various heights and designs of enclosures, result in great flexibility of selection for finned-tube units to meet the needs of load, space, and appearance.

Heat loss calculations for finned-tube heating systems are the same as those used for other types of radiation. Ratings are expressed in Btuh per linear foot or square feet Equivalent Direction Radiation per linear foot for steam, and Btuh per linear foot for water.

RATINGS OF HEAT-DISTRIBUTING UNITS

Radiators

A standard method of testing radiators was adopted by the ASHAE in 1927.[3] This Code was withdrawn, but the method is still used in industry. It provides for a standard test room, the temperature of which is to be maintained at 70 F, measured in the center of the room at an elevation of 5 ft above the floor. The steam temperature in the radiator is to be 215 F, which corresponds to 15.6 psia. The weight of condensate per hour, under these standard conditions, multiplied by the difference in the enthalpy of the steam entering the radiator and that of the condensate leaving the radiator, gives the radiator output in Btu per hour (Btuh).

If the rating in square feet Equivalent Direct Radiation is desired, divide this output by 240 (which, by definition, is the Btuh equivalent of 1 sq ft EDR). Correction of output from non-standard test conditions to output at 70 F room and 215 F steam may be made by multiplying the output under test by the ratio:

$$\frac{(\text{Standard temperature difference, steam} - \text{air})^{1.3}}{(\text{Test temperature difference, steam} - \text{air})^{1.3}}$$

Convectors

The generally accepted method of testing and rating both ferrous and non-ferrous convectors is given in *Commercial Standard* CS140-47, *Testing and Rating Convectors*,[4] which has been developed cooperatively by the Convector Manufacturers Association, the Institute of Boiler and Radiator Manufacturers, other members of the trade, and the National Bureau of Standards. This *Commercial Standard* contains details covering construction and instrumentation of the test booth or room, and procedures for determining both steam and water ratings.

Steam ratings are expressed in square feet EDR and Btu per hour (Btuh). Water ratings are expressed in Btuh at specified water temperature drops and average water temperatures.

Under the provisions of *Commercial Standard* CS140-47, the rating of a top outlet convector is established at a value not in excess of the test capacity (which is the heat extracted from the steam or water in the convector under standard test conditions). For convectors with other types of enclosures or cabinets, a percentage that varies up to a maximum of 15 percent, depending on the height and type of enclosure or cabinet, is added for heating effect.[5,6] The additions made for heating effect must be shown in the manufacturer's literature.

Baseboard

The generally accepted method of testing and rating baseboards is covered in the *I = B = R Testing and Rating Code for Baseboard Radiation*.[7] This Code contains details covering construction and instrumentation of the test booth or room, procedures for determining steam and hot water ratings, and licensing provisions for the obtaining of approval of these ratings.

Table 6 .... Factors to Convert I=B=R Finned-Tube Steam Ratings to Hot Water Ratings at Temperatures Indicated

Average Water Temperature	Factor	Average Water Temperature	Factor
150	0.45	200	0.80
155	0.49	205	0.91
160	0.53	210	0.95
165	0.57	215	1.00
170	0.61	220	1.05
175	0.65	225	1.09
180	0.69	230	1.14
185	0.73	235	1.20
190	0.78	240	1.25
195	0.82		

Baseboard ratings include an allowance for heating effect of 15 percent, added to the test capacity. The addition made for heating effect must be shown in the manufacturer's literature.

Steam ratings are expressed in Btuh per linear foot or square feet EDR per linear foot. Water ratings are expressed in Btuh per linear foot, at specified water flow rates and average water temperatures.

Finned-Tube

The generally accepted method of testing and rating finned-tube units is covered in the *I = B = R Testing and Rating Code for Finned-Tube (Commercial) Radiation*.[8] This Code contains details covering construction and instrumentation of the test booth or room, procedures for determining steam and water ratings, and licensing provisions for obtaining approval of these ratings. Steam ratings are expressed in Btuh per linear foot or square feet EDR per linear foot. Water ratings are determined from steam ratings and are expressed in Btuh per linear foot at specified water flow rates and average water temperatures. Table 6 gives factors for converting steam ratings to hot water ratings at various average water temperatures. These factors apply only when the water velocity in the element is 3.0 fps.

