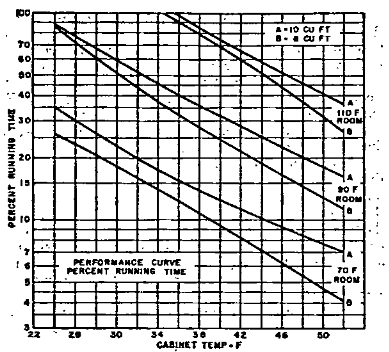

Fig. 4 .... Percentage Running Time vs. Room Temperature and Box Temperature for Typical 8-cu ft and 10-cu ft Conventional Refrigerators

tor whose major functions are cooling the cabinet interior, producing ice cubes, and providing limited frozen food-storage for very short periods of time.

2. *Combination Refrigerator-Freezer.* In this type the size of the frozen-food storage compartment is increased substantially to where it may in some instances be as large as the normal food storage compartment and additional controls are employed to maintain temperatures suitable for long time storage of frozen foods.

Characteristic energy consumption and percent running performance of the *conventional refrigerators* are shown in Figs. 4 and 5. Performance of the combination type cannot be represented by such simple curves because of wide variations in the size of the frozen-food compartments together with the variations in temperature tolerances and means of control in both the frozen-food and normal food-storage compartments acceptable to different manufacturers.

Energy consumption in a 90 F room of from 2 to 8 kwh for 24 hr and running times from 38 to 78 percent have been observed on different makes of these refrigerators in the 12 to 18 cubic foot total size. Frozen-food compartment sizes varied up to ½ of the total volume and temperatures maintained in this compartment ranged from −2 to +10 F and from 37 to 40 F in normal food storage compartment.

Specifications for testing mechanically operated refrigerators are described in Standard B38.1-1955. Figs. 4 and 5 show performance of typical 8 and 10 cubic foot refrigerators.

External and interior refrigerator temperatures may be measured by liquid in glass thermometers, electric thermocouples or electric resistance thermometers. *Glass thermometers* are relatively inexpensive but the refrigerator door must be opened in order to read them within the refrigerator interior. While this may not affect the accuracy of the reading, it slows up the testing of the refrigerator because the box temperatures must be stabilized again before initial kilowatt hour readings or running time readings can be taken.

Resistance thermometers are accurate and reliable for measuring cabinet and room air temperatures but they are too bulky to measure surface temperatures on evaporators, tubes, compressors, and so forth. *Thermocouples* with potentiometer indicators are the most satisfactory means for measuring temperatures for development work. This is because they are in-

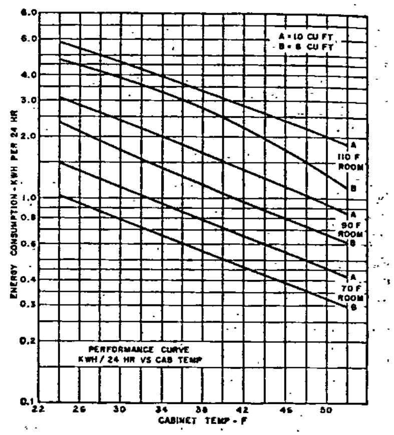

Fig. 5 .... Kilowatt Hours Consumption for 24 Hours for Typical 8-cu ft and 10-cu ft Conventional Refrigerators

expensive, small, and have such low thermal mass that they easily follow rapid changes in temperature. They can also be lagged after putting them in contact with a mass of metal or fluid to read average rather than momentary cycling temperatures. Recorders are available for use with thermocouples or resistance thermometers that will plot as many as 16 records on one chart.

During testing, it is important that the temperature gradients throughout the test room be kept to a minimum, because of the effect of room temperature on refrigerator performance. The temperature at the floor should not be essentially different from that in the rest of the room, or the cold floor air being drawn through the condenser will give inaccurate results. When testing a thermal-convection-cooled condenser located on the back of the refrigerator, it is necessary to keep the room air velocity low enough so that heat dissipation from the condenser will not be affected. The American Standard B38.1-1955 requires that the room temperature be maintained within plus or minus 1 F deg of the specified value, and that the vertical temperature gradient from the floor to a height of 7 ft shall not exceed a half a degree for each foot of vertical distance.

The best method for conducting an ice freezing test is to measure ice freezing time by means of thermocouples inserted in the ice cube that will freeze last. As the water cools, the temperature in the trays will go down rapidly to 32 F. During the actual freezing period, the temperature will stay at 32 F and at the conclusion of this period, will go down rapidly from this point. The ice is considered frozen when the temperature drops below 28 F.

If an ice tray is placed on the shelf of a dry evaporator, there will be an entirely different rate of ice freezing than if the contact surfaces between the tray and the evaporator were thoroughly wet before the test. Differences as great as two to one in ice freezing time can result from this contact variation. Therefore, it is the usual procedure to wet the evaporator surface before putting the tray in place.

Kilowatt hours can be readily measured by an integrating

kilowatt meter having a scale multiplier of 0.01 or less so that the data can be read to 0.01 kwh and estimated to 0.001 kwh. The running time of the refrigerator unit can be measured by means of self-starting electric clocks.

While there are no standard specifications for testing refrigerators under simulated field operation, such testing is desirable.

In setting up a laboratory test procedure that would simulate field conditions reasonably well, there are five variables that should be considered:

a. Dry-bulb temperature.
b. Dew-point temperature.
c. Number of refrigerator door openings.
d. Length of door openings.
e. Usage load.

