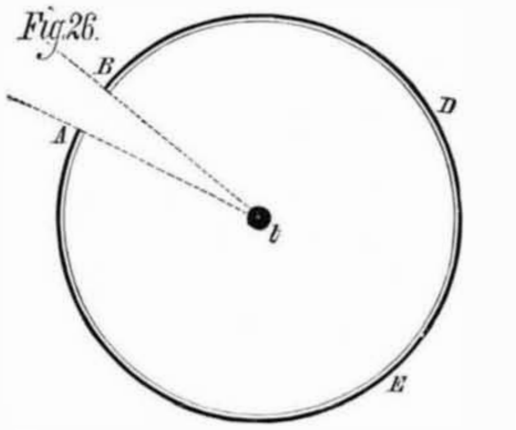
THE SUN'S RADIANT ENERGY.

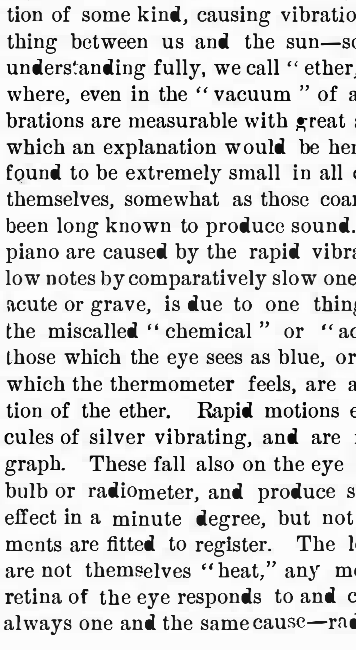
When the spectrum is allowed to fall on a sensitive plate we can, as has been mentioned, obtain a photograph of it, but, unless special means are used, not of all the lines. The photograph obtained with the salts of silver will fail altogether to reproduce the yellow part; will show something of the green and nearly all of the blue; while up in the violet end the picture is very clear, and beyond the violet, where to all appearance the spectrum has ended, a host of sharply defined lines comes out on the plate from a region where the keenest eye sees nothing whatever. This is when the instrument is directed full on the sun (not necessarily on its edge, as in a former experiment), and it would appear at first as if there must be in the white sunlight a special kind of rays, which produced not colors or vision, but chemical changes on the plate, printing there images of the slit, which were produced by something quite different from light.

Fig. 26.



If, on the other hand, we take a delicate thermometer or a radiometer, and move it into successive parts of the spectrum formed by a prism, we find little effect in the blue, more in the yellow, still more in the orange, and as much or more quite beyond the red, where, too, the eye sees nothing. Again, it seems at first that here is another kind still of radiation, causing heat, and which is distinct from that producing light, since one appears where the other does not. In some text books yet in use, diagrams even are given to show the amount of chemical, light, and heat rays in the different parts of the spectrum; but quite recently students of science arrived at a better understanding. The results of old and modern investigations are now seen to point to one conclusion. Given in general terms, this may be said to be that there is, in reality, no such thing as a chemical ray, a light ray, or a heat ray; there is nothing but radiant energy—motion of some kind, causing vibrations across space of something between us and the sun—something which, without understanding fully, we call "ether," and which exists everywhere, even in the "vacuum" of a radiometer. These vibrations are measurable with great accuracy (by processes of which an explanation would be here out of place), and are found to be extremely small in all cases, but to vary among themselves, somewhat as those coarser ones do which have been long known to produce sound. As the high notes of a piano are caused by the rapid vibration of strings, and the low notes by comparatively slow ones, but the sound, whether acute or grave, is due to one thing—motion of the air; so the miscalled "chemical" or "actinic" rays, as well as those which the eye sees as blue, or green, or red, and those which the thermometer feels, are all due to one thing—motion of the ether. Rapid motions exist, which set the molecules of silver vibrating, and are registered by the photograph. These fall also on the eye and on the thermometer bulb or radiometer, and produce some kind of mechanical effect in a minute degree, but not one which those instruments are fitted to register. The longer radiations in turn are not themselves "heat," any more than those which the retina of the eye responds to and calls "light." We have always one and the same cause—radiant energy; and we give this one thing different names: "actinism," "light," or "heat," according as the instrument which reveals its presence to the mind is some chemical substance, the retina of the eye, or a thermometer.

