

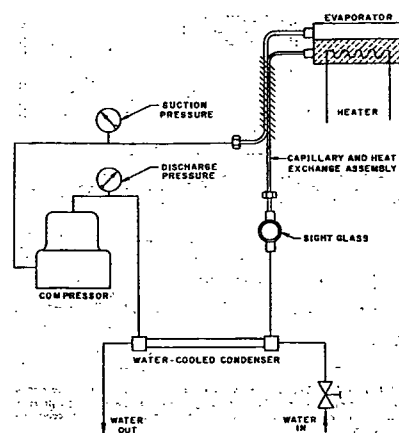


Fig. 35 . . . Test Set-Up for Determining the Capacity Balance Characteristic of a Given Combination of Compressor and Capillary and Heat Exchange Assembly

also be used as a calorimeter to simultaneously determine the capacity of the refrigerating system.

Optimum Selection and Refrigerant Charge

There is always a question as to whether or not the initial capillary selection and the charge are optimum for the unit, even in simple applications such as a condenser-to-evaporator capillary for a room air-conditioning unit. The refrigerant charge can be varied, for a given capillary selection applied to a unit, by locating a small refrigerant bottle, valved off and sitting on a scale, in the circuit. It is necessary that the interconnecting line be quite flexible and arranged so that it is filled with vapor instead of liquid. The charge is brought into the unit or removed from it by heating or cooling the bottle.

The only true test for varying the capillary restriction is to remove the element, install a new selection, and again determine the optimum charge as outlined above. A simple method, which is occasionally used, is that of pinching the capillary to determine whether or not increased resistance is needed.

It is necessary to operate the unit through the expected range of operation to determine power and cooling capacity for any given selection and charge combination.

Special Applications

The scope of capillary tubes has been extended beyond the basic expansion process or flow metering application. The mass flow may be affected through certain limits by varying the heat content of the refrigerant prior to its entrance into or along the length of the restrictor. Several important effects made possible through the use of the above principles include

temperature differential control, selective flow control, and modulated flow.

A two-temperature evaporator may readily be obtained by connecting a heat exchanger and a length of capillary tube between two coil sections. Refrigerant from the colder evaporator passes into the heat exchanger where it condenses any vapor and slightly subcools the refrigerant leaving the first coil prior to its entrance into the capillary. This means that for the low-pressure drops involved there would be very little flashing in the capillary. The compressor refrigerant and mass circulation may be held approximately constant by thermostatically controlling one evaporator to a constant temperature. These two conditions of constant flow and complete liquefaction throughout most of the restrictor insure practically constant pressure or temperature differential.

Another method for realizing a temperature differential between two evaporators is to selectively control the refrigerating effect of one of the evaporators. A short section of capillary is attached to the inlet of the high-temperature coil, which in turn is directly connected at its outlet to the low-temperature unit. The short capillary and the high-temperature evaporator are bypassed by a large bore tube containing a solenoid valve. The latter is connected to a thermostat to control the refrigerant flow around the high-temperature evaporator and thus control its average temperature with respect to that of the other cooling unit.

Refrigerant flow may be modulated by attaching an electric heater to the circuit ahead of the capillary. When the heater is energized, it causes gas bubbles to form in the liquid and thus retard its flow. The latter results in a partially refrigerated evaporator.

In a reversible system designed for both cooling and heating cycles, the latter mode usually demands more capillary resistance and less refrigerant for optimum performance. A method commonly employed is that of using a check valve in a branch of the capillary system so that its overall resistance automatically changes with a reversal of the refrigerant flow. It is possible, in heat pump systems, to arrange a reservoir in communication with the indoor coil and in heat exchange relation with the outdoor coil. This allows the total refrigerant charge to be active during the cooling cycle and to be reduced by the differential amount stored in the reservoir during the heating cycle.

Processing and Inspection

A strainer should precede the capillary to prevent mechanical clogging due to foreign particles. It is also necessary that all parts of the system be adequately evacuated to eliminate water vapor and noncondensable gases. These may cause clogging by corrosion. The oil should be free from wax separation at the minimum operating temperature.

The interior capillary surface should be smooth and uniform in diameter. Plug drawn copper is commonly used. Life tests should be conducted at low evaporator temperatures and high condensing temperatures to check on the possibility of corrosion and plugging.

Material specifications for seamless copper tube are given in *American Society for Testing Materials Specification No. B360-60*.

A procedure should be established to assure uniform flow capacities, within reasonable tolerances, for all capillaries used in product manufacture. This procedure might be conducted in the following manner.