The rating of a finned-tube unit in an enclosure having a top outlet is established at a value not in excess of the test capacity (which is the heat extracted from the steam or water in the unit under standard test conditions). For finned-tube with other types of enclosures or covers, a percentage is added for heating effect which varies up to a maximum of 15 percent, depending on the height and type of enclosure or cover. The additions made for heating effect must be shown in the manufacturer's literature.

Corrections for Non-Standard Conditions

The heat output of a radiator, convector, baseboard, or finned-tube heat-distributing unit is an exponential function of the temperature difference between the air in the room and the heating medium in the room-heating unit, or, expressed as an equation:

$$H = c(t_a - t_r)^n \qquad (1)$$

where

H = heat output, Btu per hour (Btuh).
c = a constant determined by test.

Table 7 .... Correction Factors for Various Types of Heating Units[a]

Steam Press. (Approx.) Gage Vac., In. Hg.	Steam Press. (Approx.) Abs., Psi	Temp. of Heating Medium Steam or Water	Cast Iron Radiators — Room Temp, F					Convectors — Inlet Air Temp, F					Finned Tube — Inlet Air Temp, F					Baseboard — Inlet Air Temp, F				
			80	75	70	65	60	75	70	65	60	55	75	70	65	60	65	75	70	65	60	55
22.4	3.7	150	0.39	0.42	0.46	0.50	0.54	0.35	0.39	0.43	0.46	0.50	0.36	0.42	0.46	0.51	0.57	0.38	0.42	0.45	0.49	0.53
20.3	4.7	160	0.46	0.50	0.54	0.58	0.62	0.43	0.47	0.51	0.54	0.58	0.45	0.49	0.53	0.59	0.64	0.45	0.49	0.53	0.57	0.61
17.7	6.0	170	0.54	0.58	0.62	0.66	0.69	0.51	0.54	0.58	0.63	0.67	0.53	0.57	0.61	0.67	0.72	0.53	0.57	0.61	0.65	0.69
14.6	7.5	180	0.62	0.66	0.69	0.74	0.78	0.58	0.63	0.67	0.71	0.76	0.61	0.65	0.69	0.75	0.81	0.61	0.65	0.69	0.72	0.78
10.9	9.3	190	0.69	0.74	0.78	0.83	0.87	0.67	0.71	0.76	0.81	0.85	0.69	0.73	0.78	0.84	0.89	0.69	0.73	0.78	0.82	0.86
6.5	11.5	200	0.78	0.83	0.87	0.91	0.95	0.76	0.81	0.85	0.90	0.95	0.77	0.81	0.86	0.92	0.97	0.81	0.86	0.92	0.95	1.00
Psi																						
1	15.6	215	0.91	0.95	1.00	1.04	1.09	0.90	0.95	1.00	1.05	1.10	0.91	0.94	1.00	1.06	1.11	0.91	0.95	1.00	1.05	1.09
6	21	230	1.04	1.09	1.14	1.18	1.23	1.05	1.10	1.15	1.20	1.26	1.03	1.08	1.14	1.19	1.24	1.04	1.09	1.14	1.19	1.25
15	30	250	1.23	1.28	1.32	1.37	1.43	1.27	1.32	1.37	1.43	1.47	1.20	1.26	1.31	1.37	1.43	1.22	1.27	1.32	1.37	1.43
27	42	270	1.43	1.47	1.52	1.56	1.61	1.47	1.54	1.59	1.67	1.72	1.38	1.44	1.50	1.56	1.62	1.43	1.47	1.52	1.59	1.64
52	67	300	1.72	1.75	1.82	1.89	1.92	1.85	1.89	1.96	2.04	2.08	1.67	1.73	1.79	1.86	1.92	1.75	1.82	1.89	1.92	1.96

[a] These correction factors provide means of determining output ratings for radiators, convectors, finned-tube, and baseboard units at operating conditions other than standard and, hence, also provide means of selecting these units to satisfy heating loads for a given space at any given set of operating conditions.

