The Design of the Heating and Ventilating Systems for the M. A. C. Shops

A Thesis Submitted to

The Faculty of the

MICHIGAN AGRICULTURAL COLLEGE

by

Oliver L. Friedrich Fred G. Ricker.

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INTRODUCTION.

On March 5, 1916 the Engineering Building and Shops of the Michigan Agricultural College were destroyed by fire. The Shops were old buildings; their equipment to a large extent had become obsolete and inadequate for the institution's needs. In place of the old Shops, new ones are in the course of construction which will be modern in every respect.

The prime object of the authors in the design of the heating system for the new Shops was to make them of practical value to the Engineering Department, as well as to gain practical knowledge from the results of the investigation.

The desire was to arrange the work in a systematic manner, and to give no methods or rules which were not based upon actual practice, modified by coefficients which have been obtained by actual tests or experience.

We take this opportunity to thank Dean George W. Bissell and others for the aid given to us in working this thesis.

The new Shops which are in the course of construction are three in number: one for woodworking, one for machine work, and the other for forge and foundry.

Blower systems are to be installed, one separate complete unit for each building. Each unit is to consist of a multi-blade draw thru fan, a heater using Vento coils and steam pressure of about #5 gage, and the necessary distributing ducts. The systems were designed to warm the buildings in one and one half hours, the fan being started at 6:30 A. M. and shut down at 5:00 P. M. The steam is to be left on the coils all night. In order to heat the building in one and one half hours, more heat will be required during this period than that necessary to supply the radiation and infiltration losses. Rietchel's rule was used to determine the extra number of heat units required,-

$$A = \frac{.0625\ (n-1)\ W_1}{z}.$$

where W_1 = heat lost per hour by radiation and it includes the increases made for exposure, wind, etc;
n = number of hours from the daily heating in the evening to the beginning in the morning; and

z = number of hours from the beginning of the heating in the morning to the time when the building is thoroughly heated. A should not be taken greater than one-third W, where W is the total heat loss.

The constants used were taken from the Buffalo Forge Co.'s "Fan Engineering" hand book.

Table of constants.

	k.
12" brick wall	.29
17" " "	.25
21" " "	.23
1¾" wooden doors,	.32
Glass.	1.09
Roof,	.50
" 2" plank, tar and gravel,	.26

The distributing systems were designed to equalize friction loss in the piping, so as to secure uniform distribution without the use of dampers. This was done by proportioning the piping to decrease the velocity in the main pipes as the quantity of air decreases. By this principle the velocity of the air is utilized in producing static pressure in the systems. By this means a nearly uniform static pressure is secured in all parts of the pipe line, and it also reduces friction in the smaller pipes, which would otherwise be excessive.

WOOD WORKING SHOP: Building No. 1.

This is a two story brick building 163 ft. x 50 ft. The first floor is to be used for bench and machine work. The west end contains a lumber stock room and a toilet. The second floor contains two large drawing rooms, three offices, a pattern storage room, and a hallway. The first floor will be blower heated, the main duct with its branch outlets extending down the length of the building. The two drawing rooms will have half of their radiation losses taken care of by direct radiation, the remaining heat losses to be furnished from the blower by two ducts leading up from first floor main. The offices and store room are heated by radiators. The vestibule and toilet on the first floor are also heated directly by radiators. The lumber store room is heated by high pressure steam and is not considered here.

HEATING SYSTEM FOR WOOD SHOP.

First floor to be heated by Blower.

North elevation.

140' x 17' = 2,380 sq. ft. of wall

15' x 17' = 255 sq. ft. of wall for vestibule & stairway.

2,380 - 255 = 2,125 sq. ft. of wall exposure.

5 pillars, 2'-3" x 17' = 363 sq. ft. of 21" wall.

7 windows, 12'-7.5" x 10'-9.5" = 954 sq. ft. of glass.

2,125 - (363 - 954) = 808 sq. ft. of 12" wall.

South elevation.

140' x 17' = 2,380 sq. ft. of wall.

8 pillasters, 2'-3" x 17' = 363 sq. ft. of 21" brick wall.

