Sempell

Spring-Loaded
Safety Valves

SIV 1 E 02/2000

Introduction

Sempell valves are currently being used in hundreds of chemical plants and power stations and in over 80 nuclear power stations.

Great importance is attached to the development of safety valves at Sempell. To a large degree, this pioneering effort has been directed at meeting technical challenges and market demands. The result has been the development of safety valves which satisfy the safety regulations for even larger plants.

Sempell supported the introduction of type testing for safety valves in order to establish generally binding standards for quality, performance and safe operation.

The development of modern safety valves has been Sempell's contribution to increasing the safety of these plants.

In this article, we would like to demonstrate the operating principles of spring-loaded safety valves and, using a few examples, to show you how these valves can help resolve safety problems in conventional plants and nuclear power stations.

Definition of Terms in Accordance with DIN 3320

Picture 1

A full-lift safety valve is a valve which, after reaching the set pressure (start of lift) within a 5% overpressure rise, opens in pop action up to the full lift as limited by the design. The amount of lift up to the sudden opening (proportional range) must not exceed 20 % of the total lift.

A so called normal safety valve is a valve which, after reaching the set pressure (start of lift) within a overpressure rise of not more than 10 %, reaches the lift necessary for the mass flow to be diverted. No further requirements are specified regarding the opening characteristics.

A proportional safety valve is a valve which opens more or less steadily in relation to the increase in pressure. No sudden opening occurs unless the overpressure beyond more than 10 % of the lift. After reaching the set pressure (start of lift) within a overpressure of up to 10 %, these safety valves achieve the lift necessary for the mass flow to be diverted.

Classification of Sempell Spring-Loaded Safety Valves

a) **Full-lift safety valves** are particularly suitable for use with compressible media (gases, vapours and steam).

Following a slight increase in pressure, the pressure in the system is rapidly decreased by the sudden opening (full lift characteristics) of the valve. Pressure peaks in the system to be protected are therefore avoided.

Picture 2 shows a set of non-dimensional flow force curves for assessing the operating characteristics of a series of geometrically similar valves. In this diagram, the flow force Fs is plotted against the lift H/Do for different system pressures p. The flow force on the valve disc and the guide piston is equal to the spring force at the set pressure (p = 1). As the valve lift increases, the flow force initially drops slightly and then increases to the end of the lift. The curve of the springs used in Sempell safety valves is designed so that it intersects the flow force curve.

The safety valve opens immediately and completely up to the lift limit when the opening pressure is reached, since the flow force is higher than the spring force for each lift. If the pressure supplied to the safety valve drops below the closing pressure, the flow force curve lies below the spring curve for each lift. The valve therefore closes in a single movement.

It is apparent from the flow force curves that the spring curves must be matched to the flow force curves. Harder springs are used at higher pressures (p larger than 1), while softer springs are required for lower pressures (p less than 1).

For a series of geometrically similar valves, a flow force curve for specific, predefined marginal conditions is determined in flow tests. This curve is termed a flow force characteristic. Flow force curves for other marginal conditions, i.e., pressure losses in the supply line to a safety valve and back pressures at the outlet of the valve will be determined by additional tests.

Picture 3 shows two diagrams in which the flow forces Fs are plotted against the lift H/Do as a function of the pressure loss in the supply line and the built-up back pressure. With increasing pressure loss or built-up back pressure, the flow force decreases as the lift increases. The flow force curves deviate from the flow force characteristic. These factors can be corrected within certain limits by using a modified spring characteristic.

It is important to note that the discharge mass flow decreases proportionally to the pressure loss. In the specifications, the permissible pressure loss in the supply line is limited to 3 % of the set pressure. The discharge mass flow is also reduced with a back pressure exceeting approximately 35 %. These factors must be taken into account if necessary when determining the safety valve dimensions.

Under extreme installation conditions, full-lift characteristics can cause the valve to flutter, i.e., the valve opens and closes at a high frequency (up to several 100 Hz). The valve and the adjoining system components can then be damaged due to the dynamic overloading.

Fluttering of a full-lift safety valve always occurs when, after opening the valve, the pressure loss in the supply lines caused by the discharge mass flow becomes so great that the pressure falls below closing pressure ps. This can be seen from the upper diagram. The flow force curve drops away as the pressure loss increases and, at a pressure loss of i.e. 10 %, intersects the defined spring characteristic before reaching the end of the lift. When the valve is closed, the discharge mass flow is interrupted, the pressure upstream of the valve increases and the valve opens again. Partial lifts which, in this case, could prevent fluttering are not possible with full-lift safety valves.

Overview of Sempell full-lift safety valves Series VSE

Picture 4

VSE1 and VSR1 with open valve bonnet
Area of application: Steam (superheated/saturated steam)
When t is more than 400 °C, a cooling spacer SN 110 is necessary.

Picture 5

VSE2 and VSR2 with closed bonnet
Area of application: Gases, vapours, steam up to 250 °C,
Liquids (seat for liquids SN 123 necessary)

Picture 6

VSE5 and VSR5 with closed and vented bonnet and balanced bellows
Area of application: Gases, vapours, liquids (seat for liquids SN 123 necessary)
The balanced bellows make the set pressure independent of the back pressure.

b) **Normal safety valves** have only been defined in standards published since 1980.

Normal safety valves are primarily used for incompressible media (liquids). They should be installed in the immediate vicinity of a vessel to be protected. With standard safety valves, the functional sequence is not laid down. A proportional component is possible in any section of the lift.

These safety valves are normally developed from existing full-lift safety valves. Through more concentrated diversion of the medium at the valve seat, i.e., with the Sempell safety valves with the seat for liquids SN 123, it was possible for this valve to attain the full lift with a pressure increase of less than 10 %. The valve opens in a single lift like a full-lift safety valve. The discharge coefficient is approximately $\alpha w = 0.55$. This high discharge coefficient permits the use of small valves and small lines for large discharge mass flows.

c) **Proportional safety valves** open after the set pressure p is exceeded, until a state of equilibrium is achieved between the flow force and the spring force. The resultant lift is proportional to the pressure. The proportional safety valve functions as a regulator.

Until 1980, many safety valves with a small lift and a discharge coefficient αw of less than 0.1 were marketed as proportional safety valves. They were primarily used as overflow valves. According to current specifications, these safety valves are standard safety valves due to their functional behaviour.

