Pressure Relief Valve Inspection — A Condition Monitoring Approach

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Abstract :

Pressure relief valves are important elements in the overall safety systems of many industries. While on stand by, these valves may suffer unrevealed failures due to a variety of causes and so, require periodic tests and overhauls. But the maintenance policy as of now, is not based on any accepted code of practice, nor is there any precise or sophisticated technique to test these valves. This paper investigates the failure characteristics of pressure relief valves, evaluates the effectiveness of bubble tests as a means of valve testing and then presents a new technique for on-line condition monitoring of these valves.

Introduction :

Pressure relief valves are often used to protect process vessels from over pressure, which can cause yield or catastrophic failure. Relief valves are safety equipment which can suffer unrevealed failure due to a variety of causes. The failure needs to be detected before there is a high pressure excursion, requiring the valve to open and limit the pressure rise in the vessel. The maintenance strategy for pressure relief-valves is one of periodic tests and overhauls. But it seems, there is no accepted code of practice to determine a test and overhaul interval, which is found to vary from six months to two years. Furthermore, the testing procedure is imprecise in many companies.

In most circumstances, the workshop testing of pressure relief valves is carried out with air from compressed air bottles. The set pressure of a valve is determined by slowly increasing the pressure until the valve just 'pops' open ; ie. it just lifts but no more. The onset of lift is detected either by listening or by immersing the outlet nozzle in soap water and recording the pressure which produces about two bubbles per minute. Sometimes, the outlet nozzle is immersed in plain water and the pressure is recorded at about sixty bubbles per minute. This subjective criterion of set pressure is necessary because most valves leak near the set pressure. If the valve is found to be in the 'seized open, or the 'seized closed' condition, it is overhauled

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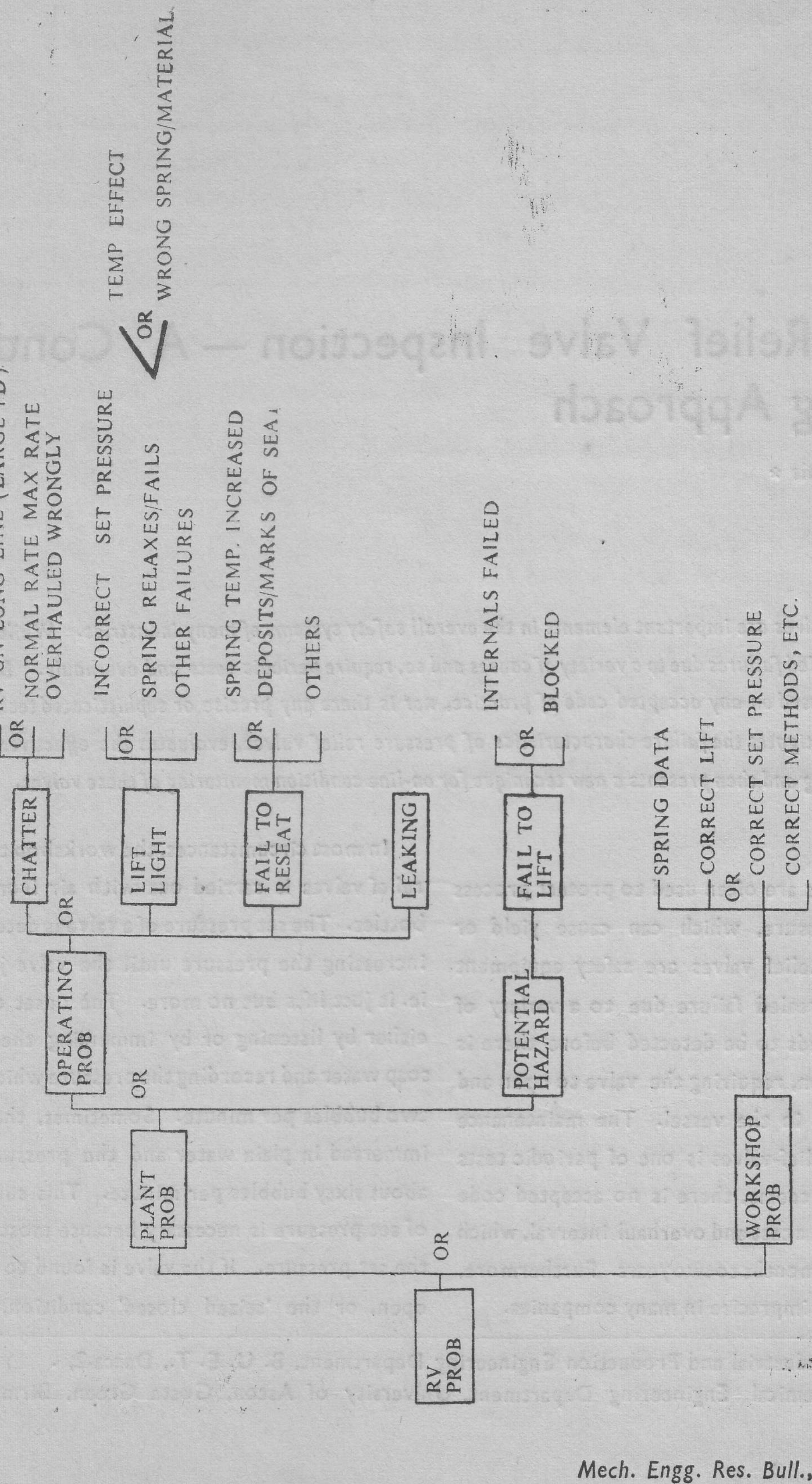