6 windows, 12'-7.5" x 10'-9.5" = 814 sq. ft. of glass

2 windows, 12'-7.5" x 4'-3" = 113 sq. ft. of glass.

4 windows, 4'-8" x 1'-125" = 21 sq. ft. of glass.

Total glass area = 957 sq. ft.

2,380 - (363 + 957 + 149) = 911 sq. ft. of 12" brick wall.

East elevation.

48' x 17' = 816 sq. ft. of wall area.

3 pillars, 2' - 8" x 17' = 136 sq. ft. of 21" brick wall.

3 windows, 10'-1 .5" x 10'-9.5" = 352 sq. ft. of glass.

816 - (136 + 352) = 328 sq. ft. of 12" brick wall.

West elevation.

Taken care of by direct radiation.

Cubical contents. = 105,560 cu. ft.

Totals,
(808 + 911 + 328) = 2,047 sq. ft. of 12" brick wall.

(363+363+136)=862 sq. ft. of 21" brick wall.

149 sq. ft. of door.

(954+957+352)=2,263 sq. ft. of glass.

Determination of heat loss in first floor of Wood-shop.

12" wall, 2.047 x .29= 593.

10% for N.W. exposure or 5% of total exposure=29.7

21" wall, 862 x .23= 198.

10% for N.W. exposure or 5% of total ex.= 9.9

1¾" doors, 149 x .32= 47.6

Windows, 2,263 x 1.09= 2,470.

10% for N.W. exposure or 5% of total ex.= 123.3

2,474.6

H=(.2415 x .0764 x 105,000+3,474.6)55=351,625 Btu.

By Rietchel's Rule,

$$A=\frac{.0625\ (13.5-1)\ 351,625}{1.5}=177,500\ \text{Btu.}$$

A is larger than one-third H, so then use one-third H.

351,625/3+351,625=468,833 Btu. (To be supplied).

$$Q=\frac{55.2\times 468,833}{60\ (140-65)}=5,750\ \text{cu. ft. of air, min.(1st floor).}$$

SECOND FLOOR.

East drawing room,-(50% of radiation losses to be taken care of by blower).

(54+42+54) 14 = 2,184 sq. ft. of exposed wall.

9 pillasters, 2'-8" x 14' = 336 sq. ft. of 21" wall.

6 windows,-12'-7.5" x 7'-8.75" = 580 sq. ft. glass.

3 windows,-10'-10.5" x 7'-8.75" = 252 sq. ft. of glass.

Total glass = 832 sq. ft. of glass.

2,184 - (336+832) = 1,016 sq. ft. of 12" wall.

Cubical contents, = 53 x 42 x 14 = 31,164 cu. ft.

West drawing room,-(50% of radiation losses to be taken care of by blower).

(54+42+54)14 = 2,184 sq. ft. of exposed wall.

9 pillasters,- 2'-8" x 14' = 336 sq. ft. of 21" wall.

6 windows,-12'7.5" x 7'-8.75" = 580 sq. ft. of glass.

3 windows,-10'-10.5" x 7'-8.75" = 252 sq. ft. of glass.

Total glass = 832 sq. ft. of glass.

2,184 - (336+832) = 1,016 sq. ft. of 12" wall.

Cubical contents, = 53 x 42 x 14 = 31,164 cu. ft.

Large store room.

Cubical contents, = 23 x 52.5 x 14 = 16,905 cu. ft.

2 offices with adjacent stairway.

Each [(11' x 17') + (5' x 6')] x 14' = 3030 cu. ft.

1 office

17' x 17' x 14' = 4,046 cu. ft.

1 corridor - 6' x 52.5' x 14' = 4,400 cu. ft.

DETERMINATION OF HEAT LOSS IN SECOND FLOOR.

East room.

12" wall, 1,010 x .23 =	233.
10% for North exposure or 4% of total exp. =	9.3
17" wall, 336 x .23 =	77.3
10% for North exposure or 4% of total =	2.6
Windows, 834 x 1.09 =	915.
10% for North exposure or 4% total =	30.5
Roof 2592. x 0.50 =	1296.
	2615.2

2615. x 70 = 183,000 B.T.U. radiation loss.