The proportional opening of a safety valve is of particular advantage with liquids, since the discharge mass flow is constantly and slowly changing.

The aim of the development work at Sempell was to construct a genuine proportional safety valve for incompressible media which had a reasonable αw discharge coefficient. The Sempell PSE proportional safety valve (picture 7) is the result of many years of extensive development work involving our in-house computer and laboratory tests.

With a discharge coefficient of $\alpha w = 0.30$, a value was achieved which permits pipes of reasonable dimensions to be used for liquids.

The design of the proportional safety valve is based on the results of extensive tests. The result is a proportional safety valve which functions well and also exhibits perfect partial-load behaviour.

Picture 8 shows the functional characteristics of a proportional safety valve with Do = 28 mm using water. The opening and closing functions were measured on the test rig.

Picture 9 shows an experimental set-up used for testing the behaviour of a proportional safety valve with water and without / with air lock. It was possible to simulate an enclosed, compressible medium in the riser and/or downpipe. In addition to pressures p0 to p2, it was also possible to measure and record the discharge mass flow by measuring the differential pressure p3.

The results are for an experiment conducted with water. When the quick-opening valve opens up suddenly, a brief pressure peak is caused, and then the pressure drops to the opening pressure p2 due to the actuation of the quick-opening valve. After the sudden closing of the quick-opening valve, the pressure drops and levels off. The lift characteristics run parallel to the pressure characteristics without oscillation. The partial lift adjusts to the discharge mass flow.

It is also important to confirm that the proportional safety valve does not flutter if compressible medium (air) is enclosed in the supply line.

It is normally difficult to adjust a valve for both phases. With the PSE proportional safety valve, it has been possible to prevent the valve fluttering, even when blowing off compressible enclosed media; the function stabilises itself automatically in a few splits of a second.

The upper half of picture 10 shows a functional experiment on a PSE proportional safety valve using water with an air lock. Initially, damped oscillations can be discerned during the air throughput. This is followed by a brief period of oscillation during the throughput of the water/air mixture. As soon as the water begins to flow through, the function of the valve immediately stabilises.

The lower half of picture 10 shows the same experiment for water with an air lock on a full-lift safety valve. While the air passes through it, the valve operates normally; the damped oscillations are caused by the lack of discharge mass flow or by excessive pressure in the supply line. During the water phase, however, severe fluttering of the valve occurs immediately, thereby leading to the experiment being terminated.

The two functional diagrams show that PSE proportional safety valves are suitable for protecting a vessel and line system for liquids if the influence of compressible media in the supply lines to the safety valves is to be expected. This was the situation, for example, for protecting sections of piping in the auxiliary circuits of nuclear stations.

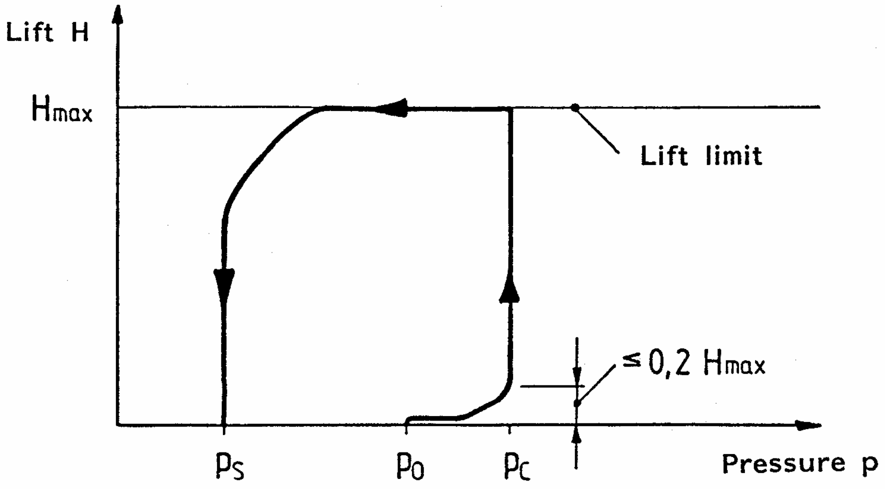
Final Observations

Knowledge of the system to be protected is essential if safety valves are to be used. The medium, the pressure loss in the supply line, the location of the vessel or piping and the speed of the pressure change, etc., must be known.

The full-lift safety valve is particularly suitable for protecting a boiler or a vessel. Early and sudden opening prevents unacceptable pressure peaks in the plant even with high pressure change speeds.

Vessel systems for liquid media can be protected by proportional safety valves. In the case of small malfunctions, small mass flows can be discharged with a partial lift. Large mass flows are, however, also under control if a larger shut-off element is incorrectly actuated.

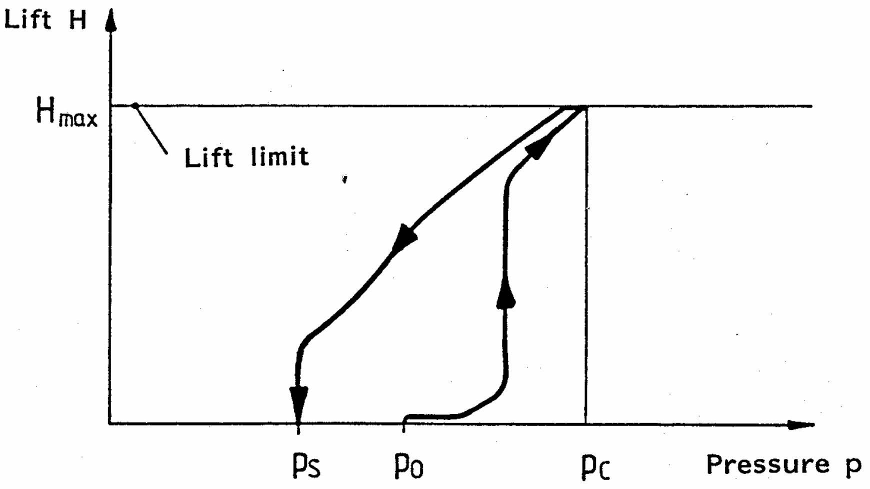
For using safety valves in stability endangered liquid systems see Sempell dynamic damper. On request we would like to send you further information.