Fig. 27.



Section of Calorimeter.

It will appear, from what has just been said, that there are substances which respond to some of the ethereal vibrations and not to others. The substance which is most generally useful in receiving and, so to speak, absorbing them, is perhaps that which has been recently put to such remarkable use by Edison—common lampblack. Let us try to measure the sun's radiant energy by measuring all of it we can get in the form of heat, and endeavor in the process to reach some idea of the temperature at its surface. There are many ways of measuring the heat, one of which, convenient for its exposition of principles, we give here, though it is not perhaps the best in practice, returning to other methods later.

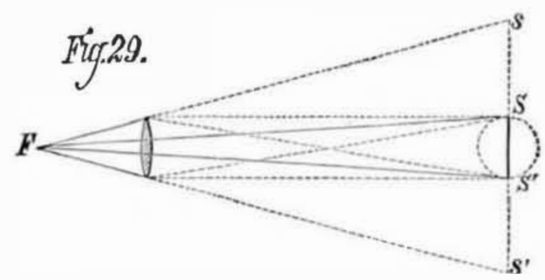
Thus, in Fig. 26, let A B D E be a large hollow sphere, inclosing a small thermometer at its center, *t*. The bulb is carefully covered with lampblack to enable it to absorb as many radiations as possible, and the inside of the sphere is blackened in the same way. Suppose the temperature of the whole at first to be that of absolute cold or at the natural zero, and that the sphere is kept at that, whatever happens. If we remove a given part of the sphere, let us say one twentieth of the surface area, A B, and fill the aperture with a piece of white-hot iron, this will send heat to *t*, and the thermometer will rise, though not to the temperature of the iron, which, for the sake of illustration, we will call 2,400°. If the whole sphere were at 2,400° the thermometer would also shortly register this (provided we could make one to stand it), but in fact it is receiving such heat from one twentieth of the sphere only, and giving it out by reradiation from the bulb to the other nineteen twentieths, that is, to the whole cold surface around it, which returns nothing. In this case, then, the temperature of the thermometer will be found by reflecting that it gives out very nearly twenty times as much heat as it receives, and that it must register nearly $\frac{2400}{20}$°, or 120°. On the other hand, suppose we, in a new experiment, find the thermometer reads 100°, and want to know the temperature of the iron. We must find what proportion the hole, covered by the hot iron, bears to the whole sphere, and multiply the 100° by this. Were the hole, for instance, in this case but one thirtieth the size of the sphere, evidently the temperature of the hot iron must have been about 3,000°. If the iron were ever so distant, provided it filled the whole aperture to an eye placed where the bulb is, no external rays could fall on *t* except from it. It is immaterial, then, in this experiment, whether the hot body is near or far, provided the hole is always kept so small that no foreign radiation enters. The reader will see the bearing of this when he reflects that if we turn the opening in the sphere toward the sun, with the above precautions, the result will be just the same as if we had plugged the aperture with a sample piece out of the sun's photosphere and of its actual temperature. We have now only to multiply the thermometer reading by the number of times the surface of the sphere is greater than the hole, and we have apparently found the real temperature there, as exactly as if we had reached across space and dipped our thermometer bulb into the actual surface of the sun.

Fig. 28.

Calorimeter.

There are many drawbacks to this plan in practice, and it is only in case radiation and temperature are proportional that it is sound in theory. Variously modified, however, it is much relied on by experimenters. Fig. 27 gives an internal, and Fig. 28 an external view of the latest construction adopted by M. Violle, of Grenoble, a distinguished recent investigator. In practice the simplicity of our first illustration is widely departed from, and the use of the instrument is much modified. T is the thermometer, whose bulb is at the center of a double sphere maintained at 0° (Centigrade) by a current of ice water circulating through tubes, *t t'*, or by ice put in at O. D is a diaphragm with various apertures; M, a mirror, in which we view the reflected image of *g*; *g* is a piece of ground glass, on which the shadow of the thermometer bulb falls when the instrument is correctly pointed to the sun. This instrument is capable of being used to give us (according to the method just explained) the temperature of the sun, or else the number of units of heat it sends out. The latter result will be presented, however, by another method subsequently, but before we can do either accurately we must find out how much heat is absorbed by our air. To do this, M. Violle has taken his whole apparatus to the summit of Mont Blanc, and finds there the radiant heat from the sun to that below almost exactly as 4 to 3. The total heat at the boundary of our atmosphere is, according to him, something like one half greater than at the sea level, a rather larger result than one obtained by another means, to be given later.

