NATIONAL BUREAU OF STANDARDS REPORT

4213

PERFORMANCE OF A GAS-FIRED WALL HEATER WITH AND WITHOUT AN AUXILIARY AIR DISTRIBUTION SYSTEM

by

O. N. McDorman
P. R. Achenbach

Report to
Federal Housing Administration
Washington, D. C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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PERFORMANCE OF A GAS-FIRED WALL HEATER WITH AND WITHOUT AN AUXILIARY AIR DISTRIBUTION SYSTEM

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Abstract

An investigation was made of the performance of a gas-fired wall heater in a house without a basement employing the booster blowers in the heater alone and in combination with an auxiliary distribution system for circulating the air through the house. The auxiliary system consisted of a 7 1/2-inch propeller fan mounted in the ceiling near the heater forcing air through an attic plenum and three connecting ducts to ceiling grilles in three remote rooms. It was found that the distribution of warmed air to the five rooms of the Test Bungalow was reasonably good without the auxiliary system and that the auxiliary system did not decrease the difference between the warmest and coldest room. The auxiliary system decreased the vertical temperature differences in the living zone and between floor and ceiling, but these differences were still higher than desired at an outdoor temperature of 0°F even with the auxiliary system in operation. The observed heat loss was about 15% lower than the value computed by recognized methods for this house. This heater, as installed and operated, produced considerable noise.

1. INTRODUCTION

In accordance with a request of the Federal Housing Administration dated August 16, 1954 a study was made of the performance of a specimen gas-fired wall heater in the Test Bungalow for two methods of air distribution. In one case air was circulated through the heater and the house without the use of ducts by means of the twin centrifugal booster blowers inside the heater casing. In the second case this same air circulation was supplemented by a propeller fan and three attic ducts to

provide direct movement of warm air from the hall adjacent to the heater to the two bedrooms and bath.

The horizontal and vertical temperature distribution and the heat loss of the house were observed for each method of air distribution at outdoor temperatures of 32°F and 0°F. The noise level produced by the equipment was also observed in the various rooms of the Test Bungalow.

2. DESCRIPTION OF TEST SPECIMEN AND DISTRIBUTION SYSTEM

The Royal Jet Heater, model FF 72, Serial No. 6543 employed twin raised port burners ignited by a pilot located near one of the burners. Twin dimpled heat exchangers were enclosed in the furnace casing, designed for vertical mounting. The specimen was rated at 72,000 Btu/hr input and 54,000 Btu/hr output. The overall dimensions were 19 1/4-inch deep, 19-inch wide and 88 1/4-inch high. The heater was equipped with a contrifugal type fan with twin scrolls mounted at the two ends of the motor shaft. The motor was rated at 1550 rpm and 107 watts. The blowers were arranged for free discharge of air vertically upward through the heater.

As tested the heater was equipped with three supply grilles and three return grilles facing toward the living room, kitchen, and hall. The center line of the supply grilles were 78 inches above the floor whereas the center line of the return grilles were 12 inches above the floor for kitchen and living room and 17 inches for the hall grille. The openings in the warm air plenum inside the heater casing were smaller than the grilles in some cases. The dimensions of the plenum openings and perforated areas of the supply and return grilles are summarized below.

Room	Openings in Plenum, inches	Supply Grilles, in.	Return Grilles, in.
Kitchen	6x7 1/2	15x9 5/8	14x8 3/4
Living Room	14x7 5/8	15x9 5/8	15 1/2x10
Hall	6x6 3/8	14 5/8x14 1/4	22 3/4x14 1/8

Two views of the heater installation in the Test Bungalow are shown in Fig. 1 and 2. Fig. 1 shows the heater as seen from the kitchen, and Fig. 2 shows it as seen from the hall.

