who have bought no less than 200 six-pounders, and the Japanese, who, on their trip through Europe two years ago, ordered at once 60 six-inch cannon, 30 of which were delivered in September last. Mr. Krupp's establishment has delivered 2,500 cannon of steel, mostly rifled breech loaders, 400 of which have a caliber of eight inches and more, the rest having from three to four and a half inches.

The workshops of Krupp cover at present ever 500 acres of land, consume daily 15,000 cwt. of coal, work by steam from 120 boilers, are illuminated by 7,000 gas lights, and employ over 8,000 men and boys, whose wages amount to about 2,500,000 dollars, or an average of 312½ dollars each per annum. A fund has been established to which every workman has to contribute an average of one groschen (about three cents) of every dollar he earns, in return for which he receives support in case of sickness, and a good pension in his age. Mr. Krupp himself contributes to this fund half as much as his workmen: so that in fact, if a workman pays for instance $1, the fund gets $1·50. From this source every workman gets, after twenty-five years service, a good pension. In case of accident, he receives full wages during the whole time of inability to work, and if sick he is supplied with medicines, and finally, burial expenses are usually paid out of this fund. Besides this, Mr. Krupp's workmen enjoy a good many other advantages. To supply them constantly with good and cheap bread, he erected bakeries in a grand style, the flour for which he buys in large quantities from Russia. Similar arrangements have been made to supply them with good and cheap potatoes, and we hear that Mr. Krupp intends to do the same with meat. These father-like arrangements prove very beneficent for both employer and workman, and have been imitated in England in many of the large manufactories.

The iron ores for the enormous demand are partly from Krupp's own mines in the late dukedom of Nassau, and near Coblentz, and are partly bought. The former give the well-known Spiegel iron. It contains a large quantity of manganese, of which, however, it is cleaned by a simple process, and contains then over 98 per cent of pure iron, the other two per cent consisting mostly of silicious earth, cobalt, nickel, copper, and a very small quantity of phosphorus. That which is to be used for cannon must be softer than ordinary steel, so as to have a certain elasticity under the force of the discharge. This softness is attained by mixing a quantity of forge iron in the steel mass. Iron and steel are cut into bars of six inches length and put in plumbago crucibles containing from thirty to sixty pounds each. The manufacture of these Krupp crucibles was a secret for a long time. At present, however, those of Ruel in London, and the Patent Crucible Company, Battersea, are deemed to be almost as good. The foundery is an enormous building, containing so many furnaces that the necessary iron and steel masses for castings of the largest dimensions can be melted there in 1,200 crucibles at the same time. About ten crucibles are placed in every furnace, resting on movable bars. The heat in the furnaces is so great that the best Scotch fire-proof stones which surround them, and sometimes even the crucibles, melt, so that the latter can be used but once. The workmen are divided into companies, and obey commands with the greatest precision, so as to be able to found the contents of the different crucibles all at once into a reservoir and thence into the mold beneath. As soon as the casting is solid it is surrounded by hot ashes and kept in a red glow until the forging takes place. As this can only be done in cool weather, the largest pieces sometimes lie two or three months in their hot beds, the necessary temperature being maintained by constant supplies of glowing ashes.

The castings consist first of round or square forms, and are afterwards forged, hammered or turned. By the regular form of the casting, a symmetrical mass is obtained, free of bubbles; the steam hammer gives the mass the necessary compactness, strength and elasticity, and generally compresses it 2 or 3 per cent, and the power of resistance rises from 760 to 1,320 cwt. per square inch. The last mass for the cannon is pretty soft and has a power of resistance from 800 to 900 cwt.

The smaller cannon consist of one solid piece: those over eight inches caliber are compound, and fastened by rings. The largest *steel* cannon yet manufactured is of eleven inches caliber. It was first cast as a cylinder of 750 hundred weight and seven feet diameter, and then forged, after which it was strengthened by rings of cast steel. Two monsters of this kind, weighing 540 cwt. each, and worth about 14,000 thalers, have been manufactured for the Russian government They are breech-loaders, and are able to throw a ball of 540 pounds with a charge of 50 pounds of gunpowder. Their destination is the Russian fortress of Kronstadt. A still larger monster of 15-inch caliber, throwing balls of 900 lbs., for the same government, will be at the grand exhibition.

The steam hammers are of great importance in Krupp's establishment. The largest of this kind has a fall of ten feet and cost about 700,000 dollars, two thirds of which were paid for the tilter or bed of the hammer, which has not sunk in the least, although the hammer has been thundering day and night. We should say that nothing could resist the power of these blows, but the large masses of red glowing steel it has often to forge bear these blows with so much resistance that they become effective only by long repeating. Mr. Krupp has therefore decided to use a three times greater power upon his steel, and to forge a hammer of 2,400 cwt. with a fall of thirteen feet. The cost thereof will be about 1,300,000 dollars.