To find the temperature of the sun from such an apparatus we virtually multiply the thermometer reading by the fraction expressing the ratio of the surface of the sun's disk to that of the celestial sphere, a ratio which is rather less than 1 to 180,000. In the observations of Soret, on Mont Blanc, the inclosed thermometer read nearly 38° Fah. above the temperature of the inclosure, and hence the temperature of the sun's surface would appear to reach at least the enormous number of 38°×180,000=6,840,000° Fah. The more prolonged and elaborate experiments of Mr. Ericsson give a temperature of about 4,000,000° Fah., and indicate that each square foot of the solar surface radiates over 300,000 units of heat per minute; in other words, each foot can furnish heat equal to that required to drive a theoretically perfect heat engine of over 7,000 horse power. There is a very fair agreement among all experimenters as to the amount of heat radiated, but a wide discrepancy as to the temperature, the very same data which above are interpreted as meaning 4,000,000° Fah. being asserted by distinguished French physicists to indicate less than 4,000° Fah. This monstrous disagreement is not due to any considerable error of measurement—all are pretty well agreed on that—but to our ignorance of the laws connecting temperature and radiation. There are two rules in use, one of which was given by Sir Isaac Newton. It says, in substance, that if a body be raised to double its former temperature, it will radiate double its former heat. The other, given by the French physicists Dulong and Petit, is in the shape of a complex formula, which virtually declares that if a body be raised to double its former temperature it will radiate more than double its former heat; in case both temperatures are high, enormously more. Proving that we get enormous heat from a limited area of the sun's surface, then, does not, in the eyes of some physicists, prove that area to be proportionately hot.

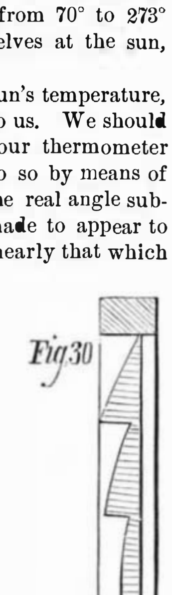


Action of Lens.

In this there is involved a very practical consideration for us, for this apparently abstruse physical question has a bearing on the duration of the human race, since that duration depends not merely on the present heat of the sun, but largely on the rate at which the sun is spending heat. Suppose some benumbed wanderer to find himself before a fire which seems as if miraculously burning for him, in a cheerless waste, where he would otherwise perish. A fire of straw may be for the moment as hot as a fire of coal; but as the first will spend its stock of heat at once and leave him to die of cold, and the second will spend it slowly and warm him for indefinite time, it is an important thing for him to know the rate at which his fire burns, and this is our own case. The human race—however it came here—finds itself before such a fire, and thus dependent upon it; for it lives on a planet whose proper surface temperature in the absence of solar radiation is variously estimated at from 70° to 273° below zero; and we are all warming ourselves at the sun, without which we should promptly die.

Let us come back to the question of the sun's temperature, then, with a sense of its personal interest to us. We should know more about it if we could carry our thermometer nearer to the sun, but we can practically do so by means of a burning lens, Fig. 29, where S F S' is the real angle subtended by the sun, *s* F *s'* that which it is made to appear to subtend by the lens, so that the effect is nearly that which would be produced by approaching till the solar diameter filled S S'. The actual construction of the burning glass on a very large scale is not now common, as we have other ways of producing intense heat always at command. When made at present they are built up in sections, as in Fig. 30, so as to avoid the necessity of an enormously thick and expensive lens. Such a one as this, in which the lens subtends an angle of about 30°, as seen from the focus, is capable of melting platinum and the most refractory surfaces; and as a great deal of the heat is absorbed by the glass or otherwise lost, if we could approach the sun till it filled such an angle to the eye, we should find the temperature even higher. It is probable that few of the materials of which the crust of the earth is composed would remain in the solid form if carried very much nearer the sun than the presumed orbit of the hypothetical "Vulcan;" and it may be remarked in passing that it is not unlikely that, in case such an intra-Mercurial planet as Professor Watson is said to have recently discovered had an orbit whose nearest approach carried it within 10,000,000 or 12,000,000 miles of the solar surface, it would prove to be heated to the point where it would be self-luminous.

