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By direction

# DESIGN DATA SHEET DDS3802-1

## METHODS of HEATING - DESCRIPTION AND SELECTION OF HEATING EQUIPMENT

CONTENTS

References:

(a) General Specifications for Ships of the United States Navy.

(b) DDS3801-1 Air Conditioning (Ventilation, Heating, and Mechanical Cooling) Heat Loads and Space Requirements.

(c) DDS3801-2 Pressure Losses of Ventilation Fittings.

(d) BuShips Hull Type Drawing No. S3802-921624, Convection Heater.

(e) BuShips Hull Type Drawing No. S3802-521735, Unit Heater.

(f) BuShips Hull Type Drawing No. S3802-66970, Ventilation Heater.

(g) BuShips Drawing No. S3802-78103, Ventilation Heater Selection Chart.

(h) Ventilation Heater Selection Slide Rule.

(i) BuShips Hull Type Drawing No. S3802-860327, Temperature Regulator.

(j) NAVSHIPS 338-0007, Instructions for Installation and Operation of Navy Standard Temperature Regulators.

(k) DDS3803-1 Methods of Cooling and Dehumidifying for Air Conditioned Spaces, Selection of Equipment and the Control of Temperature and Humidity.

DDS3802-1-a. General

1. Space temperature requirements are specified in reference (b) as may be modified by Detail Specifications of the ship. Pressure losses of ventilation heaters are given by references (c), (g) and (h). Navy standard heating equipment is shown by references (d), (e), (f) and (i).

2. Types of Systems.

(a) Direct Heating.- Heaters used in this type of system employ convection heaters or electric heaters, where the space is heated by convection and radiation.

(b)Unit systems employ unit heaters, producing forced convection.

(c) Indirect systems.- Except for small ships, most heating is done by the installation of one or more ventilation heaters in the ventilation ducts.

(d) Recirculating systems.- Spaces served by air conditioning recirculating systems sometimes employ a heater downstream from the cooling coil. This heater, in some systems, is used to heat the space during winter weather only. In some systems it acts as a reheater during the cooling season and as a heater for the space during the heating season. When used for both purposes the heater must be selected for whichever load is greater.

3. Steam available for heating, on most ships is assumed to be dry saturated steam at an average pressure of 35 psig at the inlet to the temperature regulator. Basic ratings of vent heaters, unit heaters and convection heaters are on this basis. The ratings of temperature regulators are on the basis of a pressure drop of 10 psi through the regulator at full rated load.

DDS3802-1-b Direct Heating Systems.

1. Convection heaters are used on small ships where indirect heating is not used. These systems operate with circulated hot water or steam, often at low pressure. Tables or curves should be consulted to determine performance at the water or steam temperature available. See figure 1.

2. Convection heaters are used for heating spaces which are not served by ventilation heaters or to augment the indirect heating system. These heaters are also available of non-magnetic construction for use in mine sweepers, in the vicinity of the magnetic compass and in such other spaces where this construction is necessary. The control of space temperature is manual, accomplished by positioning the damper on the unit. No other controls are used.

3. Electric heaters.

Type "D" electric heaters are similar to convection heaters, except that an electric heating element is used for transfer of heat. They are usually used in spaces where it is not practical to run steam and return piping, and as supplementary heat. Type "A" electric heaters are panel radiant heaters for mounting on bulkheads of spaces exposed to the weather.

DDS3802-1-c Unit Heaters. Unit heaters are self contained forced convection heaters, utilizing steam or hot water as the heating medium. This type of heater utilizes a heating element and a fan assembly, built in a single unit. Unit heaters are used for heating large spaces where heating rather than ventilating is required. Performance of unit heaters at various conditions can be read from Figure 2.

DDS3802-1-d Indirect Heating Systems.

Most systems aboard Naval ships are indirect, with ventilation heaters installed in ventilating ducts.

Indirect heating systems normally fall into three general classifications:

(a) Individual systems.
(b) Zone systems.
(c) Central heating systems.

An indirect heating system consists of a preheater at or near the weather air intake, and usually one or more reheaters at some place or places in the distributing duct system. Where the preheater is not located at the weather intake, insulation of the ductwork between air intake and heater is necessary to prevent sweating of the duct. The degree of preheat should be sufficient to prevent sweating of ductwork downstream of the preheater. The procedure for selection of the preheat temperature, size of preheater and selection of reheaters are given in section S3802-1-g.

Individual indirect systems make use of a reheater at each branch duct. This type system is used only where individual space load requirements do not allow the use of a zone system.

A zone system is used where a supply system serves a number of spaces which can be arranged in groups having individual spaces with similar delivery air temperature requirements at alltimes. A common preheater serves the system and each branch, serving a zone, has its reheater to govern the final temperature of air delivered to the spaces comprising this zone.

A central heating system is used where a large space or group of individual spaces are served by a single supply system which will allow the full temperature rise in the air stream to be accomplished by a single heater or combination of heaters at the weather intake.

DDS3802-1-e <u>Recirculating Systems.</u>

Recirculating systems are normally used as combination cooling and heating systems. A heater, located downstream from the cooling coil, furnishes heat for winter, utilizing the same fan and duct system as is used for cooling. Where humidity control is involved, and on some cooling systems serving two or more spaces by a common cooling coil, this heater also operates as a reheater during the cooling season. In such an installation the winter heating load and the summer reheat load are computed. The heater is selected for the larger of these two loads. These heaters are normally ventilation heaters. Where steam cannot be used in the space or where the load is very light electric duct heaters can be used. See DDS3803-1 for cooling systems.

DDS3802-1-f <u>Equipment Description.</u>

Equipment utilized in heating systems are as follows:

Ventilation heaters
Unit heaters
Convection heaters
Electric convection heaters (Type D)
Electric panel radiation heaters (Type A)
Electric duct heaters
Temperature regulators for ventilation heaters and unit heaters.

(a) Ventilation heater sizes and dimensions are shown by reference (f). Selection of sizes are given in DDS3802-1-g. Heaters are interchangeable from all supply sources. Combinations of size and fin spacing give 54 heater capacities obtainable at a given face velocity. Casing sizes allow heaters to be arranged in series, parallel, or series - parallel combinations.

(b) A unit heater consists of a heat transfer coil and fan built into a compact unit. Dimensions and capacities are shown on reference (e).

(c) Convection heaters are shown on reference (d). Control of heat is by manual adjustment of the position of the damper. No additional control is necessary.

