expects that any carelessness on his part will not be personally cognizable in the finished product. A perfect co-operation and unity of interest in what relates to the whole community, with a clear recognition of the faithful performance of his part by each individual and due compensation for the work he does thoroughly, is the acme of social life.

ARTIFICIAL REFRIGERATION.*

BY JNO. FOX.

For some time I have looked forward to the preparation of a short paper on cold storage and refrigeration. I will dwell principally on that system of refrigeration which is now under my charge at the O'Keefe Brewing Company's, namely, the Delevergne, or direct expansion system.

The substance used in this system is anhydrous ammonia. We are told that ammonia is a combination of nitrogen and hydrogen, expressed by the formula NH_3, which means that an atom of nitrogen (representing 14 parts by weight) is combined with three atoms of hydrogen (representing 3 parts by weight) at ordinary temperatures; the ammonia, or anhydrous ammonia, as it is called in its natural condition, is a gas or vapor; at a temperature of 30° F. it becomes a liquid, at the ordinary pressure of the atmosphere; and at higher temperatures also, if higher pressures are employed. The anhydrous ammonia dissolves in water in different proportions, forming what is called ammonia water, ammonia liquid, aqua ammonia, etc. At a temperature of 900° F. ammonia is decomposed into its constituents, nitrogen and hydrogen, the latter being a combustible gas. It appears that partial decomposition takes place also at lower temperatures, but probably not to the extent frequently supposed.

Ammonia is not combustible at the ordinary temperatures, and a flame is extinguished if plunged into the gas, but if ammonia be mixed with oxygen the mixed gas may be ignited, and it burns with a pale yellow flame; such mixtures may be termed explosive in a certain sense. If a flame sufficiently hot is applied to a jet of ammonia, it (or rather the hydrogen of the same) burns as long as the flame is applied, furnishing the heat required for the decomposition of the ammonia. Ammonia is not explosive, but when stored in drums and there is not sufficient space left for it to expand, when subject to a higher temperature, the drums will burst, as has often happened in hot seasons. The ammonia vapors are highly suffocating, and for that reason persons employed in rooms charged with ammonia gas must protect their respiration properly.

In the direct expansion system the liquid ammonia is directly conducted to the place where heat shall be absorbed, or we might say into the rooms to be cooled, and is here allowed to expand in a system of pipes called refrigerators or expansion coils, so that heat is absorbed directly by the ammonia gas. The gas is then drawn back to the machine or compressors, where it is again compressed and discharged into pressure tank, and from there on to condensers, where it is again liquedized.

The liquefaction is accomplished by cold water trickling over the condenser, or, we might call it condensing coils, thereby cooling the ammonia; it then passes on to the separating tank, and if any oil should get carried over, it is caught here. The ammonia then goes on through expansion valves into cold storage rooms, where the heat of the room is absorbed, thereby cooling or lowering the temperature, completing its work thus to repeat its circulation over and over again.

Now let us see what we have to consider in the shape of mechanical work performed. As you know, the equivalent of a ton of ice is 284000 heat units, or the amount of heat that would be necessary to convert a ton of ice 32° Far. into a ton of water at 32° Far. Conversely it is the amount of heat that must be extracted from a ton of water at 32° Far. in order to convert it into a ton of ice at 32° Far. Let us take, for instance, a fifty ton plant; the latent heat of one lb. of ice is one hundred and forty-two heat units; multiplying this by two thousand gives us the number of heat units in one ton. Now as we are considering a fifty-ton plant this will be 14,200,000 heat units in 24 hours of time, or, in other words, a 50-ton plant in 24 hours will absorb this number of heat units. (It might be stated here that in speaking of a plant of so many tons' capacity it is always understood to mean for a period of 24 hours.) The temperature of expanding ammonia would have to be about 10° lower than the temperature of cold storage room, which we will take as 35° Far. Consequently by using tne latent heat of vaporization at that temperature, which is 35° Far.—10° Far. = 25, we find it to be 540.03, which is refrigerating effect of 1 lb. of ammonia when the temperature of refrigeration is 25°, and that of condenser 70°. Specific heat of the ammonia being 1. The number of pounds of ammonia required per hour, therefore, in a fifty-ton plant is represented by the following equation:—14,200,000 heat units in 24 hours, ÷ 60 x [540.03 heat units per one lb. of ammonia—(70° − 25°)] x 24 = roughly, 20 lbs. per hour. The volume of 1 lb. of ammonia vapor at 25° Far. is equal to 5.26 cubic feet; consequently, compressor capacity per minute will have to be 105.20 cubic feet. Now, if we add to this 20 per cent., which is a fair allowance for losses by radiation, etc., we require an actual compressor capacity of 126.20 cubic feet per minute.

We will see how the plant of the O'Keefe Brewing Company compares with the theoretical calculation just made; the compressor cylinders are 11 x 22, which is equal to about 1¼ cubic feet capacity of each cylinder. Now the engine makes 40 revolutions per minute, and each is double acting, diameter 11 x 11 = 121 x 7854 = 95.0334 x 22 ÷ 1728 = 1.2099. Consequently at each revolution of crank shaft each compressor discharges its contents twice, which gives us a total discharge of about 192 cubic feet per minute. Now we will deduct 20 per cent. for clearance losses, etc., and we get 154 cubic feet, or about 27 feet more than required by our theoretical calculation, which would be the amount allowed to come and go on, which is close enough for all practical purposes.

In piping cold storage rooms, from what information I can gather, it is usual to allow about one square foot of pipe surface for every 3,000 heat units to be absorbed; this is equal to about 1.6 running feet of two-inch pipe. Now, for a 50-ton plant, according to this rule, we will require a sufficient amount to absorb 14,200,000 heat units in 24 hours, which in round numbers would be 7,573.3 running feet of pipe.

The condenser is a system of pipes or coils into which the ammonia, after being compressed in compressors, is forced, and where it is cooled by water trickling over the pipes. These are called atmospheric or surface

* A paper read before the Convention of the C.A.S.E.