the fulcrum equal to half the length of the arm itself. This amounts to saying that a uniform valve-arm acts the same as it would if its weight were all concentrated at the middle point of the arm. The point in a body which possesses this property is called the center of gravity of the body. As we have said, the center of gravity of a straight lever may, in practice, be considered to be half way out towards the end of the lever; but if the lever has an appreciable taper, the center of gravity will be nearer the fulcrum. The position of the center of gravity can be found, in such cases, by calculation; but it is simpler to take the lever out, and balance it across a three-cornered file, as shown in Figs. 16 and 17. It will balance when the center of gravity is just over the edge of the file, and the distance B can then be measured directly.

CALCULATION OF THE BLOWING OFF PRESSURE.—We are now prepared to give a complete example of the calculation of blowing-point of a safety-valve. Let us take the valve shown in Fig. 18. The arm is 32 in. long and weighs 3 pounds; the ball weighs 20 pounds and is set 28 inches from the fulcrum; the valve-stem is 4" from the fulcrum; the valve-disk is 2" in diameter, and the disk and stem, together, weigh 1½ pounds. It is required to find the blowing-off pressure. In the first case, let us consider the ball. It is possible to load the valve-disk directly (just as in the case of Fig. 2) with a weight which shall have precisely the same effect, in preventing the escape of steam, that the actual 20-pound ball has; and our first undertaking will be to find out how big this imaginary "dead weight" would have to be. When we say that it is to be "equivalent" to the 20-pound ball on the lever, we mean that it would just balance that ball, if it were on the left side of the fulcrum, instead of on the right; and hence, by Archimedes' principle, 28" × 20 lbs. must equal 4" multiplied by the imaginary "dead weight." Now 28 × 20 = 560, and 560 ÷ 4 = 140. In other words, the 20-pound weight, at a distance of 28" from the fulcrum, has just the same effect as a 140-pound weight would have, if placed directly upon the valve-disk. In the same way we may investigate the effect of the valve-arm. It weighs 3 pounds, and its center of gravity is 16" from the fulcrum. A three-pound weight, 16 inches from the fulcrum, is the same thing as a 12-pound weight, 4 inches from the fulcrum, because 3 × 16 = 48, and 12 × 4 = 48. Hence the valve-arm is equivalent to a 12-pound weight placed directly upon the valve-disk. The whole lever valve may therefore be regarded as equivalent to a "dead weight" valve loaded with 153½ pounds; for the ball is equivalent to a dead load of 140 pounds, the arm is equivalent to a dead load of 12 pounds, and the valve-disk and stem, taken together, weigh 1½ pounds; and 140 + 12 + 1½ = 153½. We have therefore found out that the valve will begin to blow when the total pressure of the steam against the valve-disk is 153.5 pounds. The part of the disk which is exposed to the stem is 2" in diameter, and its area is therefore 2 × 2 × .7854 = 3.1416 square inches. The total steam pressure against this area being 153.5 pounds, the pressure against each square inch of it will be 153.5 ÷ 3.1416 = 48.9 pounds (nearly). A valve with the dimensions given above will therefore blow off at just a trifle less than 49 pounds per square inch; and the calculation is similar in all cases.

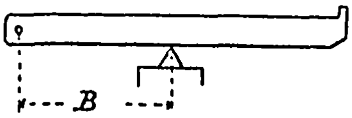

FIG. 16.

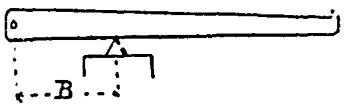

FIG. 17.

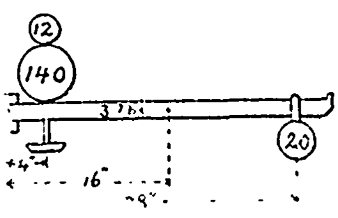

FIG. 18.—FINDING THE BLOWING PRESSURE.

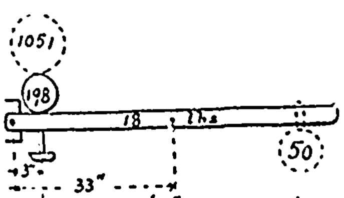

FIG. 19.—SETTING THE BALL.

SETTING THE WEIGHT.—The method of setting the weight, when the blowing-off pressure is given, is almost precisely the reverse of the calculation given above. As an example, consider the valve shown in Fig. 19. The dimensions are as follows: Diameter of the valve = 4", length of the lever = 66", weight of the ball = 50 lbs., weight of the lever = 18 lbs., weight of the valve-disk and stem = 7 lbs., distance of valve stem from fulcrum = 3". It is required to set the ball so that the valve shall blow at 100 lbs. per square inch. The calculation is as follows: The area of a 4 inch disk is 4 × 4 × .7854 = 12.56 sq. in., and if the steam pressure is 100 lbs. per square inch, the total upward pressure against the valve-disk is 12.56 × 100 = 1,256 pounds. If the valve were of the "dead weight" kind, a load of 1,256 lbs. on the valve-disk would therefore cause it to blow at 100 lbs. per square inch. We therefore have to set the ball at such a place that the action of the ball, the lever, and the direct weight of the valve-disk and stem, shall be equal to a direct load of 1,256 lbs. Now, the lever weighs 18 lbs., and its "center of gravity" is (say) 33" from the fulcrum. It is therefore equivalent to a 198-pound weight laid directly on the valve-disk; for by Archimedes' rule we must have

33" × 18 lbs. = 3" × equivalent dead load.

