0.60	0.58	0.56
52	67	300	0.58	0.57	0.55	0.53	0.52	0.51	0.49	0.56	0.54	0.53	0.51	0.49	0.48	0.47

*To determine the size of a radiator or a convector for a given space, divide the heat loss in Btu. per hour by 240 and multiply the result by the proper factor from the above table.

To determine the heating capacity of a radiator or a convector under conditions other than the basic ones with the heating medium at a temperature of 215 F., and the room temperature at 70 F. in the case of a radiator, and the inlet air temperature at 65 F. in the case of a convector, divide the heating capacities at the basic conditions by the proper factor from the above table.

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PIPE COIL HEAT EMISSION

Table No. 17 shows Btu output per lineal foot of coil for various numbers of pipes in the coil and for various sizes.

TABLE NO. 17. HEAT EMISSION OF PIPE COILS PLACED VERTICALLY ON A WALL (PIPES HORIZONTAL CONTAINING STEAM AT 215° F. AND SURROUNDED WITH AIR AT 70° F.)

Size of Pipe	1 In.	1¼ In.	1½ In.
Number of Pipes in Coil	Btu. per Linear Ft. of Coil		
Single Pipe	132	162	185
Two Pipes	252	312	348
Four Pipes	440	545	616
Six Pipes	567	702	793
Eight Pipes	651	796	907
Ten Pipes	732	907	1020
Twelve Pipes	812	1005	1135

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EFFECT OF PAINTING RADIATOR

The effect of painting a radiator is indicated in Table No. 18. It should be noted that colour has no appreciable influence on the output of the radiator. Oil paints do not depreciate heating value but bronze finishes have a material reducing effect on heat output.

TABLE 18. EFFECT OF PAINTING 32-IN. THREE COLUMN, SIX-SECTION CAST-IRON RADIATOR*

Radiator No.	Finish	Area Sq. Ft.	Coefficient of Heat Trans. Btu.	Relative Heating Value Per Cent
1	Bare iron, foundry finish	27	1.77	100.5
2	One coat of aluminum bronze	27	1.60	90.8
3	Gray paint dipped	27	1.78	101.1
4	One coat dull black heat resistant paint	27	1.76	100.0

*Comparative Tests of Radiator Finishes, by W. H. Severns (A.S.H.V.E. Transactions, Vol. 33, 1927, p. 41).

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EFFECT OF ALTITUDE

Heat Emission varies with the temperature difference between the heating medium in the radiator and the air temperature surrounding it. In the case of steam heating systems the temperature of the steam at similar gauge pressures will vary with the altitude of the locality. Tables No. 19 and 20 respectively indicate boiling points of water and heat emission (Btu) given off by various types of heating units at one pound pressure at different altitudes.

TABLE 19. BTU HEAT VALUE PER SQUARE FOOT OF EDR AT SEVERAL ALTITUDES. 70 DEGREES ROOM TEMPERATURE.

Altitude	Concealed Radiators and Tubular Direct Radiators	Single Column Radiation 38"	Two-Column Radiation 38"	Three-Column Radiation 38"	Four-Column Radiation 38"	Window Radiation	Wall Type Radiation	Pipe Coils	Per Cent
Sea level to 1,000 ft.	240	270	250	232	218	278	285	300	100
1,000 to 3,000 ft.	230	260	238	223	209	266	274	288	96
3,000 to 5,000 ft.	223	252	231	217	203	260	266	280	93
5,000 to 7,000 ft.	216	245	225	211	198	252	258	272	90
7,000 to 10,000 ft.	209	234	215	202	189	240	247	260	87

TABLE 20. BOILING POINT OF WATER AT VARIOUS ALTITUDES

Altitude About Sea Level Feet	Boiling Point Deg. Fahr.	Altitude Above Sea Level Feet	Boiling Point Deg. Fahr.
Sea Level	212	6,000	200
1,000	210	7,000	198
2,000	208	8,000	196
3,000	206	9,000	194
4,000	204	10,000	192
5,000	202	15,000	184

CONVECTORS

Convector capacities should be taken from the manufacturer's published data as the capacities of the units vary with different manufacturers for the same length. Widths vary and capacities are influenced by the height of the enclosure.

SELECTING and APPLYING UNIT HEATERS

Unit heaters should be selected to provide a circulation of air per hour equal to four or five times the cubical contents of the space to be heated. Manufacturers' catalogues should be consulted for EDR and Btu capacities. Unit heaters may be of the "blow-through" or "draw-through" type in handling air. Capacity correction Tables Nos. 22 and 23 indicate factors to be applied to standard capacities to obtain capacities for other than standard conditions of 60° entering air and 218° F. steam (2 pounds gauge pressure), and Table No. 24 for hot water applications.

Not only must a unit heater be capable of supplying the required number of heat units, but also the volume of air at the required velocity and be installed in such a manner that the heating effect is secured in the occupied zone. The application must be such that the air blast from the heater prevents the heat from being (a) pocketed, (b) spotted, or (c) stratified.

SELECTION FOR CAPACITY

The Total Capacity of the Unit Heaters Selected should Provide for:

(a) Heat losses through construction.
(b) Heat losses due to air infiltration or leakage into space heated due to loose construction or Exhaust Ventilation Requirements.
(c) Cooling effect of cold materials brought into the heated space for processing.
(d) The steam supply condition—constant—or intermittent. Extra capacity is required for "Pick up" heating where intermittent steam supply prevails.
(e) Heat gain to the space to be heated by manufacturing processes or other means.
(f) Where unit heater load is the total load on a heating system boiler, it is preferable that individual units do not exceed 25% of total boiler load, especially if they are thermostatically controlled. This will minimize boiler load fluctuations.

SELECTION OF TYPE

The type of unit selected should be determined by:

(a) Type of occupancy and nature of processes carried on in space heated.
(b) The height of installation of unit.
(c) Number of units permissible.
(d) Relation of air discharge capacity to volume of space to be heated.
(e) The noise level permitted for the location.

The following generalizations are useful in unit heater applications:

Units providing large air volume at relatively low temperatures (below 130° F.) assure more uniform floor-to-ceiling temperatures than units having low volume and high temperature air discharge.

Generally, the units should be located so the air discharge from each induces rotation of the entire air in the room so as to promote diffusion.

Unit heaters should be located so that a large percentage of the air is discharged toward the side of the building affected most by prevailing winds.

Blowing heated air directly against exposed cold surfaces should be avoided. A discharge air stream at an angle of approximately 30° providing a wiping action over the exposed surfaces has been found satisfactory.

Most economical operation is obtained with horizontal air discharge heaters when these are located as low as head room, occupancy and piping conditions permit.

Outlet velocities from vertical discharge unit heaters should be such that the discharge air stream will reach the working zone at velocities and temperatures which will not cause discomfort to occupants.

Propeller type units should not be used with extensive systems of ducts as fans are not suitable for discharging against substantial resistances. Centrifugal fan units should be used for such applications.

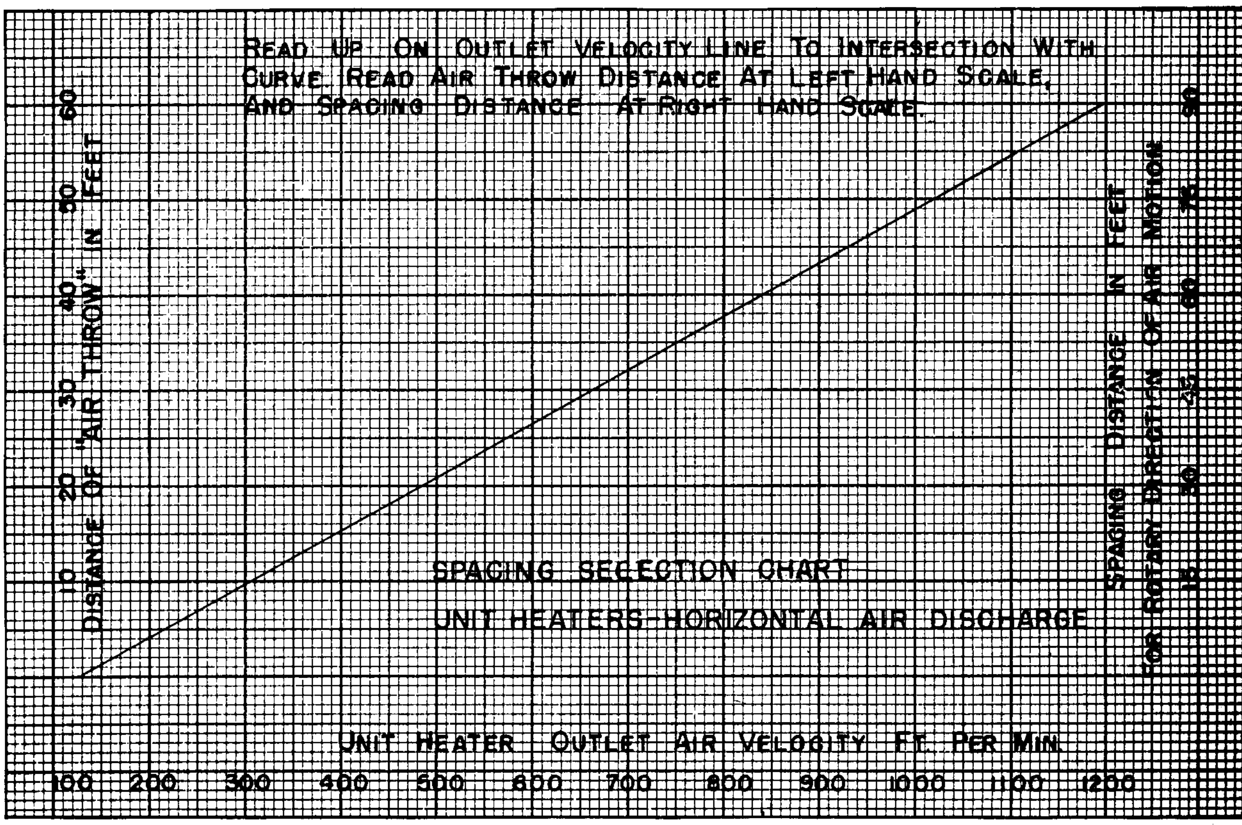

Fig. 3387

PROPELLER TYPE UNITS

These units are applicable to ceiling heights up to 20′ and should be installed from 7′6″ to 12′ above the floor level. Arrange to discharge air in a horizontal rotary motion around space to be heated and across the exterior walls. Louvres should be adjusted to direct air to flow down towards floor but not directly on to occupants of the heated space. Air direction should be arranged to avoid obstructions or so directed that the obstruction assists in the diffusion of the air discharged. Where large areas are broken up by elevators or smaller rooms projecting into the larger area, it is desirable for a heater to be provided for each space or bay formed. Unit spacing should be in relation to air discharge velocity. Fig. 3337 and Fig. 3338 will serve to aid in spacing of units.

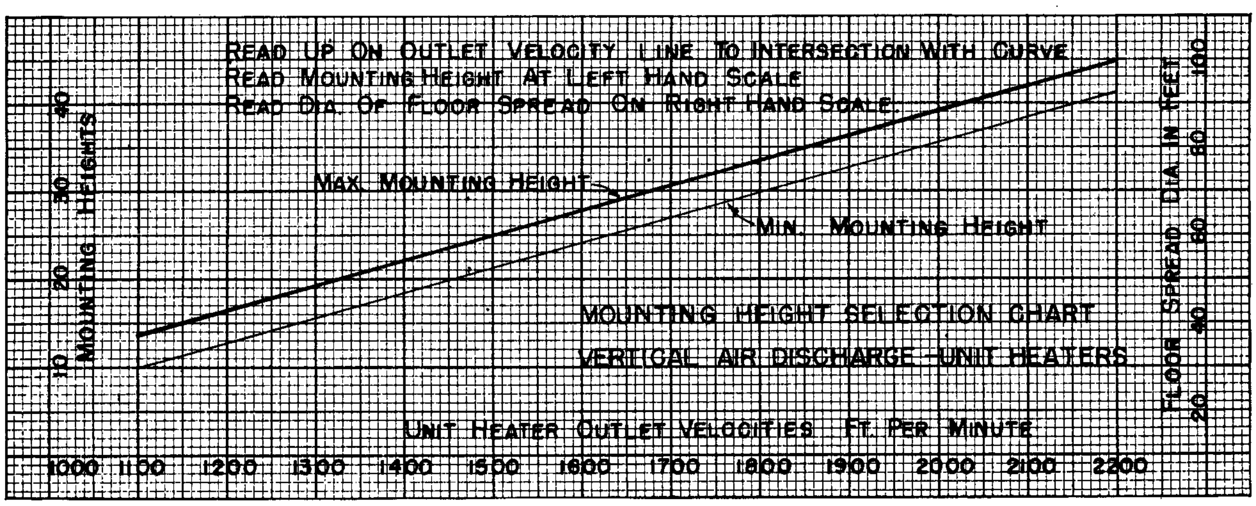

Fig. 3388

Application of Propeller Type Horizontal Air Discharge Units in offices, retail stores, show rooms, etc. should generally be made with duct work to draw air from the floor and to operate at the lower motor speeds. Where workers are at benches around or near windows, radiation should be applied under windows and unit heaters used as supplementary heating usually thermostatically controlled.

Where ceiling expanse is small in relation to the interior wall area, unit heaters may be arranged to project air discharge towards exterior walls—to force cooler air to remain adjacent to the walls.

The number of units should be such that their total air volume capacity per hour would be four times the cubical contents of the space heated and so arranged that the heating effects of the units would overlap each other.

Where large doors are frequently opened a larger supplementary heater should be arranged to discharge heated air directly from above towards the incoming air. This unit should be under thermostatic control with thermostat set a few degrees below normally desired temperature.

Propeller Type Unit Heaters with Vertically downward Air Dischage are applicable where the ceiling heights are 14 to 40 feet. For most satisfactory results outlet air temperature should not exceed 115°F. Where steam pressure higher than standard 2 lbs. is used, the heaters must be arranged with less heating surface or an arrangement provided to permit a percentage of room air to be by-passed around heating element to produce outlet temperature of approximately 115°F. Higher outlet temperatures prevent air discharge to floor level with overheating towards ceiling.

Vertical air discharge units are usually of draw-through type with air discharge velocities of from 1,000 to 2,000 ft. per minute, the outlet air velocities generally increasing as the unit size increases.

Fig. 3388 gives generally recommended mounting heights and floor surface served for various outlet velocities.

For installations at the minimum height it is generally necessary to provide louvres to deflect the discharge air stream from vertical to an angular direction in order to reduce the air velocity at working level to a rate that is not objectionable to occupants. Multi-speed units are not generally recommended since lower air capacities at lower speeds would not provide that air discharged would reach floor or working zones.

Vertical downward discharge units should be installed a sufficient distance below ceiling to provide space to remove motor when necessary and to allow air circulation over motor and facilitate lubrication. These units should be selected on the basis of the outlet velocity required to discharge the air to the working zone in relation to the height at which they must be installed. The smaller units cannot be used at the higher installation elevations with assurance that working zones will be heated.

CENTRIFUGAL FAN TYPE UNITS

These units provide for air discharges at greater velocities than propeller types. Their velocities range from 900 to 2700 ft. per minute. Air projection ranges from 10′ to 13′ for velocities of 900 ft. per minute to 100′ to 150′ for velocities up to 2700 ft. per minute. Mounting heights recommended are from 25′ to 50′ for ceiling type and duct work may be connected to the unit heater outlets to carry heated air to the more remote spaces. This type of unit may also be used as floor installations but duct work and outlets should be arranged to prevent direct discharge of air upon occupants.

Decibel Rating — Unit heaters generally should be selected for their noise level having in mind the general noise level of the space to be heated. The following table lists general noise levels likely to be anticipated in various applications. Manufacturers catalogues should be referred to for Decibel ratings of the differert unit heaters.

TABLE 21. NOISE LEVELS (DECIBEL RATINGS) FOR VARIOUS BUILDINGS AND OCCUPANCIES

	Min.	Representative	Max.
Broadcasting Studios	10	14	20
Residences, Apartments, etc.	33	40	48
Theatres, legitimate	25	30	35
Theatres, motion picture	30	35	40
Auditoriums, Concert Halls, etc.	25	30	40
Churches	25	30	35
Private Offices (acoutically treated)	30	38	45
General Offices	50	60	70
Hospitals	25	40	55
Class Rooms	30	35	45
Libraries, Museums, Art Galleries	30	40	45
Public Buildings, Court Houses, etc.	45	55	60
Stores	40	50	60
Hotel Dining Rooms	40	50	60
Restaurants, Cafeterias	50	60	70
Banking Rooms	50	55	60
Factories	65	77	90
Office Machine Rooms	60	70	80

TYPICAL UNIT HEATER APPLICATIONS

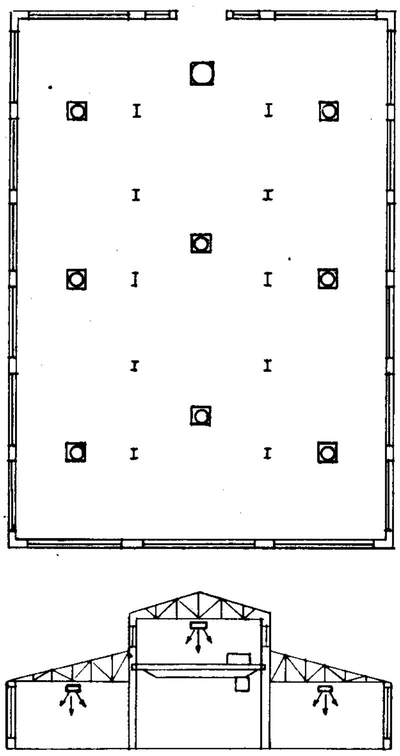

Fig. 1. Typical installation of vertical air discharge unit heaters in a heavy industry factory building.
NOTE: Large unit near door.

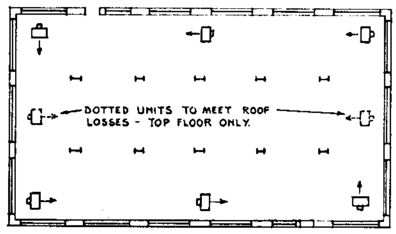

Fig. 2. Typical installation of horizontal air discharge unit heaters on factory floor providing rotary air motion around walls.

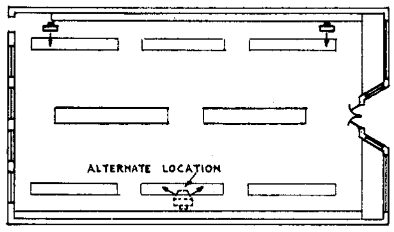

Fig. 3. Typical installation of horizontal air discharge unit heaters in retail store. Low speed units are best suited.

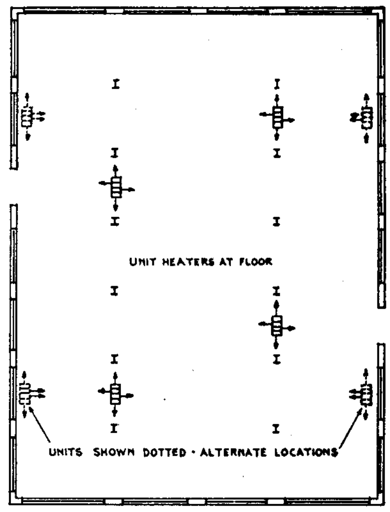

Fig. 4. Installation of centrifugal fan type unit heaters in large industrial plant.

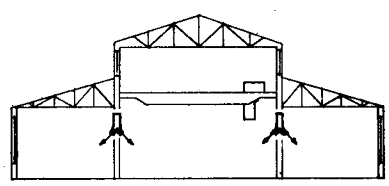

Fig. 5. Alternate installation with suspended units.

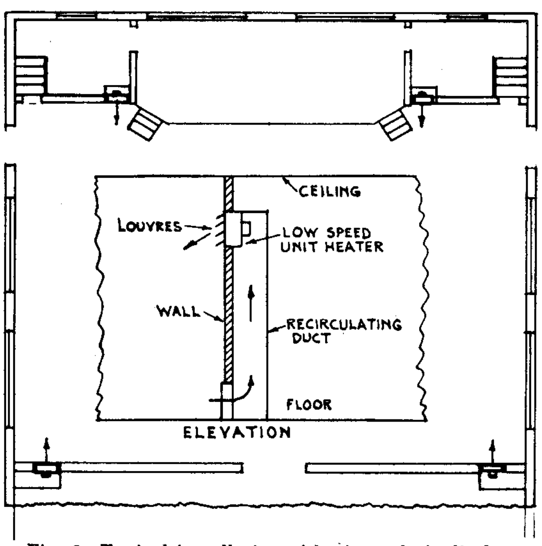

Fig. 6. Typical installation of horizontal air discharge units with circulation ducts in gymnasiums or auditoriums. Slow speed units are best suited.

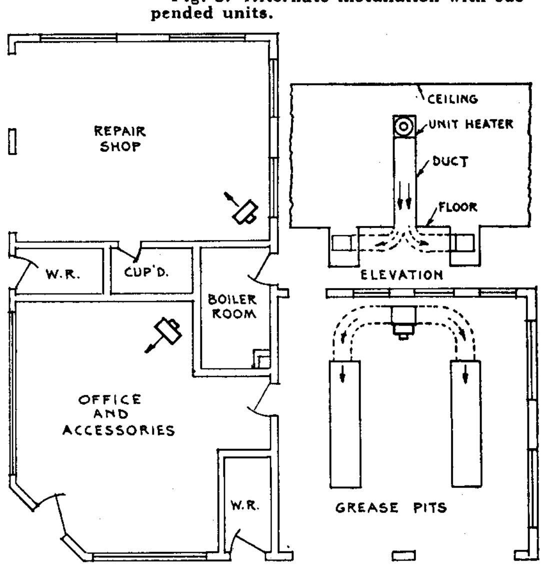

Fig. 7. Typical installation of horizontal air discharge units applied to service garages. NOTE, Unit discharging to grease pits. This same arrangement would apply where car hoists are used. The heated air assists in thawing out and drying car chassis.

ELECTRIC WIRING CONNECTIONS

Unit Heater Fan Motors may be wired for manual control or combination of temperature control with low temperature limit switch. The latter to supply or return piping to stop the fan motor when steam is shut off or water temperature is below a predetermined point. This prevents fan operating to discharge cool air.

Since motors and control equipment differ with different manufacturers of unit heaters, therefore their catalogue wiring data should be consulted. The steam or hot water supply may also be thermostatically controlled. On such application, special inter-wiring with fan motor circuit may be necessary.

CONSTANTS FOR DETERMINING CAPACITY OF BLOW-THROUGH UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND ENTERING AIR TEMPERATURES.

TABLE 22. (BASED ON STEAM PRESSURE OF 2 LB. GAGE AND ENTERING AIR TEMPERATURE OF 60° F.)

Steam Pressure Lb. Sq. In.	Entering Air Temperature											
	−10° F.	0° F.	10° F.	20° F.	30° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° [illegible]
0	1.538	1.446	1.369	1.273	1.191	1.110	1.034	0.956	0.881	0.809	0.739	[illegible]
2	1.585	1.495	1.405	1.320	1.237	1.155	1.078	1.000	0.926	0.853	0.782	[illegible]
5	1.640	1.550	1.456	1.370	1.289	1.206	1.127	1.050	0.974	0.901	0.829	[illegible]
10	1.730	1.639	1.545	1.460	1.375	1.290	1.211	1.131	1.056	0.982	0.908	[illegible]
15	1.799	1.708	1.614	1.525	1.441	1.335	1.275	1.194	1.117	1.043	0.970	[illegible]
20	1.861	1.769	1.675	1.584	1.498	1.416	1.333	1.251	1.174	1.097	1.024	[illegible]
30	1.966	1.871	1.775	1.684	1.597	1.509	1.429	1.346	1.266	1.190	1.115	[illegible]
40	2.058	1.959	1.862	1.771	1.683	1.596	1.511	1.430	1.349	1.270	1.194	[illegible]
50	2.134	2.035	1.936	1.845	1.755	1.666	1.582	1.498	1.416	1.338	1.262	[illegible]
60	2.196	2.094	1.997	1.902	1.811	1.725	1.640	1.555	1.472	1.393	1.314	[illegible]
70	2.256	2.157	2.057	1.961	1.872	1.782	1.696	1.610	1.527	1.447	1.368	[illegible]
75	2.283	2.183	2.085	1.990	1.896	1.808	1.721	1.635	1.552	1.472	1.392	[illegible]
80	2.312	2.211	2.112	2.015	1.925	1.836	1.748	1.660	1.577	1.497	1.418	[illegible]
90	2.361	2.258	2.159	2.063	1.968	1.880	1.792	1.705	1.621	1.541	1.461	[illegible]
100	2.409	2.307	2.204	2.108	2.015	1.927	1.836	1.749	1.663	1.581	1.502	[illegible]

NOTE: To determine capacity at any steam pressure and entering air temperature, multiply constant from this table by rated capaci[illegible] at 2 lb. pressure and 60° F. entering air temperature.

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CONSTANTS FOR DETERMINING CAPACITY OF DRAW-THROUGH UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND ENTERING AIR TEMPERATURES

TABLE 23. (BASED ON STEAM PRESSURE OF 2 LB. GAGE AND ENTERING AIR TEMPERATURE OF 60° F.)

Steam Pressure Lb. Sq. In.	Entering Air Temperature											
	−10° F.	0° F.	10° F.	20° F.	30° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° [illegible]
0	1.483	1.405	1.329	1.253	1.178	1.105	1.032	0.962	0.892	0.822	0.754	[illegible]
2	1.520	1.442	1.363	1.290	1.215	1.141	1.069	1.000	0.930	0.861	0.792	[illegible]
5	1.565	1.485	1.410	1.334	1.260	1.187	1.114	1.045	0.975	0.906	0.838	[illegible]
10	1.637	1.558	1.480	1.403	1.328	1.253	1.182	1.112	1.042	0.973	0.903	[illegible]
15	1.688	1.610	1.533	1.458	1.382	1.310	1.239	1.168	1.099	1.028	0.960	[illegible]
20	1.728	1.649	1.572	1.498	1.421	1.350	1.278	1.208	1.138	1.070	1.002	[illegible]
30	1.803	1.725	1.648	1.572	1.497	1.423	1.352	1.281	1.212	1.145	1.078	[illegible]
40	1.864	1.787	1.710	1.637	1.563	1.491	1.420	1.350	1.282	1.215	1.148	[illegible]
50	1.927	1.850	1.773	1.700	1.628	1.554	1.483	1.416	1.347	1.278	1.211	[illegible]
60	1.973	1.897	1.820	1.748	1.673	1.601	1.531	1.463	1.394	1.325	1.260	[illegible]
70	2.018	1.943	1.869	1.795	1.722	1.651	1.582	1.512	1.443	1.377	1.310	[illegible]
75	2.043	1.970	1.895	1.822	1.750	1.680	1.609	1.540	1.471	1.402	1.333	[illegible]
80	2.064	1.988	1.914	1.841	1.770	1.698	1.629	1.560	1.491	1.422	1.354	[illegible]
90	2.102	2.028	1.951	1.878	1.804	1.732	1.661	1.590	1.523	1.457	1.387	[illegible]
100	2.150	2.071	1.994	1.919	1.845	1.770	1.700	1.630	1.560	1.492	1.425	[illegible]

NOTE: To determine capacity at any steam pressure and entering air temperature, multiply constant from this table by rated capacit[illegible] at 2 lb. pressure and 60° F. entering air temperature.

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UNIT HEATERS — HOT WATER APPLICATION

Unit Heaters may be applied to mechanically circulated **Hot Water** Heating Systems. Table 24 lists conversion constants to determine Btu outputs when used on Hot Water Heating Systems.

To determine capacity at any inlet water temperatu[illegible] and entering air temperature, multiply constant from th[illegible] table by the rated Btu capacity of unit heater at 2 poun[illegible] steam pressure and 60° F. entering air temperature.

TABLE 24

Constants For Determining Approximate Capacities Of Unit Heaters At Varying Inlet Water Temperatures and Inlet Air Temperatures for Mechanically Circulated Hot Water Heating System Application

Entering Air Temperatures	Inlet Water Temperatures								
	140° F.	150° F.	160° F.	170° F.	180° F.	190° F.	200° F.	210° F.	220° F.
50	.55	.61	.68	.73	.79	.84	.91	.97	1.02
60	.48	.55	.61	.68	.73	.79	.84	.91	.97
70	.42	.48	.55	.61	.68	.73	.79	.84	.91
80	.36	.42	.48	.55	.61	.68	.73	.79	.84

CONSTANTS FOR DETERMINING CAPACITY OF BLOW-THROUGH UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND ENTERING AIR TEMPERATURES.

TABLE 22. (BASED ON STEAM PRESSURE OF 2 LB. GAGE AND ENTERING AIR TEMPERATURE OF 60° F.)

Steam Pressure Lb. Sq. In.	Entering Air Temperature											
	−10° F.	0° F.	10° F.	20° F.	30° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° F.
0	1.538	1.446	1.369	1.273	1.191	1.110	1.034	0.956	0.881	0.809	0.739	0.671
2	1.585	1.495	1.405	1.320	1.237	1.155	1.078	1.000	0.926	0.853	0.782	0.713
5	1.640	1.550	1.456	1.370	1.289	1.206	1.127	1.050	0.974	0.901	0.829	0.760
10	1.730	1.639	1.545	1.460	1.375	1.290	1.211	1.131	1.056	0.982	0.908	0.838
15	1.799	1.708	1.614	1.525	1.441	1.335	1.275	1.194	1.117	1.043	0.970	0.897
20	1.861	1.769	1.675	1.584	1.498	1.416	1.333	1.251	1.174	1.097	1.024	0.952
30	1.966	1.871	1.775	1.684	1.597	1.509	1.429	1.346	1.266	1.190	1.115	1.042
40	2.058	1.959	1.862	1.771	1.683	1.596	1.511	1.430	1.349	1.270	1.194	1.119
50	2.134	2.035	1.936	1.845	1.755	1.666	1.582	1.498	1.416	1.338	1.262	1.187
60	2.196	2.094	1.997	1.902	1.811	1.725	1.640	1.555	1.472	1.393	1.314	1.239
70	2.256	2.157	2.057	1.961	1.872	1.782	1.696	1.610	1.527	1.447	1.368	1.293
75	2.283	2.183	2.085	1.990	1.896	1.808	1.721	1.635	1.552	1.472	1.392	1.316
80	2.312	2.211	2.112	2.015	1.925	1.836	1.748	1.660	1.577	1.497	1.418	1.342
90	2.361	2.258	2.159	2.063	1.968	1.880	1.792	1.705	1.621	1.541	1.461	1.383
100	2.409	2.307	2.204	2.108	2.015	1.927	1.836	1.749	1.663	1.581	1.502	1.424

NOTE: To determine capacity at any steam pressure and entering air temperature, multiply constant from this table by rated capacity at 2 lb. pressure and 60° F. entering air temperature.

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CONSTANTS FOR DETERMINING CAPACITY OF DRAW-THROUGH UNIT HEATERS FOR VARIOUS STEAM PRESSURES AND ENTERING AIR TEMPERATURES

TABLE 23. (BASED ON STEAM PRESSURE OF 2 LB. GAGE AND ENTERING AIR TEMPERATURE OF 60° F.)

Steam Pressure Lb. Sq. In.	Entering Air Temperature											
	−10° F.	0° F.	10° F.	20° F.	30° F.	40° F.	50° F.	60° F.	70° F.	80° F.	90° F.	100° F.
0	1.483	1.405	1.329	1.253	1.178	1.105	1.032	0.962	0.892	0.822	0.754	0.688
2	1.520	1.442	1.363	1.290	1.215	1.141	1.069	1.000	0.930	0.861	0.792	0.728
5	1.565	1.485	1.410	1.334	1.260	1.187	1.114	1.045	0.975	0.906	0.838	0.771
10	1.637	1.558	1.480	1.403	1.328	1.253	1.182	1.112	1.042	0.973	0.903	0.838
15	1.688	1.610	1.533	1.458	1.382	1.310	1.239	1.168	1.099	1.028	0.960	0.895
20	1.728	1.649	1.572	1.498	1.421	1.350	1.278	1.208	1.138	1.070	1.002	0.936
30	1.803	1.725	1.648	1.572	1.497	1.423	1.352	1.281	1.212	1.145	1.078	1.010
40	1.864	1.787	1.710	1.637	1.563	1.491	1.420	1.350	1.282	1.215	1.148	1.081
50	1.927	1.850	1.773	1.700	1.628	1.554	1.483	1.416	1.347	1.278	1.211	1.145
60	1.973	1.897	1.820	1.748	1.673	1.601	1.531	1.463	1.394	1.325	1.260	1.194
70	2.018	1.943	1.869	1.795	1.722	1.651	1.582	1.512	1.443	1.377	1.310	1.243
75	2.043	1.970	1.895	1.822	1.750	1.680	1.609	1.540	1.471	1.402	1.333	1.268
80	2.064	1.988	1.914	1.841	1.770	1.698	1.629	1.560	1.491	1.422	1.354	1.288
90	2.102	2.028	1.951	1.878	1.804	1.732	1.661	1.590	1.523	1.457	1.387	1.321
100	2.150	2.071	1.994	1.919	1.845	1.770	1.700	1.630	1.560	1.492	1.425	1.359

NOTE: To determine capacity at any steam pressure and entering air temperature, multiply constant from this table by rated capacity at 2 lb. pressure and 60° F. entering air temperature.

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UNIT HEATERS — HOT WATER APPLICATION

Unit Heaters may be applied to mechanically circulated **Hot Water** Heating Systems. Table 24 lists conversion constants to determine Btu outputs when used on Hot Water Heating Systems.

To determine capacity at any inlet water temperature and entering air temperature, multiply constant from the table by the rated Btu capacity of unit heater at 2 pounds steam pressure and 60° F. entering air temperature.

TABLE 24

Constants For Determining Approximate Capacities Of Unit Heaters At Varying Inlet Water Temperatures and Inlet Air Temperatures for Mechanically Circulated Hot Water Heating System Application

Entering Air Temperatures	Inlet Water Temperatures								
	140° F.	150° F.	160° F.	170° F.	180° F.	190° F.	200° F.	210° F.	220° F.
50	.55	.61	.68	.73	.79	.84	.91	.97	1.02
60	.48	.55	.61	.68	.73	.79	.84	.91	.97
70	.42	.48	.55	.61	.68	.73	.79	.84	.91
80	.36	.42	.48	.55	.61	.68	.73	.79	.84

HEATING BOILERS

Heating boilers may be made of cast iron type constructed of sections either assembled horizontally or vertically or of steel having rivetted or welded shell construction.

Cast iron boilers are generally termed "round boiler" when sections are horizontal and tiered in vertical assembly. Boilers having vertical sections assembled horizontally are spoken of as "square sectional" boilers. These types of boilers are designed primarily for burning anthracite coal although they may be equipped with suitable oil burner or mechanically fired coal units and gas burners.

Cast iron boilers are suited more particularly to the smaller heating installations such as residences and small apartments and commercial buildings having heating loads up to 7500 sq. ft. installed EDR for steam systems and up to 12,000 sq. ft. installed EDR for hot water systems.

Steel boilers for heating system service are generally of the fire tube type, that is, the products of combustion pass through the tubes to breeching, either in one direction (one pass) or in two or more directions (multi-pass). See manufacturers' catalogues for various types of steel boilers.

The capacity of boiler (Btu per hour) for a given installation must be selected for the maximum heating load which shall include:

(1) Estimated total emission from the connected radiation or convectors and unit heaters, on basis of 240 Btu per EDR for steam heating systems and 150 Btu for hot water heating systems.

(2) Total estimated Btu for domestic water heating load (1000 Btu per gallon of water heated 100° F. per hour is considered as a satisfactory allowance).

(3) Estimated Btu loss from piping system; a satisfactory basis is conceded generally to be 25% of heating load requirements. (Items (1) and (2).)

(4) Corrected Btu output for heating units operating in air conditions other than 70° breathing line temperature. See Table No. 16.

(5) Additional estimate for heating-up of cold system.

(6) Estimated Requirements for Heating Coils for Air Conditioning, Ventilating or Blast Heating Equipment.

E.D.R. Requirements for steam heated equipment noted in Item 6 may be determined as follows:

(a) Where C.F.M. and temperature rise from inlet to final temperature only is given.

$$\text{E.D.R.} = \frac{\text{C.F.M.} \times \text{temperature rise} \times 60}{55.3 \times 240}$$

Example 5,000 C.F.M. raised 5° to 80°

$$\text{E.D.R.} = \frac{5{,}000 \times (80 - 5) \times 60}{55.3 \times 240} = 1695.3$$

(b) Where air washer is used, temperature rise for (a) should be increased by 15 to 20 degrees to compensate for temperature drop through air washer.

(c) Where condensing rate is given in pounds of steam per hour for the heating coils.

E.D.R. = Pounds of condensate per hour × 4.

Table No. 25 shows cast iron boiler capacities adapted from data in the A.S.H.V.E. Guide with hot water capacities included.

TABLE No. 25. BOILER CAPACITIES FOR LOW PRESSURE STEAM AND HOT WATER HEATING BOILERS

Design Load Btu per Hour	Representing Summations of Items (1) to (6) — Equivalent Sq. Ft. Radiation (EDR)		Percentage Capacity to Add for Warming Up	
	Steam @ 240 Btu	Hot Water @ 150 Btu	Hand Fired Solid Fuel	Automatically Fired
Up to 100,000	Up to 420	Up to 670	65	
100,000 to 200,000	420 to 840	670 to 1,340	60	20%
200,000 to 600,000	840 to 2,500	1,340 to 4,000	55	for
600,000 to 1,200,000	2,500 to 5,000	4,000 to 8,000	50	all
1,200,000 to 1,800,000	5,000 to 7,500	8,000 to 12,000	45	fuels
Above 1,800,000	Above 7,500	Over 12,000	40	

Standard ratings for steel heating boilers are shown in Table No. 26.

TABLE No. 26. STEEL HEATING BOILER STANDARD RATINGS (a)

HAND-FIRED RATING

Catalog			Net Load	Heating Surface Sq. Ft.	Grate Area Sq. Ft.
Steam Radiation Sq. Ft.	Water Radiation Sq. Ft.	Btu per Hour in Thousands	Steam Radiation Sq. Ft.		
1,800	2,880	432	1,389	129	7.9
2,200	3,520	528	1,702	158	8.9
2,600	4,160	624	2,020	186	9.7
3,000	4,800	720	2,335	215	10.5
3,500	5,600	840	2,732	250	11.4
4,000	6,400	960	3,135	286	12.2
4,500	7,200	1,080	3,540	322	13.4
5,000	8,000	1,200	3,945	358	14.5
6,000	9,600	1,440	4,770	429	16.4
7,000	11,200	1,680	5,608	500	18.1
8,500	13,600	2,040	6,885	608	20.5
10,000	16,000	2,400	8,197	715	22.5
12,500	20,000	3,000	10,417	893	25.6
15,000	24,000	3,600	12,500	1,072	28.4
17,500	28,000	4,200	14,584	1,250	30.9
20,000	32,000	4,800	16,667	1,429	33.2
25,000	40,000	6,000	20,834	1,786	37.4
30,000	48,000	7,200	25,000	2,143	41.2
35,000	56,000	8,400	29,167	2,500	44.7

MECHANICALLY-FIRED RATING

Catalog			Net Load	Furnace Volume, Oil, Gas or Bituminous Coal Cu. Ft.
Steam Radiation Sq. Ft.	Water Radiation Sq. Ft.	Btu per Hour in Thousands	Steam Radiation Sq. Ft.	
2,190	3,500	525	1,695	15.7
2,680	4,280	643	2,089	19.2
3,160	5,050	758	2,461	22.6
3,650	5,840	876	2,853	26.1
4,250	6,800	1,020	3,335	30.4
4,860	7,770	1,166	3,830	34.8
5,470	8,750	1,312	4,330	39.1
6,080	9,720	1,459	4,834	43.5
7,290	11,660	1,749	5,850	52.1
8,500	13,600	2,040	6,885	60.8
10,330	16,520	2,479	8,490	73.8
12,150	19,440	2,916	10,125	86.8
15,180	24,280	3,643	12,650	108.5
18,220	29,150	4,372	15,183	130.2
21,250	34,000	5,100	17,708	151.8
24,290	38,860	5,829	20,242	173.5
30,360	48,570	7,286	25,300	216.9
36,430	58,280	8,743	30,359	260.3
42,500	68,000	10,200	35,417	303.6

(a) Adopted by the Steel Heating Boiler Institute in cooperation with the Bureau of Standards, United States Department of Commerce Simplified Practice Recommendations R 157-35. Reprinted by permission from A.S.H.V.E. Heating, Ventilating, Air Conditioning Guide, 1943, Chapter 12.

HEATING BOILERS (continued)

For recommended combustion rates for manually fired solid fuel heating boilers, see Table No. 27.

TABLE No. 27. PRACTICAL COMBUSTION RATES FOR COAL-FIRED HEATING BOILERS OPERATING AT MAXIMUM LOAD ON NATURAL DRAFT OF FROM ⅛ IN. TO ½ IN. WATER(a)

Kind of Coal	Sq. Ft. Grate	Lb. of Coal per Sq. Ft. Grate per Hour
No. 1 Buckwheat Anthracite	Up to 4	3
	5 to 9	3½
	10 to 14	4
	15 to 19	4½
	20 to 25	5
Anthracite Pea	Up to 9	5
	10 to 19	5½
	20 to 25	6
Anthracite Nut and Larger	Up to 4	8
	5 to 9	9
	10 to 14	10
	15 to 19	11
	20 to 25	13
Bituminous	Up to 4	9.5
	5 to 14	12
	15 and above	15.5

[a]Steel boilers usually have higher combustion rates for grate areas exceeding 15 sq. ft. than those indicated in this table.
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To determine the size of grate area required for heating boilers burning solid fuels, apply the following formula:

$$G = \frac{H}{C \times F \times E}$$

Where G = Grate area,
H = Required total heat output of boiler in Btu per hour,
C = Combustion rate in pounds of dry coal per square foot grate per hour, depending on size of boiler and kind of fuel. See Table No. 27.
F = Calorific value of fuel Btu per pound
E = Efficiency of boiler usually taken at 0.60.

Mechanical firing of boilers may be by equipment to handle solid fuel (stokers), liquid fuel (oil burners) gaseous fuel (gas burners). Since this equipment requires special treatment in application for various types of boilers and fuel, it is recommended that manufacturers' catalogues be consulted, also current issue of the "Guide."

In large installations it is advisable to install several smaller boilers, their combined capacity to equal the total estimated load requirements. This will provide more flexibility to meet milder weather requirements and to provide continuous service in the event that any boiler may be out of service for repairs, or overhaul.

Boiler specifications are not included since heating boilers are usually constructed to a standard code controlled by governmental authority.