Fig. 30



Section of a polyzonal Burning Lens.

The writer, some time since, made a comparison of the light of the sun with that given from the molten steel in the Bessemer converter. This was chosen as an example of the greatest temperature attained on the large scale in the arts, and it is one which is known to equal that at which platina melts. Looking down the mouth of the converter we see at one stage of the process a stream of molten iron poured into the vessel in which the melted steel is already glowing in the background. Every one knows how bright white hot (and still more melting) iron appears, but in this case the steel is so much brighter, that the fluid iron in front seems like thick chocolate poured into a white cup. The steel, just before it is itself poured, seems of sun-like brilliancy, until we come to compare it with the sun itself, which was done by means of a photometer, so arranged that the steel light shone in at one side and the sunlight on the other. When the angle subtended by each source of light was equal, the image of the molten steel was put out by the presence even of much enfeebled sunshine, and ceased to be visible as the dull flame of an alcohol lamp would be if it were set beside an electric light. The area of glowing metal exposed was considerably over one square foot, and measures made with every precaution showed that any single square foot of the solar surface must be giving out much more, at any rate, than one thousand times the light that the melted steel did.

We are not, it is true, entitled to conclude from this that the heat is in exactly the same proportion, but we are justified by inference from this, and by other experiments not here given, in saying not only that the temperature on the sun's surface is far higher than that reached in our furnaces, but that the heat is in fact so enormously greater than any furnace heat here that they can scarcely be made the subjects of comparison. Other considerations, on which we cannot now enter, give the best grounds for belief that this heat is likely to be kept up sensibly at its present rate of emission for a period which, with reference to the brief history of the human race, may be called almost infinite. These are important conclusions, whose practical bearing will be more fully developed in a concluding chapter.

AMATEUR MECHANICS.

GEAR CUTTING APPARATUS.

The index plate, A,* is attached to the larger of the pulleys on the mandrel of the lathe by means of three or four screws, and the stop, C, provided with a point well fitted to the holes in the plate, is held in position on the bed plate, B, by a screw passing through a slot in the foot into the bed piece. The stop, C, is capable of springing sufficiently to admit of withdrawing the pin from the hole in the plate, and it is strong enough to hold the plate without vibration. Two standards, G, mounted on the plate, B, support pulleys over which the driving belt runs. The gear cutter head consists of a casting, D, fitted to the tool post of the slide rest, and the mandrel, E, provided with a pulley and mounted on carefully fitted centers in the casting. The casting, D, has upon opposite sides, near the upper end, ears (as shown in Fig. 3) for receiving the pulleys, *a b*, which guide the driving belt, so that the cutter may be moved across the face of the wheel, being cut without changing the tension of the belt. The extreme end of the loop formed by the belt is supported by the pulley, H, mounted on a standard rising from the lathe bed. The standard may be placed far enough from the slide rest to admit of putting the tail stock between it and the slide rest in case it should be necessary to use the tail stock for supporting the work.

The mandrel, E, is provided with a collar and a nut for clamping the cutter, F. It will be noticed that the cutter comes exactly opposite the line of the lathe centers, and that it occupies about the same position, in relation to the tool post, that the point of an ordinary turning tool does. The cutter, F, is shown in Fig. 4, enlarged. The upper view represents the side, the lower view the edge of the cutter. It has but a single tooth and is adapted to brass and similar alloys only. It may be sharpened by grinding. When iron or steel is to be cut the cutter should have several cutting edges, and the mandrel, E, should have a larger pulley, as more power will be required and the speed must be slower. By setting the slide rest at an angle bevel gears may be cut.

In a subsequent article the subject of sizing and cutting small gears will be treated. M.

