sun room, or in a location where it will be affected by direct radiant heat from the sun or from a fireplace, or by direct heat from any warm air duct, register or chimney.

2. A *fan switch* control located in the bonnet to start blower operations at temperatures between 110 and 130 F, and to stop the blower at about 25 to 30 deg below the cut-in point. The lower settings are used for high side wall register installations, and the higher settings for baseboard register installations. For most satisfactory results these settings should be as low as is feasible.

3. A *protective high limit switch* located in the bonnet to stop the system independently of the thermostat if the bonnet temperature exceeds 175 F.

4. On oil and gas burner installations, a protective control should be included which will stop the system if the fire is extinguished or if there is a failure of the ignition system.

5. On automatic stoker installations, a control is usually included which will start the operation regardless of thermostat settings whenever the bonnet temperature indicates that the fire is dying, or a time interval contactor is used that will start the stoker to run a few minutes out of each hour.

6. A *humidistat* to regulate the moisture supplied to the rooms, located either in one of the rooms or in the main return duct near the furnace.

COOLING METHODS

A slight cooling effect may be obtained under certain conditions by the use of the cooler basement air. A more positive cooling effect may be obtained by the use of an air washer where the temperature of the city or well water is sufficiently low (55 F or lower), and where a sufficient volume of water can be provided. Unless the temperature of the leaving water is below the dew-point temperature of the indoor air at the time the washer is started, both the relative and absolute humidities will be somewhat increased.

Coils of copper finned tubing through which cold water is pumped are available for cooling. They require less space than air washers and have the advantage that no moisture is added to the air when the temperature of the water rises above the dew-point. Ample coil surface and fan capacity are necessary with this type of cooling.

It is thoroughly feasible to use ice or mechanical refrigeration in connection with a warm air system and to cool the building by this method, provided the building is reasonably well constructed and insulated. Windows and doors should be tight, and awnings should be supplied on the sunny side of the building. (See also Chapters 38, 39 and 43.)

Conclusions drawn from studies[4] conducted in the University of Illinois Research Residence, subject to the limitations of the test are:

1. An uninsulated building of ordinary residential type may require the equivalent of three tons of ice in 24 hr on days when the maximum outdoor temperature reaches 100 F if an effective temperature of approximately 72 deg is maintained indoors.

2. The use of awnings at all windows in east, south, and west exposures may result in savings of from 20 to 30 per cent in the required cooling load.

3. The cooling load per degree difference in temperature is not constant but increases as the outdoor temperature increases.

4. The heat lag of the building complicates the estimation of the cooling load under any specified conditions and makes such estimates, based on the usual methods of computation, of doubtful value.

5. The seasonal cooling requirements are extremely variable from year to year, and the ratio between the degree-hours of any two seasons occurring within a 10-year period may be as high as 7.5 to 1. Hence an average value of the degree-hours cooling per season is comparatively meaningless.

6. The duct system in a forced-air heating installation can be successfully converted to a system for conveying cool air for the purpose of cooling the structure. No condensation of moisture was observed when the duct temperatures were not less than 65 F.

7. Cooling by means of water at a temperature of 60 F is not satisfactory unless an indoor temperature of less than 80 F is maintained.

8. In the selection of cooling coils, the additional frictional resistance of the coil to flow of air must be given consideration.

9. Cooling the structure by introducing large quantities of air from outdoors at night tended to reduce the amount of cooling required on the following day and was a practical means of providing more comfortable conditions in those homes where cooling systems were not available.

DESIGN PROCEDURE FOR LARGER SYSTEMS[5]

For buildings having a heat loss in excess of 150,000 Btu per hour the design procedure given in Manual No. 9, Technical Code, of the *National Warm Air Heating and Air Conditioning Association*, may be used. This procedure follows a general outline given below:

1. Calculation of design heat losses from individual spaces in the structure. (See Chapter 14.)

2. Location of registers and return intakes on floor plan, types of registers, with throws and deflections of registers desired.

3. Laying out a proposed duct system for both warm air and return air sides of the system including details of types of fittings and the actual and equivalent lengths of each branch line from bonnet to register, without sizes.

The following items are determined from tables in Manual No. 9:

4. Determination of bonnet temperature.

5. Determination of air volume to be delivered through each register and the respective register air temperatures.

6. Selection of register sizes and pressure losses to produce necessary throw, for the air volumes handled.

7. Design of duct system.
   a. Warm air branches.
   b. Return air branches.
   c. Trunk ducts for warm air and return air sides of system.

8. Selection of blower and furnace.

REFERENCES

1—Specifications for the furnace unit and the installed duct system are shown in The Yardstick (Textbook Section 8) and the Code and Manual (Textbook Section 7) published by *National Warm Air Heating and Air Conditioning Association*.

2—Performance of a Forced Warm-Air Heating System as Affected by Changes in Volume and Temperature of Air Recirculated, by A. P. Kratz and S. Konzo (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 393).

3—Automatic Controls for Forced-Air Heating Systems, by S. Konzo and A. F. Hubbard (A.S.H.V.E. Transactions, Vol. 40, 1934, p. 37).

4—Summer Cooling in the Research Residence, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick (University of Illinois *Engineering Experiment Station Bulletins* Nos. 290, 305 and 321). A.S.H.V.E. Research Report No. 1177—Summer Cooling in the Research Residence with a Gas-Fired Dehydration Cooling Unit, by A. P. Kratz, S. Konzo and E. L. Broderick (A.S.H.V.E. Transactions, Vol. 47, 1941, p. 203).

5—Proposed Design Procedure for Large Mechanical Warm Air Heating Systems, by S. Konzo, R. J. Martin, D. S. Levinson, and R. W. Roose, A.S.H.V.E. Journal Section, *Heating, Piping and Air Conditioning*, May, 1947, p. 108.