Full lift valve

$p_c \leq p_0 + 5\%$

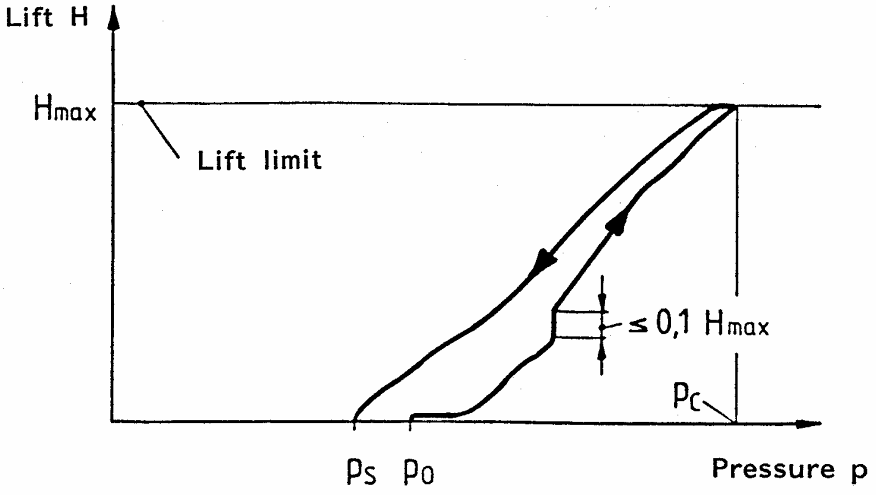
$p_s \geq p_0 - 10\%$



Standard valve

$p_c \leq p_0 + 10\%$

$p_s \geq p_0 - 10\%$



Proportional valve

$p_c \leq p_0 + 10\%$

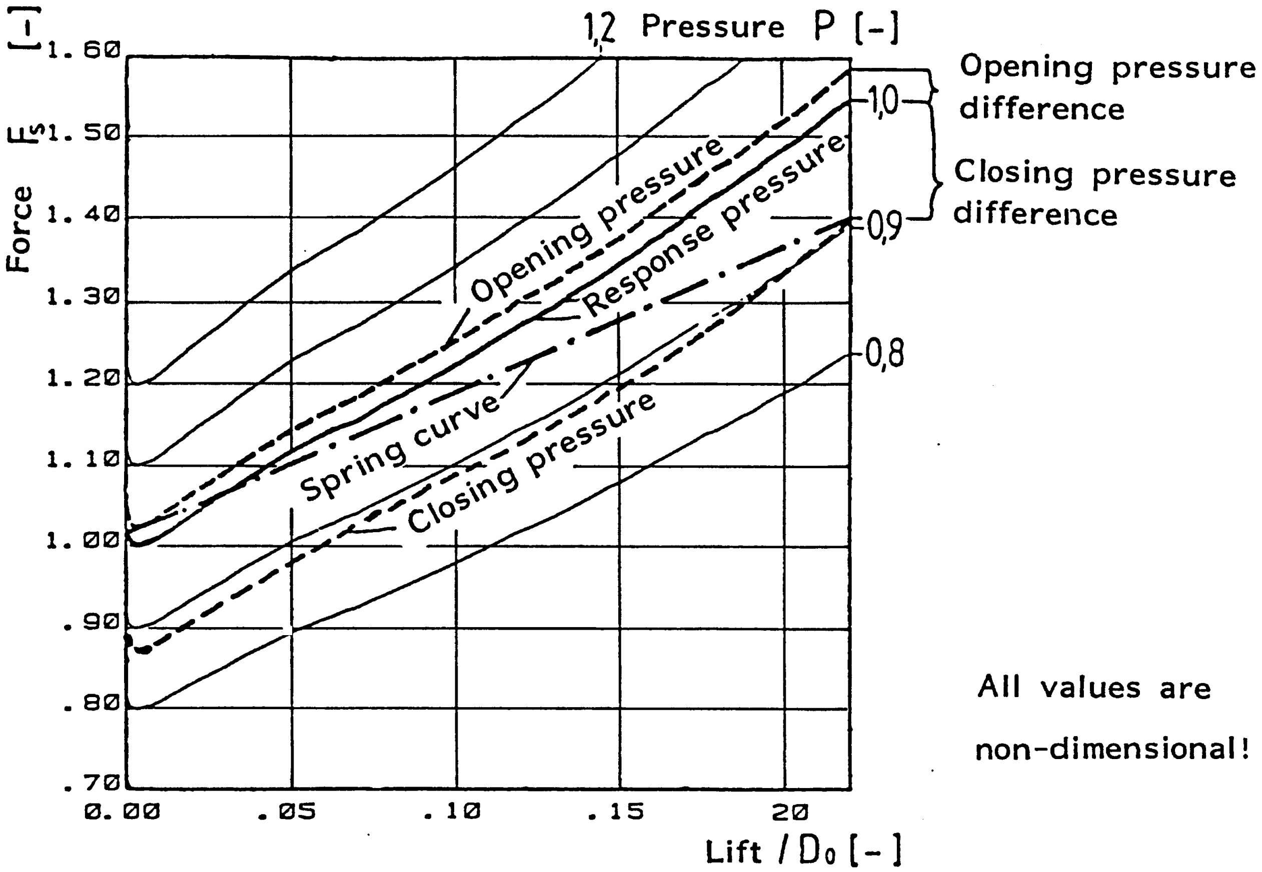
$p_s \geq p_0 - 10\%$

p_C = Response pressure