Fig. 1. Potential Causes of Relief Valve Problems.

completely and the necessary maintenance actions are taken before re-setting and re-testing (1).

However, workshop testing does not answer the problem of determining the frequency of tests and overhauls of the valves. It can be determined only by statistical analysis of the failure times of the valves with due consideration of the environmental factors. But it has often been said that condition monitoring under appropriate circumstances and as part of a total maintenance strategy is preferable to periodic preventive tests and overhauls (2). The basic principle of all the monitoring techniques involves a systematic application of conventional methods of fault diagnosis. The choice of a monitoring technique and the frequency of its application should depend upon the plant operating experience, historical data, analysis of the equipment and process conditions to judge how an item might fail and the time relationship of failure (3). It should be noted here that there are very few on-line surveillance methods for relief valves, at present.

2. Pressure Relief Valve Problems :

Regarding maintenance, pressure relief valve problems (4) fall into two categories—(i) plant problems and (ii) workshop problems. Generally, plant problems occur in three ways :

(a) fail to lift on demand, thus causing over pressuring of equipment.

(b) lift spuriously, chatter, fail to reseat, thus causing production loss.

(c) leak so that process material is lost.

The first type of problem creates very significant potential hazard. The second and third types of problems, although potentially less hazardous, cause economic loss and potential environmental pollution.

The principal causes of a pressure relief-valve lifting light are either incorrect set pressure or the relaxation or failure of the valve spring. The latter may arise from using the wrong type of spring or spring material, or from thermal damage to the spring by hot. fluids being released through the valve.

Failure to reseat after relieving upstream pressure may be caused also by spring overheating. The other causes include deposition of solid residue on the seat or plug, grooves in the seat, etc. If the valve is used to perform dirty duty, depsition of residue is likely. Failure of the valve to lift at the expected pressure may be caused either by sticking of the spindle, valve blockage or by too strong a spring.

In the workshop, some relief valve problems arise in the following ways :

(1) inadequate spring data—this causes incorrect selection of the proper spring or spring material for a particular duty.

(2) imprecise determination of lift pressure.

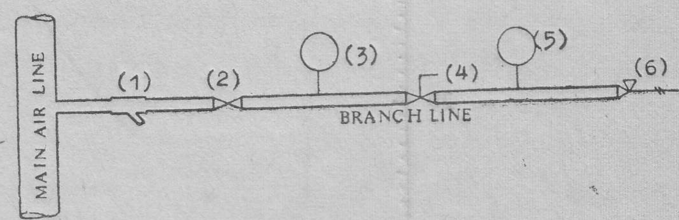
(3) problems in determining the correct set pressure.

Figure 1 summarizes the major operating and workshop problems associated with pressure relief valves.

3. Checking the Effectiveness of Bubble Tests to Determine Set Pressure :

A simple laboratory experiment was performed to determine the effectiveness of bubble observation for determining relief valve set pressure. For comparison, a hot wire anemometer was used to detect the flow of air from the valve.