Now 33 × 18 = 594, and 594 ÷ 3 = 198 lbs., as stated above. In Fig. 19 this dead load (which is equivalent to the weight of the lever itself) is represented by the small weight marked "198"; and the large dotted ball above it (whose weight we are about to find) represents the dead load that is equivalent to the 50 lb. ball out on the lever. The dotted weight, together with the 198 lb. weight, and the weight (7 lbs.) of the disk and stem, must be equal to 1,256 lbs., as we have seen. That is, the dotted weight must be 1,051 lbs.; because

1,051 + 198 + 7 = 1,256

The problem has now resolved itself into placing the 50 lb. ball at such a point that it shall be equivalent to a dead load of 1,051 pounds. The valve stem being 3" from the fulcrum, Archimedes' gives us

1,051 lbs. × 3" = 50 lbs. × distance of ball from fulcrum.

Now 1,051 × 3 = 3,153, and 3,153 ÷ 50 = 63.06 inches. That is the ball must be placed 63 inches from the fulcrum, in order that the valve may blow at 100 lbs. per square inch.

RULES.—The processes of calculation which are explained above may now be summarized in the following two rules*:

RULE I. To find the blowing pressure when the position of the ball is given. Multiply the weight of the ball by its distance (A) from the fulcrum, and divide by the distance (C) of the valve stem from the fulcrum. (This gives the dead weight that is equivalent to the ball.) Then multiply the weight of the lever by the distance (B) of its center of gravity from the fulcrum, and divide by the distance (C) of the valve stem from the fulcrum. (This gives the dead weight that is equivalent to the lever.) Add together the two "dead weights," so calculated, and add in, also, the weight of the valve-disk and stem. (This gives the total weight that is keeping the valve-disk down.) Then divide the sum thus found by the area of the valve disk, in square inches, and the quotient is the pressure, in pounds per square inch, at which the valve will blow.

RULE II.—To set the ball, so that the valve shall blow at a given pressure. Multiply the area of the valve-disk by the blowing off pressure, expressed in pounds per square inch. (This gives the total effort of the steam to force the valve-disk up.) Subtract, from this total pressure the weight of the valve and stem. The remainder is the "dead weight" to which the lever and ball, taken together, must be equivalent. Then multiply the weight of the lever by the distance (B) of its "center of gravity" from the fulcrum and divide by the distance (C) of the valve stem from the fulcrum. The result is the "dead weight" to which the lever is equivalent; and if this be subtracted from the total dead weight, just mentioned, the remainder will be the "dead weight" to which the ball alone must be equivalent. Multiply this remainder by the distance (C) of the valve stem from the fulcrum, and divide the product by the weight of the ball. The quotient is the distance, A, that the ball must be placed from the fulcrum, in order that the valve may blow off at the desired pressure.

*The letters refer to Fig. 1.

CAUTIONS.—In applying these rules two things must be carefully observed. In the first place, the diameter of the valve-disk must be measured at $a\ b$, in Fig. 20, and not at $c\ d$; for the steam acts only on the circle whose diameter is $a\ b$. Again, if the valve stem has a square top, as indicated in Figs. 21 and 22, $m\ n$ must be taken as the "distance of the valve stem from the fulcrum"; because the moment the valve raises in the least degree, the pressure of the stem is all applied to the lever at n, as is plainly indicated in Fig. 22.

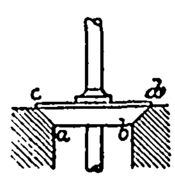

FIG. 20.

Although the foregoing article is intended simply to explain the principle underlying the lever safety-valve, it may be well to touch upon one point concerning the construction of such valves. The point we have in mind is this: When the boiler is under steam, it is an easy matter to try the valve, and find out whether it works freely or not. It ought also to be easy to do this, when the boiler is out of use; and in many cases it is so. Usually when the boiler is not under steam, it is sufficient to raise the weight and the lever, and then to try the valve stem with the thumb and finger; but some valves are so constructed that the valve-disk is free from the stem, and in such cases that the fact that the stem is free proves nothing whatever, so far as the disk itself is concerned, and the disk must be separately investigated before the valve can be pronounced in good condition. If there is no escape pipe screwed into the valve, the disk can usually be reached from the exhaust side, and its condition noted; but if such a pipe is provided (as it is, in many cases) the inspector has to examine the disk as well as he can, from the inside of the boiler. If the valve does not happen to be secured directly to the nozzle, an examination from the interior of the boiler is not practicable, and then the waste pipe has to be unscrewed, or the bonnet of the valve taken off, before the disk can be reached. These difficulties, when combined with the fact that there is often no external evidence to show whether the valve is secured to the stem or not, lead us to recommend strongly that valves with separate disks be avoided altogether. They have no very marked advantage over those in which disk and spindle are all in one piece, and as they are likely to deceive one into the belief that all is in good condition, when in reality the disk may be stuck fast, we feel justified in condemning their use altogether.

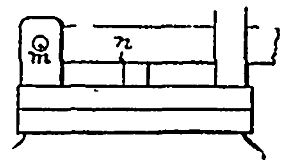

FIG. 21.

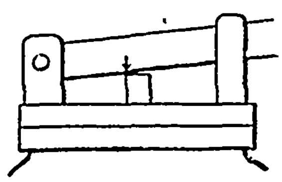

FIG. 22.

SPONTANEOUS FIRES.

LAMPBLACK has been known to take fire spontaneously:

Oiled or greasy rags have been seen to blaze up in a few minutes after having been thrown on the floor.

Dried rubbish exposed to the heat of the sun's rays has been seen to catch fire under circumstances that rendered any other cause impossible.

The sun's rays focused through a window pane on a plank in the floor containing pine sap have been known to set it on fire.

Sawdust used for cleaning floors, or absorbing spilled oil and varnish, should be removed from the buildings.

Sawdust accumulations around journals of machinery are prolific sources of fires.

Matches in the pockets of cast-off clothing are dangerous.

Varnish and turpentine cans placed too near the stove in cold weather are liable to explode and catch fire.