and, being freely open to the atmosphere, are more easily kept cool. The parts in which the pistons work are made of special metal, cast as thin as possible, and ribbed lengthways, so as to facilitate the conducting power by increasing the surface and keeping the metal thin, at the same time that the ribs serve to strengthen it. Water circulation is arranged to pass outside the cylinder, as well as through a recess formed in the forepart of the trunk, by which the cylinder is cooled and lubricated internally by the water, as well as externally without allowing the water to mix directly with the air. The trunk pistons and interior of the cylinder, being always open to inspection, can be easily kept in the most perfect working order. Owing to the weight of the trunk piston, its momentum increases toward the end of the stroke, where the resistance of the air compressed in the cylinder is increasing against it, thus greatly assisting in the work of compressing the air. At the same time the great extent of bearing surface removes any objection as to the wear, there being in reality very much less weight upon each square inch of bearing surface than in the case of the ordinary narrow piston. The inlet valves are placed one in the head of each piston, and so arranged as to open and close instantaneously by the action of their own momentum, on the reversal of the piston, independently of the formation of a vacuum or pressure in the cylinder, and as they travel with the piston, against the air when open, and also when closed, they necessarily retain their proper position throughout the whole of both backward and forward strokes. The delivery valves open direct into an air-receiving chamber in the middle, between the two working cylinders. Each delivery valve consists of a flat disk covering the whole bore of the cylinder, and so arranged that the piston may run close up to it, thus discharging the whole of the air from the cylinder, the clearance being, in fact, behind the valve instead of inside the cylinder. Thus all the danger of breakage in the case of narrow clearance and a fixed cylinder end is avoided. The delivery valve area may also be further increased, by covering the whole area of the disk with any convenient number of small delivery valves, working within the main disk valve.

With these compressors the writer never found any difficulty in raising the pressure up to 200 lb. in a single stage of compression; and, so far as he can see, there would be no difficulty in obtaining very much higher pressures, such as have hitherto been only attempted in stages, by making the cylinders of sufficient strength to withstand the pressure, and applying steam cylinders of sufficient power, and with a good leverage of the crank of the steam cylinder over the crank of the compressing cylinder. The question of stage compressing, however, belongs rather to that of the applications of compressed air, which he hopes to bring before the institute at some future time, when, perhaps, he may have been able to make some experiments in that direction. Fig. 3 is a diagram taken from a trunk compressor with cylinders of 12 in. diameter and 2 ft. stroke, after the engine had been running for about an hour. As the trial was made in the workshop immediately after the engine was completed, and there was no convenience for maintaining a continuous water circulation, the water was stagnant in the casing the whole time. It therefore shows a higher degree of heat than there should be, indicating a rise of temperature from 60° to 273° Fah. With an efficient water circulation this would be very greatly reduced. The leakage was imperceptible, not being sufficient to deflect a flame applied close to the outer edge of the cylinder.

Another important question in connection with air compressing is that of the percentage of useful effect realized. But as this paper is already sufficiently long, the writer must leave the consideration of that part of the subject to be dealt with under the head of the application of compressed air power, to which it more properly belongs, as so much of the efficiency of the system depends upon the mode of application, after we have done all in our power to attain the highest efficiency and economy in the production of the compressed air. It is, indeed, impossible to apply any fixed rule, as the results will vary with every pound variation of pressure, with the mode of application, and even with the state of the weather, the same machine producing different results on a dry and crisp day to what it does on a wet or foggy day. The results are, therefore, very variable and often contradictory.

On the preceding page is a set of tables, compiled by Mr. Isaac Shone, C.E., of Wrexham, the inventor of Shone's pneumatic sewerage system, and the patent pneumatic liquid ejector. These tables are carefully revised and largely extended from Professor Thurston's well-known tables, having six additional and entirely original columns, showing the ratio of volume to pressure, the points of the stroke at which the stated pressures are reached, and the average pressures upon the piston, both with temperature variable and constant. They will be found of great practical use by all who have to do with compressed air in facilitating calculations.

FORMULÆ.