$\frac{183,000}{2}$ = 91,500 B.T.U. to be furnished by radiators.

.2415 x .0764 x 35,616 x 70 = 46,000 B.T.U. infiltration loss.

91,500 + 46,000 = 137,500 B.T.U. to be furnished by fan.

Air to be heated from 65° - 140°

Cu. ft. of air needed per min. $= \frac{55.2 \times 137,500}{60(140-65)} = 1690.$

West room.

12" wall, 1,010 x .23 =	233.
10% for N. & W. exposure or 6.6% of total =	19.0
17" wall, 336 x .23 =	77.3
10% for N. & W. exposure or 6.6% of total =	5.3
Windows, 834 x 1.09 =	915.
10% for N. & W. exposure or 6.6% of total =	61.0
Roof 2,592 x .50 =	1296.
	3667.1

3,667. x 70 = 137,000 B.T.U. radiation loss.

$\frac{137,000}{2}$ = 95,500 B.T.U. to be furnished by radiators.

.2415 x .0764 x 35,616 x 70 = 46,000 B.T.U. infiltration loss.

93,500 + 46,[illegible]70 = 139,500 B.T.U. to be furnished by fan.

Air to be heated from 65° - 140°

Cu. ft. of air needed per min. $q = \frac{55.8 \times 139,500}{60(140-65)} = 1,710.$

DETERMINATION OF HEATER AND FAN FOR WOOD-SHOP.

Entering temperature 65.° Final temperature 140.°

Fan to furnish air for First floor and East and West rooms on second floor.

5,740 + 1,690 + 1,710 = 9,140 cu. ft. of air needed per min.

Assume a velocity of 1,200 ft./min. thru the heater.

$\frac{9,140}{1,200} = 7.62$ sq. ft. of clear area.

Use regular 50" section - 5 deep -

No. of looms - 10-Net air space-7.62 sq. in. Width of stack 50" + 2.5" for staggering = 52.5".

Use a draw thru apparatus.

Fan handles air at 140 degrees and air has 1.132 times its volume at 65 degrees.

9,140 x 1,132 = 10,370 cu. ft. of air per min.

Assume 1" total pressure.

Buffalo Forge Co.'s Coinoidal Fan.

Fan No. 6 delivers 9,750 cu. ft./min. at 533 R.P.M. and 2.17 HP.

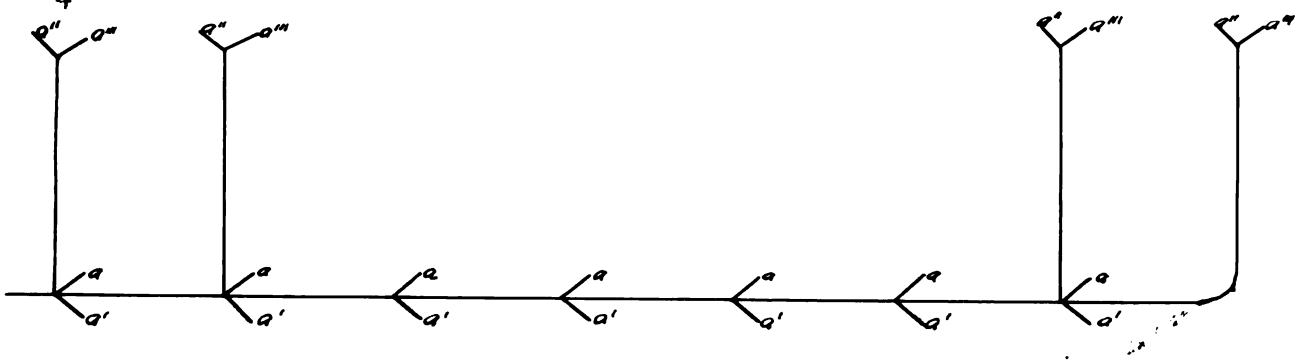
American Blower Co.'s Sirocco Fan.

Fan No. 6 delivers 9,250 cu. ft./min. at 253 R.P.M. and 2.49 HP.