(d) Electric heaters. Type "D" electric heaters are similar to convection heaters except that an electric heating element is used for heat transfer. These heaters are of two classes, bulkhead mounted for use with 440 volt 3 phase current and portable for use with 115 volt single phase current. Both are rated 1000 watts.

Type "A" Radiant Panel heaters may be used in places exposed directly to the weather, without total enclosure.

There is under development a family of duct type electric heaters. Data will be distributed as soon as available.

(e) Temperature regulators, used to control the flow of steam to ventilation heaters and unit heaters are shownoon reference (i). The performance of Navy standard temperature regulators are the same and regulators are interchangeable from all supply sources. However, spare parts are not interchangeable between regulators from various manufacturers. Model "D" regulators are two model "E" regulators mounted in a common valve body. When the total load on a preheater exceeds the capacity of the largest model "D" valve, two separate regulators must be used, in accordance with figures 3 and 4. Reference (j) shows details of installation and servicing of temperature regulators. The proper installations of temperature regulators for various heater installations are shown by figures 3 through 7. Models and sizes of temperature regulators are shown by references (i) and (j).

Temperature regulators should be selected to handle the design load on the heater, rather than the maximum possible capacity of the heater. This will decrease the tendency to hunt or possible "wire-drawing" on very light loads. Temperature regulator ratings are on the basis of a pressure drop of 10 psi through the regulator at full rated load. Regulators will operate at slightly higher loads with a resultant greater pressure drop. Location of model "L" thermostat as shown in figures 3 and 5 give added protection against the freezing of preheaters due to sluggish operation of trap or back pressure in condensate return lines.

DDS3802-1-g Equipment Selection.

(a) Ventilation Heaters.

Although ventilation heater sizes may be selected by reference (g), the slide rule type of selector, reference (h) is mush faster and easier to use. Experience indicates that the use of the selector chart, reference (g), is more apt to allow errors to occur than is the use of the selector rule.

As a general rule the use of heaters with "M" fin spacing for preheaters is preferable on the air entering side. The "M" fin spacing is somewhat easier to clean than is the "H" spacing.

The rule shows outlet temperatures of heaters together with the pressure drop across the heater. These are influenced somewhat by the transitions used to connect the heaters to the ducts. A very bad transition can create a pressure loss equal to that of the heater, and this turbulence will cause a recirculation of air within the heater.

Ventilation heaters should always be installed with headers in vertical position, or tubes horizontal, as shown by figures 3 through 7, unless conditions make it imperative to install heater in some other position.

Pressure loss of heaters mounted at an angle to the horizontal are given in reference (c). Where it is necessary to install a ventilation heater at some angle other than normal, care must be exercised that air is not trapped in the coils and that water pockets are not allowed to form.

Ventilating systems above 3000 cfm have two speed fans. The high speed is for use during hot weather. When ventilation heaters are being used the fan should operate on low speed. The selector rule gives the temperature rise at low speed with the pressure loss at high speed of the fan at one setting of the rule. The winter delivery ratio for most fans is 0.67, being the ratio 1800/1200 RPM. For a single speed fan the ratio is one.

It is usual practice to allow a total pressure loss due to the ventilation heaters of 0.6 inch, divided about 0.4 inch for the preheater and 0.2 inch for the reheater. These losses will vary with design conditions and are used as a starting point in heater selection.

In many systems there are spaces having boundaries common with hot spaces, causing a cooling load rather than a heating load for these spaces. The delivery air temperature to such a space or spaces, necessary to offset the heat gain, fixes the preheat temperature of the system. On systems where this condition does not exist the preheat temperature may be any reasonable one, usually between 40°F and 60°F. High preheat temperature is usually necessary to permit use of normal sizes of reheaters, on a system requiring high final temperatures to the spaces served by the system.

The delivery temperature required by a particular compartment to balance the heat loss of that compartment is:

$$td = \left(\frac{H}{Qs \times R \times 1.08}\right) + ti$$

Where:

td = temperature of air delivered to the space, deg. F.

ti = compartment design temperature, deg. F.

Qs = delivery to the space for high speed of fan, cfm

R = winter/summer fan speed ratio

H = heat loss from compartment, BTU/hour

Where a compartment requires cooling during the heating season this formula takes the form:

$$td = ti - \left(\frac{H}{Qs \times R \times 1.08}\right)$$

Where H now becomes the heat gain to the compartment from the hot boundaries.

Ventilation heater performance shown on the selector rule or chart are predicated on saturated steam at an average pressure of 35 psig at the temperature regulator and a drop through the regulator of 10 psi. For performance at other pressures or for hot water see figure 3.

The use of the selector slide rule is best illustrated by some typical examples.

Example 1. Select a preheater for a system using a fan 1800/1200 rpm and delivering 4000 cfm. Preheat temperature to be in the range of 40°F to 50°F.

Set "Preheater" side of the rule so that pressure loss arrow is over 0.4 inch on "M" window. At 0.67 ratio the preheat temperature will be 43°F. However the 4000 cfm does not coincide with a specific heater size. As some rise in preheat temperature is permissible move the 4000 cfm under size 29 heater. A size T29M heater will give a preheat temperature of 44°F. with a pressure loss (summer) of 0.36 inch.

Should a higher preheat temperature be desired, a size T30H heater will give a final temperature of 66°F. at a pressure loss of 0.36 inch.

Example 2. A ventilating system having a fan of 1800/1200 rpm, delivers 24,000 cfm. A group of spaces, adjacent to machinery spaces requires cooling during the heating season. One typical space requires 2000 cfm at 45°F, having a heat gain of 29,000 BTU/hr at a space temperature of 65°F.

Set preheater side of slide rule at 45°F. temperature in "M" window at 0.67 winter/summer ratio.

The pressure loss shows to be 0.33 inches. On the "Face area" index for one square foot the heater face velocity will be 1500 fpm.

$$\frac{24,000}{1500} = 16 \text{ square feet (required heater face area).}$$

A size 35 and a 37 in parallel will give 7.07+ 10.6 = 17.67 square feet. $\frac{7.07}{17.67} = 0.4$. Heaters installed in parallel must have the same fin spacing. 0.4 X 24000 = 9600 cfm will pass through the size 35 heater. Set size 35 over 9600 cfm. Preheat temperature will be 46.5°F. with a resultant pressure loss (summer) of 0.28 inch, for "M" fin spacing.

$$46.5 = ti - \frac{29,000}{2000 \times .67 \times 1.08}$$

From which the space temperature will level off at 66.5°F. This will be a satisfactory choice.

