flow of ammonia from the generator to the condenser are interposed an analyzer and a rectifier. Some water vapor will be boiled out along with the ammonia vapor in the generator. The analyzer and rectifier serve to remove this water vapor from the ammonia vapor. In the analyzer, the ammonia passes through strong solution which is on its way from the absorber to the generator. This reduces the temperature of the generated vapor somewhat to condense water vapor and the resulting heating of the strong solution expels some ammonia vapor without additional heat input. The ammonia vapor then passes through the rectifier where the residual small amount of water vapor is condensed by atmospheric cooling and drains to the generator by way of the analyzer.

The ammonia vapor, which is still warm, passes on to the condenser where it is liquefied by air cooling. The condenser is provided with fins for this purpose. The ammonia thus liquefied flows into the evaporator through a liquid trap.

Hydrogen gas enters the upper portion of the evaporator and flows downward in parallel-flow to the downward flowing liquid ammonia. The effect of the placing of a hydrogen atmosphere above the liquid ammonia in the evaporator is to reduce the partial pressure of the ammonia vapor in accordance with Dalton's law of partial pressures. While the total or gage pressure in the evaporator and the pressure in the condenser are the same, there is substantially pure ammonia in the space where condensation is taking place, and consequently the vapor pressure of the ammonia substantially equals the total pressure.

Under Dalton's law, the total pressure of a gas mixture is equal to the sum of the partial pressures of the individual gases. Consequently in the evaporator the partial ammonia vapor pressure is less than the total pressure by the value of partial pressure of the hydrogen. The lesser ammonia vapor pressure results in evaporation of the ammonia with absorption of heat from the surroundings of the evaporator and the cooling of the interior of the refrigerator.

The cool heavy (strong) gas mixture of hydrogen and ammonia vapor formed in the evaporator leaves the bottom of the evaporator and passes downward through the gas heat exchanger to the absorber.

Since the weight of a gas is proportional to its molecular weight and the molecular weight of ammonia is 17 and the molecular weight of hydrogen is 2, it follows that the specific weight of the strong gas is greater than that of the weak gas. This difference in specific weights is alone sufficient to initiate and maintain circulation between the evaporator and the absorber. The gas heat exchanger transfers heat from one gas to the other. *This saves some cooling in the evaporator* by precooling the entering gas.

In the absorber, a flow of weak solution (water weak in ammonia) comes in direct contact with the strong gas. Ammonia is absorbed by water, and the hydrogen, which is practically insoluble, passes upward from the top of the absorber through the gas heat exchanger into the evaporator. The liquid and gas flows are counter-current in the absorber. Since perfect separation of gases is not possible, some ammonia vapor passes with the hydrogen from the absorber to the evaporator and determines the low temperature limit in the evaporator.

From the absorber the strong solution flows through the liquid heat exchanger to the analyzer and thence to the strong liquid chamber of the generator. Heat applied to this chamber causes vapor to pass upward through the analyzer and to the condenser. The solution passes through an aperture in the generator partition into the weak liquid chamber. Heat applied to this chamber causes vapor and liquid to pass upward through the small diameter pipe, as in an *air lift*, to the separation vessel. Liberated ammonia vapor passes through the analyzer and thence to the condenser. The weak solution from the separation vessel flows through the liquid heat exchanger and to the absorber. The liquid heat exchanger precools the liquid entering the absorber and preheats the liquid entering the generator. Further precooling of the weak solution is obtained in the finned air-cooled loop between the liquid heat exchanger and the absorber.

Actual unit construction includes additional refinements which increase efficiency or provide operational features but the cycle described above is the fundamental cycle of absorption refrigerators.