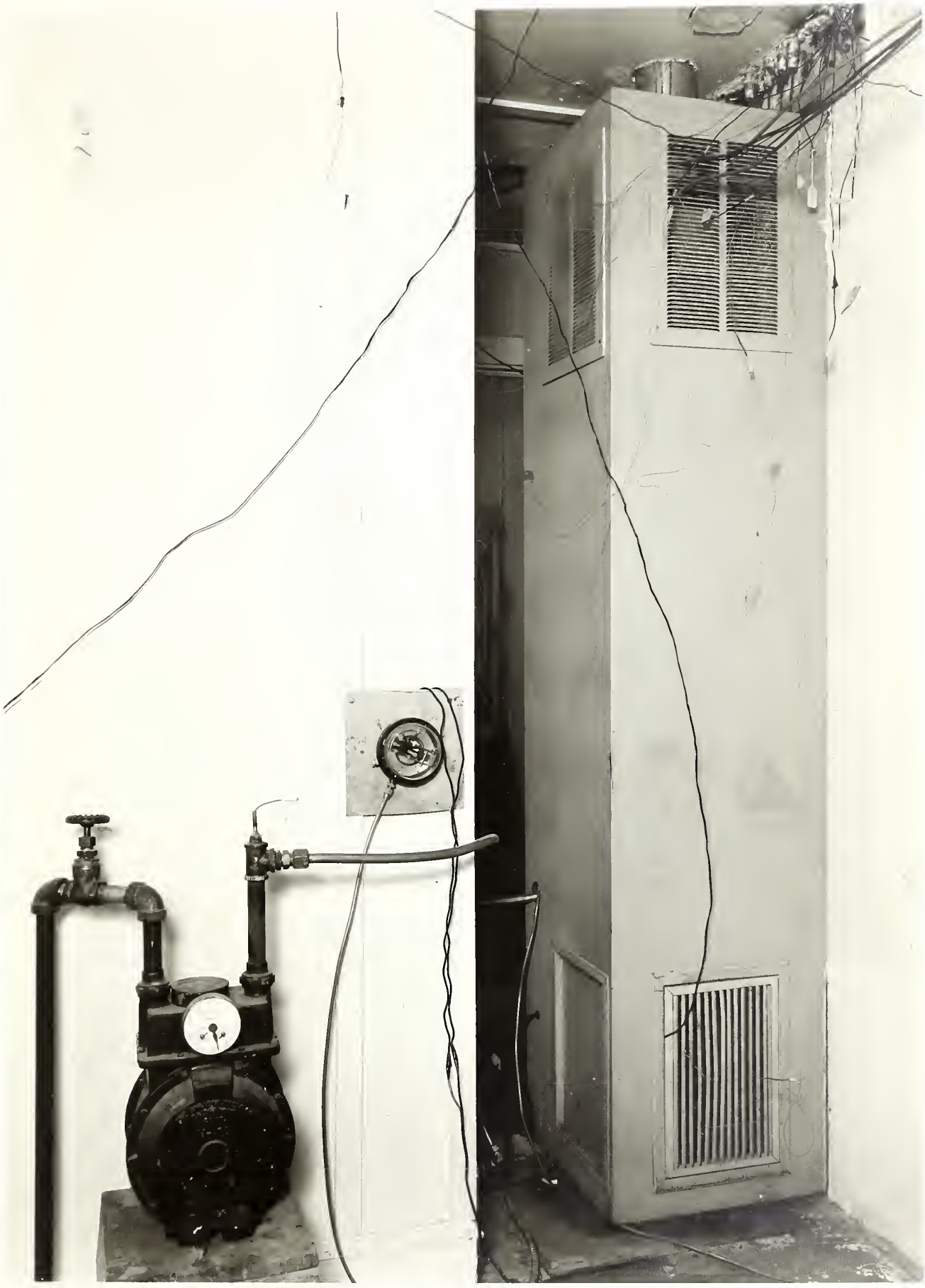

Fig. 1

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Fig. 2

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Since the heater capacity was in excess of the heat loss of the house it was operated under thermostatic control during the tests. The thermostat used was a wall thermostat manufactured by General Controls Company employing a thermoelectric circuit for actuation of the control.