STEAM FROM OTHER SOURCES

Where steam is supplied from sources other than a low pressure heating boiler (as from central station steam or a high pressure boiler) through pressure reducing valves or control valves, the amount of steam required by the heating system may be determined by the following formulae:

For steam systems: $W = \frac{240 \times R}{60 \times 966} = 0.00414 \times R.$

For hot water systems: $W = \frac{150 \times R}{60 \times 966} = 0.00259 \times R.$

Where W = Pounds steam per minute,
R = Gross radiation load per hour,
60 = Minutes in one hour,
966 = Latent heat of one pound steam at 2 P.S.I.,
240 = Btu per sq. ft. EDR, steam systems,
150 = Btu per sq. ft. EDR, hot water systems.

When steam is supplied for heating from sources other than low pressure heating boilers, the required boiler capacity in boiler horsepower may be determined as follows:

$$\text{Boiler HP} = \frac{\text{Gross Total Btu For All Heating Services}}{33{,}479}$$

or $\frac{\text{Gross Total EDR}}{138}$ for steam systems

or $\frac{\text{Net Total (installed) EDR}}{100}$ for steam systems

or $\frac{\text{Gross Total EDR}}{220}$ for hot water systems

or $\frac{\text{Net Total (installed) EDR}}{160}$ for hot water systems

HEATING BOILERS (continued)

For recommended combustion rates for manually fired solid fuel heating boilers, see Table No. 27.

TABLE No. 27. PRACTICAL COMBUSTION RATES FOR COAL-FIRED HEATING BOILERS OPERATING AT MAXIMUM LOAD ON NATURAL DRAFT OF FROM ⅛ IN. TO ½ IN. WATER(a)

Kind of Coal	Sq. Ft. Grate	Lb. of Coal per Sq. Ft. Grate per Hour
No. 1 Buckwheat Anthracite	Up to 4	3
	5 to 9	3½
	10 to 14	4
	15 to 19	4½
	20 to 25	5
Anthracite Pea	Up to 9	5
	10 to 19	5½
	20 to 25	6
Anthracite Nut and Larger	Up to 4	8
	5 to 9	9
	10 to 14	10
	15 to 19	11
	20 to 25	13
Bituminous	Up to 4	9.5
	5 to 14	12
	15 and above	15.5

(a) Steel boilers usually have higher combustion rates for grate areas exceeding 15 sq. ft. than those indicated in this table.
Reprinted by permission from A.S.H.V.E. Heating, Ventilating, Air Conditioning Guide, 1943, Chapter 12.

To determine the size of grate area required fo boilers burning solid fuels, apply the following fo

$$G = \frac{H}{C \times F \times E}$$

Where G = Grate area,
H = Required total heat output of boil per hour,
C = Combustion rate in pounds of dry square foot grate per hour, dependin of boiler and kind of fuel. See Tabl
F = Calorific value of fuel Btu per pound
E = Efficiency of boiler usually taken at

Mechanical firing of boilers may be by equi handle solid fuel (stokers), liquid fuel (oil burn eous fuel (gas burners). Since this equipment special treatment in application for various types and fuel, it is recommended that manufacturers' c be consulted, also current issue of the "Guide."

In large installations it is advisable to instal smaller boilers, their combined capacity to equal estimated load requirements. This will provide m ibility to meet milder weather requirements and to continuous service in the event that any boiler ma of service for repairs, or overhaul.

Boiler specifications are not included since heat ers are usually constructed to a standard code c by governmental authority.

STEAM FROM OTHER SOURCES

Where steam is supplied from sources other than a low pressure heating boiler (as from central station steam or a high pressure boiler) through pressure reducing valves or control valves, the amount of steam required by the heating system may be determined by the following formulae:

For steam systems: $W = \frac{240 \times R}{60 \times 966} = 0.00414 \times R.$

For hot water systems: $W = \frac{150 \times R}{60 \times 966} = 0.00259 \times R.$

Where W = Pounds steam per minute,
R = Gross radiation load per hour,
60 = Minutes in one hour,
966 = Latent heat of one pound steam at 2 P.S.I.,
240 = Btu per sq. ft. EDR, steam systems,
150 = Btu per sq. ft. EDR, hot water systems.

When steam is supplied for heating from sourc than low pressure heating boilers, the require capacity in boiler horsepower may be determined lows:

$$\text{Boiler HP} = \frac{\text{Gross Total Btu For All Heating Se}}{33{,}479}$$

or $\frac{\text{Gross Total EDR}}{138}$ for steam systems

or $\frac{\text{Net Total (installed) EDR}}{100}$ for steam syste

or $\frac{\text{Gross Total EDR}}{220}$ for hot water systems

or $\frac{\text{Net Total (installed) EDR}}{160}$ for hot water syste

HEATING BOILERS (continued)

For recommended combustion rates for manually fired solid fuel heating boilers, see Table No. 27.

TABLE No. 27. PRACTICAL COMBUSTION RATES FOR COAL-FIRED HEATING BOILERS OPERATING AT MAXIMUM LOAD ON NATURAL DRAFT OF FROM ⅛ IN. TO ½ IN. WATER(a)

Kind of Coal	Sq. Ft. Grate	Lb. of Coal per Sq. Ft. Grate per Hour
No. 1 Buckwheat Anthracite	Up to 4	3
	5 to 9	3½
	10 to 14	4
	15 to 19	4½
	20 to 25	5
Anthracite Pea	Up to 9	5
	10 to 19	5½
	20 to 25	6
Anthracite Nut and Larger	Up to 4	8
	5 to 9	9
	10 to 14	10
	15 to 19	11
	20 to 25	13
Bituminous	Up to 4	9.5
	5 to 14	12
	15 and above	15.5

[a]Steel boilers usually have higher combustion rates for grate areas exceeding 15 sq. ft. than those indicated in this table.
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To determine the size of grate area required for heating boilers burning solid fuels, apply the following formula:

$$G = \frac{H}{C \times F \times E}$$

Where G = Grate area,
H = Required total heat output of boiler in Btu per hour,
C = Combustion rate in pounds of dry coal per square foot grate per hour, depending on size of boiler and kind of fuel. See Table No. 27.
F = Calorific value of fuel Btu per pound
E = Efficiency of boiler usually taken at 0.60.

Mechanical firing of boilers may be by equipment to handle solid fuel (stokers), liquid fuel (oil burners) gaseous fuel (gas burners). Since this equipment requires special treatment in application for various types of boilers and fuel, it is recommended that manufacturers' catalogues be consulted, also current issue of the "Guide."

In large installations it is advisable to install several smaller boilers, their combined capacity to equal the total estimated load requirements. This will provide more flexibility to meet milder weather requirements and to provide continuous service in the event that any boiler may be out of service for repairs, or overhaul.

Boiler specifications are not included since heating boilers are usually constructed to a standard code controlled by governmental authority.

STEAM FROM OTHER SOURCES

Where steam is supplied from sources other than a low pressure heating boiler (as from central station steam or a high pressure boiler) through pressure reducing valves or control valves, the amount of steam required by the heating system may be determined by the following formulae:

For steam systems: $W = \frac{240 \times R}{60 \times 966} = 0.00414 \times R.$

For hot water systems: $W = \frac{150 \times R}{60 \times 966} = 0.00259 \times R.$

Where W = Pounds steam per minute,
R = Gross radiation load per hour,
60 = Minutes in one hour,
966 = Latent heat of one pound steam at 2 P.S.I.,
240 = Btu per sq. ft. EDR, steam systems,
150 = Btu per sq. ft. EDR, hot water systems.

When steam is supplied for heating from sources other than low pressure heating boilers, the required boiler capacity in boiler horsepower may be determined as follows:

$$\text{Boiler HP} = \frac{\text{Gross Total Btu For All Heating Services}}{33{,}479}$$

or $\frac{\text{Gross Total EDR}}{138}$ for steam systems

or $\frac{\text{Net Total (installed) EDR}}{100}$ for steam systems

or $\frac{\text{Gross Total EDR}}{220}$ for hot water systems

or $\frac{\text{Net Total (installed) EDR}}{160}$ for hot water systems

CHIMNEYS

Satisfactory boiler operation cannot be obtained unless chimney is of satisfactory dimensions to carry off the products of combustion and of sufficient height to develop proper draft conditions to supply the proper amount of air for combustion through the resistance of the firebed and boiler passages.

Recommended chimney sizes for heating boilers up to 10,740 sq. ft. steam and 17,250 sq. ft. hot water **loads are** shown in Table No. 28. For more detailed **formula for** chimney sizes and construction, see A.S.H.V.E. Guide.

Chimney sizes for boilers larger than shown in **Table** No. 28 and for power boilers are shown in Table No. 29 (Kent's Table of Chimney Sizes for Steam Boilers).

TABLE No. 29. KENT'S TABLE OF SIZE OF CHIMNEYS FOR STEAM BOILERS
Formula: H.P. = 33.3 (A-0.6 sq. root of A) sq. root of H. (Assuming 1 H.P. = 5 lbs of coal burned per hour)

Diameter Inches	Area A. Square Feet	Effective Area E = A 0.6 Sq. Root of A. Square Feet	HEIGHT OF CHIMNEY — COMMERCIAL HORSE POWER OF BOILER														Equivalent Square Chimney Side of Square Ins. $12\sqrt{E}+4$
			50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet	125 feet	150 feet	175 feet	200 feet	225 feet	250 feet	300 feet	
18	1.77	.97	23	25	27	29											16
21	2.41	1.47	35	38	41	44											19
24	3.14	2.08	49	54	58	62	66										22
27	3.98	2.78	65	72	78	83	88										24
30	4.91	3.58	84	92	100	107	113	119									27
33	5.94	4.48	....	115	125	133	141	149	156								30
36	7.07	5.47	....	141	152	163	173	182	191	204							32
39	8.30	6.57	....	....	183	196	208	219	229	245	268						35
42	9.62	7.76	....	....	216	231	245	258	271	289	316	342					38
48	12.57	10.44	....	....	....	311	330	348	365	389	426	460	496				43
54	15.90	13.51	....	....	....	....	427	449	472	503	551	595	636	675			48
60	19.64	16.98	....	....	....	....	536	565	593	632	692	748	800	848	894		54
66	23.76	20.83	....	....	....	....	....	694	728	776	849	918	981	1040	1097	1201	59
72	28.27	25.08	....	....	....	....	....	835	876	934	1023	1105	1181	1253	1320	1447	64
78	33.18	29.73	....	....	....	....	....	....	1038	1107	1212	1310	1400	1485	1565	1715	70
84	38.48	34.76	....	....	....	....	....	....	1214	1294	1418	1531	1637	1736	1830	2005	75
90	44.18	40.19	....	....	....	....	....	....	....	1496	1639	1770	1893	2008	2116	2318	80
96	50.27	46.01	....	....	....	....	....	....	....	1712	1876	2027	2167	2298	2423	2654	86
102	56.75	52.23	....	....	....	....	....	....	....	1944	2130	2300	2459	2609	2750	3012	91
108	63.62	58.83	....	....	....	....	....	....	....	2090	2399	2592	2771	2939	3098	3393	96
114	70.88	65.83	....	....	....	....	....	....	....	....	2685	2900	3100	3288	3466	3797	101
120	78.54	73.22	....	....	....	....	....	....	....	....	2986	3226	3448	3657	3855	4223	107
132	95.03	89.18	....	....	....	....	....	....	....	....	3637	3929	4200	4455	4696	5144	117
144	113.10	106.72	....	....	....	....	....	....	....	....	4352	4701	5026	5331	5618	6155	128

For pounds of coal burned per hour for any given size of chimney, multiply the figures in the table by 5.

TABLE No. 28. RECOMMENDED MINIMUM CHIMNEY SIZES FOR HEATING BOILERS AND FURNACES(a)

Warm Air Furnace Capacity in Sq. In. of Leader Pipe	Steam Boiler Capacity Sq. Ft. of Radiation	Hot Water Heater Capacity Sq. Ft. of Radiation	Nominal Dimensions of Fire Clay Lining in Inches	Rectangular Flue: Actual Inside Dimensions of Fire Clay Lining in Inches	Rectangular Flue: Actual Area Sq. In.	Round Flue: Inside Diameter of Lining in Inches	Round Flue: Actual Area Sq. In.	Height in Ft. Above Grate
790	590	973	8½x13	7 x11½	81			35
1000	690	1,140				10	79	
	900	1,490	13x13	11¼x11¼	127			
	900	1,490	8½x18	6¾x16¼	110			
	1,100	1,820				12	113	40
	1,700	2,800	13x18	11¼x16¼	183			
	1,940	3,200				15	177	
	2,130	3,520	18x18	15¾x15¾	248			
	2,480	4,090	20x20	17¼x17¼	298			45
	3,150	5,200				18	254	50
	4,300	7,100				20	314	
	4,600	7,590	20x24	17x21	357			
	5,000	8,250	24x24	21x21	441			55
	5,570	9,190		24x24b	576			60
	5,580	9,200				22	380	
	6,980	11,500				24	452	65
	7,270	12,000		24x28b	672			
	8,700	14,400		28x28b	784			
	9,380	15,500				27	573	
	10,150	16,750		30x30b	900			
	10,470	17,250		28x32b	896			

(a) This table is taken from the A.S.H.V.E. Code of Minimum Requirements for the Heating and Ventilation of Buildings (Edition of 1929).

(b) Dimensions are for unlined rectangular flues.

GAS-FIRED BOILER OR FURNACE

A chimney for a gas-fired boiler or furnace should be constructed similarly to the principles applicable to other boilers. The following table gives the minimum cross-sectional diameters of round chimneys for various amounts of heat supplied to the appliance and for various chimney heights, as recommended by the *American Gas Association.*

TABLE No. 29A. MINIMUM ROUND CHIMNEY DIAMETERS FOR GAS APPLIANCES (Inches)

Height of Chimney Feet	Gas Consumption in Thousands of Btu per Hour: 100	200	300	400	500	750	1000	1500	2000
20	4.50	5.70	6.60	7.30	8.00	9.40	10.50	12.35	13.85
40	4.25	5.50	6.40	7.10	7.80	9.15	10.25	12.10	13.55
60	4.10	5.35	6.20	6.90	7.60	8.90	10.00	11.85	13.25
80	4.00	5.20	6.00	6.70	7.35	8.65	9.75	11.50	12.85
100	3.90	5.00	5.90	6.50	7.20	8.40	9.40	11.00	12.40

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Detailed information on the construction of chimneys may be obtained in the "Standard Ordinance for Chimney Construction" of the National Board of Fire Underwriters.

STEAM HEATING PIPING SYSTEMS

The piping systems which follow represent good engineering practice for low pressure steam heating systems, assuming that thermostatic traps be applied to the return side of the radiator, convector or other heating unit. For data on "one pipe" and "two pipe" steam heating systems, consult the A.S.H.V.E. Guide.

Steam Heating Systems may be classified as

(1) Gravity return to boiler, Vapor Heating Systems.
(2) Gravity return to boiler with equalizing receiver, Return Heating System.
(3) Gravity System with mechanical return of condensation to boiler, Condensation Pump Systems.
(4) Vacuum Return Line Systems with vacuum pump to maintain a limited degree of vacuum on return piping and to return condensation to boiler.
(5) Differential Vacuum Systems, with vacuum pump with differential control to maintain high degree of vaccum on entire piping system with controlled differential between steam and return piping and to return condensation to boiler, with orifice in each radiator inlet valve.

The application of piping is similar in all systems in that steam piping connects between boiler and all units of radiation, convectors, etc., and a separate system of return piping connects each unit of radiation, etc., to either the boiler, direct or through equalizing receiver (return trap), condensation or vacuum pump.

Steam piping is generally graded downward in direction of steam flow except branch connections to risers and heating units, which must of necessity grade counter to steam flow to carry condensation within the piping back to mains.

Return piping is graded downwards in direction of flow to lowest point of return piping which is connected to either boiler, return trap, condensation or vacuum pump receiver.

The following tables of pipe capacities have been in use for many years and when properly applied will give satisfactory performance for the types of systems indicated.

TABLE No. 30. GRAVITY STEAM HEATING SYSTEM, RETURNS DIRECT TO BOILER—INITIAL STEAM PRESSURE ½ POUND PER SQ. INCH. CAPACITIES IN SQ. FT. EDR.

Pipe Size Inches	STEAM MAIN LENGTH IN FEET* 200	300	400	500	600
	STEAM MAIN CAPACITIES				
¾	....	....	....	....	....
1	....	....	....	....	....
1¼	....	....	....	....	....
1½	....	....	....	....	....
2	320	282	248	218	200
2½	560	456	400	352	320
3	1,000	810	710	625	570
3½	1,500	1,180	1,035	910	830
4	2,000	1,640	1,440	1,270	1,150
5	3,600	2,940	2,580	2,260	2,060
6	5,780	4,700	4,130	3,640	3,300

Pipe Size	STEAM MAIN LENGTH IN FEET* 100	200	300	400	500	600	Return Main	Steam Main Drip
	STEAM RISER CAPACITIES							
¾	40	25	23	20	18	16	.....	.....
1	80	55	46	40	36	32	300	.....
1¼	160	115	97	80	72	64	1,000	1,000
1½	250	175	150	125	110	96	1,700	2,000
2	400	320	280	240	210	180	3,300	4,000
2½	...	...	...	...	...	...	5,400	6,000
	RETURN RISER CAPACITIES							
¾	500	320	285	250	210	180	.....	.....

*The "length" equals the distance along piping from boiler to top of each riser plus allowance for elbows (see Table 32) plus 25 ft. allowance for connection to last radiator fed by riser.

Grade steam mains and steam main drips ½" in 10' downwards in direction of steam flow.

Grade return mains 1" in 10' downwards in direction of flow of condensation. Lowest point of return main or steam main drip to be not less than 24" above boiler water line.

TABLE No. 31. RADIATOR CONNECTIONS

Square Feet Direct Radiation	SUPPLY: Inlet Valve Size Inches	SUPPLY: Vertical Pipe to Inlet Valve Inches	SUPPLY: Horizontal Runout to Riser or Radiator from Main or Runout from Riser to Radiator	RETURN: Stub to Trap and Trap Size Inches	RETURN: Horizontal Runout from Radiator or Riser to Main or from Radiator to Riser
1— 25	½	½	¾"	½	¾"
26— 80	¾	¾	1"	½	¾"
81—100	¾	¾	1¼"	½	¾"
101—140	¾	¾	1¼"	½	¾"
141—170	¾	¾	1½"	½	¾"

TABLE No. 32. ALLOWANCES FOR RESISTANCE IN FEET OF PIPE EQUIVALENT†

Pipe Sizes, Inches..	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12	14	16
For Elbows.......	2	2	2	3	5	6	9	10	14	19	24	35	47	59	70	82
For Globe Valves...	2	3	3	5	7	9	14	15	21	28	36	53	70	88	106	124

†In sizing pipes, the length of the pipe must be ascertained, and the frictional resistance of fittings and valves considered.

It is customary to reduce the resistance to equivalent length of straight pipe, as in the above table, which must be added to the actual length.

STEAM HEATING PIPING SYSTEMS (continued)

TABLE No. 33. GRAVITY RETURN SYSTEM WITH EQUALIZING RECEIVER OR VENTED PUMP UNIT TO RETURN CONDENSATE TO BOILERS. INITIAL STEAM PRESSURE 1-2 POUNDS PER SQ. INCH. CAPACITIES IN SQ. FT. EDR.

Pipe Size Inches	STEAM MAIN LENGTH IN FEET*								Return Mains		Steam Main Drip
	100	200	300	400	500	600	800	1000	Length of Mains†		
									Up to 400 Ft.	Over 400 Ft.	
	STEAM MAIN CAPACITIES										
1	......	......	......	......	......	......	......	......	400	300	......
1¼	......	......	......	......	......	......	......	......	1,400	1,000	1,400
1½	......	......	......	......	......	......	......	......	2,700	1,700	2,700
2	670	570	470	410	360	330	290	250	5,500	3,400	5,500
2½	1,090	930	760	670	590	530	470	410	9,000	5,500	9,000
3	1,930	1,650	1,340	1,170	1,030	940	820	730	16,000	10,000	16,000
3½	2,810	2,400	1,950	1,710	1,510	1,370	1,200	1,060	23,000	14,000	23,000
4	3,900	3,340	2,720	2,380	2,100	1,900	1,670	1,480	32,000	20,000	32,000
5	7,000	5,950	4,850	4,260	3,740	3,400	2,980	2,640	57,000	35,000	57,000
6	11,200	9,550	7,780	6,830	6,000	5,460	4,780	4,240			
8	23,400	20,000	16,250	14,250	12,540	11,400	10,000	8,840			
10	40,800	34,800	28,400	24,800	21,900	19,900	17,400	15,400			
	STEAM RISER CAPACITIES										
¾	50	45	40	30	27	25	23	20			
1	100	90	75	60	55	50	45	40			
1¼	200	190	160	136	123	110	97	85			
1½	300	290	245	200	180	165	147	130			
2	600	570	500	410	370	330	290	250			
2½	1,000	930	800	670	600	530	470	410			
3	1,750	1,650	1,410	1,170	1,055	940	835	730			
	RETURN RISER CAPACITIES										
¾	680	600	520	430	385	340	300	260			
1	1,375	1,200	1,025	850	760	670	600	530			

For Radiator Connection Pipe Sizes, See Table 31

For Allowances for Elbows and Valves, See Table 32

†The "length" is the distance along piping from pump or return trap to farthest radiator plus allowances for elbows and valves.

*The "length" equals the distance along piping from boiler to top of each riser plus allowance for elbows (see Table 32) plus 25 ft. allowance for connection to last radiator fed by riser.

Grade steam mains and steam drips ½" in 10' downwards in direction of steam flow.

Grade return mains 1" in 10' downwards in direction of flow of condensation. Lowest point of return main or steam main drip to be not less than 24" above boiler water line when alternating receiver is used.

TABLE No. 34. VACUUM RETURN LINE HEATING SYSTEM AND DIFFERENTIAL VACUUM SYSTEM. INITIAL STEAM PRESSURE 2 POUNDS PER SQ. INCH. CAPACITIES IN SQ. FT. EDR.

Pipe Size Inches	STEAM MAIN LENGTH IN FEET*										
	100	200	300	400	500	600	800	1,000	1,500	2,000	3,000
	STEAM MAIN CAPACITIES										
1	......	......	......	......	......	......	......	......	......	......	......
1¼	......	......	......	......	......	......	......	......	......	......	......
1½	......	......	......	......	......	......	......	......	......	......	......
2	1,130	800	650	570	500	450	400	350	300	250	200
2½	2,100	1,470	1,200	1,030	925	840	735	650	550	460	380
3	3,800	2,660	2,160	1,900	1,670	1,520	1,330	1,180	990	830	680
3½	5,500	3,850	3,140	2,750	2,420	2,200	1,920	1,700	1,430	1,210	990
4	7,750	5,400	4,400	3,900	3,400	3,100	2,700	2,400	2,000	1,700	1,400
5	13,800	9,650	7,800	6,900	6,100	5,500	4,800	4,300	3,600	3,040	2,480
6	22,200	15,500	12,600	11,000	9,800	8,900	7,800	6,900	5,700	4,900	4,000
8	46,000	32,000	26,200	23,000	20,200	18,400	16,100	14,200	12,000	10,100	8,300
10	80,700	56,500	46,000	40,300	35,500	32,200	28,200	25,000	21,000	17,700	14,500
12	127,000	89,000	72,500	63,500	56,000	51,000	44,500	39,400	33,000	28,000	23,000
14	164,000	115,000	93,500	82,000	72,000	65,600	57,400	51,000	42,600	36,100	29,500
16	234,000	164,000	133,400	117,000	103,000	93,600	82,000	72,600	61,000	51,500	42,100
	STEAM RISER CAPACITIES										
¾	76	66	56	47	43	38	33	29	25	20	12
1	162	133	104	95	85	76	67	59	50	42	25
1¼	330	290	250	210	188	166	147	129	110	92	55
1½	540	450	360	325	293	260	230	200	171	143	86
2	1,152	920	688	655	590	525	467	410	350	290	170
2½	1,690	1,500	1,300	1,080	973	865	767	670	502	475	275
3	3,080	2,660	2,280	1,900	1,710	1,520	1,400	1,180	985	830	480
3½	4,400	3,850	3,300	2,750	2,475	2,200	1,950	1,700	1,455	1,210	720
4	6,200	5,400	4,600	3,900	3,500	3,100	2,750	2,400	2,050	1,700	1,000
	RETURN RISER CAPACITIES										
¾	1,100	1,000	900	800	720	640	570	500	425	350	200
1	2,400	2,000	1,800	1,600	1,400	1,200	1,100	1,000	850	700	400
1¼	5,000	4,500	3,950	3,400	2,950	2,500	2,300	2,100	1,800	1,500	900

Pipe Size Inches	RETURN MAINS — Length of Mains, Feet†			
	400	1,000	2,000	3,000
1	800	500	350	300
1¼	1,600	1,000	800	600
1½	4,000	2,500	1,800	1,500
2	11,000	7,000	5,000	4,000
2½	21,000	13,000	9,000	7,500
3	38,000	23,500	16,000	13,500
3½	55,000	34,000	24,000	20,000
4	78,000	48,000	34,000	28,000
5	138,000	86,000	60,000	50,000
6	220,000	138,000	98,000	80,000

For Radiator Connection Pipe Sizes, See Table 31

For Allowances for Elbows and Valves, See Table 32

†The "length" is the distance along piping from pump to farthest radiator plus allowances for elbows and valves.

*The "length" equals the distance along piping from boiler or control valve to top of each riser plus allowance for elbows (see Table 32) plus 25 ft. allowance for connection to last radiator fed by riser.

Grade steam mains and steam main drips ½" in 10' downwards in direction of steam flow.

Grade return mains 1" in 10' downwards in direction of flow of condensation.

PIPING SYSTEM DESIGN

Fiping Systems for Steam Heating should be designed to provide for the shortest distance from the source of steam supply to last radiator, and to provide for the maximum economy in pipe sizes.

An installation having several branch mains will be usually more economical in installation costs than one having one continuous main or circuit all around the building. See Fig. 3360 and Fig 3361. The piping arrangement shown in Fig. 3360 will require material costing approximately 28% more than that required for the arrangement shown in Fig 3361, and labor costs will also be higher.

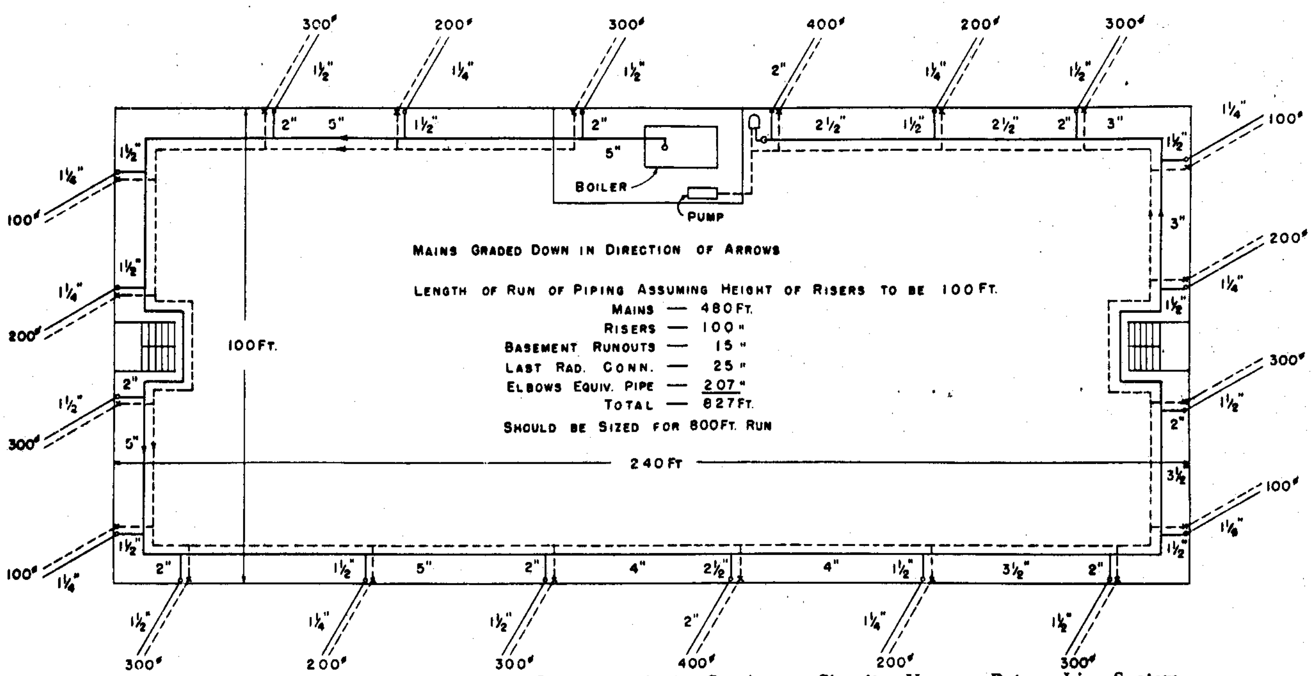


Fig. 3360. Steam Heating System Piping Layout. Single Continuous Circuit. Vacuum Return Line System.

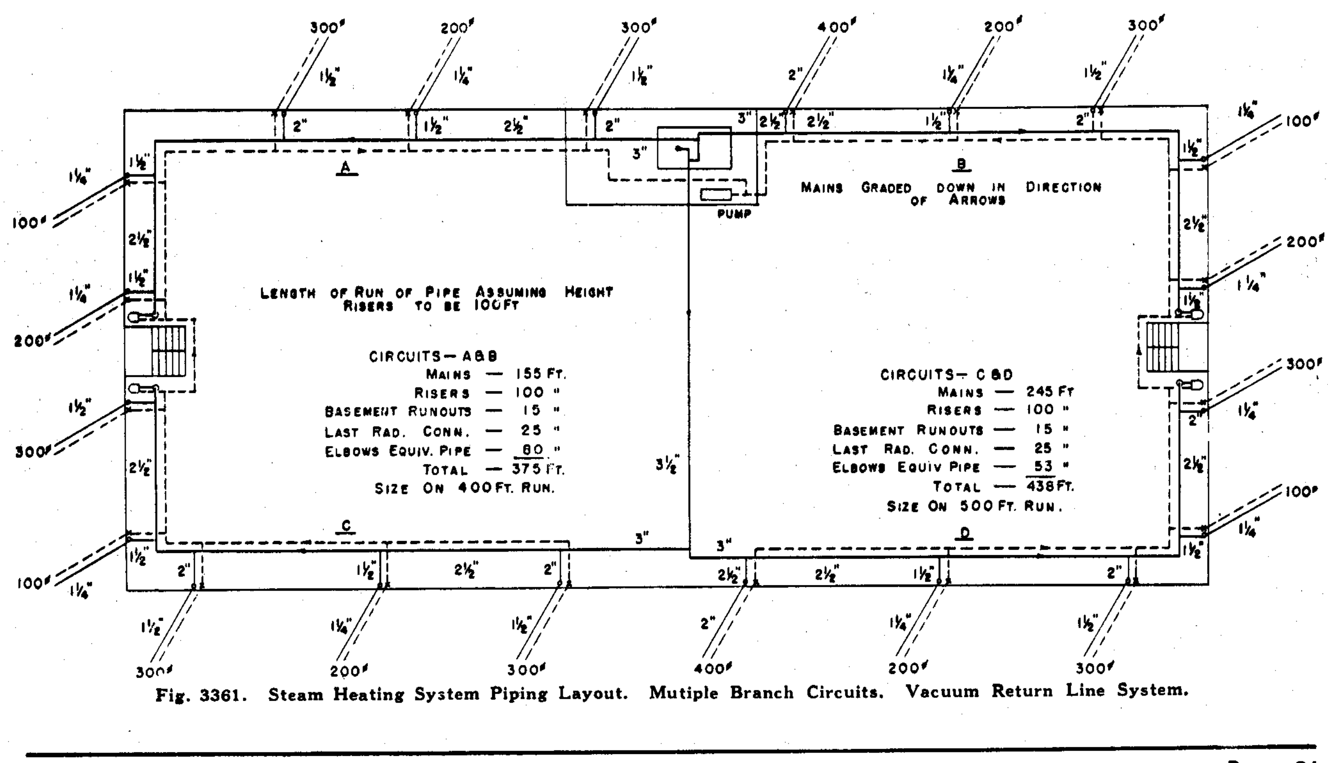


Fig. 3361. Steam Heating System Piping Layout. Mutiple Branch Circuits. Vacuum Return Line System.

PIPING SYSTEM DESIGN (Continued)

On small installations where returning condensate flows by gravity direct (Vapour System), or through an equalizing receiver (Return Trap System) to the Boiler, it is sometimes advantageous to install a reverse return system of piping as shown in Fig. 1280A, to provide equal pipe friction to and from each radiator in the circuit. This arrangement is usually not possible on larger installations because of the greater distance from the source of steam supply, to the more remote radiators.

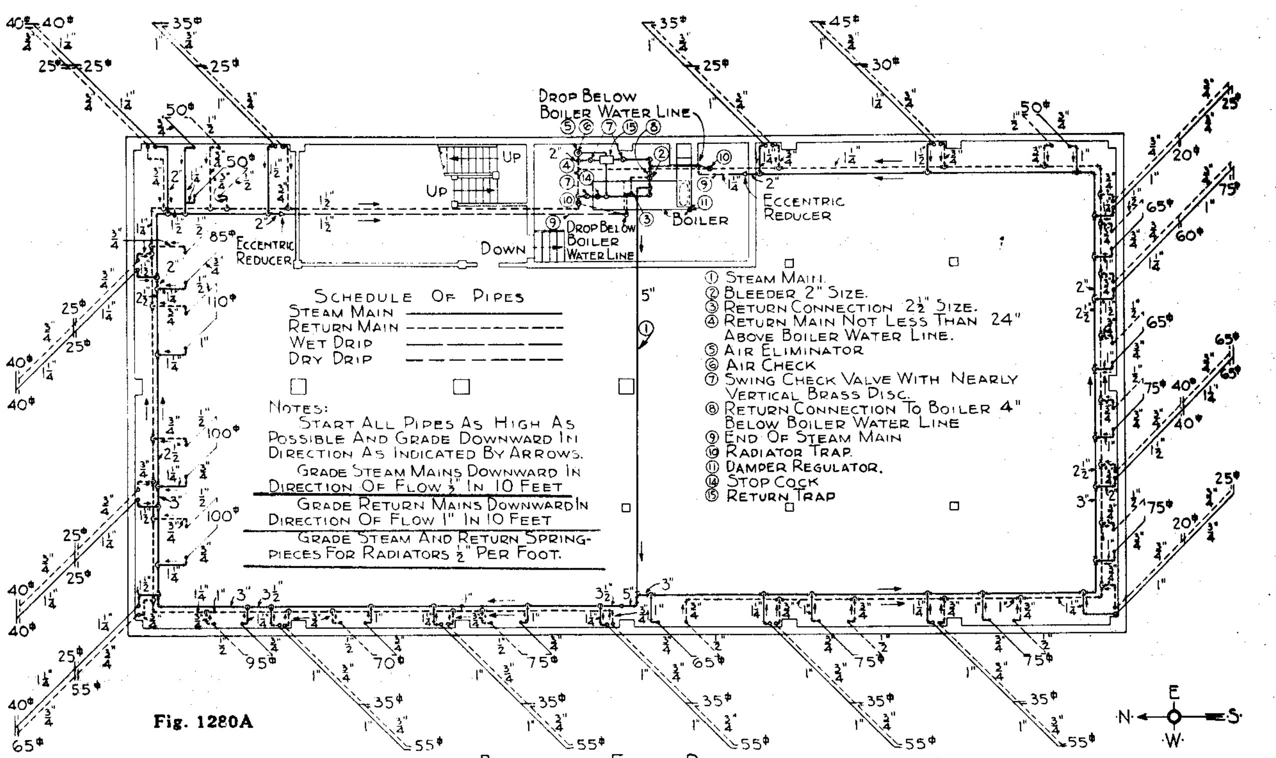


Fig. 1280A

BASEMENT FLOOR PLAN

A steam main should not be reduced below 2" in size where main or branch circuit starts 3" or less in size, and should not be reduced to smaller than 2½" in size where the main or branch circuit starts larger than 3" in size; also it should not be reduced in size smaller than any spring-piece or run-out taken from it. This is particularly recommended where several up-feed risers connect to top of steam main, and condensate must of necessity flow from the risers into the steam main. Reductions in steam mains should always be made with Eccentric Reducing Couplings.

To establish the length of main for size determinations, measure the piping as scaled, from the plan, for the mains plus the distance from the main to the top of the last riser, and then double the distance to establish the main length. When sizing has been completed, the actual length of the main plus riser, plus allowances for fittings, elbows, valves, etc., should be tabulated and the sum of these checked against the original estimated length. If less than the estimated length, sizing can be considered satisfactory, if greater, then sizing shall be checked on the new length capacities.

Intermediate risers between source of steam and last risers should be measured individually for length, and sized on the actual lengths for the risers nearest to the source of the steam supply.

When steam piping is dripped to return piping through traps, each drip connection into return should be considered as adding the equivalent direct radiation load to the return equal to 25% of the total Equivalent Direct Radiation, fed by the particular branch or circuit, or riser.

On gravity installations, when condensate from steam mains flows direct to boiler, the end of the steam main or steam main drip should not be less than 18" above boiler waterline, at the point where it drops down to connect to the wet return. This would provide for a maximum drop in pressure from boiler to end of steam main of one half pound, and allow air to vent freely from end of main through venting device.

Return mains on Gravity Return Systems should be not less than 24" above boiler waterline at lowest points. This is necessary to provide for a water column sufficient to overcome a boiler pressure of ½ pound, plus pipe friction into the boiler, and will permit the free venting of air through eliminating device, and will prevent "Flooding" of return main. Boiler pressure should be maintained at a maximum of ½ pound.

When boiler pressure is likely to exceed ½ pound maximum, because of flash type fuel being used, as soft coal or wood, and on systems without combustion control, an alternating receiver should be used to receive the condensate. This alternating receiver (Return Trap) should have the steam connection to it taken direct from the boiler, and not from a nearby steam main. When taken from the steam main there is likely to be sufficient drop in pressure to prevent the pressure within the return trap being equal to that in the boiler, causing condensate to build up in the return trap receiver above the steam valve when in discharging position. This causes noise and perhaps damage to mechanism, also "Flooding" of return main and consequent water hammer.

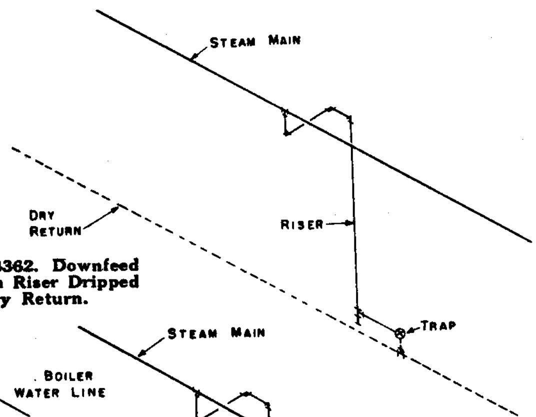


Fig. 3362. Downfeed Steam Riser Dripped to Dry Return.

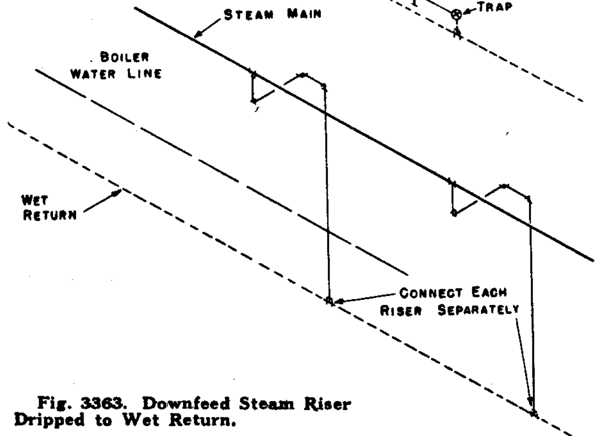


Fig. 3363. Downfeed Steam Riser Dripped to Wet Return.

PIPING SYSTEM DESIGN (Continued)

Where the particular condition of building, requires that steam main be run over head and radiators installed below steam main, the riser connections to mains may be taken out of bottom of main, and reductions in mains made at the connection to a down-feed riser. The lowest point of each steam riser must, of course, be dripped through a suitable trap to the dry return (Above Waterline) or on small systems, may be connected to a wet return (Below Waterline) in which case each steam riser must be connected separately to this wet return. See Fig. 3362 and Fig. 3363.

Runouts or spring-pieces connecting steam mains to risers of first floor radiators, which carry condensate back to steam main from the vertical connections, must grade back to main, and should have a fall of not less than 1/4" per foot in length. A grade of 1/2" per foot is preferable, especially if risers continue for several floors. In this case any expansion of risers may force runout down, and destroy grade, which may result in "Pockets" being formed, which will cut off the steam flow into riser, and may cause noise from water hammer.

See Capacity Tables for recommended grade or pitch for steam and return mains.

Return runouts should be graded the same as steam runouts. A "Pocket" formed in return runout will prevent air passing into return main, and result in air locked heating units preventing steam from entering, with resulting "cold radiators."

HEATING BOILER CONNECTIONS

It is recommended that heating boilers should have all outlets connected to piping system to provide as low a steam velocity as possible leaving boiler. This will prevent undue entrainment of moisture with the steam and avoid fluctuation of water line. See Figs. 3369, 3372 and 3373 for typical boiler connections. For actual equipment connections see manufacturers' catalogs and descriptive literature.

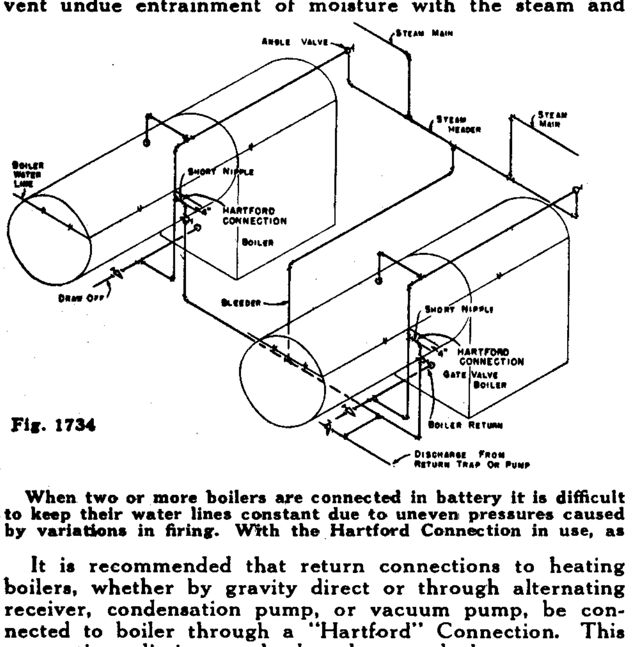


Fig. 1734

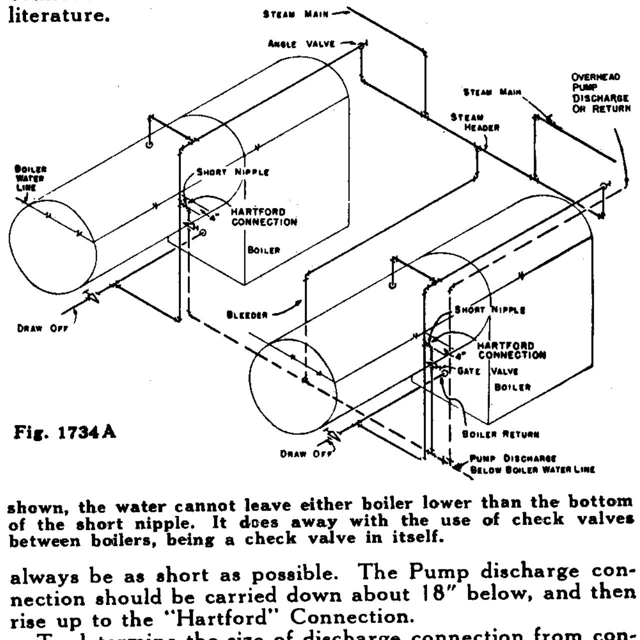


Fig. 1734A

When two or more boilers are connected in battery it is difficult to keep their water lines constant due to uneven pressures caused by variations in firing. With the Hartford Connection in use, as shown, the water cannot leave either boiler lower than the bottom of the short nipple. It does away with the use of check valves between boilers, being a check valve in itself.