Example 3. A space served by the system of example 2 requires 2000 cfm at a delivery temperature of 96°F. Setting reheater side of slide rule to give a rise from 46.5°F. (preheat temperature) to 96°F. places the selection between a size 27H and 28H. A size 27H will give a final temperature of 92°F. with a resulting pressure loss of 0.43 inch. Should this temperature provide an acceptable space temperature, and if the system will accommodate this rather high pressure loss, then a size 27H may be used. Usually this pressure loss on a system of this size cannot be tolerated. Setting 2000 cfm under size 28 and 0.67 under the ratio arrow in "H" window results in a final temperature of 101°F. and a pressure loss (summer) of 0.24 inch, which will normally be a better selection. The temperature regulator will prevent the delivery air temperature from exceeding the required 96°F. under design conditions.

Example 4. A space served by a system supplying no ther space requires 3500 cfm at a delivery temperature of °F. As the space is so located that an "R" thermostat n be properly located in the space and the 25 feet of bing is sufficient to reach to a point near the location the preheater, the heaters may be installed bolted together in series, provided a selection can be made where the o heaters are of the same casing size. Ventilation heaters stalled in series must not be drained through a common ap.

On preheater side of slide rule put pressure loss in "M" indow at .3 inch. Move 3500 cfm under size 29. The mperature from the first heater will be 46.5°F. with essure loss of 0.28 inch. On reheater side move 3500 cfm der size 29. Move ratio slide to 0.67. A size 29M will ve a final temperature of 78°F. which is too low. In the window the final temperature is 93°F. at a pressure loss .4 inch. The combined pressure loss of the two heaters series is 0.28 + 0.4 = 0.68 inch. Figure 4 shows this e of installation. The condensing load is:

$$W = \frac{Q(T-t)}{864} = \frac{3500 \times .67 \times (87-10)}{864} = 208 \text{ Lbs/hr.}$$

ze D-26 temperature regulator should be used, having "W" ostat in weather and model "R" thermostat in the space

It is sometimes necessary to select ventilation heaters onditions not shown on the heater selector slide rule. rctic service at temperatures below + 10°F. or for steam pressures other than in the range of 20 to 50 psi or for hot water as the heating medium, the performance can be determined by the formula:

$$R = \frac{R_1 \ (Ts - Ta}{Ts_1 - Ta_1}$$

Where R = temperature rise in the air stream under operating conditions, deg. F.

$R_1$ = temperature rise in air stream for normal conditions, obtained from slide rule selector, deg. F.

$Ts_1$ = temperature of steam at rating, 25 psi, 267°F

$Ta_1$ = any entering air temperature, from which value $R_1$ is obtained, deg. F.

Ts = temperature of steam or hot water for operating conditions to be used, deg. F.

Ta = temperature of air entering heater for operating condition to be used, deg. F.

Example 5.

A system delivers 6000 cfm (summer), the fan being driven by a two speed motor, 1800/1200 rpm. A final preheat temperature of between 50°F. and 55°F. is needed. Outside design temperature is 10 degrees below zero.

Set slide rule selector, preheat side for 0.4" on "H" dow. Move 6000 cfm up under size 33. The final temper- ure leaving the heater will be 67°F.

$$R_1 = 67 - 10 = 57^\circ$$

$$Ta_1 = +10^\circ$$

$$Ta = -10^\circ$$

$$Ts_1 = Ts = 267^\circ$$

$$R = \frac{57 \times (267 - (-10))}{267 - 10} = 61.5^\circ$$

al temperature $= 61.5 + (-10) = 51.5^\circ$

cial Arctic Service

Some ships destined to operate in extreme conditions of tic or antarctic weather must have special provisions for ing, particularily in regard to the preheaters. Where a ion of the air is recirculated, damper and preheater steam must be arranged to insure against freezeups, should mpers not be adjusted properly.

preheaters, where no air is recirculated, an arrangement shown by figure 7 can be used. This arrangement is ic and provides full pressure in the heaters when the air is lower than freezing temperature.

figure 7 heater "A" should be selected to carry the load when weather is at 35°F. The temperature regulator, h del "W" thermostat, should be chosen for this load.

Heater "B" should be selected to carry the balance of the design load due to a drop in weather temperature from 35°F. to + 10°F. Heater "B" should be controlled by a "D" temperature regulator, or equivalent when this load exceeds 445 lbs per hour. The temperature regulator should be selected for the above load on the coil.

Heaters "C" and "D" should be selected to carry the additional expected load below + 10°F, divided about equally between coils. Under some conditions only one of these coils will be needed.

Assume that - 10°F. weather may be encountered. Heater "C" should be selected for the additional load when weather drops from + 10°F. to zero. The heater is controlled by a thermostatic contact maker actuating a magnetic valve in steam supply. The thermostat should close circuit when weather drops to + 10°F.

Heater "D" should be selected to carry the additional load when weather drops from zero to - 10°F. The heater is controlled in the same manner as heater "C" except the thermostat should be set to close the circuit when weather drops to zero.

"Hold-in" type switches should be provided on these circuits, located adjacent to the heaters. By holding the circuit closed for a short period, maintenance personnel can determine that steam enters coils "C" and "D". These switches should remain open when released.

It is imperative that each heater have its condensate drained through its individual steam trap.

(b) Convection Heaters.

Convection heaters should be selected, having a capacity equal to the design heat loss, using the temperature of steam or hot water available for the heating medium. Figure 1 should be used for conditions other than the standard rating conditions of 35 psig steam and 70°F. space temperature. Where ventilation introduces air into the space at a temperature lower than design space temperature, this additional load must be added to the heat loss before selecting the heaters. The additional load due to ventilation air can be determined by the following formula:

$$Hv = 1.08 \times Q \times R \times (ti - to)$$

Where Hv = additional load due to ventilation air, BTU/Hr.

Q = quantity of air entering space (summer) cfm

R = Winter/summer fan speed ratio

ti = space design temperature, deg. F.

to = ventilation air temperature, deg. F.

(c) Unit Heaters.

Basic ratings of unit heaters are for installation at 8 to 10 feet above deck. With a 65°F. space temperature 5 feet above the deck, it is assumed that average temperature of air entering the unit will be 70°F. Saturated steam at 35 psig, with a drop of 10 psi through the temperature regulator, is the basic rating condition. For other conditions use figure 2. As is the case described for convection heaters, where ventilation air enters the space at a temperature lower than design space temperature, this additional load must be added to the heat loss load before selecting the units.