PROPORTIONING DUCTS IN LOOP-SYSTEM.

10,370 cu. ft. of air to be distributed by ducts.

$\frac{10,370}{4}$ = 2,592 ft./min. velocity at fan outlet.



Calculated data as taken from tables.

Main. Size.	Capacity. A.P.M.	Velocity. FT./MIN.	Branch outlet. Size.	Capacity. A.P.M.	Vel. FT./MIN.
a. 31"	10,370	1,[illegible]	15"	6[illegible]	[illegible]
a'			15"	6[illegible]	[illegible]
a" 16"	1,037.	[illegible]	14"	515	[illegible]
a'"			14"	514	[illegible]
a. 28"	8,037.	1,[illegible]	13"	450.	[illegible]
a'			14"	4[illegible]	[illegible]
a" 12"	662	[illegible]	11"	511.	[illegible]
a"'			11"	511.	[illegible]
a. 26"	[illegible]	1,7[illegible]	13"	450.	[illegible]
a'			14"	4[illegible]	[illegible]
a. 24"	5,547.	1,765.	13"	450.	4 500
a'			14"	450.	[illegible]
a. 22"	4,613.	1,75[illegible]	13"	450.	[illegible]
a'			14"	454.	[illegible]
a. 21"	3,679.	1,530.	13"	450.	[illegible]
a'			14"	454.	5 500
a. 19"	2,745.	1,[illegible]30.	14"	[illegible].	[illegible]
a'			15"	557.	5.5 500
a" 12"	57[illegible].	[illegible].	11"	2[illegible].	2.7 [illegible]
a"'			11"	2[illegible].	[illegible]

	Main. Size.	Capacity. A.P..	Velocity. Ft./min.	Size.	Branch outlet. Capacity A.P. .	Vel. Ft./min.
a"-a'	13"	1,140.	1,240.			
a"	16"	1,140	800.	15"	570. 5.5	5.0
a"'				15"	570. 5.5	5.0

Determination of direct radiation losses for second floor.

Two offices each 14' x 17' = 238 sq. ft. of exposed wall.

1 window,- 12'-7.5" x 7'-6.75" = 97.6 sq. ft. of glass.

238 - 97.6 = 140.4 sq. ft. of 12" brick wall.

12" wall,- 140.4 x .29 =	40.7
10% exposure =	4.7
Glass,- 97.6 x 1.09 =	106.2
10% exposure =	10.6
Roof,- 269 x .50 =	134.4
	305.6

H = (.2415 x .0764 x 3,038 + 305.6) x 70 = 25,300 BTU.

Middle Office.

14' x 17' = 238 sq. ft. of exposed wall.

1 window,- 12'-7.5" x 7'-6.75" = 97.6 sq. ft. of glass.

238 - 96.6 = 140.4 sq. ft. of 12" brick wall.

Radiation loss same as other offices.

H = (.2415 x .0764 x 4,046 + 305.6) x 70 = 26,660 B.T.U.

Store Room.

52.5' x 14' = 735 sq. ft. of exposed wall.

3 windows,- 12'-7.5" x 7'-6.75" = 293 sq. ft. of glass.

735 - 293 = 442 sq. ft. of wall.

12" wall,- 442 x .29 =	129.
293 x 1.09 =	319.
roof,- 52.5 x .23 = 1,210,- 1,210 x .50 =	605.
	1,053.

H = (.2415 x .0764 x 10,900 + 1,053) x 70 = 95,500 B.T.U.

Installation of radiators in Boys-Shop.

East room (second floor).

91,590 B.T.U. to be furnished by radiators.

Use Rocco (American Radiator Co.) three column radiators.

70 degrees room temperature and 5lbs. steam pressure gives 255 B.T.U. radiated from each sq. ft. of radiating surface per hour.

$\frac{91,590}{255}$ = 359. sq. ft. of heating surface.

Use 5 radiators $\frac{45}{5}$ = 71.5 sq. ft. of surface for each.

Use 26 in.-19 sections length 47.5" + 9" for each bushing = 56.5".