Figure 2. shows the experimental arrangement. A branch line of about 6 feet length was taken from the compressed air main. At the end of the branch, a relief valve was fitted. The other instruments were : a strainer



(1) *Strainer* (2) *Control valve*
(3) *Pressure gauge* (4) *Pressure reducing valve*
(5) *Pressure gauge* (6) *Relief valve*

Fig. 2. Diagram Showing the Experimental Arrangement for Determining Set Pressure of a Pressure Relief valve.

for intercepting large dirt particles, a control valve for controlling air flow and thereby the line pressure, a pressure gauge for measuring the main pressure, a pressure reducing valve for controlling the pressure upstream of the relief

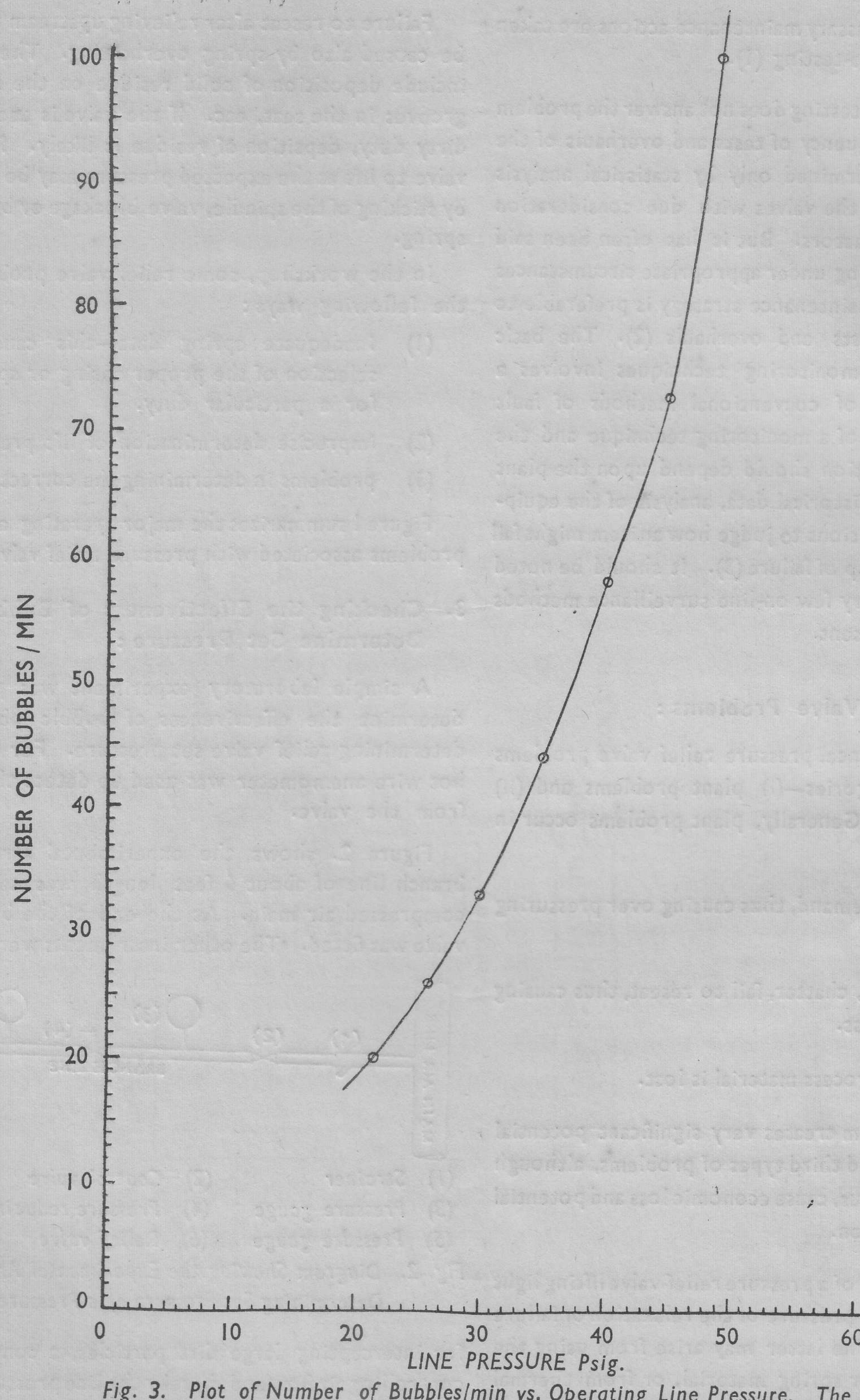


Fig. 3. Plot of Number of Bubbles/min vs. Operating Line Pressure. The graph shows the average number of bubbles that appeared at a particular line pressure. (Determination of set pressure of a pressure relief valve).

