DESIGN OF A GAS FIRED SPACE HEATER

THESIS BY - - - - - - - - - ROBERT F. MCLEAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF INDUSTRIAL DESIGNER

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MESSRS. R. N. BOWMAN, L. PRICE, JR, AND A. J. LAMPERT, OF THE RHEEM MANUFACTURING COMPANY, HAVE GIVEN GENEROUS ASSISTANCE IN DEVELOPING THE DESIGN. CONTRIBUTIONS OF TECHNICAL DATA BY HEATER MANUFACTURERS HAVE PROVED TO BE OF CONSIDERABLE VALUE. THE AMERICAN GAS ASSOCIATION, PARTICULARLY MR. FRANK FIEDLER, JR, HAS BEEN VERY HELPFUL.

ABSTRACT

WALL MOUNTED, VENTED, GAS FIRED SPACE HEATERS NOW BEING MANUFACTURED ARE SURVEYED. AN ANALYSIS OF THE MARKET REQUIREMENTS FOR SUCH A HEATER IS PRESENTED. RECENT TECHNICAL DEVELOPMENTS IN GAS HEATING ARE SUMMARIZED; A NEW TYPE OF GRID GAS BURNER IS INVESTIGATED.

FACTORS IMPORTANT TO DESIGN OF SPACE HEATERS ARE DISCUSSED. FROM THESE, A HEATER DESIGN IS EVOLVED SUITABLE FOR THE MAJORITY OF THE RESIDENCES BEING CONSTRUCTED TODAY. THE APPEARANCE IS DEVELOPED TO SUIT CONTEMPORARY ARCHITECTURE.

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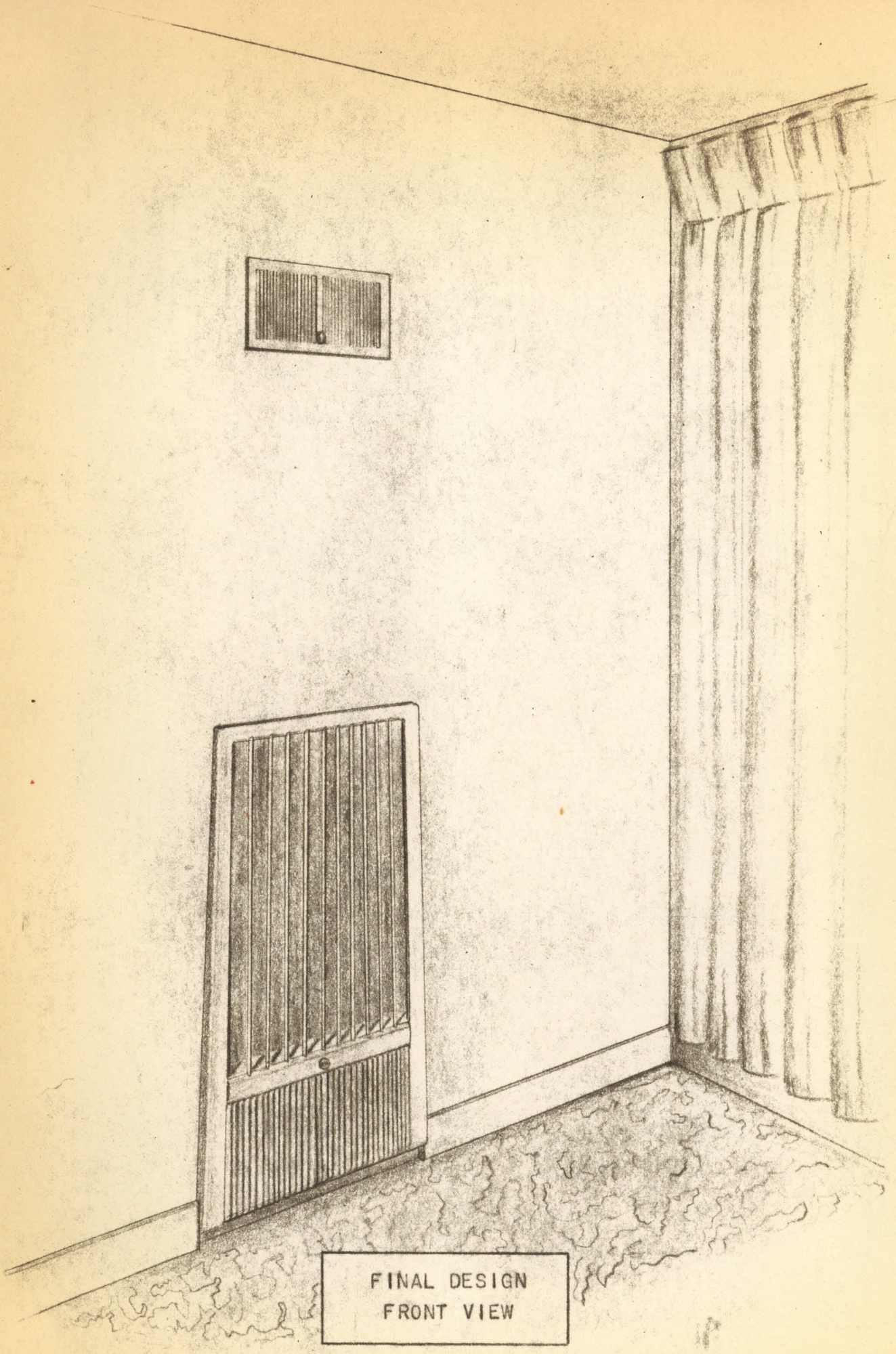

FINAL DESIGN
FRONT VIEW

DESIGN SUMMARY

DESCRIPTION

THE HEATER WHICH HAS BEEN DEVELOPED IS WALL ENCLOSED, FULLY VENTED, AND EMPLOYS CIRCULATING AIR AS THE MAJOR MEANS OF HEAT TRANSFER. IT CAN BE OPERATED WITH NATURAL, MANUFACTURED, OR LIQUIFIED PETROLEUM GASES BY SIMPLE VARIATIONS OF THE BURNER. THE MAXIMUM INPUT IS 55 000 BTU PER HOUR BASED ON THE GROSS HEATING VALUE OF THE GAS; AT AN ASSUMED EFFICIENCY OF 70%, THE OUTPUT IS 38 500 BTU PER HOUR. PROVISION HAS BEEN MADE FOR EITHER MANUAL OR AUTOMATIC THERMOSTAT CONTROL. VARIOUS COMBINATIONS OF THREE HEAT OUTLETS CAN BE EMPLOYED, AND THE HEATER CAN BE CENTRALLY LOCATED TO HEAT EFFECTIVELY SEVERAL ADJOINING ROOMS. VARIABLE VOLUME CONTROLS PROVIDE A SIMPLE MEANS OF CONTROLLING HEAT BALANCE.

FEATURES

THE FOLLOWING UNIQUE OR NOVEL FEATURES HAVE BEEN INCORPORATED:

THE HEATER IS AN INTEGRAL PART OF THE HOUSE, ITS STRUCTURAL FRAME CARRIES THE VERTICAL AND LATERAL LOADS OF THE WALL SECTION IT OCCUPIES.

A MODULAR FRAME AND PANEL SYSTEM ALLOWS INSTALLATION IN MANY TYPES OF CONSTRUCTION WITHOUT SPECIAL FRAMING.

A COMBINATION OF RADIANT PANEL AND CIRCULATING AIR OUTLETS PROVIDES MAXIMUM FLEXIBILITY AND HIGH HEATING EFFICIENCY.

THE BURNER DESIGN, WITH SLOTTED GRID TYPE PORTS, PROVIDES UNUSUALLY HIGH PRIMARY AIR CAPACITY AND ALLOWS FOR SIMPLE ALTERATION OF THE BURNER TO ACCOMODATE VARIOUS GASES.

INTRODUCTION

THE PROBLEM

THE PROBLEM IS THE DESIGN OF A GAS FIRED, WALL MOUNTED RESIDENTIAL SPACE HEATER. THE DESIGN AND CAPACITY SHALL BE SUCH THAT THE HEATER WILL BE A SATISFACTORY CENTRALLY LOCATED UNIT FOR THE AVERAGE RESIDENCE OF TODAY. UNIQUE FEATURES OF OPERATION AND INSTALLATION ARE TO BE INVESTIGATED AND, IF POSSIBLE, DEVELOPED. THE APPROVAL REQUIREMENTS OF THE AMERICAN GAS ASSOCIATION SHALL BE FULFILLED.

CONSECUTION

PRELIMINARY INVESTIGATIONS BEGAN WITH A SURVEY OF ALL THE APPROVED SPACE HEATERS IN THE CATEGORY DESCRIBED ABOVE. THE RELATIONSHIP OF SPACE HEATERS TO OTHER TYPES WAS CONSIDERED. PERUSAL OF THE PERTINENT TECHNICAL LITERATURE DISINTERED NEW DEVELOPMENT POSSIBILITIES. THE HEATING REQUIREMENTS OF TYPICAL SMALL RESIDENCES WERE STUDIED; AN IDEAL CAPACITY AND ARRANGEMENT WERE DETERMINED. MARKET ANALYSIS INDICATED PRESENT BUYING TENDENCIES AND POSSIBLE FUTURE ONES. FROM THE ABOVE, THE DESIGN WAS DEVELOPED TO SATISFY THE STANDARDS OF PERFORMANCE AND SAFETY. CONSIDERATION WAS GIVEN TO COST OF MANUFACTURE AND MARKETING POLICY. THE APPEARANCE WAS STYLED TO SUIT CONTEMPORARY ARCHITECTURE.

PRODUCT SURVEY

APPROACH

PRODUCT ANALYSIS WAS DONE TO DETERMINE THE CHARACTERISTICS OF WALL MOUNTED, VENTED SPACE HEATERS NOW ON THE MARKET. THE RELATIONSHIP OF SUCH HEATERS TO OTHER GAS FIRED TYPES WAS INVESTIGATED. TWO HEATERS WERE SELECTED FOR DETAILED STUDY. SURVEY WAS CONFINED TO UNITS APPROVED BY THE AMERICAN GAS ASSOCIATION.

DEFINITIONS

A SPACE HEATER IS DEFINED AS:

> "A SELF CONTAINED GAS-BURNING APPLIANCE INSTALLED IN AND FOR HEATING ROOMS. THIS DEFINITION SHALL NOT INCLUDE UNIT HEATERS, CENTRAL HEATING GAS APPLIANCES, NOR GARAGE HEATERS".(1)*

A VENTED APPLIANCE IS DEFINED BY:

> "IN ORDER TO BE CLASSIFIED AS A VENTED HEATER, 90% OF THE FLUE GASES SHALL BE CARRIED OUT OF THE FLUE OUTLET".(2)

WHILE A FLUE OUTLET IS:

> "THE OPENING PROVIDED IN AN APPLIANCE FOR THE ESCAPE OF THE FLUE GASES".(3)

SPACE HEATER STUDY

THE SPACE HEATERS APPROVED UNDER AMERICAN STANDARDS BY THE AMERICAN GAS ASSOCIATION WERE THE SUBJECTS OF THIS STUDY; HEATERS ON THE MARKET NOT INCLUDED IN THE APPROVED LIST ARE INSIGNIFICANT IN NUMBER.

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*NUMERALS IN PARENTHESES REFER TO REFERENCES FOLLOWING TEXT

PRODUCT SURVEY

OF THE 557 MODELS APPROVED FOR USE WITH NATURAL AND MANUFACTURED GASES, 43 ARE CLASSIFIED AS VENTED WALL CIRCULATORS, OR 7.7%; OF THE 526 MODELS APPROVED FOR USE WITH LIQUEFIED PETROLEUM GASES, 28 ARE CLASSIFIED AS VENTED WALL CIRCULATORS, OR 5.3%. THIS DOES NOT INCLUDE THOSE SPACE HEATERS APPROVED UNDER AMERICAN STANDARDS FOR USE AT HIGH ALTITUDES. (4)

THERE ARE LISTED (4) FIFTEEN MANUFACTURERS OF APPROVED MODELS OF VENTED WALL CIRCULATORS; GEOGRAPHICALLY, ONE EACH IS IN ARIZONA, TEXAS, AND INDIANA, AND TWELVE ARE IN LOS ANGELES COUNTY, CALIFORNIA. A LISTING OF THE MANUFACTURERS WITH ADDRESSES, HEATER TRADE NAMES, AND INPUT CAPACITY WITH NATURAL OR MANUFACTURED GAS, OF HEATER MODELS IS IN TABLE 1. A MORE COMPLETE SUMMARY OF WALL MOUNTED SPACE HEATERS MAY BE FOUND IN TABLE 5, APPENDIX A. THIS WAS COMPILED FROM SALES LITERATURE AND TECHNICAL DATA OBTAINED FROM THE LISTED MANUFACTURERS.

IT WILL BE NOTICED THAT THE RANGE OF HEAT INPUT CAPACITIES FOR THESE HEATERS IS 10 000 TO 60 000 BTU PER HOUR WITH NATURAL OR MANUFACTURED GASES. A CAPACITY FREQUENCY DISTRIBUTION GRAPH OF THE 43 MODELS IS SHOWN IN FIGURE 1. A COMPARISON OF VENTED WALL CIRCULATORS WITH ALL OTHER TYPES OF GAS HEATERS IS SHOWN IN FIGURE 2, WHICH WAS COMPILED FROM AMERICAN GAS ASSOCIATION APPROVALS. (4) RELATIVELY, THE VENTED WALL CIRCULATOR IS SEEN TO BE OF MEDIUM CAPACITY.

MANUFACTURER	ADDRESS	TRADE NAME	INPUT RATING*
ANDREWS HEATER COMPANY	1750 W. JEFFERSON BLVD. LOS ANGELES 7, CALIF.	SHALLOW PITLESS	25 37.5 45 60
BARNES HEATING & VENTILATING CO.	449 W. ANAHEIM AVE. LONG BEACH 13, CALIF.	PANEL-AIRE	20
COMMONWEALTH COMPANY	2127 W. COMMONWEALTH AVE. ALHAMBRA, CALIF.	COMMON- WEALTH	15 20 28 38 48 58
DAY AND NIGHT MFG. COMPANY	P. O. BOX 150, MONROVIA, CALIF.	PANELRAY	10 20 30 10-10 10-20 20-20
THE FOLSOM COMPANY, INC.	3104 OAK LANE DALLAS 10, TEXAS	CIRKLAIR	12 20 28
HAMMEL RADIATOR ENGINEERING CO.	3376 MOTOR AVE. LOS ANGELES 34, CALIF.	HAMMEL	11.5 30 45
HEATING RESEARCH CORP.	620 W. 14TH STREET ANDERSON, IND.	SAF-AIRE	10 18
IDEAL HEATING CORP.	807 E. GAGE AVE. LOS ANGELES 1, CALIF.	IDEAL	60
HOLLY MANUFACTURING COMPANY	875 S. ARROYO PKWY. PASADENA 5, CALIF.	HOLLY	37 45 58
PALMER MANUFACTURING CORP.	701 W. JEFFERSON ST. PHOENIX, ARIZONA	PALMAIRE	18 20 35
PAYNE FURNACE COMPANY	336 N. FOOTHILL ROAD BEVERLY HILLS, CALIF.	PANELAIR	40 55
ROYAL HEATERS, INC.	1024 WESTMINSTER AVE. ALHAMBRA, CALIF.	JET-FLOW	25 38 45 55
UNIVERSAL METAL PRODUCTS	2940 E. OLYMPIC BLVD. LOS ANGELES 23, CALIF.	HEATMASTER	38 45
UTILITY APPLIANCE CORP.	4851 S. ALAMEDA ST. LOS ANGELES 11, CALIF.	WALL-O-MATIC	50
WILLIAMS RADIATOR COMPANY	1821 FLOWER ST. GLENDALE 1, CALIF.		

TABLE 1 - MANUFACTURERS OF APPROVED WALL HEATERS

*BTU PER HOUR x 10^{-3}

NOTEWORTHY IS THE SIMILIARITY OF THE CAPACITY RANGE OF THESE HEATERS AND THE GRAVITY FLOOR FURNACES.

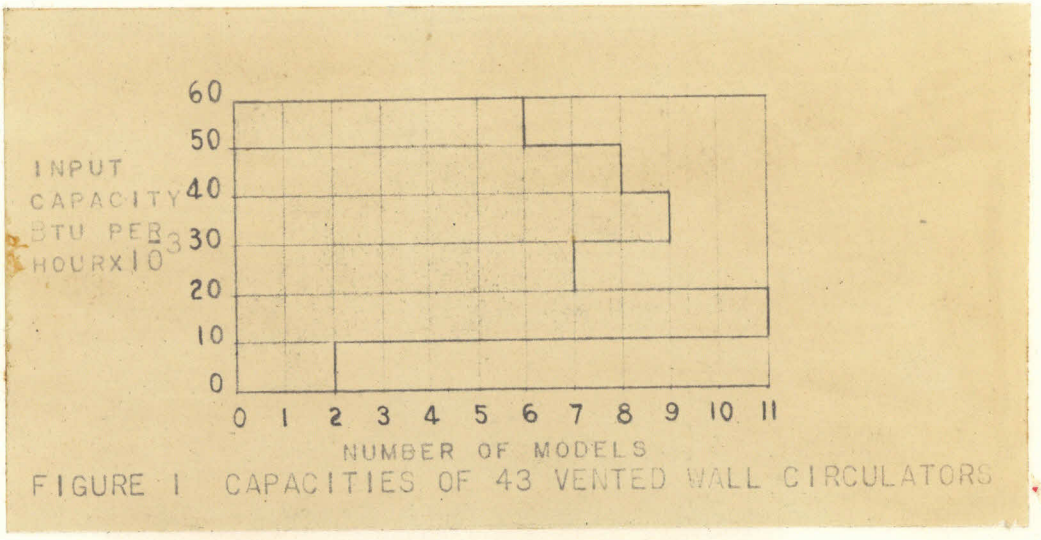


FIGURE 1 CAPACITIES OF 43 VENTED WALL CIRCULATORS

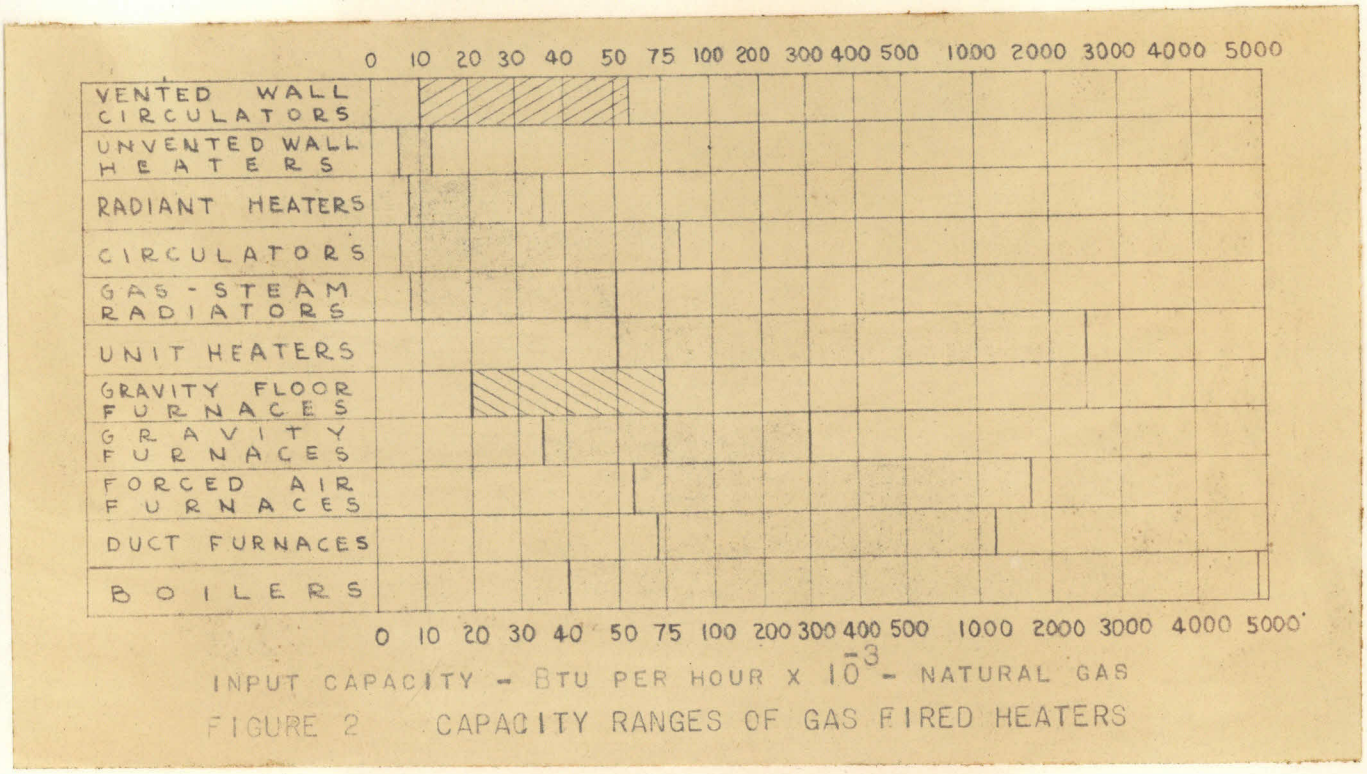


FIGURE 2 CAPACITY RANGES OF GAS FIRED HEATERS

THE USUAL VENTED WALL CIRCULATOR IS COMPOSED OF A GAS BURNER ENCLOSED IN A HEAT EXCHANGER WHICH DELIVERS THE COMBUSTION PRODUCTS TO THE VENT AND TRANSMITS THE HEAT TO THE CIRCULATING AIR. AIR CIRCULATION IS CONTROLLED AND DIRECTED BY A HOUSING WHICH CONTAINS THE NECESSARY INLET AND OUTLET GRILLES. THE HOUSING ALSO PREVENTS THE WALL STRUCTURE FROM BECOMING EXCESSIVELY HEATED. A TYPICAL HEATER IS SHOWN IN THE CUTAWAY DRAWING OF FIGURE 3.

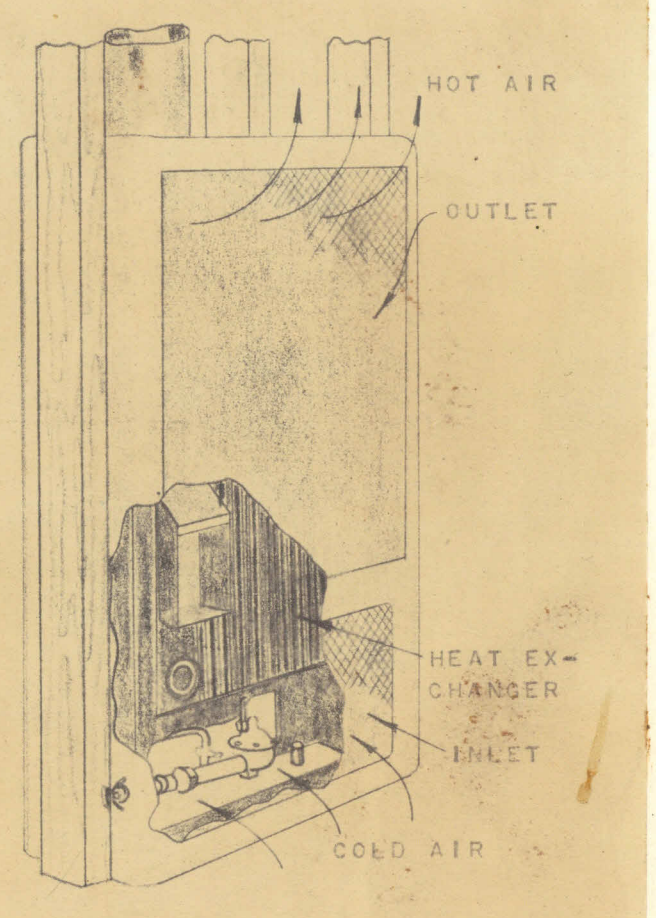


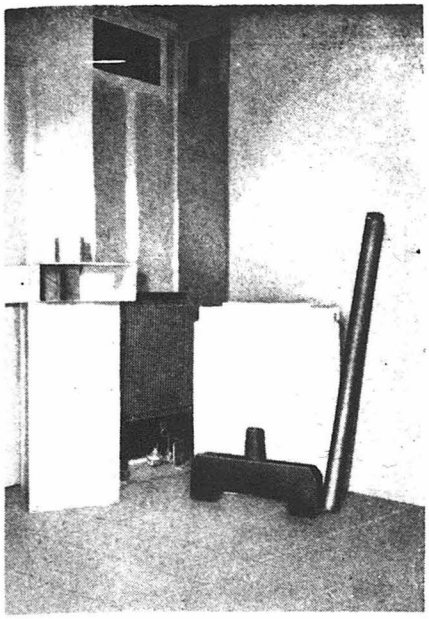
FIGURE 3 CUTAWAY OF TYPICAL VENTED WALL CIRCULATOR
(HEATMASTER, UNIVERSAL METAL PRODUCTS CO.- SEE PAGE 5)

PRODUCT SURVEY

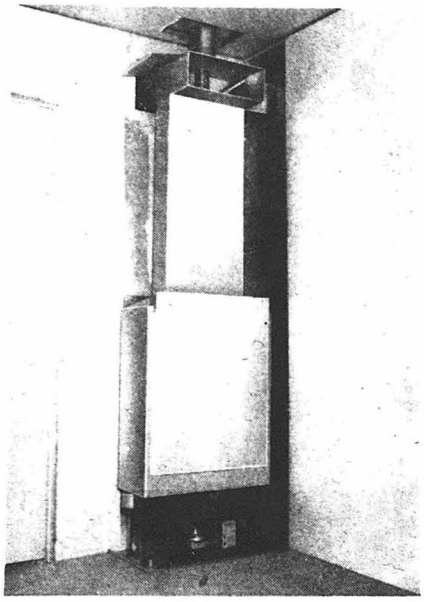
THE MAJORITY OF THE HEATERS LISTED CAN BE INSTALLED IN A 2 INCH X 4 INCH WOOD STUD WALL, USUALLY BETWEEN TWO STUD SPACES, ABOUT 30 INCHES. MOST USE A 4 INCH DIAMETER ROUND VENT OR EQUIVALENT VENT OF OVAL CROSS SECTION. THEY ARE GENERALLY EQUIPPED FOR MANUAL BURNER VALVE OPERATION; ALL HAVE PILOT BURNER IGNITION. THEY CAN BE EQUIPPED WITH AUTOMATIC THERMOSTAT CONTROLS. MOST HAVE GAS PRESSURE REGULATORS. THE RETAIL PRICES VARY FROM $50 TO $225 AS IN TABLE 5, APPENDIX A.

TWO HEATERS WERE SELECTED FOR DETAILED STUDY AS THEY REPRESENT THE MOST RECENT DEVELOPMENTS. THEY ARE THE ROYAL JET FLOW, MANUFACTURED BY ROYAL HEATERS, INC. AND THE PANELAIR, MANUFACTUREDNBY THE PAYNE FURNACE COMPANY. THESE UNITS ARE SHOWN IN FIGURE 4, DETAILED DATA APPEARS IN TABLE 5, APPENDIX A.