Let t = total absolute temp. due to the degree of tension of the air, the normal press. and temp. being taken at 14.7 lb. per sq. in. and 60° F. respectively.
 T = normal temp. — 60° F., or 515° C.
 p = ultimate press. of air given in Col. A.
 P = normal press. of air = 14.7 lb. per sq. in.
 R = ratio of compression.
 H = hyperbolic log. of R .

$$\begin{aligned} \text{Then Col. B} &= t = \left(\frac{p}{P} \right)^{0.29} \times (461.2 + T) \left\{ \begin{array}{l} \text{Fah degrees.} \\ \text{Col. C} = (\text{Col. B} - 461.2) = t - 461.2 \end{array} \right. \end{aligned}$$
$$\left. \begin{array}{l} \text{Col. D} = t = \left(\frac{p}{\bar{p}} \right)^{0.29} + (274 + T) \\ \text{Col. G} = t - 274 = \text{Col. D} - 274 \end{array} \right\} \text{Cent. degrees.}$$
$$\text{Col. F} = \text{Col. G} \times \frac{461.2 + t}{461.2 + \bar{T}} = \text{Col. G} \times \frac{461.2 + \text{Col. B}}{461.2 + 60}$$
$$\text{Col. G} = \frac{P \times 100}{p} = \frac{14.7 \times 100}{\text{Col. A}}$$
$$\text{Col. H} = \text{Col. A.} - 14.7 = p - \text{P.}$$
$$\text{Col. I} = 100 \div \text{Col. F.}$$
$$\text{Col. K} = 100 \div \text{Col. G.}$$
$$\text{Col. L} = 1 \div \text{Col. I.}$$

Col. M = 1 ÷ Col. K.

$$\text{Col. N} = p \times \frac{1 + H}{R} - P; R \frac{c}{c1}; c1 = \frac{c \times t}{T}; c = 100$$
$$\text{Col. O} = p \times \frac{1+H}{R} \text{ --- P; } R = \frac{p}{P}$$

SEAMLESS TUBING.

MESSRS. DURAND, BOSSIN & BRARD, of Paris, are manufacturing at their shops at Longueville (Seine-et-Marne) a line of tubings in which there is no soldering, and consequently no seam. These are made from various metals, such as copper, yellow metal, silver, steel, white metal, etc., in an infinite variety of forms and dimensions of cross-section, and the method of manufacture permits of their being produced of considerable length. We have endeavored, in the accompanying cut, to figure a portion of these numerous sections, but it is evident that the diversity of forms that may be made is unlimited. Nos. 1 and 7 of the cut represent the extreme sections of copper tubes that the manufacturers always

CROSS-SECTIONS OF SEAMLESS TUBING.

have in stock. They vary from one-fifth inch to one inch in external diameter. These tubes are round and corrugated (Nos. 8 to 12), or square with sharp angles (Nos. 19 to 23), or square with re-entrant angles (Nos. 24 to 26), or square with figured sides (No. 27). There are also hexagonal tubes (Nos. 28 to 30), oval tubes (Nos. 31 and 32), round thick tubes of small bore (Nos. 33 to 35), flattened ones, smooth (Nos. 39 and 40), or figured (Nos. 41 and 42), or corrugated (Nos. 43 and 44), and finally, triangular (Nos. 36 to 38), etc. The other figures which follow, from No. 45 to No. 88, will give some idea of the multiplicity of styles that are produced by this house.

These tubes are being largely used in various arts and industries, finding application in the manufacture of clocks,

musical instruments, optical apparatus, jewelry, etc., and in surgery, pyrotechnics, etc., etc.

Specimens of these tubes were shown at the last Paris Exhibition, both in copper and silver, 1,600 feet in length and seamless throughout their whole extent.

SMITH'S TWO-TON ANCHOR.

This anchor is distinguished from those generally employed by the fact that it has no stock, and that the arms are movable on the shank. For this reason it can be constructed without any welding of the parts, its strength being thereby necessarily increased.