It is recommended that return connections to heating boilers, whether by gravity direct or through alternating receiver, condensation pump, or vacuum pump, be connected to boiler through a "Hartford" Connection. This connection eliminates check valves, and the consequent friction, and prevents water leaving the boiler except by evaporation.

Check valves are omitted on gravity return to boilers only. Alternating receivers need check valves at inlet and discharge sides of the receiver, and pumps need check valves in their discharge line.

The horizontal connection to bleeder pipe from steam header to return header or connection to boiler, should always be as short as possible. The Pump discharge connection should be carried down about 18" below, and then rise up to the "Hartford" Connection.

To determine the size of discharge connection from condensation or vacuum and boiler feed pumps, the actual gallons rating of the pump per minute must be taken, rather than the condensing rate of the heating system, to determine the flow of water through the discharge pipe. Pumps used on heating systems usually have a discharge rate of three times the condensing capacity of the heating system. The method of determining the pump discharge pipe sizes is given under "Pump Selection and Connections."

HEATING BOILER CONNECTIONS (Continued)

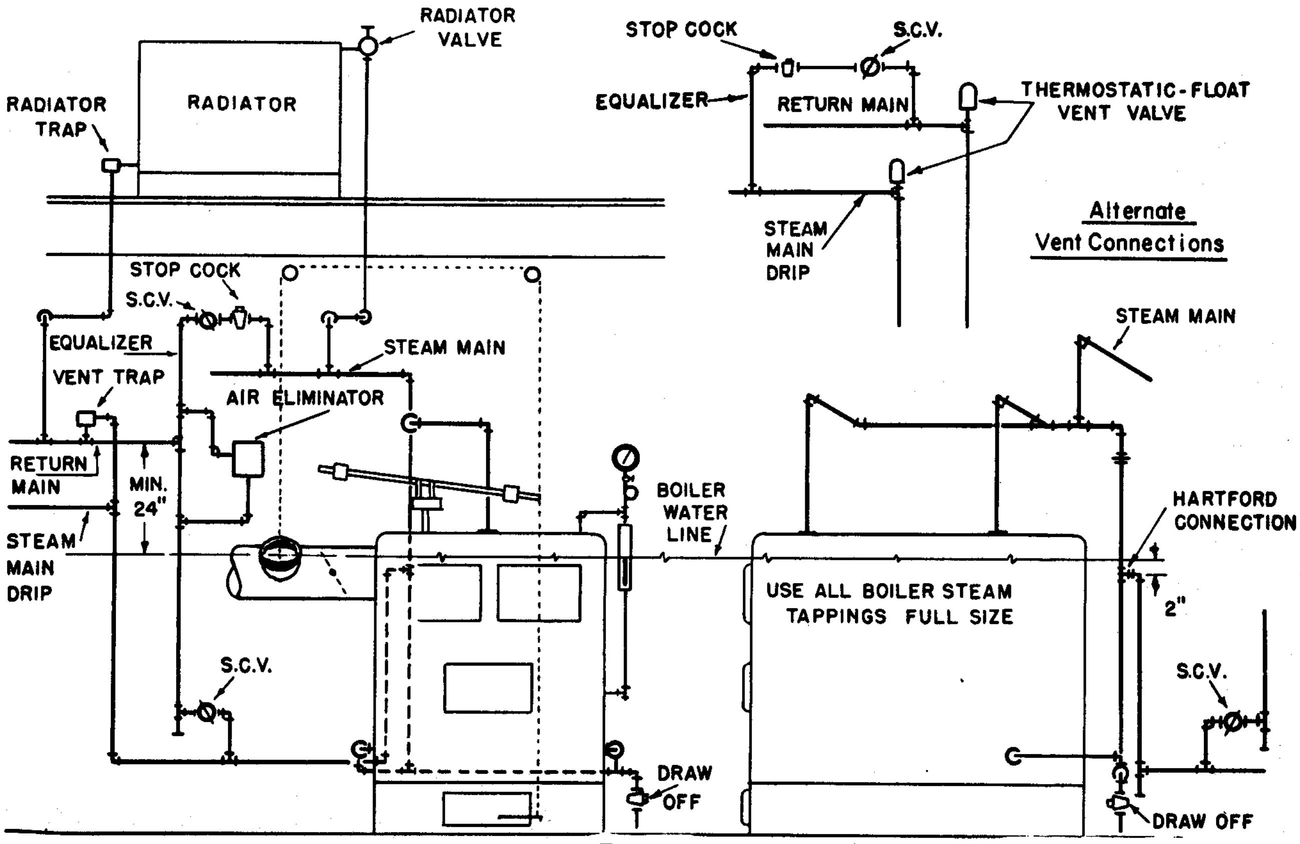


Fig. 3369 S.C.V.—Swing Check Valve

Typical connections at boiler for Gravity Return to Boiler System.

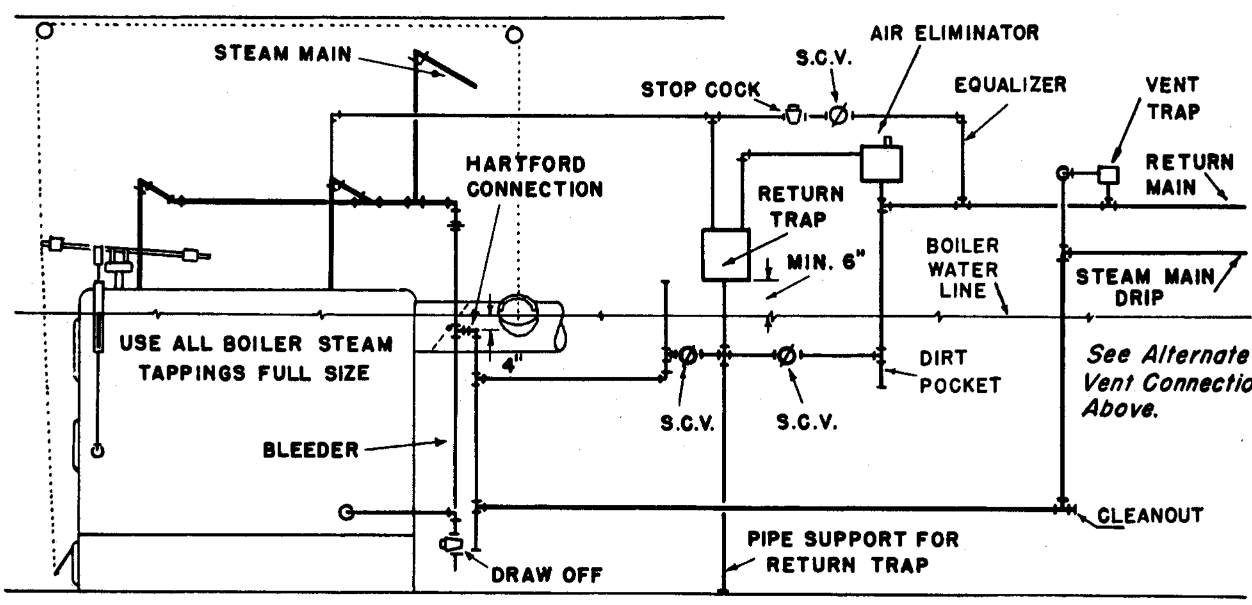


Fig. 3372 S.C.V.—Swing Check Valve

Typical connections at boiler for Gravity Return to Boiler System using Alternating Receiver (Return Trap).

HEATING BOILER CONNECTIONS (Continued)

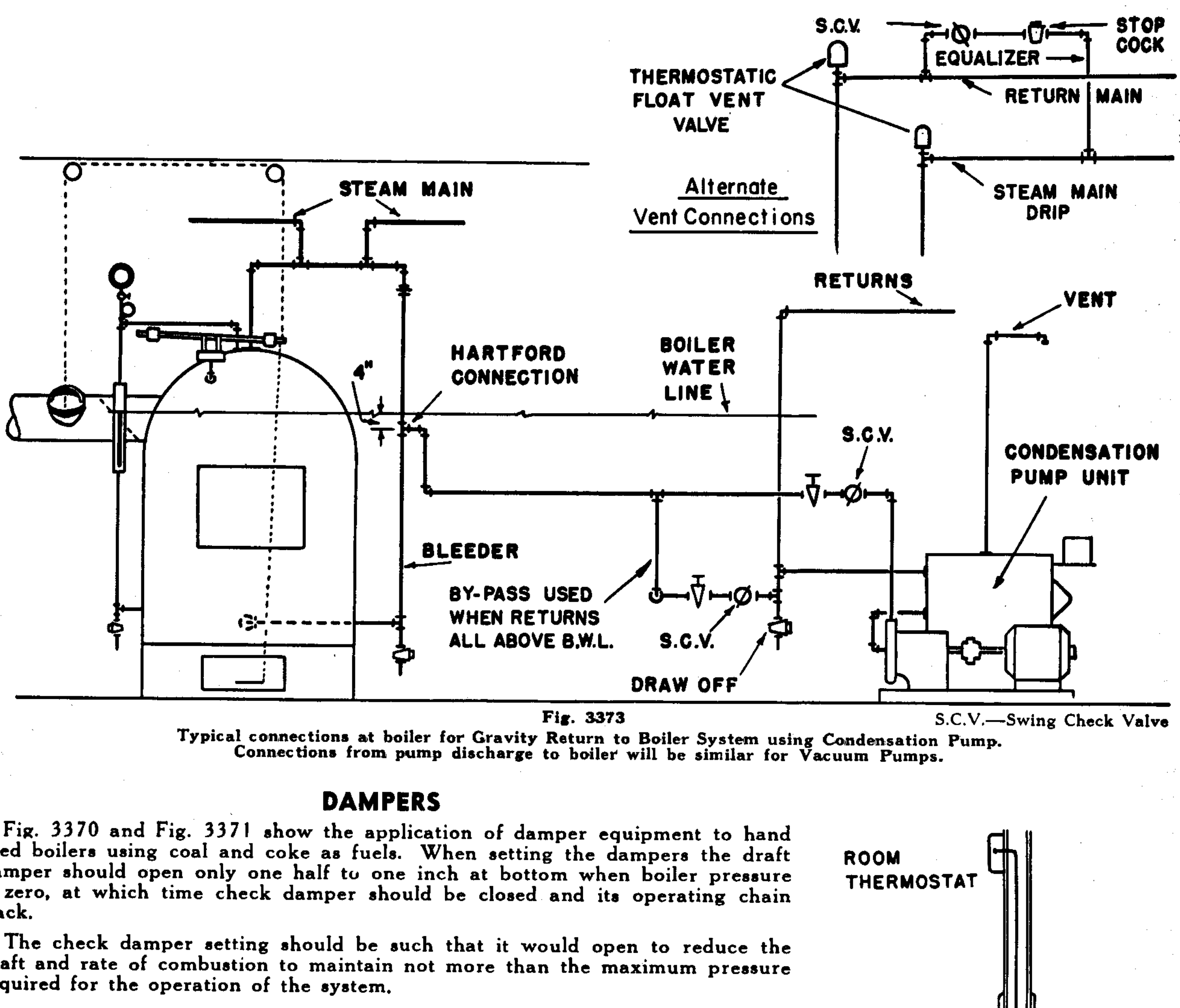


Fig. 3373 S.C.V.—Swing Check Valve

Typical connections at boiler for Gravity Return to Boiler System using Condensation Pump. Connections from pump discharge to boiler will be similar for Vacuum Pumps.

DAMPERS

Fig. 3370 and Fig. 3371 show the application of damper equipment to hand fired boilers using coal and coke as fuels. When setting the dampers the draft damper should open only one half to one inch at bottom when boiler pressure is zero, at which time check damper should be closed and its operating chain slack.

The check damper setting should be such that it would open to reduce the draft and rate of combustion to maintain not more than the maximum pressure required for the operation of the system.

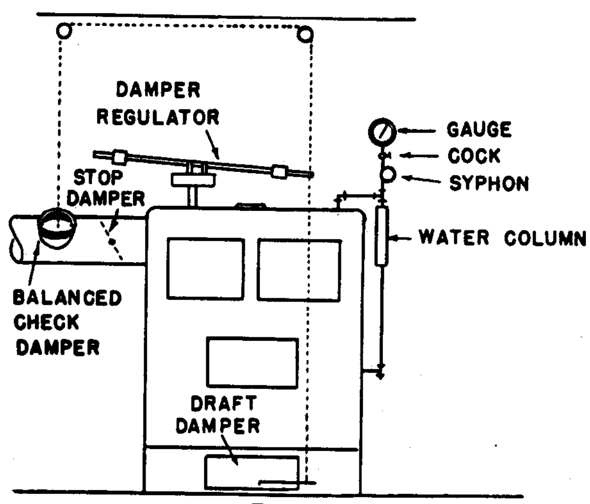


Fig. 3370

Typical Damper Regulator application to steam boiler.

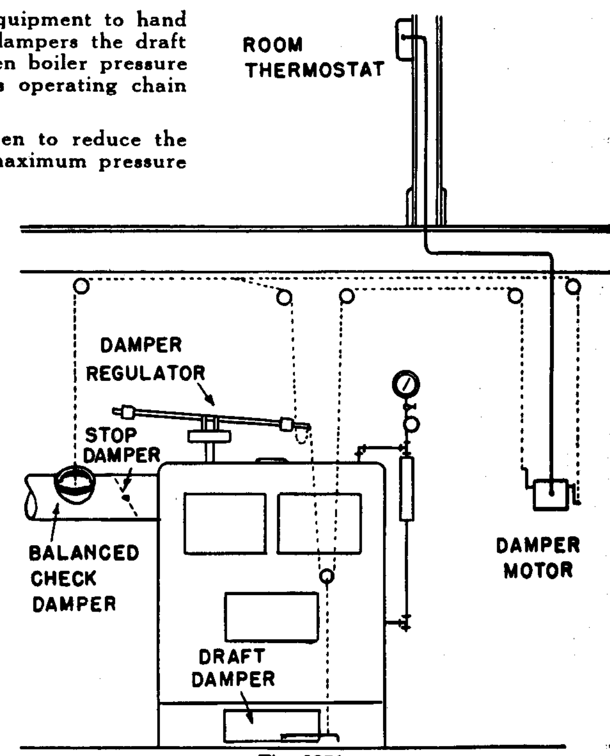


Fig. 3371

Typical application of Damper Regulator and thermostatically controlled Damper Motor to steam boiler.

HEATING BOILER CONNECTIONS (Continued)

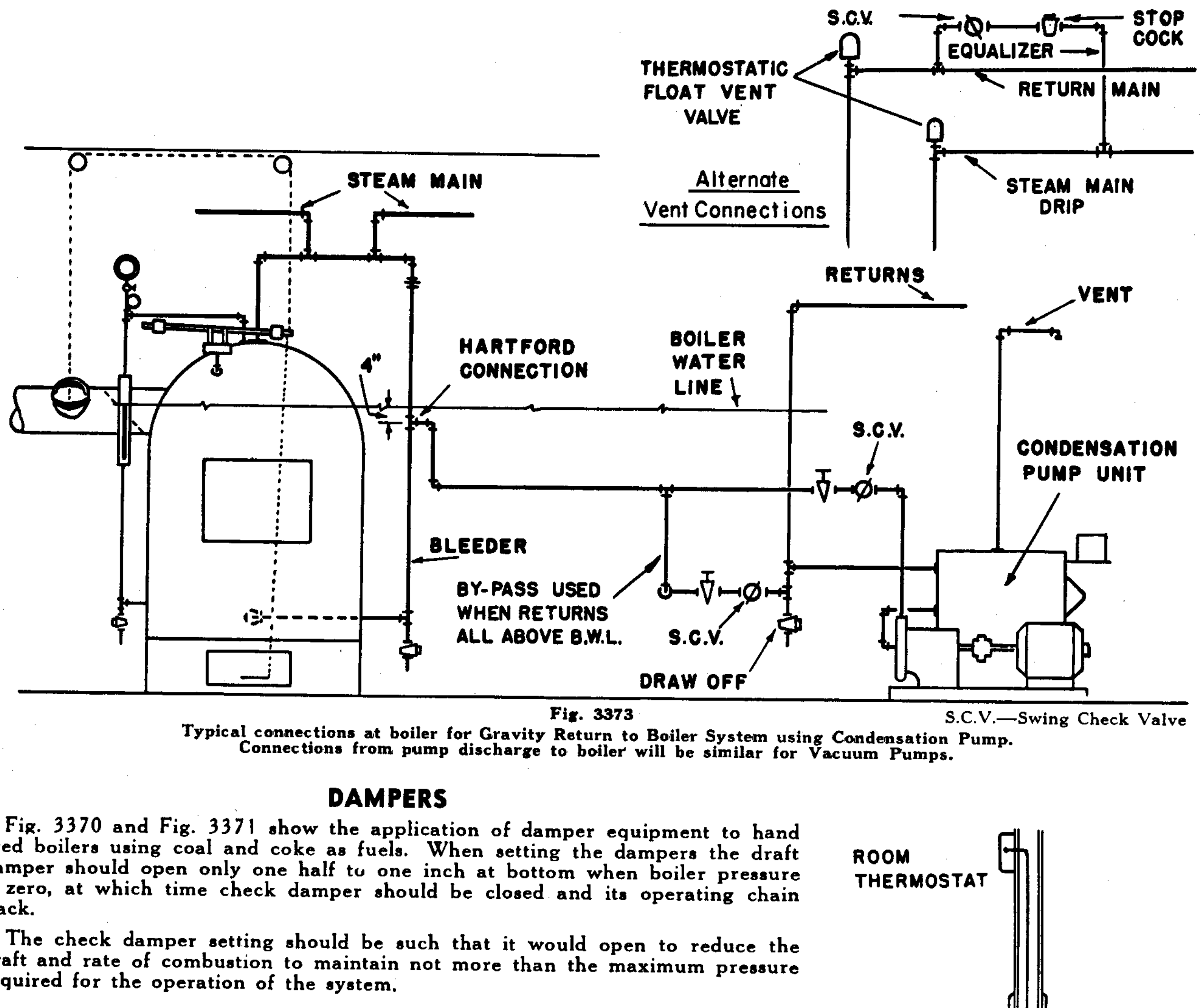


Fig. 3373 S.C.V.—Swing Check Valve

Typical connections at boiler for Gravity Return to Boiler System using Condensation Pump. Connections from pump discharge to boiler will be similar for Vacuum Pumps.

DAMPERS

Fig. 3370 and Fig. 3371 show the application of damper equipment to hand fired boilers using coal and coke as fuels. When setting the dampers the draft damper should open only one half to one inch at bottom when boiler pressure is zero, at which time check damper should be closed and its operating chain slack.

The check damper setting should be such that it would open to reduce the draft and rate of combustion to maintain not more than the maximum pressure required for the operation of the system.

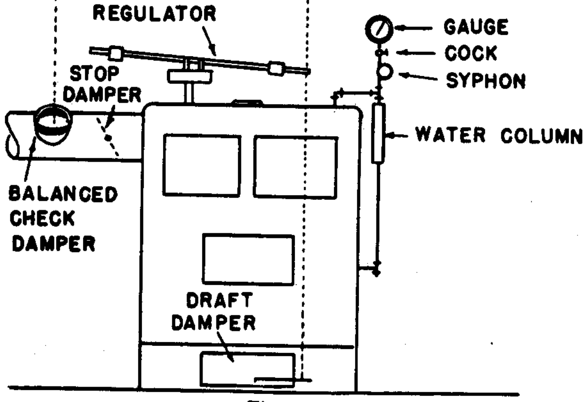


Fig. 3370

Typical Damper Regulator application to steam boiler.

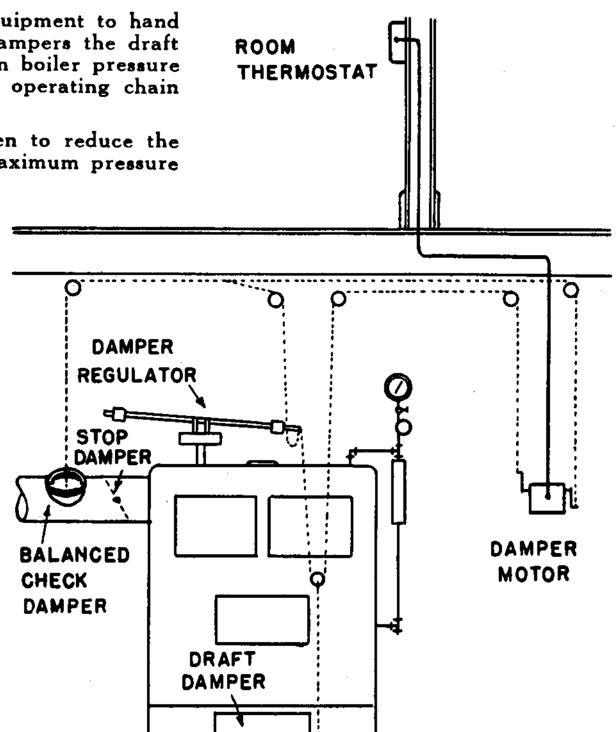


Fig. 3371

Typical application of Damper Regulator and thermostatically controlled Damper Motor to steam boiler.

PUMP SELECTION AND CONNECTIONS

Selection of condensation or vacuum pumps is determined by (a) the amount of condensation to be handled and (b) the boiler pressure plus pipe friction against which the pump must discharge.

The water handling capacity of standard heating pumps is generally three times the normal condensing rate of its EDR rating. Pumps selected on gpm. basis should have a water handling capacity three times the condensing rate of the total EDR load of the system.

Pump capacity in U. S. gallons per minute (gpm) may be determined by the following formula:

$$\text{gpm} = \frac{\text{EDR} \times \text{K} \times 3}{\text{L} \times 8.33 \times 60}$$

Where EDR = Total equivalent EDR capacity of pump
K = Btu heat emission per sq. ft. EDR at 2 pounds pressure (240 Btu)
3 = Ratio of pump capacity to condensing rate of heating system.
8.33 = Pounds per U. S. gallons of water
L = Latent heat of steam @ 2 pounds gage, or 966 Btu
60 = Minutes per hour

Example: Assume pump to be suitable for 20 pounds discharge pressure.
Total radiation load—20,000 sq. ft. EDR.
Height of Pump Discharge Line above pump—7'0"
Boiler Pressure—10 pounds (safety valve setting)
Length of Pump Discharge Line to boiler—50'0", with 5 elbows

Then Pump capacity (gpm) equals:

$$\frac{20{,}000 \times 240 \times 3}{966 \times 8.33 \times 60} = \frac{20{,}000 \times 3}{2{,}000} = 30 \text{ U. S. gpm}$$

Note: The short, practical application of this formula is indicated in the second stage of the equation, i.e. EDR × 3 divided by 2,000 = U. S. gpm.

To determine the size of the discharge pipe from the pump to the boiler, the actual gpm rating of the pump, rather than the condensing rate of the heating system, must be considered. Pump discharge pipe size may be determined by the following method using the same assumptions as in the example above and references to Tables 35 and 36.

Head in Ft. required to elevate water above Pump = 7.0
Head in Ft. equivalent for Boiler Pressure = 10 × 2.3 = 23.0

Total.................... 30.0

Head in Ft. equivalent for Pump Discharge = 20 × 2.3 = 46.0
Head in Ft. available for total friction loss in discharge pipe = 46 — 30 = 16.0

By reference to Table 35, selecting 1¼" pipe size, it is found that friction for each elbow is 8' of equivalent size pipe. Therefore, total equivalent length of discharge pipe of this size would be 50' plus 8' × 5 — 90' and the permissible friction loss per 100' of pump discharge line =

$$\frac{100}{90} \times 16 = 17.7 \text{ Ft. head.}$$

Table 36 gives total friction of 17.55 Foot Head per 100 ft. of pipe, when handling 30 Gallons of water per minute. Therefore, the minimum size of Pump Discharge will be 1¼". However, if there were any possibility that the safety valve on the Boiler would be set something above 10 pounds, then it would be advisable to use a 1½" discharge line, in which the resistance or the total friction head would pe 8.15 ft. This would permit the carrying of approximately 4 pounds more pressure on the Boiler, without increasing the total head against the Pump, beyond its normal capacity. Note: Total friction includes Friction Head plus Velocity Head.

TABLE 35.—FRICTION OF WATER IN 90 ELBOWS AND THE EQUIVALENT NUMBER OF FEET STRAIGHT PIPE

Size of Elbow, Inches	½	¾	1	1¼	1½	2	2½	3	4	5	6
Frict. Equiv. Feet Straight Pipe	5	6	6	8	8	8	11	15	16	18	18

TABLE 36.—VELOCITY HEADS† AND FRICTION HEADS†† FOR FLOW OF WATER IN PIPES

Gallons per Min. U. S.	½" Pipe		¾" Pipe		1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe		4" Pipe	
	Vel.† Head	Fric.†† Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head	Vel. Head	Fric. Head
1	0.02	1.50																
2	0.07	5.30	0.02	1.40														
3	0.16	11.30	0.05	2 90	0.02	0.90												
4	0.26	19.20	0.09	5.00	0.03	1.52	0.01	0.40		0.18								
5	0.43	29.00	0.14	7.50	0.05	2.32	0.02	0.60	0.01	0.28	0.01	0.09		0.05				
10	1.72	105.00	0.56	27.10	0.22	8.40	0.07	2.18	0.04	1.02	0.02	0.36	0.01	0.12		0.05		
15			1.26	57.00	0.58	18.90	0.24	4.65	0.12	2.25	0.04	0.81	0.02	0.25		0.11		
20			2.25	97.00	0.86	30.10	0.28	7.90	0.16	3.70	0.06	1.29	0.03	0.43	0.01	0.18		
25					1.39	45.50	0.45	11.90	0.32	5.60	0.10	1.96	0.04	0.66	0.02	0.27		
30					1.92	64.00	0.65	16.90	0.35	7.80	0.15	2.73	0.06	0.92	0.03	0.38		
35					2.65	85.00	0.88	22.30	0.47	10.30	0.20	3.66	0.08	1.23	0.04	0.51	0.01	
40					3.42	109.00	1.15	28.50	0.62	13.30	0.26	4.68	0.11	1.57	0.05	0.65	0.02	0.16
45							1.47	35.20	0.78	16.60	0.33	5.80	0.14	1.97	0.06	0.80	0.02	0.20
50							1.79	43.20	0.96	20.20	0.40	7.10	0.17	2.38	0.08	0.98	0.03	0.24
70							3.50	81.00	1.88	37.60	0.79	13.20	0.33	4.42	0.16	1.83	0.05	0.45
80							4.55	102.95	2.40	48.28	1.04	16.83	0.43	5.61	0.20	2.33	0.06	0.58
90							5.75	127.80	3.09	59.64	1.31	20.87	0.54	6.96	0.26	2.90	0.08	0.71
100									3.85	72.42	1.62	25.42	0.66	8.52	0.32	3.52	0.10	0.87
125											2.36	38.90	1.03	13.01	0.50	5.40	0.16	1.33
150											3.64	53.96	1.49	18.72	0.72	7.72	0.23	1.82

† Velocity Heads are given in feet. Multiply table values by .433 to convert to equivalent pounds pressure. Velocity Heads have been calculated from the formula: $(\text{Velocity})^2 \div 2g$, (where g equals acceleration due to gravity = 32.16).

†† Friction Heads are given in feet per 100 feet of smooth straight pipe.

When pipe is slightly rough, add 15%; when very rough, add 30% to Friction Head values. Multiply table values by .433 to convert to equivalent pounds pressure per 100 feet of pipe. This result multiplied by the actual length of the pipe in feet (including equivalent length for elbows, gate valves and check valves divided by 100 gives the total pressure loss in pounds due to friction.

RADIATOR VALVES, ORIFICE or REGULATING PLATES

Radiator valves may be of the packed, spring packed or packless type. "Packless" type valves are recommended for gravity vapor systems, vacuum return line, and Sub-atmospheric Steam Systems.

Figs. 923D, 1671A and 1168A show typical construction of all three types.

Packless

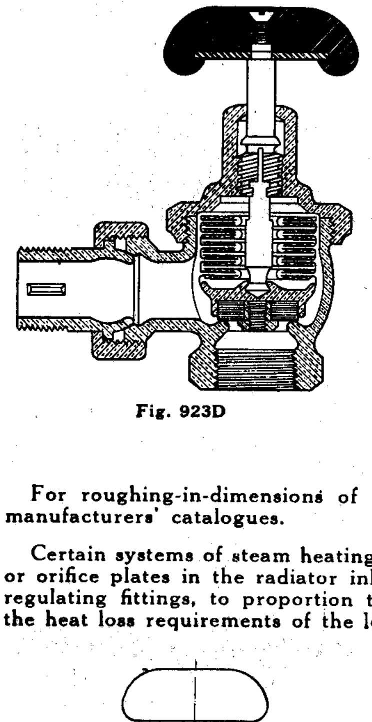


Fig. 923D

Spring Packed

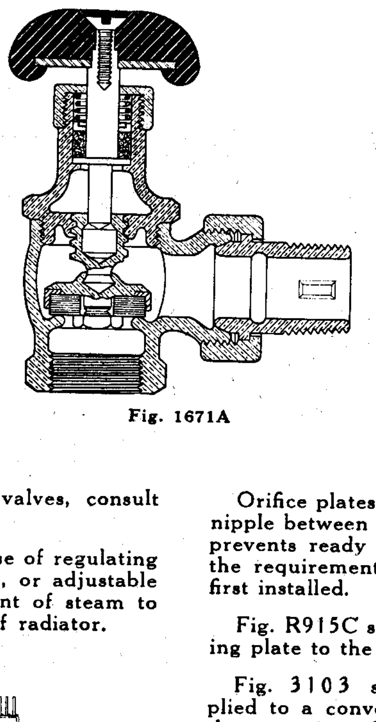


Fig. 1671A

Packed

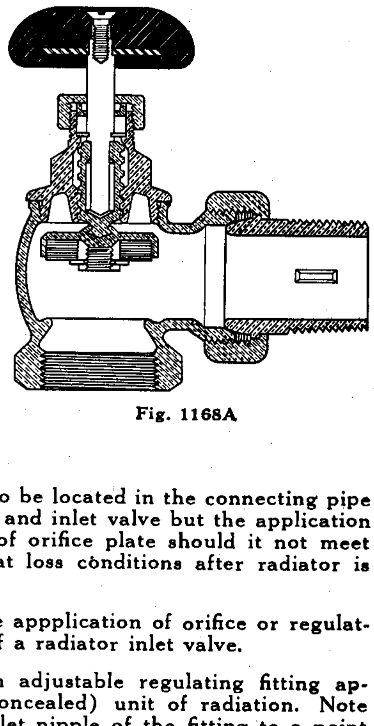


Fig. 1168A

For roughing-in-dimensions of radiator valves, consult manufacturers' catalogues.

Certain systems of steam heating make use of regulating or orifice plates in the radiator inlet valves, or adjustable regulating fittings, to proportion the amount of steam to the heat loss requirements of the location of radiator.

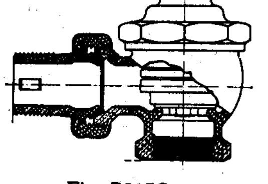


Fig. R915C

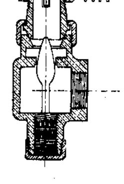


Fig. 3103

Orifice plates may also be located in the connecting pipe nipple between radiator and inlet valve but the application prevents ready change of orifice plate should it not meet the requirements of heat loss conditions after radiator is first installed.

Fig. R915C shows the appplication of orifice or regulating plate to the union of a radiator inlet valve.

Fig. 3103 shows an adjustable regulating fitting applied to a convector (concealed) unit of radiation. Note the extension of the outlet nipple of the fitting to a point above the bottom of tube of convector. This prevents condensate returning down orifice fitting should convector not be graded properly with a fall towards return end. Where radiator inlet valves are used with convectors it is desirable that the outlet nipple be provided with extended nipple if orifice plates are also applied.

Capacities of orifice plates and regulating fittings are determined by the pressure differential across them, and manufacturers' recommendations on capacities should be obtained.

RADIATOR AND DRIP TRAPS

Outlets of all units of radiation should be equipped with suitable traps to pass condensation and air automatically into the return piping, while preventing passage of steam. Typical trap applications are shown in following pages.

Where return piping is installed at an elevation below heating boiler water line or where steam is furnished by boilers operating at higher pressures, it is not possible to carry condensate from steam piping directly to boiler return. It then becomes necessary to install a trap at end of steam main and connect trap to return piping.

Small mains or branches of steam piping may be dripped through thermostatic trap but more generally it is advisable to install traps operating on both the thermostatic and float valve principles. These provide efficient air venting facilities together with large condensate handling capacity through the float valve to handle the increased quantity of condensate prevailing during heating up periods.

Float and thermostatic traps are also advisable for use on unit heater installations. Fig. Nos. 1622B, 3273A, 1973 and 1558 show trap connections for unit heaters and Fig. Nos. 924B and 925B show typical connections for ends of steam mains and for rises in steam mains.

It is recommended that wherever drip traps are installed, a substantial drip pocket for the accumulation of scale and dirt be provided at low point before drip connecton and that a strainer be installed ahead of drip trap with valve on main so strainer may be conveniently cleaned without shutting off steam supply to system.

RADIATOR AND DRIP TRAPS (Continued)

Estimate capacity required by measuring the amount of steam pipe heating surface (main and risers) in square feet that the drip trap is going to drain. Multiply this by 2 where the pipe is covered and, where it is uncovered, multiply by 3. The result will give load the trap must handle including the heavy condensation when firing up a cold system. Select trap size accordingly.

A short-cut method is to divide the amount of radiation (EDR) served by the steam piping by 4 to give the drip trap EDR capacity.

For roughing-in dimensions and capacities of radiator and drip traps, consult manufacturers' catalogs.

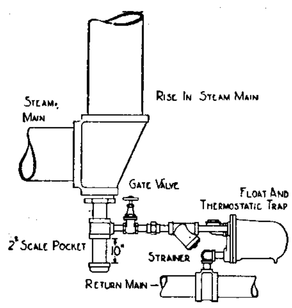


Fig. 924B. Method of dripping rise in steam main.

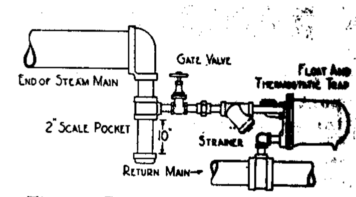


Fig. 925B. Above shows method of dripping end of steam main.

TYPICAL UNIT HEATER AND RADIATOR CONNECTIONS

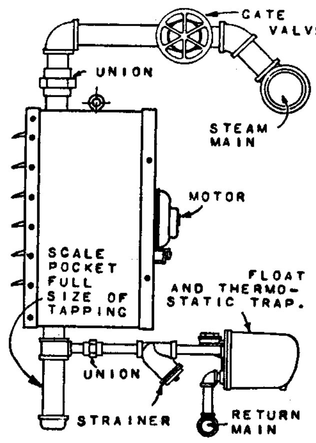


Fig. 1622B—Trap applied to horizontal air discharge unit heater.

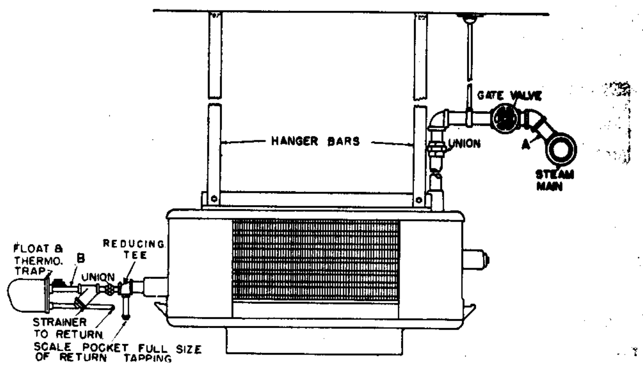


Fig. 3273A—Typical piping connections for vertical air discharge unit heater.

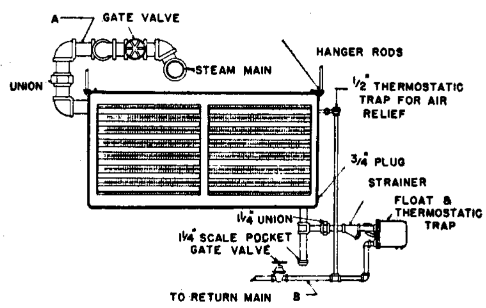


Fig. 1973. Typical connections for horizontal-tube unit heaters.

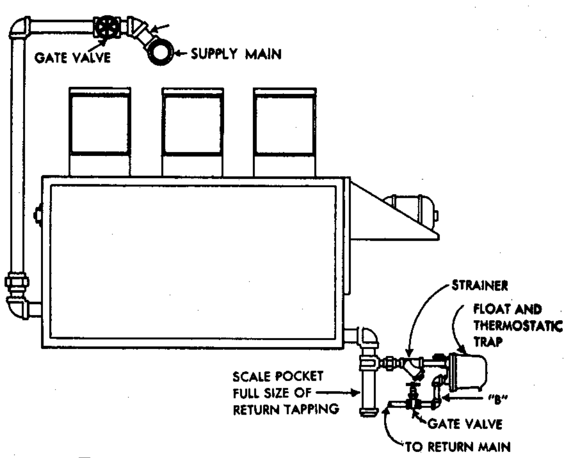


Fig. 1558. Typical connections for a large centrifugal fan type of unit heater.

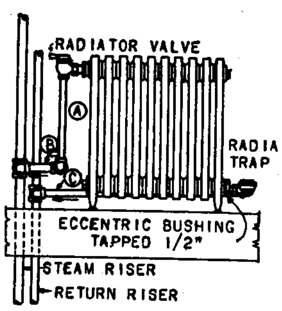


Fig. 808B. Connections where runouts are above the floor.

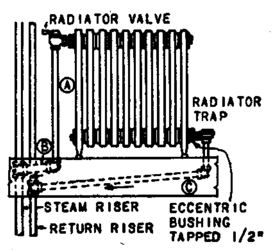


Fig. 809C. Connections where runouts are between floor and ceiling. Similar connections are used if runouts are below the ceiling.

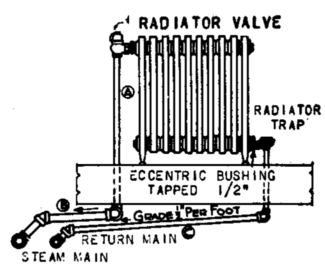


Fig. 813C. Spring pieces and connections for a first floor radiator.

TYPICAL CONVECTOR CONNECTIONS

Fig. 3407 to 3415 show typical connections to convector (concealed units). The piping from mains and risers is as for cast iron radiation (free standing).

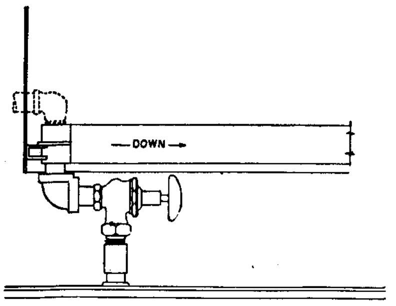


Fig. 3407. Using Angle Valve for Up-feed supply with Alternate Down-feed connections using Street Elbow.

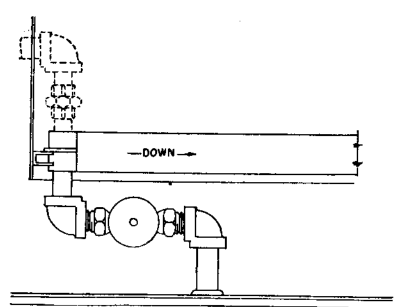


Fig. 3408. Using Straightway Valve for Up-feed supply with Alternate Down-feed connections using pipe union without Valve.

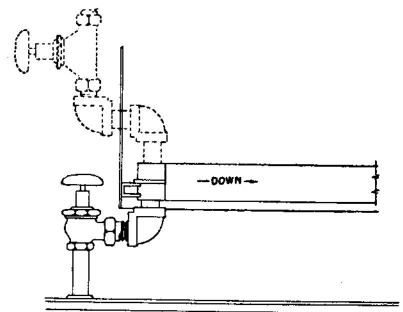


Fig 3409. Using Angle Valve for Up-feed connections with Alternate Down-feed connections using Non-offset Straightway Valve.

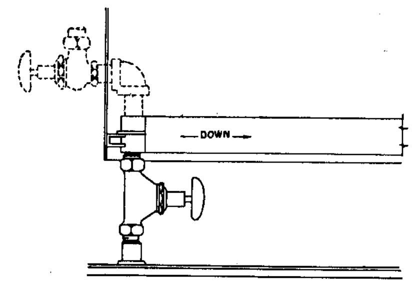


Fig. 3410. Using Non-offset Straightway Valve for Up-feed supply with Alternate Down-feed connections using Angle Valve.

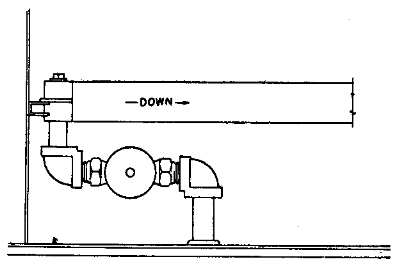


Fig. 3411. Using Straightway Valve.

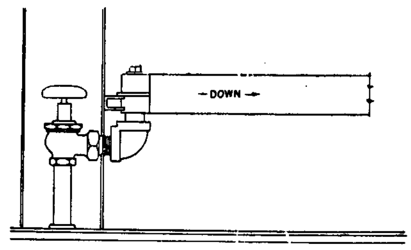


Fig. 3412. Using Angle Valve outside Recess when pipe space is provided.

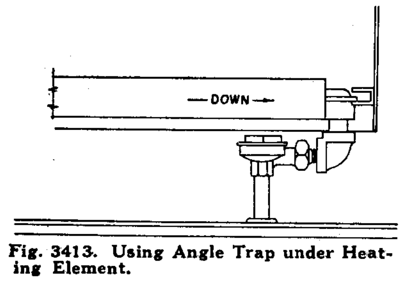


Fig. 3413. Using Angle Trap under Heating Element.