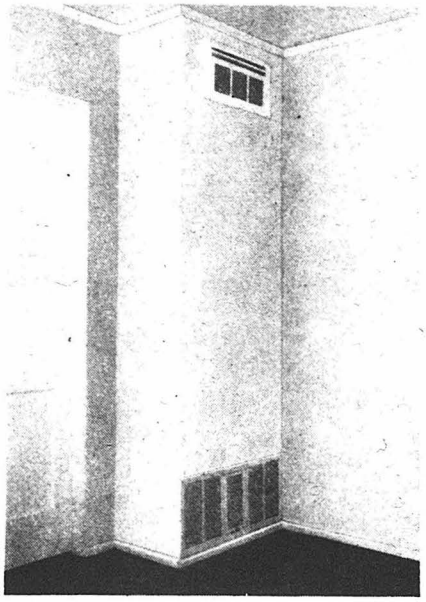
THE ROYAL JET FLOW OF LARGEST CAPACITY, 55 000 BTU PER HOUR, OCCUPIES AN INSIDE FLOOR SPACE OF 11 INCHES X 32 INCHES AND IS 8 FEET HIGH. THE FRAMING ARRANGEMENT IS SHOWN IN FIGURE 5. COLD AIR IS TAKEN IN AT THE LOWER REGISTER TO SUPPLY COMBUSTION AND CIRCULATING AIR. THE BURNER IS MOUNTED ABOUT 10 INCHES ABOVE THE FLOOR IN THE LOWER END OF THE CORRUGATED STEEL FIREBOX. COMBUSTION PRODUCTS ARE CONVEYED TO THE CENTRALLY LOCATED VENT, PASSED THROUGH THE DRAFT RELIEF HOOD AND EXHAUSTED TO THE OUTSIDE AIR. AN OUTER CASING AND A RADIATION SHIELD SURROUND THE FIREBOX AND



The burner and fire-box are in position and connected to gas lines. Prefabricated parts including registers are ready for quick assembly.

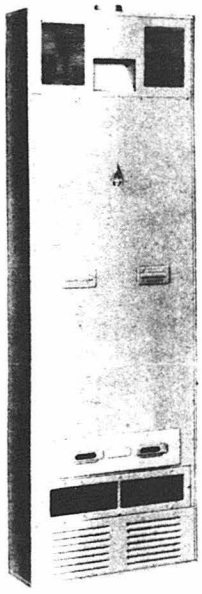


The outer-casing and radiation shield are lifted into place. The riser, register head, vent pipe and condensation box are placed in position.

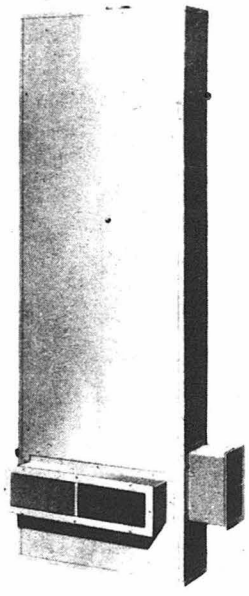


The pre-cut covering that conceals heating unit is assembled by carpenter. Cold air intake is at bottom and hot air register 6" below ceiling.

ROYAL JET FLOW



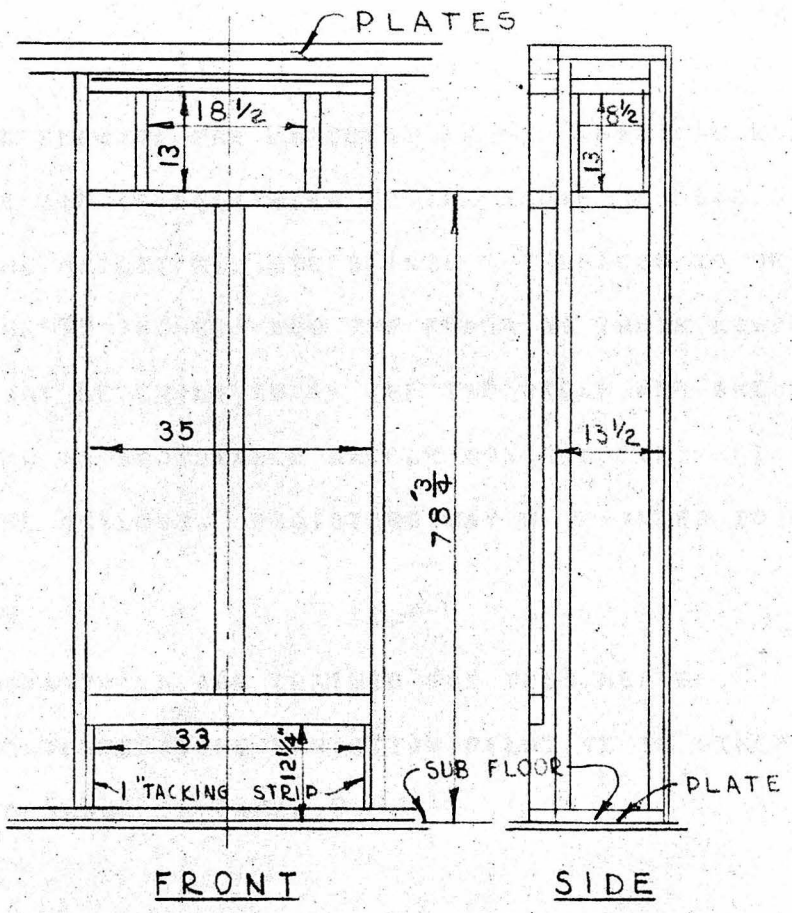
Front View

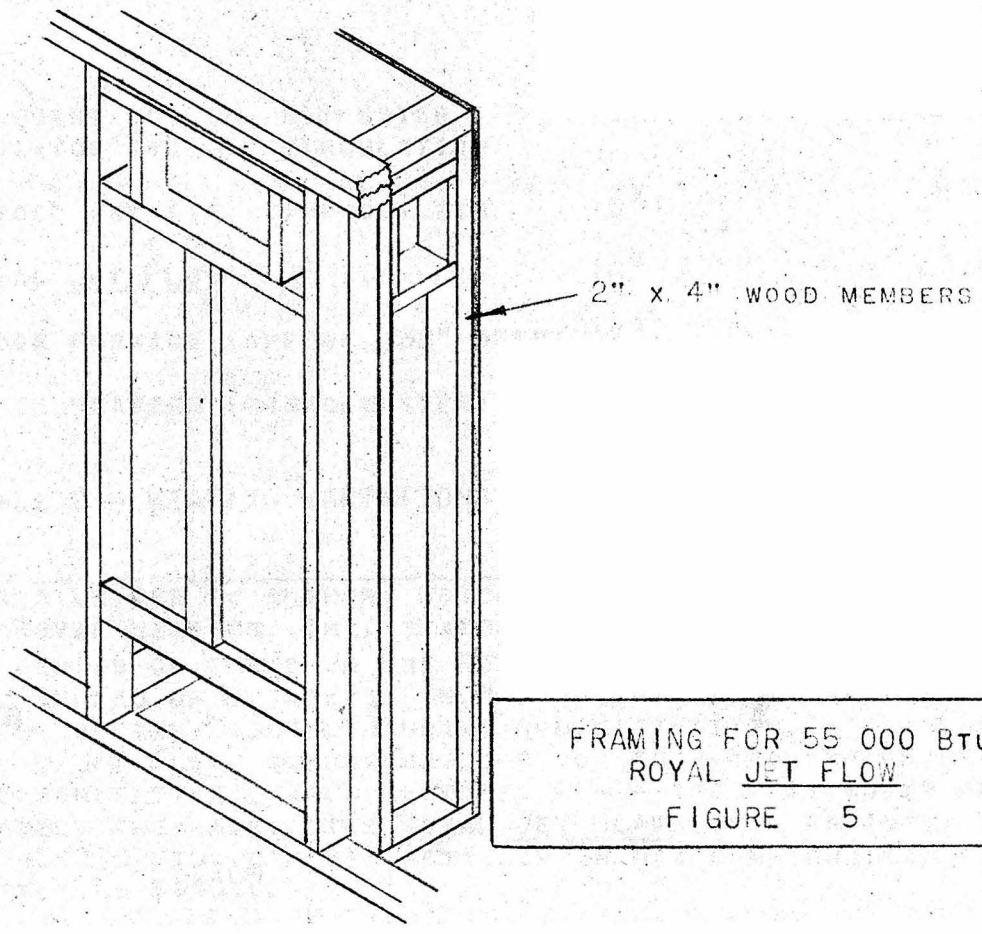


Rear View With Ducts Attached

PAYNE PANELAIR

FIGURE 4





FRAMING FOR 55 000 BTU
ROYAL JET FLOW
FIGURE 5

DIRECT THE FLOW OF THE CIRCULATING AIR INTO THE RISER DUCT. THE HEATED AIR IS DELIVERED TO THE REGISTER HEAD AND FLOWS THROUGH THE OUTLET REGISTERS INTO THE SPACES TO BE HEATED. OUTLETS ARE 79 INCHES FROM THE FLOOR AT THEIR LOWER EDGE AND THEY MAY BE EMPLOYED ON THE TWO SIDES AND ONE END OF THE HEATER. AN ADJUSTABLE BAFFLE CONTROLS THE HOT AIR FLOW TO THE SIDE OUTLETS. REGISTERS MAY BE PAINTED TO MATCH THE WALL.

SEVERAL ADVANTAGES ARE CLAIMED FOR THIS HEATER.* THE FLOOR TO CEILING TEMPERATURE VARIATION RELATIVE TO OTHER HEATING METHODS IS SHOWN IN TABLE 2.

HEATING METHOD	TEMPERATURE VARIATION ± 2" TO 60"	ROOM TO ROOM VARIATION
BASEMENT BOILER- HOT WATER RADIATOR GRAVITY CIRCULATION	5^0	3^0
FORCED HOT AIR, HIGH OUTLETS	9^0	4^0
ROYAL JET FLOW	10^0	4^0
FLOOR FURNACE (APPROX. 38" DEEP)	17^0	4^0
SPACE HEATERS (CONSOLE TYPE)	23^0	17^0

TABLE 2 - HEATING VARIATIONS WITH VARIOUS HEATERS - ° F

*IN A LETTER TO AUTHOR, OCTOBER 22, 1947, MR. R.T. LOWRIE OF ROYAL HEATERS, INC. STATES IN PART:---
"A SERIES OF TESTS ON THE ROYAL JET FLOW WAS CONDUCTED AT THE BUREAU OF STANDARDS IN WASHINGTON, D.C., AT THE REQUEST OF THE FEDERAL HOUSING ADMINISTRATION. - - - THE ROYAL JET FLOW OUTPERFORMED FLOOR FURNACES, SPACE HEATERS, AND CONVENTIONAL WALL HEATERS. - - - THE UNIT COSTS APPROXIMATELY THE SAME. THE ROYAL JET FLOW, WITH AN INPUT RATING OF 45 000 BTU, CAN BE INSTALLED IN NEW CONSTRUCTION FOR AS LITTLE AS $140.00."

THE VELOCITY OF CIRCULATION IS SAID TO APPROACH AN IDEAL VELOCITY OF 250 FEET PER MINUTE. HIGH OUTLET GRILLES KEEP DRAFTS ABOVE HEAD LEVEL. THE CIRCULATION PATH OF THE HEATED AIR IS SAID TO BE IDEAL. IT IS ALSO CLAIMED THAT THE HIGH, HOT AIRSTREAM CONVERTS THE CEILING INTO A RADIANT PANEL, BUT THE QUANTATIVE EFFECT OF THIS IS DIFFICULT TO EVALUATE AND PROBABLY NEGLIGIBLE.

THE DISADVANTAGES OF THIS HEATER RELATIVE TO OTHER VENTED WALL CIRCULATORS ARE SEVERAL. MORE SPACE IS OCCUPIED AND CONSIDERABLY MORE MATERIAL IS REQUIRED IN THE MANUFACTURE. THE FRAMING IS RELATIVELY COMPLEX AND CONSIDERABLY MORE FINISH WORK MUST BE DONE TO FIT THE SPECIALLY CUT EXTERIOR PANELS. THE UNIT MAY BE THERMALLY LESS EFFICIENT BECAUSE OF THE RELATIVELY LONGER PATH OF THE CONVECTION AIR AND CONSEQUENT HIGHER LOSSES. THE HIGH OUTLET GRILLES RESULT IN A LONGER TIME REQUIREMENT TO BRING A COLD ROOM TO COMFORT TEMPERATURE. IT COSTS MORE THAN MOST OF THE LISTED HEATERS OF EQUIVALENT CAPACITY.

THE PAYNE PANELAIR OF 55 000 BTU PER HOUR INPUT CAPACITY IS DESIGNED PRIMARILY FOR RECESSING INTO A FURRED WALL SECTION; IT MAY ALSO BE ENCLOSED IN A SMALL CLOSET OR UTILITY ROOM. IT OCCUPIES A FLOOR AREA OF 29 3/8 INCHES X 9 3/8 INCHES AND IS 84 INCHES HIGH; FINISHED IN HEAT RESISTING BAKED ENAMEL, IT MAY BE INSTALLED EXPOSED AGAINST A WALL OR IN A CORNER. ROOM AIR IS DRAWN IN AT ABOUT 76

INCHES HEIGHT AND DISCHARGED THROUGH OUTLET GRILLES ABOUT 12 INCHES ABOVE THE FLOOR, FROM ONE OR ALL THREE SIDES AS WELL AS DIRECTLY FROM THE FRONT.

TWO 1/80 HORSEPOWER SHADED POLE TYPE ELECTRIC MOTORS ARE MOUNTED ON VIBRATION INSULATORS BEHIND THE AIR GRILLES IN THE FAN COMPARTMENT AT THE TOP OF THE CASING, AND ARE DIRECTLY CONNECTED TO FIVE-BLADED PROPELLOR FANS WHICH FORCE THE AIR DOWNWARD OVER THE HEATING ELEMENT. BUILT IN DUAL THERMOSTATIC CONTROLS PROVIDE TWO SPEED FAN OPERATION. THE DIRECTION OF AIR CIRCULATION IS SEEN TO BE THE REVERSE OF THAT OF THE ROYAL JET FLOW. CENTER SECTION OF CASING ENCLOSES A RIBBED MONOSECTION HEATING ELEMENT WITH INTEGRAL RADIATOR. UPPER END FLOATS FREE BY MEANS OF SLOTTED SUPPORTS, ALL VERTICAL EXPANSION BEING ABSORBED BY FLEXIBLE WOVEN ASBESTOS JOINT AT FLUE GAS OUTLET, AFFORDING FREEDOM FROM EXPANSION NOISES. BURNERS ARE OF CAST IRON WITH SLOTTED PORTS. OPERATION IS SAID TO BE REMARKABLY STABLE AND QUIET WITH ALL GASES. THE GAS CONTROL ASSEMBLY WHICH IS ENCLOSED IN THE LOWER SECTION OF THE CASING CAN BE EASILY REMOVED. IT COMPRISES MAIN AND PILOT COCKS, LOW PRESSURE REGULATOR, ELECTRIC CONTROL VALVE WITH SAFETY PILOT, AND MANIFOLD WITH ORIFICES. A ROOM THERMOSTAT AND BUILT IN LIMIT CONTROL ARE PROVIDED. ALL WIRING AND CONTROLS ARE FACTORY ASSEMBLED.

THE OPERATION IS ENTIRELY AUTOMATIC. ROOM THERMOSTAT

CAUSES BURNERS TO TURN ON. AS AIR BECOMES WARMED, DUAL FAN CONTROL FIRST STARTS FANS AT LOW SPEED, PROVIDING DELIVERY OF WARMED AIR. IF DESIRED ROOM TEMPERATURE IS NOT OBTAINED WITHIN EIGHT MINUTES, FAN CONTROL SWITCHES FANS TO FULL SPEED. AS ROOM TEMPERATURE IS REACHED, BURNERS ARE TURNED OFF. FANS SUBSEQUENTLY SWITCH TO LOW SPEED; AND FINALLY OFF WHEN NO FURTHER HEAT IS NEEDED. IN AVERAGE WEATHER, FANS OPERATE ALMOST CONTINUOUSLY AT LOW SPEED. PANELAIR IS APPROVED FOR INSTALLATION IN DIRECT CONTACT WITH WOOD OR OTHER COMBUSTIBLE MATERIAL. APPLICATION IS LIMITED TO DIRECT DISCHARGE OF AIR FROM CASING GRILLES OR THROUGH-THE-WALL DUCTS HAVING A MAXIMUM LENGTH OF 8 INCHES.

THE ADVANTAGES ARE CLAIMED TO BE: LOW CASING AND DUCT LOSSES, WARM FLOOR AREAS, EXCEPTIONALLY HIGH HEATING EFFICIENCY FOR WALL HEATERS, AND RESULTING OPERATING ECONOMY. THE DISADVANTAGES ARE: SPECIAL FRAMING NECESSARY FOR INSTALLATION, ELECTRIC WIRING NECESSARY (115 VOLT, 60 CYCLE CURRENT), AND VERY HIGH COST, - ABOUT $225, WHICH MAKES IT THE MOST EXPENSIVE OF ALL THE HEATERS SURVEYED.

APPROACH

MARKET ANALYSIS BEGAN WITH A SURVEY OF PRESENT RESIDENCES TO DETERMINE HEATING NEEDS, AND AN INVESTIGATION OF NUMBERS AND NATURES OF RESIDENCES TO BE CONSTRUCTED. SALES RECORDS AND PREDICTED SALES FOR GAS HEATERS WERE PERUSED AND CLASSIFIED INTO NUMBERS AND TYPES. THE METHODS OF DISTRIBUTION OF GAS APPLIANCES WERE EXAMINED, AND THE POSSIBLE FUTURE OF THE GAS-FUEL INDUSTRY WAS CONSIDERED.

RESIDENTIAL PLAN STUDY

IN ORDER TO ESTABLISH THE TYPE OF HEATING EQUIPMENT SUITED TO PRESENT DAY RESIDENCES, APPROXIMATELY 120 HOUSE FLOOR PLANS WERE EXAMINED. (5) (6) (7) (8) THE RANGE OF FLOOR AREAS WAS FROM 750 TO 1500 SQUARE FEET, AS THIS IS THE RANGE IN WHICH THE GREAT BULK OF CONTEMPORARY HOMES ARE BEING BUILT. SINCE A SINGLE, CENTRALLY LOCATED HEATER IS CONTEMPLATED, THE ACTUAL LOCATION OF SUCH A UNIT WAS INDICATED ON EACH FLOOR PLAN, WHEN POSSIBLE. THE FOLLOWING OBSERVATIONS WERE MADE:

- THE LIVING-DINING AREAS OF THE MAJORITY OF THE PLANS WERE NOT SEPARATE AND COULD BE ADEQUATELY HEATED FROM ONE OUTLET LOCATION.
- MOST OF THE PLANS CONTAINED A HALLWAY CONNECTING THE LIVING AREA WITH THE BEDROOMS AND THE LATTER COULD BE HEATED THROUGH THEIR DOOR OPENINGS BY HEAT INTRODUCED INTO THE HALL.
- IT WAS FREQUENTLY POSSIBLE TO ARRANGE THE HEATER SO

THAT A DIRECT OUTLET INTO THE KITCHEN OR ONE OF THE BEDROOMS WAS POSSIBLE IN ADDITION TO THOSE DESCRIBED ABOVE.

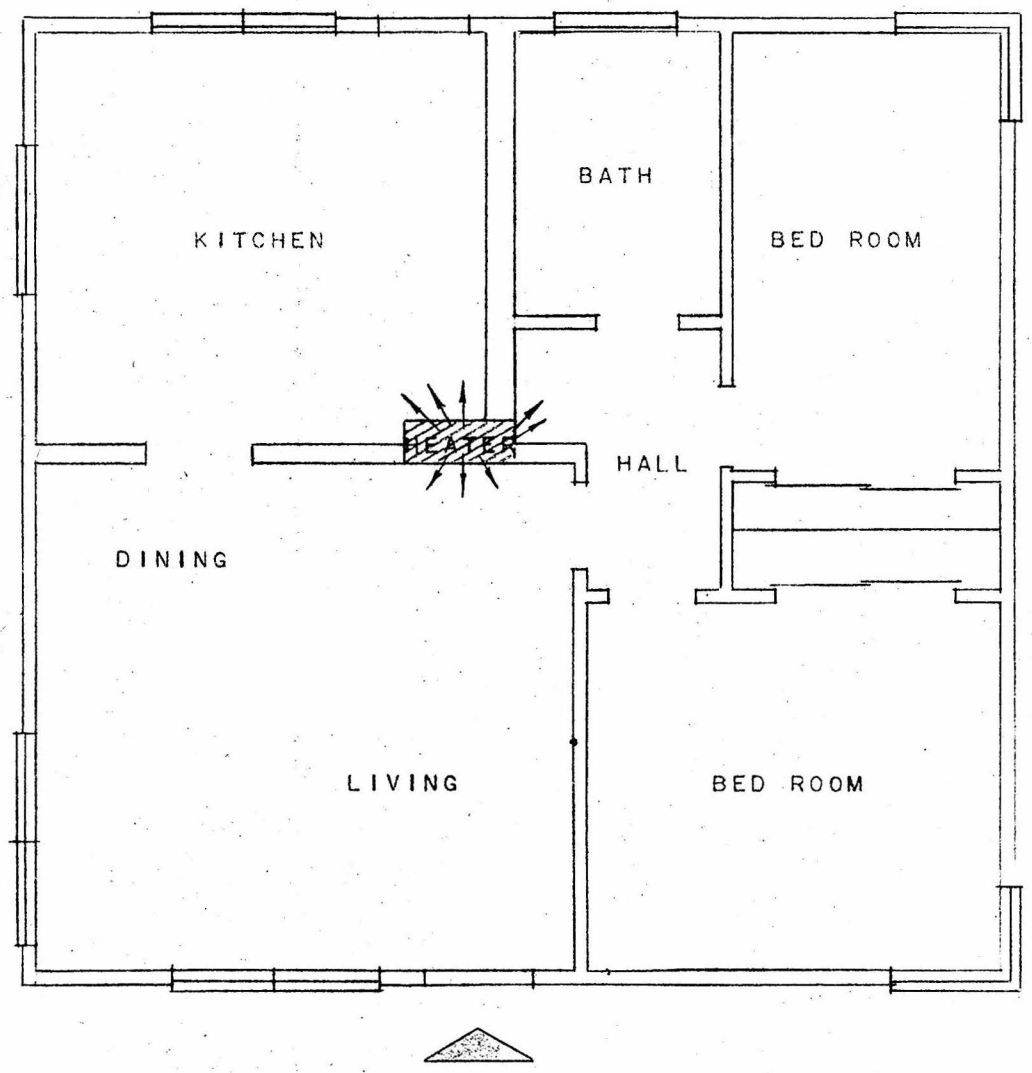
A TYPICAL FLOOR PLAN OF A TWO BEDROOM, 1000 SQUARE FOOT RESIDENCE IS SHOWN IN FIGURE 6, WITH INDICATION OF THE POSSIBILITY OF INSTALLING A CENTRAL HEATER.

THE VALIDITY OF THE ABOVE OBSERVATIONS IS SUBSTANIATIED BY NOTING THE HEATING PROVISIONS, WHEN POSSIBLE, WHICH HAVE BEEN INDICATED IN THE PLANS EXAMINED:

- THE GREAT MAJORITY OF THE SMALL HOMES REVIEWED HAVE SOME TYPE OF CENTRALLY LOCATED HEATING UNIT.
- WHEN DESIGNED FOR A RELATIVELY MILD CLIMATE, SUCH AS THE FAR WEST AND SOUTHWEST OF THE UNITED STATES, A GRAVITY TYPE CIRCULATING HEATER IS LIKELY TO BE USED.
- WHEN DESIGNED FOR RELATIVELY COLD CLIMATES, SUCH AS THE MIDDLE WEST AND EAST SECTIONS OF THE UNITED STATES, A FORCED CIRCULATION OF THE HEATING MEDIUM IS LIKELY TO BE EMPLOYED.

HENCE, IT IS ASSUMED:

- THE AVERAGE SMALL RESIDENCE CAN BE HEATED BY A SINGLE CENTRAL UNIT. SUCH A HEATER MUST BE ARRANGED TO HEAT SEVERAL ROOMS. IN THE FAR WESTERN AND SOUTHWESTERN UNITED STATES, A UNIT EMPLOYING GRAVITY CIRCULATION MAY BE USED.



PLAN OF TYPICAL SMALL RESIDENCE OF APPROXIMATELY 1000 SQUARE FEET AREA

PROPOSED HEATER INSTALLATION

FIGURE 6

RESIDENTIAL CONSTRUCTION SURVEY

IT IS CONTEMPLATED THAT THE HEATER TO BE DEVELOPED IS CHIEFLY FOR NEW CONSTRUCTION; IT WOULD BE SPECIFIED IN THE HOUSE PLANS AND BUILT IN AT ERECTION. THE DIFFICULTIES OF INSTALLING A SINGLE, CENTRAL, IN-THE-WALL UNIT IN REMODELING ARE IMMEDIATELY APPARENT. IN PASSING, IT SHOULD BE MENTIONED THAT MOST HEATER MANUFACTURERS MAKE A "LINE" OF SEVERAL TYPES, AND THAT THE FREE STANDING CONSOLES OR THE SMALL SINGLE WALL UNITS ARE LIKELY TO BE MOST SATISFACTORY FOR SALES FOR REMODELING.

MANUFACTURERS OF APPROVED HEATING EQUIPMENT ARE FOUND IN THIRTY STATES OF THE UNITED STATES AND ARE WIDELY SCATTERED GEOGRAPHICALLY. (4) SINCE, AS SHOWN ON PAGE 5, 12 OF THE 15 MANUFACTURERS ARE FOUND IN SOUTHERN CALIFORNIA, IT MAY BE ASSUMED THAT THIS TYPE OF HEATER FINDS ITS CHIEF MARKET IN THE PACIFIC STATES AND THE SOUTHWEST. THE NUMBER OF NEW, PRIVATELY FINANCED (NON-GOVERNMENT) FAMILY DWELLING UNITS STARTED IN THE NON-FARM AREAS OF THE STATES IN WHICH THE HEATER UNDER DEVELOPMENT CAN BE SOLD IS SHOWN IN TABLE 3. IT WILL BE NOTED THAT THE TOTAL NEW RESIDENTIAL UNITS FOR THE YEARS 1945, 1946, AND 1947 REPRESENTS A SUBSTANTIAL PROPORTION OF THE NATIONAL TOTAL - BETWEEN 30% AND 40%. WHILE RELIABLE PREDICTIONS OF THE FUTURE ARE NOT AVAILABLE AT THIS WRITING, OPINIONS OF THOSE IN CONSTRUCTION ACTIVITY INDICATE THAT THE SITUATION SHOWN WILL PROBABLY CONTINUE FOR SOME YEARS TO COME. THE NATIONAL

STATE	1947	%	1946	%	1945	%
TOTALS	277 000	31.4	229 900	33.0	86 700	38.2
ARIZONA	4 100	.5	2 100	.3	1 600	.7
CALIFORNIA	145 000	16.5	127 500	18.3	47 700	21.0
NEW MEXICO	4 400	.5	2 800	.4	1 000	.4
OREGON	14 300	1.6	11 200	1.6	4 300	1.9
TEXAS	87 400	9.9	70 400	10.1	25 600	11.3
WASHINGTON	21 400	2.4	15 900	2.3	6 500	2.9

TABLE 3 - NEW RESIDENTIAL UNITS CONSTRUCTED - % OF NATIONAL TOTAL RESIDENTIAL VOLUME (9)

TOTAL DOLLAR VOLUME OF RESIDENTIAL CONSTRUCTION ACTIVITIES FOR 1948 IS ESTIMATED AS $11 475 000 000, AN INCREASE OF $1 570 000 000 OVER THE 1947 TOTAL. (10)

THE AVERAGE COST OF NEW FAMILY DWELLING UNITS STARTED IN SAN FRANCISCO, CALIFORNIA DURING THE LAST QUARTER OF 1947 WAS $8 400. (9) AT AN ASSUMED AVERAGE COST OF $10 PER SQUARE FOOT FOR CONSTRUCTION, THE AVERAGE UNIT WOULD BE ABOUT 850 SQUARE FEET. LIMITS OF PLUS OR MINUS 250 SQUARE FEET ON THE ABOVE PROBABLY INCLUDE THE GREAT MAJORITY OF PRESENT RESIDENCE CONSTRUCTION.