Steel cannon were until lately the principal manufactures of Krupp, but lately he has also manufactured a good many balls and bombs for the Russian government, to which he has delivered several thousands of oblong eight and nine inch shot and shell, all the finest cast steel, the smaller sort of which contain eight pounds of powder and are able to crush iron plates five and a half inches thick. But every one of these pills costs over 100 dollars, all being hammered and forged. Similar though smaller bombs are destined for the Italians, and partly already delivered.

THE MECHANICAL EQUIVALENT OF HEAT.

Prepared for the Scientific American.

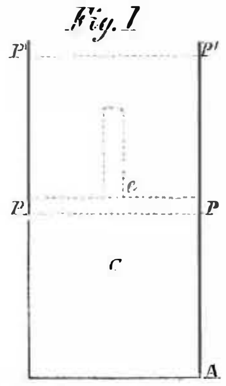
Our present mechanical equivalent of heat is established by proofs of such seeming strength and conclusiveness that it is no light matter to call its truth in question; however, I propose to show that these proofs are not really so conclusive as they appear and that our equivalent, which says a unit of heat will give 772 foot lbs. of force, has no direct proof for its support but the all direct proof which can at the present time be brought to bear on the subject would go to establish quite a different measure for the power of heat. I will first quote from "Heat considered as a mode of motion," by Professor Tyndall, to show how the equivalent has been established and will then present the reasons for making the above statement.

"Using the accurate numbers, the quantity of heat applied when the volume is constant, is to the quantity applied when the pressure is constant, in the proportion of 1 to 1·421.

"This extremely important fact constitutes the basis from which the mechanical equivalent of heat was first calculated. And here we have reached a point which is worthy of, and which will demand, your entire attention. I will endeavor to make this calculation before you.

"Let C, (in Fig. 1,) be a cylindrical vessel with a base one square foot in area. Let P,P, mark the upper surface of a cubic foot of air at a temperature of 32° Fah. The hight A P will then be one foot. Let the air be heated till this volume is doubled; to effect this it must, as before explained be raised 490° Fah. in temperature; and, when expanded, its upper surface will stand at P′ P′, one foot above its initial position. But in rising from P P to P′ P′ it has forced back the atmosphere, which exerts a pressure of 15 lbs. on every square inch of its upper surface, in other words, it has lifted a weight of 144×15=2,160 lbs. to a hight of one foot.

Fig. 1



The "capacity" for heat of the air thus expanding is 0·24 water being unity. The weight of our cubic foot of air is 1·29 ounces, hence the quantity of heat required to raise 1·29 ounces of air 490° Fah., would raise a little less than one-fourth of that weight of water 490° The exact quantity of water equivalent to our 1·29 oz. of air is 1·29×0·24=0·31 oz.

"But 0·31 oz. of water, heated to 490° is equal to 152 oz., or 9½ lbs. heated 1° Thus the heat imparted to our cubic foot of air, in order to double its volume and enable it to lift a weight of 2,160 lbs., one foot high, would be competent to raise 9½ lbs. of water 1° in temperature.

"The air has here been heated under a constant pressure, and we have learned, that the quantity of heat necessary to raise the temperature of a gas under constant pressure a certain number of degrees, is to that required to raise the gas to the same temperature when its volume is kept constant, in the proportion of 1·42 : 1 hence we have the statement—

$$1{\cdot}42 : 1 = \overset{\text{Lbs.}}{9{\cdot}5} ; \overset{\text{Lbs.}}{6{\cdot}7}$$

which shows that the quantity of heat necessary to augment the temperature of our cubic foot of air, at constant volume, 490°, would heat 6·7 lbs. of water 1°.

"Deducting 6·7 lbs. from 9·5 lbs., we find that the excess of heat imparted to the air in the case where it is permitted to expand, is competent to raise 2·8 lbs. of water 1° in temperature.

"As explained already, this excess is employed to lift the weight of 2,160 lbs. one foot high. Dividing 2,160 by 2·8, we find that a quantity of heat sufficient to raise one pound of water 1° Fah. in temperature, is competent to raise a weight of 771·4 lbs. a foot high.

"This method of calculating the mechanical equivalent of heat was followed by Dr. Mayer, a physician in Heilbron, Germany, in the spring of 1842.

"In August 21, 1843, Mr. Joule communicated a paper to the British Association, then meeting at Cork and in the third part of this paper he describes a series of experiments on magneto-electricity, executed with a view to determine the "mechanical value of heat." The results of this elaborate investigation gave the following weights raised one foot high, as equivalent to the warming of 1 lb. of water 1° Fah.

1.	896 lbs.	5.	1026 lbs.
2.	1001 lbs.	6.	587 lbs.
3.	1040 lbs.	7.	742 lbs.
4.	910 lbs.	8.	860 lbs.

"In 1844 Mr. Joule deduced from experiments on the condensation of air the following equivalents to 1 lb. of water heated 1° Fah.

823 foot lbs.
795 foot lbs.
820 foot lbs.
814 foot lbs.
760 foot lbs.

