WORK DONE BY A DROP HAMMER.

The great value of the drop hammer is its simplicity and cheapness as a means of storing energy, which can be given out again in doing the work of raising, stamping, and forging.

The drop hammer is an example of the useful application of the principle of the falling weight. In finding the work accumulated in any moving body, such, for instance, as energy stored up in a flywheel, the work of a locomotive when ascending an incline, the work of a cannon ball, and similar questions, it is necessary to introduce the force of gravity into the calculation, since the law of gravitation necessarily has an effect upon such bodies as are dealt with in these calculations. It is therefore perhaps necessary to briefly review the action of gravity on falling bodies to enable the practical mechanic to understand what the gravity constant means.

If a body be raised 16 1/12 feet, then allowed to fall freely, it will fall through this space of 16 1/12 feet in one second, and at the end of that second it will have attained a velocity of 32 1/6 feet per second. This velocity of 32 1/6 feet per second, which is simply due to the force of gravity, is denoted by **g** and the velocity **v** attained at the end of **t** seconds will be $t \times 32\ 1/6$, or $v = t \times 32\ 1/6$. Therefore the velocity of a body which has fallen for four seconds will be at the end of that time travelling at a velocity = 4 × 32 1/6 = 128 2/3 feet per second.

The mean velocity—that is, the velocity in the middle of that time—will be 2×32 1/6=64 1/3 feet per second, and the space described will be 4^2 × 16 1/12 = 257 1/3 feet.

Formula for Falling Bodies when Falling from Rest.

h = height of fall in feet.
v = velocity in feet per second.
g = force of gravity = 32.2.
t = time of fall in seconds.

$$h = \frac{g\,t^2}{2} = \tfrac{1}{2}\,g\,t^2 = \frac{v^2}{2g}$$

$$v = g\,t = \frac{2\,h}{t} = \sqrt{2\,g\,h}$$

$$t = \frac{v}{g} = \frac{2\,h}{v} = \sqrt{\frac{2\,h}{g}}$$

If the drop hammer be raised to a definite height, the work expended in raising it will be W × **i**, and in doing so the force of gravity will have to be overcome. If the hammer be now supported, there will be potential energy stored up in it, and when allowed to fall it will attain a certain velocity depending upon the distance fallen. When the hammer reaches the end of its fall, the accumulated work in the hammer will be

$$\frac{W\,v^2}{2\,g} = W\,h$$

Example. Suppose a drop hammer of 500 pound weight be raised through a height of 579 feet. The work expended in raising this hammer will be

W × **h** = 500 × 579 = 289500 foot-pounds.

If the hammer be now supported at this height, the potential energy which exists in, or is stored up, will be = 289,500 foot-pounds. When allowed to fall the accumulated work will be equal to

$$\frac{W v^2}{2 g}$$

First find v:

$$v = \sqrt{2 g h} = \sqrt{2 \times 32\tfrac{1}{6} \times 579} = 193 \text{ feet per second,}$$

when the hammer reaches the end of its fall it will have attained a velocity equal to 193 feet per second, therefore

$$\frac{W v^2}{2 g} = \frac{500 \times 193 \times 193}{2 \times 32\frac{1}{6}} = 289500 \text{ foot-pounds,}$$

and this is the same result as $W \times h$.

A certain amount of energy is passed into the drop hammer in raising it up, and when it falls the energy is given out again. There is neither gain nor loss of power. It may be that a great pressure is exerted through a small space, or a less pressure through a greater space, and in both instances the work may be the same.

If a resistance is offered to a 560-pound hammer, falling from a height of 16 feet, during the last one foot of its fall the average pressure acting against the resistance will be 8,960 pounds, the pressure being much greater at the commencement, and reducing as it reaches the last inch, the accumulated energy gradually decreasing to simply that of the weight of the hammer itself as it reaches the end of its fall.

But should the hammer be brought to rest in a fraction of 1 foot, then the resistance offered must be proportionally greater.

A stamp hammer 200 pounds in weight falls 10 feet, and in stamping a piece of metal the hammer is brought to rest in the space of the last ½ inch of its fall. What resistance has been offered by the metal article?

$$W \times h = 200 \times 10 = 2000 \text{ foot-pounds,}$$

$$\tfrac{1}{2} \text{ inch} = \tfrac{1}{2} \text{ of } \tfrac{1}{12} = \tfrac{1}{24} \text{ of 1 foot,}$$

$$\text{and since } 2000 = \frac{R \times 1}{24}$$

$$\text{therefore } R = \frac{2000 \times 24}{1} = 48000 \text{ pounds.}$$

Work done by a hand hammer. The conditions under which the hand hammer is used make it necessary that the law of gravitation shall be introduced into the calculation. Take the case of a machinist striking a blow upon the head of a chisel, or driving a nail into a piece of wood, with a 2-pound hand hammer.

As another example, consider the case of a machinist driving a key into the boss of a flywheel with a 4-pound hammer. In the first case there are two forces acting upon the hammer, namely, force of gravity and the man's muscular force. The workman raises the hammer, he then drives it home, delivering a blow upon the head of the chisel. The first portion of the distance through which the hammer moves is traversed by a movement of the whole arm from the shoulder.

This is followed up by the workman straightening his arm at the elbow, then, just as he is about to reach the head of the chisel with the hammer to strike the blow, he straightens his wrist, thereby adding impetus to the hammer, which is already rapidly falling, and in this manner a very great velocity is given, probably at the exact moment of impact the actual velocity may be 50 feet per second.

In the second example, where a blow is delivered upon the head of a steel key by a hammer, and the hammer is driven in a horizontal line, the machinist will swing the hammer through a comparatively long distance, and will probably put the weight of the upper half of his body into the blow, thereby considerably increasing the velocity of the hammer, which may be 50 feet per second, as before. In both these cases of hand hammers the accumulated work or energy stored up in the hammer will be the same as though the hammer had fallen from a sufficient height to attain that velocity which the hammer has at the moment of impact. But here the only information we have to assist us in solving the problem is the weight of the hammer and the assumed velocity at which it is moving, say 50 feet per second. Since having no particulars as to the height from which a body must fall to attain this velocity, it is necessary to introduce the law of gravitation into the calculation to enable reliable results to be obtained.

We have for the 2-pound hammer accumulated work

$$\frac{W v^2}{2 g} = \frac{2 \times 50 \times 50}{2 \times 32} = 78 \text{ foot-pounds.}$$

If the face of the hammer moves the head of the chisel 1/16 inch, then

$$\tfrac{1}{16} \times \tfrac{1}{12} = \tfrac{1}{192} \text{ of 1 foot,}$$

$$\text{and } R = \frac{78 \times 192}{1} = 14976 \text{ pounds.}$$

If a nail had been driven ¼ inch,

$$\tfrac{1}{4} \times \tfrac{1}{12} = \tfrac{1}{48} \text{ of 1 foot,}$$

$$\text{and } R = \frac{78 \times 48}{1} = 3744 \text{ pounds.}$$

In the case of the 4-pound hammer we have accumulated work

$$\frac{W\,v^2}{2\,g} = \frac{4 \times 50 \times 50}{2 \times 32} = 156 \text{ foot-pounds.}$$

If the key is driven ⅛ inch by the blow,

$$\tfrac{1}{8} \times \tfrac{1}{12} = \tfrac{1}{96} \text{ of 1 foot.}$$

$$\text{and } R = \frac{156 \times 96}{1} = 14976 \text{ pounds resistance.}$$

The work done by the jack hammer, namely, 14,976 pounds, is approximately the same that would be obtained by a dead load of 14,976 pounds giving a direct pressure.