GAS HEATER SALES SURVEY

IT HAS BEEN ESTIMATED THAT THERE WERE 2 300 000 GAS FIRED CENTRAL HEATERS IN USE IN THE UNITED STATED ON DECEMBER 31, 1947, AN INCREASE OF 13.4 % OVER 1946. (11) THE ESTIMATED

SALES FOR 1946 AND 1947 ARE SHOWN IN TABLE 4.

TYPE	1947	1946	% CHANGE
WALL HEATERS	155 000	58 000	+ 167
FLOOR FURNACES	295 000	242 000	+ 17.8
WARM AIR FURNACES	168 000	230 000	- 27.0
CONVERSION BURNERS	90 000	400 000	- 77.5
BOILERS	44 000	32 500	+ 35.4

TABLE 4 - SALES OF GAS FIRED HEATERS - 1946 AND 1947 (11) (12)

THE DROP IN SALES OF WARM AIR FURNACES AND CONVERSION BURNERS WAS OWING TO GOVERNMENT RESTRICTION ON THEIR USE IN SOME AREAS DURING 1947. THE LARGE INCREASE IN WALL HEATERS INDICATES THE GROWING IMPORTANCE OF THIS TYPE OF HEATING. NOT ALL OF THE WALL HEATERS IN TABLE 4 WERE OF THE CENTRALLY LOCATED TYPE; SEVERAL WERE USED IN SOME DWELLING UNITS. THE VERY SMALL CIRCULATORS OR RADIANT HEATERS OF ANY SIZE ARE NOT INCLUDED IN THE FIGURES, HOWEVER.

MEMBERS OF THE INDUSTRY WHO HAVE BEEN INTERVIEWED FEEL THAT THE SALES VOLUME OF SPACE HEATERS FOR 1948 WILL BE ABOUT THE SAME AS FOR 1947, BARRING EMERGENCIES. THE INCREASING USE OF GAS IS ILLUSTRATED BY THE FOLLOWING QUOTATION:

"--- IN THE NEW HOME FIELD, A STRONG PREFERENCE FOR GAS HEATING IS APPARENT. THE NATIONAL HOUSING AGENCY, FOR EXAMPLE, REPORTED RECENTLY THAT OF 620 000 DWELLING UNITS

PLANNED UNDER THE VETERANS EMERGENCY HOUSING PROGRAM UP TO JULY 26, 1946, GAS HEATING SYSTEMS WERE PROVIDED IN 52%, WITH COAL AND OIL AMOUNTING TO 27% AND 21% RESPECTIVELY." (13)

HEATER DISTRIBUTION CHANNELS

THERE ARE THREE MAJOR CHANNELS OF DISTRIBUTION FROM THE MANUFACTURER OF HEATERS TO THE ULTIMATE PURCHASER:

- MANUFACTURER TO PLUMBING AND HEATING CONTRACTORS WHO SELL THE HEATER AND MAKE INSTALLATION.
- MANUFACTURER TO WHOLESALER WHO SELLS TO CONTRACTORS AND RETAIL OUTLETS.
- MANUFACTURER SELLS TO ULTIMATE PURCHASER AND MAKES INSTALLATION THROUGH FACTORY OWNED SALES OUTLETS.

ALL OF THE ABOVE METHODS ARE EMPLOYED BY ONE OR ANOTHER OF THE MANUFACTURERS LISTED IN TABLE I, PRODUCT SURVEY.

- FOR THE PURPOSES OF THIS STUDY IT WILL BE ASSUMED THAT THE MANUFACTURER SELLS DIRECT TO THE PLUMBING AND HEATING CONTRACTOR, WHO SELLS HEATER AT PROFIT AND MAKES THE INSTALLATION.

GAS SERVICE TRENDS

A BRIEF CONSIDERATION OF THE TRENDS OF GAS SERVICE IN THE UNITED STATES HAS BEEN INCLUDED TO ASSIST IN EVALUATION OF FUTURE HEATING APPLIANCE NEEDS. (43)

FOR 1947, THERE WERE 21 500 000 CUSTOMERS OF GAS UTILITY COMPANIES; 10 268 000 WERE RECEIVING NATURAL GAS, 8 776 000 MANUFACTURED, AND 2 370 000 MIXED. A TOTAL OF 3 100 BILLION CUBIC FEET OF GASES WERE SUPPLIED. VOLUME OF NATURAL

GAS MOVING IN INTERSTATE COMMERCE WILL BE INCREASED APPROXIMATELY 1 310 BILLION CUBIC FEET IF ALL PROPOSED NEW PIPE LINE PROJECTS ARE AUTHORIZED AND CONSTRUCTED, IT IS ESTIMATED BY THE FEDERAL POWER COMMISSION. ANNUAL VOLUME OF INTERSTATE MOVEMENTS OF NATURAL GAS, WHICH AMOUNTED TO 1106 CUBIC FEET IN 1945, MIGHT INCREASE TO WELL OVER 2 000 BILLION CUBIC FEET WITHIN THE NEXT SEVERAL YEARS. PROJECTED PIPE LINES FROM TEXAS TO DETROIT, TEXAS TO NEW YORK, AND TENNESSEE TO BOSTON WILL INCREASE THE SERVICE IN THOSE COMMUNITIES. GENERALLY, THE GAS INDUSTRY IS IN A PERIOD OF EXPANSION.

SUMMARY

THE SIGNIFICANT POINTS OF THIS ANALYSIS FOLLOW:

- THE AVERAGE SMALL RESIDENCE CAN BE HEATED BY A SINGLE, CENTRAL UNIT WITH OUTLETS TO SEVERAL ROOMS.
- A LARGE PART OF THE RESIDENCES BEING CONSTRUCTED ARE IN AREAS WHERE THE HEATER BEING DEVELOPED CAN BE EMPLOYED.
- SALES OF WALL GAS HEATERS ARE INCREASING AND THE GAS INDUSTRY, IN GENERAL, IS EXPANDING.

TECHNICAL INVESTIGATIONS

APPROACH

LITERATURE ON THE GENERAL SUBJECT OF GAS HEATING WAS EXAMINED. MATERIAL PERTAINING TO MANY TYPES OTHER THAN SPACE HEATERS WAS INCLUDED IN ORDER TO INVESTIGATE THE POSSIBILITIES OF APPLYING SOME OF THE DESIGN PRINCIPLES OF THE FORMER. A NEWLY DEVELOPED GRID GAS BURNER WAS EXAMINED FOR POSSIBLE APPLICATION.

GENERAL INVESTIGATION

TWO TREATISES, FUELS AND FUEL BURNERS AND FUELS, COMBUSTION AND FURNACES (14)(15) PROVIDED A WEALTH OF GENERAL MATERIAL. AN EXCELLENT WORK, PANEL HEATING AND COOLING ANALYSIS (16), WHILE PRIMARILY CONCERNED WITH RADIANT HEATING METHODS, GAVE USEFUL INFORMATION ON THE FUNDAMENTAL NATURE OF HEATING PROCESSES.

THE PRACTICE OF THE BRITISH WAS STUDIED (17) (18) (19) (20) (21) AS IT WAS FELT THAT THEIR LIMITED FUEL SUPPLIES MIGHT RESULT IN VERY EFFICIENT USAGE. WHILE THIS WAS GENERALLY TRUE, IT WAS ALSO NOTED THAT MOST OF THE HEATERS ARE OF THE CERAMIC RADIANT TYPE, UNVENTED. HENCE, INCREASED EFFICIENCY IS ACHIEVED AT THE COST OF CONVENIENCE AND SAFETY.

THE GENERAL FIELD OF CURRENT HEATING RESEARCH WAS COVERED (22); MOST OF THE DEVELOPMENTS MENTIONED WHICH APPLY TO SPACE HEATING HAVE BEEN DISCUSSED IN THE PRODUCT SURVEY SECTION. ALSO, A REPORT ON VENTING RESEARCH (23) INDICATED THAT THE DEVELOPMENT OF SATISFACTORY APPLIANCE VENTS IS

LARGELY BY CUT AND TRY LABORATORY METHODS ALTHOUGH CERTAIN CONFIGURATIONS ARE USUALLY SATISFACTORY.

GRID GAS BURNER STUDY

A NEWLY DEVELOPED GAS BURNER WHICH EMPLOYS A STAMPED GRID TYPE PORT OF RECTANGULAR CROSS-SECTION AND OPERATES WITH UNUSUALLY HIGH PRIMARY AIR INJECTION WAS INVESTIGATED (SEE FIGURE 7). THIS BURNER FORMS THE SUBJECT OF UNITED STATES PATENT APPLICATION SERIAL 742 244 (24) AND IS USED BY PERMISSION OF MR. A.J. LAMPERT, INVENTOR. THIS BURNER PRINCIPLE HAS BEEN APPLIED TO ROUND BURNERS OF THE WATER HEATER TYPE: THE INVESTIGATION WAS MADE TO DETERMINE THE POSSIBILITIES OF APPLYING IT TO A LONG, NARROW SPACE HEATER BURNER.

LABORATORY TESTS HAVE SHOWN THAT THIS BURNER OPERATES WITH GOOD FLAME CHARACTERISTICS ON UNUSUALLY HIGH PRIMARY AIR INJECTION.* THIS ALLOWS CLOSER SPACING OF THE PORTS AND RESULTS IN A RELATIVELY SMALL BURNER. THE PORTS ARE FORMED BY A STAMPED SHEET METAL GRID WHICH PERMITS READY ADJUSTMENT OF PORT SIZE BY CHANGING THE GAGE OF THE GRID MEMBER. BECAUSE OF THIS FEATURE, A SINGLE SET OF PATTERNS MAY BE USED TO PRODUCE A BURNER WHICH WILL HANDLE A WIDE VARIETY OF GASES WITH MINIMUM MACHINING OF THE CASTINGS. THROUGHOUT THE BURNER, THE CROSS SECTIONAL AREA IS SUBSTANTIALLY CONSTANT, AND HIGH DISCHARGE VELOCITIES WHICH MIGHT CAUSE FLAME LIFTING AT THE PORTS ARE AVOIDED.

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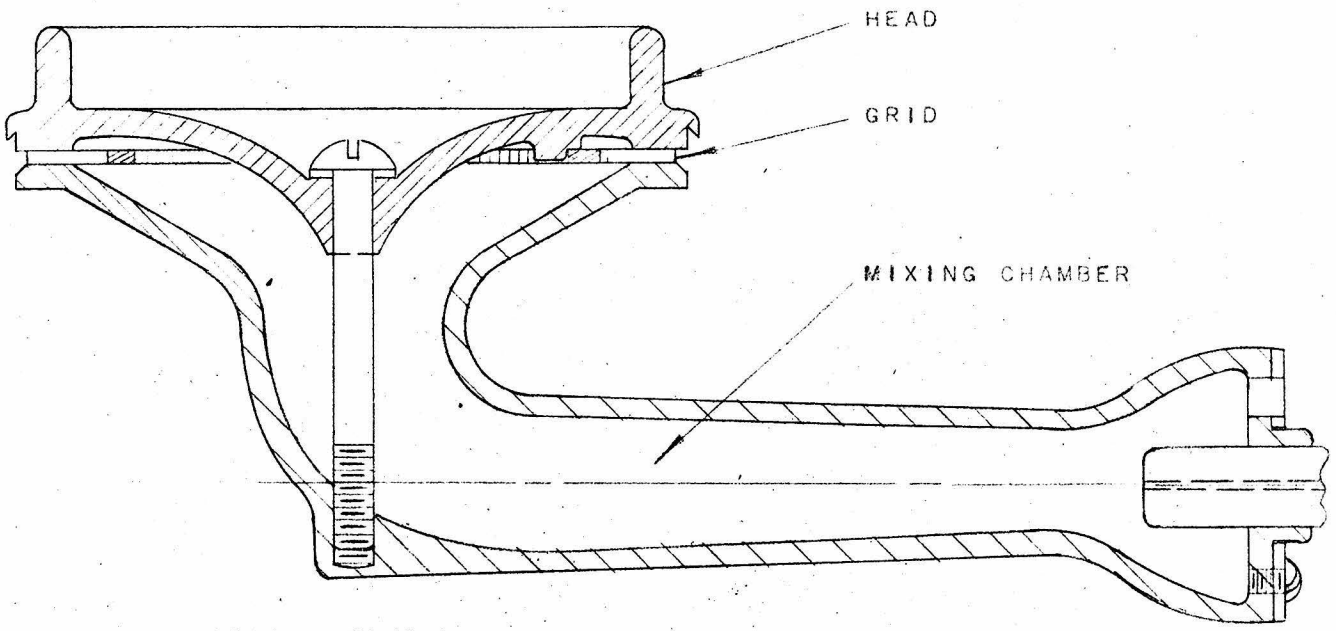
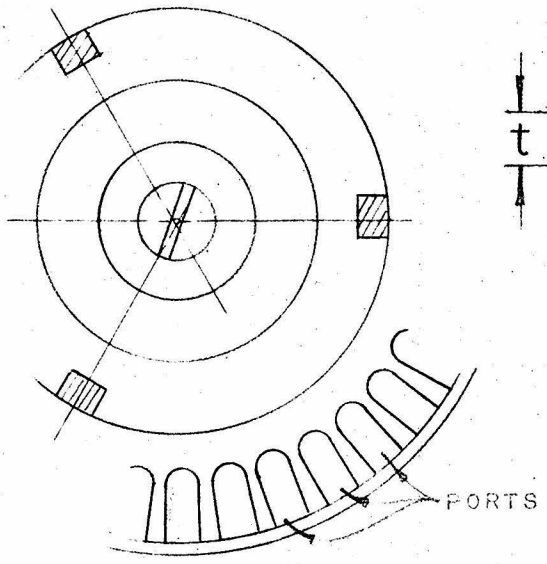
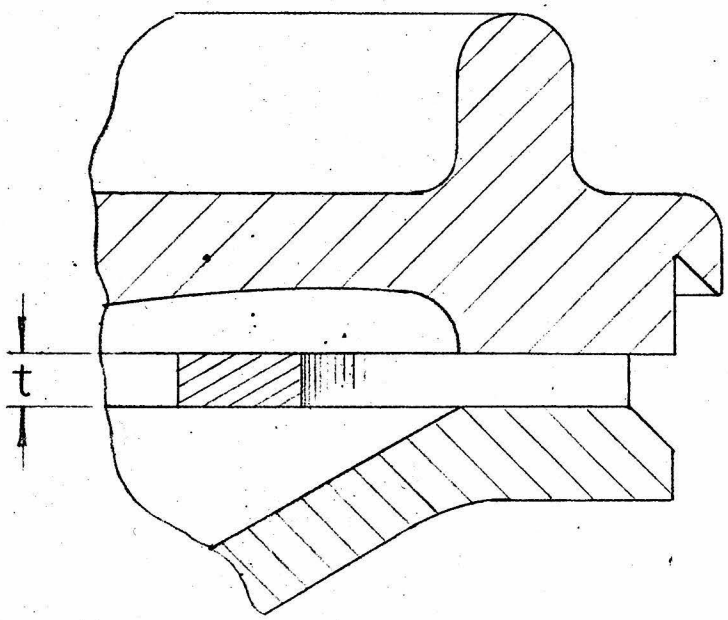
*PRIMARY AIR IS DEFINED AS: "THE AIR INTRODUCED INTO A BURNER AND WHICH MIXES WITH THE GAS BEFORE IT REACHES THE PORT OR PORTS" (1)



CROSS SECTION



PLAN



GRID GAS BURNER
FIGURE 7

THE BROADEST CLAIM OF THE PATENT APPLICATION FOLLOWS:

(SEE FIGURE 7)

"A GAS BURNER COMPRISING A BASE MEMBER HAVING AN AIR INLET, A MIXING CHAMBER, A FLARED SECTION CONNECTED TO SAID MIXING CHAMBER, AND AN ANNULAR FLANGE EXTENDING RADIALLY FROM THE LARGER PERIPHERY OF SAID FLARED SECTION, A CAP HAVING A CENTER SECTION CONCAVED IN THE DIRECTION OF THE FLARED SECTION OVERLYING IN SPACED RELATION SAID FLARED SECTION AND AN ANNULAR FLANGE ABOUT THE PERIPHERY OF SAID CONCAVED CENTER SECTION AND COMPLEMENTARY TO SAID FLARED SECTION ANNULAR FLANGE, A SPACING AND PORT FORMING GRID REMOVABLY DISPOSED BETWEEN SAID TWO COMPLEMENTARY FLANGES, THE CAP AND FLARED SECTIONS BEING ADAPTED TO DEFINE A GAS PASSAGE HAVING A SUBSTANTIALLY UNIFORM CROSS SECTIONAL AREA AS IT PROGRESSES OUTWARDLY" (24).

DESIGN CONSIDERATIONS

APPROACH

THE HUMAN FACTORS INVOLVED IN THERMAL ENVIRONMENT CONTROL WERE CONSIDERED. BASED ON THESE, THE POSSIBLE DESIGNS FOR THE CONTEMPLATED HEATER WERE DEVELOPED. EVALUATION OF THESE PRODUCED AN IDEAL GENERAL ARRANGEMENT. THE REQUIREMENTS OF THE AMERICAN GAS ASSOCIATION WHICH MUST BE MET FOR APPROVAL WERE EXAMINED.

PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS

"ALL THE SYSTEMS AND PROCEDURES FOR CONTROLLING BODY HEAT-LOSS WHICH ARE IN USE TODAY CAN READILY BE CLASSIFIED UNDER ONE OR MORE OF THREE FUNDAMENTAL CONCEPTS: (1) VARYING THE THERMAL RESISTANCE; (2) VARYING THE QUANTITY OF ENERGY SUPPLIED FROM OR DISSIPATED TO AN AUXILIARY SOURCE OR SINK; (3) VARYING THE TEMPERATURE OF THE AMBIENT AIR." (25) THE FIRST METHOD IS ENTIRELY SUBJECTIVE AND IS CHIEFLY CONCERNED WITH THE TYPE OF CLOTHING WORN; IT IS OF LITTLE SIGNIFICANCE HERE. THE IMPORTANCE OF THE OTHER TWO WILL BE EVALUATED.

COMFORT AIR CONDITIONING IS DEFINED AS:

> "THE PROCESS BY WHICH SIMULTANEOUSLY THE TEMPERATURE, MOISTURE CONTENT, MOVEMENT AND QUALITY OF THE AIR IN INCLOSED SPACES INTENDED FOR HUMAN OCCUPANCY MAY BE MAINTAINED WITHIN REQUIRED LIMITS." (26)

THE "REQUIRED LIMITS" ARE A FAIRLY BROAD RANGE OF CONDITIONS. EXPERIMENT SHOWS THAT COMFORT MAY BE REALIZED IN A ROOM WITH THE AIR AND STRUCTURAL SURFACES AT A UNIFORM TEMPERATURE, 70°F.

ALSO, IT MAY BE ATTAINED WITH AN AIR TEMPERATURE OF 60°F PROVIDED THAT THE SURFACE TEMPERATURES ARE ABOUT 80°F, OR WITH AN AIR TEMPERATURE OF 80°F IF THE SURFACE TEMPERATURES ARE 60°F. IN ALL CASES THE HUMIDITY, AIR MOVEMENT, AND QUALITY ARE THE SAME. (27)

THE ABOVE MAY BE CLARIFIED BY A CONSIDERATION OF THE FACTORS WHICH AFFECT THE THERMAL INTERCHANGE BETWEEN THE HUMAN BODY AND ITS ENVIRONMENT. THE HUMAN BODY PRODUCES ENERGY BY TISSUE OXIDATION WHICH MUST BE STORED WITH AN ACCOMPANYING RISE IN BODY TEMPERATURE, MUST BE USED IN DOING WORK, OR MUST BE TRANSFERRED TO THE ENVIRONMENT. FOR COMFORT, THE HUMAN BODY AT REST MUST ELIMINATE HEAT AT A RATE CORRESPONDING TO THE BASIC METABOLISM RATE, USUALLY ABOUT 400 BTU PER HOUR.

ALL HOUSEHOLD HEATING SYSTEMS MAY BE CONSIDERED AS COMBINING THE SOURCE OR SINK CONCEPT WITH CONTROL OF THE AMBIENT AIR TEMPERATURE. THE DEGREE TO WHICH ONE OR THE OTHER IS EMPHASIZED DETERMINES THE TYPE OF HEATING SYSTEM. THE FORCED AIR CONVECTION METHOD RELIES ALMOST ENTIRELY ON AMBIENT AIR TEMPERATURE CONTROL, WITH SOURCE OR SINK EFFECT OBTAINED ONLY FROM THE INDUCED SURFACE TEMPERATURES OF THE ROOMS. THAT TYPE OF HEATING WHICH UTILIZES THE FLOORS, CEILINGS, OR WALLS AS HEAT SOURCES IS GENERALLY CALLED RADIANT PANEL HEATING. HERE, THE SOURCE OR SINK PRINCIPLE IS MAXIMIZED WITH MINIMUM EMPLOYMENT OF CONVECTION AIR EFFECTS.

AS HAS BEEN INDICATED (SEE PRODUCT SURVEY), THE VENTED WALL HEATERS UNDER CONSIDERATION ARE PRIMARILY CONVECTION HEATERS, EMPLOYING GRAVITY AIR CIRCULATION TO WARM THE AMBIENT AIR. GRAVITY AIR CIRCULATION IS THE TERM ARISING FROM THE CONVECTION CURRENT CREATED BY THE DIFFERENCE IN SPECIFIC WEIGHT OF THE HEATED AIR LEAVING THE TOP OF THE HEATER AND THE RETURNING COOLED AIR. THE PLEASURABLE EFFECTS OF RADIANT HEAT SOURCES ARE TOO WELL KNOWN TO REQUIRE ELABORATION; THE OPEN FIREPLACE IS MENTIONED AS AN EXAMPLE. ALSO, A PURELY CIRCULATING SYSTEM REQUIRES A RELATIVELY LONG TIME TO COME TO TEMPERATURE; RADIANT HEAT, BEING SENSIBLE, IS FELT MUCH MORE QUICKLY.

AN INHERENT DIFFICULTY WITH CONVECTION AIR SPACE HEATING SHOULD BE MENTIONED HERE. IF THE INITIAL AIR TEMPERATURE IS 40°F OR LESS, UPON HEATING TO THE ACCEPTED COMFORT TEMPERATURE OF 70°F, THE HUMIDITY DROPS TO AN UNCOMFORTABLY LOW LEVEL, EVEN THOUGH IT MAY HAVE BEEN VERY HIGH INITIALLY. MOST CENTRAL HEATING SYSTEMS PROVIDE SOME TYPE OF HUMIDITY CONTROL, BUT INVESTIGATION OF THESE DEVICES HAS FAILED TO DIVULGE METHODS BY WHICH SUCH CONTROL CAN BE APPLIED TO SPACE HEATING. THUS, A FUNDAMENTAL PROBLEM REMAINS UNSOLVED.

IDEAL SOLUTION

THE FOLLOWING ARE SET FORTH AS IDEAL DESIGN REQUIREMENTS FOR A VENTED, WALL MOUNTED, SPACE HEATER WHICH IS TO BE CENTRALLY LOCATED TO HEAT SEVERAL ROOMS.

- THE CIRCULATING AIR PATH SHOULD BE RELATIVELY LONG TO PREVENT LOCALIZED CIRCULATION AND TO REACH DISTANT

ROOM AREAS.

- PROVISION FOR A RADIANT HEATING PANEL ON AT LEAST ONE SIDE SHOULD BE MADE TO PROVIDE MAXIMUM FLEXIBILITY AND COMFORT.
- THE METHOD OF INSTALLATION SHOULD BE SIMPLE AND INEXPENSIVE AND ADAPTED TO MANY TYPES OF RESIDENTIAL CONSTRUCTION.
- THE UNIT SHOULD BE ECONOMICAL TO MANUFACTURE, SHOULD MEET THE REQUIREMENTS OF THE CHAIN OF DISTRIBUTION, AND SHOULD SELL AT A PRICE COMPETITIVE WITH COMPARABLE WALL CIRCULATORS.
- OPERATION MUST BE RELIABLE AND SAFE AND THE APPROVAL REQUIREMENTS OF THE AMERICAN GAS ASSOCIATION MUST BE MET.

POSSIBLE METHODS OF ACHIEVING IDEAL

THE ABOVE ITEMS WILL BE TAKEN UP SINGLY AND VARIOUS POSSIBLE SOLUTIONS WILL BE DISCUSSED.

THE LENGTH OF THE CIRCULATING AIR PATH CAN BE INCREASED IN TWO WAYS:

- THE HOT AIR OUTLET AND THE COLD AIR RETURN CAN BE SEPARATED AS FAR AS POSSIBLE.
- THE AIR CAN BE MECHANICALLY PUMPED BY A FAN OR BLOWER.

THE MOST PRACTICAL METHOD OF ACCOMPLISHING THE FIRST ARRANGEMENT IS TO PLACE THE OUTLETS IN SUBSTANTIALLY THE SAME VERTICAL PLANE; ONE AS NEAR THE CEILING AND THE OTHER AS NEAR THE FLOOR AS PRACTICAL. THE AMERICAN GAS ASSOCIATION HAS NOT ALLOWED DUCTING OUTSIDE THE CASING OF MORE THAN

8 INCHES LENGTH ON VENTED WALL CIRCULATORS.* THE POSSIBILITY OF REMOTE DUCTED COLD AIR RETURNS IS THEREFORE ELIMINATED. AN ELECTRICALLY OPERATED FAN COULD BE USED TO ACCOMPLISH THE SECOND METHOD, ABOVE. WITH THIS, THE AIR COULD BE TAKEN IN AT THE FLOOR AND EXHAUSTED AT THE CEILING OR VICE-VERSA, AS IS DONE IN THE PAYNE PANELAIR. ANYTHING LARGER THAN A SMALL FAN OF FRACTIONAL HORSEPOWER INPUT WOULD PLACE THE HEATER IN THE CENTRAL HEATING, FORCED AIR CATEGORY AND IT WOULD NO LONGER BE A SPACE HEATER.

SMALL FANS INTRODUCE THE FOLLOWING COMPLICATIONS:

- THE HEATER MUST BE WIRED ELECTRICALLY IN AN APPROVED MANNER.
- THE USE OF AUTOMATIC THERMOSTAT CONTROL IS NECESSARY FOR SATISFACTORY OPERATION.
- THESE ADDITIONS RESULT IN AN INCREASED PRICE WHICH MAKES SALES COMPETITION WITH OTHER SPACE HEATERS DIFFICULT.

THEREFORE, THE HEATER TO BE DESIGNED WILL HAVE THE COLD AIR INLET NEAR THE FLOOR AND THE HOT AIR OUTLET NEAR THE CEILING IN THE CLOSEST POSSIBLE RELATIONSHIP TO THE HEATER CORE.

THE RADIANT HEATING PROVISIONS FALL INTO TWO EXTREME CLASSIFICATIONS:

- A RELATIVELY SMALL, HIGH TEMPERATURE PANEL MAY BE EMPLOYED.

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*THE ABOVE STATEMENT WAS CONFIRMED BY CONVERSATION WITH MR. FRANK FIEDLER, JR., ASSISTANT SUPERVISOR, AMERICAN GAS ASSOCIATION, INC., PACIFIC COAST BRANCH TESTING LABORATORIES. MR. FIEDLER FURTHER STATED THAT NO DUCTING WOULD BE ALLOWED OUTSIDE THE HEATER CASING ON SUBSEQUENT MODELS, EXCEPT FOR SHORT FLANGES.

