COMMUNICATION RECEIVED AS A DISCUSSION ON MR. TAKAKURA'S PAPER ON REFRIGERATING MACHINERY.

FROM Mr. Y. WADAGAKI. MEMBER.

The paper read by Mr. Takakura on the subject of refrigerating machinery is indeed a very good one.

Four or five types of refrigerating machines he has illustrated may be grouped under the two following heads:—

(a) Processes involving the evaporation of a liquid by heat, radiation, liquefaction and a sudden reduction of pressure.

(b) Processes involving compression of a gaseous substance, radiation (in some cases accompanied with liquefaction), and a sudden reduction of pressure.

The cold is produced by accelerated evaporation of some liquid or by rapid expansion of some compressed gas.

When the air is the agent used, the expansion cylinder can not be omitted, for the air is nearly a perfect gas and cools itself only by doing outside mechanical work.

When the agent is a liquefiable gas, the expander may be omitted, as is usually the practice, but then we have two causes of economic loss; namely, a higher initial temperature in refrigerator and the waste of mechanical work that may have been saved by the use of the expander.

With a great fall of temperature in refrigerator, the thermal effect obtained per unit of mechanical work done is not so good as in the case with a moderate range of temperature. In many cases therefore it is more desirable to deal with a large quantity of moderately cold air rather than a small quantity of very cold air. Similarly, in the manufacture of ice, it is not necessary to make the temperature of ice any colder than is absolutely required to keep its frozen state. Hence, the great importance of regulating the freezing point of the brine mixture so as to prevent the unnecessary expenditure of power.

The loss due to the fluctuation of temperature in the working cylinder in any form of heat engines depends upon the ranges of temperature between which the fluid works or is worked upon, and in the case of refrigerating machinery, the smaller this range, the better the efficiency. Therefore the compression or expansion required in the operation of ice making should always be effected in stages.

The clearance spaces at both ends of stroke in the working cylinder, whether for compression or expansion, always involve a certain amount of loss, so that it should be made as small as practicable.

In consideration of the first cost of machinery, the condensing and refrigerating surfaces are sometimes made rather small. This pennywise policy can not be recommended, as it is a sure cause of subsequent losses on account of restricted transmission of heat from one agent to another.

The cold produced by the machine may be transmitted to the storage room in three different ways. They are:—

- (a) Direct circulation of working fluid.
- (b) Cold brine circulation.
- (c) Dry air circulation.

Of these, (a) and (b) carry the fluid in pipes and take it back to the refrigerating plant after it has been used in cold room.

Whatever cold left in the fluid is thus saved. In the system (c), any cold left in the current of dry air, after it has been discharged from the cold room is entirely wasted. In (b) and (c) the transmission of cold takes place at two steps, they are therefore less efficient in this respect than the system (a). The system (b) is the heaviest of all the three.

With due precaution, the refrigerating system may be applied to keep down the temperature of magazines on board war vessels. And the examples of its application are not wanting in foreign navies.

The principal requirements of the working fluid best adapted for the refrigerating machinery are as follow:—

- (a) Low freezing point.
- (b) Low evaporating temperature.
- (c) Rapid evaporation.
- (d) Great latent heat.
- (e) Easy liquefaction (if liquefiable at all).
- (f) Moderate vapour tension.
- (g) Greater density.
- (h) Suitability for smaller and lighter plant for given output.
- (i) Low first cost of the plant.
- (j) Low working expenses.

- (k) Simplicity of mechanism and least chance of break down.
- (l) No danger of inflammation or explosion.
- (m) Not injurious to the metals containing the fluid; such as cylinders, pipes &c.
- (n) Not poisonous or disagreeable to handle.
- (o) Freedom from leakage.
- (p) Stability or constancy of quality.

Of course no substance can fulfil all the conditions enumerated above, and the engineer who has to choose any substance as the working fluid for his refrigerating machines should consider all the varying circumstances of the environs in which he has to work.

In any compression machine, the compression should be effected isothermally at low temperature by means of cold water cylinder jacket, and the initial temperature made as low as possible. Where the fluid is compressed in stages, the intermediate condenser should also be provided. Any oil or moisture contained in the working fluid must be extracted for the sake of safety and economy. The expansion of air carried in stages gives us an incidental advantage of separating and depositing the moisture in the first cylinder and thus preventing the formation of ice in the cold pipe.

Of all the agents used for the refrigerating machinery, the air is the cheapest substance. It does not attack the metals to any serious extent by itself. It has no poison in it. It has also the advantage of being perfectly stable in quality. The principal troubles in the use of air are the formation of ice in the cold pipe and the danger of explosion, due to the instantaneous inflammation of oil present in the

pipe, under the combined influence of the dense oxygen and the heat of compression. With dense air machine, therefore, it is imperatively necessary to provide a good type of moisture trap and oil extractor. The air supplied to the machine must also be free from any dust or other inflammable matter. We have already seen that the low initial temperature in the compressor, sufficient cooling of air during the compression and the carrying out of compression in stages with intermediate cooling are the necessary conditions for economical compression. These conditions are also essential for the safe operation of air compressing machinery. In connection with cooling of air during the compression it may here be stated that a long stroke compressor with a small diameter of cylinder has an advantage over a short stroke compressor with a large diameter of cylinder of presenting more cooling surface, volume for volume.