Electric heaters are selected by the formula:

$$KW = \frac{BTU/Hr.}{3413}$$

Thus one Type "D" heater will be required for a heat loss of 3413 BTU/hr.

DDS3802-1-h <u>Controls.</u>

(a) Ventilation heaters used in ventilating systems are to be controlled by means of Navy standard temperature regulators. The selection and installation of these regulators are covered by reference (j). Where ventilation heaters are used as re-heaters in recirculating cooling systems, their control depends upon the control system used for the system. Current practice uses a modulating or proportioning motorized steam valve inter-connected with the cooling coil control. (See DDS3803-1).

(b) Convection heaters are manually controlled by a damper which is operated by a control knob on the front panel of the unit. No additional control is necessary.

(c) Unit heaters, when operating with normal steam pressures, 20 to 50 psig, are to be controlled with Model "E" temperature regulators, having Model "R" thermostat located in the space served. (See figure 8). Consult reference (j) for thermostat location. Where necessary the thermostat may be located in the air stream back of the fan. Temperature within the space is usually not maintained as uniform with this location as it would be with thermostat properly located in the space itself.

Unit heaters operating on steam pressures below 20 psig should be provided with temperature regulators having a charge of fluid suitable for low pressure steam.

Unit heaters operating on hot water must be controlled by using a thermostatically operated contact maker to actuate the motor controller. Control becomes two position or "on-off". A switch should be provided to short out the control to enable operation of the fan in hot weather. (See figure 8)

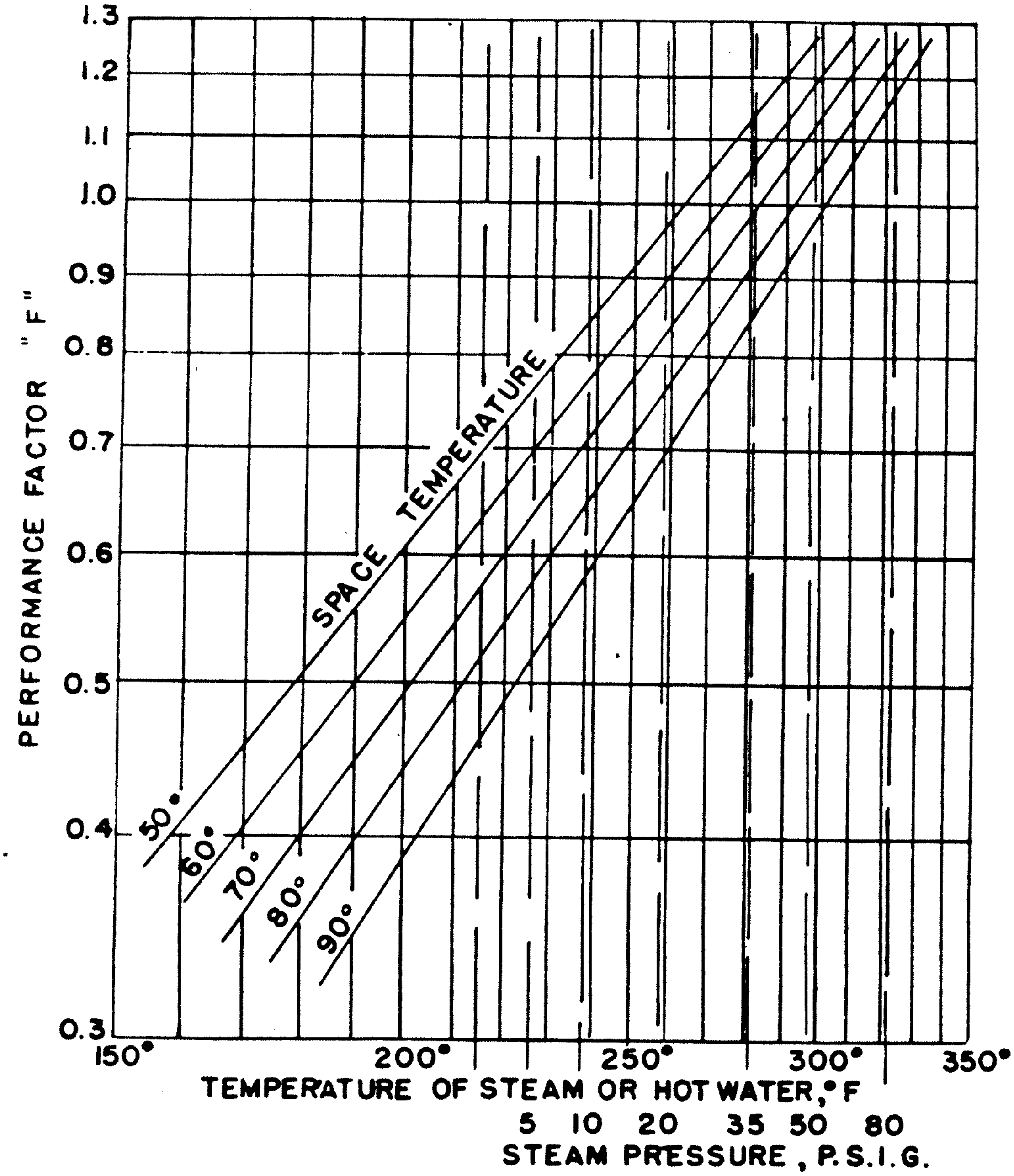
All electric heaters are controlled by "on-off" switch or two position control. Types "D" and "A" are manually controlled.

Electric duct type heaters are usually controlled by the thermostat in the space, operating through suitable relays. (See DDS3803-1)

Navy standard temperature regulators are procured with capillary tube lengths as shown by reference (i). Extra tube should be coiled and secured as described in reference (j). It is impractical to furnish other tube lengths. The stocking problem would be almost chaotic and replacement during war conditions would be extremely difficult.

Control of a reheater by Navy standard temperature regulator is shown by figure 9.

Oversizing of preheaters or temperature regulators increases the possibility of freezing condensate in the heater tubes.



