SAFETY VALVES—THEIR HISTORY, ANTECEDENTS, INVENTION AND CALCULATION.

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It will be seen from the above that the weights act at two different points, and that there are three levers to be considered:

First. The long lever L of the weight W, which is the distance from the weight W to the fulcrum f.

Second. The lever x, due to the weight w, of the lever arm a, valve v, and stem s, which is the distance from the centre of gravity g to the fulcrum f.

Third. The short lever l, which is the distance from the fulcrum f to the centre of the valve stem s.

The centre of gravity g, of the lever arm a, is found by balancing it over a sharp edge, with the valve v and stem s attached at the proper distance g from the fulcrum f. The weight w of the lever arm a, valve v, and stem s, multiplied by the distance x from the centre of gravity g to fulcrum f, gives the *momentum*, as before stated, of the lever arm a, which is a constant quantity in the graduations of the lever arm a, for different pressures of steam.

The form of the lever arm a affects the location of the centre of gravity g; but when this centre is known, the shape of the lever arm a does not affect the static momentums. The area and weight can be expressed in any unit of weight, as well as the levers in any unit of length. For greater accuracy, the centre of the fulcrum f, weight W, and valve stem s, connections to lever arm a should be in straight and horizontal lines; and in finding the centre of gravity g, the valve v and stem s must be in their natural position when the lever arm a is balanced over a sharp edge, in order to find the centre of gravity of the system.

The action of the combination is readily understood by the illustration—namely, that the two static momentums, weight w, multiplied by the long lever L, added to the momentum $w\,x$ of the lever arm a, valve v, and stem s, multiplied by the distance x, from the centre of gravity g to fulcrum f, act opposite and must be equal to the momentum of the force F of the steam pressure p, multiplied by the area A of the valve v, and this product by the length of the short lever l, or the static momentums. The algebraical expressions of the foregoing may be set up as follows:

$$W\,L + w\,x = A\,p\,l \qquad \text{.......... .... 1}$$

Or, in words: The area A of the valve v, multiplied by the steam pressure p, per square inch, and this product by the length of the short lever l, equals the weight W, multiplied by the length of the long lever L, plus the weight w of the lever arm a, valve v, and spindle s, multiplied by the distance x from the fulcrum f, to the centre of gravity g, or the momentum $w\,x$, of lever arm a. That is to say, the static momentums are in equilibrium.

To find the weight W on a given safety valve when the steam pressure p is known, and all the other dimensions known:

$$\text{Weight } W = \frac{A\,p\,l - w\,x}{L} \qquad \text{.... .... 2}$$

Rule.—multiply the area A of the valve, in square inches, by the steam pressure p, in pounds per square inch, and this product by the length of the short lever l, in inches; from this last product subtract the momentum $w\,x$, of the lever arm a; divide this remainder by the length of the long lever L, and the quotient will be the weight W in pounds required.

To find the length of the long lever L, the area A of the valve, the steam pressure p, and all the other dimensions being known:

$$\text{Lever } L = \frac{A\,p\,l - w\,x}{W} \qquad \text{..................... 3}$$

Rule.—Subtract the momentum $w\,x$ of the lever arm a from the area A of the valve in square inches, multiplied by the steam pressure p in pounds per square inch, and this product by the length of the short arm l, and divide this remainder by the weight W in pounds; the quotient will be the distance in inches from fulcrum f to place the weight W.

To find the pressure p per square inch at which a safety valve will blow off, the weight W, and all the other dimensions being known:

$$\text{Pressure } p = \frac{W\,L + w\,x}{A\,l} \qquad \text{.................... 4}$$

Rule.—To the momentum of the lever arm a, add the product of the weight W, multiplied by the length of the lever arm L; divide the sum by the product of the area A, multiplied by the length of the short lever l, and this quotient will be the steam pressure p in pounds per square inch.

To find the area A in square inches, the weight W, and steam pressure p, and all the other dimensions being known:

$$\text{Area } A = \frac{W\,L + w\,x}{p\,l} \qquad \text{......................... 5}$$

Rule.—To the momentum $w\,x$, of the lever arm a, add the product of the weight W, multiplied by the length in inches of the lever L; this sum, divided by the product of the steam pressure p in pounds per square inch by the length of the short lever l, will be the area A in square inches.