The shank, M, is T-shaped, and its lower end is traversed by the axle, N, which moves freely therein, but is fixed firmly to the arms, PP', by bolts. These arms, the form of which is shown in the sections A and B and C and D, are provided with two claws, R and R', which, when the anchor has been cast and is dragging over the bottom, press against the latter and force the points to incline and grapple the first obstacle that they meet with. The arms are movable only within a certain angle, which is determined by the shoulder pieces with which the shank and arms are provided. The weights are distributed as follows: Shank, 1,700 pounds; two arms, 2,110 pounds; axle, 350 pounds; and rings, 240 pounds—total, 4,400 pounds.

The large companies which have adopted this anchor are the Cunard Company, the Peninsular and Oriental Company, and the Union Steamship Company. The English Navy also uses them on several of its vessels; among others, on the Rover, the Hydra, and the Eclipse.

MECHANICAL REFRIGERATION.

By J. K. KILBOURN.

THE development of machinery and methods for mechanical refrigeration is comparatively speaking of recent date. The different systems now before the public have all been brought out within thirty years. In the laboratories the purely scientific aspects of the various methods are understood, but in the workshop, and with the public generally, they are as a sealed book. The practical information concerning these different systems as yet rests with the few experimenters who have given time and thought to their development. The limits of this article will not permit the writer to speak of the scientific theories of the various systems; but he will confine his remarks to that system and class of machinery where cooling is effected by the alternate compression and expansion of air, leaving it to future opportunity to take up other branches of this subject.

"Regnault's experiments determine that the specific heat of a given weight of gas, which is approximately perfect, does not vary with the temperature nor with the pressure or density of the gas;" hence it follows that the potential heat energy of a given weight of air is neither increased nor diminished by any amount of compression. In other words, a pound of air at a given temperature, say 60°, will heat or cool any substance having a temperature above or below that of the air, the same number of degrees in every stage of compression, it being immaterial whether the volume is one cubic foot or thirteen. By compressing air, a cooling or condensing medium of comparatively high temperature can be made available, and it has no other object.

By the system under discussion cooling is effected by the transference of heat from the air to be cooled to a cooling or condensing medium, usually water, which when charged with heat is run to waste. The initial temperature of the air to be cooled is raised by compression to such a degree above that of the cooling medium, that in the equalization of temperature heat is abstracted from the air under compression. When expansion follows this cooling, the terminal temperature of the air is the initial temperature minus the heat abstracted, and the heat discharged by the condensing water is the measure of the cooling effected. From the various prospectuses in circulation one might consider that cool dry air was an exclusive production, subject to the pains and penalties of patent monopolies, whereas it is almost a necessary incident to cooling.

Saturated air contains aqueous vapor in quantities varying with the temperature. One cubic foot at 33° having but 2·21 grains, at 50° 4·10 grains, at 100° 19·84 grains, conse-

SMITH'S TWO-TON ANCHOR.

quently reducing the temperature from 100° to 33° causes the liquefaction of 17.63 grains of vapor, which can be collected and removed as a liquid; failing in this, frost and snow are formed, causing no little trouble. Various methods have been devised to overcome this difficulty. In a paper recently read before the Institution of Mechanical Engineers by Mr. Lightfoot, an ingenious arrangement was described. By this method a partial expansion to a predetermined extent reduced the temperature of the air to about 35° . The vapor condensed by this reduction of temperature is deposited on metallic surfaces, collected in suitable receptacles, and run off, after which the air is further expanded to atmospheric pressure. In theory this method appears well; but satisfactory results would require uniformity of temperature in the condensing water not attainable in practical working. In the paper before referred to, the author criticises Bell and Coleman's method of condensing this surplus vapor by a system of metallic pipes; but the objections the author points out cannot be maintained. It is assumed that by both methods the temperature after compression and cooling is the same; then the amount of vapor to be deposited and run off would in each case be equal. By the system of metallic pipes exposed to the action of the spent cold air passing from the chamber, the surplus vapor is condensed and the latent heat of vaporization as well as the heat of the air under compression is absorbed by the "spent cold air" before entering the compression cylinder, and is afterward abstracted and discharged by the cooling water, and every unit so discharged reduces the final temperature of the air after expansion by the same amount.