p_C = Opening pressure

p_S = Closing pressure

PICTURE 1

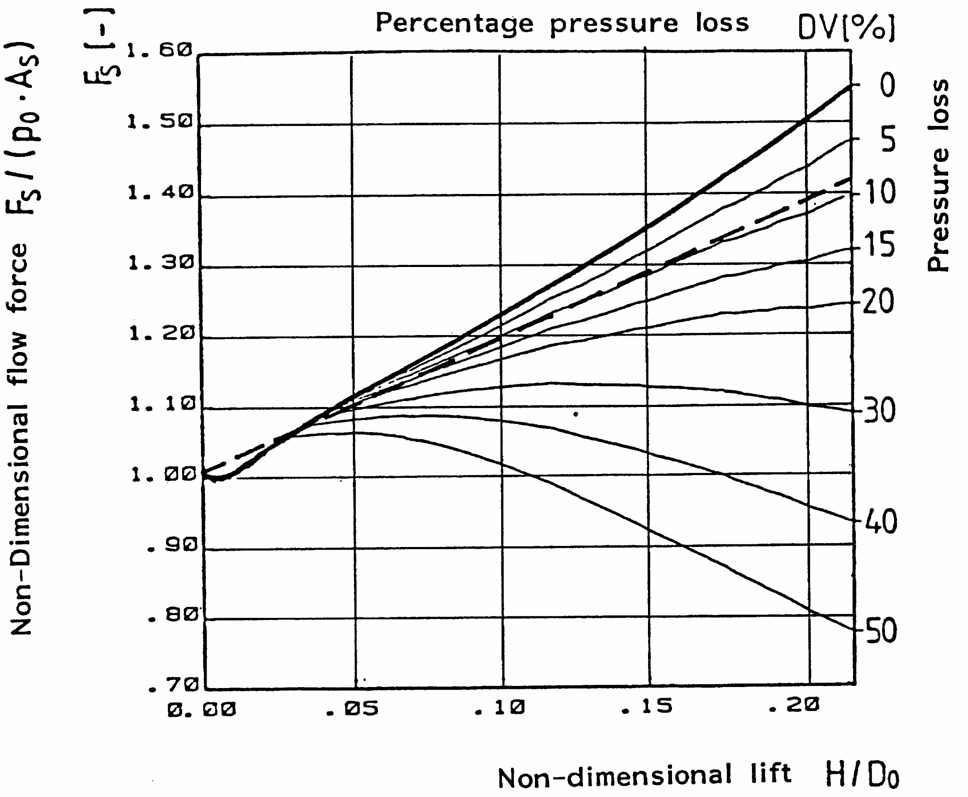


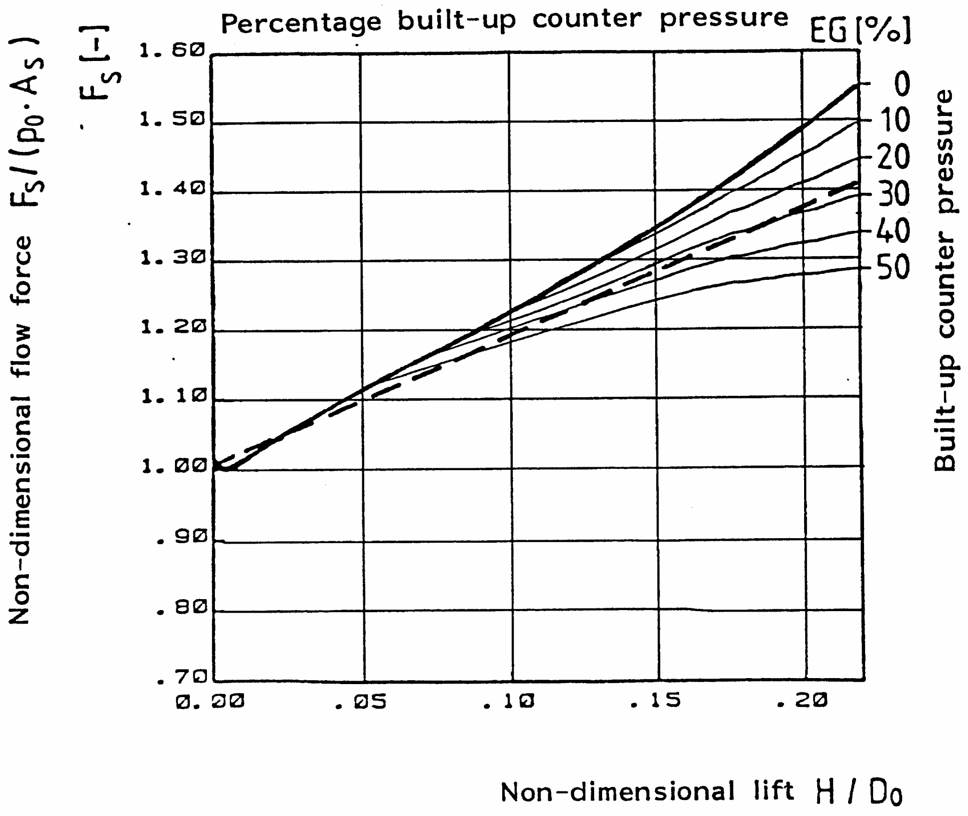
All values are non-dimensional!

Set of non-dimensional flow force curves to assess the functional characteristics of a series of geometrically similar valves