To find the weight w of the lever arm a, valve v and stem s, the area A in square inches, and steam pressure p, and all the other dimensions being known:

$$\text{Weight of lever } w = \frac{A - p\,l - W\,L}{x} \qquad \text{....... ...6}$$

Rule.—Subtract the product of the weight W, multiplied by the length of lever L, from the product of the area A multiplied by the steam pressure p, and this product by the length of the short lever l; this remainder, divided by the lever x, or distance of the centre of gravity g from fulcrum f, the quotient will be the weight of lever a, and valve v and stem s.

To find the distance x in inches from the centre of gravity g to fulcrum f, the area A in square inches, of the valve, the steam pressure p in pounds per square inch, and all the other dimensions being given:

$$\text{Distance } x = \frac{A\,p\,l - W\,L}{w} \qquad \text{.................. 7}$$

Rule.—Multiply the weight W by the length of the lever L; from this product subtract the product from the area A, multiplied by the steam pressure p, and this product by the length of lever l; divide the remainder by the weight w, of the lever arm a, valve v and stem s.

Having given the levers L, l, and x the area A ($D^2 \times 0.7854$), steam pressure p, and the weight w, the weight W is calculated by formula 2.

Example 2.—A safety valve has a diameter of D=2 inches, and the lever to a pressure of steam p=80 pounds per square inch, with the following dimensions:

A=area of valve D=2 inches (2×2×0.7854) 3.1416 L=long lever in inches 30
l=short lever in inches.............. 4
x=distance of centre of gravity g................ ... .15
w=weight in pounds of lever arm a, valve v and stem s......... 6
p=steam pressure per square inch in pounds...................80

What will be the weight required?

$$\text{Formula 2}: W = \frac{A\,p\,l - w\,x}{L}$$

$$W = \frac{3.1416 \times 80 \times 4 - 6 \times 15}{30} = 30.5 \text{ pounds.}$$

Example 3.—Suppose a safety valve to be of the following dimensions, at what distance L from the fulcrum f must the weight W be placed to carry a steam pressure p=50 pounds per square inch?

A=area of valve D=3 inches (3×3×0.7854)........................7.068
p=steam pressure per square inch in pounds..................50
l=short lever in inches........................... 4
w=weight of lever arm a valve v and stem s in pounds.........10
x=distance of centre of gravity g in inches......................18
W=weight in pounds............... 50

$$\text{Formula 3}: L = \frac{A\,p\,l - w\,x}{W}$$

$$\text{Lever } L = \frac{7.068 \times 50 \times 4 - 10 \times 18}{50} = 22.6 \text{ inches.}$$

Example 4.—A safety valve having the following dimensions, at what pressure p per square inch will it blow off?

L=length of long lever in inches..............................30
l=length of short lever in inches............................... 3
W=weight in pounds..50
w=weight of lever arm a, valve v and stem s.........................12
x=length from fulcrum f to centre of gravity g, in inches.........15
A=area of valve in square inches.............................. 7

$$\text{Formula 4}: p = \frac{W\,L + w\,x}{A\,l}$$

$$\text{Steam pressure } p = \frac{50 \times 30 + 12 \times 15}{7 \times 3} = 80 \text{ pounds.}$$

Example 5.—The following dimensions, and the steam pressure p per square inch to be carried, to find the area of valve A?

L=length of long lever in inches..............................30
l=length of short lever in inches.............................. 4
W=weight in pounds..30
w=weight of lever arm a, valve v and stem s, in pounds..........12
x=distance from fulcrum f to centre of gravity g, in inches.......10
p=steam pressure in pounds per square inch.....................40

$$\text{Formula 5}: A = \frac{W\,L + w\,x}{p\,l}$$

$$\text{Area } A = \frac{30 \times 30 + 12 \times 10}{40 \times 4} = 6.375 \text{ square inches.}$$

or about 2⅞ inches in diameter.

Example 6.—A safety valve of the following dimensions, to find the weight of the lever arm a, valve v and stem s, the distance x and steam pressure p being given.

A=area of valve in square inches...... 2
p=steam pressure in pounds per square inch....................80
L=length of long lever in inches..............................20
l=length of short lever in inches.. .... 1.5
W=weight in pounds.. 10
x=distance from centre of gravity g to fulcrum f in inches.......10

$$\text{Formula 6}: w = \frac{A\,p\,l - W\,L}{x}$$

$$\text{Weight } w = \frac{2 \times 80 \times 1.5 - 10 \times 20}{10} = 4 \text{ pounds.}$$

Example 7.—A safety valve of known dimensions, given to find the distance x from centre of gravity g to fulcrum f, in inches.

A=area of valve in square inches.................... 20
p=steam pressure in square inches..............................30
L=length of long lever in inches.................................40