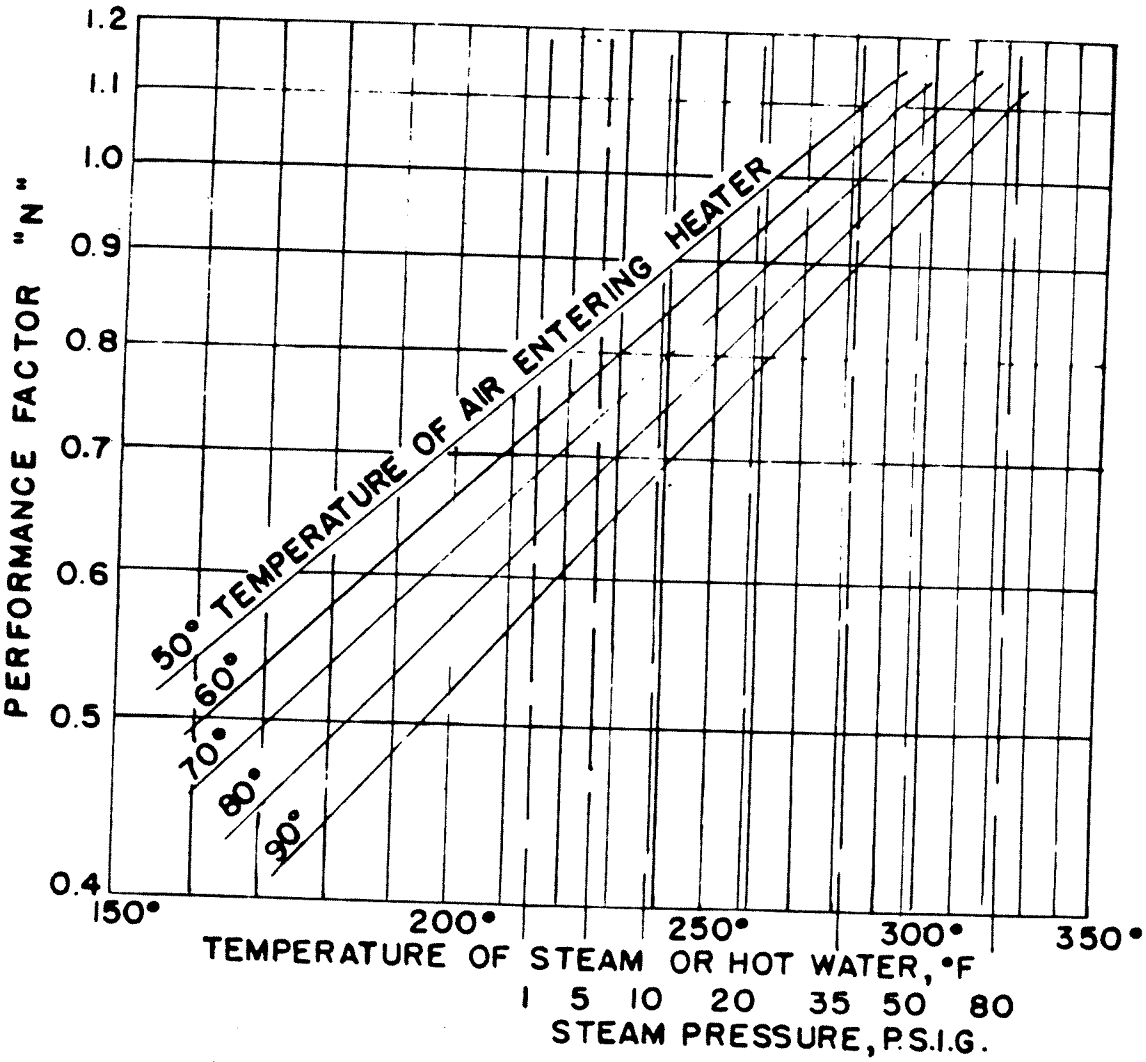

PERFORMANCE OF NAVY STANDARD CONVECTION HEATER AT CONDITIONS OTHER THAN RATING CONDITIONS.

DETERMINE THE VALUE OF "F" FOR EXISTING CONDITIONS. MULTIPLY THE STANDARD RATING AT 35 P.S.I.G. BY "F" TO OBTAIN HEATER CAPACITY AT EXISTING CONDITIONS.

TO SELECT HEATER - DIVIDE THE DESIGN LOAD BY "F" AND SELECT HEATER FROM THE PUBLISHED CAPACITIES

ENTERING AIR TEMPERATURE IS ASSUMED 5° BELOW SPACE TEMPERATURE.

FIGURE I.

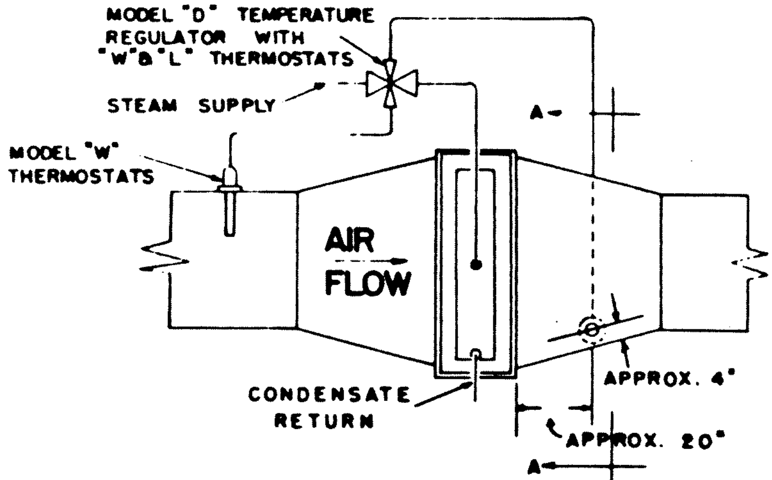



PERFORMANCE OF NAVY STANDARD UNIT HEATERS AT CONDITIONS OTHER THAN 35 P.S.I.G. AT THE REGULATOR AND 70° ENTERING AIR.