A RELATIVELY LARGE, LOW TEMPERATURE PANEL MAY BE EMPLOYED.

THE LARGE PANEL MIGHT BE OF NEARLY FULL HEATER WIDTH AND OF NEARLY FLOOR TO CEILING HEIGHT. IT WOULD PROBABLY OPERATE AT A TEMPERATURE LOW ENOUGH THAT A GUARD GRILLE WOULD NOT BE REQUIRED. IT COULD THEREFORE BE INSTALLED FLUSH WITH THE WALL IN AN ARCHITECTURALLY PLEASING MANNER. HOWEVER, IT WOULD BE DIFFICULT TO COVER SUCH A PANEL WITH MATCHING WALL MATERIAL IN SOME CASES; E.G., WOOD PANELING. FURTHER, IT WOULD BE DIFFICULT TO MAKE PROPER INTERNAL CIRCULATING AIR PROVISIONS WITH A LARGE RADIANT PANEL; AIR VELOCITIES MIGHT BE TOO LOW. NOISES RESULTING FROM PANEL EXPANSION AND CONTRACTION MIGHT BE DIFFICULT TO ELIMINATE. ALSO, SUCH A PANEL WOULD PROBABLY HAVE TO BE A CASING AROUND THE PRIMARY COMBUSTION CHAMBER ELEMENT, AND THE COSTS OF MATERIAL AND MANUFACTURE WOULD BE HIGH.

THE RELATIVELY SMALL HIGH TEMPERATURE PANEL MUST HAVE A GRILLE TYPE GUARD, AND IT IS DESIRABLE THAT THE PRIMARY COMBUSTION CHAMBER SURFACE BE EMPLOYED AS THE RADIANT PANEL. HOWEVER, IT IS DIFFICULT TO FIND FINISHES IN LIGHT COLORS WHICH WILL STAND HIGH TEMPERATURES (APPROXIMATELY 900°F) SO THAT MATCHING ROOM COLORS IS DIFFICULT. CIRCULATING AIR PROVISIONS CAN BE RATHER SIMPLY ARRANGED AND EXPANSION NOISES CAN BE CONTROLLED.

<u>THEREFORE, THE RADIANT PANEL WILL BE OF THE SMALL, HIGH TEMPERATURE TYPE WITH GRILLE GUARD. THE ACTUAL COMBUSTION CHAMBER WILL BE EMPLOYED, IF POSSIBLE.</u>

THERE ARE TWO GENERAL CONCEPTS WHICH MAY BE FOLLOWED PERTAINING TO THE METHOD OF INSTALLATION.

- THE HEATER MAY BE A FREE STANDING, SHIELDED UNIT WHICH FITS INTO THE HOUSE WALL STRUCTURE.
- THE HEATER MAY BE AN INTEGRAL PART OF THE WALL IT OCCUPIES, CARRYING VERTICAL AND LATERAL LOADS IN ITS FRAME AND BEING ADAPTABLE TO VARIOUS TYPES OF CONSTRUCTION WITH VARIABLE, MODULAR PANELS.

THE FIRST TYPE OF INSTALLATION RESULTS IN A HEATER OF RELATIVELY LOW FIRST COST WHICH IS WELL ADAPTED TO STUD WALL CONSTRUCTION. FOR SMALL UNITS, INSTALLATION IS SIMPLE AND ACCESSIBILITY FAIRLY GOOD. HOWEVER, FOR UNITS OF THE SIZE OF THE ROYAL JET FLOW, INSTALLATION BECOMES A RELATIVELY COSTLY AND INVOLVED PROCEDURE. LARGE METAL LINERS MUST BE PROVIDED TO KEEP TEMPERATURES WITHIN LIMITS; TWO CASINGS ARE BUILT AROUND SUCH HEATERS, THE METAL LINERS AND THE HOUSE WALL. VENTING MAY REQUIRE CONSIDERABLE CUTTING AND REINFORCING OF HEATERS.

THE SECOND METHOD OF INSTALLATION RESULTS IN A UNIT OF RELATIVELY HIGHER FIRST COST WHICH MAY MEET OPPOSITION IN THE FIELD BECAUSE IT IS NEW AND NOT THE CUSTOMARY TYPE. HOWEVER, THE METHOD OF INSTALLATION IS VERY SIMPLE AND CONSIDERABLE LABOR SAVINGS SHOULD RESULT. FRAMING AND PANELING IS NO LONGER A HAND TAILORED JOB; IT IS TAKEN FROM THE SITE TO THE FACTORY WHERE MASS PRODUCTION METHODS MAY BE EMPLOYED. FURTHER, IT IS EASILY ADAPTABLE TO METHODS OF CONSTRUCTION OTHER THAN STUD WALL, SUCH AS CONCRETE BLOCK, FRAMED STRUC-

TURES, AND POURED CONCRETE. MODULAR TYPE PANELING FACTORY FABRICATED, RESULTS IN SIMPLE FINISHING. VENTING CONSTRUCTION MAY BE SIMPLIFIED.

THE PRECEEDING CONCLUSIONS IN THIS SECTION HAVE POINTED TO A RELATIVELY LARGE, FULL WALL HEIGHT HEATER. THEREFORE, AN INTEGRAL, LOAD CARRYING FRAME WITH MODULAR WALL PANELING WILL BE EMPLOYED TO REALIZE MINIMUM INSTALLATION COSTS.

IN THE FIELD OF HEATING APPLIANCES, TWO GENERAL METHODS OF MANUFACTURE ARE ENCOUNTERED.

- THE DETAIL PARTS ARE OF THE SIMPLEST TYPE MADE LARGELY ON HAND OPERATED MACHINES AND WITH MINIMUM POWER MACHINERY. ASSEMBLY OPERATIONS ARE NUMEROUS AND SOMETIMES COMPLICATED.
- THE DETAIL PARTS ARE RELATIVELY COMPLEX, MADE LARGELY ON POWER OPERATED PRESSES AND REQUIRING SPECIAL TOOLS AND DIES. ASSEMBLY OPERATIONS ARE RELATIVELY SIMPLE.

IT IS WELL KNOWN THAT THE FIRST OF THE ABOVE METHODS IS CHARACTERISTIC OF SMALL, LOW CAPITAL OPERATIONS. PRODUCTION IS LOW, LABOR COSTS ARE HIGH, AND BURDEN IS LOW. THE SECOND IS CHARACTERISTIC OF HIGH PRODUCTION OPERATIONS. LABOR COSTS ARE LOW AND BURDEN IS RELATIVELY HIGH.

IT WILL BE ASSUMED THAT WITHIN THE LIMITS OF PRACTICABILITY, THE SECOND PHILOSOPHY WILL BE FOLLOWED IN THE DESIGN. THE SOUTH GATE, CALIFORNIA PLANT OF THE RHEEM MANUFACTURING COMPANY HAS BEEN STUDIED; IT FALLS IN THE SECOND CATEGORY AND THE HEATER WILL BE DESIGNED FOR SUCH A PLANT.

REQUIREMENTS FOR APPROVAL

WITHOUT DISCUSSION PERTINENT SECTIONS OF THE APPROVAL REQUIREMENT FOR GAS SPACE HEATERS OF THE AMERICAN GAS ASSOCIATION WILL BE QUOTED: (28)

"PART I

SEC. 15. VENTING

A. EVERY SPACE HEATER HAVING A GAS INPUT RATING IN EXCESS OF 50 000 BTU PER HOUR SHALL BE OF THE VENTED TYPE.

B. THE DESIGN OF VENTED HEATERS SHALL BE SUCH THAT THE PRODUCTS OF COMBUSTION FROM ALL BURNERS ARE CARRIED OUT OF THE APPLIANCE THROUGH A SINGLE FLUE OUTLET. ---

SEC. 17. MATERIALS AND CONSTRUCTION

C. SHEET METAL HEATING ELEMENTS AND BAFFLES SHALL BE OF A THICKNESS NOT LESS THAN NO. 20 U.S. STANDARD GAGE.

D. RADIATION SHIELDS SHALL BE OF A THICKNESS NOT LESS THAN NO. 26 U.S. STANDARD GAGE.

E. EXCEPT FOR FINISH STRIPS, ORNAMENTAL TRIMMINGS AND PARTS OTHERWISE SPECIFIED, SHEET METAL PARTS SHALL BE OF A THICKNESS NOT LESS THAN NO. 22 GAGE FOR CIRCULATORS AND NO. 26 U.S. STANDARD GAGE FOR RADIANT HEATERS AND RECESSED PORTIONS OF RECESSED WALL TYPE HEATERS.

F. THE CONSTRUCTION OF EVERY PART OF THE HEATER SHALL BE SUCH THAT IT WILL NOT SHOW UNDUE SIGNS OF BECOMING WARPED, BENT OR BROKEN AS TO NEGATE

THE HEATER'S COMPLIANCE WITH ANY OF THESE REQUIREMENTS. ---

G. MATERIALS SHALL BE OF SUCH COMPOSITION THAT THEY WILL NOT DISINTEGRATE TO THE EXTENT THAT PARTICLES WILL SEPARATE AND DROP UPON THE BURNER AND AFFECT COMBUSTION.

H. THE BODY FINISH SHALL BE DURABLE AND UNIFORMLY APPLIED. AFTER THE TERMINATION OF ALL TESTS SPECIFIED HEREIN, IT SHALL NOT SHOW UNDUE DISCOLORATION OR DETERIORATION.

SEC. 20. ASSEMBLY

A. JOINTS OF HEATING SURFACES IN VENTED TYPES OF SPACE HEATERS SHALL BE OF DURABLE AND RIGID CONSTRUCTION, SUCH AS WELDED, BRAZED, MACHINED AND BOLTED, TONGUE AND GROOVE, SLIP, LAP, OR SCREW JOINT, AND SHALL NOT DEPEND PRIMARILY ON CEMENT FOR TIGHTNESS.

B. ALL VITAL PARTS SHALL BE SUBSTANTIAL TO THE EXTENT THAT THEY WILL NOT BE BROKEN OR DAMAGED BY ORDINARY HANDLING.

C. THE CONSTRUCTION SHALL BE SUCH THAT VITAL PARTS OF THE HEATER CANNOT READILY BE INCORRECTLY INSERTED.

D. THE GENERAL ASSEMBLY OF THE HEATER SHALL BE OF A NEAT AND WORKMANLIKE CHARACTER WITH ALL PARTS WELL FITTED AND WITH BOLTS DRAWN UP TIGHTLY TO GIVE RIGIDITY.

E. THE CONSTRUCTION OF PARTS NOT COVERED BY THESE

REQUIREMENTS SHALL BE IN ACCORDANCE WITH REASONABLE CONCEPTS OF SAFETY, SUBSTANTIALITY AND DURABILITY."

PART II

SEC. 20. HEATING EFFICIENCY

A. VENTED SPACE HEATERS HAVING INPUT RATINGS IN EXCESS OF 20 000 BTU PER HOUR SHALL HAVE AN EFFICIENCY OF NOT LESS THAN 70% BASED ON THE HIGHER HEATING VALUE OF THE GAS."

SEC. 12. FLOOR, WALL AND FLUE TEMPERATURES

C. THE MAXIMUM TEMPERATURE AT POINTS OF CONTACT BETWEEN A RECESSED CIRCULATING TYPE WALL HEATER AND ANY PORTION OF THE WALL OR BUILDING STRUCTURE SHALL NOT BE MORE THAN 90°F IN EXCESS OF ROOM TEMPERATURE.

D. THE AVERAGE TEMPERATURE OF THE FLUE PRODUCTS FROM A CIRCULATING TYPE SPACE HEATER SHALL NOT EXCEED 550°F WHEN DETERMINED IN ACCORDANCE WITH THE METHOD OF TEST SPECIFIED --

SEC. 13. ALLOWABLE AIR TEMPERATURE

A VENTED RECESSED WALL TYPE CIRCULATOR SHALL NOT DISCHARGE AIR AT A TEMPERATURE IN EXCESS OF 350°F ABOVE ROOM TEMPERATURE AT ANY ONE POINT."

FINAL DESIGN

APPROACH

THE HEATER INPUT CAPACITY WAS DETERMINED FROM REQUIREMENTS CALCULATED FOR A SMALL RESIDENCE. DESIGNS OF THE INDIVIDUAL HEATER ELEMENTS WERE DEVELOPED. THE EXTERNAL APPEARANCE WAS STYLED TO SUIT CONTEMPORARY ARCHITECTURE.

HEATER CAPACITY

THE CAPACITY OF GAS HEATERS IS DETERMINED BY TWO FACTORS: FIRST IS THE APPROXIMATE OUTPUT REQUIRED TO HEAT THE SPACE FOR WHICH THE HEATER IS INTENDED. SECOND, THIS MUST BE ADJUSTED ACCORDING TO THE "LINE" MADE BY THE MANUFACTURER AND OFFERED BY THE COMPETITION.

AN ESTIMATE OF HEATING CAPACITY REQUIREMENTS WAS MADE BASED UPON AN ASSUMED RESIDENCE OF REASONABLE SIZE AND AVERAGE HEAT LOSS. FOR SUCH A CALCULATION, THE FEDERAL HOUSING AUTHORITY HAS ORIGINATED A SHORT-CUT METHOD FOR RESIDENTIAL HEAT LOSS DETERMINATIONS WHICH EMPLOYS FOUR SELECTED TRANSMISSION COEFFICIENTS. (29) FORMULA APPLYS TO DETACHED HOUSES APPROXIMATELY RECTANGULAR IN SHAPE WITH TOTAL EXTERIOR DOOR AND WINDOW AREAS EQUAL TO 25% OF THE FLOOR AREA AND WITH A MAXIMUM FLOOR AREA OF 1500 SQUARE FEET.

THE AREA WAS TAKEN AS SQUARE, 32 FEET BY 32 FEET OR ABOUT 1000 SQUARE FEET OF USEFUL AREA. THE CEILING HEIGHT WAS ASSUMED TO BE 8 FEET, GIVING A VOLUME OF 8000 CUBIC FEET. TWENTY FIVE PERCENT OF THE VERTICAL AREA WAS ASSUMED TO BE WINDOWS AND DOORS; THE VERTICAL WALL AREA EQUALS THE FLOOR AREA. THE FOLLOWING TYPE OF CONSTRUCTION WAS ASSUMED:

- GENERAL -- FRAME WITH PIER FOUNDATION, FLAT ROOF. WALLS -- 2 INCH X 4 INCH STUDS WITH 1 INCH WOOD SHEATHING, BUILDING PAPER AND STUCCO EXTERIOR, $\frac{1}{2}$ INCH INSULATING BOARD LATH AND PLASTER INTERIOR.
- FLOOR -- DOUBLE WOOD FLOOR ON JOISTS -- 25/32 INCH PINE SUBFLOOR AND 13/16 INCH HARDWOOD FINISH FLOORING.
- ROOF -- FLAT WITH LATH AND PLASTER CEILING, WOOD, $\frac{1}{2}$ INCH INSULATING BOARD, AND BUILT UP ROOFING TO MAKE A TOTAL THICKNESS OF $1\frac{1}{2}$ INCHES.

AS SHOWN IN APPENDIX B, THE HEAT REQUIRED TO MAINTAIN AN INTERIOR TEMPERATURE OF 65^{0}F WITH AN OUTSIDE TEMPERATURE OF 30^{0}F IS 39,200 BTU PER HOUR. USING THE PREVIOUSLY ASSUMED HEATER EFFICIENCY OF 70%, THE HEATER INPUT IS $\frac{39\ 200}{.70}$ BTU PER HOUR OR 56 000 BTU PER HOUR.

- IN ORDER TO PROVIDE READY COMPARISON WITH THE HEATERS ANALYSED IN DETAIL IN THE PRODUCT SURVEY, THE DESIGN INPUT OF THE HEATER BEING DEVELOPED WILL BE 55 000 BTU PER HOUR BASED ON THE HIGHER HEATING VALUE OF THE GAS.

BURNER DESIGN

THE BURNER IS DEFINED AS:

"A DEVICE FOR THE FINAL CONVEYANCE OF THE GAS, OR A MIXTURE OF GAS AND AIR, TO THE COMBUSTION ZONE."

1. INJECTION BURNER. A BURNER EMPLOYING THE ENERGY OF A JET OF GAS TO INJECT AIR FOR COMBUSTION INTO THE BURNER AND MIX IT WITH THE GAS AT LINE PRESSURE.

A. ATMOSPHERE INJECTION BURNER. A BURNER IN

WHICH THE AIR AT ATMOSPHERIC PRESSURE IS INJECTED INTO THE BURNER BY A JET OF GAS" (30)

THE ATMOSPHERIC INJECTION BURNER AS DEFINED ABOVE IS USED ON SPACE HEATERS OF THE TYPE BEING DEVELOPED. A CONSIDERABLE AMOUNT OF EXPERIMENT BY THE AMERICAN GAS ASSOCIATION AND OTHERS HAS RESULTED IN MUCH PUBLISHED DATA ON BURNERS. (31) (32) (33) USING SUCH DATA, THE POSSIBILITIES OF UTILIZING A GRID TYPE SPACE HEATER BURNER WITH THE PRINCIPLES AS SET FORTH IN THE MARKET INVESTIGATION WILL BE DEVELOPED.

THE PUBLISHED DATA ON BURNERS IS CHIEFLY CONCERNED WITH TWO AIMS:

- DESIGN OF BURNERS FOR SATISFACTORY FLAME CHARACTERISTICS.
- DESIGN OF BURNERS FOR QUIET OPERATION.

IN THE FIRST CATEGORY, THE CHIEF CONCERN IS WITH THE PRIMARY AIR INJECTION AND WITH GAS FLOW VELOCITIES. IT WILL BE ASSUMED THAT THE BURNER IS FOR NATURAL GAS, TOTAL INPUT OF 55 000 BTU PER HOUR BASED ON THE GROSS OR HIGHER HEATING VALUE OF THE FUEL AT A GAS PRESSURE OF 7.0 INCHES OF EQUIVALENT WATER COLUMN ABOVE ATMOSPHERIC. AS WAS INDICATED IN THE SECTION ON TECHNICAL INVESTIGATIONS, THE GRID GAS BURNER OPERATES SATISFACTORILY AT CONSIDERABLY HIGHER THAN THE PRIMARY AIR INJECTION OF 60% OF THE USUAL BURNER. THE BURNER DESCRIBED HAS BEEN PROVED AT 80% PRIMARY AIR; THIS INJECTION WILL BE ASSUMED FOR THE PRESENT DESIGN.

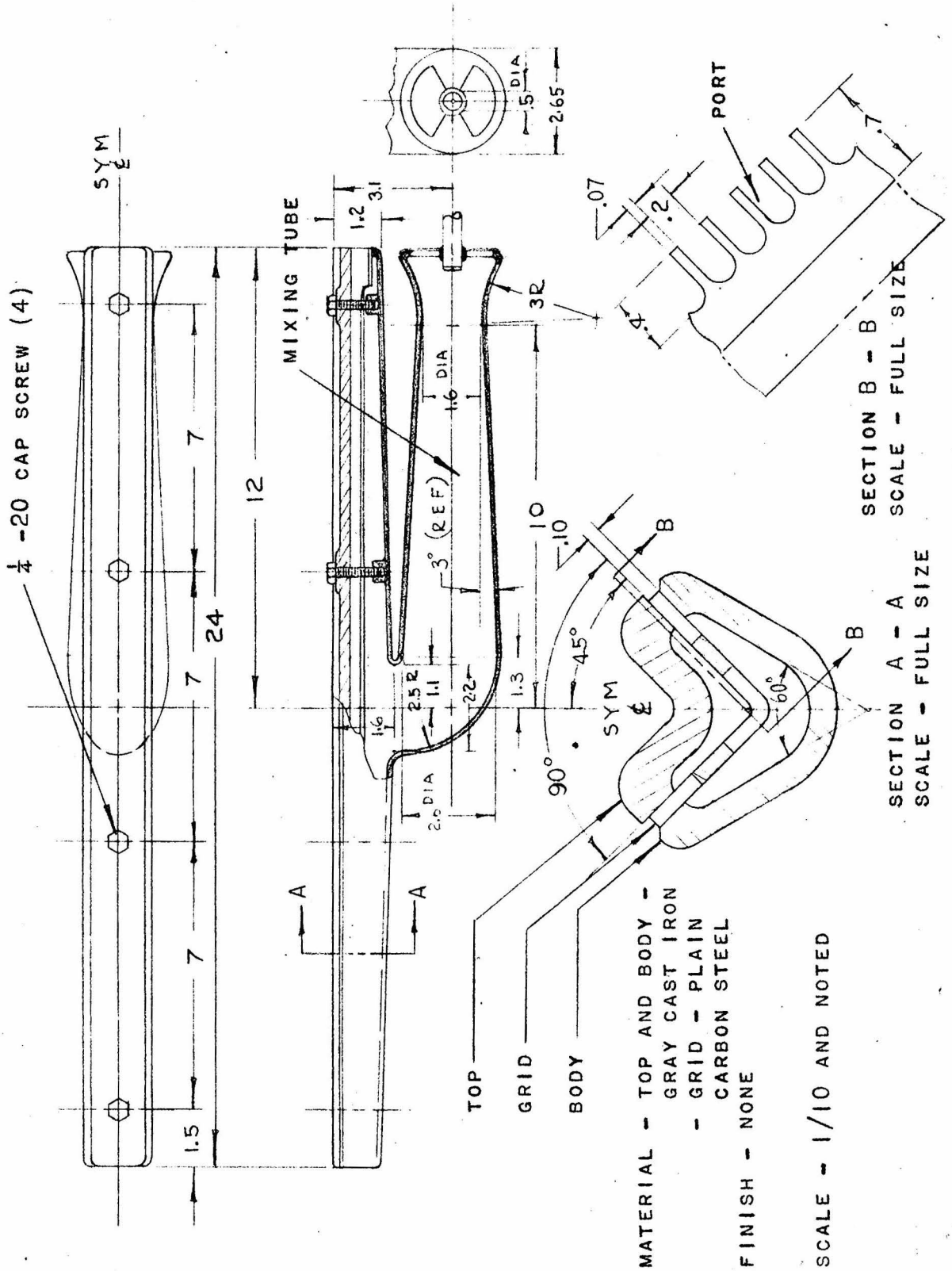
ALSO, IT IS PLANNED TO SPECIFY THAT THE HEATER BE USED AT ALL TIMES WITH A GAS PRESSURE REGULATOR WHICH LIMITS THE

GAS PRESSURE TO A MAXIMUM OF 125% OF NORMAL AND NOMINAL DESIGN VALUES WILL BE TAKEN FROM THE LITERATURE. SINCE DESIGN VALUES DEPEND UPON THE BURNER CONFIGURATION, AN ASSUMED GENERAL ARRANGEMENT BASED UPON THE GRID PORT PRINCIPLES IS SHOWN IN FIGURE 8. THE BURNER IS SEEN TO INCLUDE AN ORIFICE, AND A ONE PIECE VENTURI TYPE MIXING CHAMBER AND TRANSITION SECTION, 24 INCHES LONG. THE PORTS ARE ON BOTH SIDES OF THE LONG, NARROW GRID AND INCLINED AT AN ANGLE OF 45^{0} WITH THE HORIZONTAL.* A GRID RETAINING CASTING IS BOLTED TO THE TRANSITION CASTING AND ITS CONVEX INTERNAL SHAPE ASSISTS IN PROVIDING SMOOTH GAS FLOW TO THE PORTS.

THE SPECIMEN GRID GAS BURNER OF FIGURE 7 HAS BEEN EVALUATED IN TERMS OF A BURNER PERFORMANCE CONSTANT, K, AS SHOWN IN APPENDIX C. THE PHYSICAL CONFIGURATION OF THE BURNER, THE TEST GAS CONDITIONS, AND THE AIR-GAS MIXTURE PERCENTAGE AND TEMPERATURES ARE SEEN TO BE INVOLVED IN THE EXPRESSION. SINCE THE EVALUATED GRID GAS BURNER IS OF A MORE NEARLY IDEAL SHAPE THAN THE SPACE HEATER BURNER, THE VALUE OF K, 3.69×10^{5}, WILL BE REDUCED 20% OR $K^{1} = 2.95 \times 10^{5}$. ALSO, THE AIR-GAS MIXTURE AT THE PORTS WILL BE ASSUMED TO BE AT 400^{0}F IN THE SPACE HEATER. FROM THESE ASSUMPTIONS, A BURNER PORT INPUT RATING OF 16 100 BTU PER HOUR PER SQUARE INCH OF PORT AREA IS OBTAINED AS SHOWN IN APPENDIX C.** THIS IS WITH

*"PORTS SHALL BE LOCATED ON THE UPPER HALF OF BURNERS AND DRILLED AT ANGLES AT LEAST 30^{0} FROM THE HORIZONTAL." APPROVAL REQUIREMENTS FOR GAS SPACE HEATERS; AMER. GAS ASS'N.; JAN. 1, 1943; PAGE 1.

**SIMILAR VALUES FOR BURNERS IN TABLE 6, PAGE 17 OF PRIMARY AIR INJECTION CHARACTERISTICS OF ATMOSPHERIC GAS BURNERS, RESEARCH BULLETIN NO. 26, AMER. GAS ASS'N. WERE FOUND TO BE TOO HIGH BY APPROXIMATELY 20.5%. VALUES DISAGREE WITH MATHEMATICAL DERIVATIONS OF REFERENCE.



BURNER
FIGURE 8

THE RATIO OF AVERAGE MIXING TUBE AREA OR

$$\frac{\text{AREA AT THROAT} + \text{AREA AT OUTLET}}{2}$$

AND THE TOTAL PORT AREA EQUAL TO 1.00 AS HAS BEEN PREVIOUSLY MENTIONED AS BEING DESIRABLE FOR GRID TYPE BURNERS. THE TOTAL PORT AREA REQUIRED IS $\frac{55\ 000\ \text{BTU}\cdot\text{HR}\cdot\text{IN}^2}{16\ 100\ \text{BTU}\cdot\text{HR}}$ OR 3.42 SQUARE INCHES. WITH AN ASSUMED GRID THICKNESS OF .10 INCHES, AND PORT LENGTH OF .20 INCHES, 172 PORTS ARE SEEN TO BE REQUIRED; 86 ARE ON EACH SIDE OF THE GRID. THE SPACE BETWEEN THE PORTS IS .07 INCHES OR 35% OF THE PORT WIDTH. THE PORT DEPTH IS TAKEN AS A MINIMUM OF 2 TIMES THE WIDTH OR .40 INCHES. THE AVERAGE DIAMETER OF THE MIXING TUBE IS:

$$d_m = \sqrt{\frac{A_p}{.785}} = \sqrt{\frac{3.42}{.785}} = 2.10 \text{ INCHES}$$

THE CALCULATIONS FOR THE BURNER HAVE BEEN MORE COMPLETELY WORKED OUT IN APPENDIX C, THE PROPORTIONS OF THE MIXING TUBE ARE ACCORDING TO THE BEST PRACTICE FOR VENTURI TYPE MIXERS. (34) MIXING TUBE LENGTH, A RELATIVELY INSENSITIVE VARIABLE IN BURNER DESIGN (35), HAS BEEN TAKEN AS 10.0 INCHES. THE PRIMARY AIR INLET OPENINGS ARE 125% OF THE PORT AREA (36) OR 4.27 SQUARE INCHES. THE ORIFICE OUTLET TO THROAT DISTANCE IS TAKEN EQUAL TO THE THROAT DIAMETER, OR A RATIO OF 1.00 (37). A FIXED ORIFICE HAS BEEN EMPLOYED OF THE CHANNEL TYPE; FOR 1130 BTU PER CUBIC FOOT NATURAL GAS A NO. 31 (.120 INCHES) D.M.S. DIAMETER WOULD BE REQUIRED. (38) TO ACCOMODATE VARIOUS GASES, THIS ORIFICE SIZE MAY EASILY BE VARIED.