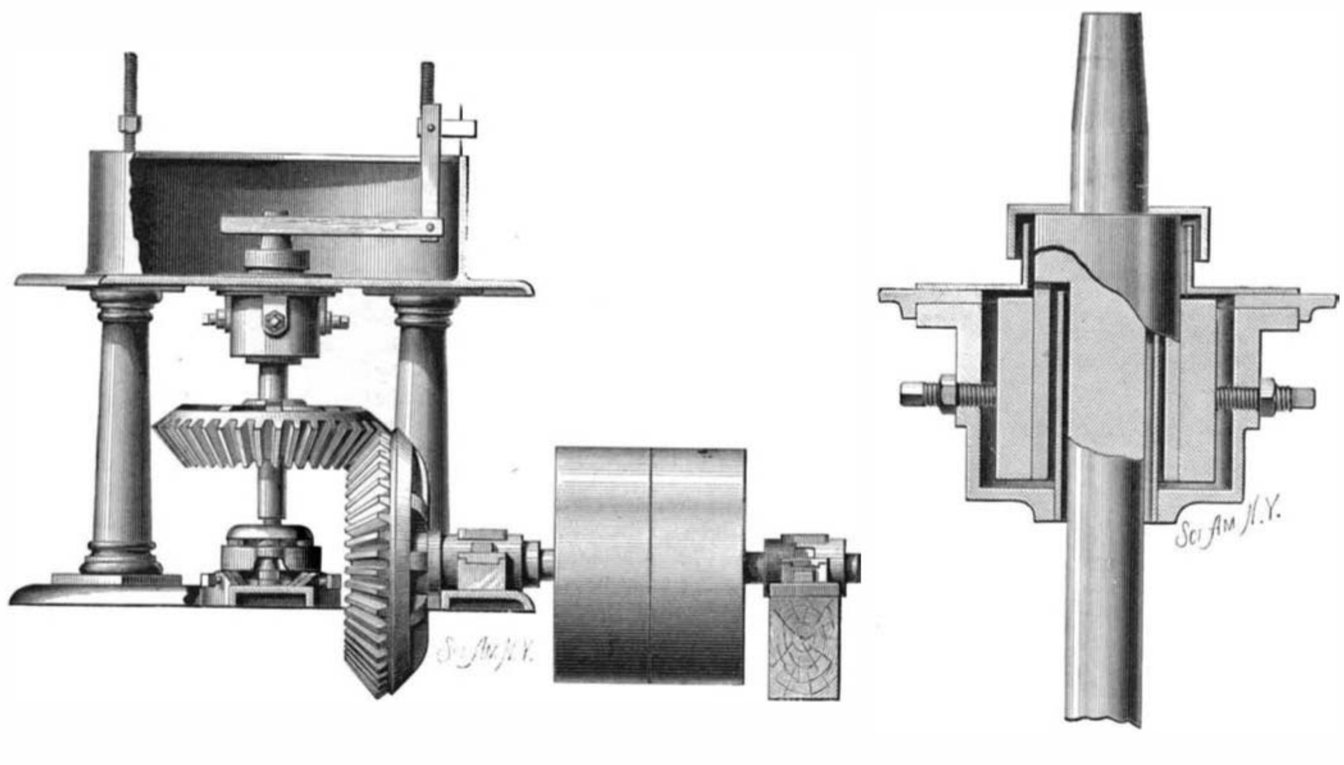
* See "Index Plates for Gear Cutting," page 20, current volume of SCIENTIFIC AMERICAN.

AN IMPROVED MILL.