PART II: HOUSEHOLD FREEZERS

The functions of the household freezer are to provide a storage space at a temperature of 0 F or below and a fast freezing zone where limited quantities of fresh food may be frozen in a reasonably short time with minimum disturbance of the stored-load temperature. These functions should be performed with the following objectives in view:

1. Minimum temperature variations due to cycling of the refrigerating unit.
2. Well insulated cabinet for economical power consumption.
3. External surface temperatures in line with household refrigerator practice.
4. Ease of access to all parts of refrigerated space.
5. Efficient, reliable and quiet refrigeration system.
6. Sturdy construction including adequate moisture vapor sealing.
7. Durable and attractive appearance with low odor levels considered in the choice of internal materials.

CABINETS

Modern chest type freezers are of all-steel construction with synthetic enameled exteriors. The exterior shell is stiffened at the base by the bottom pan, which supports the insulation, and a sub-base or angle iron frame. The top of the shell is strengthened by a rigid tie with the interior compartment. This rigid tie may be in the form of a wood frame with a decorative breaker strip of rubber or plastic, or plastic laminates may be used for both the decorative and structural functions. Baked enamel on steel has received preference for the construction of interior compartments with aluminum also in general use. Steel and copper tubing are both in general use for evaporator circuits. Interior compartments are generally supported by the bottom pan of the outer shell on blocks of rigid insulation. Lid construction generally consists of an inwardly flanged sheet steel exterior carrying a plastic laminate inner panel and a balloon-type rubber gasket. Counterbalancing springs and a lid latch with provisions for locking are standard equipment.

Upright freezers have followed the pattern of household refrigerators or the larger reach-in refrigerators. Interior locker doors may be used to reduce air spillage and to form convenient loading shelves when the main door is opened. The question of air spillage from upright cabinets has received considerable attention. Laboratory tests comparing chest and upright types indicate no significant difference in operating costs with a reasonable number of door openings per day. When the opening frequency is high, as in a commercial dispensing cabinet, the frost accumulation in the upright type may become objectionable, but in household use this objection has not been experienced.

Since a household freezer may be operated in damp locations such as a cellar or may be used in a modern kitchen, it is important that exterior surface temperatures be kept high enough to avoid objectionable condensation. The surface adjacent to the breaker strips is usually the critical area in this respect. A minimum cross-sectional area of materials of low thermal conductivity consistent with durability must be used. Air circulation across the surface of the breaker strips should be retarded as much as possible. This should be accomplished by restriction, rather than by isolation of the air, as the latter method will lead to a troublesome frost condition. Surface temperature depressions of 4 F deg below ambient in a 70 F room should be acceptable. To avoid condensation in this area a low-wattage insulated heater wire may be attached to the inside surface of the shell near the top or near the front in the case of upright design. A similar heater may be used in the door when necessary. Where condensing unit design permits, a portion of the condenser tubing may be attached to the inside surface of the shell to elevate these surface temperatures. Center mullions in multiple lid cabinets are frequently a source of condensation. It is advisable to provide for free air circulation under the cabinet to avoid condensation under the bottom pan.

Insulation thickness of 3 to 4 in. is used on the average, except in the lid, where considerably less insulation is usually provided. Insulation has been predominantly of the glass fiber and mineral wool types in batt form. The so-called high density form of these insulations which offers slightly better insulation than standard grades has been extensively used. Recent changes in manufacture of these fibrous insulations have produced finer fibers with more insulating value per dollar of cost. Silica aerogel, certain expanded plastics and special gases replacing the air in mass insulation offer interesting possibilities for increasing the storage space by reducing the insulation volume with materials of exceptionally high insulating value. Since a substantial portion of the heat leakage of a cabinet occurs through the gaskets, breaker strips and mechanical supports, it is difficult to realize completely the gain in insulating effect indicated by the low conductivity factors of these materials.