THERE ARE SIX FACTORS WHICH MUST BE CONSIDERED IN THE DESIGN OF THE BURNER FOR QUIET OPERATION (39):

- FLAME NOISE
- FLASH-BACK OR LIGHTING BACK CONCUSSION
- ORIFICE NOISE
- AIR INSPIRATION AND MIXING NOISE
- NOISE OF IGNITION
- NOISE OF EXTINCTION

THE FIRST FIVE ARE KEPT AT LOW LEVELS BY PROPER BURNER CONFIGURATION. SINCE STANDARD PRACTICE HAS BEEN GENERALLY FOLLOWED IN THE BURNER PROPORTIONS, IT WILL BE ASSUMED THAT THE BURNER WILL OPERATE AT A SATISFACTORY LOW SOUND LEVEL. A MATHEMATICAL APPROACH TO THE PROBLEM OF NOISE OF EXTINCTION HAS BEEN DEVELOPED (40). HOWEVER, AS SHOWN IN APPENDIX C, THE CALCULATED VALUE OF THE FUNCTION FOR THE BURNER BEING DESIGNED IS FOR LARGER THAN THE RANGE FOR WHICH DATA IS PRESENTED. HENCE, IT WOULD BE NECESSARY TO RESORT TO LABORATORY TEST TO DETERMINE THE NOISE OF EXTINCTION. THE NOISE OF THE GRID TYPE BURNER UPON WHICH THE PRESENT DESIGN IS BASED IS NOT OBJECTIONABLE AND IT WILL BE ASSUMED THAT THE NOISE OF THE LATTER COULD BE SATISFACTORILY CONTROLLED.

HEAT EXCHANGER DESIGN

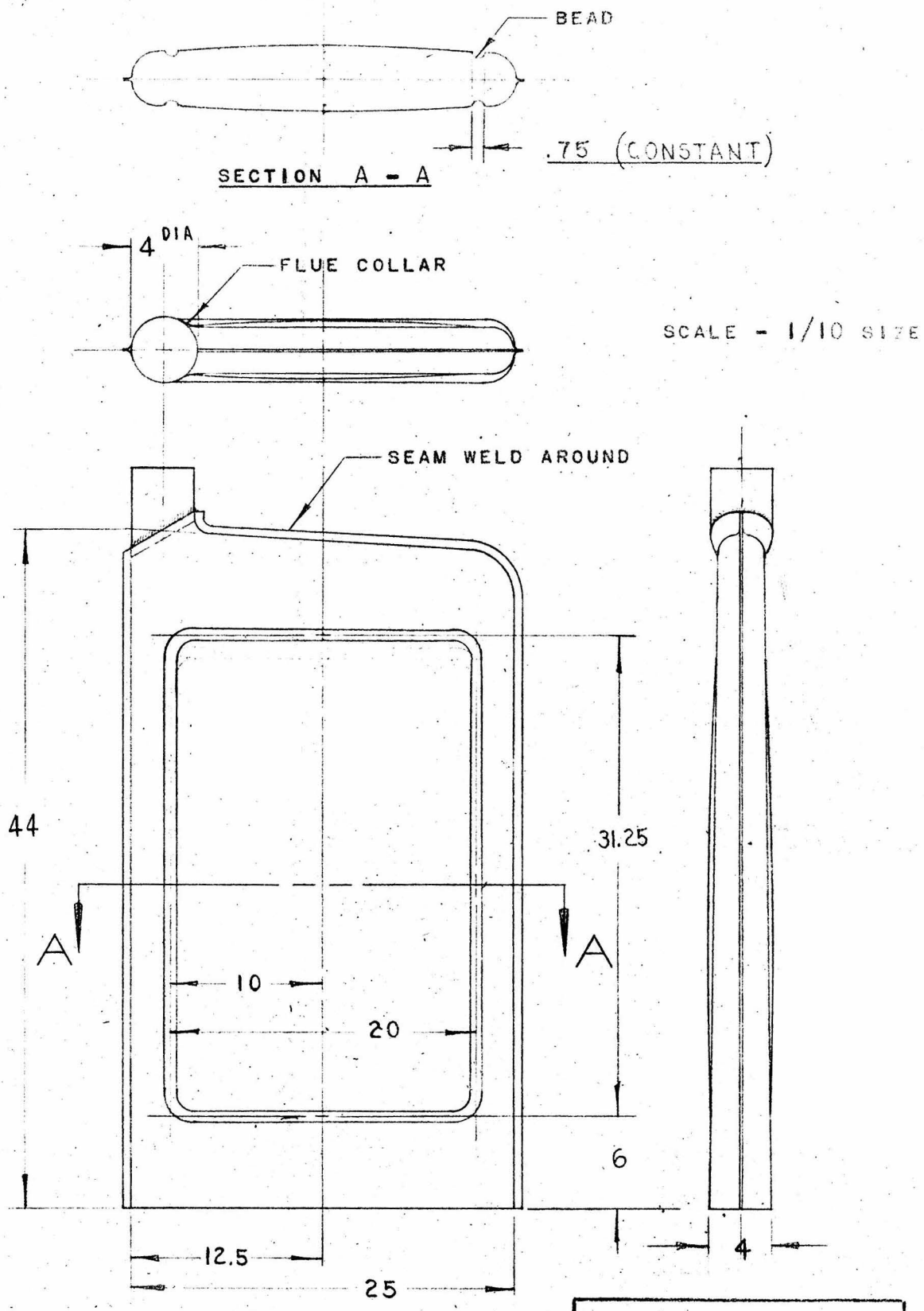
THE HEAT EXCHANGER SERVES SEVERAL FUNCTIONS:

- IT SHIELDS THE BURNER AND DIRECTS SECONDARY AIR FLOW.
- IT CONVEYS THE PRODUCTS OF COMBUSTION TO THE DRAFT HOOD, INDUCING TURBULENCE BY BAFFLING TO INCREASE HEAT EXCHANGE.
- IT CONDUCTS AND RADIATES HEAT.

BECAUSE OF THE MANY VARIABLES INVOLVED, DESIGN OF HEAT EXCHANGERS IS USUALLY REDUCED TO THE SIMPLEST TERMS AND DEVELOPMENT IS DONE LARGELY BY LABORATORY TEST. A COMMONLY EMPLOYED MAXIMUM HEAT EXCHANGE VALUE IS 22 BTU PER HOUR PER SQUARE INCH OF HEAT EXCHANGER SURFACE. THE AMERICAN GAS ASSOCIATION REQUIRES THAT THE FLUE GAS LOSSES MUST NOT EXCEED 30% OF THE HEAT INPUT AND TO ALLOW A DESIGN MARGIN, 80% HEAT EXCHANGE WILL BE ASSUMED. HENCE .80 (55 000 BTU PER HOUR) OR 44 000 BTU PER HOUR WILL BE EXCHANGED. THUS, $\frac{44\ 000\ IN^2}{22}$ OR 2000 SQUARE INCHES OF SURFACE ARE REQUIRED. THE WIDTH IS TAKEN AS 25 INCHES; THE HEIGHT ABOVE THE BURNER MUST BE $\frac{2000\ IN}{2X25}$ OR 40 INCHES AS BOTH SIDES OF THE HEAT EXCHANGER WILL BE EMPLOYED. A MORE ELABORATE CALCULATION OF THE REQUIRED HEAT EXCHANGE AREA, BASED ON PARALLEL FLOW CONCEPTS IS SHOWN IN APPENDIX D, VERIFYING THE ABOVE CALCULATIONS.

THE HEAT EXCHANGER IS SHOWN IN FIGURE 9. THE BOTTOM OPENING IS 25 INCHES BY 4 INCHES AND IT EXTENDS 4 INCHES BELOW THE LEVEL OF THE BURNER PORTS. THE HEAT EXCHANGER IS SEEN TO TAPER IN THICKNESS FROM BOTTOM TO 3 INCHES AT THE TOP. THIS IS DONE TO COMPENSATE FOR THE DECREASE IN SPECIFIC VOLUME OF THE COMBUSTION PRODUCTS AS THEY ARE COOLED AND THE INCREASE IN SPECIFIC VOLUME OF THE CIRCULATING AIR AS IT IS HEATED. BAFFLING, TO INCREASE HEAT EXCHANGE BY INDUCING TURBULENCE HAS BEEN INDICATED, ALTHOUGH THE FINAL PLACEMENT OF BAFFLES WOULD BE SUBJECT TO TEST.

IT WILL BE NOTICED THAT THE VENT HAS BEEN PLACED AT THE



MATERIAL - #20 U.S. GAGE SHEET STEEL
LOW CARBON - FREE DRAWING
FINISH - ENAMEL - SPRAYED AND BAKED

HEAT EXCHANGER
FIGURE 9

VERTICAL EDGE OF THE EXCHANGER. THIS HAS BEEN DONE TO ALLOW THE DRAFT HOOD AND VENT TO BE INSTALLED COMPLETELY FREE OF THE CIRCULATING AIR DUCTING. THE BAFFLING WOULD HAVE TO BE SO ARRANGED TO PROVIDE GOOD FLOW TO THE VENT WITHOUT COOL SPOTS IN THE OPPOSITE CORNER OF THE EXCHANGER. BECAUSE OF THE LOW PERCENTAGE OF SECONDARY AIR NECESSARY TO COMPLETE COMBUSTION, THE LOWER OPEN AREA WOULD PROBABLY BE ADEQUATE. AGAIN TEST WOULD BE EMPLOYED TO DEVELOP THE FINAL DIMENSIONS.

THE HEAT EXCHANGER IS FORMED IN TWO HALVES FROM NO. 20 (.036 INCH) U.S. STANDARD GAGE SHEET STEEL OF PLAIN CARBON, FREE DRAWING TYPE. THE SURFACES ARE CURVED AND BEADING HAS BEEN INCORPORATED, AS SHOWN, TO PREVENT "OILCANNING" AND NOISE FROM EXPANSION AND CONTRACTION. TO ASSEMBLE, BAFFLES WOULD BE WELDED TO ONE HALF BY THEIR FLANGES, AND THE TWO HALVES WOULD BE SEAM WELDED ALONG THE CONTACTING FLANGES. THE 4 INCH DIAMETER FLUE COLLAR WOULD BE WELDED IN PLACE, AS SHOWN.

DRAFT HOOD DESIGN

THE DRAFT HOOD IS DEFINED AS:

> "A DEVICE PLACED IN, AND MADE A PART OF, THE FLUE PIPE FROM AN APPLIANCE, OR IN THE APPLIANCE ITSELF WHICH IS DESIGNED TO (1) INSURE THE READY ESCAPE OF PRODUCTS OF COMBUSTION IN THE EVENT OF NO DRAFT, BACK DRAFT, OR STOPPAGE BEYOND THE DRAFT HOOD; (2) PREVENT A BACK DRAFT FROM ENTERING THE APPLIANCE; AND (3) NEUTRALIZE THE EFFECT OF STACK ACTION OF THE CHIMNEY

FLUE UPON THE OPERATION OF THE APPLIANCE." (41)

THE DEVELOPMENT OF DRAFT HOODS IS LARGELY A TEST LABORATORY PROCEDURE, BUT THE FOLLOWING CONFIGURATION IS GENERALLY EMPLOYED:

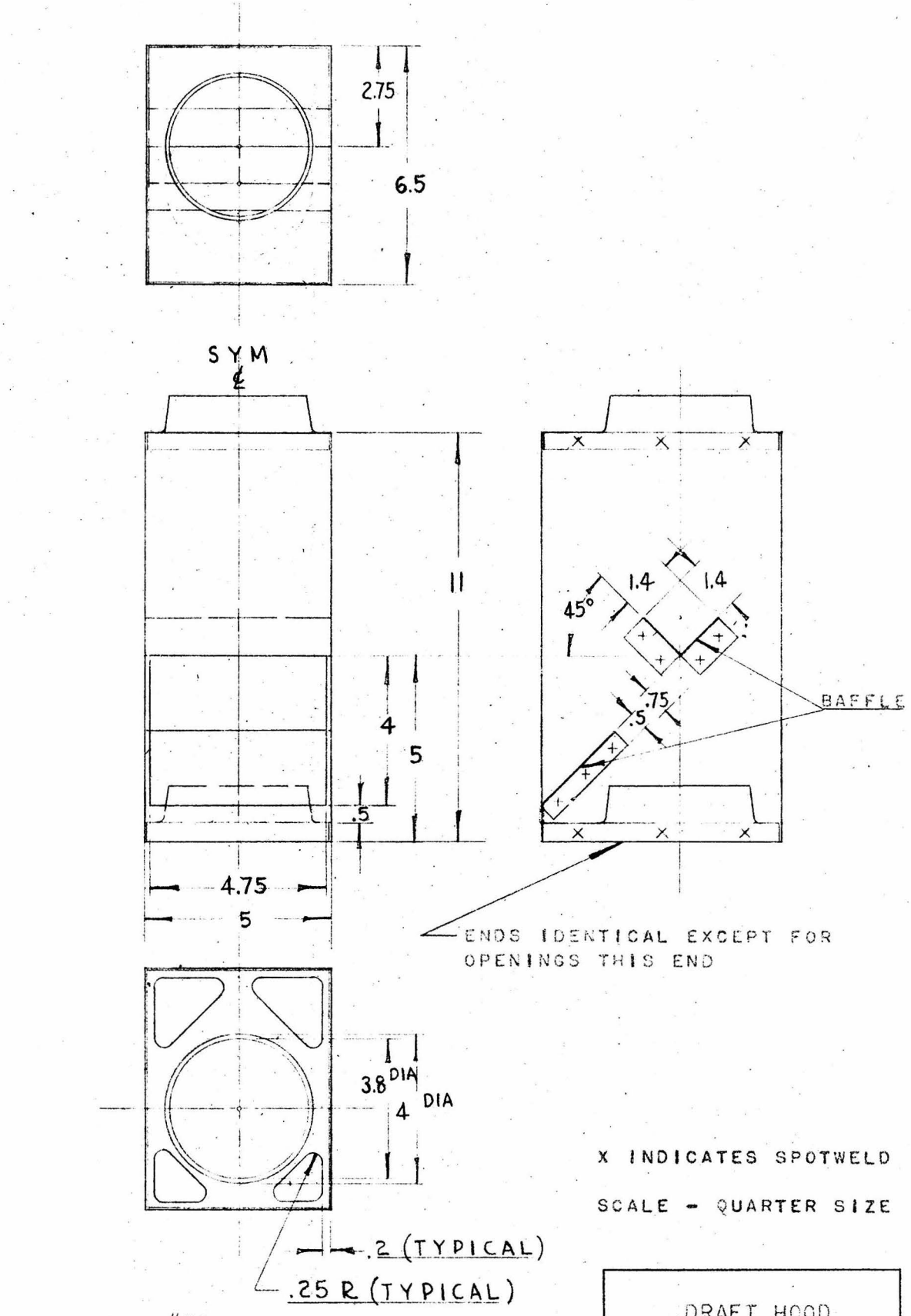
- THE UPDRAFT PASSAGE OF COMBUSTION PRODUCTS IS AS UNRESTRICTED AS POSSIBLE, THE DIRECT DOWNDRAFT PASSAGE OF GASES IS PREVENTED BY BAFFLING AND DEFLECTED INTO OPENINGS IN THE BOTTOM OR SIDES OF THE HOOD. THE OPENINGS SERVE THE FURTHER PURPOSE OF RELIEVING THE EFFECT OF THE CHIMNEY FLUE DRAFT DURING NORMAL OPERATION.

THE PROPOSED DRAFT HOOD IS SHOWN IN FIGURE 10; IT IS RECTANGULAR IN PLAN WITH FLOW DEFLECTORS AS SHOWN IN SECTION. IT IS OPEN AT THE BOTTOM, WITH A FLANGE TO WHICH THE FLUE COLLAR FITS. THE OFFSET OF THE FLANGE IS TO PREVENT MISPLACEMENT OF THE HOOD DURING INSTALLATION, SO AS TO PARTIALLY OBSTRUCT THE AIR PASSAGE. THE TAPERED COLLAR AT THE TOP PROVIDES FOR THE 4 INCH DIAMETER VENT PIPE WHICH IS EMPLOYED.

THE DRAFT HOOD IS OF NO. 20 (.036 INCH) U.S. STANDARD GAGE, PLAIN CARBON STEEL. IT IS ESSENTIALLY A BRAKE FORMED BOX WITH DRAWN FLANGED COLLARS AT TOP AND BOTTOM. THE BOX IS FOLDED AND SPOT WELDED, THE BAFFLES ARE SPOT WELDED IN PLACE, AND THE ENDS ARE SIMILARLY ATTACHED.

DUCTING AND SHIELDING

THE PURPOSE OF THE DUCTING IS TO CONVEY THE CIRCULATION AIR TO THE OUTLET REGISTERS AND TO CONTROL THE DIRECT RADIATION



X INDICATES SPOTWELD

SCALE - QUARTER SIZE

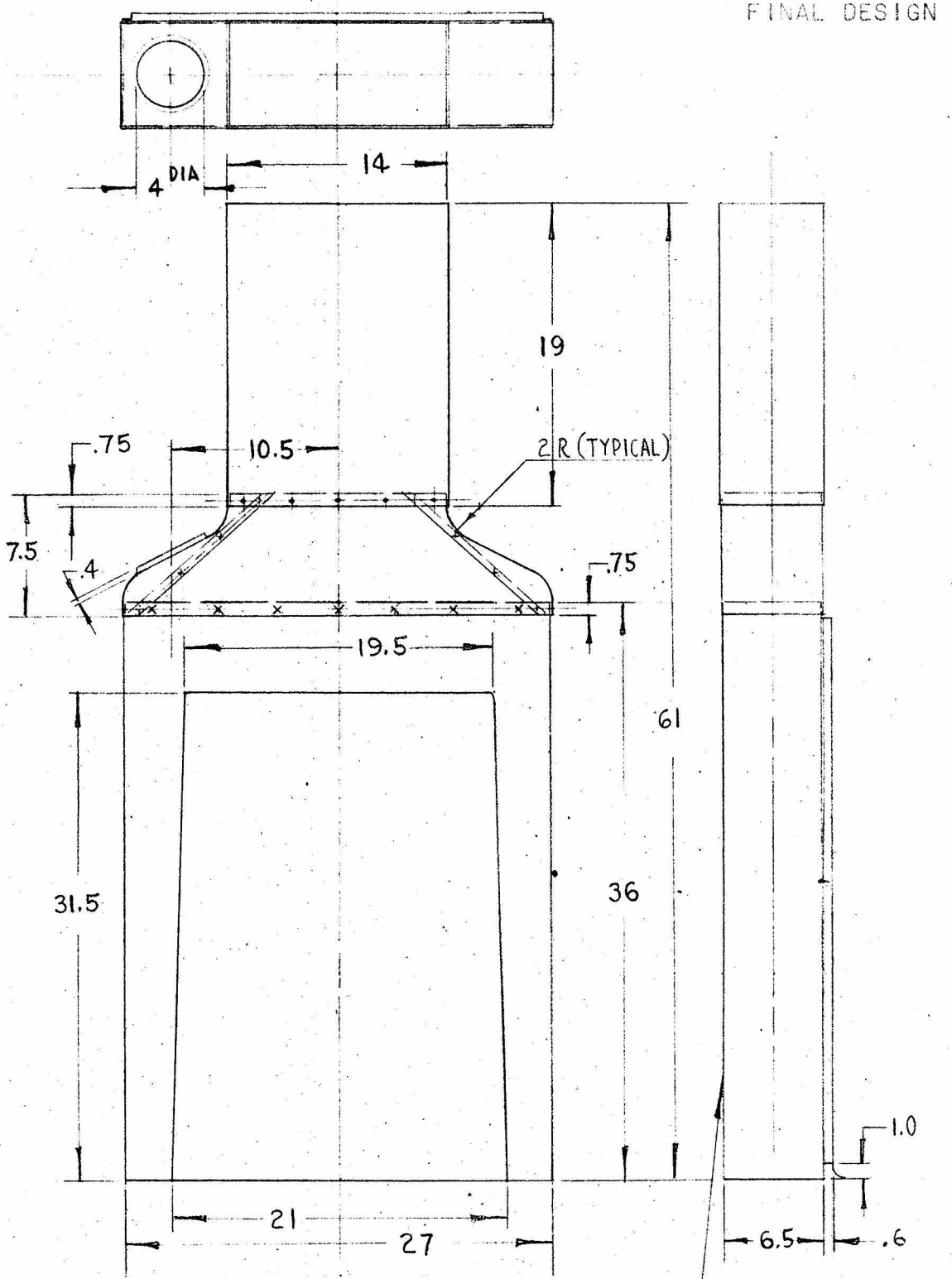
MATERIAL - #20 U.S. GAGE SHEET STEEL
LOW CARBON - FREE DRAWING
FINISH - ENAMEL - SPRAYED AND BAKED

DRAFT HOOD
FIGURE 10

FROM THE HEAT EXCHANGER. THE SECONDARY SHIELDS HELP TO KEEP THE SURROUNDING WALL TEMPERATURES WITHIN SATISFACTORY LIMITS AND ALSO INCREASE DIRECT CIRCULATION AIR FLOW. AS SHOWN IN FIGURE 11, THE DUCTING GENERALLY SURROUNDS THE HEAT EXCHANGER; IT IS 27 INCHES WIDE BY 6.5 INCHES AT THE BOTTOM, AND OF CONSTANT SECTION FOR THE HEIGHT OF THE HEAT EXCHANGER. A FLANGED CUTOUT OF 21 INCHES BY 31.5 INCHES IS INDICATED; THIS WILL BE MADE WHERE THE RADIANT PANEL FEATURE OF THE HEATER IS EMPLOYED, TO ALLOW FREE RADIATION FROM THE HEAT EXCHANGER SURFACE. A SMOOTH TRANSITION TO A 6.5 INCH BY 14 INCH RISER IS PROVIDED, IN WHICH IS INCLUDED A SLIGHTLY FLANGED OPENING FOR THE FLUE COLLAR. THE RISER IS TOPPED BY A REGISTER HEAD, OF WHICH TWO TYPES WILL BE EMPLOYED. ONE TYPE WILL HAVE TWO OUTLETS, 6 INCHES BY 14 INCHES AS SHOWN IN FIGURE 12; THE SECOND WILL HAVE ADDED A THIRD END OUTLET OF 6 INCHES BY 8 INCHES, MAKING A TOTAL OF THREE OUTLETS. THE TRANSITION FROM VERTICAL TO HORIZONTAL FLOW IS ASSISTED BY GENEROUS TURNING RADII.

THE DUCTING MAY BE MADE OF SHEET STEEL OR ALUMINUM SHEET OF APPROXIMATELY NO. 22 (.030 INCH) U.S. STANDARD GAGE. THE TRANSITION SECTION WOULD BE DIE FORMED. THE BOX AROUND THE HEAT EXCHANGER, THE TRANSITION SECTION AND THE RADIATION SHIELDS WOULD BE A SPOTWELDED ASSEMBLY. THE DUCT RISER AND THE REGISTER HEAD WOULD BE ASSEMBLED WITH SHEET METAL SCREWS, AND WOULD FIT THE FLANGE OF THE TRANSITION SECTION, AS SHOWN. THE CUTOUT IN THE REGISTER HEAD FOR THE END DUCT WOULD BE COVERED WITH A PLATE WHEN NOT IN USE; TO INSTALL

FINAL DESIGN



WHEN GRILLE CUTOUT IS NOT MADE, SHIELD ADDED THIS SIDE

X INDICATES SPOTWELD

MATERIAL - #22 U.S. GAGE SHEET STEEL OR ALUMINUM (.040 GAGE)

SCALE - 1/10 SIZE

FINISH -

DUCTING AND SHIELDING
FIGURE 11

THE END DUCT IT WOULD SIMPLY BE REMOVED AND THE DUCT HELD IN PLACE BY SCREWS THROUGH ITS FLANGES.

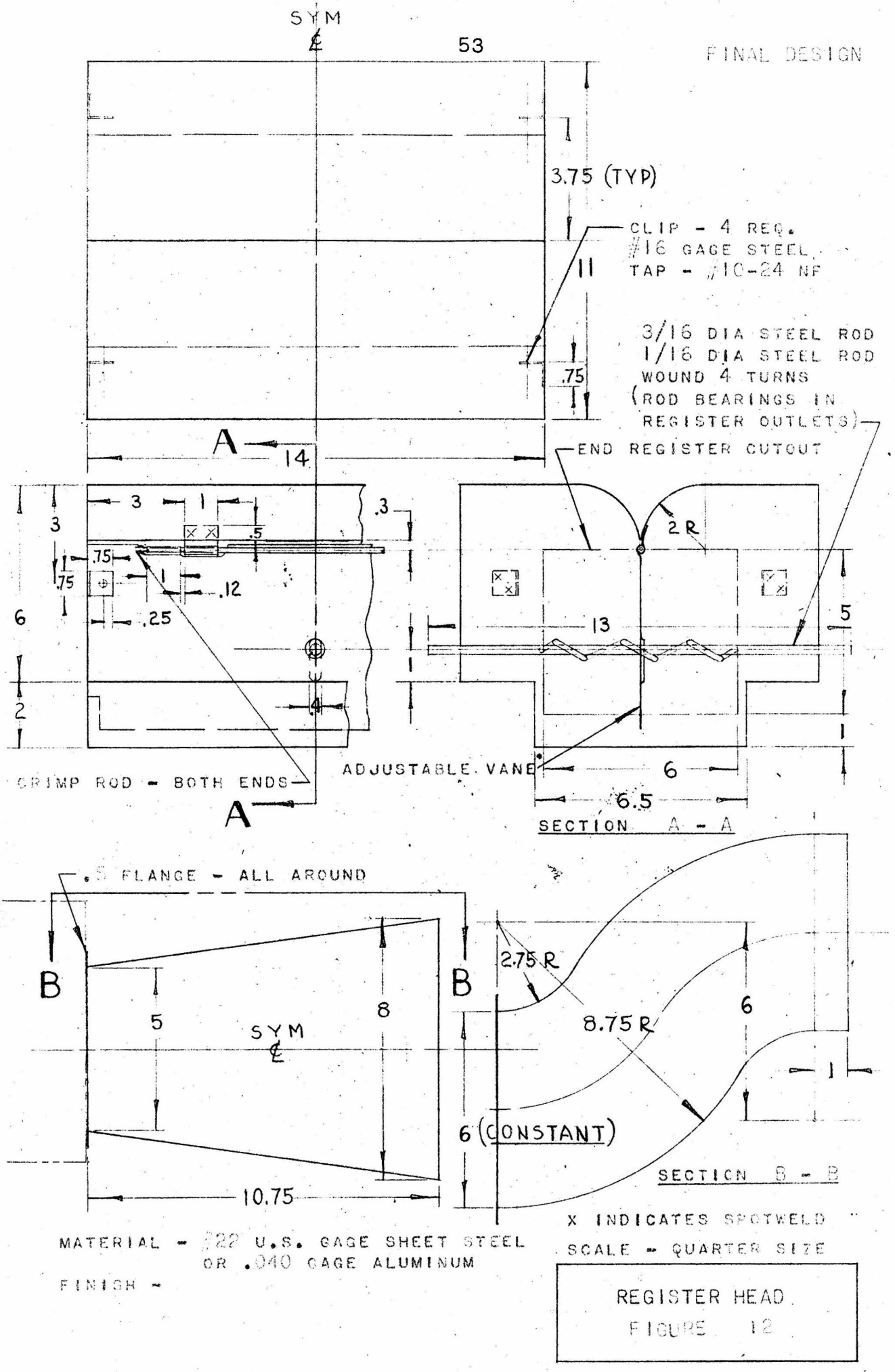
A HINGED, ADJUSTABLE FLOW DAMPER HAS BEEN INCORPORATED IN THE RISER HEAD, AS SHOWN. CONTROL KNOBS FOR POSITIONING THE DAMPER ARE PROVIDED ON BOTH GRILLS; KNOBS ARE OF IVORY INJECTION MOLDED POLYSTYRENE RESIN SELECTED BECAUSE OF ITS STABILITY AT HIGH TEMPERATURES. THE HELICALLY COILED SPRING WIRE ATTACHED TO THE 3/16 INCH DIAMETER STEEL CONTROL ROD RIDES IN A SLOT IN THE DAMPER AND CAUSES IT TO MOVE AS THE KNOBS ARE TURNED.