valve and a pressure gauge 3 feet upstream of the relief valve. Pressure drop between this gauge and the relief valve was negligible. When the anemometer was used to detect air flow, the relief valve discharged to the atmosphere ; otherwise, the relief valve discharged via a short plastic hose immersed to a depth of 1 inch under water.

Figures 3 and 4 show the variations in the number of bubbles appearing and the hot wire anemometer reading

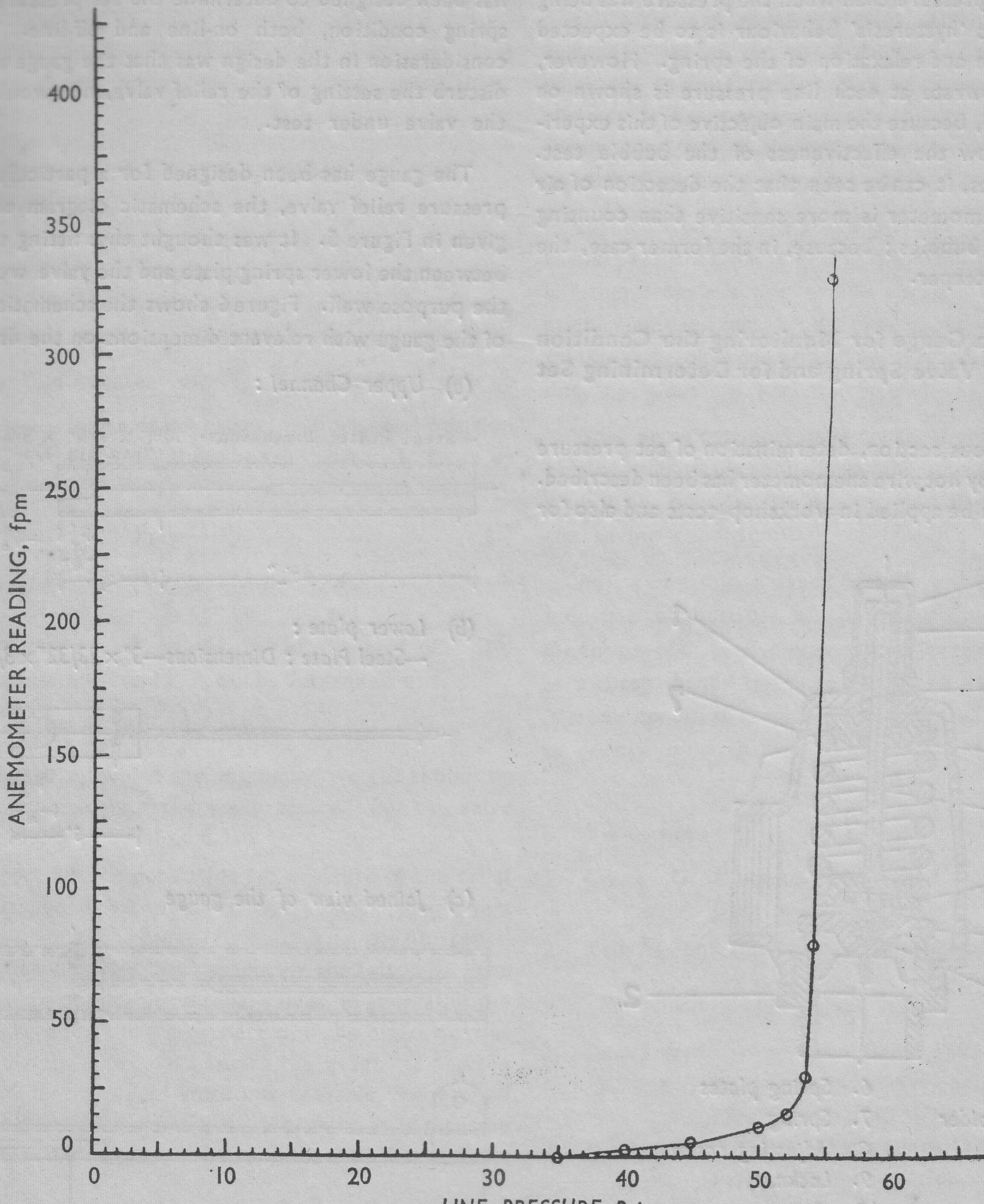
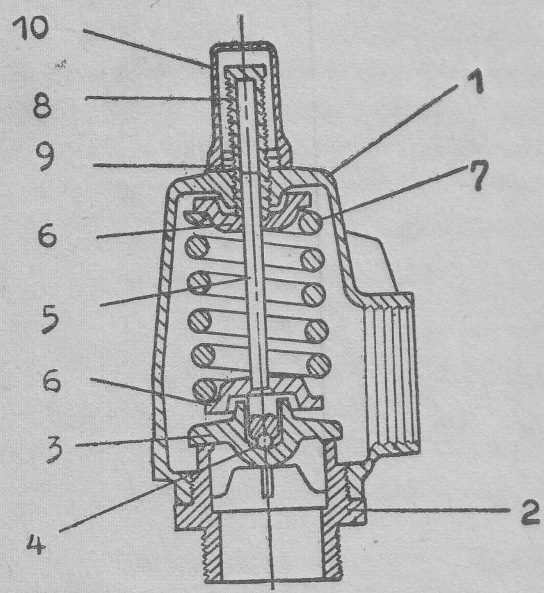