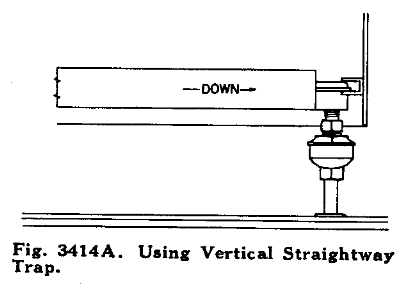


Fig. 3414A. Using Vertical Straightway Trap.

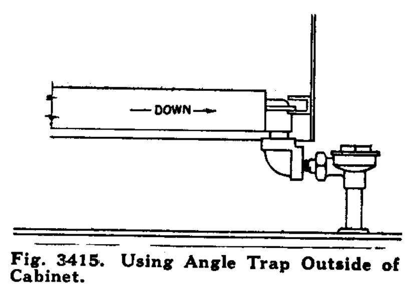


Fig. 3415. Using Angle Trap Outside of Cabinet.

GOOD PIPING PRACTICE

The successful and quiet operation of steam heating systems depends to a considerable extent on the proper grading of the piping system. The piping must be free of sags or pockets so that air may pass without obstruction from the steam piping and heating units to the return piping to be vented from the system. Fig. 872 and 1657 show right and wrong ways of piping installation.

Fig. 952 shows upfeed and downfeed connections from steam main.

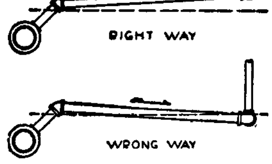


Fig. 872
Showing correct and incorrect grades of runouts.

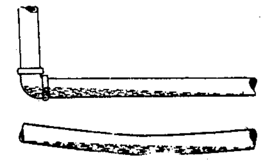


Fig. 1657
Typical water pockets resulting from improperly pitched or bent piping.

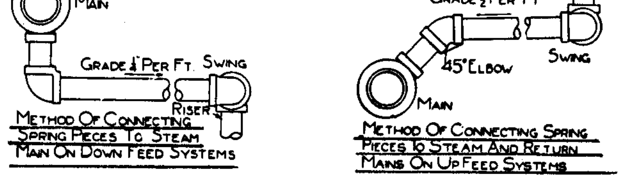


Fig. 952

PROVISION FOR EXPANSION

Sags and pockets may be caused in piping by the expansion of piping after installation and provision must be made to avoid these. Figs. 3364, 3365 and 3366 show methods of taking care of expansion in horizontal and vertical piping.

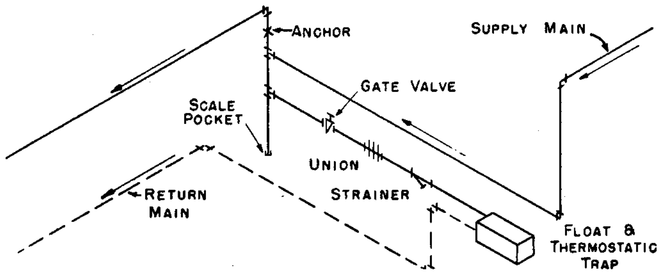


Fig. 3364. Expansion connection for horizontal steam piping.

EXPANSION CONNECTION FOR RISERS

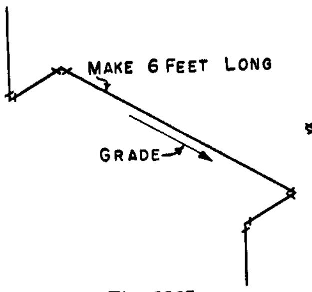


Fig. 3365

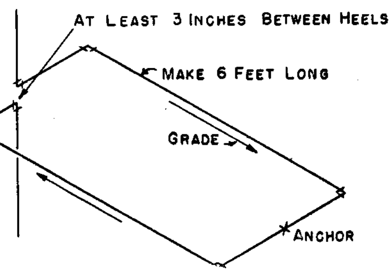


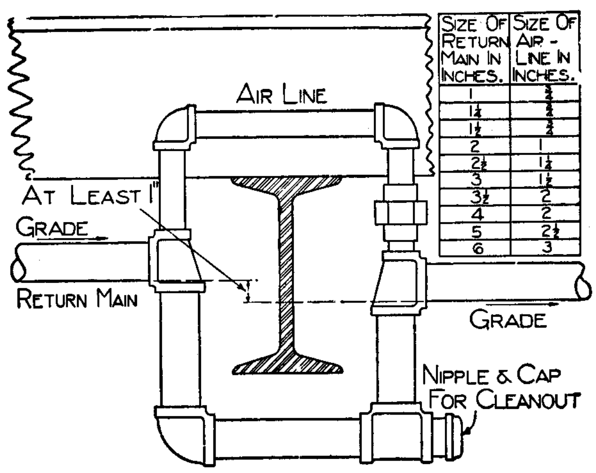
Fig. 3366

Figs. 3365 and 3366 will care for 50 ft. of piping above and below connection. Provide equal expansion in both directions. Riser should be anchored midway between each expansion connection.

Expansion may also be taken care of by packed expansions joints or joints of the packless type constructed of corrugated or bellows-like members. Consult manufacturers' catalogues for description and methods of applications.

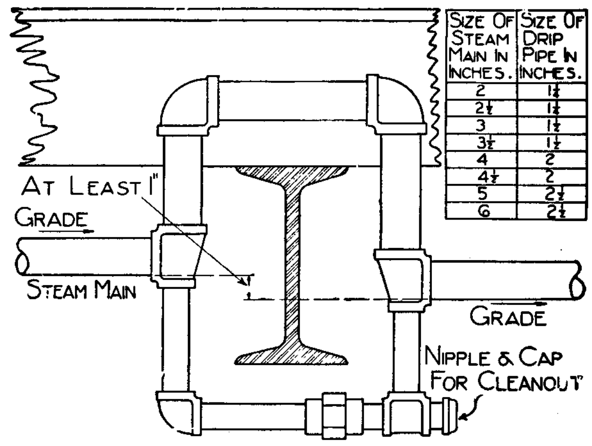
METHODS OF MEETING OBSTRUCTIONS

Certain conditions may make it necessary to pass piping across doors and windows or over and under beams. Fig. 949 and 948 show steam and return piping connections around beams. Fig. 3406 shows method of looping return around doorways or similar conditions where returns must be dropped but can be raised at a point farther along installation.



Size Of Return Main In Inches.	Size Of Air-Line In Inches.
1	¾
1¼	¾
1½	¾
2	1
2½	1¼
3	1½
3½	2
4	2
5	2½
6	3

Fig. 948. Method of looping return main around beam or other obstruction.



Size Of Steam Main In Inches.	Size Of Drip Pipe In Inches.
2	1¼
2½	1¼
3	1½
3½	1½
4	2
4½	2
5	2½
6	2½

Fig. 949. Method of looping steam main without dripping to boiler or using separate return.

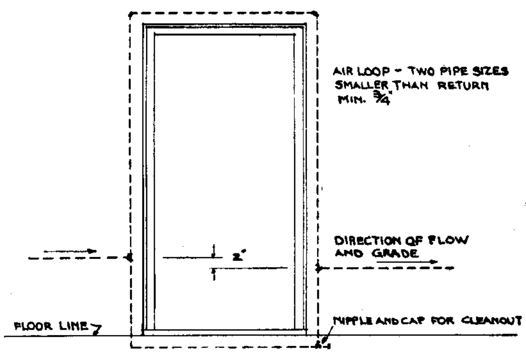


Fig. 3406. Method of crossing doorways with return piping. Low return pipe across doorway may be above floor protected by a "saddle" over it or may be installed in trench. Pipe should be protected against freezing when crossing outside doorways.

EQUALIZING CONNECTIONS

On systems with boilers fired with automatic combustion units and where steam is supplied through thermostatically operated control valves, it is advisable to install an equalizer connection between steam and return piping. This may be installed anywhere in systems, and this connection is shown by Fig. 1153. This connection permits rapid equalization of steam and return main conditions should the closing of control valve or retarding of combustion cause an induced vacuum on steam side of system. The check valve must be one that will remain tight so steam does not leak through it into return piping.

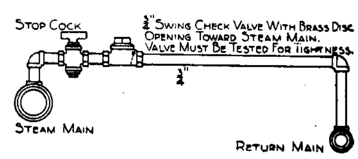


Fig. 1153. Equalizer.

VALVES IN PIPING

Globe valves should not be used in horizontal piping. Use gate valves only.

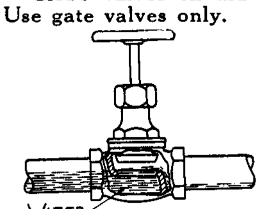


Fig. 950. Globe valve should not be used in horizontal line.

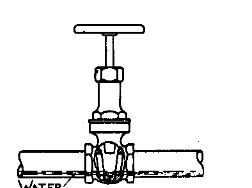


Fig. 951. Gate valve in horizontal run allows free passage of water.

Check valves should be of horizontal swing type with brass discs. Vertical lift check valves should never be used.

LIFT CONNECTIONS

On vacuum return line systems it is sometimes necessary to raise condensate from a low return piping system to one at a higher level. This may be accomplished by a "lift" connection as shown by Fig. 1181. The height of the "lift" should be not more than 6 ft., but "lift" connection may be installed in several steps when each step should be not more than 4 ft. The minimum vacuum to be maintained should be not less than 1 inch for every foot of lift in any one step. Fig. 958A shows lift connection from radiator below return main. The thermostatic trap should be installed above return main. Fig. 955A and 956A show lift connection at ends of steam mains using thermostatic trap and float and thermostatic trap.

Lift connections should not be used on differential vacuum systems since the differential between steam and return piping is only a few inches of vacuum, especially during milder weather conditions. However, lift connection is permissible between the accumulator tank outlet and pump suction. See Fig. 1181.

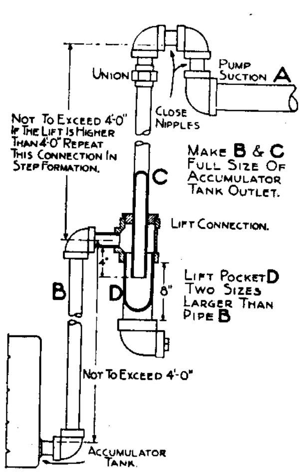


Fig. 1181. Showing how lift connection in vacuum return main may be built of pipe and fittings.

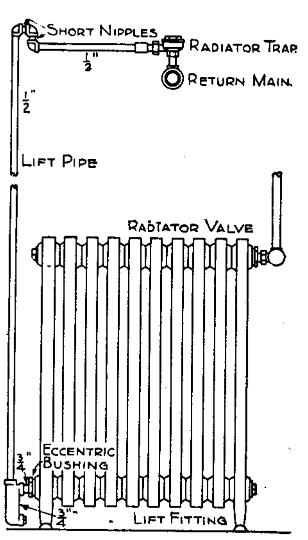


Fig. 958A. Lift fitting and trap location when radiator is below return main of vacuum return line system.

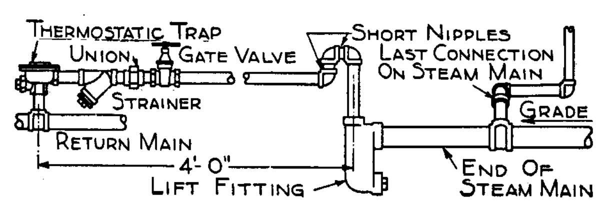


Fig. 955A. Drip connection using Thermostatic Trap to drain small steam main with drip point below return. Vacuum return line systems only.

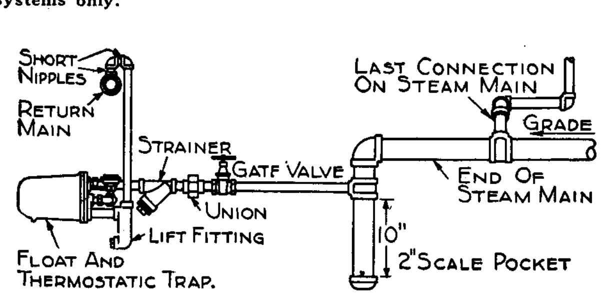


Fig. 956A. Drip connection using Float and Thermostatic Trap for draining steam main with drip point below return. Applies to vacuum return line systems only.

PIPE COILS

Pipe coil heating units, while not generally used in modern heating installations, have a place in greenhouse heating particularly, and Fig. 811C, 812, 816A and 817A show usual connections for pipe coil installations.

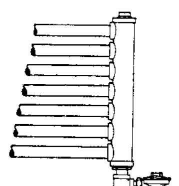


Fig. 811C. Trap used on vertical coil.

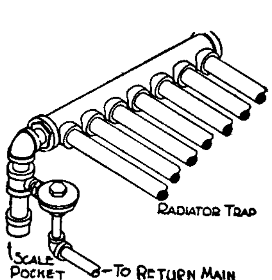


Fig. 812. Trap used on horizontal coil.

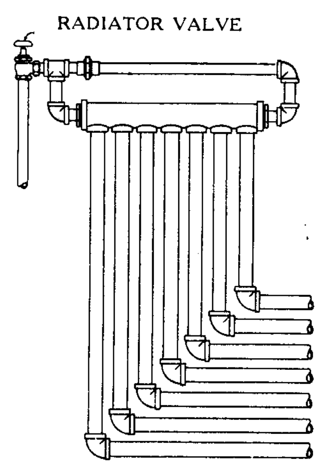


Fig. 816A. Supply connections to coils of seven pipes or more.

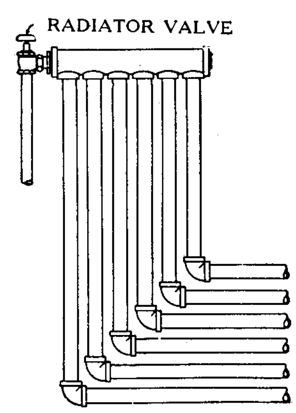


Fig. 817A. Supply connections to coils of six pipes or less.

BLAST HEATING AND VENTILATING UNITS

Typical steam and return piping connections to ventilating and air conditioning heating units are shown by Figs. 1200 and 1201.

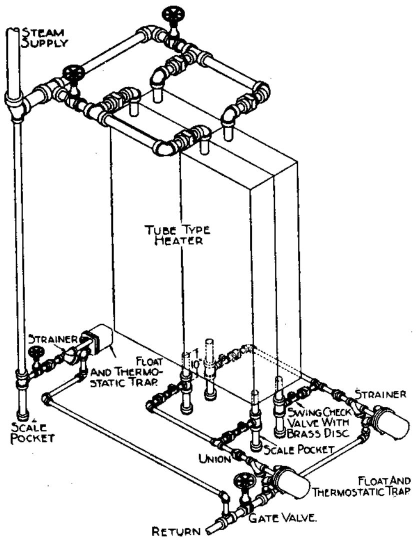


Fig. 1200. This method of connection is recommended for vertical tube type heaters. For detailed applications of temperature regulating equipment, consult manufacturers' catalogs.

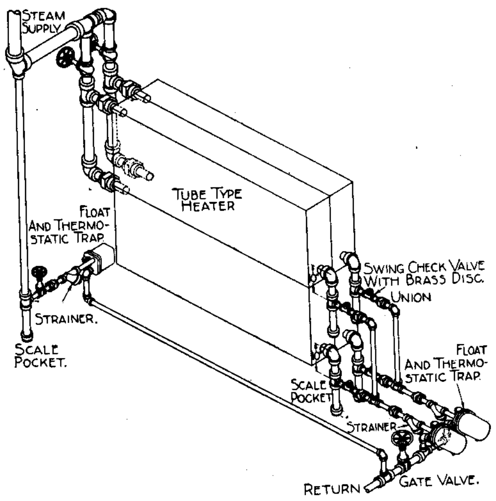


Fig. 1201. This method of connection is recommended for horizontal tube type heaters. For detailed applications of temperature regulating equipment, consult manufacturers' catalogs.

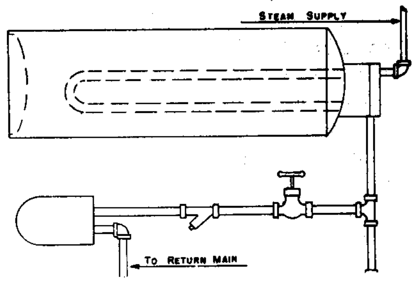


Fig. 3367. Float and Thermostatic Trap connections to storage tank water heater.

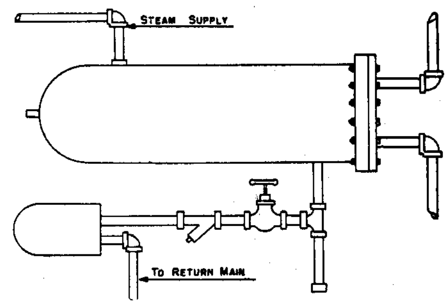


Fig. 3368. Float and Thermostatic Trap connections to instantaneous water heater or converter.

PRESSURE REDUCING VALVES

Where steam is generated in high pressure boilers it is necessary to reduce the pressure for low pressure heating equipment and the installation of pressure reducing valves is necessary. Pressure reducing valves should be selected for size by the load (pounds of steam) required per hour by the heating system and in accordance with the difference in steam pressure between that supplied to the valve and the reduced pressures required for the heating system. Pressure reducing valves should never be selected for size on the basis of the pipe size required for the heating system. Consult manufacturers' catalogues and capacity tables for proper data.

Pressure reducing valves are of double seated and single seated types with various arrangements of ports or openings in valve. The double seated types will provide closer regulation on varying initial pressure conditions but are not suited to "dead end" service, that is, where load is likely to be considerably restricted or entirely closed off. For this service use only single seated pressure reducing valves.

Figs. 1178 and 2053 show typical installation connections for pressure reducing valves. A by-pass should always be installed around each valve to facilitate repairs and to provide for emergency supply of steam in the event of failure of the valve. By-pass should generally be two sizes smaller than inlet size of valve. Gate valves should be installed on either side of pressure reducing valve to isolate it for inspection and repair. The control pipe should be connected into low pressure main at least 10 ft. from the valve. A water accumulator is advisable where very low reduced pressures and close regulation of reduced pressure is desired.

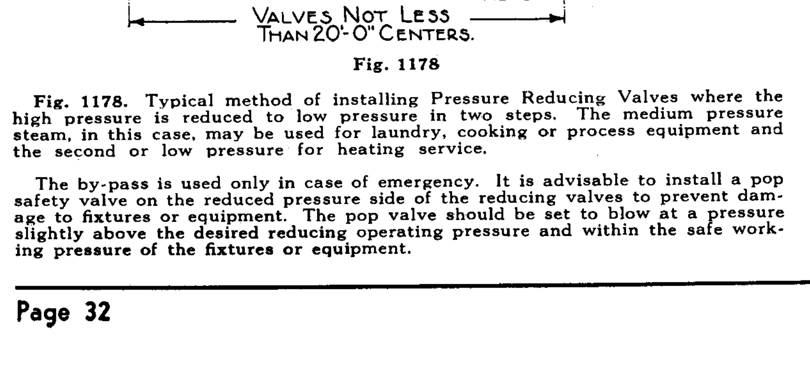


Fig. 1178

Fig. 1178. Typical method of installing Pressure Reducing Valves where the high pressure is reduced to low pressure in two steps. The medium pressure steam, in this case, may be used for laundry, cooking or process equipment and the second or low pressure for heating service.

The by-pass is used only in case of emergency. It is advisable to install a pop safety valve on the reduced pressure side of the reducing valves to prevent damage to fixtures or equipment. The pop valve should be set to blow at a pressure slightly above the desired reducing operating pressure and within the safe working pressure of the fixtures or equipment.

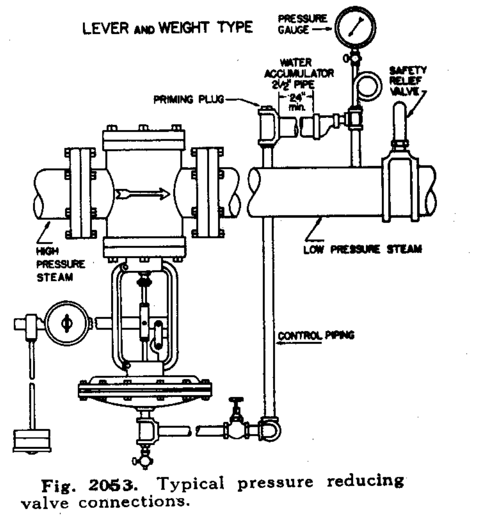


Fig. 2053. Typical pressure reducing valve connections.

FLASH TANKS

High pressure returns should not be connected to low pressure heating system returns.

Fig. 1041A shows application of flash tank when necessary to discharge condensate from higher pressure steam equipment into low pressure system vacuum return lines.

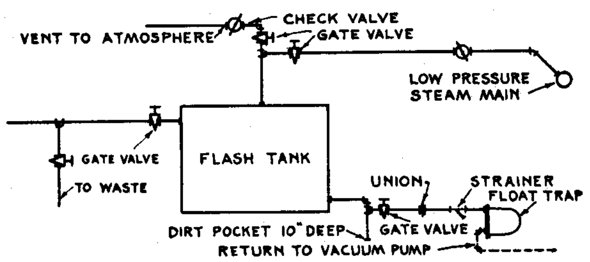


Fig. 1041A

It is advisable wherever possible to run separate return piping from high pressure equipment. However, where the amount of high temperature condensate is relatively small compared to the quantity of low pressure equipment condensation (say 10 or 15%) high pressure returns may be passed through a flash tank before passing into low pressure return piping.

The vent tapping of the flash tank is connected to the low pressure heating main. When high pressure condensate enters the flash tank which will be at the pressure condition of the low pressure steam main, some of the condensate will flash to steam in flash tank. This steam or vapor and air mixture will pass into steam main and condensate will cool to a temperature of boiling water at the lower pressure and pass out through float trap into vacuum return line.

Thermostatic or float and thermostatic traps are not suitable for draining where high temperature condensate discharges into vacuum return line from flash tanks. Traps with float valves only should be used. Air vents on high pressure equipment might be open when steam is closed off and air could pass through them into flash tank and through thermostatic feature of trap whereas if no condensate is returning to flash tank the float valve would be closed, sealing high pressure from low pressure return.

A check valve is necessary in connection from flash tanks to low pressure steam mains to prevent the steam passing into the high pressure equipment, and flash tank, when high pressure steam might be closed off.

The size of flash tank depends on amount and temperature of condensate to be handled. The minimum size of tank recommenned is 12" diameter x 12" long. A 1" vent tapping is usually sufficient and the inlet and outlet tappings to suit returns and trap requirements. Consult manufacturers' catalogues for float trap sizes and capacities.

For larger capacities the following tank sizes are suggested:

Pounds Condensate to be handled per Hour.	Size of Tank Dimensions in Inches. Dia.		Length
1000 lbs.	12"	x	12"
4000 lbs.	18"	x	18"
10000 lbs.	18"	x	24"
18000 lbs.	18"	x	36"

CONDENSATION METERS

Condensation meters provide a means to register the amount of steam used by various zones of a heating system or as a check on the amount of steam used for heating apart from process and other uses.

Condensation meters may be of the tilting bucket type or rotary type with several buckets of known volume arranged around the shaft. Each oscillation or rotation of the bucket assembly operates a calibrated counter mechanism which reads directly in pounds of condensation passed through the meter.

Condensation meters should always be selected according to maximum load requirements. If it is to be used with a vacuum pump, it should be of the vacuum type. The meter should be installed at a point in the return line where it will receive all condensate from the radiators and other steam using units and in a place convenient for reading and inspection. The meter will not measure steam or vapor in its gaseous state. The outlet piping from the meter must be so arranged that the condensate will flow away freely. Discharge to the meter from a receiving tank should be by gravity. When measuring the discharge from a vacuum pump, a vented receiver of ample capacity should always be installed ahead of the meter. The tank to be set horizontal and be of shallow depth so as to minimize increase in static head.

Where installing a meter in a vacuum return line served by a vacuum pump of the type where the float control does not independently start and stop the motor, great care must be taken that the water will not back up in the meter discharge pipe.

When condensation is to be measured after being discharged from a pump, the pump must discharge to a vented receiver of ample capacity set at least 12" above meter inlet so condensate can flow by gravity to the meter.

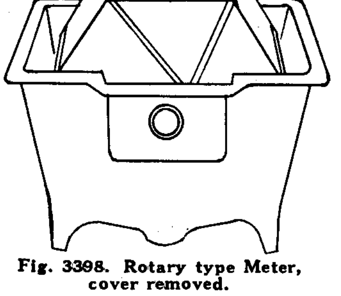


Fig. 3398. Rotary type Meter, cover removed.

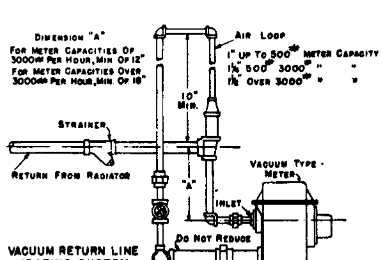


Fig. 3391

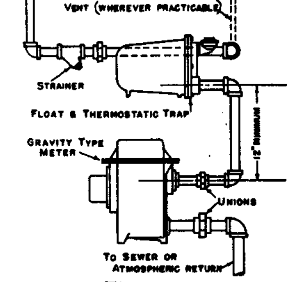


Fig. 3390

Gravity Heating System
Meter connection — gravity flow to meter—traps on all radiators or constant flow master trap on return.

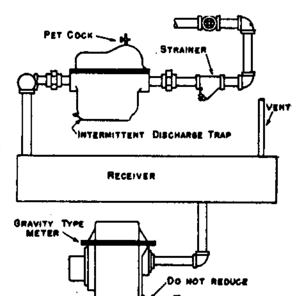


Fig. 3389

Gravity Heating System
Meter connection — gravity flow to meter — intermittent flow master trap.

THE DEGREE DAY METHOD OF COMPARING HEATING RESULTS

Often times it is of value to be able to formulate comparisons of heating loads of buildings in various sections of the country, or compare the cost of heating one building with the cost of heating another, or to compare the cost of heating a building for one heating season with another season, taking the difference in outside temperature into consideration. In making comparisons, care should be used that proper allowance is made to place each operation on an equal basis with the other to obtain a correct conclusion.

A study of actual building temperature made by the American Gas Association determined that when a building was maintained at 70° F. during daytime hours and the heating shut down during the night and a minimum temperature maintained of approximately 55° F., the daily mean indoor temperature averaged 65° F. It was also determined that when the outdoor temperature was lower than 65° F. artificial heat was required in the building.

From the studies made, the American Gas Association devised the "Degree Day" Method of establishing and comparing heating requirements and loads, the "Degree Day" being the product of one degree of temperature and one day of time.

The base temperature for establishing the degree days is 5° F. below daytime building temperatures. For instance:

For a 70° Day building temperature the degree day temperature is 65° F.
For a 60° Day building temperature the degree day temperature is 55° F.

The degree days for each day are determined by subtracting the mean of the minimum and maximum temperature recorded for the day from the degree day base temperature (daytime inside temperature minus 5° F.). For example: Assuming a day having a minimum temperature of 10° F. and a maximum of 40° F., the mean temperature would be 25° F. If this is subtracted from the degree day base temperature of 65° F., (assuming a daytime building temperature of 70° F.) then there would be 40 degree days.

$$65 - \left[\frac{(10 + 40)}{2}\right] = 40 \text{ degree days.}$$

Should it be possible to only secure the mean monthly temperature, then (65 Minus mean monthly temperature) times days in month would be the total degree days for the particular month.

The U. S. Weather Bureau tabulates and will furnish records of the daily mean temperatures and the A.S.H.V.E. GUIDE furnishes tables of "Normal" degree days for heating seasons for many towns and cities.

It may be desired to compare the cost of operation of a heating system from one month to another having decided difference in the average outside temperatures. The total number of degree days for each month may be calculated and quantity of fuel burned or steam condensed measured. From this data, a direct comparison of operation and quantity of fuel or steam consumed per degree day may be obtained for each month. The following is an example of this:

Example: For the month of December, the mean temperature was 25° F., 25,000 lbs. of coal were consumed to heat a building; and for January of the next year the mean temperature was 30° F., 24,000 lbs. of coal were consumed to heat the same building.

The results are calculated as follows:

Dec. (65° — 25°) × 31 days = 1240 degree days
Jan. (65° — 30°) × 31 days = 1085 degree days
Dec. 25,000 lbs. ÷ 1240 degree days = 20.16 lbs. per degree day
Jan. 24,000 lbs. ÷ 1085 degree days = 22.1 lbs. per degree day

From the above it is apparent that fuel was being wasted in January when compared with December, due to overheating the building or improper firing. If it is desired to calculate the waste on the percentage basis, it may be done as follows:

$$100 \times \left[\frac{(22.1 - 20.16)}{20.16}\right] = 9.6\%$$

It is sometimes required to compare different buildings of different heating loads with one another. These may be compared on a "Fuel per degree day per thousand E.D.R. Basis" or

$$\frac{\text{Fuel quantity} \times 1000}{\text{Radiation load} \times \text{degree days}}$$

Example:	Building (1)	Building (2)
Pounds fuel consumed	593600	198800
Equivalent direct Radiation Loads	7639 sq. ft.	3538 sq. ft.
Degree days for Period	7148	6300

Building (1)

$$\frac{593600 \times 1000}{7639 \times 7148} = 10.15 \text{ lbs. per degree day per 1000 sq. ft. EDR.}$$

Building (2)

$$\frac{198800 \times 1000}{3538 \times 6300} = 9.3 \text{ lbs. per degree day per 1000 sq. ft. EDR.}$$

The comparison indicates that building No. 2 is more economical on fuel than building No. 1 assuming other building conditions are equal.

ENGINEERING DATA

STEAM MEMORANDA

A cubic inch of water evaporated is converted into 1 cubic foot of steam (approximately).

The density of steam at atmospheric pressure is 0.03732 lbs. per cu. ft.

26.79 cubic feet of steam weigh 1 pound; 13.817 cubic feet of air weigh 1 pound.

Locomotives average a consumption of 3,000 gallons of water per 100 miles run.

The best designed boilers, well set, with good draft, and skillful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

On 1 square foot of grate an average of from 10 to 12 pounds of hard coal can be burned, or 18 to 20 pounds of soft coal per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Steam engines, in economy, vary from 14 to 60 pounds of steam and from 1½ to 7 pounds of coal per hour indicated horsepower.

Condensing engines require from 20 to 30 gallons of water, at an average low temperature, to condense the steam represented by every gallon of water evaporated in the boilers supplying the engines—approximately for most engines, we say, from 1 to 1½ gallons condensing water per minute, per indicated horsepower.

Steam: Since a pound of steam at atmospheric pressure (14.7 pounds per square inch) occupies a space of more than 26 cubic feet, and a pound of water occupies only about 28 cubic inches, it follows that if a vessel, such as a steam boiler containing water and steam, is closed so that the steam is confined and each pound is not allowed to expand to this 26 cubic feet, a pressure above that of the atmosphere will be produced. The water will now boil at a higher temperature corresponding to the higher pressure.

On the other hand, if a vessel containing steam at atmospheric pressure is closed, and the fire checked, the temperature of the steam will be lowered, and each pound will tend to occupy less than 26 cubic feet. This it cannot do because, owing to the elastic quality of steam, it completely fills the available space at a lesser density, and a partial vacuum is the result. This partial vacuum permits the water to boil at a lower temperature than 212 degrees.

For every pressure of the steam there is a definite temperature at which the water will boil.

Steam, Volume of: If water at 39.2 degrees Fahrenheit is evaporated into steam at atmospheric pressure, the volume of steam will be 1,646 times as great as the volume of water from which it was evaporated.

If water at boiling point is evaporated into steam at atmospheric pressure, the volume of steam will be 1,577 times as great as the volume of water from which it was evaporated.

In other words, a cubic inch of water will produce almost a cubic foot of steam or vapor.

Properties of Saturated Steam

Vacuum Inches of Mercury	Absolute Pressure Lbs. per Sq. Inch	Boiling Point, or Steam Temp.	Volume of 1 Lb. of Steam Cu. Ft.	Heat of the Liquid Btu	Latent Heat of Evap. Btu	Total Heat of Steam Btu
29	.452	76.62	706.	44.66	1048.6	1093.2
28	.944	99.93	351.5	67.90	1035.6	1103.6
27	1.435	114.22	236.8	82.15	1027.7	1109.8
26	1.926	124.77	179.5	92.67	1021.7	1114.4
25	2.417	133.22	145.0	101.10	1017.0	1118.1
24	2.908	140.31	121.9	108.18	1012.9	1121.1
23	3.399	146.45	105.4	114.31	1009.4	1123.8
22	3.890	151.87	92.9	119.73	1006.3	1126.0
21	4.382	156.75	83.1	124.61	1003.5	1128.1
20	4.873	161.19	75.2	129.05	1001.0	1130.0
19	5.364	165.24	68.7	133.10	998.6	1131.7
18	5.855	169.00	63.3	136.86	996.4	1133.3
17	6.346	172.51	58.7	140.38	994.3	1134.7
16	6.837	175.80	54.7	143.67	992.4	1136.1
15	7.329	178.91	51.3	146.79	990.6	1137.4
14	7.82	181.82	48.30	149.71	988.8	1138.5
13	8.31	184.61	45.61	152.50	987.1	1139.6
12	8.80	187.21	43.27	155.11	985.6	1140.7
11	9.29	189.75	41.12	157.66	984.0	1141.7
10	9.78	192.19	39.16	160.10	982.6	1142.7
9	10.28	194.50	37.41	162.42	981.2	1143.6
8	10.77	196.73	35.81	164.65	979.9	1144.5
7	11.26	198.87	34.35	166.81	978.5	1145.3
6	11.75	200.96	32.99	168.90	977.2	1146.2
5	12.24	202.92	31.77	170.87	976.0	1146.9
4	12.73	204.85	30.62	172.81	974.8	1147.6
3	13.22	206.70	29.56	174.67	973.7	1148.4
2	13.71	208.50	28.58	176.48	972.5	1149.1
1	14.20	210.25	27.67	178.24	971.4	1149.7
Pounds Gauge						
0	14.70	212.0	26.79	180.00	970.4	1150.4
1	15.70	215.3	25.20	183.3	968.2	1151.6
2	16.70	218.5	23.78	186.6	966.2	1152.8
4	18.70	224.4	21.40	192.5	962.4	1154.9
6	20.70	229.8	19.45	198.0	958.8	1156.8
8	22.70	234.8	17.85	203.0	955.5	1158.6
10	24.70	239.4	16.49	207.7	952.5	1160.2
15	29.70	249.8	13.87	218.2	945.5	1163.7
25	39.70	266.8	10.57	235.6	933.6	1169.2
50	64.70	297.7	6.68	267.2	911.2	1178.4
75	89.70	320.1	4.91	290.3	894.2	1184.4
100	114.70	337.9	3.891	308.8	880.0	1188.8
125	139.70	352.9	3.225	324.4	867.8	1192.2

Interpolated from Marks and Davis Temperature Tables. For more complete tables see the current issue of A.S.H.V.E. GUIDE.

Flow of Steam in Pipes

P = Loss in pressure in lb.
d = Actual inside diameter of pipe in inches
L = Length of pipe in feet including allowance for elbows and valves (see table, page 81)
D = Weight of 1 cu. ft. steam
W = lb. of Steam per Min.

$$W = 87.0 \sqrt{\frac{PDd^5}{\left(1+\frac{3.6}{b}\right)L}}$$

$$P = 0.000132 \left(1+\frac{3.6}{d}\right)\frac{W^2L}{Dd^5}$$ Babcock Formula

Press Loss in Oz.	Col. 1 $87.0\sqrt{\frac{P}{100}}$	Pipe Size	Col. 2 $\sqrt{\frac{d^5}{1+\frac{3.6}{d}}}$	Steam Press by Gauge	Col. 3 $\sqrt{D}$	Length of Pipe in Feet	Col. 4 $\sqrt{\frac{100}{L}}$
1	2.175	1	0.536	0.0	0.193	20	2.240
2	3.076	1¼	1.178	0.3	0.195	40	1.580
3	3.767	1½	1.828	1.3	0.201	60	1.290
4	4.350	2	3.710	2.3	0.207	80	1.120
5	4.863	2½	6.109	5.3	0.223	100	1.000
6	5.328	3	11.183	10.3	0.248	120	0.912
7	5.755	3½	16.705	15.3	0.270	140	0.841
8	6.152	4	23.631	20.3	0.290	160	0.793
10	6.878	5	43.719	30.3	0.326	180	0.741
12	7.534	6	71.762	40.3	0.358	200	0.710
14	8.138	8	149.382	50.3	0.388	250	0.632
16	8.700	10	272.592	60.3	0.415	300	0.578
20	9.727	12	437.503	75.3	0.452	350	0.538
24	10.655	14	566.693	100.3	0.507	400	0.500
28	11.509	16	816.872	125.3	0.557	450	0.477
32	12.304	....	....	150.3	0.603	500	0.447
40	13.756	....	....	175.3	0.645	600	0.407
48	15.069	....	....	200.3	0.685	700	0.378
80	19.454	....	....	....	....	800	0.354
160	27.512	....	....	....	....	900	0.333
320	38.908	....	....	....	....	1000	0.316
480	47.652	....	....	....	....	1500	0.258

Multiply columns 1 × 2 × 3 × 4 = lb steam per min. that will flow through a straight pipe for a given condition.

Example. 1 oz. drop, 2 in. pipe, 1.3 lb pressure and 100 ft. long = 2.175 × 3.710 × 0.201 × 1 = 1.6219 lb per min. then 1.6219 × 60 — 20 per cent = 77.85 lb of steam per hr.

Preceding table does not allow for entrained water in low-pressure steam, condensation in covered pipe and roughness in commercial pipe, therefore reduce calculated capacities approximately 20 per cent.

From A. S. H. & V. E. Guide.

Chart showing loss of pressure when a given amount of steam per minute is delivered through a pipe of given size

Logrithmic Steam Flow Chart by Professor H. V. Carpenter from Mechanical Equipment of Buildings, by Harding and Willard

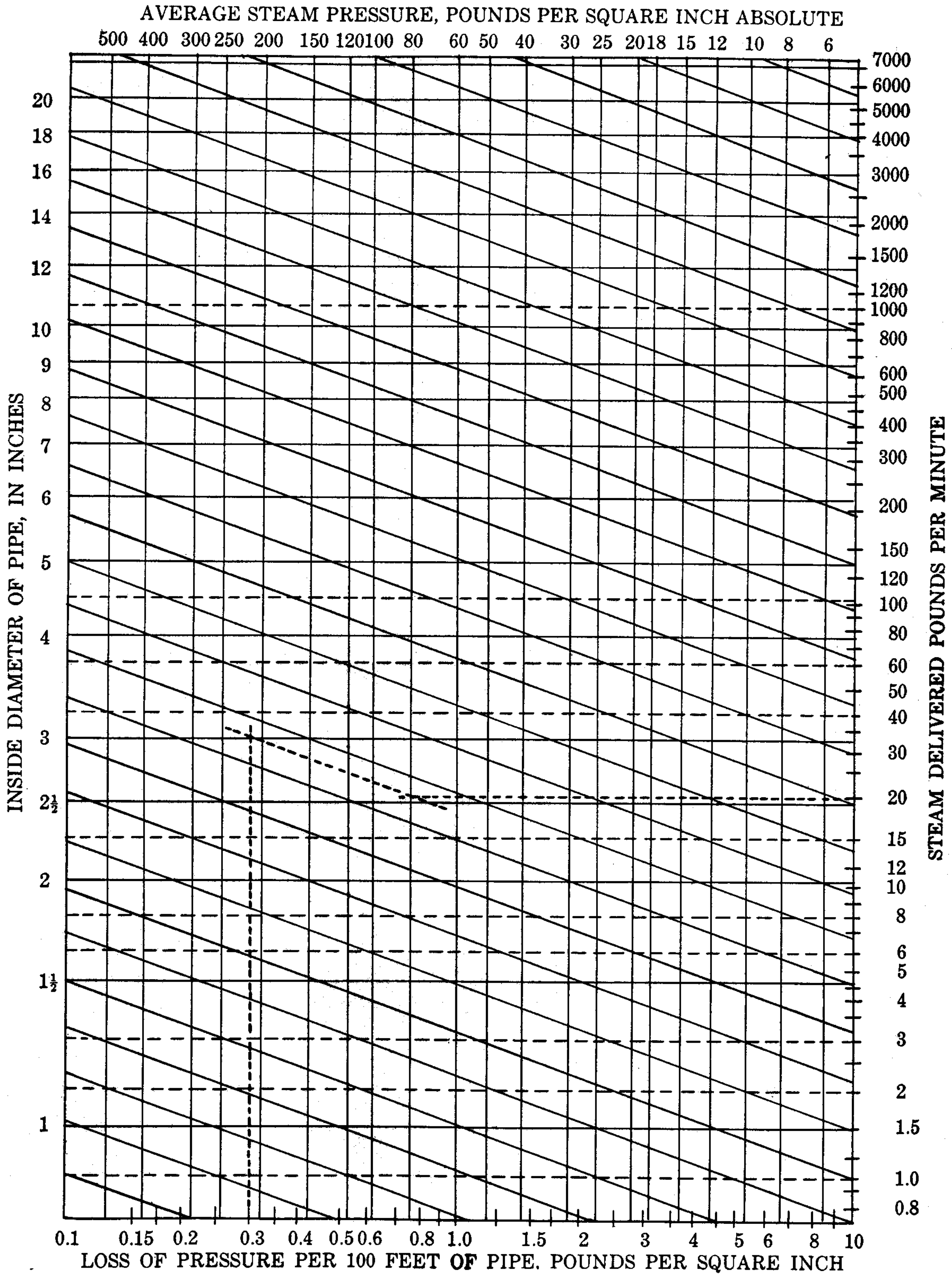


Fig. 3419

Examples. Follow the heavy dotted lines, and assume an allowable pressure loss of 0.3 lb. per 100 ft. for a 3-in. pipe at an average pressure of 80 lb. absolute. The weight of steam delivered will be 21 lb. per min. Again, assume a drop of 1 lb. per 100 ft. for a 10-in. pipe delivering 860 lb. per min. The average absolute pressure must be 60 lb. per sq. in. Finally, assume a 20-in. pipe is delivering 4,000 lb. per min. at an average absolute pressure of 250 lb. per sq. in. The drop in pressure will be 0.15 lb. per 100 ft. of pipe.

STEAM CONSUMPTION OF PROCESS EQUIPMENT

The following data on steam consumption of laundry, kitchen and hospital equipment was selected from data compiled by the National District Heating Association and published in their "Proceedings" of 1942.

Sources of data on steam requirements of other process steam equipment were varied. They are listed in the "Proceedings," N.D.H.A. '42.