OUTLET REGISTERS

THE CHIEF PURPOSE OF THE OUTLET REGISTER IS TO DISTRIBUTE THE WARM AIR IN A DIFFUSION STREAM PATTERN. DEPENDING UPON THE SHAPE OF THE ROOM AND THE LOCATION OF THE REGISTER, THE DESIRED ANGLE OF DIFFUSION WILL VARY FROM ABOUT 45^{0} TO 120^{0} AS VIEWED IN THE HORIZONTAL PLANE (42). THIS IS BEST ACCOMPLISHED BY EMPLOYING VERTICAL VANES IN THE REGISTER WHICH DEFLECT THE AIR AS IT EMERGES FROM THE DUCT. THE 7.5 INCHES HIGH BY 15 INCHES WIDE SIDE REGISTER IS SHOWN IN FIGURE 13; AN AVERAGE FREE AREA OF 75% RESULTS IN A TOTAL OUTLET OF 84 SQUARE INCHES. THE VANES MAY BE ADJUSTED BY TWISTING WITH A SPECIAL KEY TO A PREDETERMINED POSITION TO VARY THE DIFFUSION OF THE AIRSTREAM.

THE END OUTLET REGISTER IS 9.5 INCHES HIGH BY 7 INCHES WIDE. GENERALLY, THE DESIRED FLOW FROM IT WILL BE ASYMMETRIC; TO CONTROL FLOW DIRECTION, THE PRESET REGISTER CAN BE MOUNTED WITH THE OUTER VANE EDGES TO RIGHT OR LEFT.

FINAL DESIGN



REGISTER HEAD
FIGURE 12

THIS IS SHOWN IN FIGURE 13.

THE FLUSH MOUNTED REGISTERS HAVE SYNTHETIC RUBBER GASKETS, AS ILLUSTRATED, WHICH SEAL TIGHTLY AGAINST THE WALL SURFACE AND PREVENT AIR LEAKAGE AND WALL STREAKING. THE CENTER OF THE REGISTERS IS APPROXIMATELY 6 FEET 4 INCHES FROM THE FLOOR; THE STREAM WILL BE OVER THE HEAD OF MOST OCCUPANTS. ALL REGISTERS WOULD BE DRAWN AND FORMED FROM NO.26 (.018 INCH) U.S. STANDARD GAGE PLAIN CARBON SHEET STEEL.

RETURN AIR REGISTER AND GRILL

THE COLD AIR RETURN REGISTER, WHICH ALSO ALLOWS COMBUSTION AIR TO FLOW TO THE BURNER, HAS VERTICAL VANES AND IS INSTALLED IN A MANNER SIMILAR TO THE HOT AIR REGISTERS. THE VANES ARE ORIENTED TO ACCOMODATE CONVERGING AIRFLOW. THE OPENING IS 9 INCHES HIGH BY 20 INCHES WIDE. FABRICATION IS SIMILAR TO THAT OF THE OUTLET REGISTERS.

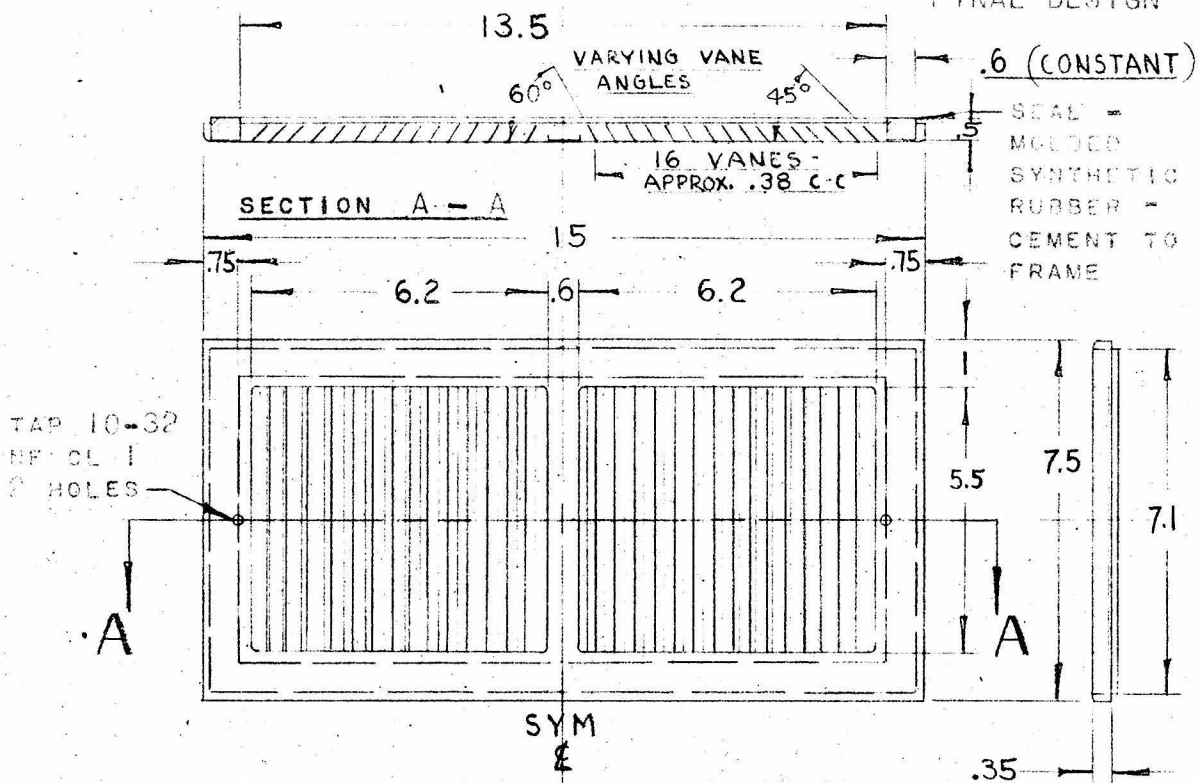
WHEN THE RADIANT PANEL FEATURE IS TO BE EMPLOYED, THE COLD AIR RETURN AND PANEL GUARD WILL BE A SINGLE ASSEMBLY. THE PANEL OPENING IS ABOUT 21 INCHES BY 26 INCHES AND 11 VERTICAL GUARD BARS ABOUT 1.6 INCHES ON CENTERS RUN THE FULL LENGTH OF THE OPENING. THIS IS SHOWN IN FIGURE 14; CONSTRUCTION IS SIMILAR TO OTHER REGISTERS.

FRAME DESIGN

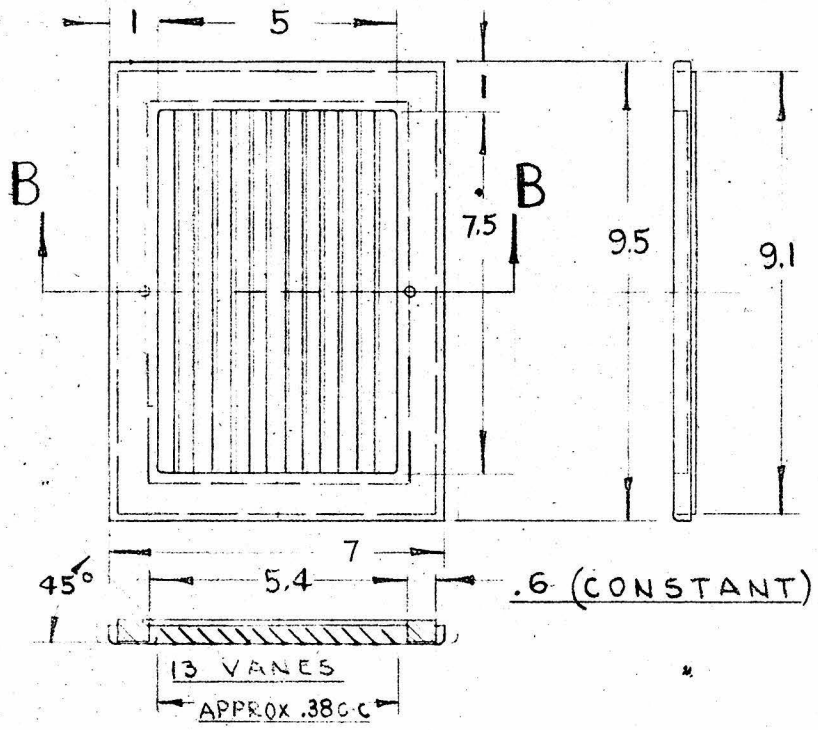
AS HAS BEEN STATED, THE FRAME IS TO BE A STRUCTURAL PART OF THE WALL SECTION IT OCCUPIES. AS SUCH, IT MUST MEET THE FOLLOWING REQUIREMENTS:

- IT MUST HAVE STRENGTH EQUIVALENT TO THE MEMBERS IT REPLACES.

FINAL DESIGN



REGISTER - SIDE OUTLET



REGISTER - END OUTLET

NOTE- FOR DETAILS SEE VIEW ABOVE

SCALE - QUARTER SIZE

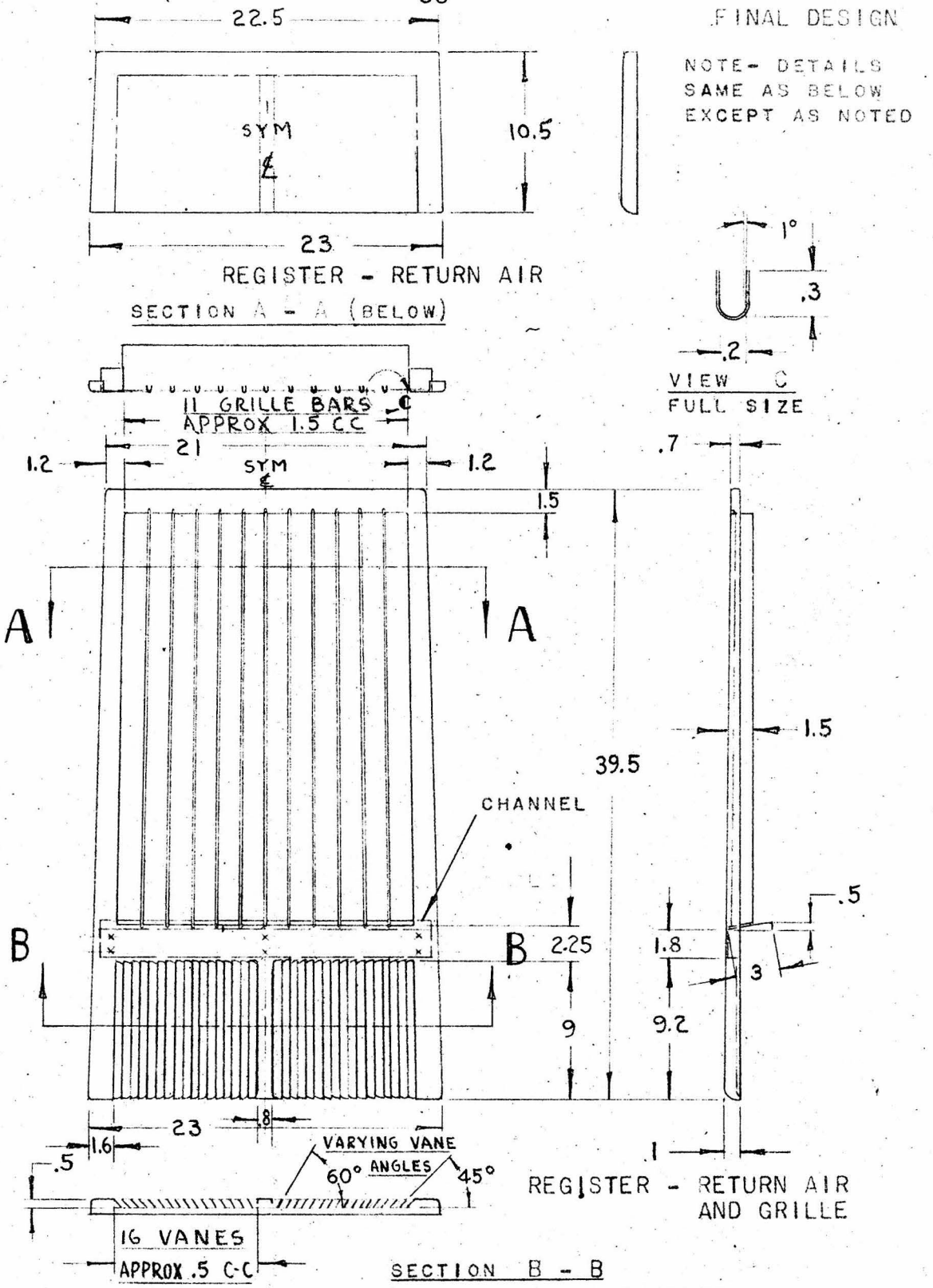
MATERIAL - #26 U.S. GAGE SHEET STEEL - PLAIN CARBON

FINISH - ENAMEL - SPRAYED AND BAKED

OUTLET REGISTERS
FIGURE 13

FINAL DESIGN

NOTE- DETAILS SAME AS BELOW EXCEPT AS NOTED



X INDICATES SPOTWELD

MATERIAL - #26 U.S. GAGE SHEET STEEL
FREE DRAWING - PLAIN CARBON

SCALE - 1/10 SIZE

FINISH - ENAMEL - SPRAYED AND BAKED

RETURN AIR REGISTER AND GRILLE
FIGURE 14

- IT MUST HAVE MEMBERS IN POSITIONS EQUIVALENT TO THOSE
- IT REPLACES TO ALLOW ATTACHING THE SURROUNDING WALL STRUCTURE.
- IT MUST BE EASILY INSTALLED AND ADAPTED TO VARIOUS FORMS OF CONSTRUCTION.

THE FRAME IS BEING DEVELOPED PRIMARILY FOR 2 INCH BY 4 INCH STUD WALL CONSTRUCTION, WITH STUDS ON 16 INCH CENTERS. THE MAIN STRUCTURAL COLUMNS WILL BE PLACED ON 32 INCH CENTERS, TO OCCUPY TWO STUD SPACES. TWO FRAMES WILL BE DESIGNED, ONE FOR USE WHEN ONLY THE SIDE OUTLETS ARE INSTALLED AND ONE FOR THE END AND SIDE OUTLETS.

A BASIC STRUCTURAL MEMBER HAS BEEN DEVELOPED COMPOSED OF A WOOD SCANTLING OF RECTANGULAR CROSS SECTION TO WHICH A FORMED STEEL ANGLE IS BONDED. THIS IS SHOWN IN FIGURE 15.

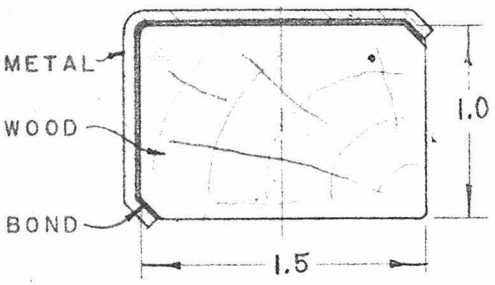


FIGURE 15- BASIC STRUCTURAL MEMBER

THE WOOD IS SELECT STRUCTURAL GRADE DOUGLAS FIR, KILN DRIED AND MILLED TO SIZE. AN EXCELLENT BONDING MATERIAL IS CASCO FLEXIBLE CEMENT* WHICH HAS GOOD WATER AND HEAT RESISTANCE, IS ECONOMICAL AND CAN EASILY BE APPLIED. SCREWS WILL BE USED AS AN ADDED FASTENING AND THE EDGES OF THE ANGLE WILL BE CRIMPED AROUND THE WOOD AS SHOWN. THE FORMED STEEL

*CASEIN COMPANY OF AMERICA, 350 MADISON AVE, NEW YORK 17, N.Y.

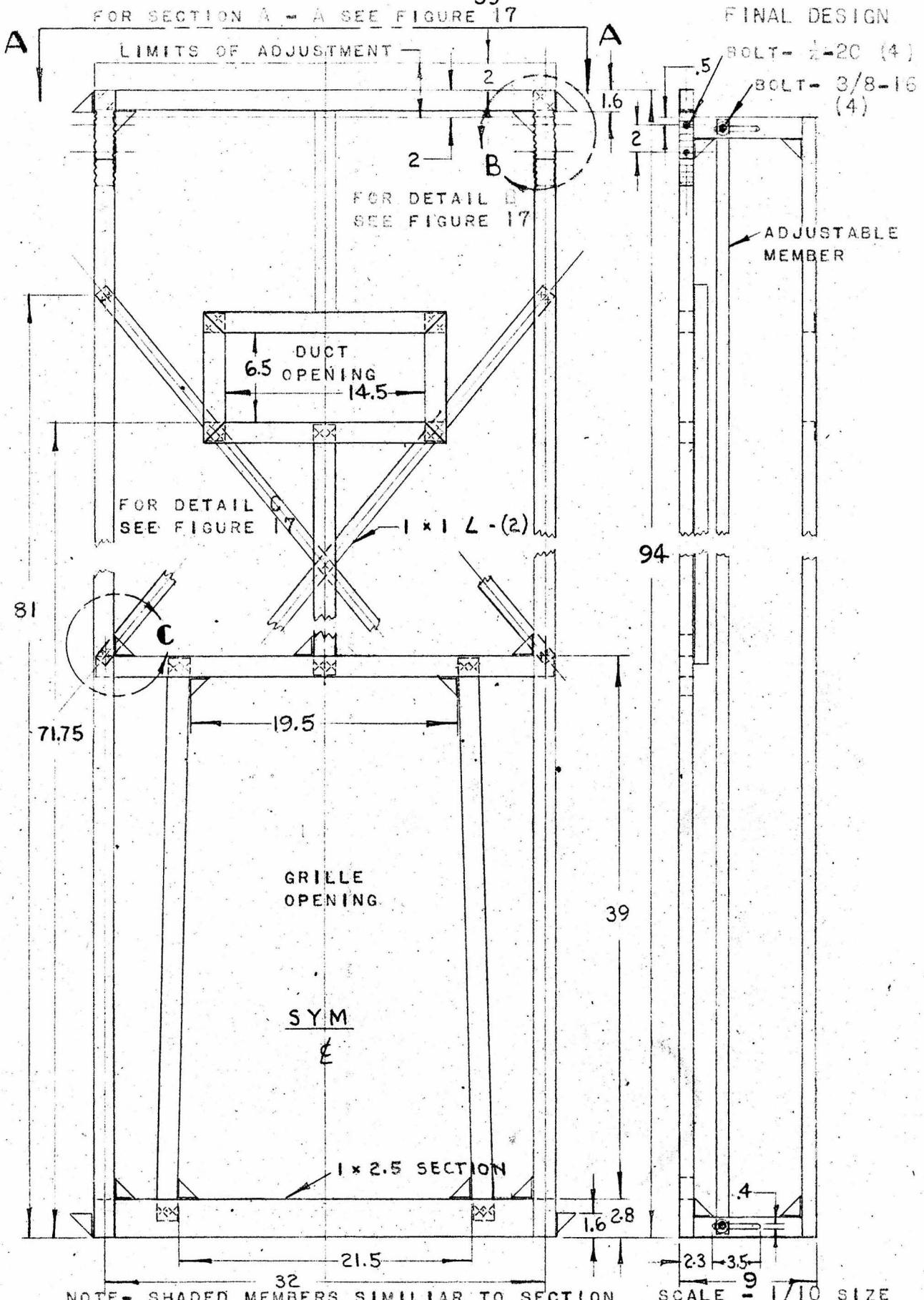
ANGLE CAN BE VARIED IN GAGE ACCORDING TO THE STRENGTH REQUIREMENTS; NO. 24 (.024 INCH) U.S. STANDARD GAGE IS THE MINIMUM THAT WILL BE EMPLOYED. AN ANALYSIS OF THE LOAD CARRYING CAPACITIES OF 2 INCH BY 4 INCH STUDDING AND THAT REQUIRED OF THE BASIC STRUCTURAL MEMBER IS IN APPENDIX E.

THE FRAMES ARE SHOWN IN FIGURE 16; IT WILL BE NOTICED THAT ONE HAS AN OVERALL DEPTH OF 9 INCHES AND THE OTHER 14 INCHES. OTHERWISE, THEY ARE THE SAME. THE STEEL AND WOOD COLUMNS ARE SO PLACED THAT THE ANGLE PROTECTS THE WOOD FROM HEAT. ADJUSTABLE COLUMN MEMBERS ARE INDICATED; USE OF THESE WILL BE DISCUSSED UNDER INSTALLATION, FOLLOWING. SUPPORTING FRAMES FOR OUTLETS ARE INCORPORATED. RIGIDITY OF THE FRAMES IN INCREASED BY THE "X" TYPE BRACING IN THE FRONT PANEL. ADJUSTABLE FLANGED MEMBERS ARE SHOWN AT THE TOP OF EACH 7 FOOT-10 INCH CORNER COLUMN; THE BOLTED FASTENINGS AND MATCHING SERRATIONS ALLOW ADJUSTMENT FOR VARIOUS HEIGHTS FROM 7 FEET-10 INCHES TO 8 FEET-2 INCHES.

THE FRAMES ARE FABRICATED FROM PLAIN CARBON STEEL SHEET, MOST MEMBERS BEING SIMPLY BRAKE FORMED. DIE FORMED ATTACHING CLIPS ARE SPOT WELDED TO ALL MEMBERS WHICH ARE TO BE BONDED TO WOOD, BEFORE BONDING. THE WOOD AND STEEL MEMBERS ARE THEN SPOTWELDED TO THE CONNECTING MEMBERS AND THE ENTIRE FRAME IS THUS ASSEMBLED. THE MINIMUM STEEL THICKNESS IS NO. 22 U.S. STANDARD GAGE.