West Room.

$\frac{93,592}{255}$ = 367 sq. ft. of heating surface:

Use 5 radiators $\frac{367}{5}$ = 73.5 sq. ft. of surface for each.

Use 3-26 in.-20 sections - length 50"+9.5" = 59.5" long.

Use 2-26 in.-19 sections - length 47.5" + 9" = 56.5" long.

Two offices with stairway adjacent.

$\frac{25300}{255}$ = 99.2 sq. ft. of radiating surface.

Use 1-26 in.-27 sections - length 67.5"+13" = 80.5" long.

Middle office.

$\frac{26,530}{255}$ 104 sq. ft. of heating surface.

Use 1-26 in.-23 sections - length 7[illegible]" +13.5" = 83.5 in. long.

Corridor (first floor).

2 radiators - 6 sections - 26 in. high - length 15" +2.5" = 17.5" long.

Store room. 95,500/255 = 375 sq. ft. of radiating surface.

Use 3 radiators 125 sq. ft. each -26" - 32 sections 80" +15.5" = 95.5" long.

Toilet room. 1 radiator - 26" high - 32 sections - 80" + 15.5" = 95.5" long.

MACHINE SHOP: Building No. 2.

This is a one story brick building, 163 ft. x 50 ft. with saw tooth roof construction. It is to be used for a machine shop with a temporary cement laboratory partitioned off at the west end of the building. The building will be blower heated, with two main pipes running the length of the building, one down each bay. This is necessary in order to place them above the trusses where they will not interfere with the line shafting in one bay and a traveling crane in the other.

The cement laboratory, being very dusty, will be heated by direct radiation; but, as it is only a temporary room, the blower system is designed to heat it upon the removal of the partition.

HEATING SYSTEM FOR LAUNDRY SHOP.

Determination of radiating surfaces.

North elevation.

160' x 17' = 2,720 sq. ft. (total side wall).

3 windows, 3.5' x 9' = 612 sq. ft.

2 windows, 3' x 3.5' = 51 sq. ft., total 663 sq. ft. of glass.

2 doors, 3.5' x 9' = 153 sq. ft.

2,720' - (663' + 153') = 1,904 sq. ft. of brick wall.

10 pillasters, 2.25' x 13.5' = 304 sq. ft. of 17' wall.

1,904' - 304 = 1,600 sq. ft. of 12" wall.

South elevation.

Same as North elevation.

East elevation.

17' x 48' = 816 sq. ft. up to roof.

216 sq. ft. in gables.

816 + 216 = 1,032 sq. ft. in end wall.

2 windows, 1' x 4' = 8 sq. ft.

2 " 3'-2" x 9' = 57 sq. ft.

2 " 3' x 3.5' = 51 sq. ft. total 116 sq. ft. glass.

1,032 - (116 + 112) = 804 sq. ft. of 12" wall.

West elevation.

1,032 sq. ft. in end wall.

2 windows, 3.5' x 3' = 51 sq. ft.

2 " 3'-2" x 9' = 57 sq. ft. total 108 sq. ft. glass.

2 doors, 3.5' x 9' = 153 sq. ft.

1,032 - (153 + 108) = 771 sq. ft. of 12" wall.

Cubical contents, = 165,120 cu. ft.

Totals.

1,600 + 1,600 + 804 + 771 = 4,775 sq. ft. of 12" wall.

304 + 304 = 608 sq. ft. of 17" wall.

663 + 663 + 116 + 108 = 1,550 sq. ft. of glass. (Side walls).

Roof.

6' x 160' x 2 = 1,920 sq. ft. in sky lights.(Glass).

(19.5' x 2) + (2 x 2') + (5.5' x 2) x 160' = 7,680 sq. ft. of roofing.

Determination of heat loss in Machine-shop.