"As the experience of the experimenter increased, we find that the coincidence of his results become closer. In 1845, Mr. Joule deduced from experiments with water, agitated by a paddle wheel, an equivalent of

890 foot lbs.

"Running up his results in 1845, and taking the mean, he found the equivalent to be

817 foot lbs.

"In 1847, he found the mean of two experiments to give as an equivalent

781·8 foot lbs.

"Finally, in 1849 applying all the precautions suggested by seven years experience, he obtained the following numbers for the mechanical equivalent of heat:—

772·692, from friction of water, mean of 40 experiments
774·083, from friction of mercury, mean of 50 experiments
774·987, from friction of cast-iron, mean of 20 experiments

For reasons assigned in his paper, Mr. Joule fixes the exact equivalent of heat at 772 foot lbs.

"According to the method pursued by Mayer, in 1842, the mechanical equivalent of heat is

771·4 foot lbs.

"Such a coincidence relieves the mind of every shade of uncertainty, regarding the correctness of our present mechanical equivalent of heat."

This subject will be completed in another article.

CURIOSITIES OF COMBUSTION.

BY PROFESSOR CHARLES A. SEELY.

"Combustion is the disengagement of heat and light which accompanies chemical combination." This is a very good definition, the best one I remember to have seen. I intend this as a high compliment for I have observed that school-book definitions often need more explanation than the thing defined. It is a very interesting and profitable mental exercise, to discover the heterogeneous things that a definition owing to its inaccuracy of language, is obliged to cover. Any book on the physical sciences will furnish good material. It is a very ancient amusement. Plato once defined man to be a "two-legged animal without feathers," a definition of man about as precise as ever was made. But Diogenes plucked a goose, and throwing it into the Academy, exclaimed, "Plato, behold your man." So I might bring phosphorus and rotten wood which shine in the dark and to a delicate thermometer exhibit heat, as cases of combustion. But Dr. Ure, the author of the definition, might very aptly retort, as did the preacher whose sermon was criticised, "better it if you can." And I should be forced to reply, "I cannot unless you allow me to use a great many more words."

The combustion with which we are most familiar is that where oxygen is one of the elements concerned. A very interesting peculiarity of this ordinary combustion is the fact that its beginning requires a high temperature. We consider coal, wood, oil, sulphur, and gunpowder very combustible, but there is no combustion, although oxygen be present, until they be set on fire or ignited, that is, until some portion be heated up to a high temperature. Oxygen is very different from other supporters of combustion in this respect, for with them combustion begins at ordinary temperatures. If suddenly chlorine were put in the air in place of oxygen, or if the oxygen should assume its active form known as ozone, every thing combustible upon the earth would take fire and be consumed with fervent heat in a few hours. This property of oxygen, to which I allude, is another of the striking evidences of the adorable Wisdom everywhere to be found in the order of nature.

The temperature of ignition varies greatly for the different combustibles. Phosphorus, sulphur, and sodium take fire below a red heat, while the ignition point with others is so high that we rarely have an opportunity to see them burn. The combustible nature of iron, lead, copper, silver, and gold, was not even suspected until a recent period. We know now that they burn even more readily and fiercely than any common fire, when once they are kindled; if I wanted to make the most gorgeous pyrotechnic display I would make a bonfire in which I would burn up a few tuns of iron. The ignition temperatures have been determined for only a few substances. Here is useful work to be commended to the rising generation of chemists. The facts ought to be determined and put into the form of a table.

The philosophy of spontaneous combustion is now well determined and can be made plain to everyone. Heat is always a product of oxidation, or in other words, heat always accompanies the union of oxygen with another substance. The amount of heat produced is, moreover, exactly proportioned to the amount of oxidation. If a day or a year be employed in burning (oxidizing) a pound of coal the amount of heat in the two cases is precisely the same. The rapidity of burning has nothing to do with quantity of heat; it is a question of intensity, quite another thing. The pound of coal burning in a minute gives an intense heat and consequently light, but let that heat be distributed over the space of a year, and it would require an instrument far more delicate than our senses to detect that which would appear in a second or a day. In slow burning or oxidation the heat is simply diluted in time or space. Let a child's supply of candy be divided and administered constantly, and in the homeopathic doses he would never suspect that candy had any taste.

The rust which is produced from a pound of iron indicates or represents an amount of heat sufficient to raise nearly 3,000 pounds of water 1° Fah; that is such a quantity of heat was produced by the rusting or oxidation. As the specific heat of iron is one-ninth (nearly) that of water, this quantity of heat is sufficient to raise the temperature of one pound of iron to the temperature of 27,000°, or nine pounds to 3,000° which last is without doubt above the ignition point of iron. Suppose the heat of rusting be retained in the rust. Would not we have a spontaneous combustion which would be fearful even to think of!

In ordinary oxidation the heat leaks away by radiation and conduction as fast as it is generated. Let us see how we may retain it. As oxidation takes place only at the surface it is plain that its rapidity will be increased just as we increase