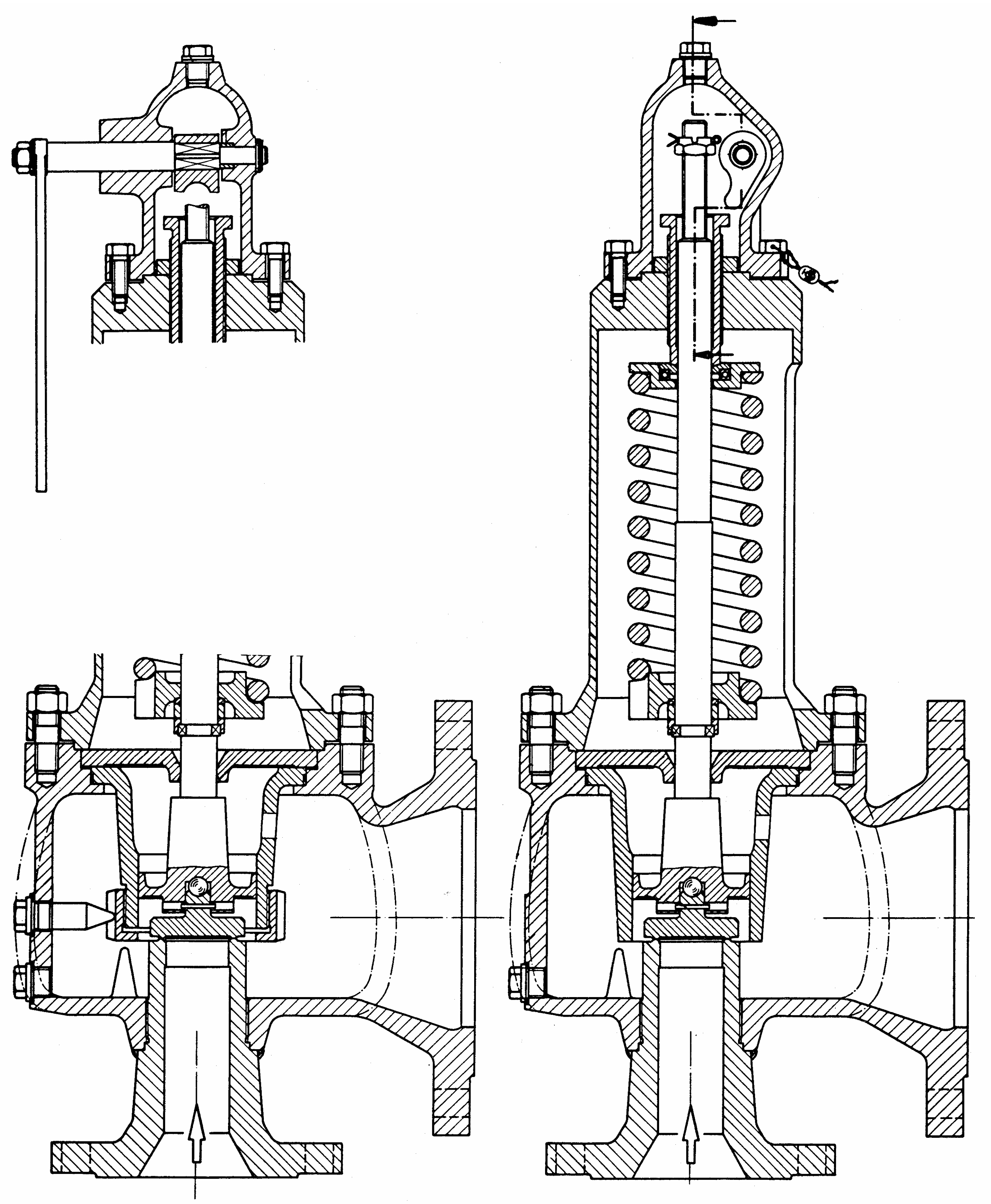
PICTURE 2

Non-dimensional Flow Force Response Curves



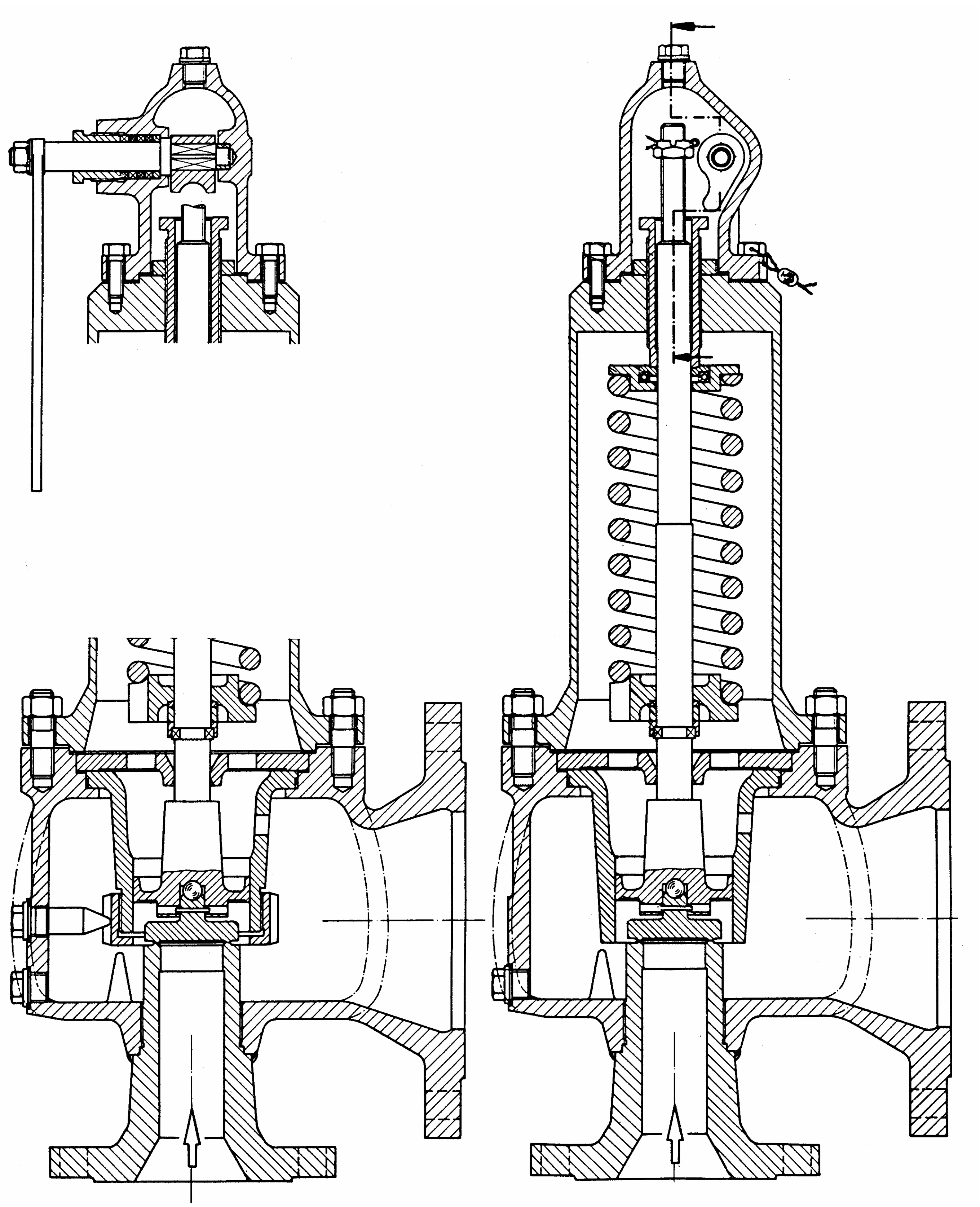


PICTURE 3

