THE STRENGTH OF SHAFTING.

SOME FACTS AND RULES GOVERNING IT.

In considering the strength of shafting, the engineer ought to keep in mind several important facts. One is, that a shaft increases in strength very much faster than its diameter, its strength being in the proportion of the cube of the diameter. Men will often say "a 2-inch shaft ought to do it, but we will put in a size larger to be on the safe side." By doing so they allow a much larger factor of safety than they thought of, because a small increase in diameter means a large increase in strength. If we assume that a 1-inch shaft will safely drive at a certain speed 3-horse power, a 2-inch shaft under the same conditions would drive 24-horse power, and a 3-inch shaft 81-horse power. Their strengths vary as the cube of their diameters vary. The cube of 1 is $1 \times 1 \times 1 = 1$, the cube of 2 is $2 \times 2 \times 2 = 8$, and the cube of 3 is $3 \times 3 \times 3 = 27$. If a 1-inch shaft will drive 3-horse power, the 2-inch shaft will drive as much more as the cube of its diameter is in excess of the cube of 1. The cube of 2 is 8, and therefore its comparative power is $8 \times 3 = 24$-horse power, and the cube of 3 being 27, its power in this case is $3 \times 27 = 81$-horse power. To use a shaft of 3 inches diameter, instead of 2 inches, would have given in this case a shaft capable of driving 81-horse power, instead of 24. On this basis a 1-inch shaft having a strength of 1, a 2-inch shaft would have a strength of 8, a 3-inch shaft a strength of 27, a 4-inch shaft a strength of 64, a 5-inch shaft a strength of 125, and so on, as the cube of the diameter. This fact of the rapid increase in the strength of shafting with a small increase in diameter, must be borne in mind, and that this strength varies as the cube of the diameter.

The second fact is, that the power a shaft will drive is in direct proportion as its speed. If a shaft drives 3-horse power at 100 revolutions per minute, at 200 revolutions it will drive 6-horse power, and at 300 revolutions 9-horse power, and so on. Therefore, the faster a shaft runs the diameter may be smaller in proportion in order to drive a given horse power.

The third fact is, that shafts break more often from bending than from the torsional strain put upon them, and therefore that shafts must be of sufficient size to prevent bending or else must have the hangers so near to each other that they will bend very little. To bend a shaft there is the weight of the shaft itself between the points of support, and also the weight of the pulleys and the weight of the stress and load on the belts. The weight of the pulleys and shaft is downward, and the pull of the belts may be up or down or at any angle. It follows, then, that a shaft loaded with pulleys must have a larger number of hangers than an unloaded shaft, and that the pulleys must be placed as near to the hangers as possible. The bending of a shaft brings about a considerable loss in power from the friction of the shaft in its bearings, beside the tendency of the shaft to break. The bending and twisting of the shaft both contribute to break it, but the bending has most to do with it. Shafts, therefore, should be of such size that they will not bend more than $\frac{1}{100}$ of an inch per foot in length.

The fourth fact is, that heavy lines of shafting cost more money to put up and cost more money to run them. The condition of the surfaces of shaft and bearings may be the same in the case of the small and large shafts, and this would make the co-efficient of friction the same. The power required to drive the shaft alone being the product of the weight of the shaft, the distance the surface of the shaft moves through, and the co-efficient of friction, the larger shaft will take more power to turn it, because it is heavier and its surface moves through a greater distance. Take the case of a 2-inch and 4-inch shaft. The 4-inch shaft weighs four times as much as the 2-inch shaft, and this weight is moved through twice the distance because its circumference is twice as great. It is a costly proceeding from the coal-pile standpoint, to put in heavier shafting than is necessary to do the work with the least bending and twisting.

Shafts are subject to a torsional strain to twist them, and in long shafts or lines of shafting this becomes an important factor. A shaft should be strong enough to limit the twist to 1° in 20 diameters. For instance, a 2-inch shaft should not twist more than 1° in every 40 inches. This shaft would have to be 600 feet long to twist half a circle, that is, for one end of the shaft to be one-half a turn behind the driving end. Where the power is taken off the end of a long line of shafting the twisting of the shaft will be more noticeable, and give trouble by oscillating so that a balance wheel is necessary.

The fifth fact is, that shafts are designated by the character of their work, as first movers, second movers and third movers. The first, or prime mover, is the engine-crank shaft, and the jack shaft receiving the load. The second movers are the long lines of distributing shafting, and the third movers are the shorter lines of countershafting. The prime mover is made much stronger to do a certain amount of work than a second mover, and the third mover is of still lessened strength.

Having these facts in mind, the following rules are given.

To find power a shaft will safely transmit: Cube the diameter, multiply by revolutions per minute, and by 1 for prime mover, 2 for second mover, and 3 for third mover. Divide product by 100.

To find diameter of shaft for given horse power: Multiply horse power by 100, divide by revolutions per minute, and this quotient by 1, 2 or 3, according as shaft is to be used as first, second or third mover. Extract the cube root of quotient.

To find greatest permissible distance between hangers for loaded shaft: Square the diameter, multiply by 200, and extract cube root of product.

Where the shaft has no pulleys between hangers, instead of multiplying by 200 use 500, and proceed as before.

Taking examples: What power will a 3-inch shaft, as a second mover, transmit at 225 revolutions per minute?

$3 \times 3 \times 3 = 27 \times 225 = 6{,}075 \times 2 = 12{,}150 \div 100 = 121\frac{1}{2}$ horse power.

What is diameter of shaft used as second mover to transmit 75-horse power at 175 revolutions?

$75 \times 100 = 7{,}500 \div 175 = 42{\cdot}86 \div 2 = 21{\cdot}83$. Cube root of 21·83 is 2 75, equals diameter of shaft.

What distance apart shall hangers be on 3-inch shafts, pulleys and belts on?

$3 \times 3 = 9 \times 200 = 1{,}800$. Cube root of $1{,}800 = 12+$, equals greatest distance in feet between hangers.

What distance apart may hangers be to support a 3-inch shaft with no pulleys between supports?

$3 \times 3 = 9 \times 500 = 4{,}500$. Cube root of 4,500 is 16+, equals greatest distance between hangers.

In very long lines of shafting the bearings should be nearer together toward the end of the line, and shafts running at a high speed should have the hangers nearer together to give a greater bearing surface to prevent heating. In cases where these rules are used the pulleys should be placed near the hangers or else the distance between hangers reduced. The rules give the maximum in either direction.—*Boston Journal of Commerce.*

ANTIQUITY OF STEAM HEATING.

Steam heating is not new. When at Pompeii, Geo. H. Babcock found that the old Roman baths there were heated by steam, and heated in a better and more scientific manner than is practised at the present time. The walls were double, and the steam, of course not above atmospheric pressure, was carried up through these walls all round the room. The walls were thus heated to a temperature approximating to that of the steam, and the occupants of the room were exposed to a radiation from all directions. This, Mr. Babcock held, is the true theory of heating, and the system of steam heating by indirect radiation, or heating the enveloping air only, is unscientific, expensive and uncomfortable.

It is of interest to add here that the late Joseph Harrison, Jr., of Philadelphia, in delivering a lecture before the Franklin Institute several years ago, said that he had seen in the Museum at Naples a boiler substantially of the same construction as the modern, vertical, tubular boiler. This boiler was found at Pompeii, and was made of copper.