KITCHEN EQUIPMENT

	Operating Pressure Pounds Gauge	Pounds Steam Per Hour	
		Max.	In Use
Steam Jacket Kettles			
40 Gal. Cap. American Aluminum Co.	8	55	......
Full Jacket Cast Iron Kettle at Various Steam Pressures	2	62	24
	5	133	36
	10	174	97
	15	228	116
Half Jacket, Cast Iron Kettle at Various Steam Pressures	2	38	16
	15	43	24
Candy Kettles			
Per sq. ft. of Jacket	30	60	......
Per sq. ft. of Jacket	75	100	......
Dish Warmers			
Size 5'6" x 9" x 5'4", Htg. Surface, 25.02 sq. ft. Htg. Element, Inside Temp. 149°F.	2	16	15
Steam Tables			
Size 3'3" x 1'9" x 5" Deep, Htg. Surface 0.99 Sq. Ft.	2	31	14
Same Table at 5 lbs. Press.	5	32	20.5
Size 9'0"x22"x8", 3.33 sq. ft. Copper Element	8	70	......
Size 6'9" x 28"	....	......	24
Size 9'0" x 28"	....	......	32
Compartment Cookers			
Three Compartment	....	......	75
Bain Marie			
Size 9'0" x 18"	....	......	41
Coffee and Hot Water Urns			
Test on 8 Gal Urn, 1.66 Sq. Ft. Brass Element at Various Pressures	5	46	10
	10	85	40
	15	120	75
3.32 Sq. Ft. Brass Element at Various Pressures	2	43	13
	5	75	25
	10	144	57
	15	150	75
	25	200	139

APPROXIMATE UNIT STEAM CONSUMPTION OF KITCHEN APPLIANCES

Appliance	Lb. Steam per Hour
Stock and Vegetable Kettles (per 5 gal.)	20.0
Coffee Urns (per gal.)	3.4
Water Urn (per gal.)	5.0
Steam Tables (per sq. ft.)	1.7
Plate and Cup Warmers (per 20 cu. ft.)	35.0
Vegetable Steamers (per compt.)	40.0
Soup Warmer, 30" x 30" x 28"	100.0
Clam, Lobster, and Potato Steamers (per compt.)	40.0
Egg Boilers (3 compts.)	18.0
Oyster Pots	18.0
Bain Marie (per sq. ft.)	3.4
Food Warming Ovens (per 20 cu. ft.)	35.0
Silver Burnisher and Washer	69.0
Dish Washer (per tray)	60.0

Note: Above figures represent average operating conditions after warm-up period and do not include hot water. Pressures will vary from 7 to 20 lb. gauge.

HOSPITAL EQUIPMENT

	Cap. Bottles	Depth of Water	Operating Pressure Pounds Gauge	Pounds Steam Per Hour	
				Max.	In Use
Sterilizers (Non-Pressure Type)					
For Bottles or Pasteurization Start with water at 70°. Then Maintained at Boiling for Period of 20 Min.	36	3"	40	36	36
	54	3"	40	51	51
	72	3"	40	69	69
For Instruments and Utensils	Size				
Start with Water at 70°, Then Boil Vigorously for 20 Minutes	8"x 9"x18"	3½"	40	27	27
	9"x20"x10"	3½"	40	30	30
	10"x12"x22"	4"	40	39	39
	12"x16"x24"	4"	40	60	60
	10"x12"x36"	4"	40	66	66
	16"x15"x20"	10"	40	92	92
	20"x20"x24"	10"	40	144	144
Sterilizers (Pressure Type)	Size				
For Surgical Supplies. Sterilizing, Period, 30 Minutes at Temperature of 240°-250° F.	12"x20"		40	22	22
	14"x22"		40	28	28
	16"x24"		40	38	38
	16"x36"		40	54	54
	20"x28"		40	60	60
	20"x36"		40	78	78
	20"x48"		40	98	98
	20"x60"		40	124	124
	10"x20"		35-60	9.5	9.5
	24"x48"		35-60	50.0	50.0
For Instruments. Sterilizing Period, 20 Minutes at 240°-250°F.	12"x20"		40	48	48
	14"x22"		40	60	60
	16"x24"		40	72	72
Sterilizers (Pressure Type) (Autoclave)	Size				
Sterilizing Period, 30 Minutes at 240°-250°	15½"x24"		40	24	24
	17½"x26"		40	32	32
	21½"x30"		40	40	40
	24"x36"		35-60	42	42
Water Sterilizers	Cap., Gals.				
Start With Water at 70° and Maintain at Temperature of 240°-250° for 15 Minutes	6		40	76	76
	10		40	120	120
	15		40	180	180
	25		40	300	300
	50		40	600	600
Unit Requirements for Water Sterilizer = 2.5 lb. steam per Gal. Sterilized			35-60	......	......
Mattress Disinfector					
Size 30"x42"x84"			35-60	......	42
Size 60"x66"x108"			35-60	......	318
Blanket Warmer					
Size 18"x24"x72"			35-60	......	4

TANNERY EQUIPMENT

	Operating Pressure Pounds Gauge	Pounds Steam Per Hour	
		Max.	In Use
Lime Vat (Cap. 800 Gal. per Vat) Per Set of 3 Vats	......	697	......
Paddle Vat (Cap. 1000 Gal.)	......	448	......
Revolving Drums	......	531	......
Iron Plate on Press. 9" Coil Plate is 2'6"x2'6" at 150°	......	100	......

CLOTHING MANUFACTURING EQUIPMENT

	Operating Pressure of Equipment Pounds Gauge	Pounds Steam Per Hour Max.	In Use
Cloth Sponging			
1 Sponging Machine			
1 Refinishing Roll			
1 Semi-decating unit			
1 Manifold			
1 Wetting-out tank for cold water shrinking			
1 Drier			
Total Load	90-100	......	1,000
1 Under Press	65	......	20
1 Steam Iron (Standard)	....	......	15
Hosiery Dyeing			
24 Hosiery Drying Forms—Total per Table of 24 Forms	40	......	60
Mfg. of Men's Clothing			
16 Presses (With Central Elec. Vac.)			
3 Shoulder Presses			
2 Collar Presses			
4 Edge Presses			
5 Body Presses			
2 Back Presses			
16 Operated by Five Men	65	......	122
8 Under Presses, Central Electric Vacuum	65	......	103
120 Lineal Ft., 2", Insulated Main	65	......	37
Avg. Unit Use per Press	65	......	7.6
Avg. Unit Use per Under Press	65	......	12.9

LAUNDRY EQUIPMENT

	Operating Pressure Pounds Gauge	Pounds Steam Per Hour Max.	In Use
Tumbler (Drying Machine)			
Size 40"x94"	80-100	......	360
Size 30"x36"	80-100	......	225
Mangle (Flat Work Ironer)			
Size 8 roll	80-100	......	480
Size 6 roll	80-100	......	415
Large Shirt Body Press	80-100	......	190
Cuff and Neck Band Press	80-100	......	15
Standard Press	80-100	......	105
Feather cleaning and sterilizing (Cap. 15 pillows per hour)	80-100	......	175
1 Mangle, Amer. Laundry			
5 Presses			
1 Sleever			
1 Sock Drier			
1 Dry Tumbler			
Total Group Use	90	......	......
Line Loss Only	90	......	......
Washers, 3'0" Diameter	60	......	......
Washers, 6'0" Diameter	170	......	......
50 Gal. Starch Kettle	60	......	......

CLEANING AND PRESSING EQUIPMENT

Clothes Presses	Operating Pressure Pounds Gauge	Pounds Steam Per Hour Max.	In Use
U. S. Hoff-Man (Electric Vacuum)	18	......	25
U. S. Hoff-Man (Electric Vacuum)	30	......	25
Large Press. (Steam Vacuum)	65	......	30
Large Press. (Elec. Vacuum)	65	......	20

	Operating Pressure of Equipment Pounds Gauge	Pounds Steam Per Hour Max.	In Use
Individual use per Steam-Electric Iron	35	......	8.4
Individual use per Press	42	......	12.2
Individual use per Sleever	45	......	5

WATER MEMORANDA

Doubling the diameter of a pipe increases its capacity 4 times. Friction of liquids in pipes increases as the square of the velocity.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to ½ pound pressure per square inch; this allows for ordinary friction.

Weight of One Cubic Foot of Pure Water

At 32 degrees Fahr. (freezing point) .... 62.418 lbs.
At 39.1 degrees Fahr. (maximum density) .... 62.425 lbs.
At 62 degrees Fahr. (standard temperature) .... 62.355 lbs.
At 212 deg. Fahr. (boiling point, under 1 atmosphere) .. 59.76 lbs.
Imperial gallon = 277.274 cubic in. of water at 62° Fahr. . 10. lbs.
U. S. gallon = 231 cubic in. of water at 62° F .... 8.3356 lbs.
Water expands in bulk from 40 degrees to 212 degrees .... = One twenty-third.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic foot of steam (approximately).

Friction of Water in Pipes

Loss of Head in Feet Due to Friction, per 100 Feet of New, Smooth, Wrought Iron Pipe

Multiply the friction loss in feet by 0.433 to give equivalent loss of pressure in pounds.

Gal. per Minute	½ Inch Pipe	¾ Inch Pipe	1 Inch Pipe	1¼ Inch Pipe	1½ Inch Pipe	2 Inch Pipe	2½ Inch Pipe	3 Inch Pipe	4 Inch Pipe	5 Inch Pipe	6 Inch Pipe	8 Inch Pipe	10 Inch Pipe
5	29.00	7.50	2.32	0.60	0.28	0.09	0.05	.....	.....	.....	.....	.....	.....
10	.....	27.10	8.40	2.18	1.02	0.36	0.12	0.05	.....	.....	.....	.....	.....
15	.....	57.00	18.90	4.65	2.25	0.81	0.25	0.11	.....	.....	.....	.....	.....
20	.....	97.00	30.10	7.90	3.70	1.29	0.43	0.18	.....	.....	.....	.....	.....
25	.....	.....	45.50	11.90	5.60	1.96	0.66	0.27	.....	.....	.....	.....	.....
30	.....	.....	64.00	16.90	7.80	2.73	0.92	0.38	.....	.....	.....	.....	.....
40	.....	.....	109.00	28.50	13.30	4.68	1.57	0.65	0.16	.....	.....	.....	.....
50	.....	.....	.....	43.20	20.20	7.10	2.38	0.98	0.24	.....	.....	.....	.....
75	.....	.....	.....	.....	42.70	14.90	5.07	2.11	0.52	0.17	.....	.....	.....
100	.....	.....	.....	.....	73.00	25.60	8.60	3.52	0.88	0.29	0.10	.....	.....
125	.....	.....	.....	.....	.....	38.90	13.01	5.40	1.33	0.46	0.20	.....	.....
150	.....	.....	.....	.....	.....	54.00	18.72	7.72	1.82	0.63	0.23	.....	.....
175	.....	.....	.....	.....	.....	92.10	23.70	9.75	2.40	0.84	0.34	.....	.....
200	.....	.....	.....	.....	.....	.....	30.90	12.80	3.12	1.06	0.44	.....	.....
225	.....	.....	.....	.....	.....	.....	44.30	16.00	4.72	1.33	0.53	.....	.....
250	.....	.....	.....	.....	.....	.....	.....	19.70	4.80	1.60	0.66	.....	.....
275	.....	.....	.....	.....	.....	.....	.....	23.60	5.71	1.94	0.82	.....	.....
300	.....	.....	.....	.....	.....	.....	.....	27.10	6.70	2.25	0.92	.....	.....
350	.....	.....	.....	.....	.....	.....	.....	.....	8.44	2.92	1.15	0.28	.....
400	.....	.....	.....	.....	.....	.....	.....	.....	10.92	3.72	1.50	0.37	.....
450	.....	.....	.....	.....	.....	.....	.....	.....	13.88	4.62	1.87	0.46	.....
475	.....	.....	.....	.....	.....	.....	.....	.....	14.34	5.06	2.16	0.49	.....
500	.....	.....	.....	.....	.....	.....	.....	.....	17.16	5.55	2.22	0.57	.....
550	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.60	3.93	0.97	.....
600	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.90	4.12	1.06	.....
650	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.20	4.25	1.10	.....
700	.....	.....	.....	.....	.....	.....	.....	.....	.....	10.90	4.82	1.17	.....
750	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.28	5.11	1.22	0.42
1000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.98	2.17	0.74
1500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.84	1.62
2000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.70	2.84

Pressure for Different Heads of Water at 62 Degrees Fahr.

1 foot head = 0.43302 lb per sq. in. 1 inch head = 0.5774 ounces per sq. in.

Inches of Water to Ounces Per Square Inch

Head, inches..	1	2	3	4	5	6	7	8	9	10	11	12
Pressure, inches	.577	1.15	1.73	2.31	2.89	3.46	4.04	4.62	5.20	5.77	6.35	6.93

Head of Water at 62 Degrees Fahr. Corresponding to Different Pressures

pound per sq. in. = 2.3095 feet head. 1 ounce per sq. in. = 1.732 of water

Ounces per Square Inch to Inches of Water

Pressure, ounces..	1	2	3	4	5	6	7	8
Head, inches.....	1.73	3.46	5.20	6.93	8.66	10.39	12.12	13.85
Pressure, ounces..	9	10	11	12	13	14	15	16
Head, inches.....	15.59	17.32	19.05	20.78	22.52	24.25	25.98	27.71

Friction of Water in 90° Elbows and the Equivalent Number of Feet Straight Pipe

Size of Elbow, inches	½	¾	1	1¼	1½	2	2½	3	4	5	6
Friction Equiv. Feet Straight Pipe....	5	6	6	8	8	8	11	15	16	18	18

CAPACITIES OF COPPER TUBING — STEAM HEATING SYSTEMS

Capacities of copper tubing when used on Steam Heating System may be taken to equal those of standard steel pipe of same nominal sizes. While it is true that internal areas of copper tubing are generally less than those of steel pipe of same nominal sizes, the smoother inside surface and the freedom from fouling due to absence of rust and corrosion compensate for the slightly smaller areas.

Some authorities advise that satisfactory results may be obtained when using copper tubing by increasing the capacities given for steel pipe by the following percentage for relative nominal diameters and when used with solder or compression type fittings.

1", 1¼", 1½" sizes increase 5% to 10%
2", 3", 3½", 4" sizes increase 15%
2½" size increase 24%

The above data taken from Copper Tube Hand Book issued by the Copper & Brass Research Ass'n. The relative areas of standard steel pipe and copper tubing are given in following table when considering Type M hard copper tube.

COMPARATIVE INTERNAL DIAMETERS AND AREAS
STEEL PIPE AND COPPER TUBE

Nominal Size	Internal Dia. Ins.		Internal Area Sq. Ins.	
	Steel Pipe	Copper Tube	Steel Pipe	Copper Tube
⅛	.270	.200	.057	.031
¼	.364	.325	.104	.083
⅜	.493	.450	.191	1.59
½	.622	.569	.304	.254
⅝	....	.690	....	.374
¾	.824	.811	.533	.516
1	1.048	1.055	.861	.874
1¼	1.380	1.291	1.496	1.309
1½	1.610	1.527	2.036	1.831
2	2.067	2.009	3.356	3.170
2½	2.468	2.495	4.780	4.890
3	3.067	2.981	7.383	6.980
3½	3.548	3.459	9.887	9.397
4	4.026	3.935	12.730	12.161
5	5.045	4.907	19.986	18.911
6	6.065	5.881	28.890	27.163
8	7.981	7.785	50.027	47.600
10	10.018	9.701	78.823	73.913
12	12.000	11.617	113.098	105.992

NOTE: Internal diameters and areas for Types K and L tubing will be slightly less than those for M tubing.

For the approximate capacity of copper tubes for water mains with allowances made for fittings are given in table following:

APPROXIMATE CAPACITY OF COPPER TUBE IN U. S. GALLONS PER MINUTE

Tube Size	⅜"		½"		⅝"		¾"		1"	
Pressure Drop Lbs. P.S.I.	S	L	S	L	S	L	S	L	S	L
5	3	0.7	6	2	10	3	14	5	35	11
10	4	1.0	10	3	17	5	25	7	50	17
20	6	2.0	14	4	24	7	35	11	70	25
30	8	2.5	16	5	30	9	45	14	90	30
40	9	2.7	18	6	36	11	55	17	100	35
50	10	3.0	20	7	42	13	65	20	110	40

Tube Size	1¼"		1½"		2"		2½"		3"	
Pressure Drop Lbs. P.S.I.	S	L	S	L	S	L	S	L	S	L
5	70	20	100	35	200	75	400	150	700	200
10	100	30	150	50	325	110	600	225	1000	300
20	150	45	215	75	500	165	900	300	1500	500
30	180	60	275	95	600	200	1100	350	1800	600
40	220	70	310	115	700	250	1300	450	2200	700
50	240	80	350	130	800	280	1500	500	2500	800

NOTES: Columns marked S give deliveries through short lines, such as branches 15-ft. or shorter. Columns marked L give deliveries through lines approximately 100-ft. long.

Maximum pressure drop of 20 pounds per 100 ft. run is recommended to reduce noise to a practical minimum.

A 10-pound drop in 100 ft. for residence installations is recommended.

The following table gives sizes of short branches to fixture connections for various initial water pressures:

SIZES OF COPPER TUBE WATER SUPPLY FOR SHORT BRANCHES TO PLUMBING FIXTURES

FIXTURE	PRESSURES		
	High Over 60 Lbs.	Medium 30 to 60 Lbs.	Low Under 30 Lbs.
To Baths	½ In.	¾ In.	¾ In.
Lavatories	⅜	½	½
Tank Closets	⅜	⅜	½
Valve Closets	1	1	1¼
Pantry Sinks	½	½	½
Kitchen Sinks	½	½	¾
Slop Sinks	½	¾	¾
Showers	½	½	¾
Urinals (Flush Tank)	½	¾	¾
Urinals (Flush Valve)	¾	¾	¾
Drinking Fountains	⅜	⅜	½

COPPER TUBE WATER CAPACITY DATA

The following tables are taken from "Copper Tube Hand Book" issued by the Copper & Brass Research Association.

Where steel pipe sizes have been determined the copper tube size suitable for same requirements may be selected from table following:

STEEL PIPE AND COPPER TUBE SIZES FOR RELATIVE CAPACITIES FOR HOT AND COLD WATER SERVICE

Iron Pipe Nominal Diameter	CORRESPONDING SUITABLE SIZES FOR COPPER TUBE	
	Hot Water	Cold Water
½ inch	⅜ inch	⅜ inch
¾ inch	½ inch	½ inch
1 inch	¾ inch	¾ inch
1¼ inch	1 inch	1 inch
1½ inch	1 inch	1¼ inch
2 inch	1¼ inch	1½ inch
2½ inch	1½ inch	2 inch
3 inch	2 inch	2½ inch

The Rate of Flow of water to various plumbing fixtures is given in following table:

U. S. G. P. M. USED BY VARIOUS FIXTURES

FIXTURES	RATE OF FLOW (gallons per minute)
Each Bath	8-10
Lavatory	5-8
Tank closet	3-5
Flush valve closet	30-40
Shower	5-8
Sink	8-10
Laundry tub	8-10
Garden hose	5-10

When determining the size of mains to supply the various fixtures the total rate will be less than the rate on table above times the number of fixtures as not all fixtures would be in use at same time. The following rules are recommended to determine main sizes—estimate total requirements for all fixtures and divide by the value indicated for various types of buildings.

For residences, apartments, schools, office buildings, divide by 4.

For Clubs and Hotels, divide by 3.

For gymnasiums, hospitals, public comfort stations, divide by 2.

For public baths, laundries and factories allow full amount shown for each fixture.

THEORETICAL DISCHARGE OF NOZZLES IN U. S. GALLONS PER MINUTE

HEAD		Velocity of Discharge Feet per Sec.	DIAMETER OF NOZZLE IN INCHES								
Pounds	Feet		1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	53.1	72.4
15	34.6	47.25	0.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5
20	46.2	54.55	0.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102.
25	57 7	61.0	0.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114.
30	69.3	66.85	0.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125.
35	80.8	72.2	0.69	2.77	6.21	11.1	24.8	44.2	69.0	99.5	135.
40	92.4	77.2	0.74	2.96	6.64	11.8	26.6	47.3	73.8	106.	145.
45	103.9	81.8	0.78	3.13	7.03	12.5	28.2	50.1	78.2	113.	153.
50	115.5	86.25	0.83	3.30	7.41	13.2	29.7	52.8	82.5	119.	162.
55	127.0	90.4	0.87	3.46	7.77	13.8	31.1	55.3	86.4	125.	169.
60	138.6	94.5	0.90	3.62	8.12	14.5	32.5	57.8	90.4	130.	177.
65	150.1	98.3	0.94	3.77	8.45	15.1	33.8	60.2	94.0	136.	184.
70	161.7	102.1	0.98	3.91	8.78	15.7	35.2	62.5	97.7	141.	191.
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101.	146.	198.
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104.	150.	205.
85	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108.	155.	211.
90	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111.	160.	217.
95	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114.	164.	223.
100	230.9	122.0	1.17	4.67	10.5	18.7	42.1	74.7	117.	168.	229.
105	242.4	125.0	1.20	4.79	10.8	19.2	43.1	76.5	120.	172.	234.
110	254.0	128.0	1.23	4.90	11.0	19.6	44.1	78.4	122.	176.	240.
115	265.5	130.9	1.25	5.01	11.2	20.0	45.1	80.1	125.	180.	245.
120	277.1	133.7	1.28	5.12	11.5	20.5	46.0	81.8	128.	184.	251.
125	288.6	136.4	1.31	5.22	11.7	20.9	47.0	83.5	130.	188.	256.
130	300.2	139.1	1.33	5.33	12.0	21.3	48.0	85.2	133.	192.	261.
135	311.7	141.8	1.36	5.43	12.2	21.7	48.9	86.7	136.	195.	266.
140	323.3	144.3	1.38	5.53	12.4	22.1	49.8	88.4	138.	199.	271.
145	334.8	146.9	1.41	5.62	12.6	22.5	50.6	89.9	140.	202.	275.
150	346.4	149.5	1.43	5.72	12.9	22.9	51.5	91.5	143.	206.	280.
175	404.1	161.4	1.55	6.18	13.9	24.7	55.6	98.8	154.	222.	302.
200	461.9	172.6	1.65	6.61	14.8	26.4	59.5	106.	165.	238.	323.

HEAD		Velocity of Discharge Feet per Sec.	DIAMETER OF NOZZLE IN INCHES								
Pounds	Feet		1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2
10	23.1	38.6	94.5	120	148	179	213	289	378	479	591
15	34.6	47.25	116.	147	181	219	260	354	463	585	723
20	46.2	54.55	134.	169	209	253	301	409	535	676	835
25	57.7	61.0	149.	189	234	283	336	458	598	756	934
30	69.3	66.85	164.	207	256	309	368	501	655	828	1023
35	80.8	72.2	177.	224	277	334	398	541	708	895	1106
40	92.4	77.2	189.	239	296	357	425	578	756	957	1182
45	103.9	81.8	200.	253	313	379	451	613	801	1015	1252
50	115.5	86.25	211.	267	330	399	475	647	845	1070	1320
55	127.0	90.4	221.	280	346	418	498	678	886	1121	1385
60	138.6	94.5	231.	293	362	438	521	708	926	1172	1447
65	150.1	98.3	241.	305	376	455	542	737	964	1220	1506
70	161.7	102.1	250.	317	391	473	563	765	1001	1267	1565
75	173.2	105.7	259.	327	404	489	582	792	1037	1310	1619
80	184.8	109.1	267.	338	418	505	602	818	1070	1354	1672
85	196.3	112.5	276.	349	431	521	620	844	1103	1395	1723
90	207.9	115.8	284.	359	443	536	638	868	1136	1436	1773
95	219.4	119.0	292.	369	456	551	656	892	1168	1476	1824
100	230.9	122.0	299.	378	467	565	672	915	1196	1512	1870
105	242.4	125.0	306.	388	479	579	689	937	1226	1550	1916
110	254.0	128.0	314.	397	490	593	705	960	1255	1588	1961
115	265.5	130.9	320.	406	501	606	720	980	1282	1621	2005
120	277.1	133.7	327.	414	512	619	736	1002	1310	1659	2050
125	288.6	136.4	334.	423	522	632	751	1022	1338	1690	2090
130	300.2	139.1	341.	432	533	645	767	1043	1365	1726	2132
135	311.7	141.8	347.	439	543	656	780	1053	1390	1759	2173
140	323.3	144.3	354.	448	553	668	795	1082	1415	1790	2212
145	334.8	146.9	360.	455	562	680	809	1100	1440	1820	2250
150	346.4	149.5	366.	463	572	692	824	1120	1466	1853	2290
175	404.1	161.4	395.	500	618	747	890	1210	1582	2000	2473
200	461.9	172.6	423.	535	660	799	950	1294	1691	2140	2645

NOTE.—The actual quantities will vary from these figures, the amount of variation depending upon the shape of nozzle and size of pipe at the point where the pressure is determined. With smooth taper nozzles the actual discharge is about 94 per cent of the figures given in the tables.

NUMBER OF GALLONS IN ROUND TANKS

Diameter, Inches

Depth or Length	18-inch	24-inch	30-inch	36-inch	42-inch	48-inch	54-inch	60-inch	66-inch	72-inch
1 Inch	1.10	1.96	3.06	4.41	5.99	7.83	9.91	12.24	14.81	17.62
1 ft.	13.	23.	37.	53.	72.	94.	119.	147.	178.	211.
1½ ft.	20.	35.	55.	79.	108.	141.	179.	220.	267.	317.
2 ft.	26.	47.	73.	106.	144.	188.	238.	294.	355.	423.
2½ ft.	33.	59.	92.	132.	180.	235.	298.	367.	444.	529.
3 ft.	40.	71.	110.	159.	216.	282.	357.	441.	533.	634.
3½ ft.	46.	82.	129.	185.	252.	329.	417.	514.	622.	740.
4 ft.	53.	94.	147.	211.	288.	376.	476.	587.	711.	846.
4½ ft.	59.	106.	165.	238.	324.	423.	536.	661.	800.	952.
5 ft.	66.	118.	183.	264.	360.	470.	597.	734.	889.	1157.
5½ ft.	73.	129.	202.	291.	396.	517.	657.	808.	977.	1263.
6 ft.	79.	141.	220.	317.	432.	564.	714.	881.	1066.	1369.
7 ft.	92.	164.	257.	370.	504.	658.	833.	1028.	1244.	1580.
8 ft.	106.	188.	294.	423.	576.	752.	952.	1175.	1422.	1792.
9 ft.	119.	212.	330.	476.	648.	846.	1071.	1322.	1599.	2003.
10 ft.	132.	235.	367.	529.	720.	940.	1190.	1469.	1777.	2115.
12 ft.	157.	282.	440.	634.	864.	1128.	1428.	1762.	2133.	2537.
14 ft.	185.	329.	514.	740.	1008.	1316.	1666.	2056.	2488.	2960.
16 ft.	211.	376.	587.	846.	1152.	1504.	1904.	2350.	2844.	3383.
18 ft.	238.	423.	661.	952.	1296.	1692.	2142.	2644.	3199.	3806.
20 ft.	264.	470.	734.	1057.	1440.	1880.	2380.	2937.	3554.	4229.

One-inch depth is given to facilitate figuring intermediate depths.
For tanks having a diameter other than those given in the table, multiply the square of the diameter in inches by the length in feet and multiply this product by 0.0408 to obtain tank capacity in U. S. gallons. When both diameter and length are given in inches, the capacity in U. S. gallons equals $0.0034 \times d^2 L$.

Number of U. S. Gallons in Rectangular Tanks—For one foot in depth

Length of Tank

Width of Tank	2 ft.	2 ft. 6 in.	3 ft.	3 ft. 6 in.	4 ft.	4 ft. 6 in.	5 ft.	5 ft. 6 in.	6 ft.	6 ft. 6 in.	7 ft.	7 ft. 6 in.	8 ft.	8 ft. 6 in.	9 ft.	9 ft. 6 in.	10 ft.	10 ft. 6 in.	11 ft.	11 ft. 6 in.	12 ft.
2 ft.	30	37	45	52	60	67	75	82	90	97	105	112	120	127	135	142	150	157	165	172	180
2 ft. 6 in.		47	56	65	75	84	94	103	112	122	131	140	150	159	168	178	187	196	206	215	224
3 ft.			67	79	90	101	112	123	135	146	157	168	180	191	203	213	224	236	247	258	269
3 ft. 6 in.				92	105	118	131	144	157	170	183	196	209	223	236	249	262	275	288	301	314
4 ft.					120	135	150	165	180	194	209	224	239	254	269	284	299	314	329	344	359
4 ft. 6 in.						151	168	185	202	219	236	252	269	286	303	320	337	353	370	387	404
5 ft.							187	206	224	243	262	281	299	318	337	355	374	393	411	430	449
5 ft. 6 in.								226	247	267	288	309	329	350	370	391	411	432	453	473	494
6 ft.									269	292	314	337	359	381	404	426	449	471	494	516	539
6 ft. 6 in.										316	340	365	389	413	438	462	486	511	535	559	583
7 ft.											367	393	419	445	471	497	524	550	576	602	628
7 ft. 6 in.												421	449	477	505	533	561	589	617	645	673
8 ft.													479	509	540	569	598	628	658	688	718
8 ft. 6 in.														540	572	604	636	668	699	731	763
9 ft.															606	640	673	707	741	774	808
9 ft. 6 in.																675	711	746	782	817	853
10 ft.																	748	785	823	860	898
10 ft. 6 in.																		825	864	903	943
11 ft.																			905	946	987
11 ft. 6 in.																				989	1032
12 ft.																					1077

FUEL DATA

In the tables which follow have been reproduced from Kent's Mechanical Engineers Handbook "Power" Eleventh Edition

COAL DATA

Classification of Coal

Class	Type of Coal	Volatile, Percent of Combustible	Oxygen in Combustible Percent	Moisture in Air-dry, Ash-free Coal, Percent	B.T.U. per Pound of Combustible	B.T.U. per Pound of Air-dry, Ash-free Coal
I	Anthracite	Under 10	1 to 4	Under 1.8	14,800 to 15,400	14,600 to 15,400
II	Semi-anthracite	10 to 15	1 to 5	Under 1.8	15,400 to 15,500	15,200 to 15,500
III	Semi-bituminous	15 to 30	1 to 6	Under 1.8	15,400 to 16,050	15,300 to 16,000
IV*	Cannel	45 to 60	5 to 8	Under 1.8	15,700 to 16,200*	15,500 to 16,050*
V	Bituminous, high grade	30 to 45	5 to 14	1 to 4	14,900 to 15,600	14,350 to 14,400
VI	Bituminous, medium grade	32 to 50	6 to 14	2.5 to 6.5	13,800 to 15,100	11,300 to 14,400
VII	Bituminous, low grade	32 to 50	7 to 14	5 to 12	12,400 to 14,600	11,300 to 13,400
VIII	Sub-bituminous lignite	27 to 60	10 to 33	7 to 26	9,600 to 13,250	7,400 to 11,650

*Eastern cannel. The Utah cannel coal has a much lower heating value.

SCREEN SIZES OF ANTHRACITE

Size	Passes Through	Retained On	Approx. Weight Per Cu. Ft.
Broken	$4\frac{7}{16}$"	$3\frac{7}{16}$"	52 —55
Egg	$3\frac{7}{16}$"	$2\frac{8}{16}$"	53 —58
Stove	$2\frac{8}{16}$"	$1\frac{9}{16}$"	....
Chestnut	$1\frac{9}{16}$"	$\frac{11}{16}$"	52.5—56.5
Pea	$\frac{12}{16}$"	$\frac{8}{16}$"	53.5—54.5
No. 1 Buckwheat	$\frac{9}{16}$"	$\frac{5}{16}$"	50.5
No. 2 Buckwheat (Rice)	$\frac{5}{16}$"	$\frac{3}{16}$"	....
No. 3 Buckwheat (Barley)	$\frac{3}{16}$"	$\frac{3}{32}$"	....

PROPORTIONS OF SOFT AND HARD COAL TO BE USED FOR HAND FIRING

	Soft Coal	Hard Coal
No. 1 Buckwheat—Forced Draft	30%	70%
No. 1 Buckwheat—Natural Draft	40%	60%
No. 2 Buckwheat—Forced Draft	40%	60%
No. 2 Buckwheat—Natural Draft	50%	50%
No. 3 Buckwheat—Forced Draft	50%	50%
No. 3 Buckwheat—Natural Draft	65%	35%

MIXTURES OF HARD AND SOFT COAL for hand-fired boilers as shown in this table are given in Tech. Paper 220, U. S. Bureau of Mines. The coking qualities of the soft coal prevent draft and grate losses of the fine anthracite, while the higher fixed carbon of the anthracite increases the heating value of the mixture.

ANALYSES OF REPRESENTATIVE COALS

Class No.	1	2	3	4a	4b	5	6
Kind	Anthracite Culm	Semi-anthracite	Semi-bituminous	Bituminous, Coking	Bituminous, Non Coking	Sub bituminous	Lignite
Location	Penna.	Ark.	W. Va.	Pa.	Ohio	Wyo.	Tex.
Moisture	2.08	1.28	0.65	0.97	7.55	8.68	9.88
Volatile combustible	7.27	12.82	18.80	29.09	34.03	41.31	36.17
Fixed carbon	74.32	73.69	75.92	60.85	52.57	46.49	43.65
Ash	16.33	12.21	4.63	9.09	5.85	3.52	10.30
Loss on air-drying	3.40	1.10	1.10	4.20	Undet.	11.30	23.50
ULTIMATE ANALYSIS OF COAL DRIED AT 221° F.							
Hydrogen	2.63	3.63	4.54	4.57	5.06	5.31	4.47
Carbon	76.86	78.32	86.47	77.10	75.82	73.31	64.84
Oxygen	2.27	2.25	2.68	6.67	10.47	15.72	16.52
Nitrogen	0.82	1.41	1.08	1.58	1.50	1.21	1.30
Sulphur	0.78	2.03	0.57	0.90	0.82	0.60	1.44
Ash	16.64	12.36	4.66	9.18	6.33	3.85	11.43
RESULTS CALCULATED TO AN ASH- AND MOISTURE-FREE BASIS							
Volatile combustible	8.91	14.82	19.85	32.34	39.30	47.05	45.31
Fixed carbon	91.09	85.18	80.15	67.66	60.70	52.95	54.69
ULTIMATE ANALYSIS							
Hydrogen	3.16	4.14	4.76	5.03	5.41	5.50	5.05
Carbon	92.20	89.36	90.70	84.89	80.93	76.35	73.21
Oxygen	2.72	2.57	2.81	7.34	11.18	16.28	18.65
Nitrogen	0.98	1.61	1.13	1.74	1.61	1.25	1.47
Sulphur	0.94	2.32	0.60	1.00	0.87	0.62	1.62
CALORIFIC VALUE IN B.T.U. PER LB., BY DULONG'S FORMULA							
Air-dried coal	12,472	13,406	15,190	13,951	12,510	11,620	10,288
Combustible	15,286	15,496	16,037	15,511	14,446	13,235	12,889

APPROXIMATE HEATING VALUES OF COALS

Percent Volatile Matter in Coal Dry and Free from Ash	Heating Value, B.T.U. per lb. of Combustible	Equivalent Water Evaporated Lb., From and at 212° F. per lb. of Combustible
0	14,580	15.09
3	14,940	15.47
6	15,210	15.75
10	15,480	16.03
13	15,660	16.21
20	15,840	16.40
28	15,660	16.21
32	15,480	16.03
37	15,120	15.65
40	14,760	15.28
43	14,220	14.72
45	13,860	14.35
47	13,320	13.79
49	12,420	12.85

WEIGHT OF BITUMINOUS AND SEMI-BITUMINOUS COAL

Coal from	Size†	Pounds per Cubic Foot
Alabama	D.	45.5
Alabama	R.M.	51-54
Arkansas	R.M.	49.5-59.5
Colorado	Lump	50.5-52.5
Colorado	D.	49.5
Georgia	60-10-30	54
Illinois	D. Lump	49.5
Illinois	R.M.	54.5-55.5
Illinois	Lump	44-48.5
Iowa	60-25-15	46.5
Kansas	95- 5- 0	55.5
Kentucky	95- 5- 0	43.0-54.5
Kentucky	Lump	45-47.5
Montana	90- 5- 5	52
Ohio	90- 5- 5	49
Ohio	70-15-15	47.5
Ohio	60-30-10	46.5
Ohio	40-20-20	50.0
Oklahoma	40-20-20	50.0
Oklahoma	35-45-20	48.5
Pennsylvania	90- 5- 5	47-49.5
Pennsylvania	70-20-10	50.5
Pennsylvania	60-25-10	50.5
Pennsylvania	20-30-50	52
Pennsylvania	10-15-75	52
Pennsylvania	0-10-90	49.5-53.5
Pennsylvania	0- 0-100	52
Pennsylvania	Lump	46.5
Utah	90- 0- 5	44.5
West Virginia‡	75-15-10	55.5
West Virginia†	60-30-10	47.0
West Virginia‡	20-10-70	55.0
West Virginia‡	5-10-85	55.5
West Virginia‡	4- 2-94	54
West Virginia‡	3- 5-92	57.5
West Virginia‡	0- 5-95	56.5

†D—Domestic; R.M.—Run-of-Mine; the figures represent the respective percentages of lump, nut and slack.
‡Semi-bituminous.

AVERAGE LOSS OF BOILER EFFICIENCY DUE TO ASH IN COAL

Percentage of Ash	10	20	30	40	50
Anthracite coal	12	23	45	70	100
Bituminous coal	10	20	40	75	100
Western coal	5	18	32	98	....

ANALYSES AND ASH FUSION TEMPERATURES OF VARIOUS COALS
COAL IN AS RECEIVED CONDITION

Sample No.	Grade*	State	County	Bed	Moisture %	Fixed Carbon %	Volatile Matter %	Ash %	Sulphur %	Heating Value B.T.U. Per Lb.	Ash Fusion Temperatures, Deg. F. Initial	Softening	Fluid
1	SB	Pa.	Somerset	B	1.7	75.4	15.9	7.0	0.8	14,280	2550	2930	a
2	SB	Md.	Allegheny	Big Vein	1.0	72.1	19.1	7.8	0.9	14,260	2840	2930	a
3	SB	Pa.	Clearfield	B	1.5	65.9	24.2	8.4	1.9	14,120	2450	2520	2580
4	SB	Pa.	Somerset	C Prime	1.6	72.8	15.7	9.9	2.0	13,770	2180	2440	2580
5	SB	Pa.	Cambria	Miller or B	1.2	72.3	21.2	5.3	1.2	14,670	2520	2650	2710
6	B	Ohio	Meigs	8-A	5.2	45.0	37.6	12.2	2.4	11,820	2020	2190	2390
7	B	Ill.	Williamson	No. 6	9.6	44.4	33.4	12.6	3.6	11,260	1960	2070	2290
8	B	Pa.	Westmoreland	Pittsburgh	1.3	55.4	32.3	11.0	1.5	13,390	2460	2600	2700
9†	B	Pa.	Westmoreland	Pittsburgh	1.3	57.0	33.5	8.2	1.6	13,890	2460	2570	2700
10	SB	W. Va.	New River Coal		1.6	70.5	20.7	7.2	1.0	14,240	2440	2580	2630
11	SB	W. Va.	Pocahontas Coal		1.8	71.3	20.9	6.0	0.6	14,480	2160	2300	2440
12	B	Ohio	Jefferson	Pittsburgh No. 8	2.2	53.3	35.6	8.9	2.2	13,280	2090	2210	2330
13	SB	W. Va.	Raleigh	Beckley	1.5	73.8	17.6	7.1	0.8	14,310	2630	2800	2850
14	SB	Pa.	Mercer	Brookville	1.5	70.2	17.7	10.6	1.4	13,640	2590	2640	2830
15	B	Ill.	Williamson	No. 6	5.6	50.4	33.4	10.6	2.0	12,130	2110	2280	2460
16	B	Pa.	Westmoreland	Pittsburgh	1.9	54.8	32.5	10.8	1.8	13,200	2360	2520	2640
17	B	Pa.	Allegheny	Pittsburgh	2.4	54.0	34.2	9.4	1.4	13,280	2100	2270	2430
18	B	Pa.	Westmoreland	Pittsburgh	1.4	58.2	33.8	6.6	0.8	14,080	2580	2730	2840
19	SB	Pa.	Somerset	Miller or B	1.3	72.8	16.7	9.2	1.9	13,940	2390	2470	2560
20†	SB	Pa.	Somerset	Miller or B	1.3	74.1	16.7	7.9	1.4	14,200	2500	2630	2780
21	B	Ill.	Mixture from 7 mines		12.5	38.3	33.0	16.2	3.2	10,190	1930	1990	2170

*SB—Semi-bituminous; B—Bituminous. †Washed coal, same as next preceding sample. a—Did not attain temperature of fluidity.

WOOD FUEL DATA

HEATING VALUE OF WOODS
(Based on U. S. Dept. of Agriculture Bull. No. 753)

	Weight per cord, lb.		Heating Value, B.T.U. per lb.		Equivalent lb. of Coal of 13,500 B.T.U. per lb.	
	Green	Air-dry	Green	Air-dry	Green	Air-dry
Ash, white	4300	3800	4628	5395	0.343	0.400
Beech	5000	3900	3940	5359	.292	.397
Birch, yellow	5100	4000	3804	5225	.282	.387
Chestnut	4900	2700	2633	5778	.195	.428
Cottonwood	4200	2500	3024	6000	.224	.444
Elm, white	4400	3100	3591	5710	.266	.423
Hickory	5700	4600	4053	5391	.300	.399
Maple, sugar	5000	3900	4080	5590	.302	.414
Maple, red	4700	3200	3745	5969	.277	.442
Oak, red	5800	3900	3379	5564	.250	.412
Oak, white	5600	4300	3972	5558	.294	.412
Pine, yellow	3100	2300	7097	9174	.526	.680
Pine, white	3300	2200	4226	5864	.313	.434
Walnut, black	5100	4000	4078	4650	.302	.344
Willow	4600	2300	2370	5870	.176	.435

A cord of Wood is a pile 4'x4'x8' = 128 cu. ft. comprising approximately 56% Solid wood and 44% Interstitial spaces.