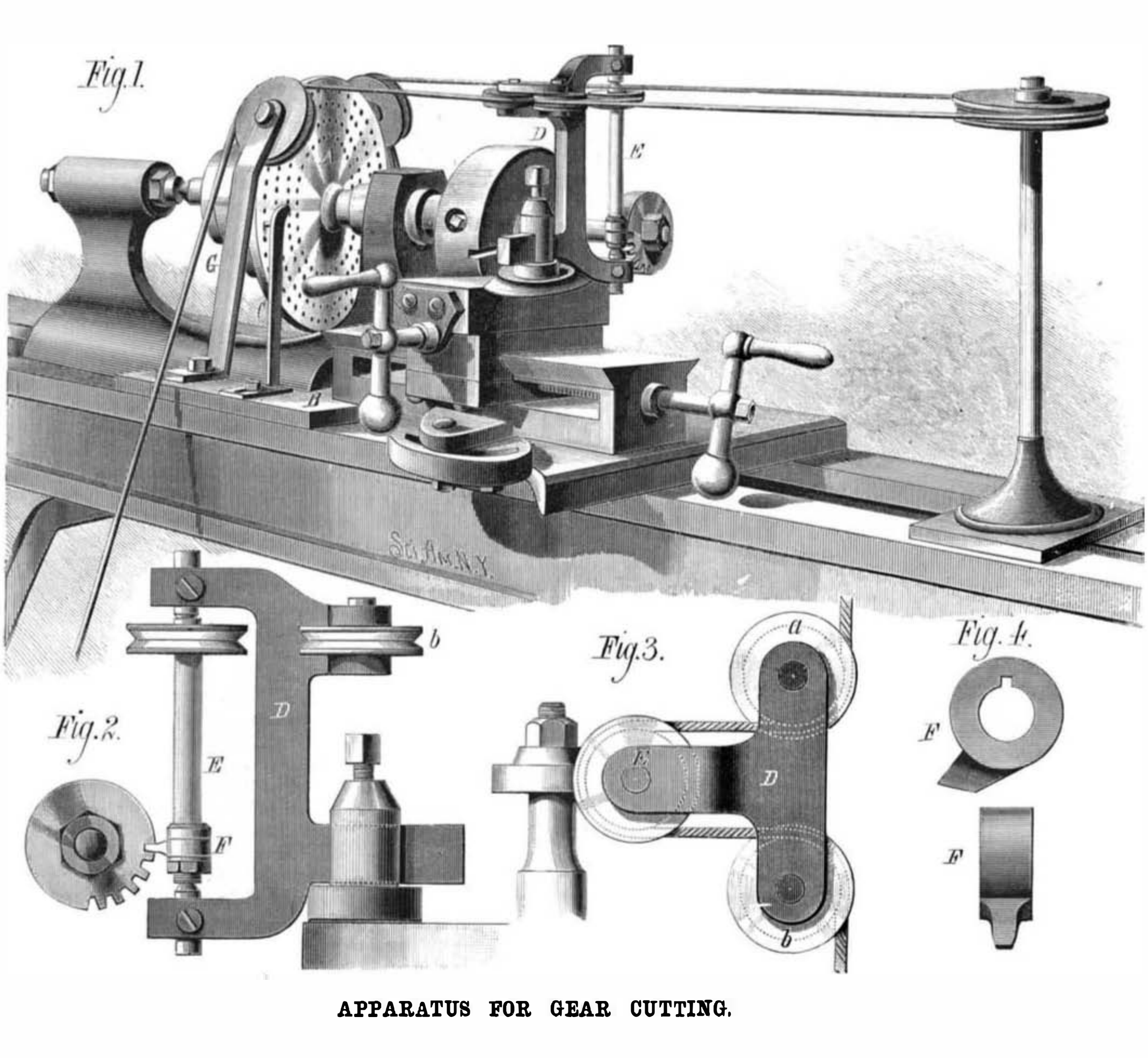
We give herewith engravings representing some recent improvements on the Munson mill, which was described in these columns some time since. The late improvements relate to the tramming of the spindle, to a novel device for lubrication, and to other points of merit.

The manufacturers of this mill say that the so-called portable mills now being sold in the market answer very well on coarse grains and coarse grinding, but for fine work they do not meet the demands of the trade; they are constructed without regard to the tramming of the spindles or the importance of keeping them in their true working positions. The metal boxes, which are held up against the collar or the neck of spindles, are continually wearing out, and unless some provision is made whereby the spindles may be perfectly and accurately adjusted, the work performed is of an inferior quality, and the loss of power by friction greatly increased. The Munson mill is made on mechanical principles, and special pains have been taken in their construction to obviate these defects. The curb of the mill, being cast in one piece, has its inside rim turned perfectly true, and by means of a tram stick or index, as shown in our illustration, any deviation or any perceptible change in the position of the spindle, no matter how slight, can be easily detected and easily adjusted.

The spindles are made of solid wrought iron or hammered iron and are provided with inserted solid steel points ground in on a taper fit with emery and oil, making an absolutely perfect bearing, which may be easily removed when injured. The neck or collar is forged solid on the spindle and reamed out to fit within the bush; inside the bush Babbitt metal boxes are placed, which are held up against the collar by set screws. The bush is provided with a central vertical tube around which the collar works, the tube passing up between the collar and the bottom of the spindle, the collar in the bush forming the bearing surface of the spindle. The bush is covered by a cap having a circular central opening through which the spindle passes. The bush once filled with oil will keep the bearing of the spindle perfectly



MUNSON BROTHERS' MILL.



APPARATUS FOR GEAR CUTTING.