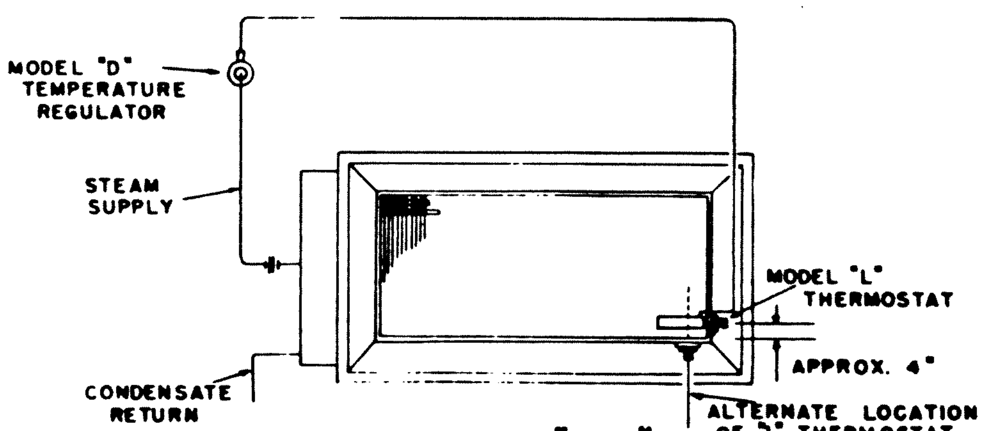
DETERMINE THE VALUE OF "N" FOR EXISTING CONDITIONS. MULTIPLY THE STANDARD RATING AT 35 PSIG BY "N" TO OBTAIN HEATER CAPACITY AT EXISTING CONDITIONS.

TO SELECT HEATER - DIVIDE THE DESIGN LOAD BY "N" AND SELECT HEATER FROM THE PUBLISHED CAPACITIES.

FIGURE 2.




ELEVATION-SUPPLY END OF HEATER




SECTION "A-A"

## PREHEATER

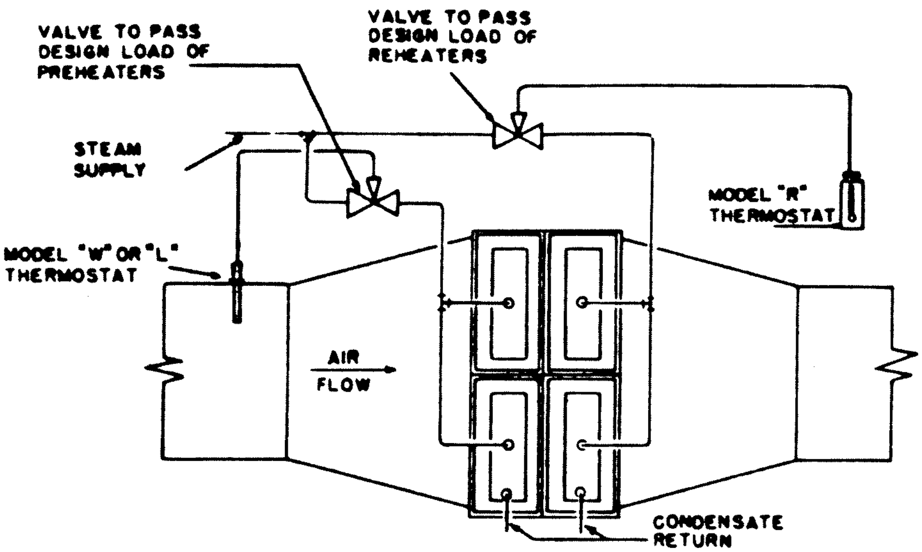
USING MODEL "D" TEMPERATURE REGULATOR WHERE DESIGN LOAD DOES NOT EXCEED 445 POUNDS OF STEAM PER HOUR.

LOCATING MODEL "L" THERMOSTAT AS SHOWN WILL PROVIDE AN ADDED PROTECTION AGAINST FREEZING CONDENSATE IN HEATER

NOTE: MODEL "L" THERMOSTAT SHOULD BE LOCATED NEAR BOTTOM OF TRANSITION OR DUCT ABOUT 20 INCHES AWAY FROM THE HEATER AND ON SIDE OPPOSITE TO THE STEAM SUPPLY HEADER.

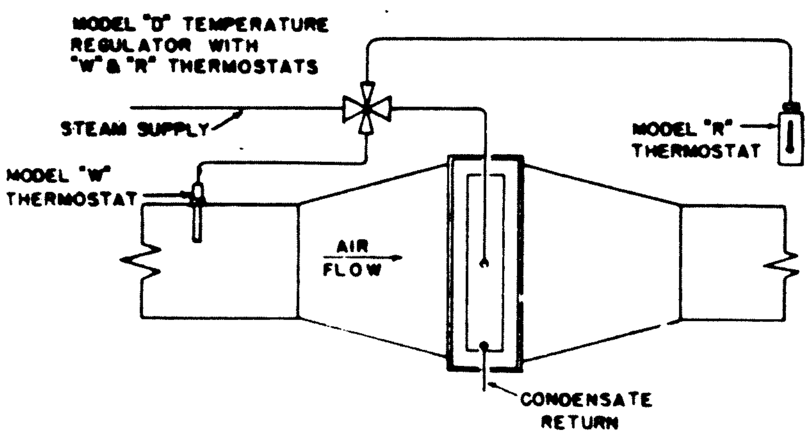
SEE FIG.4 FOR CONTROL ARRANGEMENT WHERE THE DESIGN LOAD EXCEEDS 445 POUNDS OF STEAM PER HOUR