ANALYSES AND CALORIFIC VALUES OF MOISTURE-FREE PEAT

Location		Volatile	Fixed Carbon	Ash	B.T.U. Per Lb.
Connecticut	Min.	16.37	6.08	77.55	1,708
Connecticut	Max.	61.17	31.58	7.25	10,001
Florida	Min.	11.42	38.53	50.05	1,202
Florida	Max.	67.80	30.67	1.53	10,865
Maine	Min.	29.88	12.31	57.81	3,634
Maine	Max.	59.95	31.93	8.12	9,779
Massachusetts	Min.	54.13	30.69	15.18	8,663
Massachusetts	Max.	57.04	34.61	8.35	9,308
Michigan	Min.	42.54	18.03	39.43	5,845
Michigan	Max.	60.77	32.22	7.01	10,026
New Hampshire	Min.	31.00	14.24	54.76	4,046
New Hampshire	Max.	66.74	28.67	4.59	10,280
New York	Min.	26.25	10.46	63.29	3,515
New York	Max.	67.10	28.99	3.91	10,307
North Carolina	....	51.88	28.83	19.29	8,249
North Carolina	....	51.88	28.83	19.29	8,249
Wisconsin	Min.	23.69	5.91	70.40	2,608
Wisconsin	Max.	62.77	27.71	9.52	9,391

COKE DATA

ANALYSES AND HEATING VALUES OF GAS COKE

Kind of Coal	COAL								COKE				
	Moisture	Ash	Volatile	Fixed Carbon	Sulphur	B.T.U. per Pound	Condition*	Moisture	Ash	Volatile	Fixed Carbon	Sulphur	B.T.U. per Pound
Pittsburgh:													
As received	1.92	6.41	32.82	58.85	1.12	14,026	A	8.54	11.46	0.97	79.03	0.84	11,552
Dry	....	6.54	33.46	60.00	1.14	14,301	B	....	12.53	1.06	86.41	0.92	12,631
Alabama:													
As received	2.71	4.29	29.13	63.87	0.50	13,990	A	....	....	....	....	....	....
Dry	....	4.41	29.94	65.65	0.51	14,380	B	....	11.40	1.59	81.01	0.52	12,883
Colorado:													
As received	7.17	14.55	32.36	45.92	1.00	10,953	A	21.31	19.93	1.40	57.28	0.68	8,417
Dry	....	15.67	34.86	49.47	1.08	11,799	B	....	25.35	1.78	72.87	0.87	10,706
Kentucky:													
As received	2.46	6.25	31.18	60 11	0.43	13,885	A	12.43	10.09	0.92	76.56	0.36	11,210
Dry	....	6.41	31.97	61.62	0.44	14,234	B	....	11.52	1.05	87.43	0.41	12,802

***Condition—A—3 days after quench; B—from retorts.**

ANALYSES OF CLAIRTON BY-PRODUCT COKE

Sample No.	Moisture	Volatile Matter	Fixed Carbon	Ash	B.T.U. per Lb.	
					As Fired	Ash and Moisture Free
1	3.6	2.1	80.0	14.3	11,770	14,330
2	2.3	2.3	81.1	14.3	11,890	14,260
3	0.8	1.1	80.5	17.6	11,720	14,370

ANALYSES OF WET- AND DRY-QUENCHED COKE

Analysis	Original Coal	Wet-Quenched Coke		Dry-Quenched Coke	
		Moisture Free	As Received	Moisture Free	As Received
B.T.U. per lb.	14,300	13,039	11,463	13,088	13,023
Volatile matter, percent	36.47	1.71	1.49	1.16	1.15
Fixed Carbon, percent	58.97	91.29	79.51	91.48	91.03
Ash, percent (calculated on ash and moisture free basis)	4.56	7.00	6.10	7.36	7.32
Moisture, percent	....	....	12.90	....	0.50
Sulphur, percent (separately determined)	0.75	0.75	0.75	0.68	..

FUEL OIL DATA

ANALYSES AND CALORIFIC VALUE OF VARIOUS FUEL OILS

Oil	Chemical Analysis					Specific Gravity	Flash Point deg. F.	Fire Point deg. F.	B.T.U. per lb. as Reported	B.T.U. per lb. by formula
	C	H	O	N	S					
Beaumont, Tex.	84.60	10.90	2.87	....	1.63	0.92	142	181	19,060	19,142
Colinga, Cal.	86.37	11.30	....	1.14	0.60	0.95	162	....	18,720	18,948
Bakersfield, Cal.	85.0	12.0	1.0	0.2	0.8	....	....	....	18,600	....
Penna. crude	84.9	13.7			....	0.89	....	....	19,210	19,350
Penna. light	82.0	14.8	1.4		....	0.83	....	....	17,930	19,809
West Va., crude	84.3	14.1	3.2		....	0.84	....	....	18,400	19,736
Ohio, crude	83.4	14.7	1.6		0.6	0.80	....	....	19,580	20,065
Mexican, crude	82.8	12.19			2.83	0.91	77	120	18,493	19,215
Baku, Russia, heavy	86.6	12.3	1.3	....	....	0.94	....	....	19,440	19,017
			0.43	1.72						
			1.11							

GAS FUEL DATA

ANALYSES OF NATURAL GAS COLLECTED IN 31 CITIES IN THE U. S.
(Tech. Paper 158, U. S. Bureau of Mines)

Town	Paraffin Hydro-carbons CnH2n +2	Methane, CH_4	Ethane, C_2H_6	Carbon Dioxide CO_2	Nitrogen N_2	Calculated Gross Heating Value B.T.U. per Cu. Ft. (760 mm. Pressure)		Calculated Specific Gravity (Air—1)
						0° C.	60° F.	
Fayette, Alabama	97.6	97.6	0.0	0.3	2.10	1039	983	0.57
Alma, Arkansas	99.2	99.2	0.0	0.20	0.6	1057	1000	.56
Little Rock, Arkansas	96.7	96.7	0.0	1.00	2.3	1030	974	.57
Los Angeles, California	93.5	77.5	16.0	6.50	0.0	1123	1062	.70
Olney, Illinois	97.1	37.5	59.6	0.0	1.7*	1591	1505	.86
Palestine, Illinois	95.6	95.6	0.0	0.5	3.9	1018	963	.58
Geneva, Indiana	98.8	75.4	23.4	0.0	1.2	1238	1171	.68
Coffeyville, Kansas	98.0	98.0	0.0	1.2	0.8	1044	988	.57
Pittsburgh, Kansas	93.0	90.5	2.5	0.4	6.6	1010	955	.60
Ashland, Kentucky	79.0	75.0	24.0	.0	1.0	1245	1178	.68
Lexington, Kentucky	99.0	76.4	22.6	.0	1.0	1234	1167	.67
Kansas City, Missouri	90.8	84.1	6.7	.8	8.4	1025	965	.63
Elmira, New York	99.0	84.0	15.0	.0	1.0	1174	1111	.63
Bolivar, New York	97.4	59.8	37.6	.4	2.2	1336	1264	.75
Buffalo, New York	99.6	88.1	11.5	.0	0.4	1152	1090	.61
Pavilion, New York	98.7	91.9	6.8	.0	1.3	1105	1045	.59
Wellsville, New York	98.0	78.1	19.9	.0	2.0	1212	1137	.65
Ashtabula, Ohio	98.7	82.2	16.5	.0	1.3	1182	1118	.65
Lima, Ohio	96.3	83.5	12.8	.0	3.7	1127	1066	.63
Piqua, Ohio	90.9	78.3	12.6	.2	8.9	1068	1010	.66
Sandusky, Ohio	96.0	83.5	12.5	.2	3.8	1122	1061	.63
Utica, Ohio	93.9	74.8	19.1	.3	5.8	1152	1090	.68
Guthrie, Oklahoma	91.9	73.5	18.4	.0	8.1	1125	1064	.68
Sapulpa, Oklahoma	98.8	93.1	5.7	.4	0.8	1098	1039	.59
Altoona, Pennsylvania	99.0	90.0	9.0	.2	0.8	1126	1065	.60
Oil City, Pennsylvania	97.7	64.3	33.4	.0	3.3	1306	1235	.74
St. Marys, Pennsylvania	99.2	88.0	11.2	.0	0.8	1146	1084	.61
Sharon, Pennsylvania	99.3	32.3	67.0	.0	.7	1591	1505	.89
Charleston, West Virginia	99.3	76.8	22.5	.0	.7	1236	1169	.67
Clarksburg, West Virginia	99.3	66.6	32.7	.0	.7	1318	1247	.72
Fairmont, West Virginia	99.0	82.0	17.0	.1	.9	1189	1125	.64

*Contained also 1.2% hydrogen sulphide H_2S.

HEAT CONTENT OF MIXTURES OF BLAST-FURNACE AND COKE-OVEN GAS PERCENTAGES BY VOLUME

Blast-Furnace Gas Percent	Coke-Oven Gas Percent	B.T.U. per Cu. Ft.
95	5	119.1
90	10	141.1
85	15	163.1
80	20	185.1
75	25	207.1
70	30	229.1
65	35	251.1
60	40	273.1
55	45	295.1

Blast-Furnace Gas Percent	Coke-Oven Gas Percent	B.T.U. per Cu. Ft.
50	50	317.1
45	55	339.1
40	60	361.1
35	65	383.1
30	70	405.1
25	75	427.1
20	80	449.1
15	85	471.1
10	90	493.1
5	95	515.1

AIR DATA

AIR CHANGES FOR VENTILATION FOR VARIOUS ESTABLISHMENTS

Assembly Halls	1 to 4 Min.
Bakeries	1 to 3 Min.
Billiard and Pool Rooms	1 to 5 Min.
Bowling Alleys	1 to 5 Min.
Cabins	5 Minutes
Conduits	1 to 5 Min.
Dance Halls	1 to 3 Min.
Foundries	2 to 5 Min.
Garages	3 to 5 Min.
Laboratories	2 to 5 Min.
Laundries	½ to 5 Min.
Lodge Rooms	1 to 5 Min.
Offices	1 to 8 Min.
Restaurants—Dining Rooms	1 to 8 Min.
Restaurants—Kitchens	1 to 2 Min.
Stores	1 to 5 Min.
Ship Holds	10 Minutes
Theatres—Auditoriums	1 to 4 Min.
Theatres—Projecting Booths	1 Minute
Toilets	3 to 5 Min.
Tunnels	1 to 10 Min.

Consult Local and State Laws for applications in different localities.
For Capacities of Fans, Heaters and other air conditioning equipment consult manufacturers' catalogues and engineering data.

RECOMMENDED AIR VELOCITIES FOR AIR CONDITIONING SYSTEMS

TYPES OF INSTALLATION	Residences, Broad-casting Studics, etc.	Schools, Theatres and Public Buildings	Industrial Applications
EQUIPMENT DESIGNATIONS	VELOCITIES IN FEET PER MINUTE		
Initial Air Intake	750	800	1,000
Air Washers	500	500	500
Extended Surface Heaters or Coolers (Face Velocity)	450	500	500
Suction Connections	750	800	1,000
Through Fan Outlet (Sirocco):			
For 1.5″ Static Pressure	.....	2,200	2,400
For 1.25″ Static Pressure	.....	2,000	2,200
For 1″ Static Pressure	1,700	1,800	2,000
For .75″ Static Pressure	1,400	1,550	1,800
For .5″ Static Pressure	1 200	1,300	1,600
Horizontal Ducts	700	900	1,000-2,000
Branch Ducts and Risers	550	600	1.000-1,600
Supply Grilles and Openings	300	300 grille	400 opening
Exhaust Grilles and Openings	350	400 grille	500 opening
Duct Outlets at High Elevation	.....	1,000	....

RECOMMENDED AIR VELOCITIES AND TIP SPEED FOR FAN OPERATION

Resistance Pressure	Fan Discharge Velocity Feet per Minute	Tip Speed of Fan Feet per Minute
¼"	1000	1500
½"	1200	2000
¾"	1500	2500
1"	1800	2900
1¼"	2000	3200
1½"	2200	3500

RECOMMENDED SUPPLY GRILLE HEIGHTS IN INCHES FOR CONVENTIONAL GRILLE CONSTRUCTION, BASED ON 350 FEET PER MIN. AIR VELOCITY THROUGH FREE AREA

Difference Between Room Air and Entering Air, Dry-Bulb Temperature	WIDTH OF CONDITIONED ROOM IN FEET					
	8 ft.	12 ft.	16 ft.	20 ft.	24 ft.	30 ft.
	GRILLE HEIGHT IN INCHES					
10° F.	4	8	10	12	16	18
12° F.	4	6	8	10	12	16
14° F.	4	4	6	8	10	12
16° F.	3	4	6	8	10	12
18° F.	3	4	6	8	10	12
Recommended Height of Grille Above Floor	8' 0"	8' 6"	9' 0"	9' 6"	10' 0"	10' 0"

RESISTANCE OF 90° ELBOWS

	Radius of Throat in Terms of Duct Width or Diameter							
	¼	½	¾	1	1½	2	3	4
Length of duct offering equivalent resistance in terms of width or diameter............	34	20	14	10	6	4.3	4.8	5.2

GAGE OF METAL FOR DUCTS

Diameter In Inches	Maximum Dimensions in Inches	Gauge U. S. Standard
6 to 9	4 to 18	No. 26
20 to 29	19 to 30	No. 24
30 to 39	31 to 60	No. 22
40 to 49	61 to 120	No. 20

B.T.U'S. GIVEN UP BY 1 CU. FT. OF AIR COOLING FROM DISCHARGE OUTLET TEMPERATURE TO TEMPERATURE INSIDE BUILDING

Temp. Inside Building Degrees F.	Outlet Temperatures										
	180	160	140	135	130	125	120	115	110	100	90
80	1.474	1.218	0.944	0.872	0.800	0.726	0.651	0.574	0.497	0.337	0.172
70	1.622	1.370	1.101	1.032	0.960	0.887	0.814	0.738	0.662	0.505	0.343
65	1.696	1.447	1.180	1.110	1.040	0.968	0.895	0.821	0.745	0.589	0.428
60	1.770	1.522	1.258	1.190	1.120	1.049	0.977	0.903	0.828	0.674	0.514
55	1.844	1.599	1.336	1.270	1.200	1.129	1.058	0.985	0.911	0.758	0.601
50	1.918	1.675	1.415	1.348	1.280	1.210	1.139	1.068	0.994	0.843	0.686

Above table from "Vento Heaters."

THIS TABLE SPECIFIES THE QUANTITY OF HEAT IN B.T.U. REQUIRED TO RAISE 1 CU. FT. OF AIR THROUGH ANY GIVEN TEMPERATURE INTERVAL

External Temp. Degrees F.	Temperature of Air in Room							
	40	50	60	70	80	90	100	110
—40	1.802	2.027	2.252	2.479	2.703	2.928	3.154	3.379
—30	1.540	1.760	1.980	2.200	2.420	2.640	2.860	3.080
—20	1.290	1.505	1.720	1.935	2.150	2.365	2.580	2.795
—10	1.051	1.262	1.473	1.684	1.892	2.102	2.311	2.522
0	0.822	1.028	1.234	1.439	1.645	1.851	2.056	2.262
10	0.604	0.805	1.007	1.208	1.409	1.611	1.812	2.013
20	0.393	0.590	0.787	0.984	1.181	1.378	1.575	1.771
30	0.192	0.385	0.578	0.770	0.963	1.155	1.345	1.540
40	....	0.188	0.376	0.564	0.752	0.940	1.128	1.316
50	....	....	0.184	0.367	0.551	0.735	0.918	1.102
60	....	....	....	0.179	0.359	0.538	0.718	0.897
70	....	....	....	....	0.175	0.350	0.525	0.700

PIPING

Dimensions of Standard Weight Wrought Iron and Steel Pipe

(National Tube Works)

Nominal Inside Diam.	Actual Outside Diam.	Actual Inside Diam.	Thickness of Metal	Internal Circumference	External Circumference	Length of Pipe per sq. ft. Inside Surface	Length of Pipe per sq. ft. Outside Surface	Internal Area		External Area		Length of Pipe cont'g 1 cu. ft.	U. S. Gallons per Ft. of Pipe	Weight of Pipe per Lin. Ft.	Weight of Water per Lin. Ft. of Pipe	No. of Threads per Inch	Length of Perf. Thread
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Feet	Feet	Sq. Ins.	Sq. Ft.	Sq. Ins.	Sq. Ft.	Feet	Gals.	Lbs.	Lbs.	No.	
⅛	.405	.270	.068	.848	1.272	14.151	9.434	.057	.0004	.128	.0009	2500.0	.0029	.24	.024	27	
¼	.540	.364	.088	1.144	1.696	10.500	7.075	.104	.0007	.229	.0016	1383.280	.0054	.42	.045	18	
⅜	.675	.493	.091	1.552	1.552	2.121	5.658	.191	.0013	.357	.0025	754.322	.0099	.56	.083	18	
½	.840	.622	.109	1.957	2.639	6.132	4.547	.304	.0C21	.554	.0038	473.840	.0158	.84	.132	14	
¾	1.050	.824	.113	2.589	3.299	4.635	3.638	.533	.0037	.866	.0060	270.016	.0277	1.12	.231	14	
1	1.315	1.048	.134	3.292	4.131	3.645	2.904	.861	.0060	1.358	.0094	167.246	.0447	1.67	.373	11½	.51
1¼	1.660	1.380	.140	4.335	5.215	2.768	2.301	1.496	.0104	2.164	.0150	96.257	.0777	2.24	.648	11½	.54
1½	1.900	1.610	.145	5.058	5.969	2.372	2.010	2.036	.0141	2.835	.0197	70.727	.1058	2.68	.882	11½	.55
2	2.375	2.067	.154	6.434	7.461	1.848	1.608	3.356	.0233	4.430	.0308	42.908	.1743	3.61	1.453	11½	.58
2½	2.875	2.468	.204	7.753	9.032	1.548	1.329	4.780	.0332	6.492	.0451	30.337	.2483	5.74	2.070	8	.89
3	3.500	3.067	.217	9.635	10.996	1.245	1.091	7.383	.0513	9.621	.0668	19 504	.3835	7.54	3.197	8	.95
3½	4.000	3.548	.226	11.146	12.566	1.077	0.955	9.887	.0687	12.566	.0875	14.567	.5136	9.00	4.291	8	1.00
4	4.500	4.026	.237	12.648	14.137	0.949	.849	12.730	.0884	15.904	.1104	11.312	.6613	10.66	5.512	8	1.05
5	5.563	5.045	.259	15.849	17.475	.757	.687	19.986	.1388	24.301	.1688	7.205	1.038	14.50	8.652	8	1.16
6	6.625	6.065	.280	19.054	20.813	.630	.577	28.890	.2006	34.472	.2394	4.984	1.500	18.76	12.503	8	1.26
8	8.625	7.981	.322	25.076	27.096	.479	.443	50.027	.3474	58.426	.4057	2.876	2.599	28.18	21.664	8	1.46
10	10.75	10.018	.366	31.476	33.772	.381	.355	78.823	.5474	90.763	.6303	1.827	4.095	40.06	34.134	8	1.68
12	12.75	12.000	.375	37.699	40.055	.318	.300	113.098	.7854	127.677	.8867	1.273	5.875	49.00	48.972	8	1.88
13	14	13.25	.375	41.626	43.982	.288	.273	137.887	.9577	153.938	1.0690	1.044	7.163	54.00	59.708	8	2.09
14	15	14.25	.375	44.768	47.124	.268	.255	159.485	1.1075	176.715	1.2272	0.900	8.285	58.00	69.060	8	2.10
15	16	15.25	.375	47.909	50.266	.250	.239	182.665	1.2685	201.062	1.3963	.793	9.489	62.00	79.097	8	2.20
....	18	17.25	.375	54.193	56.549	.221	.212	239.706	1.6229	254.470	1.7671	.616	12.141	70.00	101.203	....	....
....	20	19.25	.375	60.476	62.832	.198	.191	291.040	2.0211	314.159	2.1817	.495	15.119	78.00	126.026	....	....
....	22	21.25	.375	66.759	69.115	.180	.174	354.657	2.4629	380.134	2.6398	.406	18.424	85.00	153.575	....	....
....	24	23.25	.375	73.042	75.398	.164	.159	424.558	2.9483	452.390	3.1416	.339	22.055	93.00	183.842	....	....

Pipe from ⅛ inch to 1 inch inclusive is butt-welded, and proved to 300 lbs. per sq. in. Pipe 1¼ inch and larger is lap-welded, and proved to 500 lbs. per sq. inch.

Square Feet of Actual Surface per Lineal Foot of Pipe

On all lengths over one foot, fractions less than tenths are added to or dropped. For equivalent direct radiation multiply actual surface by 1.25.

Lgth. of Pipe	Size of Pipe ¾	1	1¼	1½	2	2½	3	4	5	6	8
1	.275	.346	.434	.494	.622	.753	.916	1.175	1.455	1.739	2.257
2	.5	.7	.9	1.	1.2	1.5	1.8	2.4	2.9	3.5	4.5
3	.8	1.	1.3	1.5	1.9	2.3	2.7	3.5	4.4	5.2	6.8
4	1.1	1.4	1.7	2.	2.5	3.	3.6	4.7	5.8	7.	9.
5	1.4	1.7	2.2	2.4	3.1	3.8	4.6	5.8	7.3	7.7	11.3
6	1.6	2.1	2.6	2.9	3.7	4.5	5.5	7.	8.7	10.5	13.5
7	1.9	2.4	3.	3.4	4.4	5.3	6.4	8.2	10.2	12.1	15.8
8	2.2	2.8	3.5	3.9	5.	6.	7.3	9.4	11.6	13.9	18.
9	2.5	3.1	3.9	4.4	5.6	6.8	8.2	10.6	13.1	15.7	20.3
10	2.7	3.5	4.3	4.9	6.2	7.5	9.1	11.8	14.6	17.4	22.6
11	3.	3.8	4.8	5.4	6.8	8.3	10.	12.9	16.	19.1	24.9
12	3.3	4.1	5.2	5.9	7.5	9.	11.	14.1	17.4	20.9	27.1
13	3.6	4.5	5.6	6.4	8.1	9.8	11.9	15.3	18.9	22.6	29.4
14	3.8	4.8	6.1	6.9	8.7	10.5	12.8	16.5	20.3	24.3	31.6
15	4.1	5.2	6.5	7.4	9.3	11.3	13.7	17.6	21.8	26.1	33.9
16	4.4	5.5	6.9	7.9	10.	12.	14.6	18.8	23.2	27.8	36.1
17	4.7	5.9	7.4	8.4	10.6	12.8	15.5	20.	24.7	29.5	38.4
18	5.	6.2	7.8	8.9	11.2	13.5	16.5	21.2	26.2	31.3	40.6
19	5.2	6.6	8.3	9.4	11.8	14.3	17.4	22.3	27.6	33.1	42.9
20	5.5	6.9	8.7	9.9	12.5	15.	18.3	23.5	29.1	34.8	45.2
21	5.8	7.3	9.1	10.4	13.	15.8	19.2	24.7	30.5	36.5	47.4
22	6.	7.6	9.6	10.9	13.7	16.5	20.2	25.9	32.	38.3	49.7
23	6.3	8.	10.	11.3	14.3	17.3	21.1	27.	33.5	40.	52.
24	6.6	8.3	10.4	11.9	14.9	18.	22.	28.2	34.9	41.7	54.2
25	6.9	8.6	10.9	12.3	15.6	18.8	22.9	29.3	36.3	43.5	56.4

Lgth. of Pipe	Size of Pipe ¾	1	1¼	1½	2	2½	3	4	5	6	8
1	.275	.346	.434	.494	.622	.753	.916	1.175	1.455	1.739	2.257
26	7.1	9.	11.3	12.8	16.2	19.5	23.8	30.5	37.8	45.2	58.6
27	7.4	9.4	11.7	13.3	16.8	20.3	24.7	31.7	39.3	47.	61.
28	7.7	9.7	12.2	13.8	17.4	21.	25.6	32.9	40.7	48.7	63.2
29	8.	10.	12.6	14.3	18.	21.8	26.6	34.1	42.2	50.4	65.5
30	8.3	10.4	13.	14.8	18.7	22.5	27.5	35.3	43.6	52.1	67.7
31	8.5	10.7	13.5	15.3	19.3	23.3	28.4	36.4	45.1	53.9	70.
32	8.8	11.1	13.9	15.8	19.9	24.1	29.3	37.6	46.5	55.6	72.2
33	9.1	11.4	14.3	16.3	20.5	24.8	30.2	38.8	48.	57.4	74.4
34	9.4	11.7	14.7	16.8	21.2	25.6	31.1	40.	49.5	59.1	76.7
35	9.6	12.1	15.2	17.3	21.8	26.3	32.	41.1	50.9	60.8	79.
36	9.9	12.5	15.6	17.8	22.4	27.	33.	42.3	52.4	62.6	81.3
37	10.2	12.8	16.1	18.3	23.	27.8	33.9	43.5	53.8	64.3	83.5
38	10.5	13.2	16.5	18.8	23.7	28.5	34.8	44.6	55.2	66.	85.8
39	10.7	13.5	16.9	19.3	24.3	29.3	35.7	45.8	56.7	67.8	88.
40	11.	13.8	17.4	19.8	24.9	30.1	36.6	47.	58.2	69.5	90.2
41	11.3	14.2	17.8	20.3	25.5	30.8	37.6	48.2	59.6	71.3	92.5
42	11.5	14.5	18.2	20.8	26.1	31.6	38.5	49.4	61.1	73.	94.8
43	11.8	14.9	18.7	21.3	26.8	32.3	39.4	50.6	62.5	74.8	97.
44	12.1	15.2	19.1	21.8	27.4	33.1	40.3	51.7	64.	76.5	99.3
45	12.4	15.6	19.5	22.2	28.	33.8	41.2	52.9	65.5	78.2	101.6
46	12.7	15.9	20.	22.7	28.6	34.6	42.2	54.	67.	80.	103.8
47	12.9	16.3	20.4	23.2	29.2	35.3	43.	55.2	68.4	81.7	106.
48	13.2	16.6	20.8	23.7	29.9	36.1	43.9	56.4	69.8	83.5	108.4
49	13.5	17.	21.3	24.2	30.5	36.8	44.8	57.6	71.2	85.1	110.5
50	13.8	17.3	21.7	24.7	31.1	37.6	45.8	58.7	72.7	87.	112.8

For greater lengths of pipe, use multiples from this table.

EQUATION OF PIPES

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus, one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power (i.e., as the 2.5 power). The following table has been calculated on this basis. The figure opposite the intersection of any two sizes is the number of the smaller-sized pipes required to equal one of the larger. Thus, one 4-inch pipe is equal to 5.7 2-inch pipes.

Diameter Inches	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	24
2	5.7	1														
3	15.6	2.8	1													
4	32	5.7	2.1	1												
5	55.9	9.9	3.6	1.7	1											
6	88.2	15.6	5.7	2.8	1.6	1										
7	130	22.9	8.3	4.1	2.3	1.5	1									
8	181	32	11.7	5.7	3.2	2.1	1.4	1								
9	243	43	15.6	7.6	4.3	2.8	1.9	1.3	1							
10	316	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.3	1						
11	401	70.9	25.7	12.5	7.2	4.6	3.1	2.2	1.7	1.3						
12	499	88.2	32	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1					
13	609	108	39.1	19	10.9	7.1	4.7	3.4	2.5	1.9	1.2					
14	733	130	47	22.9	13.1	8.3	5.7	4.1	3.0	2.3	1.5	1				
15	871	154	55.9	27.2	15.6	9.9	6.7	4.8	3.6	2.8	1.7	1.2				
16		181	65.7	32	18.3	11.7	7.9	5.7	4.2	3.2	2.1	1.4	1			
17		211	76.4	37.2	21.3	13.5	9.2	6.6	4.9	3.8	2.4	1.6	1.2			
18		243	88.2	43	24.6	15.6	10.6	7.6	5.7	4.3	2.8	1.9	1.3	1		
19		278	101	49.1	28.1	17.8	12.1	8.7	6.5	5	3.2	2.1	1.5	1.1		
20		316	115	55.9	32	20.3	13.8	9.9	7.4	5.7	3.6	2.4	1.7	1.3	1	
22		401	146	70.9	40.6	25.7	17.5	12.5	9.3	7.2	4.6	3.1	2.2	1.7	1.3	
24		499	181	88.2	50.5	32	21.8	15.6	11.6	8.9	5.7	3.8	2.8	2.1	1.6	1
26		609	221	108	61.7	39.1	26.6	19	14.2	10.9	7.1	4.7	3.4	2.5	1.9	1.2
28		733	266	130	74.2	47	32	22.9	17.1	13.1	8.3	5.7	4.1	3	2.3	1.5
30		871	316	154	88.2	55.9	38	27.2	20.3	15.6	9.9	6.7	4.8	3.6	2.8	1.7
36			499	243	130	88.2	60	43	32	24.6	15.6	10.6	7.6	5.7	4.3	2.8
42			733	357	205	130	88.2	63.2	47	36.2	19	15.6	11.2	8.3	6.4	4.1
48				499	286	181	123	88.2	62.7	50.5	32	21.8	15.6	11.6	8.9	5.7
54				670	383	243	165	118	88.2	67.8	43	29.2	20.9	15.6	12	7.6
60				871	499	316	215	154	115	88.2	55.9	38	27.2	20.3	15.6	9.9

Standard Companion Flanges and Bolts Dimensions (For Working Pressure up to 125 Lbs.)

Size Inches	Diam. of Flange Inches	Bolt Circle Inches	No. of Bolts	Size of Bolts, Inches	Length of Bolts
¾	3½	2½	4	⅜	1⅜
1	4¼	3⅛	4	½	1½
1¼	4⅝	3½	4	½	1½
1½	5	3⅞	4	½	1¾
2	6	4¾	4	⅝	2
2½	7	5½	4	⅝	2¼
3	7½	6	4	⅝	2¼
3½	8½	7	8	⅝	2½

Bolt holes are in multiples of four so that flanges may be made to face any quarter and bolt holes straddle the center line.
Bolt holes are drilled ⅛ inch larger than nominal diameter of bolts.

Size Inches	Diam. of Flange Inches	Bolt Circle Inches	No. of Bolts	Size of Bolts, Inches	Length of Bolts
4	9	7½	8	⅝	2¾
5	10	8½	8	¾	2¾
6	11	9½	8	¾	3
8	13½	11¾	8	¾	3¼
10	16	14¼	12	⅞	3½
12	19	17	12	⅞	3½
14	21	18¾	12	1	4
16	23½	21¼	16	1	4¼

When ordering specify size and diameter of companion flange. Example, a two-inch companion flange would be described 2"x6".

WEIGHTS OF BRASS, RED BRASS AND COPPER PIPE

Standard Pipe Sizes—Regular

Standard Pipe Size (I. P. S.)	Diameter, Inches		Thickness, Inches	Pounds per Foot			Feet per Pound		
	Outside	Inside	Wall	67 Brass	85 Red Brass	Copper	67 Brass	85 Red Brass	Copper
⅛	0.405	0.281	0.0620	0.246	0.253	0.259	4.07	3.95	3.86
¼	0.540	0.375	0.0825	0.437	0.450	0.460	2.29	2.22	2.17
⅜	0.675	0.494	0.0905	0.612	0.630	0.643	1.63	1.59	1.56
½	0.840	0.625	0.1075	0.911	0.938	0.957	1.10	1.07	1.04
¾	1.050	0.822	0.1140	1.24	1.27	1.30	0.806	0.787	0.769
1	1.315	1.062	0.1265	1.74	1.79	1.83	0.575	0.559	0.546
1¼	1.660	1.368	0.1460	2.56	2.63	2.69	0.391	0.380	0.372
1½	1.900	1.600	0.1500	3.04	3.13	3.20	0.329	0.319	0.313
2	2.375	2.062	0.1565	4.02	4.14	4.23	0.249	0.242	0.236
2½	2.875	2.500	0.1875	5.83	6.00	6.14	0.172	0.167	0.163
3	3.500	3.062	0.2190	8.31	8.56	8.75	0.120	0.117	0.114
3½	4.000	3.500	0.2500	10.85	11.17	11.41	0.092	0.090	0.088
4	4.500	4.000	.02500	12.29	12.66	12.94	0.081	0.079	0.077
4½	5.000	4.500	0.2500	13.74	14.15	14.46	0.073	0.071	0.069
5	5.563	5.063	0.2500	15.40	15.85	16.21	0.065	0.063	0.062
6	6.625	6.125	0.2500	18.44	18.99	19.41	0.054	0.053	0.052
7	7.625	7.062	0.2815	23.92	24.63	25.17	0.042	0.041	0.040
8	8.625	8.000	0.3125	30.05	30.95	31.63	0.033	0.032	0.032
9	9.625	8.937	0.3440	36.94	38.03	38.83	0.027	0.026	0 026
10	10.750	10.019	0.3655	43.91	45.20	46.22	0.023	0.022	0.022

SIZES AND WEIGHTS OF COPPER TUBES

Nominal Size Inch	Outside Diameter Inch	Inside Diameter Inch			Wall Thickness Inch			Permissible Variation in Gauge ± Inch			Pounds per Foot		
	Type K-L-M	Type K	Type L	Type M	Type K	Type L	Type M	Type K	Type L	Type M	Type K	Type L	Type M
⅛	.250	.186	.200	.200	.032	.025	.025	0.001	0.001	0.001	.085	.068	.068
¼	.375	.311	.315	.325	.032	.030	.025	.001	.001	.001	.134	.126	.106
⅜	.500	.402	.430	.450	.049	.035	.025	.004	.0035	.0025	.269	.198	.144
½	.625	.527	.545	.569	.049	.040	.028	.004	.0035	.0025	.344	.284	.203
⅝	.750	.652	.666		.049	.042		.0045	.004		.418	.362	
¾	.875	.745	.785	.811	.065	.045	.032	.0045	.004	.003	.641	.454	.328
1	1.125	.995	1.025	1.055	.065	.050	.035	.0045	.004	.0035	.839	.653	.464
1¼	1.375	1.245	1.265	1.291	.065	.055	.042	.0045	.0045	.0035	1.04	.882	.681
1½	1.625	1.481	1.505	1.527	.072	.060	.049	.005	.0045	.004	1.36	1.14	.940
2	2.125	1.959	1.985	2.009	.083	.070	.058	.005	.005	.0045	2.06	1.75	1.46
2½	2.625	2.435	2.465	2.495	.095	.080	.065	.005	.005	.0045	2.92	2.48	2.03
3	3.125	2.907	2.945	2.981	.109	.090	.072	.005	.005	.0045	4.00	3.33	2.68
3½	3.625	3.385	3.425	3.459	.120	.100	.083	.005	.005	.005	5.12	4.29	3.58
4	4.125	3.857	3.905	3.935	.134	.110	.095	.006	.005	.005	6.51	5.38	4.66
5	5.125	4.805	4.875	4.907	.160	.125	.109	.006	.006	.005	9.67	7.61	6.66
6	6.125	5.741	5.845	5.881	.192	.140	.122	.007	.006	.006	13.87	10.20	8.91

For underground services and general plumbing purposes with severe conditions—Type K, hard or soft.
For general plumbing purposes—Type L, hard or soft.
For general plumbing and heating purposes, with sweat fittings only, and with normal water conditions—Type M, hard.

THERMAL EXPANSION OF PIPE IN INCHES PER 100 FT.a

(For superheated steam and other fluids refer to temperature column)

Saturated Steam			Elongation in Inches per 100 Ft. from −20 F up			
Vacuum Inches of Hg.	Pressure Pounds per Square Inch Gage	Temperature Degrees Fahrenheit	Cast-Iron Pipe	Steel Pipe	Wrought-Iron Pipe	Copper Pipe
		−20	0	0	0	0
		0	0.127	0.145	0.152	0.204
		20	0.255	0.293	0.306	0.442
		40	0.390	0.430	0.465	0.655
29.39		60	0.518	0.593	0.620	0.888
28.89		80	0.649	0.725	0.780	1.100
27.99		100	0.787	0.898	0.939	1.338
26.48		120	0.926	1.055	1.110	1.570
24.04		140	1.051	1.209	1.265	1.794
20.27		160	1.200	1.368	1.427	2.008
14.63		180	1.345	1.528	1.597	2.255
6.45		200	1.495	1.691	1.778	2.500
	2.5	220	1.634	1.852	1.936	2.720
	10.3	240	1.780	2.020	2.110	2.960
	20.7	260	1.931	2.183	2.279	3.189
	34.5	280	2.085	2.350	2.465	3.422
	52.3	300	2.233	2.519	2.630	3.665
	74.9	320	2.395	2.690	2.800	3.900
	103.3	340	2.543	2.862	2.988	4.145
	138.3	360	2.700	3.029	3.175	4.380
	180.9	380	2.859	3.211	3.350	4.628
	232.4	400	3.008	3.375	3.521	4.870
	293.7	420	3.182	3.566	3.720	5.118
	366.1	440	3.345	3.740	3.900	5.358
	451.3	460	3.511	3.929	4.096	5.612
	550.3	480	3.683	4.100	4.280	5.855

Saturated Steam		Elongation in Inches per 100 Ft. from −20 F up			
Pressure Pounds per Square Inch Gage	Temperature Degrees Fahrenheit	Cast-Iron Pipe	Steel Pipe	Wrought Iron Pipe	Copper Pipe
664.3	500	3.847	4.296	4.477	6.110
795.3	520	4.020	4.487	4.677	6.352
945.3	540	4.190	4.670	4.866	6.614
1115.3	560	4.365	4.860	5.057	6.850
1308.3	580	4.541	5.051	5.268	7.123
1525.3	600	4.725	5.247	5.455	7.338
1768.3	620	4.896	5.437	5.660	7.636
2041.3	640	5.082	5.627	5.850	7.893
2346.3	660	5.260	5.831	6.067	8.153
2705	680	5.442	6.020	6.260	8.400
3080	700	5.629	6.229	6.481	8.676
	720	5.808	6.425	6.673	8.912
	740	6.006	6.635	6.899	9.203
	760	6.200	6.833	7.100	9.460
	780	6.389	7.046	7.314	9.736
	800	6.587	7.250	7.508	9.992
	820	6.779	7.464	7.757	10.272
	840	6.970	7.662	7.952	10.512
	860	7.176	7.888	8.195	10.814
	880	7.375	8.098	8.400	11.175
	900	7.579	8.313	8.639	11.360
	920	7.795	8.545	8.867	11.625
	940	7.989	8.755	9.089	11.911
	960	8.200	8.975	9.300	12.180
	980	8.406	9.196	9.547	12.473
	1000	8.617	9.421	9.776	12.747

aFrom *Piping Handbook*, by Walker and Crocker. This table gives the expansion from −20F. to the temperature in question. To obtain the amount of expansion between any two temperatures take the difference between the figures in the table for those temperatures. For example, if a steel pipe is installed at a temperature of 60 F. and is to operate at 300 F. the expansion would be 2.519 − 0.593 = 1.926 in.

HEATING POWER OF BRASS AND IRON PIPE

(Lying horizontal in water storage tank)

To bring out reliable working information the Institute of Thermal Research of the American Radiator Company prepared a comparative chart which is reproduced here. It is plotted from numerous tests made with brass and iron pipings, lying in horizontal position in a tank of water. To allow for bad water and the consequent fouling and pitting of pipes, only half of the actual condensing power is shown on the chart.

Example 1. It is required to condense 500 pounds of steam per hour in a pipe-coil immersed in the water of a storage tank. How many square feet of pipe should the coil contain?

Temperature of steam in pipe..220°
Initial temperature of water... 40°
Terminal temperature of water......................................160°
Mean temperature of water...100°
Temperature difference steam and water......................120°

Observe that the line for IRON pipe intersects the vertical line of 120 degrees temperature difference at the horizontal line representing 22.4 pounds. The intersection of the line for BRASS pipe shows 34.5 pounds.

The quantity of pipe required in square feet is determined by dividing the 500 pounds of steam which must be condensed per hour by the quantity of steam one square foot of pipe will condense. Thus:

For iron pipe....500 ÷ 22.4 = 22.2 sq. ft. would be required.
For brass pipe..500 ÷ 34.5 = 14.5 sq. ft. would be required.

Example 2. Suppose a tank containing 300 U. S. gallons of cold water at 60 degrees F. is to be heated by low pressure steam (at 5 pounds pressure) to a temperature of 140 degrees, in 2 hours; how many sq. ft. of brass pipe will be required, and how much steam will be condensed per hour?

300 U. S. gallons weight 300 × 8.33................2500 pounds
Total temperature rise desired............................80 degrees
Temperature rise per hour..................................40 degrees
Heat required per hour = 2500 × 40................100,000 Btu.
Temperature of steam at 5 pounds' pressure
(approx.)..227 degrees
Mean temperature of water...............................100 degrees
Mean temperature difference between steam
and water..127 degrees

Where the line for BRASS pipe intersects the vertical for 127 degrees, read the transmission per sq. ft., 36,500 Btu., and the condensing power, 38 pounds of steam per sq. ft. per hour. The total sq. ft. of BRASS pipe required will then be 100,000 ÷ 36,500 = 2.74 sq. ft. The condensation per hour would be 2.74 × 38 = 104.1 pounds.

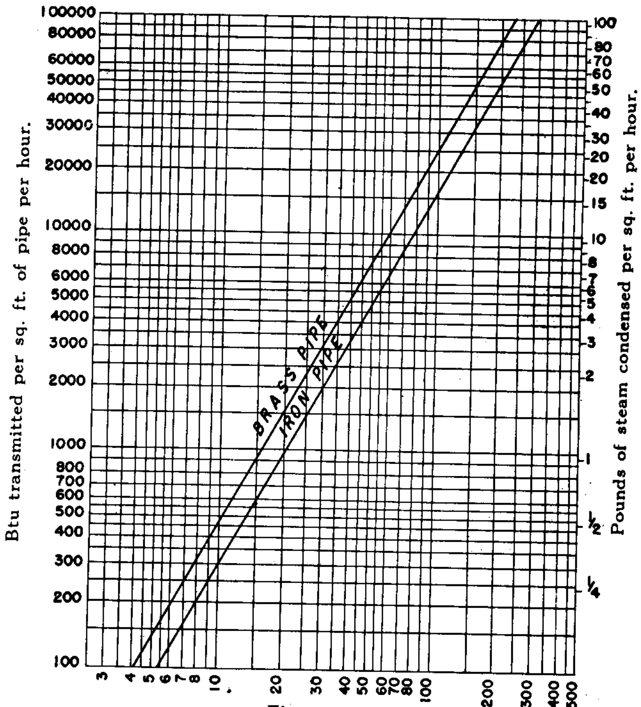


Fig. 3417

Temperature difference in fahr. degrees between steam in coil and steam or average temperature of water in tank.

Factor of safety of 50% is included to allow for bad water and consequent fouling and pitting of pipes. Chart plotted with coil lying horizontal in tank.

HEAT LOSSES FROM PIPING

The following Tables 1-2-3-4 are reprinted from Chapter 43, A.S.H.V.E. Guide 1943.

Table 1. Heat Losses from Horizontal Bare Steel Pipes.
Expressed in Btu per hour per linear foot per degree Fahrenheit difference in temperature between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	HOT WATER				STEAM		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F (100 Lb.)
	TEMPERATURE DIFFERENCE						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
½	0.455	0.495	0.546	0.534	0.612	0.706	0.760
¾	0.555	0.605	0.666	0.715	0.748	0.866	0.933
1	0.684	0.743	0.819	0.877	0.919	1.065	1.147
1¼	0.847	0.919	1.014	1.086	1.138	1.324	1.425
1½	0.958	1.041	1.148	1.230	1.288	1.492	1.633
2	1.180	1.281	1.412	1.512	1.578	1.840	1.987
2½	1.400	1.532	1.683	1.796	1.883	2.190	2.363
3	1.680	1.825	2.010	2.153	2.260	2.630	2.840
3½	1.900	2.064	2.221	2.433	2.552	2.974	3.215
4	2.118	2.302	2.534	2.717	2.850	3.320	3.590
5	2.580	2.804	3.084	3.303	3.470	4.050	4.385
6	3.036	3.294	3.626	3.886	4.074	4.765	5.160
8	3.880	4.215	4.638	4.960	5.210	6.100	6.610
10	4.760	5.180	5.680	6.090	6.410	7.490	8.115
12	5.590	6.070	6.670	7.145	7.500	8.800	9.530

Note:—For data on piping insulation, refer to current issue of the A.S.H.V.E. GUIDE.