The auxiliary distribution system consisted of a 7 1/2 inch diameter propeller type fan rated at 58 watts mounted in the center hallway ceiling exhausting into a 10"x10"x16" plenum above the ceiling. Extending from this plenum in the attic were three six inch diameter insulated ducts connected to supply registers in the ceilings of the bath, north bedroom and south bedroom.

The lengths of these ducts were, nine feet for the bath, eight feet for the north bedroom and 12 feet for the south bedroom. The location of the auxiliary fan with respect to the heater is shown in Fig. 2. The location of the heater and the attic ducts are indicated on the plan of the Test Bungalow shown in Fig. 3.

3. TEST EQUIPMENT AND PROCEDURE

The Test Bungalow remained in the same condition with respect to insulation and construction features, as for other heating systems recently tested. Significant factors were as follows: plastered ceiling, fluorescent illumination, weatherstripped windows and doors, uninsulated outside walls, basement ceiling consisted of 1-inch rigid insulation board nailed directly to the under side of the floor joists. The ceiling was insulated from the attic space with two layers of commercial "double thick" rock wool. The effective thickness was determined to be 5.4 inches. The Test Bungalow was operated as a basementless house for these tests even though it had a full basement. The basement temperature was controlled for similar tests to provide comparative data.

The temperature distribution was ascertained by means of 200 thermocouples enclosed in three inch cork spheres located at five stations and five levels in each of the four large room and three stations and five levels in the bath and at other suitable stations on the floor, embedded in the ceiling surface, on the sidewalls, and in basement, attic and out-of-doors. Additional thermocouples, of the parallel multiple-junction type were placed at the heater inlets and outlets. The temperature of the gas supply was measured by means of a thermocouple inserted in the gas stream.

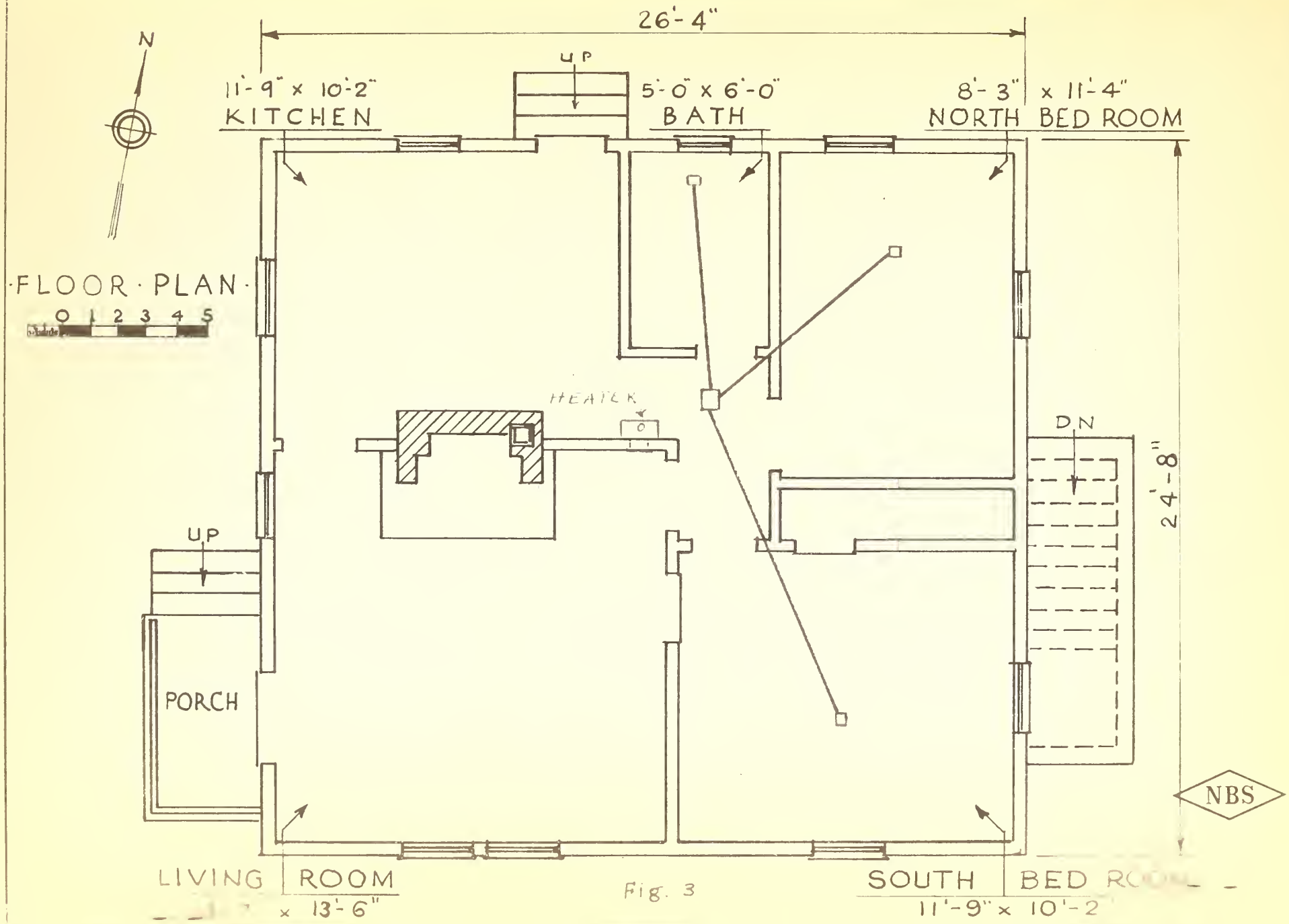
N
26'-4"
UP
11'-9" x 10'-2"
KITCHEN
5'-0" x 6'-0"
BATH
8'-3" x 11'-4"
NORTH BED ROOM
FLOOR PLAN
0 1 2 3 4 5
HEATER
DN
24'-8"
UP
PORCH
NBS
LIVING ROOM
x 13'-6"
SOUTH BED ROOM
11'-9" x 10'-2