FIGURE 5



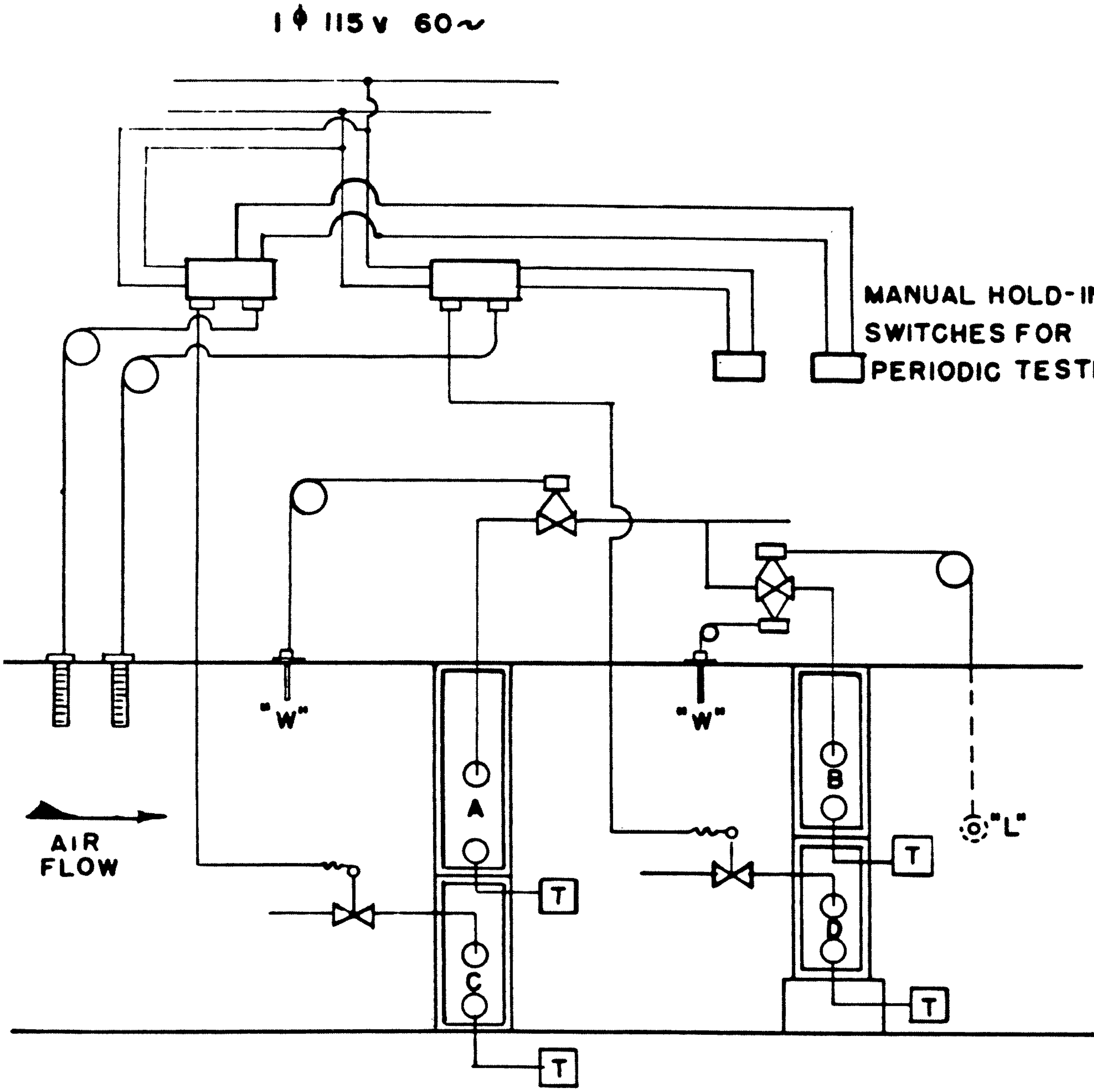

COMBINATION HEATER
PREFERRED CONTROL ARRANGEMENT

FIGURE 4




COMBINATION HEATER
WHERE ONE HEATER WILL PRODUCE THE REQUIRED TEMPERATURE RISE.