Standard conditions for a radiator are 215 F heating medium temperature and 70 F room temperature (at the center of the space and at the 5 foot level). Standard conditions for convectors, finned-tube and baseboard units are 215 F heating medium temperature and 65 F inlet air temperature. It should be noted that 65 F inlet air for convectors, finned-tube or baseboard units represent the same room comfort conditions as 70 F room air temperature for a radiator.

To determine the output of a heating unit under conditions other than standard, multiply the standard heating capacity by the appropriate factor for the actual operating heating medium and room or inlet air temperatures.

t_a = average temperature of heating medium, Fahrenheit. For hot water the arithmetical average of the entering and leaving water temperatures is used.
t_r = room air temperature, Fahrenheit. Air temperature 60 in. above the floor is generally used for radiators while the entering air temperature is used for all other types of heating units.
n = an exponent which equals 1.3 for cast-iron radiators, 1.4 for baseboard radiation, and 1.5 for convectors. For finned-tube units n varies with both air and heating medium temperatures. Correction factors to convert outputs at standard rating conditions to outputs at other conditions are given in Tables 6 and 7.

APPLICATIONS

In general, radiators, convectors, finned-tube, and baseboard units are installed in areas of greatest heat loss—under windows, along cold walls, or at doorways.

These units may be used in any type of steam or low temperature water system, and in some medium temperature water systems. However, units with different performance characteristics should not be installed in the same zone, i.e., cast-iron radiators should not be mixed with finned-tube type baseboards, see Chapters 10 and 11 of the 1964 GUIDE AND DATA BOOK.

Present trends in the design of hot water heating systems indicate two basic changes which affect the application of finned-tube and baseboard units. The first of these is the increasing popularity of medium- and high-temperature water systems, see Chapter 12 of the 1964 GUIDE AND DATA BOOK. Associated with this is the use of relatively large temperature drops through the system, drops of as much as 60 to 80 deg in low-temperature systems and as high as 200 deg in high-temperature systems. These higher temperature drops result in lower water velocities in the finned-tube elements, which necessitate an understanding of the resulting effect on heat output.

The Institute of Boiler and Radiator Manufacturers sponsored a test program at the University of Illinois to determine the effect of water velocity on heat output of various sizes of finned-tube elements. Fig. 2 is a plot of the results of this program showing rating factors versus velocity. There is little significant variation in output over the range from 0.5 fps to 6.0 fps (factors from 0.93 to 1.03 where 1.0 is at 3.0 fps). However, at a point between 0.4 and 0.25 fps, the factor drops rapidly. This is the critical velocity range, at which flow changes from turbulent to streamline. Little testing has ever been done on output of finned-tube radiation under streamline flow. It is obvious, therefore, that velocities below these points should be avoided in a hot water heating system, since results could not be accurately predicted.

The designer should check water velocity throughout the system and select finned-tube or baseboard element on the basis of velocity as well as average temperature. Manufacturers of finned-tube and baseboard today offer a variety of tube sizes, ranging from ¾ in. copper tubes for small baseboard elements to 2 in. IPS for large finned-tube units, which permit considerable latitude in selection, to aid in maintenance of turbulent flow conditions over a wide range of flows.

In areas where zone control, rather than individual room control, can be employed, it is advantageous to place all finned-tube units in the zone in series, to help maintain turbulent flow. It should be remembered in such a series loop installation that temperature drop must be considered in selecting the element for each separate room in the loop.

Primary-secondary pumping or the use of a secondary heat

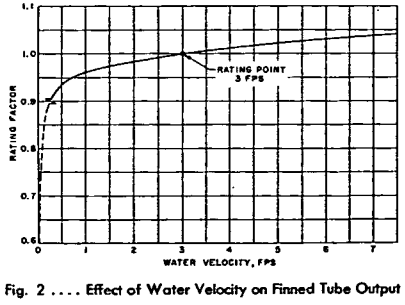


Fig. 2 .... Effect of Water Velocity on Finned Tube Output