Table 2 .... Relation of Resistor Voltage to Heat Delivery

Condition	Volts	Heat Delivered %
Electric system, nominal value	120/240	103.3
For design of equipment, at terminals	118/236	100
Range, as basis for design		
Minimum	110/220	86.8
Maximum	124/248	110.5
On secondary distribution system		
Favorable zone, as to voltage conditions		
Minimum	110/220	86.8
Maximum	125/250	112.0
Tolerable zone		
Minimum	107/214	82.2
Maximum	127/254	116.8
Emergency conditions	90/180	58.3

design of heating system, and internal sources of heat. The *NEMA Manual* reports that based upon experience with many thousand electric heating installations, the value recommended for C is 18.5 unless local experience of a statistical nature has established a more reliable value for the particular area concerned. *REA Bulletin* 142-1 *Electric House Heating* suggests correction factors for degree days to be applied to the NEMA formula when the annual degree days are less than 1800.

For block-type electric rates, multiplying the annual kilowatt-hour energy consumption by the cost per kilowatt-hour indicates the annual cost. For demand rates, the assistance of the local utility company should be secured to estimate demand and energy uses by the month on the particular rate involved. It may be pointed out that for residential systems properly applied with thermostatic control *in each room*, the maximum operating demand is about 75 percent of the total calculated load.

Voltage Requirements

The preferred nominal system voltage at point of electric utilization by equipment, for single-phase 3-wire systems necessary with space heating, is 120/240 volts, as stipulated by standards of the electrical industry (*EEI Publication* R-6 and *NEMA Publication* No. 117 issued May 1949). For household heating appliances mentioned in the standards, such as air heaters, water heaters, and cooking ranges, the *equipment voltage rating for design* is specified as 118/236 volts, and the range of *voltages to be used as a basis of design* extends from 110/220 minimum to 124/248 maximum. However, natural variations exist from time to time in the conditions at different points in any secondary distribution system and will affect both voltage level and range of fluctuations. Under emergency conditions on electricity supply systems, voltages of the order of 90/180 may be encountered. Heat delivery by resistors with these voltage values, expressed in percent of rated delivery with the normal 118/236 volts (at terminals) is given in Table 2.

Voltages stipulated for secondary distribution systems are at point of service entrance to the building; the drop of voltage in the house supply wiring to terminals of the heating equipment may be 2 to 3 percent, thus reducing heat delivery by some 5 to 8 percentage points below the *favorable zone* and *tolerable zone* values included in the last column of Table 2. Accordingly, it is necessary the designers of electric heating installations obtain specific information from the local electric utility company on both existing and anticipated future conditions at the location, before specifying the capacity and voltage for equipment, wiring, and controls.

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CHAPTER 18

WARM AIR HEATING SYSTEMS

Forced Warm Air Systems; Air Distribution; Supply Outlets and Return Grilles; Duct Construction; Simplified Methods of Design for Perimeter Systems of Loop, Radial, and Extended-Plenum Types; Return Duct System for Perimeter Installations; Inside Wall Delivery Systems; Design of Large Systems; Automatic Controls; Adjustment of System; Warm Air Ceiling Panel Systems; Summer Operation; Gravity Warm Air Systems

WARM air heating systems may be conveniently divided into two classifications depending upon the manner in which the motive power for circulating the warm air is supplied. In *gravity* systems, the motive head is due to the difference in weight between the heated air leaving the top of the furnace casing and the cooler return air entering the bottom of the casing. In a *forced* warm air heating system, all or part of the motive head is supplied by a fan. Although a great many gravity warm air heating systems are in use, only a limited number of new gravity installations are now being made. Emphasis will therefore be placed upon the design and installation of forced warm air heating systems.

FORCED WARM AIR SYSTEMS

In forced warm air heating systems, the air circulation is effected by motor-driven centrifugal fans, commonly referred to as blowers. The advantages of forced air systems are:

1. The furnace may be placed in any part of the structure.
2. Distribution ducts can be made small enough to be inconspicuous and out of the way, or be completely concealed from view where desired.
3. Circulation of air is positive, and in a properly designed system, can be controlled in such a way as to give a comfortably uniform temperature distribution.
4. Humidity control is readily attained.
5. The air may be cleaned by filters or other means.
6. If properly designed or suitably adapted, the same air distribution system can be used for summer cooling as for winter heating.
7. The use of the fan permits flexibility in the location of supply and return grilles as required to obtain proper distribution of air for comfort.
8. Controlled quantities of ventilation air may be drawn into the system and conditioned before it is introduced into occupied portions of the structure. Recirculated air can be treated as necessary to obtain the desired quality.

Warm air heating systems are equally adaptable for use in residential and non-residential structures. Although most commonly found in one and two family residences, recent developments in equipment and system design have contributed to the increased use of warm air heating systems in school buildings, apartment houses, and commercial and industrial structures. Other factors which have contributed to this trend include the desire to use one distribution system for both winter and summer air conditioning, and the desire of owners to turn over to the tenant responsibility for all utilities in apartments and commercial buildings.

The construction features of forced warm air furnace units and the function and selection of the various parts of a system are discussed in Chapter 35 and other publications.[1]

AIR DISTRIBUTION

The conditions of comfort obtained in a room are influenced greatly by the type of supply outlet used, and the locations of the supply outlets and return grilles. In general it has been found that changes in the type, air velocity, and location of the supply outlet affect the room conditions much more than the changes in the location of the return grilles. Although the principles of air distribution which are discussed in Chapter 20 apply in the design of warm air heating systems, simplified methods of selecting outlet size and location are usually used. Three methods of locating outlets and grilles are in common use. *One method* is to locate all supply outlets in or near the outside wall, usually beneath windows, and to use outlet grilles or diffusers which deliver the air upward in a fan-shaped pattern to blanket the cold area. This arrangement causes mixing of the warm supply air with the cool air from the high-heat-loss area and with the cold air from infiltration, to prevent drafts. This method of introducing warm air into a structure is called *perimeter heating*. A *second method* is to locate the supply openings on the inside wall, near the floor or near the ceiling, and locating the return openings near the greatest outside exposure. A *third method* is to locate the supply outlets in the ceiling, and the return openings near the greatest outside exposure. Any of these methods of introducing the supply air can be used for summer air conditioning.

In any case, the warm air registers should be so located and so designed that the air stream never discharges directly against people at rest. Tests[2] in Warm Air Research Residences No. 1 and No. 2 at the University of Illinois, have indicated that nearly continuous blower operation gave better results than intermittent operation. This type of operation is more commonly achieved by suitable adjustments of air quantity and fan switch settings than by continuous operation of the blower.[3]

Supply Outlets and Return Grilles

The type of supply outlet that should be used depends upon the type of distribution system to which it is applied. With perimeter duct systems, the supply outlets are usually located in the floor, in the baseboard, or low in the side-wall and underneath a window. In order to be most effective, perimeter diffusers must deliver the air upward and in a fan-shaped pattern so as to blanket the window or cold wall with warm air, thus mixing with and tempering the