Fig. 3

The absolute values of the heat transmitted to the attic were determined with the aid of twenty heat flow meters placed over the first layer of rock wool insulation in the attic.

After steady state conditions had been maintained in outside and inside temperatures for approximately eight hours, test periods of about 12 hours commenced, during which observations of the inside temperatures for approximately 150 stations were recorded at four hour intervals. Hourly recordings were made of the following temperatures: outside air, 30-inch level at five room centers, five positions in basement, five locations on furnace, gas supply temperature, and the closet. The accuracy of the measuring circuit was checked hourly using melting ice as a standard. Gas consumption, electrical energy used for lighting the house, electrical energy consumed by fan motors, and gas pressure were recorded hourly.

4. TEST RESULTS AND CONCLUSIONS

The temperature distributions observed in the Test Bungalow during four tests under steady state conditions are summarized in Tables 1-4 inclusive. Table 5 summarizes the performance of the heater, the heat loss of the house, and some of the more significant temperatures in the structure. Two tests were made at outdoor temperatures of 32°F and 0°F, respectively, without the auxiliary distribution system. Tests were then made under these same conditions with the auxiliary distribution system in use. Table 6 summarizes the results of the noise measurements made in the house.

Temperature Distribution

The average of the temperatures observed at five levels in each of the five rooms of the house are summarized in Tables 1 and 4 when the auxiliary distribution system was not in use and in Tables 2 and 3 when it was in use. The station at the center of the living room 30 inches above the floor was used as the control point although the thermostat was located on an inside wall of the living room at the same height above the floor. It will be noted in these four tables that the variation in average temperature between rooms at the 30 inch level was approximately one degree and it was independent of whether the auxiliary system was used or not. The variation in

average temperature between rooms was considerably greater at all other levels of observation than at the 30-inch level increasing to 6.9°F at the 60-inch level with the auxiliary system in operation and 5.2°F at the same level without the auxiliary system for an outdoor temperature of 0°F in each case. The horizontal temperature distribution was not significantly improved in this house by the operation of the auxiliary distribution system.