Table 2. Heat Loss from Horizontal Bare Bright Copper Pipe.
Expressed in Btu per hour per linear foot per degree Fahrenheit between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	HOT WATER (Type K Copper Tube)				STEAM (Standard Pipe Size Pipe)		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F. (100 Lb)
	TEMPERATURE DIFFERENCE						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
½	0.180	0.210	0.218	0.229	0.299	0.338	0.355
¾	0.236	0.275	0.291	0.307	0.357	0.408	0.418
1	0.290	0.338	0.354	0.373	0.440	0.492	0.523
1¼	0.340	0.400	0.418	0.443	0.510	0.571	0.598
1½	0.390	0.463	0.473	0.507	0.598	0.671	0.710
2	0.490	0.525	0.600	0.623	0.719	0.813	0.851
2½	0.580	0.675	0.709	0.750	0.840	0.953	1.008
3	0.680	0.788	0.848	0.871	0.987	1.107	1.165
3½	0.760	0.888	0.946	1.000	1.114	1.235	1.307
4	0.940	1.000	1.045	1.107	1.210	1.361	1.456
4½	....	....	....	....	1.335	1.495	1.488
5	1.020	1.200	1.255	1.320	1.465	1.670	1.755
6	1.160	1.375	1.410	1.500	1.685	1.890	1.942
8	1.460	1.725	1.820	1.890	2.100	2.373	2.510

Note:—For data on piping insulation, refer to current issue of the A.S.H.V.E. GUIDE.

HEAT LOSSES FROM PIPING (Continued)

Table 3. Heat Loss from Bright Copper Pipe Given One Thin Coat of Clear Lacquer.
Expressed in Btu per hour per linear foot per degree Fahrenheit between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	HOT WATER (Type K Copper Tube)				STEAM (Standard Pipe Size Pipe)		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F (100 Lb.)
	TEMPERATURE DIFFERENCE						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
1/2	0.240	0.265	0.282	0.307	0.401	0.461	0.478
3/4	0.320	0.356	0.373	0.414	0.477	0.571	0.578
1	0.390	0.437	0.463	0.507	0.598	0.681	0.710
1 1/4	0.470	0.537	0.554	0.614	0.700	0.812	0.840
1 1/2	0.540	0.612	0.645	0.714	0.830	0.966	0.990
2	0.690	0.762	0.818	0.892	1.005	1.164	1.201
2 1/2	0.840	0.937	0.991	1.085	1.178	1.361	1.420
3	0.960	1.025	1.135	1.270	1.400	1.625	1.700
3 1/2	1.100	1.250	1.318	1.442	1.580	1.845	1.905
4	1.241	1.400	1.480	1.556	1.750	2.040	2.130
4 1/2	....	....	....	....	1.910	2.240	2.350
5	1.480	1.685	1.790	1.965	2.130	2.415	2.610
6	1.700	1.936	2.052	2.272	2.450	2.810	2.990
8	2.200	2.500	2.630	2.854	3.120	3.425	3.730

Note:—For data on piping insulation, refer to current issue of the A.S.H.V.E. GUIDE.

Table 4. Heat Loss from Horizontal Tarnished Copper Pipe.
Expressed in Btu per hour per linear foot per degree Fahrenheit between the pipe and surrounding still air at 70° F.

Nominal Pipe Size (Inches)	HOT WATER (Type K Copper Tube)				STEAM (Standard Pipe Size Pipe)		
	120 F	150 F	180 F	210 F	227.1 F (5 Lb.)	297.7 F (50 Lb.)	337.9 F (100 Lb.)
	TEMPERATURE DIFFERENCE						
	50 F	80 F	110 F	140 F	157.1 F	227.7 F	267.9 F
1/2	0.250	0.287	0.300	0.321	0.433	0.500	0.530
3/4	0.340	0.381	0.409	0.429	0.533	0.543	0.654
1	0.440	0.475	0.509	0.536	0.636	0.746	0.803
1 1/4	0.500	0.559	0.618	0.622	0.764	0.878	0.934
1 1/2	0.580	0.656	0.710	0.750	0.904	1.033	1.120
2	0.730	0.825	0.890	0.957	1.101	1.273	1.364
2 1/2	0.880	1.000	1.091	1.143	1.305	1.490	1.605
3	1.040	1.175	1.272	1.343	1.560	1.800	1.940
3 1/2	1.180	1.350	1.454	1.535	1.750	2.020	2.170
4	1.460	1.500	1.635	1.715	1.941	2.240	2.430
4 1/2	....	....	....	....	2.131	2.465	2.650
5	1.600	1.812	1.980	2.071	2.387	2.770	2.990
6	1.840	2.125	2.270	2.430	2.740	3.210	3.440
8	2.400	2.685	2.910	3.110	3.310	4.050	4.370

Note:—For data on piping insulation, refer to current issue of the A.S.H.V.E. GUIDE.

PIPE FITTINGS AND CONNECTIONS

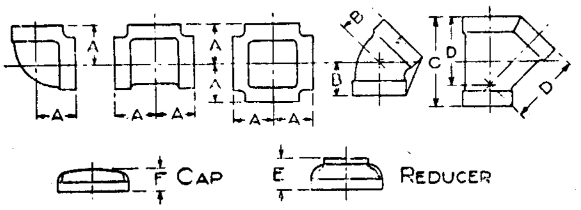


Fig. 935

Size Inches	A	B	C	D	E	F
1/4	13/16	3/4	....	....	....	....
3/8	15/16	13/16	....	....	....	....
1/2	1 1/8	7/8	2 1/2	1 7/8	....	....
3/4	1 5/16	1	3	2 1/4	....	....
1	1 7/16	1 1/8	3 1/2	2 3/4	....	....
1 1/4	1 3/4	1 5/16	4 1/4	3 1/4	2 1/8	....
1 1/2	1 15/16	1 7/16	4 7/8	3 13/16	2 1/4	....
2	2 1/4	1 11/16	5 3/4	4 1/2	2 7/16	....
2 1/2	2 11/16	1 15/16	6 3/4	5 3/16	2 11/16	....
3	3 1/8	2 3/16	7 7/8	6 1/8	2 15/16	....
3 1/2	3 7/16	2 3/8	8 7/8	6 7/8	3 1/8	....
4	3 3/4	2 5/8	9 3/4	7 5/8	3 3/8	2 1/16
4 1/2	4 1/16	2 13/16	10 5/8	8 1/2	3 5/8	2 3/16
5	4 7/16	3 1/16	11 5/8	9 1/4	3 7/8	2 3/8
6	5 1/8	3 7/16	13 7/16	10 3/4	4 3/8	2 5/8
7	5 13/16	3 7/8	15 1/4	12 1/4	4 13/16	2 7/8
8	6 1/2	4 1/4	16 15/16	13 5/8	5 1/4	3 1/8
9	7 3/16	4 11/16	20 11/16	16 3/4	5 11/16	3 3/8
10	7 7/8	5 3/16	20 11/16	16 3/4	6 3/16	3 5/8
12	9 1/4	6	24 1/8	19 5/8	7 1/8	4 1/4

The above dimensions are subject to slight variations (from Crane).

Length of Thread on Pipe That is Screwed Into Fittings to Make a Tight Joint

Dimensions in Inches

Size	A	Size	A
1/8	1/4	3 1/2	1 1/16
1/4	3/8	4	1 1/16
3/8	3/8	4 1/2	1 1/8
1/2	1/2	5	1 3/16
3/4	1/2	6	1 1/4
1	9/16	7	1 1/4
1 1/4	5/8	8	1 5/16
1 1/2	5/8	9	1 3/8
2	11/16	10	1 1/2
2 1/2	15/16	12	1 5/8
3	1		

Dimensions given do not allow for variation in tapping or threading (from Crane).

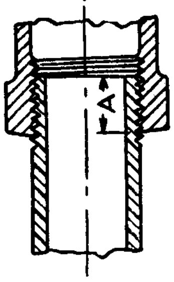


Fig. 936

BRANCH CONNECTIONS

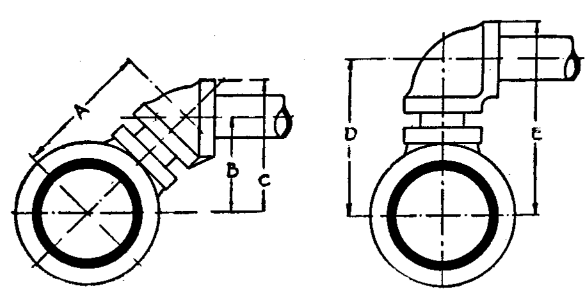


Fig. 896

Minimum Height of Connections Off Pipe Mains

Mains Inches	Branches Inches	A In.	B In.	C In.	D In.	E In.	Branches Inches	Mains Inches
2	1	3 3/8	2 3/8	3 13/32	3 31/32	5	1	2
2	1 1/4	3 11/16	2 5/8	3 7/8	4 7/16	5 11/16	1 1/4	2
2	1 1/2	4	2 27/32	4 7/32	4 13/16	6 3/16	1 1/2	2
2 1/2	1	3 3/4	2 21/32	3 11/16	4 11/32	5 3/8	1	2 1/2
2 1/2	1 1/4	4 1/16	2 7/8	4 1/8	4 13/16	6 1/16	1 1/4	2 1/2
2 1/2	1 1/2	4 3/8	3 3/32	4 15/16	5 3/16	6 9/16	1 1/2	2 1/2
2 1/2	2	4 7/8	3 7/16	5 1/8	5 7/8	7 9/16	2	2 1/2
3	1	4 1/16	2 7/8	3 29/32	4 21/32	5 11/16	1	3
3	1 1/4	4 3/8	3 3/32	4 11/32	5 1/8	6 3/8	1 1/4	3
3	1 1/2	4 11/16	3 5/16	4 11/16	5 1/2	6 7/8	1 1/2	3
3	2	5 5/16	3 11/16	5 3/8	6 3/16	7 7/8	2	3
3	2 1/2	5 9/16	3 15/16	6	6 13/16	8 7/8	2 1/2	3
3 1/2	1	4 11/32	3 1/16	4 3/32	4 15/16	5 31/32	1	3 1/2
3 1/2	1 1/4	4 21/32	3 5/16	4 9/16	5 13/32	6 21/32	1 1/4	3 1/2
3 1/2	1 1/2	4 31/32	3 17/32	4 9/32	5 25/32	7 5/32	1 1/2	3 1/2
3 1/2	2	5 15/32	3 7/8	5 9/16	6 15/32	8 5/32	2	3 1/2
3 1/2	2 1/2	5 27/32	4 1/8	6 3/16	7 3/32	9 5/32	2 1/2	3 1/2
4	1	4 11/16	3 5/16	4 11/32	5 9/32	6 5/16	1	4
4	1 1/4	5	3 17/32	4 25/32	5 3/4	7	1 1/4	4
4	1 1/2	5 5/16	3 3/4	5 1/8	6 1/8	7 1/2	1 1/2	4
4	2	5 13/16	4 1/8	5 13/16	6 13/16	8 1/2	2	4
4	2 1/2	6 3/16	4 3/8	6 7/16	7 7/16	9 1/2	2 1/2	4
5	1 1/4	5 17/32	3 29/32	5 5/32	6 9/32	7 17/32	1 1/4	5
5	1 1/2	5 27/32	4 1/8	5 1/2	6 21/32	8 1/32	1 1/2	5
5	2	6 11/32	4 1/2	6 3/16	7 11/32	9 1/32	2	5
5	2 1/2	6 23/32	4 3/4	6 13/16	7 31/32	10 1/32	2 1/2	5
6	1 1/4	6 3/16	4 3/8	5 1/8	6 15/16	8 3/16	1 1/4	6
6	1 1/2	6 1/2	4 5/8	6	7 5/16	8 11/16	1 1/2	6
6	2	7	4 31/32	6 21/32	8	9 11/16	2	6
6	2 1/2	7 3/8	5 7/32	7 9/32	8 5/8	10 11/16	2 1/2	6
8	2	8 1/4	5 27/32	7 17/32	9 1/4	10 15/16	2	8
8	2 1/2	8 5/8	6 1/8	8 3/16	9 7/8	11 15/16	2 1/2	8
8	3	9	6 3/8	8 3/4	10 7/16	12 13/16	3	8

The above table prepared by F. de Bois Ingals, M. E., indicates dimensions of branch connections when made up as close as possible with close nipple between tee on main and branch nipple.

OFFSET CONNECTIONS

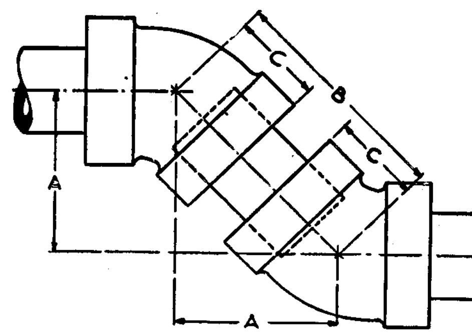


Fig. 897

TABLE—45 DEGREE OFFSETS								
	Close Nipple				Short Nipple			
Pipe Size	Length of Nipple	Offset A	Center to Center B	Center to Face C	Length of Nipple	Offset A	Center to Center B	Center to Face C
½	1⅛	1 5/16	1⅞	⅞	1½	1 9/16	2¼	⅞
¾	1⅜	1 11/16	2⅜	1	2	2 3/16	3	1
1	1½	1⅞	2⅝	1⅛	2	2¼	3⅛	1⅛
1¼	1⅝	2⅛	3	1 5/16	2½	2¾	3⅞	1 5/16
1½	1¾	2⅜	3⅜	1 7/16	2½	2 15/16	4⅛	1 7/16
2	2	2 13/16	4	1 11/16	2½	3 3/16	4½	1 11/16
2½	2½	3 3/16	4½	1 15/16	3	3 9/16	5	1 15/16
3	2⅝	3 9/16	5	2 3/16	3	3 13/16	5⅜	2 3/16
3½	2¾	3 13/16	5⅜	2⅜	4	4 11/16	6⅝	2⅜
4	3	4 5/16	6⅛	2⅝	4	5 1/16	7⅛	2⅝
4½	3	4½	6⅜	2 13/16	4	5 3/16	7⅜	2 13/16
5	3¼	4 15/16	7	3 1/16	4½	5 13/16	8¼	3 1/16
6	3¼	5⅜	7⅝	3 7/16	4½	6¼	8⅞	3 7/16
7	3½	6 3/16	8¾	3⅞	5	7¼	10¼	3⅞
8	3½	6⅝	9⅜	4¼	5	7 11/16	10⅞	4¼

The Offset "A" is equal to the distance "B" divided by 1.414.

ROLLING OFFSETS

It is often necessary to calculate the length of a piece of pipe between two 45-degree fittings where there is both a drop and a spread. In the sketch below, "A" represents the drop, "B" the spread, "X" the center to center distance. Using the formula: $X = 1.414\sqrt{A^2+B^2}$, which means that the center to center distance equals 1.414 times the square root of the sum of the drop squared plus the spread squared.

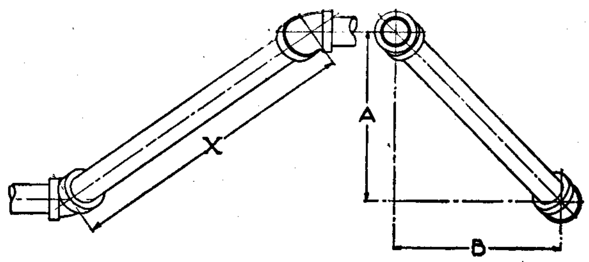


Fig. 1211

Example

Drop A = 12″

Spread B = 8″

$$X = 1.414\sqrt{(12)^2+(8)^2}$$
$$= 1.414\sqrt{\quad 208}$$
$$= 1.414 \times 14.42''$$
$$= 20.38''$$

For rolling offsets using other than 45° ells, the numbers given in the "Table for Offset Calculations," page 250, may be substituted for 1.414 as follows:

For rolling offsets using 5⅝° ells....$X = 10.207\sqrt{A^2+B^2}$

For rolling offsets using 11¼° ells....$X = 5.126\sqrt{A^2+B^2}$

For rolling offsets using 22½° ells....$X = 2.613\sqrt{A^2+B^2}$

For rolling offsets using 30° ells........$X = 2\sqrt{A^2+B^2}$

For rolling offsets using 60° ells........$X = 1.155\sqrt{A^2+B^2}$

Elbows of 22½°, 45° and 60° are usually carried in stock. Others may be obtained on special order.

OFFSET CALCULATIONS

By Warren E. Hill

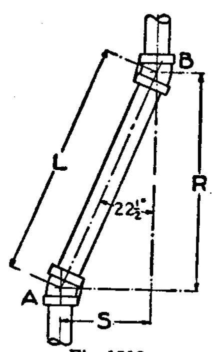


Fig. 1212

Example

Set S = 10″, 22½° angle

Length L = S × Factor (from table below)

L = 10″ × 2.6131

= 26.131″ approx. 26⅛″

The Right Triangle is the basis of the solution of all offsets. The angle from which a fitting derived its name is the angle shown as 22½ degrees in Fig. 1212 as A and B.

Note that the three sides of the triangle are lettered and that each side may be referred to as part of the offset. "S" stands for the short side or "SET" of the offset," "L" for the long side or "LENGTH" of center to center distance of the fittings, and "R" for the "RUN" side.

In calculating the usual offset, side "S" is known and side "L" is required, thus the figures in the top line of the following table are most frequently used.

To Find Side	When You Know Side	Multiply Side	For 5⅝° Ells By	For 11¼° Ells By	For 22½° Ells By	For 30° Ells By	For 45° Ells By	For 60° Ells By
L	S	S	10.207	5.1258	2.6131	2.00	1.41421	1.1547
S	L	L	.0980	.1951	.3827	.50	.707	.866
R	S	S	10.153	5.0273	2.4142	1.732	1.	.5773
S	R	R	.0985	.1989	.4142	.5773	1.	1.732
L	R	R	1.0048	1.0196	1.0824	1.1547	1.41421	2.00
R	L	L	.9952	.9809	.9239	.866	.7071	.500

SHORT METHOD OF FIGURING HEAT LOSSES—THROUGH GLASS AND WALL

TABLE I

HEAT LOSS, ETC. THROUGH GLASS

Square Feet of Equivalent Direct Radiation for Heat Loss Through Two-Pane Windows, Including Sash
Room Temp., 70° F. Outside Temp., 0° F.

Width of Glass	Width of Opening	Height Glass	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"	38"	40"	42"	44"
		HEIGHT OF WINDOW OPENING IN FEET AND INCHES															
		Height of Opening	3'–2"	3'–6"	3'–10"	4'–2"	4'–6"	4'–10"	5'–2"	5'–6"	5'–10"	6'–2"	6'–6"	6'–10"	7'–2"	7'–6"	7'–10"
16"	1'—8"	STANDARD SIZES OF TWO-LIGHT WINDOWS	2.32	2.54	2.80	3.06	3.28	3.54	3.76	4.03	4.24	4.51	4.73	4.99	5.21	5.47	5.69
18"	1'—10"		2.54	2.80	3.06	3.33	3.63	3.89	4.16	4.42	4.68	4.94	5.21	5.47	5.73	5.99	6.26
20"	2'—0"		2.76	3.06	3.37	3.63	3.94	4.24	4.51	4.81	5.12	5.38	5.69	5.99	6.26	6.56	6.83
22"	2'—2"		3.02	3.33	3.63	3.94	4.24	4.59	4.90	5.21	5.51	5.86	6.17	6.48	6.78	7.09	7.48
24"	2'—4"		3.24	3.59	3.89	4.24	4.59	4.94	5.29	5.60	5.95	6.30	6.65	6.96	7.31	7.66	8.01
26"	2'—6"		3.46	3.85	4.20	4.59	4.94	5.29	5.64	6.04	6.39	6.74	7.13	7.48	7.83	8.23	8.58
28"	2'—8"		3.59	4.07	4.46	4.86	5.25	5.64	6.04	6.43	6.83	7.22	7.57	7.96	8.36	8.75	9.14
30"	2'—10"		3.94	4.33	4.77	5.16	5.60	5.99	6.39	6.83	7.22	7.66	8.05	8.49	8.88	9.28	9.71
32"	3'—0"		4.16	4.59	5.03	5.47	5.91	6.34	6.78	7.22	7.66	8.09	8.53	8.97	9.41	9.84	10.28
34"	3'—2"		4.38	4.86	5.29	5.78	6.26	6.69	7.18	7.61	8.09	8.53	9.01	9.45	9.93	10.41	10.85
36"	3'—4"		4.64	5.12	5.60	6.08	6.56	7.04	7.53	8.01	8.53	9.01	9.49	9.98	10.46	10.94	11.42
38"	3'—6"		4.86	5.38	5.86	6.39	6.91	7.39	7.92	8.44	8.93	9.45	9.98	10.50	10.98	11.46	11.99
40"	3'—8"		5.08	5.60	6.17	6.69	7.22	7.74	8.31	8.84	9.36	9.89	10.41	10.98	11.51	12.03	12.56
42"	3'—10"		5.29	5.86	6.43	7.00	7.57	8.09	8.66	9.23	9.80	10.33	10.89	11.46	12.03	12.60	13.13
44"	4'—0"		5.56	6.13	6.69	7.31	7.88	8.44	9.06	9.63	10.24	10.81	11.38	11.99	12.51	13.13	13.69

RULES FOR USING TABLES

1. Determine window dimensions or masonry opening for each window from plans and select the required radiation from Table I. If there are outside doors in the room, handle the same as for windows.
2. Measure the lineal feet of exposed wall plus *one-half of the sum of the widths of all windows from the plans and obtain the radiation required for the given ceiling height from Table II.
   *This allowance for windows is approximate but is sufficiently accurate and on the safe side. If greater accuracy is desired, determine the width which gives proper value and add that fraction of the sum of the widths of all windows. Thus, this value may be ¼, ⅓, etc.
3. Add the amounts of radiation obtained for windows and walls together to give the "Net Radiation" and correct this for exposures and other allowances

TABLE II

Square Feet of Equivalent Direct Radiation for Heat Loss Through Wall Area of Various Dimensions
Room Temp., 70° F. Outside Temp., 0° F.

RUNNING FEET OF EXPOSED WALL WITHOUT REGARD TO WINDOW OPENINGS

Height of Ceiling or Width of Room in Feet	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
8	5.25	6.13	7.00	7.88	8.75	9.63	10.50	11.38	12.25	13.13	14.00	14.88	15.75	16.63	17.50	18.38	19.25	20.13	21.00
8½	5.58	6.56	7.44	8.42	9.30	10.28	11.15	12.14	13.02	14.00	14.88	15.86	16.74	17.72	18.60	19.58	20.46	21.44	22.32
9	5.91	6.89	7.88	8.86	9.85	10.83	11.82	12.80	13.78	14.77	15.75	16.74	17.72	18.71	19.69	20.68	21.66	22.65	23.63
9½	6.24	7.33	8.31	9.41	10.39	11.49	12.47	13.57	14.55	15.64	16.63	17.72	18.71	19.80	20.79	21.88	22.86	23.96	24.94
10	6.56	7.66	8.75	9.85	10.94	12.03	13.13	14.22	15.32	16.41	17.50	18.60	19.69	20.79	21.88	22.97	24.07	25.16	26.26
10½	6.89	8.10	9.19	10.39	11.49	12.69	13.78	14.99	16.08	17.29	18.38	19.58	20.68	21.88	22.97	24.18	25.27	26.47	27.57
11	7.22	8.42	9.63	10.83	12.03	13.24	14.44	15.64	16.85	18.05	19.25	20.46	21.66	22.86	24.07	25.27	26.47	27.68	28.88
11½	7.55	8.86	10.06	11.38	12.58	13.89	15.10	16.41	17.61	18.93	20.13	21.44	22.65	23.96	25.16	26.47	27.68	28.99	30.19
12	7.88	9.19	10.50	11.82	13.13	14.44	15.75	17.07	18.38	19.69	21.00	22.32	23.63	24.94	26.27	27.57	28.88	30.19	31.51
12½	8.21	9.63	10.94	12.36	13.68	15.10	16.41	17.83	19.15	20.57	21.88	23.30	24.62	26.04	27.35	28.77	30.09	31.51	32.82
13	8.53	9.96	11.38	12.80	14.22	15.64	17.07	18.48	19.80	21.33	22.76	24.18	25.60	27.02	28.44	29.87	31.29	32.71	34.13
13½	8.86	10.39	11.82	13.35	14.77	16.30	17.72	19.25	20.68	22.21	23.63	25.16	26.58	28.12	29.54	31.07	32.49	34.02	35.45
14	9.19	10.72	12.25	13.78	15.32	16.85	18.38	19.91	21.44	22.97	24.51	26.04	27.57	29.10	30.63	32.16	33.70	35.23	36.76

Height of Ceiling or Width of Room in Feet	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
8	21.88	22.76	23.63	24.51	25.38	26.26	27.13	28.01	28.88	29.76	30.63	31.51	32.38	33.26	34.13	35.01	35.88	36.76	37.63
8½	23.30	24.18	25.16	26.04	27.02	27.90	28.88	29.76	30.74	31.62	32.60	33.48	34.46	35.34	36.32	37.20	38.17	39.06	40.04
9	24.62	25.60	26.58	27.57	28.55	29.54	30.52	31.51	32.49	33.48	34.46	35.45	36.43	37.41	38.40	39.38	40.37	41.35	42.34
9½	26.04	27.02	28.12	29.10	30.19	31.18	32.27	33.26	34.35	35.34	36.43	37.41	38.51	39.49	40.59	41.57	42.66	43.65	44.74
10	27.35	28.44	29.54	30.63	31.73	32.82	33.91	35.01	36.10	37.20	38.29	39.38	40.48	41.57	42.67	43.76	44.85	45.95	47.04
10½	28.77	29.87	31.07	32.16	33.37	34.46	35.66	36.76	37.96	39.06	40.26	41.35	42.56	43.65	44.85	45.95	47.15	48.25	49.45
11	30.09	31.29	32.49	33.70	34.90	36.10	37.31	38.51	39.71	40.92	42.12	43.32	44.53	45.73	46.93	48.14	49.34	50.54	51.75
11½	31.51	32.71	34.02	35.23	36.54	37.74	39.06	40.26	41.57	42.78	44.09	45.29	46.60	47.80	49.12	50.32	51.63	52.84	54.15
12	32.82	34.13	35.45	36.76	38.07	39.38	40.70	42.01	43.32	44.64	45.95	47.26	48.57	49.89	51.20	52.51	53.82	55.14	56.45
12½	34.24	35.56	36.98	38.29	39.71	41.03	42.45	43.76	45.18	46.50	47.92	49.23	50.65	51.97	53.39	54.70	56.12	57.44	58.86
13	35.56	36.98	38.40	39.82	41.24	42.67	44.09	45.51	46.93	48.35	49.78	51.20	52.62	54.04	55.47	56.89	58.31	59.73	61.15
13½	36.98	38.40	39.93	41.35	42.88	44.31	45.84	47.26	48.79	50.21	51.75	53.17	54.70	56.12	57.65	59.08	60.61	62.03	63.56
14	38.29	39.82	41.35	42.88	44.42	45.95	47.48	49.01	50.54	52.07	53.61	55.14	56.67	58.20	59.73	61.26	62.80	64.33	65.86

SHORT METHOD OF FIGURING HEAT LOSSES—THROUGH GLASS AND WALL

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HEAT LOSS, ETC. THROUGH GLASS

Square Feet of Equivalent Direct Radiation for Heat Loss Through Two-Pane Windows, Including Sash
Room Temp., 70° F. Outside Temp., 0° F.

Width of Glass	Width of Opening	Height Glass	16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"	38"	40"	42"	44"
		HEIGHT OF WINDOW OPENING IN FEET AND INCHES															
		Height of Opening	3'–2"	3'–6"	3'–10"	4'–2"	4'–6"	4'–10"	5'–2"	5'–6"	5'–10"	6'–2"	6'–6"	6'–10"	7'–2"	7'–6"	7'–10"
16"	1'—8"	STANDARD SIZES OF TWO-LIGHT WINDOWS	2.32	2.54	2.80	3.06	3.28	3.54	3.76	4.03	4.24	4.51	4.73	4.99	5.21	5.47	5.69
18"	1'—10"		2.54	2.80	3.06	3.33	3.63	3.89	4.16	4.42	4.68	4.94	5.21	5.47	5.73	5.99	6.26
20"	2'—0"		2.76	3.06	3.37	3.63	3.94	4.24	4.51	4.81	5.12	5.38	5.69	5.99	6.26	6.56	6.83
22"	2'—2"		3.02	3.33	3.63	3.94	4.24	4.59	4.90	5.21	5.51	5.86	6.17	6.48	6.78	7.09	7.48
24"	2'—4"		3.24	3.59	3.89	4.24	4.59	4.94	5.29	5.60	5.95	6.30	6.65	6.96	7.31	7.66	8.01
26"	2'—6"		3.46	3.85	4.20	4.59	4.94	5.29	5.64	6.04	6.39	6.74	7.13	7.48	7.83	8.23	8.58
28"	2'—8"		3.59	4.07	4.46	4.86	5.25	5.64	6.04	6.43	6.83	7.22	7.57	7.96	8.36	8.75	9.14
30"	2'—10"		3.94	4.33	4.77	5.16	5.60	5.99	6.39	6.83	7.22	7.66	8.05	8.49	8.88	9.28	9.71
32"	3'—0"		4.16	4.59	5.03	5.47	5.91	6.34	6.78	7.22	7.66	8.09	8.53	8.97	9.41	9.84	10.28
34"	3'—2"		4.38	4.86	5.29	5.78	6.26	6.69	7.18	7.61	8.09	8.53	9.01	9.45	9.93	10.41	10.85
36"	3'—4"		4.64	5.12	5.60	6.08	6.56	7.04	7.53	8.01	8.53	9.01	9.49	9.98	10.46	10.94	11.42
38"	3'—6"		4.86	5.38	5.86	6.39	6.91	7.39	7.92	8.44	8.93	9.45	9.98	10.50	10.98	11.46	11.99
40"	3'—8"		5.08	5.60	6.17	6.69	7.22	7.74	8.31	8.84	9.36	9.89	10.41	10.98	11.51	12.03	12.56
42"	3'—10"		5.29	5.86	6.43	7.00	7.57	8.09	8.66	9.23	9.80	10.33	10.89	11.46	12.03	12.60	13.13
44"	4'—0"		5.56	6.13	6.69	7.31	7.88	8.44	9.06	9.63	10.24	10.81	11.38	11.99	12.51	13.13	13.69

RULES FOR USING TABLES

Determine window dimensions or masonry opening for each window from plans and select the required radiation from Table I. If there are outside doors in the room, handle the same as for windows.

Measure the lineal feet of exposed wall plus *one-half of the sum of the widths of all windows from the plans and obtain the radiation required for the given ceiling height from Table II.

*This allowance for windows is approximate but is sufficiently accurate and on the safe side. If greater accuracy is desired, determine the width which gives proper value and add that fraction of the sum of the widths of all windows. Thus, this value may be ¼, ⅓, etc.

Add the amounts of radiation obtained for windows and walls together to give the "Net Radiation" and correct this for exposures and other allowances

TABLE II

Square Feet of Equivalent Direct Radiation for Heat Loss Through Wall Area of Various Dimensions
Room Temp., 70° F. Outside Temp., 0° F.

RUNNING FEET OF EXPOSED WALL WITHOUT REGARD TO WINDOW OPENINGS

Height of Ceiling or Width of Room in Feet	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
8	5.25	6.13	7.00	7.88	8.75	9.63	10.50	11.38	12.25	13.13	14.00	14.88	15.75	16.63	17.50	18.38	19.25	20.13	21.00
8½	5.58	6.56	7.44	8.42	9.30	10.28	11.15	12.14	13.02	14.00	14.88	15.86	16.74	17.72	18.60	19.58	20.46	21.44	22.32
9	5.91	6.89	7.88	8.86	9.85	10.83	11.82	12.80	13.78	14.77	15.75	16.74	17.72	18.71	19.69	20.68	21.66	22.65	23.63
9½	6.24	7.33	8.31	9.41	10.39	11.49	12.47	13.57	14.55	15.64	16.63	17.72	18.71	19.80	20.79	21.88	22.86	23.96	24.94
10	6.56	7.66	8.75	9.85	10.94	12.03	13.13	14.22	15.32	16.41	17.50	18.60	19.69	20.79	21.88	22.97	24.07	25.16	26.26
10½	6.89	8.10	9.19	10.39	11.49	12.69	13.78	14.99	16.08	17.29	18.38	19.58	20.68	21.88	22.97	24.18	25.27	26.47	27.57
11	7.22	8.42	9.63	10.83	12.03	13.24	14.44	15.64	16.85	18.05	19.25	20.46	21.66	22.86	24.07	25.27	26.47	27.68	28.88
11½	7.55	8.86	10.06	11.38	12.58	13.89	15.10	16.41	17.61	18.93	20.13	21.44	22.65	23.96	25.16	26.47	27.68	28.99	30.19
12	7.88	9.19	10.50	11.82	13.13	14.44	15.75	17.07	18.38	19.69	21.00	22.32	23.63	24.94	26.27	27.57	28.88	30.19	31 51
12½	8.21	9.63	10.94	12.36	13.68	15.10	16.41	17.83	19.15	20.57	21.88	23.30	24.62	26.04	27.35	28.77	30.09	31.51	32.82
13	8.53	9.96	11.38	12.80	14.22	15.64	17.07	18.48	19.80	21.33	22.76	24.18	25.60	27.02	28.44	29.87	31.29	32.71	34.13
13½	8.86	10.39	11.82	13.35	14.77	16.30	17.72	19.25	20.68	22.21	23.63	25.16	26.58	28.12	29.54	31.07	32.49	34.02	35 45
14	9.19	10.72	12.25	13.78	15.32	16.85	18.38	19.91	21.44	22.97	24.51	26.04	27.57	29.10	30.63	32.16	33.70	35.23	36.76

Height of Ceiling or Width of Room in Feet	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
8	21.88	22.76	23.63	24.51	25.38	26.26	27.13	28.01	28.88	29.76	30.63	31.51	32.38	33.26	34.13	35.01	35.88	36.76	37.63
8½	23.30	24.18	25.16	26.04	27.02	27.90	28.88	29.76	30.74	31.62	32.60	33.48	34.46	35.34	36.32	37.20	38.17	39.06	40 04
9	24.62	25.60	26.58	27.57	28:55	29.54	30.52	31.51	32.49	33.48	34.46	35.45	36.43	37.41	38.40	39.38	40.37	41.35	42.34
9½	26.04	27.02	28.12	29.10	30.19	31.18	32.27	33.26	34.35	35.34	36.43	37.41	38.51	39.49	40.59	41.57	42.66	43.65	44.74
10	27.35	28.44	29.54	30.63	31.73	32.82	33.91	35.01	36.10	37.20	38.29	39.38	40.48	41.57	42.67	43.76	44.85	45 95	47.04
10½	28.77	29.87	31.07	32.16	33.37	34.46	35.66	36.76	37.96	39.06	40.26	41.35	42.56	43.65	44.85	45.95	47.15	48.25	49.45
11	30.09	31.29	32.49	33.70	34.90	36.10	37.31	38.51	39.71	40.92	42.12	43.32	44.53	45.73	46.93	48.14	49.34	50.54	51.75
11½	31.51	32.71	34.02	35.23	36.54	37.74	39.06	40.26	41.57	42.78	44.09	45.29	46.60	47.80	49.12	50.32	51.63	52.84	54.15
12	32.82	34.13	35.45	36.76	38.07	39.38	40.70	42.01	43.32	44.64	45.95	47.26	48.57	49.89	51.20	52.51	53.82	55.14	56.45
12½	34.24	35.56	36.98	38.29	39.71	41.03	42.45	43.76	45.18	46.50	47.92	49.23	50.65	51.97	53.39	54.70	56.12	57.44	58.86
13	35.56	36.98	38.40	39.82	41.24	42.67	44.09	45.51	46.93	48.35	49.78	51.20	52.62	54.04	55.47	56.89	58.31	59.73	61.15
13½	36.98	38.40	39.93	41.35	42.88	44.31	45.84	47.26	48.79	50.21	51.75	53.17	54.70	56.12	57.65	59.08	60.61	62.03	63.56
14	38.29	39.82	41.35	42.88	44.42	45.95	47.48	49.01	50.54	52.07	53.61	55.14	56.67	58.20	59.73	61.26	62.80	64.33	65.86

TABLE GIVING FULL AREA IN SQUARE FEET OF TWO-PANE WINDOWS, INCLUDING THE SASH, ALLOWING 4 INCHES TO THE WIDTH AND 6 INCHES TO THE HEIGHT. FRAME AND SASH OF WOOD.

Width of Glass	Width of Opening	Height of Glass in Each Pane in Inches														
		16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"	38"	40"	42"	44"
		Height of Window Opening in Feet and Inches														
		3'-2"	3'-6"	3'-10"	4'-2"	4'-6"	4'-10"	5'-2"	5'-6"	5'-10"	6'-2"	6'-6"	6'-10"	7'-2"	7'-6"	7'-10"
16"	1'-8"	5.3	5.8	6.4	7.0	7.5	8.1	8.6	9.2	9.7	10.3	10.8	11.4	11.9	12.5	13.0
18"	1'-10"	5.8	6.4	7.0	7.6	8.3	8.9	9.5	10.1	10.7	11.3	11.9	12.5	13.1	13.7	14.3
20"	2'-0"	6.3	7.0	7.7	8.3	9.0	9.7	10.3	11.0	11.7	12.3	13.0	13.7	14.3	15.0	15.6
22"	2'-2"	6.9	7.6	8.3	9.0	9.7	10.5	11.2	11.9	12.6	13.4	14.1	14.8	15.5	16.2	17.1
24"	2'-4"	7.4	8.2	8.9	9.7	10.5	11.3	12.1	12.8	13.6	14.4	15.2	15.9	16.7	17.5	18.3
26"	2'-6"	7.9	8.8	9.6	10.5	11.3	12.1	12.9	13.8	14.6	15.4	16.3	17.1	17.9	18.8	19.6
28"	2'-8"	8.2	9.3	10.2	11.1	12.0	12.9	13.8	14.7	15.6	16.5	17.3	18.2	19.1	20.0	20.9
30"	2'-10"	9.0	9.9	10.9	11.8	12.8	13.7	14.6	15.6	16.5	17.5	18.4	19.4	20.3	21.2	22.2
32"	3'-0"	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5
34"	3'-2"	10.0	11.1	12.1	13.2	14.3	15.3	16.4	17.4	18.5	19.5	20.6	21.6	22.7	23.8	24.8
36"	3'-4"	10.6	11.7	12.8	13.9	15.0	16.1	17.2	18.3	19.5	20.6	21.7	22.8	23.9	25.0	26.1
38"	3'-6"	11.1	12.3	13.4	14.6	15.8	16.9	18.1	19.3	20.4	21.6	22.8	24.0	25.1	26.2	27.4
40"	3'-8"	11.6	12.8	14.1	15.3	16.5	17.7	19.0	20.2	21.4	22.6	23.8	25.1	26.3	27.5	28.7
42"	3'-10"	12.1	13.4	14.7	16.0	17.3	18.5	19.8	21.1	22.4	23.6	24.9	26.2	27.5	28.8	30.0
44"	4'-0"	12.7	14.0	15.3	16.7	18.0	19.3	20.7	22.0	23.4	24.7	26.0	27.4	28.6	30.0	31.3

Example: A window containing two lights each measuring 26"x28" would have an area, including sash, of 12.9 square feet, which should be used as exposed glass area in the calculation of the radiation.

TABLE OF CRACK LENGTH IN FEET FOR TWO-PANE WINDOWS INCLUDING THE SASH, ALLOWING 4 INCHES TO WIDTH AND 6 INCHES TO HEIGHT-FRAME AND SASH OF WOOD.

Width of Glass	Width of Opening	Height of Glass in Each Pane in Inches														
		16"	18"	20"	22"	24"	26"	28"	30"	32"	34"	36"	38"	40"	42"	44"
		Height of Window Opening in Feet and Inches														
		3'-2"	3'-6"	3'-10"	4'-2"	4'-6"	4'-10"	5'-2"	5'-6"	5'-10"	6'-2"	6'-6"	6'-10"	7'-2"	7'-6"	7'-10"
16"	1'-8"	11.3	12.0	12.6	13.3	14.0	14.6	15.3	16.0	16.6	17.3	18.0	18.6	19.3	20.0	20.6
18"	1'-10"	11.8	12.5	13.1	13.8	14.5	15.1	15.8	16.5	17.1	17.8	18.5	19.1	19.8	20.5	21.1
20"	2'-0"	12.3	13.0	13.6	14.3	15.0	15.6	16.3	17.0	17.6	18.3	19.0	19.6	20.3	21.0	21.6
22"	2'-2"	12.8	13.5	14.1	14.8	15.5	16.1	16.8	17.5	18.1	18.8	19.5	20.1	20.8	21.5	22.1
24"	2'-4"	13.3	14.0	14.6	15.3	16.0	16.6	17.3	18.0	18.6	19.3	20.0	20.6	21.3	22.0	22.6
26"	2'-6"	13.8	14.5	15.1	15.8	16.5	17.1	17.8	18.5	19.1	19.8	20.5	21.1	21.8	22.5	23.1
28"	2'-8"	14.3	15.0	15.6	16.3	17.0	17.6	18.3	19.0	19.6	20.3	21.0	21.6	22.3	23.0	23.6
30"	2'-10"	14.8	15.5	16.1	16.8	17.5	18.1	18.8	19.5	20.1	20.8	21.5	22.1	22.8	23.5	24.1
32"	3'-0"	15.3	16.0	16.6	17.3	18.0	18.6	19.3	20.0	20.6	21.3	22.0	22.6	23.3	24.0	24.6
34"	3'-2"	15.8	16.5	17.1	17.8	18.5	19.1	19.8	20.5	21.1	21.8	22.5	23.1	23.8	24.5	25.1
36"	3'-4"	16.3	17.0	17.6	18.3	19.0	19.6	20.3	21.0	21.6	22.3	23.0	23.6	24.3	25.0	25.6
38"	3'-6"	16.8	17.5	18.1	18.8	19.5	20.1	20.8	21.5	22.1	22.8	23.5	24.1	24.8	25.5	26.1
40"	3'-8"	17.3	18.0	18.6	19.3	20.0	20.6	21.3	22.0	22.6	23.3	24.0	24.6	25.3	26.0	26.6
42"	3'-10"	17.8	18.5	19.1	19.8	20.5	21.1	21.8	22.5	23.1	23.8	24.5	25.1	25.8	26.5	27.1
44"	4'-0"	18.3	19.0	19.6	20.3	21.0	21.6	22.3	23.0	23.6	24.3	25.0	25.6	26.3	27.0	27.6

Example: A window containing two lights 26"x28" would have a total crack length of 17.8 feet which should be used to determine the air infiltration by the "Crack Method."