PANEL DESIGN

A SYSTEM OF VARIABLE STEEL PANELS HAS BEEN DEVISED TO AL-



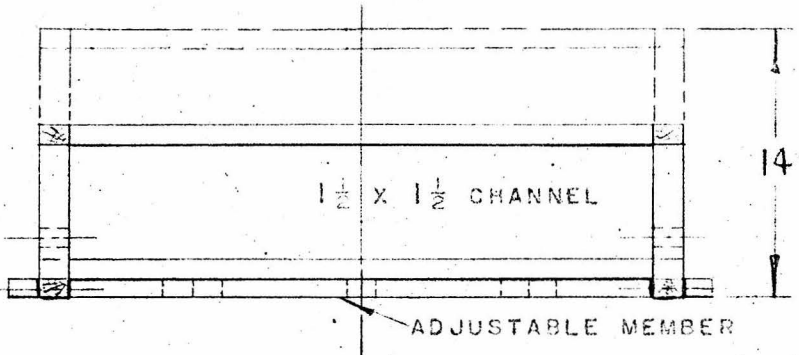
NOTE- SHADED MEMBERS SIMILIAR TO SECTION OF FIGURE 15 X INDICATES SPOTWELD

MATERIAL - #24 U.S. GAGE SHEET STEEL PLAIN CARBON

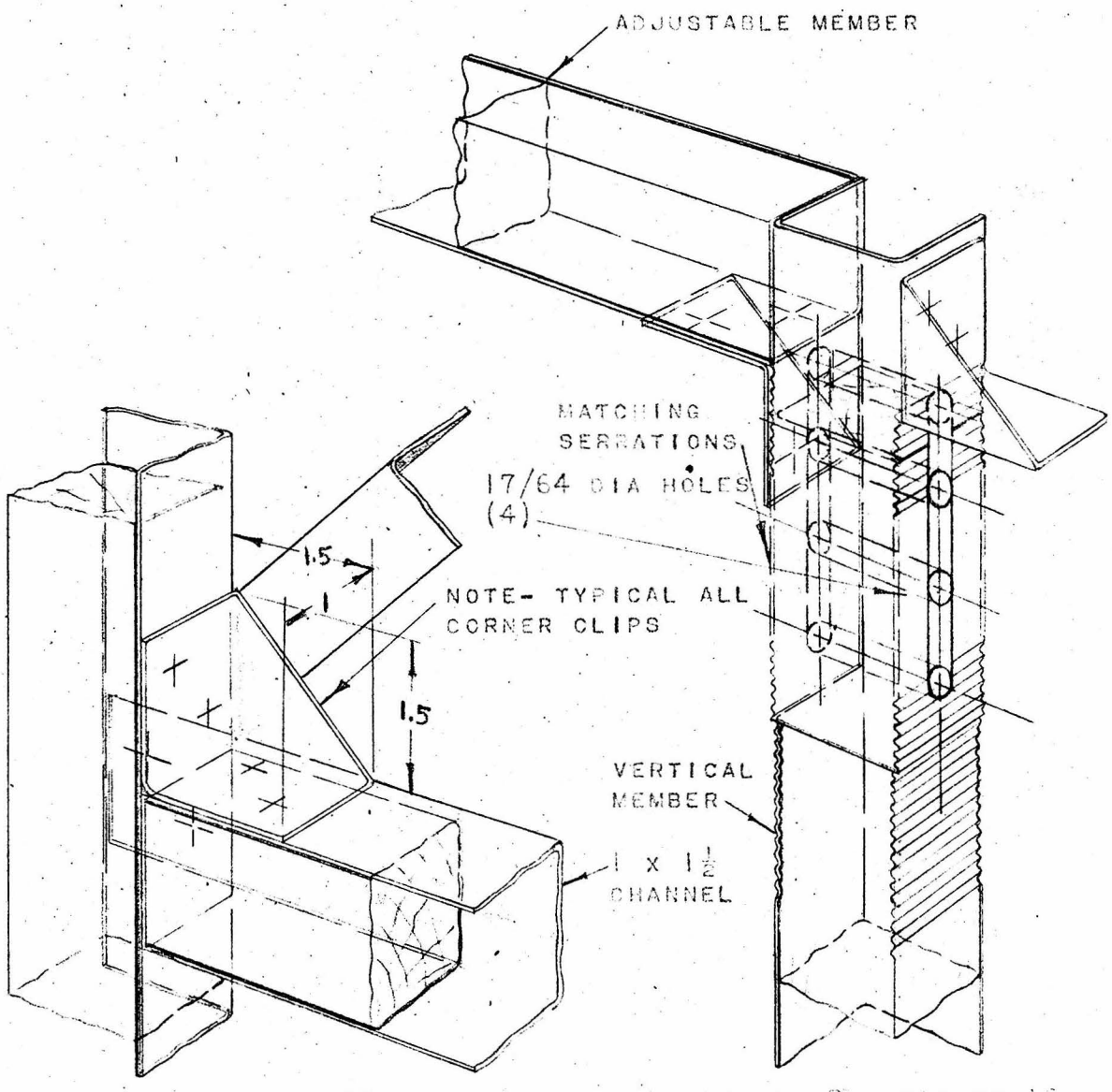
FINISH-

SCALE - 1/10 SIZE

FRAME
FIGURE 16



FRAME - PLAN VIEW
VIEW A - A OF FIGURE 16



DETAIL A - FIGURE 17

DETAIL B - FIGURE 16

X INDICATES SPOTWELD

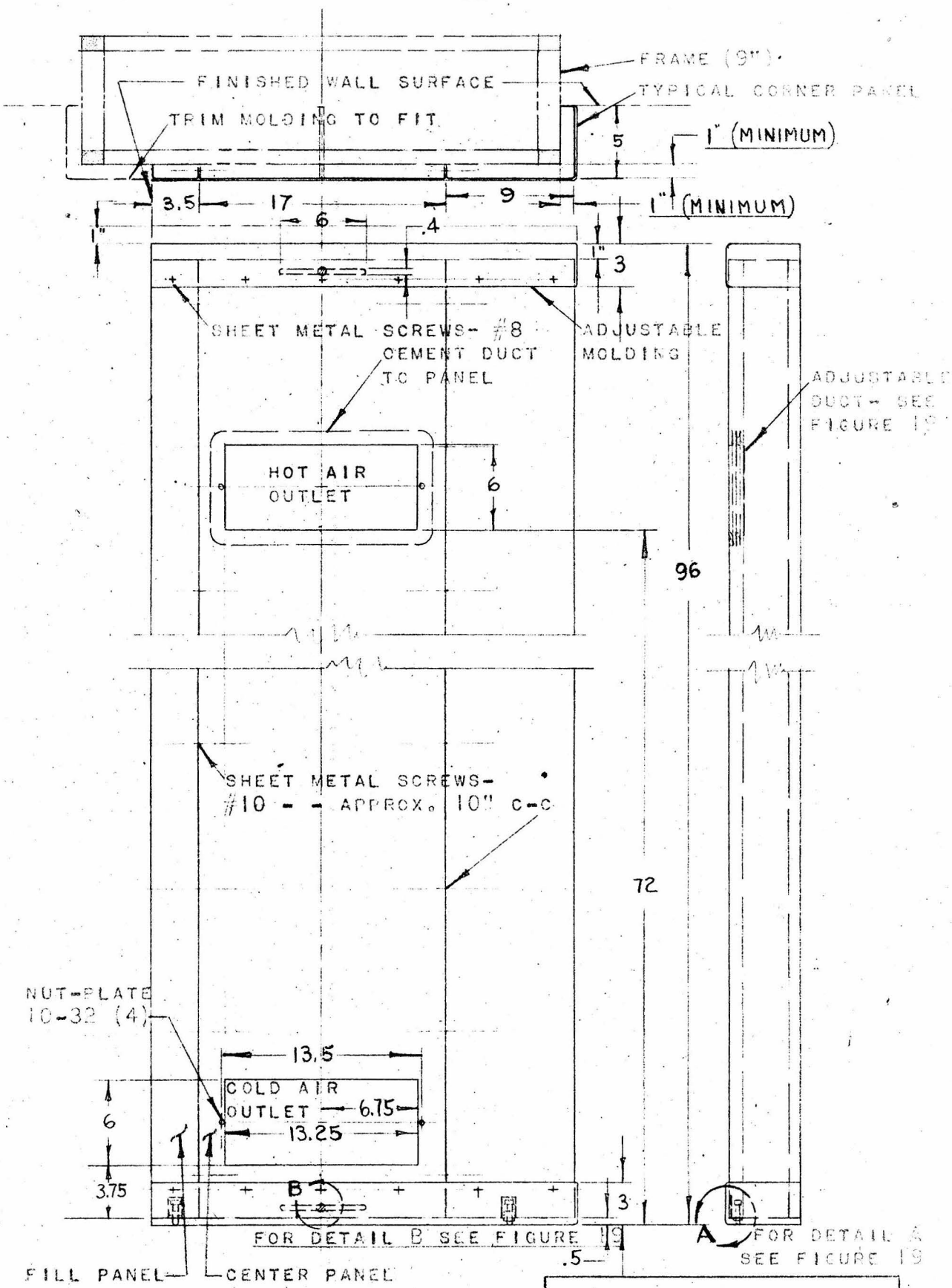
FRAME DETAILS
FIGURE 17

LOW THE HEATER TO BE INSTALLED IN MANY TYPES OF CONSTRUCTION WITH FACILITY. A TYPICAL PANEL INSTALLATION IS SHOWN IN FIGURE 18. IT WILL BE OBSERVED THAT TWO MAIN TYPES ARE EMPLOYED, CORNER PANELS AND SIDE PANELS. OPENINGS ARE PROVIDED FOR OUTLETS IN PROPER RELATIONSHIP TO THE HEATER CORE. TWO CORNER PANELS ARE EMPLOYED; A NARROW ($4\frac{1}{2}$ INCH) ONE FOR THE 9 INCH FRAME, AND A WIDE ($9\frac{1}{2}$ INCH) PANEL FOR THE 14 INCH FRAME. THE LATTER CONTAINS AN OPENING FOR THE SIDE OUTLET. FULL LENGTH INTERNAL SHIELDS ARE PROVIDED AT POINTS WHERE WALLS ARE ATTACHED, AS SHOWN.

THE ADJUSTABLE SCREW FITTING WHICH ALLOWS INSTALLATION OF THE PANEL IN VARIOUS WAYS IS SHOWN IN DETAIL IN FIGURE 19. UPPER AND LOWER MOLDINGS ARE ADJUSTABLE TO ALLOW PROPER ORIENTATION OF THE PANELS AND TO COMPENSATE FOR VARIOUS CEILING HEIGHTS. ALL RAW EDGES ARE CONCEALED. THE PANELS ARE FORMED OF NO. 26 U.S. STANDARD GAGE PLAIN CARBON STEEL SHEET.

CONTROLS

BURNER CONTROLS ARE AVAILABLE IN MANY VARIATIONS AND ARE USUALLY PURCHASED BY THE HEATER FABRICATOR FROM ORGANIZATIONS WHICH SPECIALIZE IN THEIR MANUFACTURE. IT IS RECOMMENDED THAT AUTOMATIC THERMOSTAT CONTROLS BE USED WITH A HEATER OF THE TYPE BEING DEVELOPED. THIS RESULTS IN THE MOST CONVENIENT OPERATION; MANUAL CONTROLS MAY EASILY BE PROVIDED. THE THERMOSTAT SHOULD BE REMOTELY MOUNTED IN THE LARGEST ROOM BEING HEATED IN A READILY ACCESSIBLE PLACE.



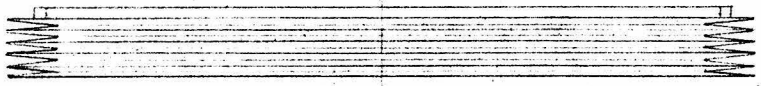
MATERIAL- #26 U.S. STANDARD GAGE SHEET STEEL- PLAIN CARBON

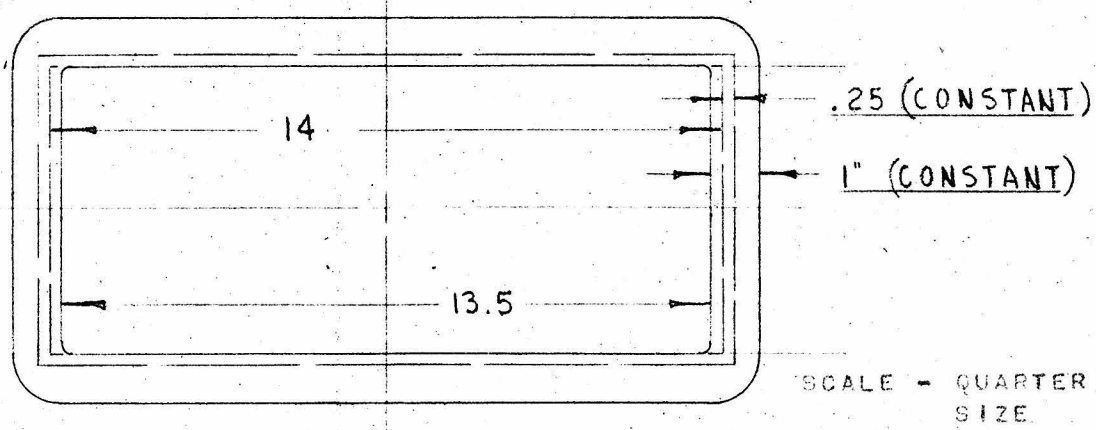
FINISH - ENAMEL - SPRAYED AND BAKED

PANELS- TYPICAL

FIGURE 18

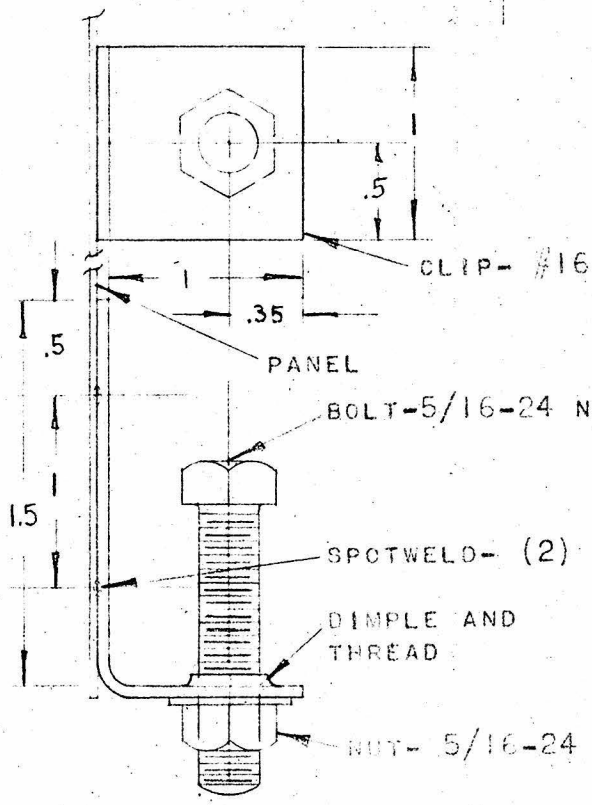
ELASTIC SECTION TO FIT
REGISTER HEAD OUTLET



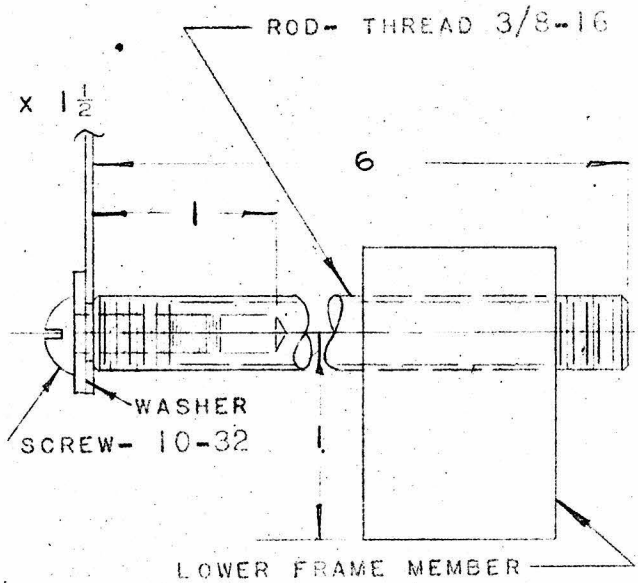


SCALE - QUARTER SIZE

DUCT - ADJUSTABLE OUTLET
MATERIAL - COTTON FABRIC IMPREGNATED WITH HEAT RESISTING SYNTHETIC RUBBER



DETAIL A - FIGURE 18



DETAIL B - FIGURE 18
(REVOLVED)

SCALE - FULL SIZE AND NOTED

PANEL DETAILS
FIGURE 19

A SEPARATE ASSEMBLY WOULD BE FABRICATED COMPRISING THE BURNER, CONTROL VALVES, AND SHIELDING. A PRESSURE REGULATOR, PILOT ASSEMBLY, AND MAIN BURNER VALVE OF $\frac{1}{2}$ INCH STANDARD PIPE SIZE WOULD BE FABRICATED AND SUPPLIED WITH THE HEATER. AN EXCELLENT SYSTEM WHICH IS AVAILABLE* IS ACTUATED BY THE PILOT PROVIDING (1) A PILOT FLAME FOR MAIN BURNER IGNITION, (2) THERMAL GENERATION OF SUFFICIENT ELECTRICAL ENERGY TO DIRECTLY OPERATE AN ENTIRE REMOTE CONTROL SYSTEM FOR THE APPLIANCE, (3) POSITIVE, AUTOMATIC SAFETY SHUT-OFF OF CONTROL SYSTEM IF PILOT FLAME FAILS. THE PILOT GENERATOR SUPPLES CURRENT NECESSARY TO OPERATE A MAGNETIC DIAPHRAGM GAS VALVE WHICH CONTROLS THE GAS SUPPLY TO THE BURNER. A REMOTELY MOUNTED ROOM THERMOSTAT HAS AN ADJUSTABLE TEMPERATURE RANGE FROM 50 TO 90^{0}F AND A NIGHT CUTOFF SWITCH; IT IS SAID TO HAVE A SENSITIVITY TO $\frac{1}{2}^{0}$F. IN CASE THE PILOT FLAME FAILS, THE GENERATION OF CURRENT CEASES, AND THE GAS VALVE IS AUTOMATICALLY AND PERMANENTLY CLOSED.

THE BURNER ASSEMBLY WOULD INCLUDE SHIELDING ON BOTTOM AND SIDES, ATTACHING ANGLES, AND MOUNTING BRACKETS FOR THE COMBUSTION CHAMBER AND SHIELDING.

ASSEMBLY

AN ASSEMBLY DRAWING IS SHOWN IN FIGURE 20; THE METHOD OF ASSEMBLY IS DESCRIBED UNDER INSTALLATION.

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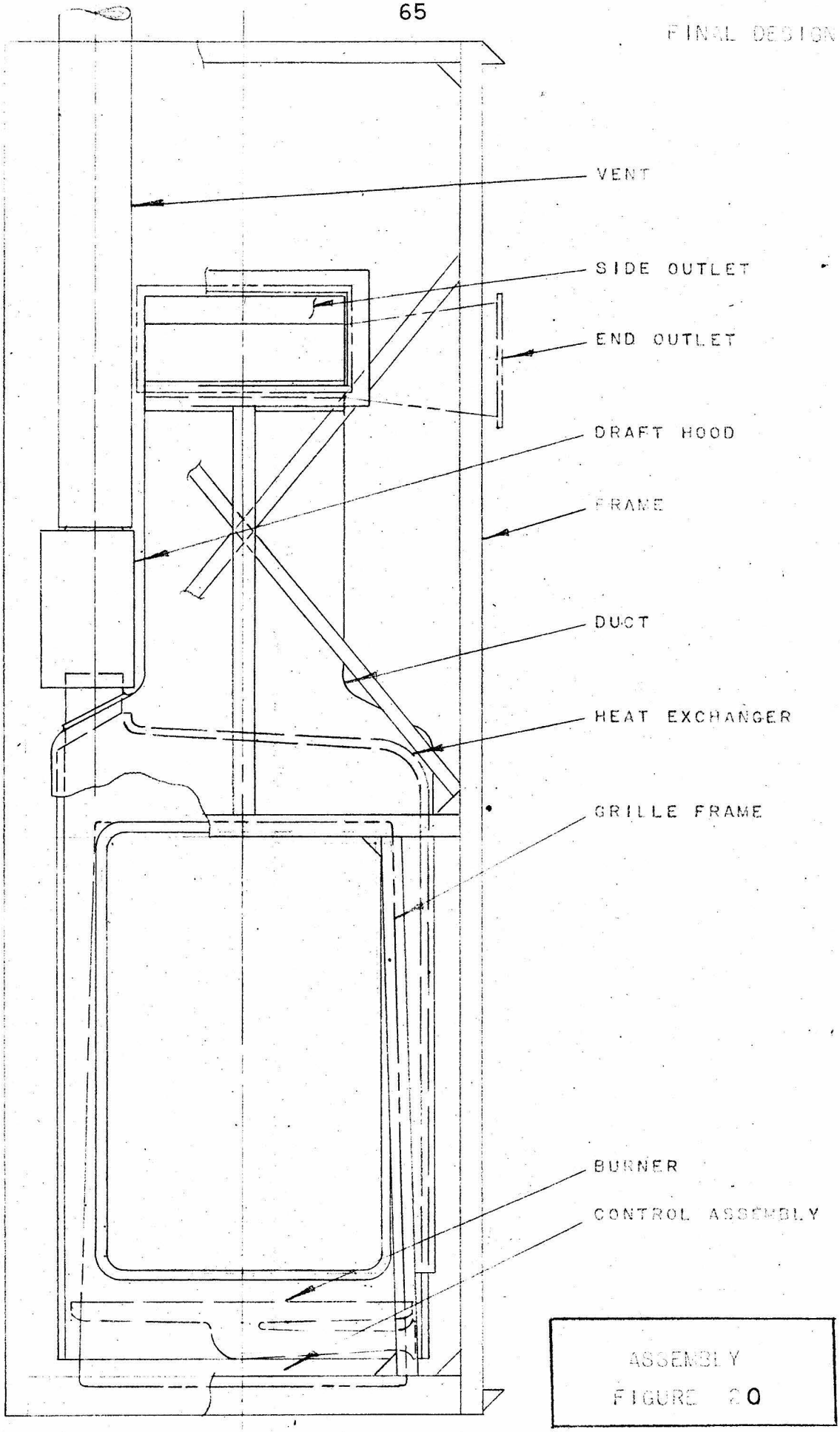
*B-60 GAS ACTUATED PACKAGE SET; GENERAL CONTROLS CO., GLENDALE, CALIF.



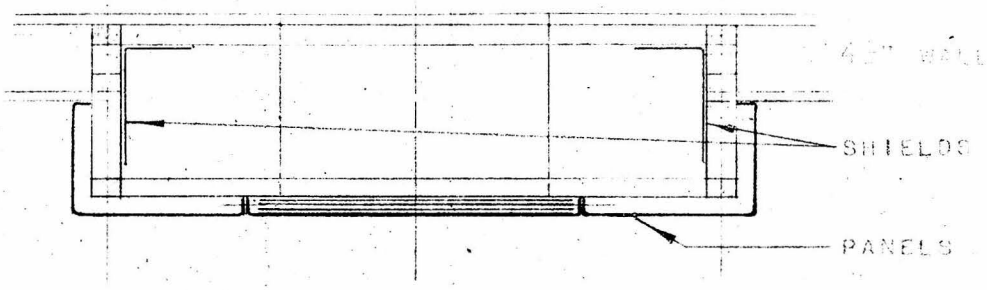
ASSEMBLY
FIGURE 20

INSTALLATION

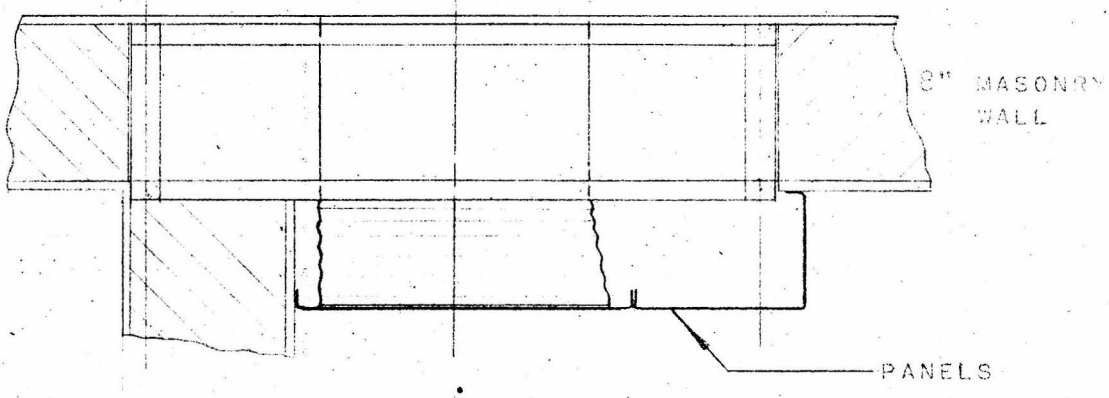
THE SEVERAL WALL ARRANGEMENTS IN WHICH THE HEATER CAN BE INSTALLED ARE SHOWN IN FIGURE 21; ALL OTHER PRACTICAL INSTALLATIONS ARE VARIATIONS OF THOSE ILLUSTRATED. IT WILL BE NOTICED THAT GENERALLY ONE SIDE AND ONE END ARE FINISHED TO HARMONIZE WITH WALL CONSTRUCTION; THE REMAINING SIDES ARE ENCLOSED WITH THE STEEL PANELS. ONE SIDE OF THE HEATER MUST ALWAYS BE ENCLOSED WITH THE STEEL PANELS TO PROVIDE ACCESSIBILITY TO THE CORE.

METHOD OF INSTALLATION IN 2 INCH BY 4 INCH FRAME CONSTRUCTION IS AS FOLLOWS: HEATER FRAME IS INSTALLED WHEN HOUSE FRAMING IS ERECTED. LOWER CHANNELS OF FRAME WILL BE RESTED ON SUBFLOORING AND BRACKETS PROVIDED NAILED TO PLATES. ADJUSTABLE FITTINGS ON THE FRONT UPPER CORNERS WILL BE NAILED TO HEADERS AND BOLTS THROUGH FITTINGS TIGHTENED. LATHING OR SHEATHING MAY BE NAILED TO THE WOOD MEMBERS OF THE FRAME; THE VERTICAL COLUMNS, UPPER AND LOWER CHANNELS, AND THE OUTLET FRAMES MAY BE EMPLOYED. AS SHOWN, THE ADJUSTABLE COLUMN MEMBERS ARE USED TO ATTACH THE NECESSARY WALL SHEATHING AT EITHER THE SIDE OR THE END OF THE FRAME. FINISH MAY THEN BE APPLIED TO THE WALLS. INTERNAL SHIELDS ARE INDICATED WHERE WALLS ATTACH; THEY KEEP THE TEMPERATURES WITHIN LIMITS AND PREVENT DRAFT HOOD SPILLAGE FROM ENTERING THE WALLS. STANDARD $\frac{1}{2}$ INCH GAS PIPING SHOULD BE LED THROUGH THE SUBFLOOR AND PROVISIONS FOR THE VENT SHOULD BE MADE.

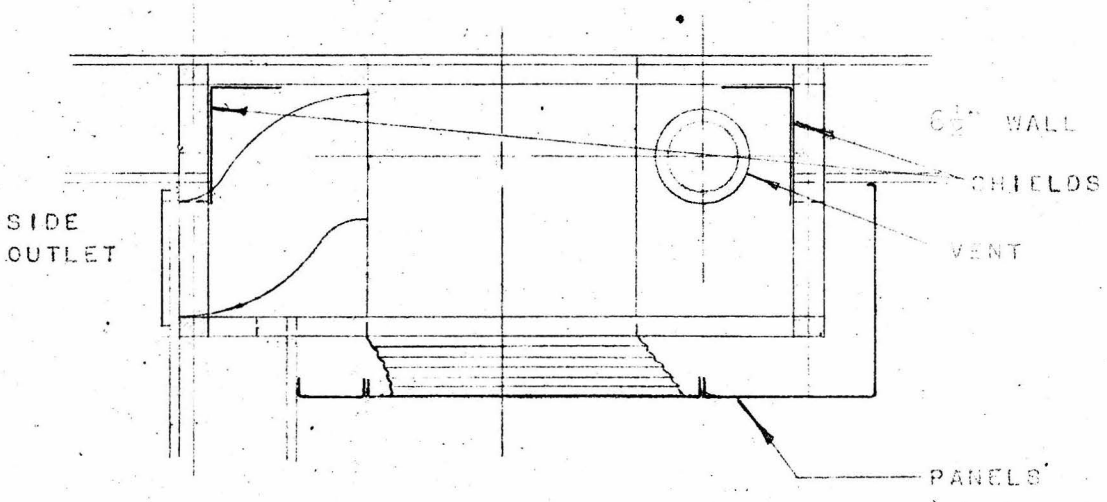
WHEN INSTALLING THE CORE, THE SHIELDED BURNER AND CONTROL



FLEXIBLE DUCT



SHALLOW (9") FRAME



DEEP (14") FRAME

INSTALLATION ARRANGEMENTS

FIGURE 21

ASSEMBLY WILL FIRST BE PLACED AT SPECIFIED DISTANCE ABOVE THE SUBFLOOR BY CLIPS ATTACHED TO THE FRAME. THE HEAT EXCHANGER WILL BE FASTENED TO THE BURNER ASSEMBLY AT BRACKETS PROVIDED. IF AN END OUTLET IS TO BE EMPLOYED, THE REVERSIBLE HEAT EXCHANGER WILL BE SO PLACED THAT THE VENT WILL BE AT THE OPPOSITE END FROM THE OUTLET. THE LOWER DUCT AND TRANSITION SECTION SHOULD BE PLACED ON BRACKETS WITH DUE REGARD FOR RADIANT OUTLET, IF EMPLOYED. THE UPPER DUCT AND REGISTER HEAD AND SIDE OUTLET, IF ANY, ARE INSTALLED NEXT AND TRIMMED FLUSH WITH WALL SURFACES. THE VENT MAY BE INSTALLED WITH DRAFT HOOD IN PLACE. WHEN THE LARGE FRAME IS USED, AN ADJUSTABLE DUCT IS SCREWED TO THE SIDE REGISTER OUTLET AND TRIMMED FLUSH WITH WALL AFTER FINISHING. NEXT, PANELS MAY BE ATTACHED TO ADJUSTABLE CLIPS; THEY ARE DESIGNED TO FIT FLUSH AGAINST THE WALL SURFACES AND THE DISTANCE FROM THE FRAME IS VARIABLE. REGISTERS MAY BE FASTENED TO CLIPS IN OUTLET DUCTS BY SCREWS, THE RUBBER GASKETS SEALING AGAINST THE WALL SURFACES. HEATER MAY BE CONNECTED AND TESTED; THE GRILLE VANES SHOULD BE ADJUSTED FOR DIFFUSION PATTERN.

IT IS PROBABLE THAT A TOTAL OF THREE OUTLETS COULD BE EMPLOYED IN VARIOUS COMBINATIONS. HENCE, WHEN THE RADIANT PANEL IS USED, ONLY TWO OUTLET REGISTERS MAY BE INSTALLED. THE LOSS IN CIRCULATING AIR FLOW WHEN USING THE RADIANT PANEL CAUSES THIS RESTRICTION.

APPEARANCE

THE HEATER APPEARANCE HAS BEEN CAREFULLY DEVELOPED TO HARMONIZE WITH CONTEMPORARY ARCHITECTURE. THUS, THE LINES ARE RECTILINEAR IN NATURE AND AN ATTEMPT HAS BEEN MADE TO AVOID SOFT, ROUNDED SURFACES OF THE SO-CALLED STREAMLINE TYPE. ONLY THE GRILLES, THROUGH WHICH AIR FLOWS SHOULD EXHIBIT STREAMLINING AND THIS HAS BEEN EXTENDED ONLY TO THE TREATMENT OF THE VANES.

THE VERTICAL VANES IN THE GRILLES WERE DICTATED BY FUNCTION; THEY HAVE BEEN PROPORTIONED TO PREVENT SEEING INTO THE HEATER. THE GRILLE AND COLD AIR RETURN REGISTER HAVE BEEN UNIFIED BY THE TREATMENT OF THE VERTICALS. SLIGHTLY TAPERED SURFACES FROM FLOOR TO TOP REDUCE THE APPARENT SPACE OCCUPIED BY THE GRILLE.