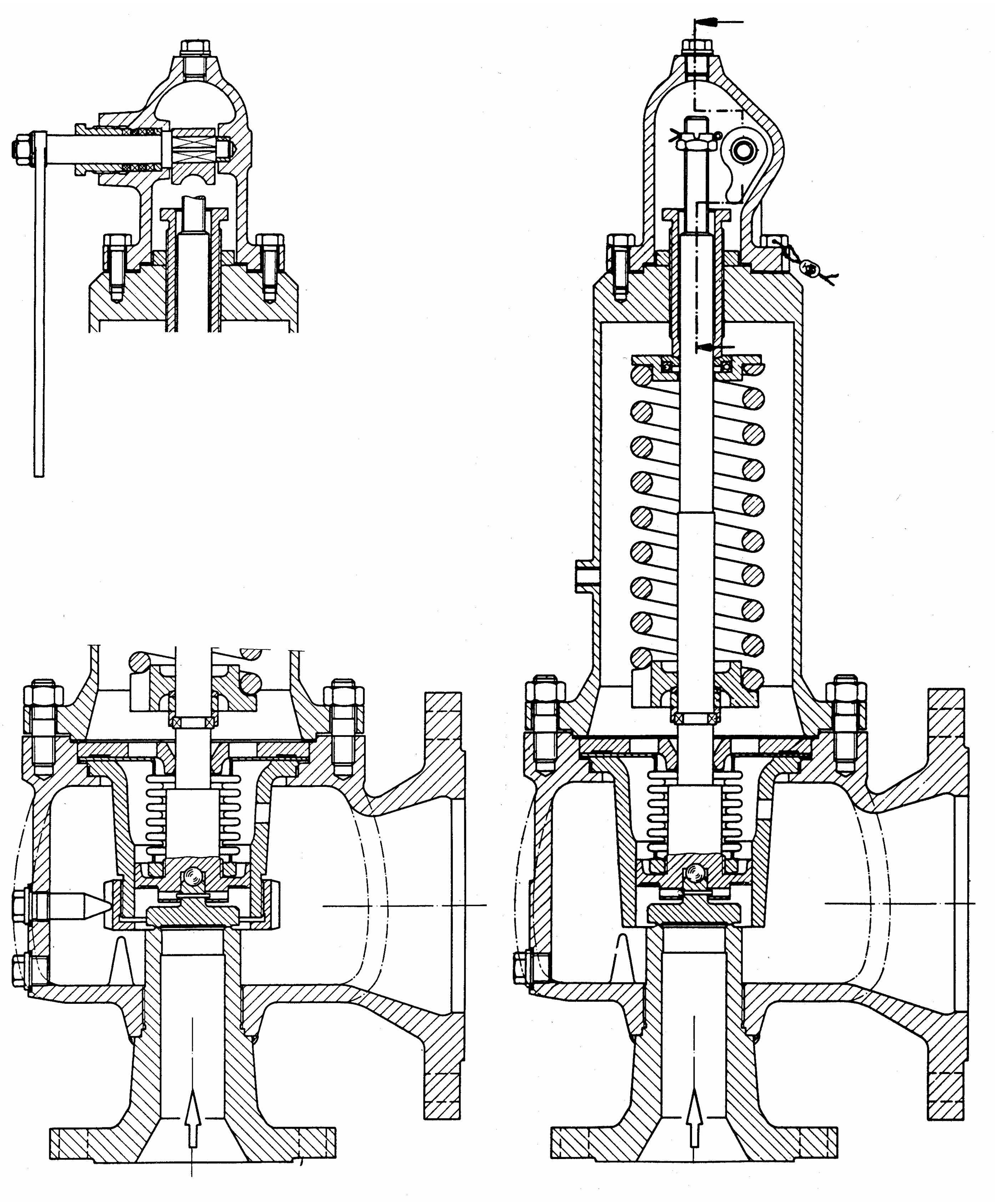


PICTURE 4

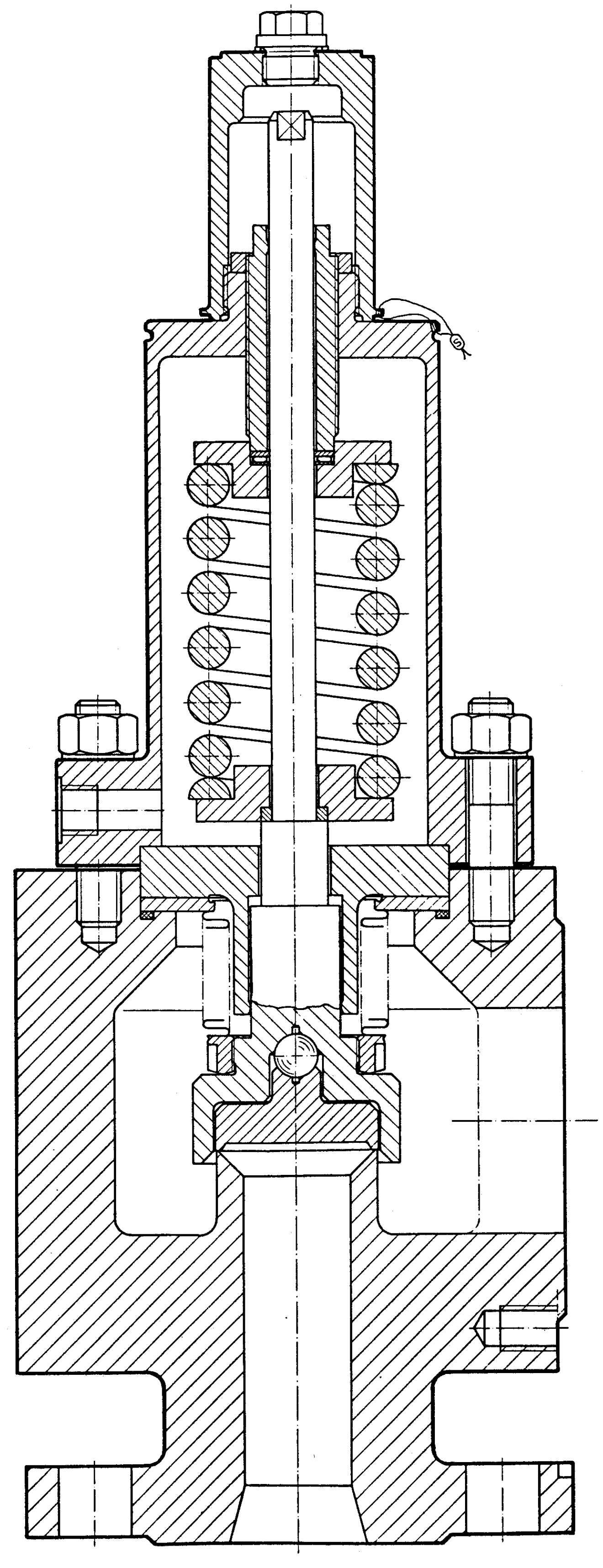
Full Lift Safety Valve VSE2 . VSR2
closed Bonnet