The vertical temperature differences in the living zone, from two to sixty inches above the floor, and from floor to ceiling, two to ninty-four inches above the floor, are summarized below:

Vertical Temperature Differences

Height Above Floor, Inches	With Auxiliary System	Without Auxiliary System
	Outdoor temperature 32°F	
2-60	9.5	10.4
2-94	15.0	17.3
	Outdoor temperature 0°F	
2-60	16.7	19.1
2-94	26.0	30.5

This summary shows that the auxiliary distribution system lowered the vertical temperature differences from one to 2.4 degrees in the living zone and from 2.3 to 4.5 degrees from floor to ceiling for the range of outdoor temperatures used. Tables 1-4 show that the reduction in vertical temperature differences from floor to ceiling was accomplished primarily by lowering the temperature at the 94-inch level.

Tables 1-4 show that the maximum horizontal temperature variation within rooms was not greatly affected by the auxiliary distribution system. The average of the intraroom variations was about 2.2°F at an outdoor temperature of 32°F and 3.5°F at an outdoor temperature of 0°F/

The attic temperature was increased only slightly by the use of the auxiliary ducts indicating that the attic ducts and plenum did not transfer much heat to the attic.

Heat Loss

If the average total heat requirement for these tests as shown in Table 5 is plotted against the indoor - outdoor temperature difference based on average temperature at the 30-inch level a tangent of 418 Btu/hr (°F) would be obtained. This value is very nearly equal to that obtained in the Test Bungalow with other heaters of this type.

The observed heat loss of the house was substantially the same irrespective of whether the auxiliary distribution system was used or not. The computed heat loss of the Test Bungalow using the methods recommended in the 1954 "Guide" of the American Society of Heating and Air Conditioning Engineers averaged about 15 percent higher than the observed values.

The heat loss from the living space to the attic was measured with 20 heat flow meters distributed over the entire ceiling area so that each represented approximately an equal area. The observed heat loss through the ceiling, insulated with 5.4 inches of rock wool, averaged about five percent of the total heat loss of the house. The heat loss through the ceiling with the auxiliary distribution system in use was about half of one percent less than without it. This is attributed partly to the lower temperature beneath the ceiling and partly to the higher temperature in the attic when the auxiliary system was in use.

The temperature rise of the air between return and supply grilles indicates that the blowers in the heater circulated about 500 cfm of air when operating. A comparison of the air temperature at the return grilles in Table 5 and the temperatures at the two inch level in the several rooms of the house indicates that the return air was drawn into the heater at a level considerably above the floor or it was warmed several degrees before reaching the heater if taken from floor level.

Noise

The noise level observed in three rooms of the house at levels 24 and 60 inches above the floor are reported in Table 6. The noise level ranged from 55 to 59 decibels on the 40 db weighted network, from 59 to 65 decibels on the 70 db weighted network, and from 61 to 69 decibels on the flat network. These values are all higher than those

cited in the 1954 ASHAE Guide for representative residences. The system could have been made quieter by using sheet metal screws in some of the vibrating members or by the use of the speed control in the fan circuit which was not installed by the manufacturer for these tests.

5. DISCUSSION AND CONCLUSIONS

The data observed in the Test Bungalow while operating the Model FF-72 Royal heater with and without the auxiliary distribution system indicate the following conclusions:

1. The difference in average temperature between rooms was quite low at the 30-inch level and exceeded 5°F only slightly in the living zone when the heater used its own blowers and the outdoor temperature was 0°F. The auxiliary distribution system did not significantly improve the horizontal temperature pattern.

The auxiliary distribution would probably be of greater value in houses whose floor plan did not permit the heater to be located as near the center of the house as for the test installation.

2. The vertical temperature differences in the living zone at an outdoor temperature of 0°F were a little greater than the 15°F that experience has indicated is about the maximum that can be tolerated with comfort. The auxiliary air distribution system decreased the vertical temperature difference in the living zone 2.4°F on the average at this same outdoor temperature.

3. The insulation on the attic plenum and ducts appeared to effectively limit the heat transfer from these components to the attic.

4. Radiation from the ceiling surface to floor did not play a significant role for this system. Average ceiling surface temperatures ranged from 77°F to 84°F for this series of tests.