12" N. & W. walls.	2,304 x .29 =	668.2
10% for Northwest exposure, =		69.3
12" S. & E. walls,	2,304 x .29 =	668.2
17" N. & W. walls,	304 x .25 =	76.0
10% for Northwest exposure =		7.6
17" S. & E. walls,	304 x .25 =	76.0
2" plank, tar and gravel roof, 8,000 x .26 =		2,080.
1¾" doors, 571 x .32 =		183.
10% for N. W. exposure or 5% of total exp.=		5.2
Windows, N. & W. walls, 775 x 1.09 =		844.
10% for N. W. exposure, =		84.5
Windows, S. & E. walls =		845.
Skylight, 1,920 x 1.09 =		2,100.
10% North exposure, =		210.
		7,970.6

H = (.2415 x .0764 x 165,120 + 7,970.6) x 60 = 715,000 BTU.

By Rietchel's Rule, A = $\frac{.0024\ (15.5 - 1)\ 715,000}{1.5}$ = 360,000 Btu.

715,000/3 + 715,000 = 953,333 Btu. (To be supplied).

Determination of Heater for Machine-Shop.

Use Vento coils, heating air from 65° to 140°.

Cubic feet of air needed per min., $= \frac{55.2(953,333)}{60(140-65)} = 11,700$

Assume a velocity of 1,200 thru heater.

$\frac{11,700}{1,200} = 9.75$ sq. ft. of clear area.

Use regular 60" section,-16 sq. ft. Height = 60 - 12" width = 9¾".

Regular 5" centers,-11 loops,-10.13 sq. ft. of clear area.

Width of stack = 55" ± 2½" for staggering.

$\frac{11,700}{10.13} = 1,150$ ft./min. thru heater.

Use draw thru apparatus.

Fan handles air at 140°, and air has 1.132 times its vol. at 65°.

11,700 x 1.132 = 13,250 cu. ft./min. to be handled by fan.

Assume 1" total pressure.

Buffalo Forge Co.'s Coincidal Fan.

Fan #7,-delivers 13,260 cu. ft./min. at 269 R.P.M. and 2.96 HP.

Actual B.H.P. = $2.96 \times \frac{460+72}{460+149} = 2.6$ H.P. (Use 3 H.P. Motor).

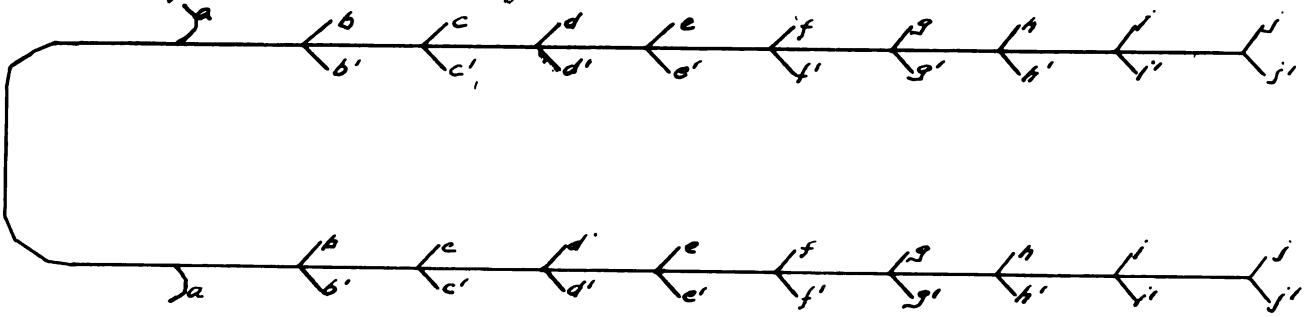
American Blower Co.'s Sirocco Fan.

Fan #7,- delivers 11,200 cu. ft./min., at 291 R.P.M. and 3.4 BHP.

PROPORTIONING DUCTS IN [illegible]-1902.

12,800 cu. ft./min. to be distributed by ducts.

Due to the obstruction formed by the crane and line shafting, it was necessary to run two branches over the trusses,-one down each bay.



Calculated data as taken from tables.