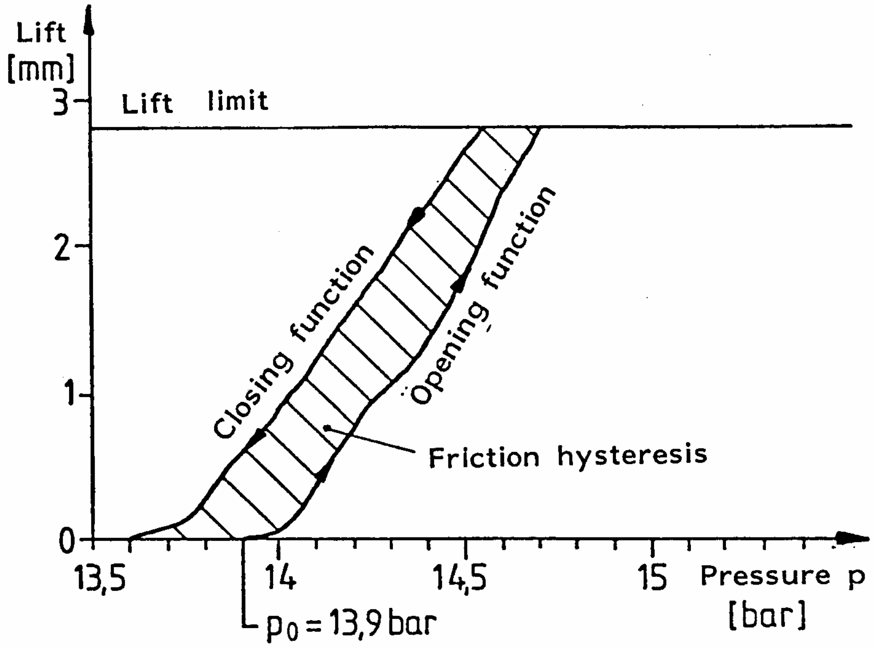
PICTURE 5



PICTURE 6

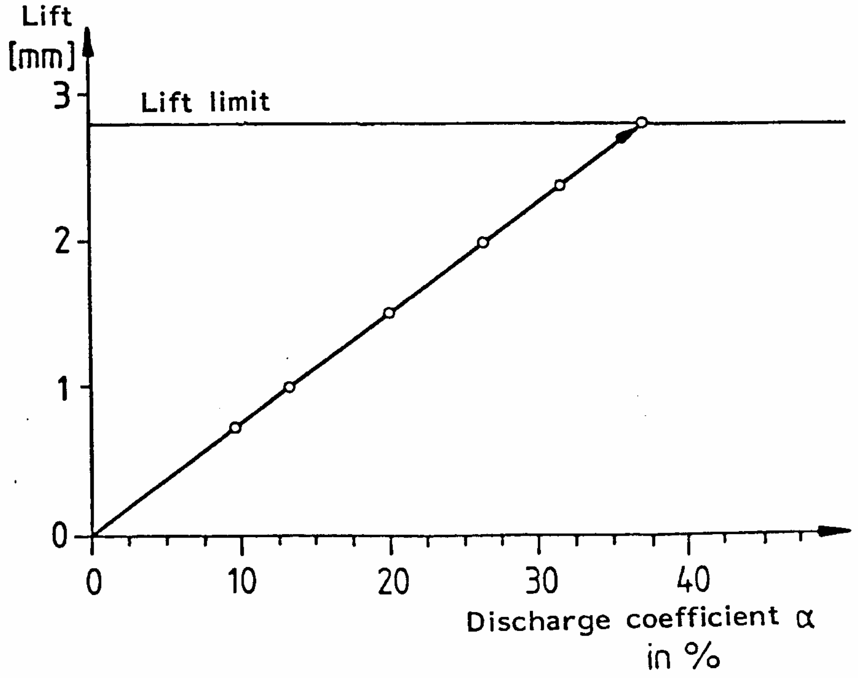


PICTURE 7

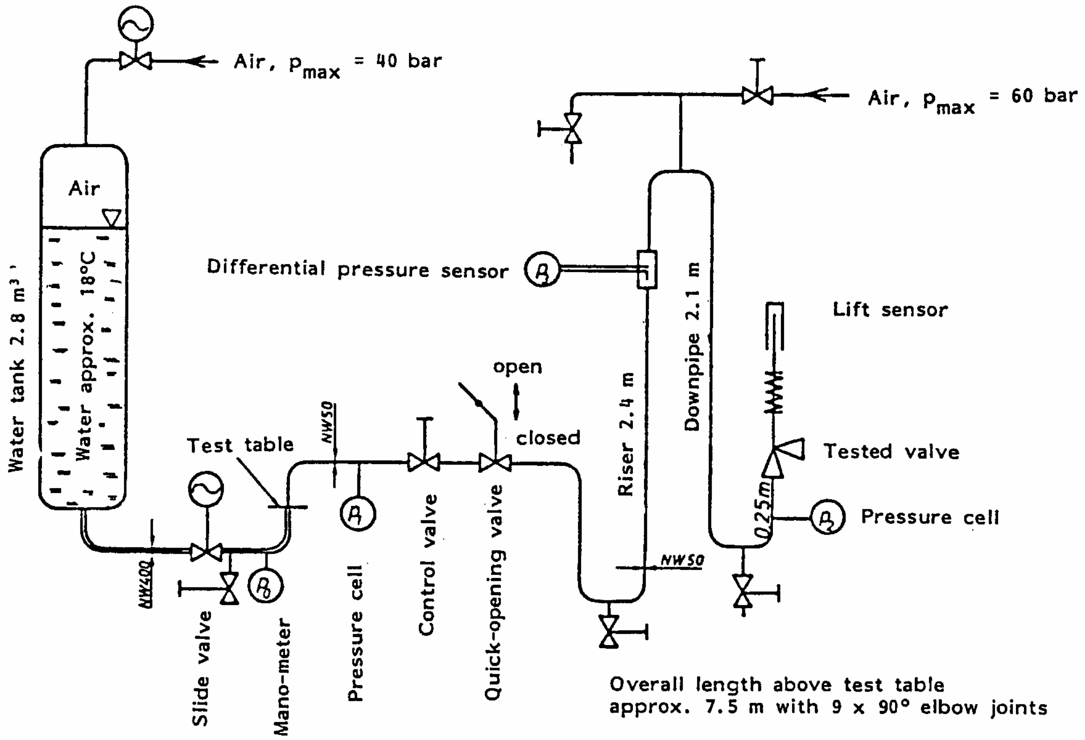