FIGURE 6

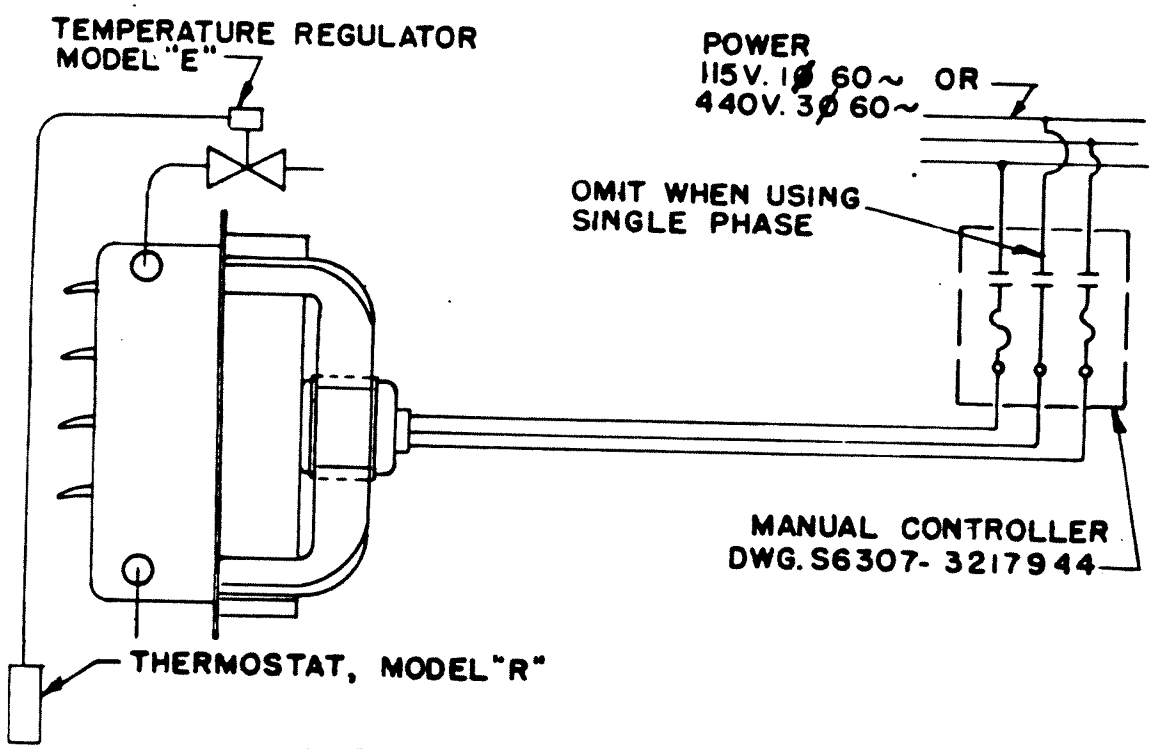



LOCATE "L" THERMOSTAT AS SHOWN IN FIGS 3 & 5

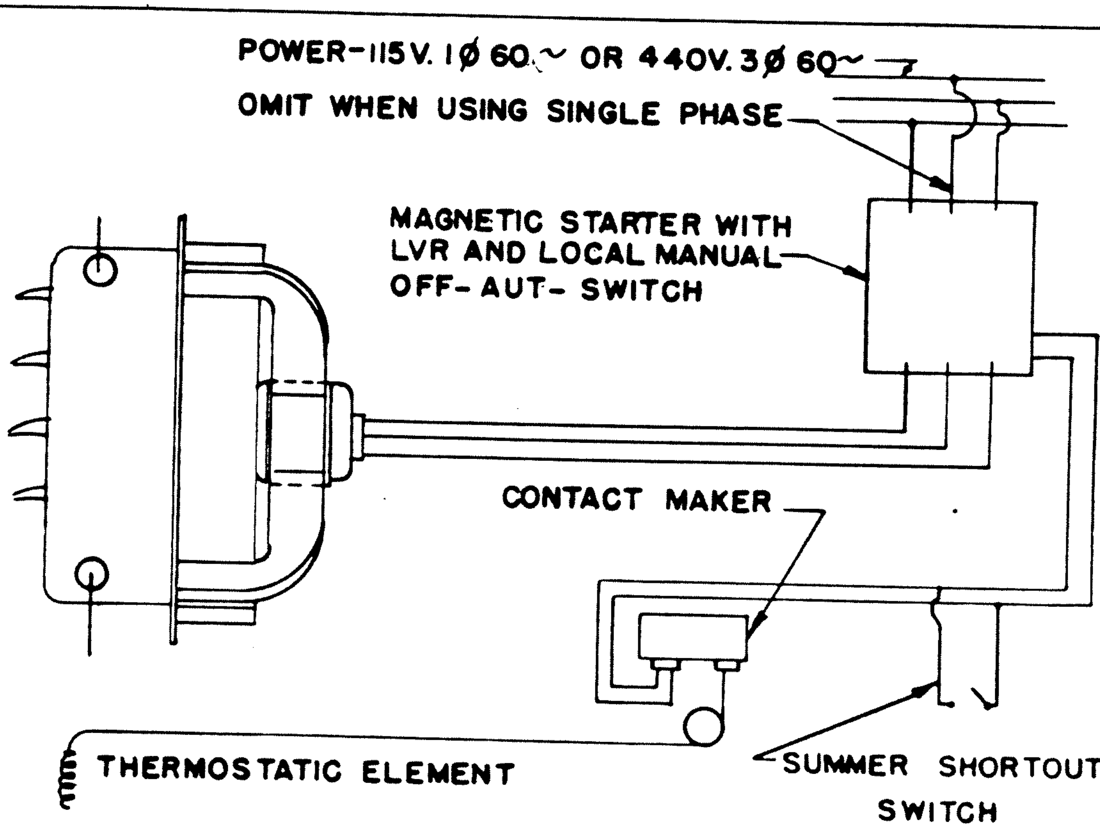
PARALLEL COILS SHOULD HAVE THE SAME FIN SPACING

PREHEATER ARRANGEMENT
FOR ARCTIC AND ANTARCTIC CONDITIONS

FIGURE 7

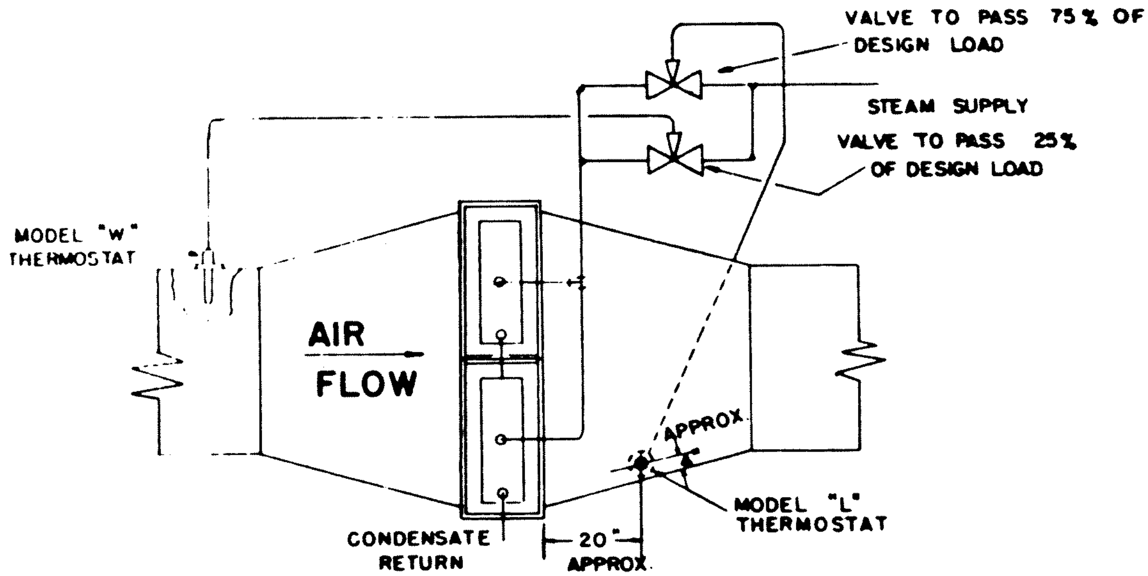



UNIT HEATER USING STEAM



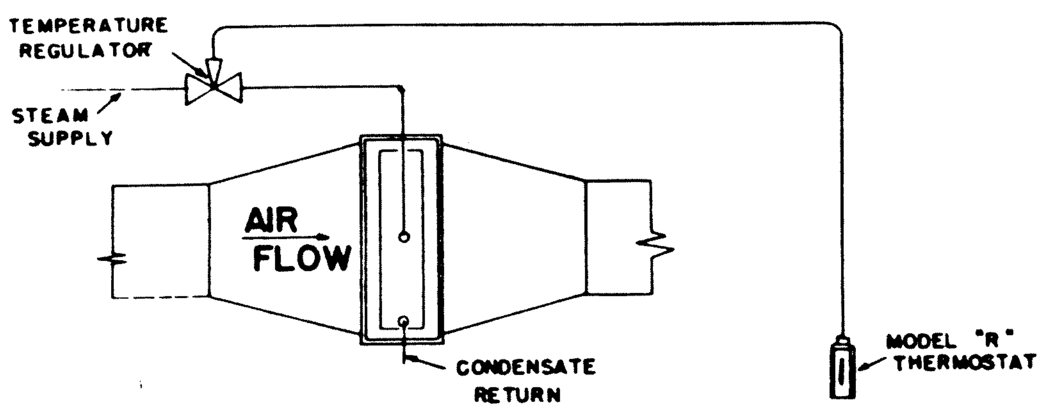

UNIT HEATER USING HOT WATER

FIGURE 8




PREHEATER
CONTROL ARRANGEMENT WHERE DESIGN LOADS EXCEEDS 445 LBS. OF STEAM PER HOUR.

FIGURE 3




REHEATER
CONTROL ARRANGEMENT

FIGURE 9