By the method of condensing the surplus vapor by the "act of expansion" the latent heat of the vapor is taken up by the expanded air, and the final temperature would be raised to the extent of the units of heat taken up, and this result corresponds with the author's statement, that is, with the Bell and Coleman method, the final temperature was 96° below zero, while by the author's system the final temperature was only 68° below zero. By either method, when the excess of vapor over saturation at the temperature has been liquefied and run away, the air is as dry as it can be made by any *mechanical appliances*.

Referring again to Mr. Lightfoot's paper, it appears by the tabulated results of test experiments that a machine that delivers 15,000 cubic feet of cold air per hour with initial temperature of cooling water at 57° requires 23·6 indicated horse power, and for this delivery there was discharged by the condensed water 43,840 units of heat, or an equivalent of making 244 pounds of ice per hour. In other words, by this system 23·6 indicated horse power will produce in 24 hours the equivalent of 52 cwt. of ice, a very low efficiency as compared with the systems using condensible gases as the frigorific medium. The certified results of some of the more volatile of these gases show a production of 12 tons of ice per ton of coal burned. In addition to this low efficiency the excessive weight of the machinery and consequent excessive first cost may be considered as prominent objections to this system; when used on seagoing vessels the fact that every extra ton of machinery or coal excludes a like amount of paying freight adds importance to the objections named. On the other hand, the use of air as the frigorific medium in place of chemicals is an advantage which cannot be ignored, and moreover it is a system easily understood and free from inherent difficulties to overcome in construction.

The advantages and disadvantages are believed to have been fairly stated in the foregoing remarks, and it is hoped that what has been said will make this branch of mechanical refrigeration more clearly understood.—*Engineering.*

[Continued from SUPPLEMENT No. 278, page 4428.]

SIMPLE HOLTZ MACHINE AND EXPERIMENTS IN STATIC ELECTRICITY.*

By GEORGE M. HOPKINS.

The simple machine shown in the annexed engraving is nearly if not quite as efficient as the best make, and it is much simpler than the one previously described.

Taking it for granted that the reader is already pretty well acquainted with the essential points of a Holtz machine, I

will confine my description mainly to the points of difference between the machine now under consideration and the one before described. As the principal dimensions are given on the engraving, it will be unnecessary to repeat them here.

The revolving plate, C', is fastened with cement to the end

of a wooden sleeve, which is similar to an ordinary spool, with a groove turned in one of its heads. This sleeve turns on a quarter-inch pin projecting from the post, D', and is driven by a large wheel having the bearings of its shaft in the same post, D'. This arrangement economizes space,

* In the preceding article, on page 4426, in describing the experiment with the folded paper and electroscope, the types say the electricity is "marked;" they should say, the electricity is "masked."

Simple Holz Machine Rear View:

and dispenses with one post; but it would probably be better to support the driving wheel on a post of its own. This would admit of using a longer belt and a larger wheel.

As the glass might become loosened if cemented directly to the flange on the end of the sleeve, I first cover the flange with pitch, gutta percha, and shellac cement, and warm it

If the glass does not run truly it may be warmed, and the sleeve may be placed on the pin and revolved, and while the cement is still plastic the glass may be trued up.

Two grooved vertical posts, A, support the two glass plates. B, B², which in this machine take the place of the fixed apertured plate in the machine described in the former

article. They are placed far enough apart to allow the collar of the plate, C', to revolve between them, and they are placed as near the revolving plate as possible without touching.

The paper inductors and gilt paper teeth are formed and applied as in the other case. Instead of the glass posts for supporting the collecting combs, and instead of the Leyden jar form of condenser, a double Franklin plate or condenser, *E*, is used. This plate is supported in wooden feet, *G*,

so that it becomes thoroughly attached to the wood. I then coat a thin disk of leather with cement, and attach it to the flange, and finally cement the leather to the glass. If the leather is of such a porous nature that it does not hold the glass with sufficient rigidity, it is well to apply a little thin shellac varnish to its edges to stiffen it.

and is longer than the plates, B', B². It has square pieces of tin foil attached to opposite sides near opposite ends. The corners of these pieces of tin foil are rounded to prevent the escape of electricity, and the two pairs of tin foil pieces are placed apart, about half the diameter of the revolving plate, C', and the distance between the inner and outer piece of tin foil