Fig. 4. Plot of Hot wire Anemometer Reading vs. Line Pressure. The graph shows the air flow reading of anemometer at a particular line pressure. (Determination of set pressure of a pressure relief valve).

in feet per minute (fpm), respectively, with the variation in line pressure. For both cases, readings were taken, first increasing the pressure and then decreasing the pressure. It was found that flowrate was somewhat higher while decreasing the pressure than when the pressure was being increased. This 'hysteresis' behaviour is to be expected for compression and relaxation of the spring. However, the average flowrate at each line pressure is shown on Figures 3 and 4, because the main objective of this experiment was to show the effectiveness of the bubble test. From the figures, it can be seen that the detection of air flow by the anemometer is more sensitive than counting the number of bubbles ; because, in the former case, the curve is much steeper.

4. Design of a Gauge for Monitoring the Condition of a Relief Valve Spring and for Determining Set Pressure :

In the previous section, determination of set pressure of a relief valve by hot wire anemometer has been described. The method can be applied in workshop tests and also for on-line condition monitoring if the gas or vapour released is not hazardous. Otherwise, the relief valve will be piped into a vent header system and flow from the valve cannot be measured easily. To overcome this problem, a gauge has been designed to determine the set pressure and the spring condition, both on-line and off-line. The main consideration in the design was that the gauge would not disturb the setting of the relief valve, nor would it open the valve under test.

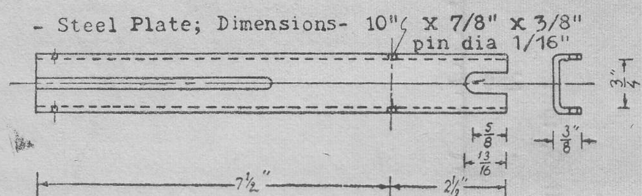


1. Body — *6. Spring plates*
2. Valve Holder — *7. Spring*
3. Valve — *8. Adjusting screw*
4. Ball — *9. Locknut*
5. Spindle — *10. Cap*

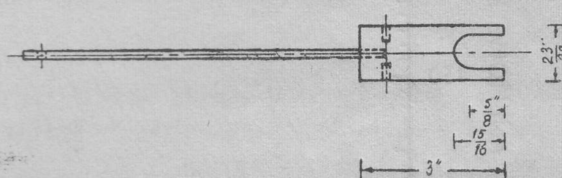
Fig. 5. Schematic diagram of a pressure relief valve for which set pressure measuring gauge has been designed.

The gauge has been designed for a particular type of pressure relief valve, the schematic diagram of which is given in Figure 5. It was thought that fitting the gauge between the lower spring plate and the valve would serve the purpose well. Figure 6 shows the schematic diagrams of the gauge with relevant dimensions on the drawings.