5. The test results do not indicate that the heat requirements of a house using this model heater would be greater than the computed heat loss.

6. The heater was considered to be undesirably noisy when the fans were operating at full speed.

TABLE 1

Temperature Distribution with Royal Heater, Model FF-72
Outdoor Temperature 31.3°F

Height Above Floor	Average Room Temperature					Average of 5 Rooms	Maximum Horizontal Temperature Difference Between Rooms
	Kitchen	Living Room	Bath Room	North Bedroom	South Bedroom		
inches	°F	°F	°F	°F	°F	°F	°F
2	66.1	66.8	67.1	63.8	65.7	65.9	3.3
30	70.1	70.3	70.7	69.8	70.4	70.3	0.9
60	77.0	76.8	77.6	74.0	75.9	76.3	3.6
78	82.2	80.4	82.6	76.2	78.1	79.9	6.4
94	86.3	83.7	86.1	79.2	80.7	83.2	7.1
	Maximum Horizontal Temperature Variation Within Rooms						
30	2.8	2.2	1.4	2.4	2.6	2.3	
	Vertical Temperature Difference, Room Average						
2-60	10.9	10.0	10.5	10.2	10.2	10.4	
2-94	20.2	16.9	19.0	15.4	15.0	17.3	

Average Basement Temperature	46.9°F
Average Attic Temperature	43.5°F
Average Ceiling Surface Temperature	78.3°F
Average Floor Surface Temperature	65.5°F

TABLE 2

Temperature Distribution with Royal Heater, Model FF-72
Outdoor Temperature 31.7°F
Auxiliary Distribution System

Height Above Floor	Average Room Temperature					Average of 5 Rooms	Maximum Horizontal Temperature Difference Between Rooms
	Kitchen	Living Room	Bath Room	North Bedroom	South Bedroom		
Inches	°F	°F	°F	°F	°F	°F	°F
2	66.0	66.9	67.0	66.1	65.6	66.3	1.4
30	70.4	70.7	70.8	71.3	70.6	70.8	0.9
60	76.6	76.6	77.5	73.2	75.4	75.9	4.3
78	80.9	80.3	79.8	74.3	76.9	78.4	6.6
94	84.9	83.5	82.2	77.0	79.1	81.3	7.9
	Maximum Horizontal Temperature Variations Within Rooms						
30	3.0	2.2	1.2	2.4	2.2	2.2	
	Vertical Temperature Difference, Room Average						
2-60	10.6	9.7	10.5	7.1	9.8	9.5	
2-94	18.9	16.6	15.2	10.9	13.5	15.0	

Average Basement Temperature	47.5°F
Average Attic Temperature	44.1°F
Average Ceiling Surface Temperature	76.7°F
Average Floor Surface Temperature	65.6°F

TABLE 3

Temperature Distribution with Royal Heater, Model FF-72
Outdoor Temperature 0.0°F
Auxiliary Distribution System

Height Above Floor Inches	Average Room Temperature					Average of 5 Rooms °F	Maximum Horizontal Temperature Difference Between Rooms °F
	Kitchen °F	Living Room °F	Bath Room °F	North Bedroom °F	South Bedroom °F		
2	61.2	63.2	62.9	60.4	61.4	61.8	2.8
30	69.5	70.2	70.2	70.9	69.6	70.1	1.4
60	77.7	80.0	81.9	75.0	78.2	78.6	6.9
78	87.0	86.9	84.7	77.2	80.9	83.3	9.8
94	92.3	91.8	88.4	81.6	84.8	87.8	10.7
	Maximum Horizontal Temperature Variations With Rooms						
30	4.5	3.5	2.2	2.1	4.1	3.3	
	Vertical Temperature Difference, Room Average						
2-60	16.5	16.8	19.0	14.6	16.8	16.7	
2-94	31.1	28.6	25.5	21.2	23.4	26.0	

Average Basement Temperature	37.9°F
Average Attic Temperature	26.1°F
Average Ceiling Surface Temperature	80.5°F
Average Floor Surface Temperature	61.7°F