For the sake of safety and economy, the valves of compressors should have a steady and definite action and be free from shocks and friction.

Oils employed for the internal lubrication of air compressors should be of very best quality, possessing high flashing and ignition points. The valve chambers of the compressor should be such as would admit an easy inspection and cleaning. An approved type of automatic lubricator should be fitted to the air compressing cylinder to regulate the supply of oil within a safe bound. It is also very desirable to make a special provision for the insertion of pyrometers or thermometers for ascertaining the temperature of the compressed air at any stage of operation, in order to guard against the danger of ex-

plosion. Greatest possible care should be exercised in laying out the pipes for compressed air to avoid the pocket wherein a quantity of oil may accumulate. When a large quantity of compressed air is introduced into a pipe whose other end is closed by a valve, the low pressure air originally present in the pipe is suddenly compressed as if forced by a pump plunger and raises its own temperature to a considerable extent; and an explosion may take place at any moment, if conditions co-exist to expose a large quantity of inflammable oil to the joint influence of great heat and pressure, in the presence of dense oxygen.

In connection with the refrigerating machinery on dense air system, the advantage of a high initial pressure must not be lost sight of.

The high initial pressure of air in the compressor will not only improve the economical performance of the plant to some extent, it has also the great merit of reducing the size and weight of the machinery for a given output. A small loss of the compressed air through leakage has of course to be supplemented by a primer pump.

Water is just as cheap as air in the quantity used as refrigerating agent, and it is said to be largely used by the natives of India in the manufacture of domestic ice. It is perfectly non-poisonous, does not corrode the metals by itself. Its vapour tension at ordinary temperature is very low. When pure it does not change its quality any length of time. On evaporation it carries a great latent heat. It would appear therefore to be the best agent for the refrigerating agent, were it not for the fact that its freezing and boiling temperatures are rather high and that the evaporation under reduced pressure does

not take place rapidly enough to make it a commercial success when used as the refrigerating agent.

Ammonia assumes a gaseous state at ordinary temperature and under atmospheric pressure. It has therefore to work at increased pressure to be kept in a liquid state during a part of the cycle of operation. Mr. Takakura is quite right in saying that its vapor tension is very high. In compression machines using the ammonia as the refrigerating agent, the working pressure is from 135 to 180 lbs per square inch. As Mr. Takakura says, the ammonia has a remarkable property of dissolving itself in one—seven hundredth parts of its own volume of water. The absorption machine is worked on this remarkable property of ammonia. It is of necessity worked at much higher pressure than the compression machine. It is said that in hot climates with the thermometer standing at 95° F. the pressure would reach 300 lbs per square inch and it is seldom less than 180 lbs. Other difficulties with ammonia, as mentioned in Mr. Takakura's paper, are its corrosive action on metals, frequent and heavy leak, accompanied with a disagreeable odour, the impossibility to use the grease as lubricant, and the danger due to the deposit that often forms at the bottom of the boiler, in the absorption machine, if fitted with furnaces.

The advantages claimed for ammonia absorption machines are the following:

- (a) No expander is necessary.
- (b) Boiler itself does duty of the compressor.
- (c) The absorbent itself does duty of vacuum pump.
- (d) The application of work is most direct, and therefore the

machine works very economically.

With these advantages, the ammonia absorption machine has a serious source of loss, inherent in its system. Some ten per cent of water carried with vaporized ammonia absorbs seven hundred times of its own volume of ammonia before the latter reaches the absorption vessel. This will not only reduce the refrigerating effect of the ammonia thus absorbed, but also by filling up a part of the space in the refrigerating pipes would diminish their cooling efficiency. Merits and demerits of several other substances used as the refrigerating agent have been clearly stated by Mr. Takakura, and it is not necessary to dwell any longer on this subject, except to mention a few facts which require a special emphasis. These are:—

Sulphureous acid (SO₂)

- (a) More easily liquefiable than ammonia.
- (b) No chemical action on metals or fat.
- (c) Not combustible.
- (d) Its price cheap.
- (e) Has a great lubricating property in itself.
- (f) It has however to work at an increased pressure like ammonia.

Carbonic acid (CO₂)

- (a) Has no affinity for copper, and attacks no metals nor any other substances.
- (b) Its vapor is much denser than ammonia; therefore, the machine can be made much smaller for a given output and more strong.

(c) Inodorous and not poisonous in the quantity used.
Ether and alcohol.

(a) Work at diminished pressure and therefore comparatively safe.

(b) More or less leakage of atmospheric air into the partial vacuum.

(c) The air mixed with the substance tends to acidify it.

(d) Ether which is superior to all other substances in most respects has an awkward tendency under the influence of frequent condensation and rarefaction to transform itself into less volatile isomers.

Whatever method may be employed in the manufacture of ice, it is always very desirable that it should be made from pure water, quite free from any poisonous substance. This safeguard can be best secured by the use of distilled water which can be obtained at a small cost by taking advantage of the latent heat of exhaust steam from the refrigerating engines.