A high resistance to moisture vapor penetration through the outer shell of a freezer cabinet is of the utmost importance for satisfactory performance during the long operating life normally expected. While the accumulation of moisture in the insulation by the process of diffusion can be controlled by mediocre sealing of the shell, the influx of moisture-laden air due to the small changes in internal air pressure which occur with cycling of the refrigerating unit (and the less frequent pressure changes due to door openings) is independent of the area of the opening. In actual practice the pressure difference may be continually equalized by some venting arrangement such as the lid or door gasket, but the design must be such that the moisture entering such a vent will be deposited on a surface where it can be readily removed during defrosting. The process will work effectively only if the shell is sealed so that its resistance to air flow is much greater than the resistance of the venting means. Joints in the external shell are sealed with various forms of wax, tars, and plastisols. The effectiveness of sealing has been effectively checked by both air pressure and vacuum methods.

The problem of locating the condensing unit has been treated in three ways. The small sizes of cabinets generally have a shallow food compartment which allows the condensing unit to be located under the bottom insulation. This arrangement offers a more accessible interior than the deeper compartments, but the ratio of floor area to usable volume is high. The lowest ratio of floor area to usable volume is offered by the design which locates the compressor under a step in the food compartment. This arrangement, which may require more costly fabrication, offers a convenient fast-freezing zone if the bottom as well as the vertical surfaces of the shallow portion of the compartment is refrigerated. In the larger cabinets the condensing unit may be contained in an enclosure added to one end of the insulated cabinet. This design usually results in waste volume above the condensing unit, and in some cases, this has been arranged as a food thawing zone or a storage compartment for wrapping materials.

Equipment for the convenience of the user include such items as: *wire shelves, baskets and partitions, interior light,* temperature indicator, and warning devices, all of which may be factory installed or sold as accessories.

REFRIGERATING SYSTEMS

The evaporator in the majority of current chest type freezers consists of tubing bonded to the exterior surface of the food compartment. Generally, the tubing is placed only on the vertical walls, except where it is desired to form a fast-freezing surface by refrigerating a portion of the bottom or a shelf. A common form of this type of evaporator uses copper or steel tubing which is held against the exterior of the compartment wall by various types of clips or clamps. A mastic with good thermal conduction or tar may be used as a filleting material. Aluminum food compartments and aluminum tubing may be joined in an intimate mechanical and thermal bond by the use of a special brazing process. The expensive equipment required for this process as well as subsequent surface treatment of interior surfaces has limited its use. The use of aluminum evaporator tubing introduces a special problem where connections are made to tubes of another material. This problem may be solved by the use of special pre-welded joints which are brazed in place by the customary processes. Wide variations are found in the choice of tube spacing and length. The factors of cost and pressure drop in the evaporator tubing require a short tube length on necessarily large centers, whereas the factors of temperature drop from tube to wall and in the wall between tubes call for a long tube length and small center distances. Chest type freezer evaporators are also formed from refrigerated plates mounted vertically, parallel to the food compartment walls, or as dividers between sections. These plates may be of tube and plate type, or the brazed double-wall type with integral refrigerant passages. Upright freezer evaporators usually consist of horizontal refrigerated plates which act as shelves. In some cases these shelves are of an open construction of expanded metal or wire bonded to the refrigerant tubing.

Automatic defrosting freezers are now available in which the evaporator surface is generally shielded from view within the refrigerated space and air circulation is accomplished by forced convection with a small fan. The evaporator surface is periodically defrosted by *heat from hot refrigerant gas* or direct electric heaters. The defrost period is normally only a few minutes and is automatically initiated by a timer switch. In the selection of condensing unit size for this type of cooling it must be recognized that the heat load for a given freezer cabinet will be raised to a considerable degree by adding forced convection as a factor in the heat leak plus the fan motor heat if the motor is located within the refrigerated space.

CONDENSING UNITS

Experience in the household refrigerator industry has indicated a preference for the use of hermetically sealed systems with capillary tube expansion device for freezers where reliability is of paramount importance. Ease of replacement should be considered.

The low suction pressures involved in this application require good compressor construction with high volumetric efficiency. Compressor motor loads will be relatively light in