TABLE 4

Temperature Distribution with Royal Heater, Model FF-72
Outdoor Temperature -0.3°F

Height Above Floor	Average Room Temperature					Average of 5 Rooms	Maximum Horizontal Temperature Difference Between Rooms
	Kitchen	Living Room	Bath Room	North Bedroom	South Bedroom		
Inches	°F	°F	°F	°F	°F	°F	°F
2	61.8	63.9	64.7	59.4	61.9	62.3	5.3
30	70.4	70.6	71.3	69.9	70.3	70.5	1.4
60	82.8	82.3	83.5	78.3	80.5	81.5	5.2
78	91.3	88.9	91.3	82.3	84.5	87.7	9.0
94	96.9	94.1	96.7	87.3	89.0	92.8	9.6
	Maximum Horizontal Temperature Variations with Rooms						
30	4.5	3.7	2.0	4.0	4.0	3.6	
	Vertical Temperature Difference, Room Average						
2-60	21.0	18.4	18.8	18.9	18.6	19.1	
2-94	35.1	30.2	32.0	27.9	27.1	30.5	

Average Basement Temperature	37.7°F
Average Attic Temperature	24.5°F
Average Ceiling Surface Temperature	83.9°F
Average Floor Surface Temperature	62.5°F

TABLE 5

SUMMARY OF RESULTS

PERFORMANCE OF ROYAL JET HEATER
MODEL FF-72

Test No.		1	2	3	4
Method of Air Circulation		Blower	Auxiliary Distribution and Blower		Blower Only
Outside Temperature	°F	31.3	31.7	0.0	-0.3
Observed Gas Consumption	cu.ft/hr	20.40	20.59	40.48	39.47
Correction Factor		0.97	0.97	0.98	0.98
Corrected Gas Consumption	cu.ft/hr	19.79	19.97	39.67	38.68
Heating Value	Btu/cu.ft	1044	1042	1039	1040
Heat Input to Furnace	Btu/hr	20,660	20,810	41,220	40,230
CO_2 in Flue Gases	Percent	6.75	6.75	6.75	6.75
Stack Temperature	°F	737	737	737	737
Indirect Efficiency	Percent	68	68	68	68
Heat Output of Furnace	Btu/hr	14,050	14,150	28,030	27,360
Electrical Heat Input	Btu/hr	2,000	2,070	2,190	2,020
Observed Heat Loss of House	Btu/hr	16,050	16,220	30,220	29,380
Ceiling Heat Loss	Btu/hr	870	800	1,340	1,440
Computed Heat Loss of House	Btu/hr	18,590	18,640	33,410	33,750
Power Consumption of Blower	Watts	60	84	121	79
Average Temp., 30 inch Level	°F	70.3	70.8	70.1	70.5
Basement Air Temperature	°F	46.9	47.5	37.9	37.7
Attic Air Temperature	°F	43.5	44.1	26.1	24.5
Ceiling Surface Temperature	°F	78.3	76.7	80.5	83.9
Average Cold Wall Temp. 30 to 60 in. above floor	°F	66.3	66.1	62.8	65.7
Floor Surface Temperature	°F	65.5	65.6	61.7	62.5
Air Temp. at Return Grilles	°F	70.7	71.1	66.9	68.2
Air Temp. at Supply Grilles	°F	203.3	201.1	195.4	197.5

TABLE 6

Summary of Sound Level Measurements in Test Bungalow with Royal Jet Heater, Model FF-72

Room	Height of Microphone Above Floor Inches	Weighting Net Work	Sound Level, Decibels	
			Background	Fan on Max. Speed
Kitchen	60	flat	48	69
		70	34	65
		40	24-	59
Kitchen	24	flat	48	67
		70	34	64
		40	24-	59
Living Room	60	flat	46	65
		70	31	63
		40	24-	59
Living Room	24	flat	46	63
		70	31	62
		40	24-	59
South Bedroom	60	flat	44	62
		70	34	59
		40	24-	55
South Bedroom	24	flat	44	61
		70	34	59
		40	24-	56

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