To simulate severe field usage, the following conditions may serve as a pattern for a suitable test procedure. A dry-bulb temperature of 90 F is suggested. This is 2 F deg below the dry-bulb temperature which is not exceeded more than 5 percent of the 12 hr during the middle of the day from June to September, inclusive, of a normal summer. A dewpoint of 81 F represents a condition along the Gulf Coast which was not exceeded more than 5 percent of the total hours from June to September, inclusive, for a normal summer. Some data available indicate that not more than 2 percent of the refrigerator users open the refrigerator door more than 80 times per 24 hr. There is some deviation from this figure, depending upon the season of the year and the size of the refrigerator. A value of 10 door openings per (24 hr) (cu ft) of refrigerator volume may be reasonable. A door opening period of from 10 to 15 sec is suggested. Laboratory tests indicated that at 60 F dewpoint and 90 F dry-bulb temperature door openings of greater than 10 sec duration have little effect on the amount of moisture pickup on the evaporator. Over a 12-hr interval, 80 door openings of approximately 13-sec duration can be worked into a schedule of six approximately one-hour periods of door openings. It is suggested that to duplicate the food load in the refrigerator, an equivalent weight of 78 F water in glass jars be substituted for the food in a fully loaded refrigerator. A schedule of twice a week shopping and the preparation of three meals a day can be assumed, with simulated food added to or taken from the refrigerator accordingly. In addition, one tray of ice cubes should be frozen for each of the three meals.

Much can be learned from the standpoint of development by operating the compressor unit with a calorimeter of some kind. One type of calorimeter consists of a relatively short copper tube surrounding a tubular electric heater. Refrigerant is admitted in one end of the tube through a constant pressure expansion valve, and the heat input adjusted until the desired degree of superheat is obtained at the output. A modification of this particular idea has been used in connection with flooded evaporators. One feature of a good calorimeter is a small thermal mass so that its response to a change is rapid, thus reducing testing time. A calorimeter achieving these characteristics particularly well employs a heater immersed in the liquid of a secondary refrigerant circuit, while the evaporator of the compressor under test functions as a condenser for this secondary circuit. The control on the calorimeter turns the heater on and off in response to the pressure of the secondary system while the total heater input over a period of time is measured by a kilowatt-hour meter.

Cabinet heat-leakage tests can be run in several ways, as follows:

1. The cabinet may be placed in a hot room and the refrigerant passed to the evaporator at a rate necessary to maintain a constant cabinet temperature. The heat leakage per degree may then be determined from the quantity of refrigerant circulated, the condition of the refrigerant entering and leaving and the interior and exterior cabinet temperature.

2. The cabinet may be placed in a cool room (about 50 F) and the cabinet interior heated with electric heaters to a point where the mean temperature of the insulation is about 75 F. The overall heat loss may then be determined from the heater input and the interior and exterior cabinet temperatures.

3. The cabinet may be operated in a hot room with a calibrated refrigerating unit of the type normally installed in the cabinet. This method takes into account the localized heating of cabinet surfaces from the condenser and compressor, and gives the most accurate overall results under operating conditions approaching normal.

4. Ice may be placed in the cabinet and its rate of melting measured.

OPERATING CYCLE OF THE HEAT-OPERATED ABSORPTION REFRIGERATORS

Absorption refrigerating machines based on the Platen-Munters system have been the most successful of the heat-operated refrigerating cycles so far applied to household refrigerators. It is a three-fluid system and all locations in the hermetically sealed unit are at the same total pressure, aside from minor variations which arise from the presence of fluid columns and which are used to circulate the fluids.

The charge includes an aqua-ammonia solution of a strength of about 28 percent concentration (ammonia by weight) and hydrogen. The charge for a typical unit is approximately 2.0 lb ammonia, 5.2 lb water and 0.03 lb hydrogen.

The elements of the system include a generator (sometimes called boiler or still), a condenser, an evaporator and an absorber. (See Fig. 6.) There are three distinct fluid circuits in the system: an ammonia circuit including the generator, condenser, evaporator and absorber; a hydrogen circuit including the evaporator and absorber; and a solution circuit including the generator and absorber.

Heat is applied to the generator by a gas burner or other source of heat to expel ammonia from solution. The ammonia vapor thus generated flows to the condenser. In the path of

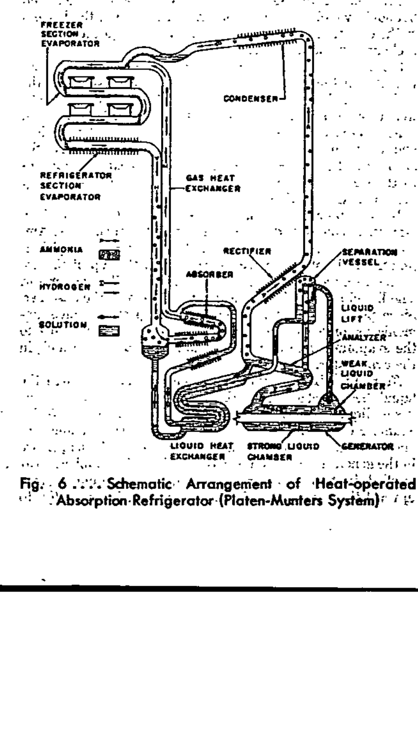

Fig. 6 .... Schematic Arrangement of Heat-operated Absorption Refrigerator (Platen-Munters System)