The final capillary, determined from tests, is removed from the unit and given an air flow capacity rating, using the wet-

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test meter method described in ASHRAE Standard 28-57. Master capillaries are then produced, by using the wet-test meter air flow equipment, to provide the maximum and minimum flow capacities for the particular unit. The maximum flow capillary has a flow capacity equal to that of the test capillary plus a specified tolerance. The minimum flow capillary has a flow capacity equal to that of the test capillary less a specified tolerance. One sample of the maximum and minimum capillaries is sent to the manufacturer of capillary tubes, to be used as tolerance guides for elements supplied for a particular unit. Samples are also sent to the inspection group for quality control.

Preliminary Selection

The preliminary selection of a condenser-to-evaporator capillary for a given compressor rating may be determined by referring to Fig. 36. It should be noted that the compressor rating is based on the refrigeration per pound specified. The curves of Fig. 36 apply to typical operating conditions, which are indicated on the charts. If desired, the ratings may be converted to mass flow in pounds per hour by dividing the compressor capacity by the refrigeration per pound given on the chart. For the preliminary selection no distinction is made between units which do and do not have heat exchangers. The 15 F subcooling referred to in Fig. 36 pertains to the total subcooling obtained in the unit, whether this be in the condenser alone or in the condenser plus a heat exchanger.

In the selection of a capillary for a specific application, practical considerations will influence the length. For example, the minimum length will be determined by geometric considerations, such as the physical distance between the high side and low side and the length of capillary tube required for optimum heat exchange. It may also be dictated by considerations of exit velocity and noise, and the possibility of plugging with foreign materials. The maximum length may be determined primarily by considerations of cost. It is fortunate therefore, that the flow characteristics of a capillary can be independently adjusted by varying either its bore or length. Thus it is feasible, first, to independently select the most convenient length and then (within certain limits) select a bore to give the desired flow. An alternate procedure is to first select a standard bore and then adjust the length as required.

Standard diameters and wall thickness for capillary tubes are given in *ASTM Specification No. B360-60*.

Simplified Calculation Procedure

It is possible to calculate the optimum capillary size corresponding to any given set of system operating conditions. These conditions of pressure, mass flow, and inlet subcooling or quality in turn are a function of the unit design and a choice of the service operating conditions.

It is customary to adjust the capillary on room air conditioners to give maximum unit capacity at ASHRAE rating conditions of 80 F DB, 67 F WB indoors and 95 F DB, 75 F WB outdoors. It is possible that optimum performance may be obtained when there is considerable subcooling in the refrigerant prior to its entrance into the capillary.

In all cases it is necessary that the unit be tested to assure that the capillary performs properly under various limiting conditions. For instance, the capillary of a household refrigerator which may have been sized to give optimum performance on no-load cycles at a particular ambient temperature should be tested to see that it operates properly during pull-down, during maximum and minimum ambient and loading conditions.

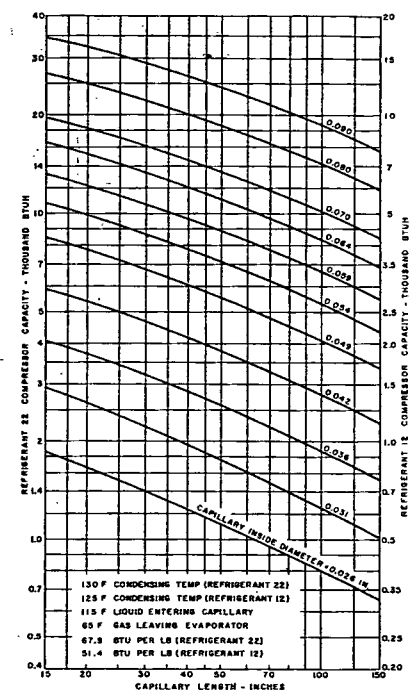


Fig. 36 . . . Preliminary Selection Chart for Refrigerants 12 and 22 Condenser-to-Evaporator Capillary

The ratings presented in Figs. 37 and 38 are general application ratings for Refrigerants 12 and 22. In presenting them in this form, an attempt has been made to provide ease of usage even though some accuracy is sacrificed in the process. The rating curves are most versatile since they can be used to directly calculate flow rate from a given capillary selection and flow condition, or to determine a capillary selection from a flow condition and flow rate.

These ratings, while presented in the form shown originally by Hopkins,⁴ show somewhat different values because they were recalculated from the later work of Whitesel.^{5,6} The difference is particularly noticeable in the gas flow-through portion of the ratings.

It is obvious that the ratings based only on Figs. 37 and 38 yield only approximate results since suction pressure is not shown as a parameter. Actually, this is not a serious fault because Bolstad demonstrated that drop in back pressure over a wide range causes a negligible increase in refrigerant