SQUARE FEET GROSS WALL SURFACE, FLOOR AREA OR CEILING

Ht. of Ceiling or Width of Room in Feet	Length of Exposed Wall or Length of Room in Feet										Ht. of Ceiling or Width of Room in Feet
	5'	6'	8'	10'	12'	14'	16'	18'	20'	24'	
8'	40	48	64	80	96	112	128	144	160	192	8'
8½'	43	51	68	85	102	119	136	153	170	204	8½'
9'	45	54	72	90	108	126	144	162	180	216	9'
9½'	48	57	76	95	114	133	152	171	190	228	9½'
10'	50	60	80	100	120	140	160	180	200	240	10'
10½'	53	63	84	105	126	147	168	189	210	252	10½'
11'	55	66	88	110	132	154	176	198	220	264	11'
11½'	58	69	92	115	138	161	184	207	230	276	11½'
12'	60	72	96	120	144	168	192	216	240	288	12'
13'	65	78	104	130	156	181	208	234	260	312	13'
14'	70	84	112	140	168	196	224	252	280	336	14'
15'	75	90	120	150	180	210	240	270	300	360	15'
16'	80	96	128	160	192	224	256	288	320	384	16'
17'	85	102	136	170	204	238	272	306	340	408	17'
18'	90	108	144	180	216	252	288	324	360	432	18'
19'	95	114	152	190	228	266	304	342	380	456	19'
20'	100	120	160	200	240	280	320	360	400	480	20'
21'	105	126	168	210	252	294	336	378	420	504	21'
22'	110	132	176	220	264	308	352	396	440	528	22'
23'	115	138	184	230	276	322	368	414	460	552	23'
24'	120	144	192	240	288	336	384	432	480	576	24'
25'	125	150	200	250	300	350	400	450	500	600	25'

CUBICAL CONTENTS OF ROOMS

Floor Dimensions	Having Ceilings of the Following Heights							
	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
5 x 8	320	340	360	380	400	420	440	480
5 x 10	400	425	450	475	500	525	550	600
6 x 8	384	408	432	456	480	504	528	576
6 x 10	480	510	540	570	600	630	660	720
7 x 8	448	476	504	532	560	588	616	672
7 x 10	560	595	630	665	700	735	770	840
8 x 10	640	680	720	760	800	840	880	960
8 x 12	768	816	864	912	960	1008	1056	1152
8 x 14	896	952	1008	1064	1120	1176	1232	1344
9 x 10	720	765	810	855	900	945	990	1080
9 x 12	864	918	972	1026	1080	1134	1188	1296
9 x 14	1008	1071	1134	1197	1260	1323	1386	1512
10 x 12	960	1020	1080	1140	1200	1260	1320	1440
10 x 14	1120	1190	1260	1330	1400	1470	1540	1680
10 x 16	1280	1360	1440	1520	1600	1680	1760	1920
10 x 18	1440	1530	1620	1710	1800	1890	1980	2160
12 x 14	1344	1428	1512	1596	1680	1764	1848	2016
12 x 18	1728	1836	1944	2052	2160	2268	2376	2592
14 x 16	1792	1904	2016	2128	2240	2352	2464	2688
14 x 20	2240	2380	2520	2660	2800	2940	3080	3360
16 x 20	2560	2720	2880	3040	3200	3360	3520	3840
16 x 24	3072	3264	3456	3648	3840	4032	4224	4608
18 x 22	3168	3366	3564	3762	3960	4158	4356	4752
18 x 30	4320	4590	4860	5130	5400	5670	5940	6480
20 x 24	3840	4080	4320	4560	4800	5040	5280	5760
20 x 30	4800	5100	5400	5700	6000	6300	6600	7200

BOILERS AND ENGINES

Showing the Loss in Conductivity of Boiler Plate Due to Difference in Thickness of Soot Deposit (Applying to secondary surface)

Thickness of Soot	Loss Per Cent
Clean	0.0
1/32 inch	9.5
1/16 inch	26.2
1/8 inch	45.2
3/16 inch	69.0

Proceedings, Institute of Marine Engineers.

Horsepower of Boilers and Engines

Standard adopted by American Society of Mechanical Engineers defines the boiler horsepower as the equivalent evaporation of 34.5 lb of water from and at 212 degrees per hour. This is the same as 33,479 Btu per hour.

The best designed boilers, well set, with good draft, and skillful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

On 1 square foot of grate can be burned on an average from 10 to 12 pounds of hard coal, or 18 to 20 pounds of soft coal per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Compound engines will develop a horsepower on 15 pounds of steam.

Single condensing engine will develop a horsepower on 22 to 28 pounds of steam.

Automatic non-condensing engines will develop a horsepower on 28 to 32 pounds of steam.

Slide-valve throttle-governing engine will develop a horsepower on 62½ pounds of steam.

Horsepower of a Steam Engine

a—Area of the piston in square inches.
p—Mean velocity pressure of steam on piston per square inch.
v—Velocity of piston per minute.

$$\text{Then H P} = \frac{a \times p \times v}{33{,}000}$$

The mean pressure in the cylinder when cutting off at

1/4 stroke	= boiler pressure multiplied by	.597
1/3 "	= " " "	.670
3/8 "	= " " "	.743
1/2 "	= " " "	.847
5/8 "	= " " "	.919
2/3 "	= " " "	.937
3/4 "	= " " "	.966
7/8 "	= " " "	.992

To find the diameter of a cylinder of an engine of a required nominal horsepower:

$$\frac{5500}{v} \text{ multiplied by H P} = a$$

To find the weight of the rim of the fly-wheel for an engine:

$$\frac{\text{Nominal H P multiplied by 2,000}}{\text{Sq. of velocity of circumference in ft. per second}} = \text{wt. in cwts.}$$

TEMPERATURE CONVERSION FORMULA

To find Fahrenheit temperature when Centigrade temperature is known—(Centigrade Reading × 1.8) + 32 = Fahrenheit.

To find Centigrade temperature when Fahrenheit temperature is known—$\frac{(\text{Fahrenheit Reading} - 32)}{1.8}$ = Centigrade temperature. See Temperature Conversion Tables.

TEMPERATURE CONVERSION TABLES

Note—The numbers in **black face** refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale.

(Approximate)
0 to 400

C		F	C		F
—17.8	**0**	32	19.4	**67**	152.6
—17.2	**1**	33.8	20.0	**68**	154.4
—16.7	**2**	35.6	20.4	**69**	156.2
—16.1	**3**	37.4	21.1	**70**	158.0
—15.5	**4**	39.2	21.7	**71**	159.8
—15.0	**5**	41.0	22.2	**72**	161.6
—14.4	**6**	42.8	22.8	**73**	163.4
—13.9	**7**	44.6	23.3	**74**	165.2
—13.3	**8**	46.4	23.9	**75**	167.0
—12.8	**9**	48.2	24.4	**76**	168.8
—12.2	**10**	50.0	25.0	**77**	170.6
—11.6	**11**	51.8	25.6	**78**	172.4
—11.1	**12**	53.6	26.1	**79**	174.2
—10.6	**13**	55.4	26.6	**80**	176.0
—10.0	**14**	57.2	27.2	**81**	177.8
— 9.4	**15**	59.0	27.8	**82**	179.6
— 8.9	**16**	60.8	28.3	**83**	181.4
— 8.3	**17**	62.6	28.9	**84**	183.2
— 7.8	**18**	64.4	29.4	**85**	185.0
— 7.2	**19**	66.2	29.9	**86**	186.8
— 6.7	**20**	68.0	30.4	**87**	188.6
— 6.1	**21**	69.8	31.0	**88**	190.4
— 5.5	**22**	71.6	31.6	**89**	192.2
— 5.0	**23**	73.4	32.2	**90**	194.0
— 4.4	**24**	75.2	32.6	**91**	195.8
— 3.9	**25**	77.0	33.3	**92**	197.6
— 3.3	**26**	78.8	33.8	**93**	199.4
— 2.8	**27**	80.6	34.4	**94**	201.2
— 2.2	**28**	82.4	35.0	**95**	203.0
— 1.7	**29**	84.2	35.5	**96**	204.8
— 1.1	**30**	86.0	36.1	**97**	206.6
— .6	**31**	87.8	36.6	**98**	208.4
0	**32**	89.6	37.2	**99**	210.2
.6	**33**	91.4	37.8	**100**	212.0
1.1	**34**	93.2	37.8	**100**	212
1.7	**35**	95.0	43.3	**110**	230
2.2	**36**	96.8	48.9	**120**	248
2.8	**37**	98.6	54.4	**130**	266
3.3	**38**	100.4	60	**140**	284
3.9	**39**	102.2	65.6	**150**	302
4.4	**40**	104.0	71	**160**	320
4.9	**41**	105.8	76.7	**170**	338
5.6	**42**	107.6	82.2	**180**	356
6.1	**43**	109.4	87	**190**	374
6.7	**44**	111.2	93.3	**200**	392
7.2	**45**	113.0	98.9	**210**	410
7.8	**46**	114.8	100	**212**	413
8.3	**47**	116.6	104	**220**	428
8.9	**48**	118.4	110	**230**	446
9.4	**49**	120.2	115	**240**	464
10.0	**50**	122.0	121	**250**	482
10.6	**51**	123.8	127	**260**	500
11.1	**52**	125.6	132	**270**	518
11.7	**53**	127.4	138	**280**	536
12.2	**54**	129.2	143	**290**	554
12.8	**55**	131.0	149	**300**	572
13.3	**56**	132.8	154	**310**	590
13.7	**57**	134.6	160	**320**	608
14.4	**58**	136.4	165	**330**	626
15.0	**59**	138.2	171	**340**	644
15.6	**60**	140.0	177	**350**	662
16.7	**62**	143.6	182	**360**	680
16.1	**61**	141.8	188	**370**	698
17.2	**63**	145.4	193	**380**	716
17.8	**64**	147.2	199	**390**	734
18.2	**65**	149.0	204	**400**	752
18.9	**66**	150.8			

USEFUL INFORMATION

EQUIVALENT VALUE IN DIFFERENT UNITS

1 H.P.=

746	watts
.746	K.W.
33,000	ft.-lbs. per minute
500	ft.-lbs. per second
2,545	heat-units per hour
42.4	heat-units per minute
.707	heat-unit per second
.175	lb. carbon oxidized per hour
2.64	lbs. water evaporated per hour from and at 212°F.

1 H.P. Hour=

746	K.W. hours
1,980,000	ft.-lbs.
2,545	heat-units
273,740	k.g.m.
.175	lb. carbon oxidized with perfect efficiency
2.64	lbs. water evaporated from and at 212°F.
17.0	lbs. water raised from 62° to 212°F.

1 Kilowatt=

1,000	watts
1.34	H.P.
2,654,200	ft.-lbs. per hour
44,240	ft-lbs. per minute
737.3	ft.-lbs. per second
3,412	heat-units per hour
56.9	heat-units per minute
.948	heat-unit per second
.2275	lbs. carbon oxidized per hour
3.53	lbs. water evaporated per hour from and at 212°F.

1 Watt per Sq. In.=

8.19	heat-units per sq. ft. per minute
6,371	ft. lbs. per sq. ft. per minute
.193	H.P. per sq. ft.

1 Kilogram Meter=

7.233	Ft.-lbs.
.00000365	H.P. hour
.00000272	K.W. hour
.0093	heat-unit

1 Lb. Water Evaporated from and at 212°F.=

.283	K.W. hour
.379	H.P. hour
965.7	heat-units
103,900	k.g.m.
1,019,000	joules
751,300	ft.-lbs.
.0664	lb. of carbon oxidized

1 Heat-unit=

1,055	watt seconds
778	ft.-lbs.
107.6	kilogram meters
.000293	K.W. hour
.000393	H.P. hour
.0000688	lb. carbon oxidized
.1001036	lb. water evaporated from and at 212°
1	Heat-unit per Sq. Ft. per Min.
.122	watt per sq. in.
.0176	K.W. per sq. ft.
.0236	H.P. per sq. ft.

1 Watt=

1	joule per second
.00134	H.P.
3,412	heat-units per hour
.7373	ft.-lbs. per second
.0035	lb. water evaporated per hour
44.24	ft. lbs. per minute

1 K.W. Hour=

1,000	watt hours
1.34	H.P. hours
2,645,200	ft.-lbs.
3,600,000	joules
3,412	heat-units
367,000	kilogram meters
235	lb. carbon oxidized with perfect efficiency
3.53	lbs. water evaporated from and at 212°
22.75	lbs. of water raised from 62° to 212°

1 Joule=

1	watt second
.000000278	K.W. hour
.102	k.g.m.
.0009477	heat-units
.7373	ft.lb.

1 Ft.-lb.=

1.356	joules
.1383	k.g.m.
.0000000377	K.W. hour
.001285	heat-unit
.0000005	H.P. hour

1 Lb. Carbon Oxidized with Perfect Efficiency=

14,544	heat-units
1.11	lbs. anthracite coal oxidized
2.5	lbs. dry wood oxidized
21	cu. ft. illuminating gas
4.26	K.W. hours
5.71	H.U. hours
1,315,000	ft.-lbs.
15	lbs. water evaporated from and at 212°

EQUIVALENTS OF ELECTRICAL UNITS

1 Watt = 44.236 foot-pounds minute
1 Watt = 2654.16 footpounds hour
1 Kilowatt = 44235 foot-pounds minute
1 Kilowatt = 1.34 H.P.
1 Kilowatt = 0.955 B.T.U. per second
1 Kilowatt = 57.3 B.T.U. per minute
1 Kilowatt = 3438 B.T.U. per hour
1 Horse Power = 33000 foot-pounds minute
1 Horse Power = 746 Watts
1 Horse Power = 42.746 B.T.U. per minute
1 Horse Power = 2564.76 B.T.U. per hour
1 B.T.U. (British Thermal Unit) = 772 ft lbs.

1 B.T.U. = 17.452 watt minutes
1 B.T.U. = 0.2909 watt hour
*Latent heat of evaporation of water = 966 B.T.U.
*Latent heat of melting of water = 142 B.T.U.
To evaporate 1 lb. water from and at 212° = 16.859 K.W. minutes.
To evaporate 1 lb. water from and at 212° = 0.281 K.W. hours
*Weight per cu. ft. of water = 62.42 lbs.
*Weight per gallon of water = 8.33 lbs.

*Note—Those not relative to electric or mechanical equivalent should be omitted.

Metric and English Measures

	Metric			English	
	1	metre	=	39.37	inches
				3.28	feet
	.3048	metre	=	1	foot
	1	centimetres	=	.3937	inch
	2.54	centimetres	=	1	inch
	1	millimetre	=	.03937	in. (1-25 in., nearly)
	25.4	millimetres	=	1	inch
	1	kilometre	=	1093.61	yards
	1	sq. metre	=	10.764	square feet
	.0929	sq. metre	=	1	square foot
	1	sq. cent	=	.155	square inch
	6.452	sq. cents	=	1.	square inch
	1	sq. mill	=	.00155	square inch
	645.2	sq. mills	=	1	square inch
Volume	1	cubic metre	=	35.314	cubic feet
	.02832	cubic metre	=	1	cubic foot
	1	cubic decim	=	61.023	cubic inches
				.0353	cubic foot
	28.32	cubic decims	=	1	cubic foot
	16.387	cubic cent'ms	=	1	cubic inch
	1	cubic cent	=	1	millimetre
				.061	cubic inch
Capacity		litre = 1 cu. decimetre	=	61.023	cubic inches
				.0353	cubic foot
				.2642	gallon (U.S.)
				2.202	pounds of water at 62 degrees Fahr.
	28.317	litres	=	1	cubic foot (7.481 U.S. gallons)
	4.543	litres	=	1	gallon (Imperial)
	3.785	litres	=	1	gallon (U.S.)
Weight	28.35	grammes	=	1	ounce avoirdupois
	1	kilogramme	=	2.2046	pounds
	.4536	kilogramme	=	1	pound
	1	metric ton		.9842	ton of 2240 lbs., or
	1000	kilogrammes	=	19.68	cwts. of 2204.6 lbs.
	1.012	metric ton			
	1016	kilogrammes	=	1	ton of 2240 pounds
Pressure and Weight	1	lb. per sq. inch	=	144	lb per square foot
				2.0355	inches of mercury at 32 degrees Fahr.
				2.0416	inches of mercury at 62 degrees Fahr.
				2.309	ft. of water at 62 degrees Fahr.
				27.71	inches of water at 62 degrees Fahr.
	1	Atmospheric (14.7 lb. per sq. in.)	=	2116.3	lb per square foot
				33.947	ft. of water at 62 degrees Fahr.
				30	inches of mercury at 62 degrees Fahr.
				29.922	inches of mercury at 32 degrees Fahr.
				760	millimetres of mercury at 32 degrees Fahr.
	1	Foot of Water at 62 degrees F.	=	.433	lb per square inch
				62.355	lb per square foot
	1	Inch of Mercury at 62 degrees F.	=	.491	lb or 7.86 oz. per sq. in.
				1.132	ft. of water at 62 degrees Fahr.
				13.58	inches of water at 62 degrees Fahr.

Miscellaneous

1	gramme per square millimetre	=	1.422	lb. per square inch
1	kilogramme per square millimetre	=	1422.32	lb. per square inch
1	kilogramme per square centimetre	=	14.223	lb. per square inch
1.0335	kg. per sq. centimetre 1 atmosphere	=	14.7	lb. per square inch
0.070308	kilogramme per square centimere	=	1	lb. per square inch

General Data

1 Calorie	=	3.968	Btu
1 Btu	=	0.252	calorie
1 lb per sq. in.	=	703.08	kilogrammes per m^2
1 Kilogramme per m^2	=	.00142	lb per sq. in.
1 Calorie per m^2	=	.3687	Btu per sq. ft.
1 Btu per sq. ft.	=	2.712	calories per m^2
1 Calorie per m^2 per degree difference Cent.	=	.2048	Btu per sq. ft. per degree difference Fahr.
1 Btu per sq. ft. per degree difference Fahr.	=	4.882	calories per m^2 per degree difference Cent.
1 Btu per lb.	=	.556	calories per kilog.
1 Calorie per kilog	=	1.8	Btu per lb.
1 Litre of Coke at 26.3 lb per cubic foot	=	.93	lb
1 lb of Coke at 26.3 lb per cu. ft.	=	1.076	litres

Water expands in bulk from 40 degrees to 212 degrees = One twenty-third.

A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic foot of steam (approximately).

RULES RELATIVE TO THE CIRCLE

To Find Circumference

Multiply diameter by 3.1416, or divide diameter by 0.3183.

To Find Diameter

Multiply circumference by 0.3183, or divide circumference by 3.1416.

To Find Radius

Multiply circumference by 0.15915, or divide circumference by 6.28318.

To Find Side of an Inscribe Square

Multiply diameter by 0.7071, or multiply circumference by 0.2251, or divide circumference by 4.4428.

To Find Side of an Equal Square

Multiply diameter by 0.8862, or divide diameter by 1.1284, or multiply circumference by 0.2821, or divide circumference by 3.545.

Square

A side multiplied by 1.1442 equals diameter of its circumscribing circle.

A side multiplied by 4.443 equals circumference of its circumscribing circle.

A side multiplied by 1.128 equals diameter of an equal circle.

A side multiplied by 3.547 equals circumference of an equal circle.

Square inches multiplied by 1.273 equals circle inches of an equal circle.

To Find the Area of a Circle

Multiply circumference by one-quarter of the diameter, or multiply the square of diameter by 0.7854, or multiply the square of circumference by 0.7958, or multiply the square of ½ diameter by 3.1416.

To Find the Surface of a Sphere or Globe

Multiply the diameter by the circumference, or multiply the square of diameter by 3.1416, or multiply 4 times the square of radius by 3.1416.

Table of Decimal Equivalents of Fractions of One Inch

Fraction	Dec. Equiv.	Fraction	Dec. Equiv.	Fraction	Dec. Equiv.	Fraction	Dec. Equiv.
1–64	.0156	17–64	.2656	33–64	.5156	49–64	.7656
1–32	.0312	9–32	.2812	17–32	.5312	25–32	.7812
3–64	.0468	19–64	.2968	35–64	.5468	51–64	.7968
1–16	.0625	5–16	.3125	9–16	.5625	13–16	.8125
5–64	.0781	21–64	.3281	37–64	.5781	53–64	.8281
3–32	.0937	11–32	.3437	19–32	.5937	27–32	.8437
7–64	.1093	23–64	.3593	39–64	.6093	55–64	.8593
1–8	.125	3–8	.375	5–8	.625	7–8	.875
9–64	.1406	25–64	.3906	41–64	.6406	57–64	.8906
5–32	.1562	13–32	.4062	21–32	.6562	29–32	.9062
11–64	.1718	27–64	.4218	43–64	.6718	59–64	.9218
3–16	.1875	7–16	.4375	11–16	.6875	15–16	.9375
13–64	.2031	29–64	.4531	45–64	.7031	61–64	.9531
7–32	.2187	15–32	.4687	23–32	.7187	31–32	.9687
15–64	.2343	31–64	.4843	47–64	.7343	63–64	.9843
1–4	.25	1–2	.5	3–4	.75	1	1.0

SPECIFIC HEAT OF SOLIDS, LIQUIDS AND GASES

TABLE 1. SPECIFIC HEAT OF SOLIDS

Materials	Temperature F.	Specific Heat	Authority
Alloys			
Brass, Red	32	0.0899	S
Brass, Yellow	32	0.0883	S
Bronze (80*Cu*, 20*Sn*)	57-208	0.0862	S
Monel Metal	68-2370	0.127	S
Aluminum	80-212	0.212	S
Asbestos	68-208	0.195	S
Brickwork	....	0.195	H
Carbon (Graphite)	104-1637	0.314	I
Coal	....	0.278	H
Coke	....	0.201	H
Concrete	....	0.270	H
Copper	64-212	0.0928	S
Fire Clay Brick	77-1832	0.258	I
Glass			
Crown	50-122	0.161	S
Flint	50-122	0.117	S
Gold	64	0.0312	S
Gypsum	....	0.259	H
Ice	32	0.487	S
Ice	−40	0.434	S
Iron, Pure	32	0.1043	S
Iron, Pure	32-600	0.127	M
Iron, Cast	68-212	0.1189	H
Iron, Wrought	59-212	0.1152	H
Lead	32	0.0297	S
Nickel	32	0.1032	S
Masonry	....	0.2159	H
Plaster	....	0.2	H
Platinum	58-212	0.0319	S
Rocks			
Gneiss	63-210	0.196	S
Granite	54-212	0.192	S
Limestone	59-212	0.216	S
Marble	32-212	0.21	S
Sandstone	....	0.22	S
Silver	32	0.0536	S
Steel	....	0.1175	H
Sulphur	240-320	0.220	S
Silica Brick	77-1832	0.263	I
Tin	77	0.0548	S
Woods (Average)	68	0.327	S
Zinc	32	0.0913	S

TABLE 2. SPECIFIC HEAT OF LIQUIDS

Liquid	Temperature F.	Specific Heat	Authority
Alcohol, Ethyl	32	0.548	S
Alcohol, Methyl	59-68	0.601	S
Glycerine	59-122	0.576	S
Lead (Molten)	360	0.041	H
Mercury	68	0.03325	S
Petroleum	70-136	0.511	S
Sea Water			
Sp. Gr. 1.0043	64	0.980	S
Sp. Gr. 1.0463	64	0.903	S
Water	59	1.000	S

TABLE 3. SPECIFIC HEAT OF GASES AND VAPORS

Substance	Temperature F.	Specific Heat at Constant Pressure	Ratio of Specific Heat C_p/C_v	Specific Heat at Constant Volume (Computed)	Authority
Air	32-392	0.2375	1.405	0.169	S
Ammonia	80-392	0.5356	1.277	0.419	S
Carbon Dioxide	52-417	0.2169	1.3003	0.1668	S
Carbon Monoxide	79-388	0.2426	1.395	0.1736	S
Coal Gas	68-1900	0.3145	....	....	S
Flue Gas	......	0.24 (Approx.)	....	....	H
Hydrogen	70-212	3.41	1.419	2.402	S
Nitrogen	32-392	0.2438	1.41	0.1729	S
Oxygen	55-404	0.2175	1.3977	0.155	S
Water Vapor	212	0.421	1.305	0.322	S
Water Vapor	356	0.51	....	....	S

NOTES: When one temperature is given the true specific heat is given, otherwise the value is the mean specific heat between the given limits.

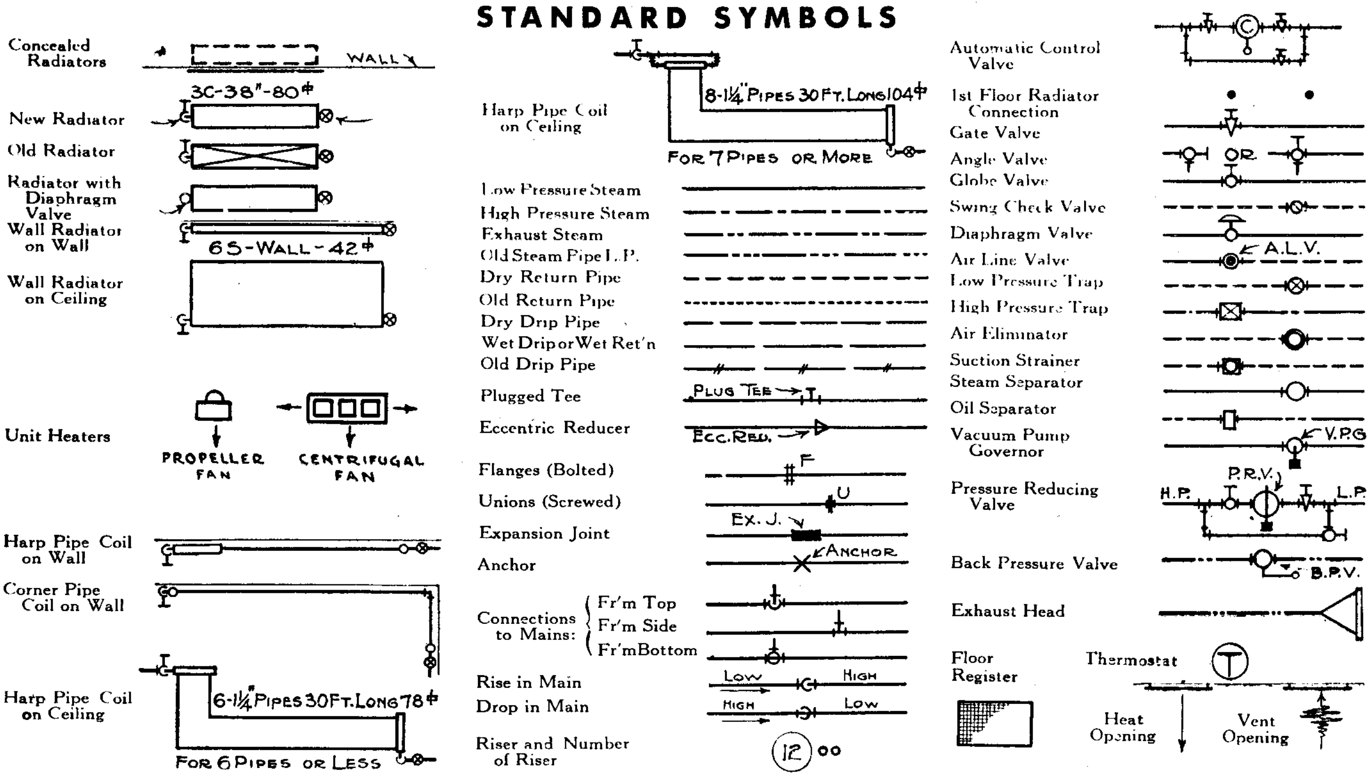
AUTHORITIES: S—Smithsonian Physical Tables, 1933; I—International Critical Tables; H—Heating, Ventilation and Air Conditioning, by L. A. Harding and A. C. Willard; M—Engineers' Handbook, by Lionel S Marks.

CIRCUMFERENCES AND AREAS OF CIRCLES

Diameter in Inches	Area Sq. In.	Area Sq. Ft.	Circumference Inches	Circumference Feet
¼	0.049	0.0003	0.785	0.0652
½	0.196	0.0014	1.571	0.1309
¾	0.442	0.0031	2.356	0.1964
1	0.785	0.0054	3.142	0.2618
1¼	1.227	0.0085	3.927	0.3273
1½	1.767	0.0123	4.712	0.3927
1¾	2.405	0.0167	5.498	0.4582
2	3.142	0.0218	6.283	0.5236
2¼	3.976	0.0276	7.069	0.5891
2½	4.909	0.0341	7.854	0.6546
2¾	5.939	0.0412	8.639	0.7200
3	7.069	0.0491	9.425	0.7854
3¼	8.296	0.0576	10.21	0.8510
3½	9.621	0.0668	10.99	0.9160
3¾	11.04	0.0767	11.78	0.9818
4	12.57	0.0873	12.57	1.047
4¼	14.19	0.0986	13.35	1.113
4½	15.90	0.1104	14.14	1.178
4¾	17.72	0.1231	14.92	1.243
5	19.64	0.1364	15.71	1.309
5¼	21.65	0.1504	16.49	1.374
5½	23.76	0.1650	17.28	1.440
5¾	25.97	0.1840	18.06	1.505
6	28.27	0.1964	18.85	1.571
6¼	30.68	0.2131	19.64	1.637
6½	33.18	0.2304	20.42	1.702
6¾	35.79	0.2486	21.21	1.768
7	38.49	0.2673	21.99	1.833
7¼	41.28	0.2867	22.78	1.899
7½	44.18	0.3068	23.56	1.964
7¾	47.17	0.3276	24.35	2.029
8	50.27	0.3491	25.13	2.094
8¼	53.46	0.3713	25.92	2.160
8½	56.75	0.3942	26.70	2.225
8¾	60.13	0.4175	27.49	2.291
9	63.62	0.4418	28.27	2.356
9¼	67.20	0.4668	29.06	2.422
9½	70.88	0.4923	29.85	2.488
9¾	74.66	0.5185	30.63	2.553
10	78.54	0.5454	31.42	2.618
10½	86.59	0.6010	32.99	2.750
11	95.03	0.6600	34.56	2.880
11½	103.9	0.7215	36.13	3.011
12	113.1	0.7854	37.70	3.142
12½	122.7	0.8520	39.27	3.273
13	132.7	0.9218	40.84	3.403
13½	143.1	0.9937	42.41	3.535
14	153.9	1.069	43.98	3.665
14½	165.1	1.146	45.55	3.796
15	176.7	1.227	47.12	3.927
15½	188.7	1.310	48.69	4.058
16	201.1	1.396	50.27	4.189
16½	213.8	1.485	51.84	4.321
17	226.9	1.576	53.41	4.451
17½	240.5	1.670	54.98	4.582
18	254.5	1.767	56.55	4.712
18½	268.8	1.867	58.12	4.845
19	283.5	1.969	59.69	4.974
19½	298.6	2.074	61.26	5.105
20	314.2	2.182	62.83	5.236
20½	330.1	2.293	64.40	5.367
21	346.4	2.405	65.97	5.498
21½	361.1	2.508	67.54	5.629
22	380.1	2.640	69.12	5.760
22½	397.6	2.761	70.69	5.891
23	415.5	2.885	72.26	6.021
23½	433.7	3.012	73.83	6.153
24	452.4	3.142	75.40	6.283
24½	471.4	3.274	76.97	6.415
25	490.9	3.409	78.54	6.545
25½	510.7	3.547	80.11	6.676
26	530.9	3.687	81.68	6.807
26½	551.6	3.832	83.25	6.938
27	572.6	3.976	84.82	7.069
27½	593.9	4.125	86.39	7.199

Diameter in Inches	Area Sq. In.	Area Sq. Ft.	Circumference Inches	Circumference Feet
28	615.8	4.276	87.97	7.330
28½	637.9	4.430	89.54	7.462
29	660.52	4.587	91.11	7.592
29½	683.5	4.747	92.63	7.725
30	706.8	4.909	94.25	7.854
31	754.8	5.241	97.39	8.116
32	804.3	5.585	100.5	8.378
33	855.3	5.940	103.7	8.639
34	907.9	6.305	105.8	8.901
35	962.1	6.681	109.9	9.163
36	1018.0	7.069	113.1	9.425
37	1075.0	7.467	116.2	9.686
38	1134.0	7.876	119.4	9.948
39	1195.0	8.296	122.5	10.21
40	1256.0	8.727	125.6	10.47
41	1320.0	9.168	128.8	10.73
42	1385.0	9.621	131.9	10.99
43	1452.0	10.08	135.1	11.26
44	1521.0	10.56	138.2	11.52
45	1590.0	11.04	141.4	11.78
46	1662.0	11.54	144.5	12.04
47	1735.0	12.05	147.7	12.30
48	1810.0	12.51	150.8	12.57
49	1886.0	13.09	153.9	12.83
50	1963.0	13.64	157.1	13.09
51	2043.0	14.19	160.2	13.35
52	2124.0	14.75	163.4	13.61
53	2206.0	15.32	166.5	13.88
54	2290.0	15.90	169.6	14.14
55	2376.0	16.50	172.8	14.40
56	2463.0	17.10	175.9	14.66
57	2552.0	17.72	179.1	14.92
58	2642.0	18.35	182.2	15.18
59	2734.0	18.99	185.4	15.45
60	2827.0	19.63	188.5	15.71
61	2922.0	20.29	191.6	15.97
62	3019.0	20.97	194.8	16.23
63	3117.0	21.65	197.9	16.49
64	3217.0	22.34	201.1	16.76
65	3318.0	23.04	204.2	17.02
66	3421.0	23.76	207.3	17.28
67	3526.0	24.48	210.5	17.54
68	3632.0	25.22	213.6	17.80
69	3739.0	25.97	216.8	18.06
70	3848.0	26.73	219.9	18.33
71	3959.0	27.49	223.1	18.59
72	4072.0	28.27	226.2	18.85
73	4185.0	29.07	229.3	19.11
74	4301.0	29.87	232.5	19.37
75	4418.0	30.68	235.6	19.63
76	4536.0	31.50	238.8	19.90
77	4657.0	32.34	241.9	20.16
78	4778.0	33.18	245.0	20.42
79	4902.0	34.04	248.2	20.68
80	5027.0	34.91	251.3	20.94
81	5153.0	35.78	254.5	21.21
82	5281.0	36.67	257.6	21.47
83	5411.0	37.57	260.8	21.73
84	5542.0	38.48	263.9	21.99
85	5675.0	39.41	267.0	22.25
86	5809.0	40.34	270.2	22.51
87	5945.0	41.28	273.3	22.78
88	6082.0	42.24	276.5	23.04
89	6221.0	43.20	279.6	23.30
90	6362.0	44.18	282.7	23.56
91	6504.0	45.17	285.9	23.82
92	6648.0	46.16	289.0	24.09
93	6793.0	47.17	292.2	24.35
94	6940.0	48.19	295.3	24.61
95	7088.0	49.22	298.4	24.87
96	7238.0	50.27	301.6	25.13
97	7390.0	51.32	304.7	25.39
98	7543.0	52.38	307.9	25.66
99	7698.0	53.46	311.0	25.92
100	7854.0	54.54	314.2	26.18

STANDARD SYMBOLS



Figs. 887B—888A

GLOSSARY OF HEATING TERMS

Actual Evaporation: By this term is meant the total quantity of water (in pounds) evaporated from the temperature of the feed water to steam at 212 degrees Fahrenheit.

Atmospheric Pressure: The pressure exerted by the atmosphere may be established by the simple experiment of taking a glass tube with an area of 1 square inch and approximately 30 inches high, with one end closed; filling same with mercury and inverting the tube in mercury, it will be found at the sea-level that the mercury will stand in the column 29.9 inches high, or practically 30 inches. As 1 cubic foot of mercury weighs 850 pounds, 1 cubic inch would weigh 0.49 pounds; and as the mercury in the tube under the pressure of the atmosphere stands 30 inches high, and the area is 1 square inch, there would be 30 cubic inches of mercury in the tube, which would weigh 30 x 0.49 or 14.7 pounds. As this column of mercury, weighing 14.7, is entirely sustained by the pressure of the atmosphere, it may be stated that the normal pressure at sea-level is 14.7 pounds per square inch. This pressure varies with the altitude and under different conditions of the barometer.

Boiler Heating Surface—Direct: That surface which receives the radiant heat of the fire, or that surface on which the fire shines.

The transmission of heat through direct surface is practically constant for like temperature differences.

Boiler Heating Surface—Indirect Flue: That surface in a boiler on which the fire does not shine, but through which the constantly cooling gases pass to the smokestack.

The value of indirect, or flue surface, is extremely variable, because the escaping gases are constantly cooling; the rate of transmission becomes less and less as the gases approach the smoke outlet.

B. t. u. (British Thermal Unit, Heat Unit): The quantity of heat required to raise 1 pound of water 1 degree Fahrenheit.

Caking Coal: Term which is usually applied to coal which fuses together when burning, as opposed to free-burning coal.

Calorie: The Continental heat unit, or calorie, is the quantity of heat required to raise the temperature of 1 kilogram of water 1 degree Centigrade, and as 1 kilogram is equal to 2.205 pounds and 1 degree Centigrade is equal to 1.8 degrees Fahrenheit, it is obvious that one calorie measures the same quantity of heat as does 3.969 B. t. u. This is shown by multiplying 1.8 by 2.205. It is usual when translating from the English and American standard to the Continental or Metric standard of heat measure to call 1 calorie equal to 3.97 B. t. u.

Caloric Power of any combustible substance is the number of B. t. u. per pound, which is the measure of heat stored in the fuel.

Caloric Power Available: That portion of the calorific power which is absorbed by the water in the boiler, and transferred to the piping and radiation for heating purposes.

Calorimeter: A double-walled vessel is immersed in a tank of water. Within the inner vessel is placed a cartridge or shell. A small quantity of fuel is powdered and put in the cartridge, together with a sufficient amount of oxygen needed for complete combustion. The combustible is ignited by dropping therein a copper wire heated red-hot, or set off by an electric spark. As combustion takes place the cartridge is revolved so that the surrounding water comes in contact with the heated surfaces. A thermometer projected into the water records the initial temperature, and finally, the maximum temperature to which

As the water has been carefully ...hed how many degrees tempera... has been raised. The maximum ... the thermal value or heating ...

...rmal values of the different varie...ed.

...d to designate such part of fuel ... and is composed of non-combustible

...arbon monoxide.

...carbon dioxide or carbonic acid gas.

... Emission: This term is usually ap... emitted, or given off, by 1 square foot of ... for 1 degree temperature difference be... steam or water in the radiator and the surr...

...cient of Transmission: Is the quantity of heat, ex... in terms of B. t. u., which will pass through 1 ...t of surface in one hour for 1 degree tempera...erence.

...stion Chamber: That portion of fire-pot or fire-...een the surface of fuel-bed and the crowning sur-...enter.

...stion, Rate of: The rate of combustion is a term ...applied to the quantity of coal burned per square ... grate per hour. The term may also be used to ...s the quantity of fuel burned by the boiler per

...ensation: The act of reducing vapor or steam to ...y cooling.

...densing Power (of Radiation): The condensing ...of radiation is the quantity of steam (in pounds) ... a radiator will condense per square foot per hour.

Conduction: Conduction is the transfer of heat between ... bodies or parts of a body which touch each other. In...al conduction takes place between the parts of one ...inuous body, and external conduction through the sur...e of contact of a pair of distinct bodies.

Convection: Convection, or carrying of heat, means the ...sfer or diffusion of the heat in a fluid mass by means of ...e motion of the particles of that mass.

The conduction, properly so called, of heat through a stagnant mass of fluid is very slow in liquids, and almost, if not wholly, inappreciable in gases. It is only by the continual circulation and mixture of the particles of the fluid that uniformity of temperature can be maintained in the fluid mass, or heat transferred between the fluid mass and a solid body.

Efficiency (Boiler). (Based on Coal Consumption): The percentage of calorific power absorbed by the water in the boiler.

Equivalent Evaporation is the total quantity of water (in pounds) evaporated from a temperature of 212 to steam at 212 degrees Fahrenheit.

Evaporation: The act of resolving, or the state of being resolved, into vapor. The conversion of boiling water by heat into vapor or steam.

Evaporative Power (of a Boiler) is the quantity of water (in pounds) which 1 pound of coal burned in said boiler will evaporate.

Evaporative Power (of Fuel): The quantity of ... (in pounds) which 1 pound of fuel will evaporate in ...ing. Theoretical evaporation is the quantity of ... evaporated by 1 pound of fuel burning to perfect ...bustion.

Free-Burning Coal: Term applied to coal which ... not fuse together when burning; otherwise a non-c... coal.

Heating Surface (H. S.): The heating surface ... boiler is that portion of the inner walls separating th... or heated glass from the water.

Heat Transmission: When the temperature on opp... sides of any surface are unequal, the heat will flow thr... the material from the warmer to the cooler side. T... called heat transmission.

Ignition Temperature: The ignition temperature ... substance is that temperature to which it must be rai... the presence of oxygen to cause the two to unite by ...bustion. It is rather indefinite and varies for different ... of fuel. The exact temperature can only be determin... direct experiment with the partciular variety of fuel ... test. For coal it is approximately considered 800 de... Fahrenheit.

Latent Heat is that quantity of heat necessary to e...orate 1 pound of water into steam at same temper...

Radiation of Heat: Radiation of heat takes plac... tween bodies at all distances apart, and follows the la... the radiation of light.

The heat rays proceed in straight lines, and the inte... of the rays radiated from any one source varies inve... as the square of their distance from the source.

ABBREVIATIONS

Alternating-current	...
Ampere	...
Area	...
Atmosphere	...
Average	...
Boiler pressure	...
Boiling point	...
British thermal unit	...
Cubic foot	...
Cubic feet per minute	...
Cubic feet per second	...
Degree	deg...
Degree Fahrenheit	...
Diameter	D or ...
Direct-current	...
Foot	...
Gallon	...
Gallons per minute	...
Gallons per second	...
Horsepower	...
Inch	...
Ounce	...
Revolutions per minute	...
Square foot	...
Square inch	in...

... has been raised. As the water has been carefully ... it is easily established how many degrees tempera... pound of water has been raised. The maximum ...ained establishes the thermal value or heating ... the combustible.

...is means, the thermal values of the different varie... coal are established.

...: Term used to designate such part of fuel ...ses together, and is composed of non-combustible ...l.

... Symbol for carbon monoxide.

... Symbol for carbon dioxide or carbonic acid gas.

...fficient of Heat Emission: This term is usually ap... the heat emitted, or given off, by 1 square foot of ...ion per hour for 1 degree temperature difference be... the steam or water in the radiator and the surr...ng air.

...-efficient of Transmission: Is the quantity of heat, ex...ed in terms of B. t. u., which will pass through 1 ...re foot of surface in one hour for 1 degree tempera... difference.

...bustion Chamber: That portion of fire-pot or fire- between the surface of fuel-bed and the crowning sur... of heater.

...bustion, Rate of: The rate of combustion is a term ...y applied to the quantity of coal burned per square ... grate per hour. The term may also be used to ...ate the quantity of fuel burned by the boiler per

...densation: The act of reducing vapor or steam to ... by cooling.

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Boiler pressure...
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British thermal unit..
Cubic foot..
Cubic feet per minute...
Cubic feet per second...
Degree...
Degree Fahrenheit..
Diameter...D
Direct-current..
Foot..
Gallon..
Gallons per minute...
Gallons per second...
Horsepower...
Inch...
Ounce...
Revolutions per minute..
Square foot...
Square inch...

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