THE EXTERNAL FINISH OF THE GRILLE ASSEMBLY AND THE PANELS WOULD BE BAKED ENAMEL OF WARM, LIGHT COLORS SUCH AS IVORY OR TAN. THE REGISTERS, WHEN MOUNTED IN A FINISHED WALL, COULD BE PAINTED TO MATCH; PRIME COATINGS ONLY WOULD BE FACTORY APPLIED. THE HEAT EXCHANGER SURFACE WOULD BE FINISHED WITH A HEAT RESISTING PORCELAIN ENAMEL OF THE SINGLE COAT TYPE. A LIGHT BLUE GRAY COLOR CAN BE OBTAINED IN THIS MATERIAL.

CONCLUSION

A GAS FIRED SPACE HEATER HAS BEEN DEVELOPED WITH THE FOLLOWING FEATURES NOT OFFERED IN THOSE NOW ON THE MARKET:

- THE FRAME IS AN INTEGRAL PART OF THE HOUSE AND SPECIAL FRAMING HAS BEEN ELIMINATED.
- A MODULAR PANEL SYSTEM ELIMINATES CUTTING AND FITTING OF SPECIAL PANELS
- VARIABLE OUTLET COMBINATIONS PROVIDE OUTSTANDING FLEXIBILITY OF INSTALLATION.

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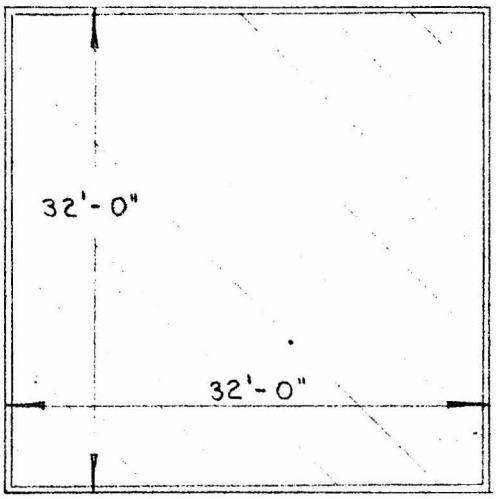
TABLE 5

VENTED WALL CIRCULATOR SPACE HEATERS APPROVED BY THE AMERICAN GAS ASSOCIATION

MANUFACTURER	ADDRESS	TRADE NAME	MODEL NUMBERS	RATED INPUT Btu $\times 10^3$	FUELS USED: NATURAL GAS	FUELS USED: MANUFACTURED GAS	FUELS USED: LIQUIFIED PETROLEUM GAS	ROUGH DIMENSIONS IN: HEIGHT	ROUGH DIMENSIONS IN: WIDTH	ROUGH DIMENSIONS IN: WALL THICKNESS	OVERALL DIMENSIONS: HEIGHT	OVERALL DIMENSIONS: WIDTH	OVERALL DIMENSIONS: DEPTH	VENT SIZE	APPROXIMATE SHIPPING WEIGHT	FINISH	BURNER TYPE	EQUIPMENT	RETAIL PRICE	APPEARANCE	REMARKS
ANDREWS HEATER CO.	1750 W. JEFFERSON LOS ANGELES 7, CALIF.	SHALLOW PITLESS	S-25 TVD	25	✓	✓		16"	22"	4"	17½"	24½"	WITH FLOOR 19"	3" ROUND	118 LBS.			LOW PRESSURE GAS REGULATOR MANUAL BURNER AND PILOT VALVE		PLEASING, SIMPLE MODERN STYLING	GRADE TO FLOOR MUST BE 27" FOR 5" CLEARANCE
			-37.5	37.5	✓	✓		20	24	4	23½	27¼	24	3-4 "	145	BAKED ENAMEL	RAISED PORT CAST IRON				
			-45	45	✓	✓		20	24	6	23½	27¼	26¾	4" "	154						
			-50	50	✓	✓		20	22	6	23½	25½	33	4" "	200						
			-60	60	✓	✓		20	24	6	23½	27¼	36	4" "	200						
* COMMONWEALTH COMPANY	2127 W. COMMONWEALTH AVE. ALHAMBRA CALIF.	COMMON-WEALTH	L-15 SWH	15	✓	✓	✓	36½"	24½"	4"	37½"	28¼"	FINISHED 5½"	4" ROUND	82 LBS.	PRIMED ALUMINUM (CAN BE PAINTED)		SAME AS ABOVE	$82.90	OVER STYLED	
			-20	20	✓	✓	✓	43	24½		44	28¼	10¼		94				97.23		
			-28	28	✓	✓	✓	43	24½		44	28¼	12¼		108				98.82		
			-38	38	✓	✓	✓	43	26½		44	30¼	14¼		131				100.82		
			L-20 DWH	20	✓	✓	✓	43	24½		44	28¼	5½		125				104.25		
			28	28	✓	✓	✓	43	24½		44	28¼	7½		137				106.00		
			38	38	✓	✓	✓	43	26½		50	30¼	9½		152				108.20		
			48	48	✓	✓	✓	49½	26½		50	30¼	12½		196				115.00		
			58	58	✓	✓	✓	49½	26½		50	30¼	15½		216				123.35		
DAY AND NIGHT MANUFACTURING COMPANY	BOX 150 MONROVIA CALIF.	PANELRAY	10 WP	10	✓	✓	✓	58⅝	10¼	4"	59⅜	13³/₁₆	5¼	OVAL 2⅛ × 5⅝				SAME AS ABOVE		GOOD	
			20	20	✓	✓	✓		14¼			17¹¹/₁₆	5¼	" × 7³/₁₆							
			30	30	✓	✓	✓		17¾			21³/₁₆	5¼	" × 9³/₁₆							
			10-10 WP	20	✓	✓	✓		10¼			13³/₁₆	6¾	" × 5⅝							
			10-20	30	✓	✓	✓		14¼			17¹¹/₁₆	6¾	" × 7³/₁₆							
			20-20	40	✓	✓	✓		14¼			17¹¹/₁₆	6¾	" × 7³/₁₆							
HAMMEL RADIATOR ENGINEERING CO.	3376 MOTOR AVE. LOS ANGELES 34, CALIF.	HAMMEL	WH-12	11.5	✓	✓	✓	31	14	4				3" OVAL		BAKED ENAMEL		SAME AS ABOVE		FAIR	
			30	30	✓	✓	✓	37½	30	4				"							
			40	45	✓	✓	✓	41½	30	6				4" ROUND							
HOLLY MANUFACTURING CO.	875 SO. ARROYO PKWY. PASADENA 2, CALIF.	HOLLY	37W	37	✓	✓	✓	* 51	27¾	4	51½	28¾	5¼	4" OVAL		BAKED ENAMEL	SLOTTED PORT	SAME AS ABOVE		GOOD	*BOTTOM MUST BE > 3" FROM FLOOR
			45W	45	✓	✓	✓	51	27¾	8	51½	28¾	9	4 ROUND							
HEATING RESEARCH CORP.	BOX 391 ANDERSON, INDIANA	SAF-AIRE	10	10	✓	✓	✓	23¼	14	4	25	18¼	9¼	LUNSTRUM EXTERIOR		BAKED ENAMEL		SAME AS ABOVE		OVER STYLED	EXTERIOR WALL INSTALLATION ONLY
			20	20	✓	✓	✓	23¼	14	4	25	18¼	9¼								
IDEAL HEATING CORPORATION	807 E. GAGE AVE. LOS ANGELES 1, CALIF.	IDEAL	60-6W	60	✓	✓		52¼	25¾	17⅛						BAKED ENAMEL		SAME AS ABOUT		POOR	
PAYNE FURNACE CO.	336 NO. FOOTHILL RD. BEVERLY HILLS, CALIF.	PANELAIR	55 PA	40	✓	✓	✓	84	29⅜	9⅜	84	29⅜	9⅜	4" ROUND	260	BAKED ENAMEL	SLOTTED PORT	PRESSURE REGULATOR THERMOSTAT	236.00	FAIR	BUILT IN FURRED SECTION OR CLOSET
			55 PA	55	✓	✓	✓	84	29⅜	9⅜	84	29⅜	9⅜	4 "	260						
ROYAL HEATERS, INC.	1024 WESTMINSTER AVE ALHAMBRA, CALIF.	JET-FLOW	25W	25	✓	✓	✓	96	29	9	96	32¼	14½	4" ROUND	195			LOW PRESSURE GAS REGULATOR MANUAL BURNER AND PILOT VALVE		FAIR	
			38 W	38	✓	✓	✓	96	29	13½	96	32¼	19		220						
			45 W	45	✓	✓	✓	96	29	13½	96	32¼	19		220						
			55 W	55	✓	✓	✓	96	35	13½	96	38¼	19		250						
UNIVERSAL METAL PRODUCTS	2940 E. OLYMPIC BLVD. LOS ANGELES 23, CALIF.	HEATMASTER IN-THE-WALL	38SW	38	✓	✓	✓	48	30	4	49	31		4" OVAL	141	BAKED ENAMEL	SLOTTED PORT	SAME AS ABOVE		FAIR	
			45DW	45	✓	✓	✓	48	30	4	49	31		"	153						
UTILITY APPLIANCE CORP.	4851 S. ALAMEDA ST. LOS ANGELES 11, CALIF.	WALL-O-MATIC	50WD	50	✓	✓	✓	51⅛	24⅜	4	51¾	26	11⁹/₁₆	4" OVAL	200	BAKED ENAMEL		SAME AS ABOVE		GOOD	
WILLIAMS RADIATOR CO.	1821 FLOWER ST. GLENDALE 1, CALIF.	WARMOLATOR	35 W	35	✓	✓	✓	43¼	22¾	4	48¾	26¼	9¼	4" OVAL	135	BAKED ENAMEL		SAME AS ABOVE		FAIR	
			45 W	45	✓	✓	✓	49	23⅜	4	50	25¼	11¾	"	155						
*BARNES HEATING-VENTILATING CO.	449 W. ANAHEIM ST. LONG BEACH 6 CALIF.	BARNES	20	20	✓	✓		58⅝	14¼	4	59¾	16½	6¾	4" OVAL		HAMMERTONE	SLOTTED PORT	SAME AS ABOVE		GOOD	

HEATING LOAD FOR SMALL RESIDENCE

REFERENCE - HEATING, VENTILATING, AND AIR CONDITIONING GUIDE, 1947



ASSUMPTIONS -

1. AREA = 1000 $ft.^2$
2. CEILING HEIGHT = 8 ft.
3. WALL AREA ≅ 1000 $ft.^2$
4. 25% WALL AREA DOORS AND WINDOWS
5. ENTIRE AREA HEATED
6. SOUTH PACIFIC COAST DESIGN TEMPERATURES
7. INSIDE TEMPERATURE = 65°F
   OUTSIDE " = 30°F
   WIND VELOCITY = 15 $\frac{mi.}{hr.}$
   (REF. - PAGES 244, 245)

TOTAL HEAT LOSS RATE, H_t: (REF. - PAGE 379)

$$H_t = A\left(G + U_w + U_c + U_f\right)(t_d - t_o)$$

WHERE:
- A = FLOOR AREA
- G = GLASS AND INFILTRATION FACTOR
- U_w = TRANSMISSION COEFFICIENT, WALL
- U_c = " " , CEILING
- U_f = " " , FLOOR
- t_d = DESIGN TEMPERATURE, INSIDE
- t_o = " " , OUTSIDE

CONSTRUCTION

1. DOORS AND WINDOWS - SINGLE THICKNESS WITH WEATHERSTRIPPING G = .40
2. WALLS - 2 in. × 4 in. STUDS WITH 1 in. WOOD SHEATHING, BUILDING PAPER AND STUCCO EXTERIOR; $\frac{1}{2}$ in. INSULATING BOARD, LATH AND PLASTER INTERIOR - U_w = .19 (REF. - PAGE 126)
3. FLOOR - DOUBLE WOOD FLOOR ON JOISTS - $\frac{25}{32}$ in. PINE SUBFLOOR AND $\frac{13}{16}$" HARDWOOD FINISH FLOORING - U_f = .34 (REF. PAGE 132)
4. ROOF - FLAT, WITH LATH AND PLASTER CEILING; WOOD - $\frac{1}{2}$ in INSULATING BOARD AND BUILT UP ROOFING = $1\frac{1}{2}$ in - U_f = .19 (REF. PAGE 135)

$$H_t = 1000\ ft^2\left(.40 + .19 + .34 + .19\right)\frac{Btu}{hr \cdot ft^2 \cdot °F}(65 - 30)°F = \underline{39\,200\ \frac{Btu.}{hr.}}$$

GRID GAS BURNER-EVALUATION

REFERENCE - PRIMARY AIR INJECTION CHARACTERISTICS OF ATMOSPHERIC GAS BURNERS - BULLETIN #26, AMERICAN GAS ASSOCIATION, MAY 1944

THE BURNER DESCRIBED ON PAGES 25-28 AND SHOWN IN FIGURE 7 WILL BE USED TO OBTAIN A PERFORMANCE CONSTANT, K, WHICH WILL BE SUITABLY MODIFIED FOR APPLICATION TO THE SPACE HEATER UNDER DEVELOPMENT

FOR AN ATMOSPHERIC INJECTION BURNER, PERCENT PRIMARY AIR, P_a:

$$P_a = K \frac{\sqrt[4]{A_m \times A_p}}{\sqrt{R}} \times \frac{\sqrt[4]{Pd}}{\sqrt{H}} \times \sqrt{\frac{T_1}{T_2}}$$

WHERE:

(REFERENCE - PAGES 33-36)

- K = BURNER PERFORMANCE CONSTANT
- A_m = AVERAGE AREA MIXING TUBE, in^2
- A_p = TOTAL PORT AREA, in^2
- R = BURNER INPUT, $\frac{Btu}{hr.}$
- P = GAS PRESSURE, in. H_2O equiv.
- d = GAS DENSITY - (AIR = 1.0)
- H = GAS HEATING VALUE - $\frac{Btu}{ft^3}$
- T_1 = ABSOLUTE TEMPERATURE, AIR GAS MIXTURE, MIXING TUBE
- T_2 = ABSOLUTE TEMPERATURE, AIR GAS MIXTURE, BELOW BURNER PORTS

FOR GRID GAS BURNER, TESTS HAVE SHOWN:

WHEN $A_m = A_p = .5\ in^2$; $T_1 = T_2 = 80°F + 460° = 540°R$;
THEN $R = 20\,000\ \frac{Btu}{hr}$ AND $P_a = 80\%$; AT
AGA TEST CONDITIONS: $P = 7$ in, $d = .65$, AND $H = 1135\ \frac{Btu}{ft^2}$

$$\sqrt[4]{\frac{Pd}{H^2}} = \sqrt[4]{\frac{(7.0)(.65)\ in}{\left(1135\ \frac{Btu}{ft^3}\right)^2}} = .0434$$

FOR K

$$K = \frac{P_a \sqrt{R}}{.0434} \times \frac{1}{\sqrt{A_m A_p}} \times \sqrt{\frac{T_2}{T_1}} = \frac{80\sqrt{20000}}{.0434\sqrt[4]{(.5)(.5)}} \sqrt{\frac{540°}{540°}}$$

$$K = \underline{3.69 \times 10^5}$$

GAS BURNER DIMENSIONS

REFERENCE - SAME AS PRECEEDING PAGE

ASSUME

$K' = 80\%\, K = .80\,(3.69 \times 10^5) = 2.95 \times 10^5$

$P_d = 80\%$, $A_m = A_p$, $R = 55\,000 \frac{Btu}{hr}$

FOR PORT AREA, A_p, FROM PROCEEDING:

$$\frac{\sqrt{R}}{\sqrt{A_p}} = \frac{K'}{P_d}\sqrt[4]{\frac{Pd}{H^2}} \times \sqrt{\frac{T_1}{T_2}}$$

$$\frac{R}{A_p} = \frac{K'^2}{P_d^2} \times \frac{\sqrt{Pd}}{H} \times \frac{T_1}{T_2} = \frac{(2.95 \times 10^5)^2 (4.34 \times 10^{-2})^2}{6.4 \times 10^3}\left(\frac{540}{860}\right) = .63\frac{(2.95)^2(4.34)^2}{6.40} \times 10^3$$

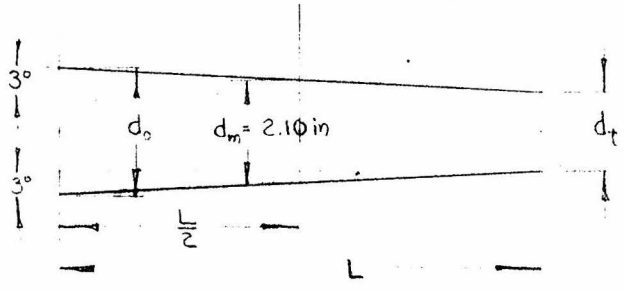
$$\frac{R}{A_p} = 16\,100 \frac{Btu}{hr \cdot in.^2}$$

$$A_p = \frac{55\,000\ Btu \cdot hr \cdot in^2}{16100\ Btu \cdot hr} = \underline{3.42\ in^2 - \text{TOTAL PORT AREA}}$$

MIXING TUBE AVERAGE DIAMETER, d_m ($A_p = A_m$)

$$d_m = \sqrt{\frac{3.42 in^2}{.785}} = \underline{2.10\ in}$$

MIXING TUBE THROAT AND OUTLET



MIXING TUBE SECTION

FOR d_t AND d_o

$$d_m = \frac{d_o + d_t}{2}$$

$$d_o = 2d_m - d_t$$

AND

$$d_o = d_t + 2L \tan 3°$$

$$d_o = d_t + .10L$$

HENCE,

$$2d_t = 2d_m - .10L$$

SINCE $d_m = 2.10$ in., AND ASSUME $L = 10$ in;

$d_t = (2.10 - .5)$ in $= \underline{1.60\ in.}$

$d_o = 1.60 + (.10)(10) = \underline{2.60\ in.}$

GAS BURNER DIMENSIONS (CONTINUED)

FOR GRID PORT SIZE : (SEE FIGURE 8)

ASSUME ; GRID THICKNESS , t, = .10 ; BURNER LENGTH = 24 in.

TOTAL PORT LENGTH , l_p

$$l_p = \frac{3.42\ in^2}{.10\ in} = 34.2\ in$$ (17.1 inches per side of burner)

SPACE BETWEEN PORTS IS $\frac{24 - 17.1}{24} \times 100\% = \underline{29\%}$

ASSUME : BURNER PORTS , .10 in. × .20 in. , SPACES .07in × .10 in

DEPTH OF PORT = 2 × WIDTH OR .40 in.

NUMBER OF PORTS PER SIDE, n_p, IS $\frac{3.42\ in^2}{2 \times .10 \times .20\ in^2} = \underline{85.5 \text{ OR } 86}$

NOISE OF EXTINCTION OF BURNER

REFERENCE - RESEARCH IN FUNDAMENTALS OF ATMOSPHERIC GAS BURNER DESIGN; RESEARCH BULLETIN #10; AMERICAN GAS ASSOCIATION; MARCH, 1940

CALCULATION OF EXPRESSION FOR NOISE OF EXTINCTION

THE NOISE OF EXTINCTION HAS BEEN EXPERIMENTALLY DETERMINED TO BE A FUNCTION OF THE FOLLOWING: (REF. PAGE 140)

$$\frac{D^2 A}{L}\left(\frac{a}{.0089}\right)^2\left(\frac{T}{560}\right)^{.17L}$$

WHERE:

D = AVERAGE DIAMETER OF MIXER TUBE, in.
A = TOTAL PORT AREA, in^2
L = LENGTH OF MIXER TUBE, in.
a = AREA OF INDIVIDUAL PORT, in^2
T = ABSOLUTE TEMPERATURE OF MIXER TUBE, °K

FOR THE BURNER BEING DESIGN:

D = 2.10 in A = 3.42 in^2 L = 10.0 in T = 400°+460° = 860°R.

AS HAS BEEN SHOWN PREVIOUSLY.

ALSO, FOR RECTANGULAR PORT, REFERENCE, PAGES 136-137, GIVES FOR a THE AREA OF THE EQUIVALENT ROUND PORT WHOSE DIAMETER, d_e, IS $\frac{t}{.70}$, APPROXIMATELY, WHERE t IS THE THICKNESS OF THE RECTANGULAR PORT.

HENCE, $a = .785\left(\frac{t}{.70}\right)^2 = .785\left(\frac{.10}{.70}\right)^2 = .016\ in^2$

THEREFORE:

$$\frac{D^2 A}{L}\left(\frac{a}{.0089}\right)^2\left(\frac{T}{560}\right)^{.17L} = \frac{(2.10)^2(3.42)}{10}\left(\frac{.016}{.0089}\right)^2\left(\frac{860}{560}\right)^{1.7} = (5.16)(3.23)(2.07)$$

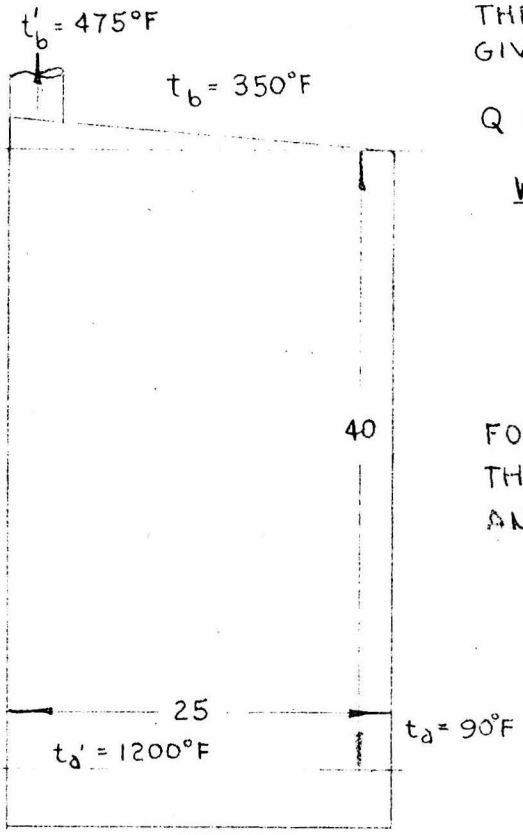
$$= \underline{34.6}$$

THE REFERENCE DATA GIVES PERMISSIBLE PRIMARY AIR INJECTION PLOTTED AGAINST VALUES OF THE ABOVE FROM 0.0 TO 0.3. THE VALUE COMPUTED IS SEEN TO EXCEED THIS RANGE BY MANY TIMES. HENCE, NO COMPARISON IS POSSIBLE

CALCULATED HEAT EXCHANGER AREA

REFERENCE - FAIRES, VIRGIL M., APPLIED THERMODYNAMICS; THE MACMILLAN COMPANY, 1938

A CALCULATION OF THE HEAT EXCHANGE BY CONVECTION OF THE EFFECTIVE AREA OF THE HEAT EXCHANGER AS DESIGNED IS SHOWN BELOW. A CONCEPT OF PARALLEL FLOW EXCHANGE HAS BEEN EMPLOYED.



ASSUMED EFFECTIVE AREA AND TEMPERATURES - HEAT EXCHANGER

THE TOTAL HEAT EXCHANGE IS GIVEN BY : (REFERENCE, PAGE 362)

$$Q = U A \Delta t_m$$

WHERE

Q = TRANSFERRED HEAT, $\frac{Btu}{hr.}$

U = COEFFICIENT OF TRANSMITTANCE, $\frac{Btu.}{hr.ft^2.°F}$

A = AREA, ft^2

Δt_m = LOGARITHMIC MEAN TEMPERATURE DIFFERENCE, °F

FOR PARALLEL FLOW OF GAS IN THIN METAL WALL EXCHANGER, AND FREE CONVECTION :

$$U = 3 \frac{Btu}{hr.ft^2.°F}$$ (REF. PAGE 361)

$$\Delta t_m = \frac{\Delta t_1 - \Delta t_2}{\ln(\Delta t_1 / \Delta t_2)}$$ WHERE

$\Delta t_1 = t_a' - t_b'$ AND

$\Delta t_2 = t_b - t_a$ (REF. PAGE 362)

TEMPERATURES AS SHOWN IN SKETCH ASSUMED ON BASIS OF LABORATORY DATA SUPPLIED TO AUTHOR

$$\Delta t_m = \frac{(1200 - 90) - (475 - 350)\ °F}{\ln \frac{1110}{125}} = \frac{995°F}{2.17} = 450°F$$

$$Q = U A \Delta t_m = (3)\, 2\left(\frac{1000\ in^2 \cdot ft^2}{144\ in^2}\right)(450°F) = 18\,700\ \frac{Btu}{hr.}$$

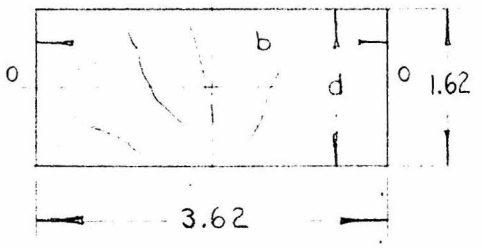
SINCE CONSERVATIVE VALUES HAVE BEEN ASSUMED, AND RADIATION HAS NOT BEEN TAKEN INTO ACCOUNT, THE ACTUAL EXCHANGE WOULD BE CONSIDERABLY HIGHER THAN ABOVE. LABORATORY TESTS TO DETERMINE A SUITABLE VALUE OF U WOULD BE NECESSARY.

STRUCTURAL FRAME LOADING

REFERENCE - UNIFORM BUILDING CODE; 1946 EDITION; PACIFIC COAST BUILDING OFFICIALS CONFERENCE

COMPRESSION LOADING:

VERTICAL FRAME MEMBER REPLACES 2 INCH X 4 INCH X 8 FOOT WOOD STUD. ALLOWABLE COMPRESSION STRESS, SELECT DOUGLAS FIR,C, IS 1 466 POUNDS PER SQUARE INCH, AND MODULUS OF ELASTICITY,E, IS 1.6×10^6 POUNDS PER SQUARE INCH. (REFERENCE - TABLE 25A)



CROSS SECTION OF 2 INCH X 4 INCH STANDARD WOOD STUD - 8 FEET LONG

FOR MOMENT OF INERTIA, I_{oo}

$$I_{oo} = \frac{bd^3}{12} = \frac{(3.62)(1.62)^3 \text{ in}^4}{12}$$

$$I_{oo} = 1.28 \text{ in}^4$$

AREA, $A = (1.62)(3.62)\text{in}^2 = 5.89 \text{in}^2$

RATIO, $\frac{\text{LENGTH}}{\text{LEAST WIDTH}}$, $\frac{l}{d}$,

$$\frac{l}{d} = \frac{8 \text{ ft} \times 12 \text{ in}}{1.62 \text{ in ft}} = 59$$

FOR COLUMN, $K = \frac{\pi}{2}\sqrt{\frac{E}{6C}}$, HENCE

$$K = \frac{\pi}{2}\sqrt{\frac{1.6 \times 10^6}{(6)1.5 \times 10^3}} = 21$$

SINCE $\frac{l}{d} > K$ $(59 > 21)$,

$$\frac{P}{A} = \frac{.274\,E}{\left(\frac{l}{d}\right)^2}$$ (REFERENCE - PAGE 104 - CONTAINS SAFETY FACTOR OF 3)

$$P = .274 \frac{1600 \times 10^3 \text{ lb}}{(59)^2 \text{ in}^2}(5.89) \text{ in}^2 = \underline{740 \text{ pounds}}$$

THE COLUMN AS SHOWN IN FIGURE 15, MUST BE DESIGNED TO TAKE THE ABOVE LOAD. THE MOST SATISFACTORY RESULTS WOULD BE OBTAINED FROM A SERIES OF LABORATORY TESTS, INVOLVING VARIOUS GAGES OF THE METAL ANGLE MEMBER. LATERAL LOAD RESISTANCE WOULD ALSO HAVE TO BE DEVELOPED THROUGH TEST OF THE COMPLETE FRAME.