	Branch Main A or B			Branch outlet		
	Size	Capacity A.P.M.	Velocity FT./min.	Size	Capacity A.P.M.	Velocity FT./min.
a.	25"	6,400	1,280	18"	896	14	500
a'						
b.	24"	5,504	1,750	11"	272	4.5	500
b'				11"	272	4.5	500
c.	23"	4,928	1,710	11"	272	4.5	500
c'				11"	272	4.5	500
d.	22"	4,352	1,650	11"	272	4.5	500
d'				11"	272	4.5	500
e.	21"	3,776	1,570	11"	272	4.5	500
e'				11"	272	4.5	500
f.	20"	3,200	1,465	11"	272	4.5	500
f'				11"	272	4.5	500
g.	18"	2,624	1,475	11"	272	4.5	500
g'				11"	272	4.5	500
h.	16"	2,048	1,470	11"	272	4.5	500
h'				11"	272	4.5	500
i.	14"	1,472	1,370	11"	272	4.5	500
i'				11"	272	4.5	500
j.	12"	896	1,140	14"	448	7	500
j'				14"	448	7	500

FORGE-SHOP and FOUNDRY - Building No. 3.

This is a one story brick building, 163 ft. x 50 ft. with saw tooth roof construction. It is to be used for forge and foundry work, with a fire proof separating wall. The Farm Mechanics Forge-Shop will eventually be moved into this building, and the Foundry moved to a separate building. The building will be blower heated, with one main pipe extending down the center of the building. The system is designed to take care of the entire building to be used as a Forge Shop. This is necessary because the Foundry is to be replaced by the Farm Mechanics Forge-Shop and allowance has to be made for the air drawn out by the exhaust fan for forges.

HEATING SYSTEM FOR FORGE SHOP.

Radiation losses same as in machine shop.

Exhaust fan for forges removes about 5000 cu.ft. of air per min.

Cu.ft. of air needed /min. $= \frac{55.2 \times 953.333}{60(140-65)} = 11,700$ a. P. m.

Total = $\frac{4,880}{16,580}$ a. P. m.

Use a velocity of 1,200 ft.per minute thru the heater.

$\frac{16,580}{1200}$ = 13.8 sq. ft. of cle r area.

Use regular 60" section - 5 deep 16 sq.ft.

No. of loops - 15,net air space 13.81 sq.in.-width of stack in in. 75 +2.5 for staggerin = 77.5 in.

Use a draw thru apparatus.

Fan handles air at 140 degrees and air has 1,132 times its volume at 65 degrees.

16,580 x 1.132 = 18,750 cu. ft. per min. to be handled by fan.

Assume 1" total pressure.

Buffalo Forge Co. Coinoidal Fan.

Fan No. 8 handles 17,549 cu.ft. at 25?R.P.m. and 3.0?a.P.

American Blower Co. Sirocco Fan.

Fan No. 8 handles 18,500 cu.ft. at 19?R.P.m. and 3.37a.P.

PROPORTIONING DUCTS IN FORGE-SHOP.

18,750 cu.ft. to be distributed by ducts.

Area of outlet of fan=9 sq. ft.

First length of pipe is 42" in diam.

Calculated data as taken from tables.

	Size.	Main Capacity C.F.M.	Velocity. FT./Min.	Size	Branch outlet. Capacity C.F.M.	Velocity. FT./Min.
a.	42"	17,750	1,950	21"	1,210	7. 500
a'				23"	1,410	7. 500
b.	40"	16,130	1,850	18"	800	4.5 500
b'				19"	850	4.5 500
c.	38"	14,440	1,830	18"	800	4.5 500
c'				19"	850	4.5 500
d.	36"	12,750	1,800	18"	800	4.5 500
d'				19"	850	4.5 500
e.	34"	11,060	1,795	18"	800	4.5 500
e'				19"	850	4.5 500
f.	32"	9,370	1,630	18"	800	4.5 500
f'				19"	850	4.5 500
g.	30"	7,680	1,570	18"	800	4.5 500
g'				19"	850	4.5 500
h.	27"	5,500	1,510	18"	800	4.5 500
h'				19"	850	4.5 500
i.	24"	4,300	1,570	18"	800	4.5 500
i'				19"	850	4.5 500
j.	20"	2,620	1,200	21"	1,210	7. 500
j'				23"	1,410	7. 500