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TECHNICAL METHOD

A REFRIGERATOR DESIGNED FOR A HOSPITAL BLOOD BANK

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In most hospitals the blood for transfusion is stored in refrigerators designed for the storage of food. These refrigerators are frequently cooled by a relatively small evaporator coil, the temperature of which is below 0° C.

Such a cooling method has the following disadvantages.

First, the small cooler or evaporator becomes quickly covered with ice or snow, particularly when the cabinet is in heavy use. It then has to be defrosted by switching off the machine every few days. This is not only a nuisance in a busy hospital laboratory but introduces another element of hazard into blood transfusion.

Secondly, pools of air at different temperatures exist throughout the cabinet. The air immediately around and below the cooler is coldest, and the warmest air will be found away from the cooler, at the top and near the door. Tests of a well-known 15 cu. ft. refrigerator have shown that the temperature variation within the cabinet may be 8° C. or more. If care is not taken the temperature of blood stored too near the cooler may fall to or below zero, and freezing is not unknown.

Thirdly, should something go wrong with the refrigerating machine or a fuse blow, or some similar stoppage occur, the temperature of the stored blood will rise in a few hours to that approaching the ambient air. There is normally no provision for delaying this rapid rise of temperature so as to allow a reasonable time for the detection of the defect and the carrying out of the necessary repair.

The refrigerator now described was designed to eliminate or reduce these faults. At the same time other useful features, including accuracy and steadiness of temperature control, were introduced.

The Refrigerator

The storage chamber is essentially a rectangular compartment of about 25 cu. ft. capacity, measuring 40 in. wide × 42 in. high × 26 in. deep internally. The cabinet is insulated with 3-in. compressed cork slab, and two insulated doors are provided to give ready access to the four tiers of metal shelving. For convenience the insulated cabinet is raised 24 in. above the floor on a base which is part of the structure.

The back and two sides of the cabinet are formed by a double steel wall with a 3-in. space between, and this is filled with water. This water jacket contains the copper cooling coil which is connected to the refrigerating machine. The coil lies behind the middle two-fourths of the back and sides. When in operation it becomes covered with ice, the thickness of which varies according to the thermostat setting. At the settings required for blood storage the tank does not become solid with ice. In effect the jacket contains a mixture of ice and water, and therefore its surface must be at or above that of thawing ice, viz., 0°. The very large surface presented to the cabinet storage space becomes the cooler, and as the tank lines the sides and back of the cabinet a fairly even distribution of cooling is effected. As noted later this could probably be improved.

No Defrosting.—The thermostat, which is immersed in the water of the jacket, is set at or above 0° (usually 1° to 4°).

The temperature of the cooling surface is above 0°, and water vapour cannot freeze on it. Defrosting is unnecessary, since frosting does not occur. The water condenses on the cold back and sides of the cabinet interior. These walls become damp, and, although this is not a serious defect, the dampness could be considerably reduced by the substitution of four or more doors for the two provided.

"Hold-over" Period.—The water-jacket contains a large volume of cold water. The high specific heat of water as well as the latent heat available from the ice on the coil permits the water to absorb a considerable amount of heat with little change in temperature. In this way a hold-over period is provided should the refrigerator mechanism fail. The cabinet will remain sufficiently cold up to 12 or 18 hours, during which time the blood need not be transferred to another refrigerator. A test of this hold-over period is recorded below.

The temperature of a bottle of water on the top shelf of the cabinet was observed with a continuous-recording thermometer. The thermostat had been set at 1°. The water temperature was 4° when the electric motor was switched off. During the next nine hours the cabinet was opened every half-hour or so. Five hours after switching off, the temperature of the water had just reached 5°, at seven hours the temperature was 6°, at 10 hours 7°, at 12 hours 8°, and at 16 hours 9°. The ambient temperature was about 20°.

Thus if a defect occurs at night the hold-over period is sufficiently long to maintain adequate refrigeration of the blood throughout the night. It might even allow limited use the following morning if the defect can be fairly quickly repaired.

Temperature Control and Recording.—A sensitive thermostat pressure element of conventional pattern is immersed in the water jacket above the cooling coil, and is connected by capillary tube to the thermostat switch which controls the operation of the refrigeration compressor motor. The switch, which is mounted on the outside of the refrigerator, has a range of settings (in degrees of temperature, with a differential of ±1°), by means of which the water in the jacket can be regulated to a desired temperature.

A continuous and permanent record of temperature within the cabinet is made with a standard clock type of instrument whereby the temperature is inked on to a calibrated paper chart which is changed daily. The thermometer itself is a vapour-pressure instrument: the bulb is immersed in a bottle of water within the refrigerator, and the capillary tubing leads to the externally situated recording clock. This is a mechanical instrument independent of failure of the electricity supply.

Cabinet Temperature.—Gradients of temperature, partly due to stratification and partly due to posterior and lateral cooling, have not been eliminated, but the large cooling surfaces have reduced them. In all refrigerators temperature differences are accentuated by frequent opening of the cabinet doors when warm air enters and replaces the cold air in the top and front of the cabinet.

The gradients of temperature within the cabinet were estimated by reading the temperatures of bottles of water placed at the front, in the middle, at the back, and at the sides of all four shelves. The temperatures were read at or before 9 a.m., and once or twice during the next nine hours. The readings were taken during busy and not-so-busy working days, after busy and quiet nights, etc., at ambient temperatures from 14° to 22°, and for different settings of the thermostat. A difference varying from 0.5° to 2° was found between the front and the back of the four shelves and was greatest in the uppermost shelf. Stratification mainly affected this shelf, and was minimal below it. Hence the largest difference of temperature was found between the front of the top shelf and the back of the lower shelves. This difference is usually 2° or 3°, but on busy days may be as much as 4°. Further reduction of temperature stratification and this temperature difference could probably be obtained by having the cooling coils face the upper two-thirds of the back and sides rather than the middle two-fourths as at present. Other possible designs of the water jacket will spring to mind.

A mean cabinet temperature was estimated under different working and environmental conditions, and the bottle of water containing the bulb of the externally recording thermometer was so placed that this temperature was recorded. The temperature of 75% to 90% of the cabinet space is within ±1° of this reading, and the whole storage space is within ±2°.

The desired mean cabinet temperature of 3° to 4° is maintained day and night and under different conditions through periodic changes of the thermostatic setting.

Night Alarm Bell for Door Closure.—At night blood may be removed from the refrigerator. To ensure that the refrigerator doors are properly closed, an alarm-bell system is in use. A loud bell rings when one or other door is opened, and does not stop until both doors are properly closed.

During the daytime this alarm system is switched off.

Refrigerating Machine.—This is a methyl chloride machine driven by a ⅓-h.p. motor. No matter how quiet a refrigerator motor is, it usually causes some vibration in the laboratory and may interfere with microscopy, etc. In order to avoid this the refrigerating machine is sited outside the laboratory and is piped to the refrigerator.

The thermostatic control, refrigeration control switches, and thermometer recorder are mounted on the side of the cabinet, where they may be readily handled and observed.

Tests and experience over a period of many months show that excellent results are easily obtained, and that the design is a definite advance on any form of small storage cabinet with which the writer has had experience to date.

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