(a) Upper Channel :



(b) Lower plate :
—Steel Plate : Dimensions—3" × 23/32" × 3/16"



(c) Joined view of the gauge

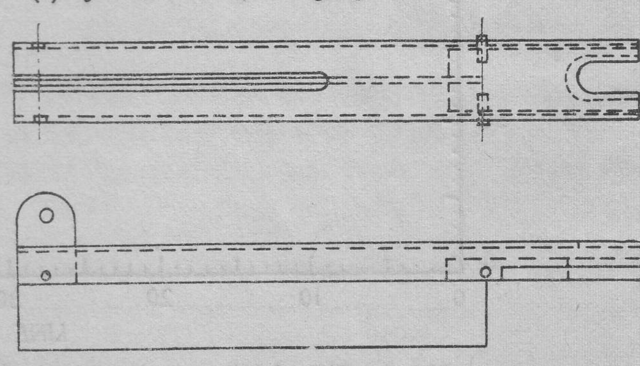


Fig. 6. Design Drawings of the Gauge for Measuring the Set Pressure of a Relief Valve (Drawings not to the scale).

The working principle of the gauge is similar to that of a lever as explained by Figure 7, F_1 is the force exerted

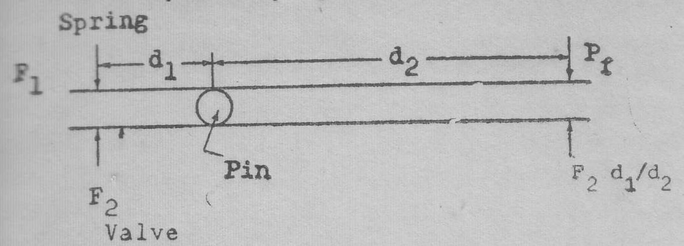


Fig. 7. Illustration of the working principle of relief valve gauge.

by the spring on the spring plate, F_2 is the upward thrust by the fluid on the valve plate and P_f is the weight to be suspended. To determine the set pressure, only forces F_1 and P_f are relevant; neglecting the self-weight of the gauge. The counter force $F_2 \frac{d_1}{d_2}$ is required only to keep the lower plate of the gauge in a horizontal position (Fig. 6). From Figure 7, it can be seen that F_1 is given by the following relationship:

$$F_1 = \frac{d_2}{d_1} P_f \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Denoting by P_s the set pressure and by A_s the cross-sectional area of the valve, F_1 can be given as:

$$F_1 = P_s \times A_s \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

From equations 1 and 2, P_s can be determine as:

$$P_s = \left(\frac{d_2}{d_1} \times \frac{1}{A_s} \right) P_f = R\, P_f \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

R is the factor by which the suspended weight should be multiplied to calculate the set pressure. For the valve of this study, R is equal to 8.324.

The procedure to determine set pressure of the relief valve is to suspend that amount of weight which just lowers the upper plate of the gauge (Figure 6) from the horizontal line and then multiply this weight by the factor R. The method can be applicable to relief valves, in general, if the valves discharge to the atmosphere or if the outlet nozzles can be isolated in order to insert the gauge. Since the valves of different makes were not available, the method could not be tested generally. However, it is assumed that the basic principle will be valid for all makes of relief valve.

5. Conclusions :

From the study of this paper, the following conclusions are in order:

(i) From the failure characteristics of pressure relief valves (section 2), the major cause of the valve failure is variations in the force provided by the valve spring. So, any step to determine correctly the set pressure and the spring condition of the valve can be considered as an important technical development.

(ii) Section 3 shows that the bubble test to determine the set pressure is not very effective. Hot wire anemometer is rather more effective for this purpose, and the method can be employed successfully for workshop test and also for on-line conition monitoring if the gas or vapour released does not pose any potential hazard.

(iii) From section 4, it is apparent that the gauge can be more universally applied than the hot wire anemometer, since it not only gives set pressure but also an indication of the spring condition.

(iv) Following a study of different types of valves, industrial applications of the gauge can be undertaken. On the proof of its effectiveness, the gauge can be developed as a cheap, handy instrument, and so, the feasibility of periodic condition monitoring of relief valves in situ will be greatly enhanced.

6. References :

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