Opening difference = 4,3 % } relative to p_o
Closing difference = 2,2 %

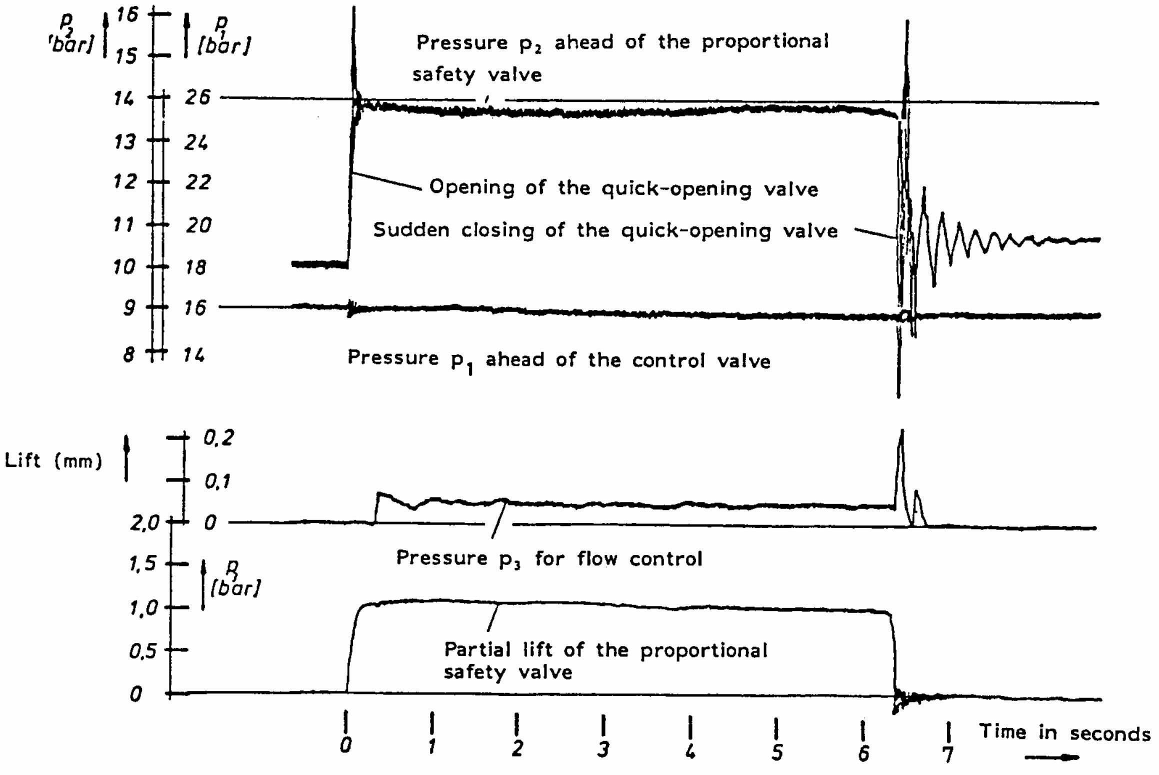
minimum nozzle diameter D_o = 28 mm



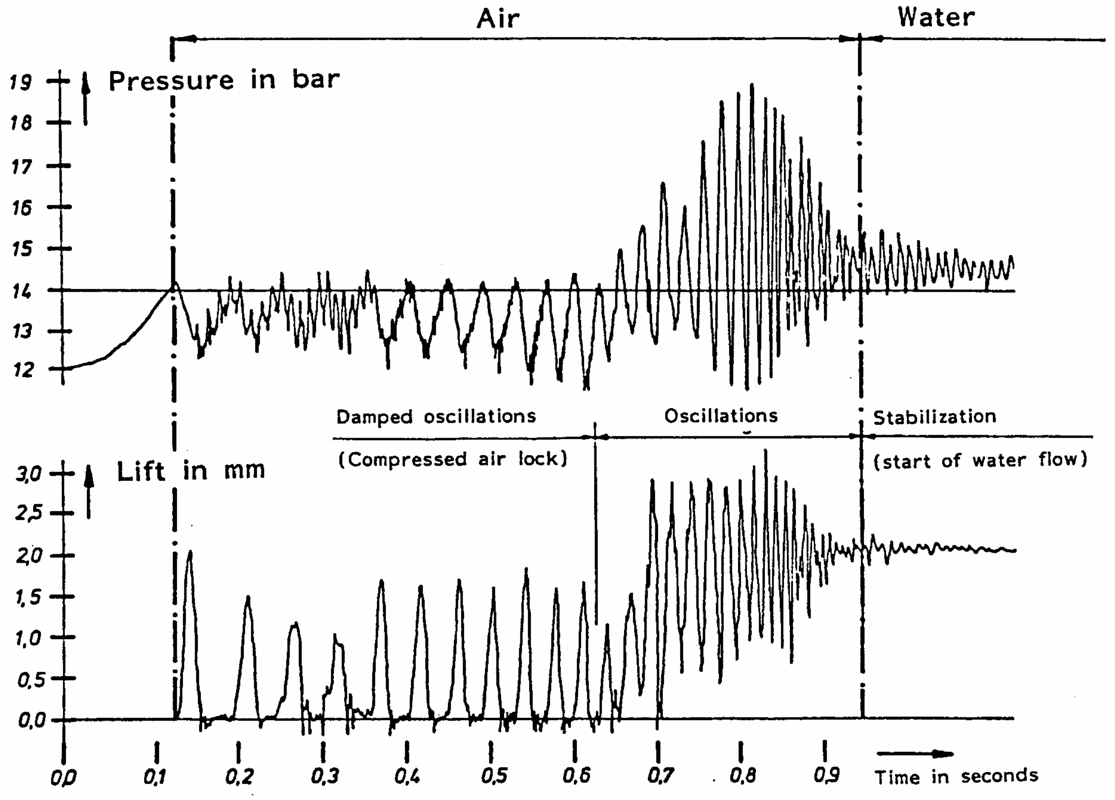
PICTURE 8



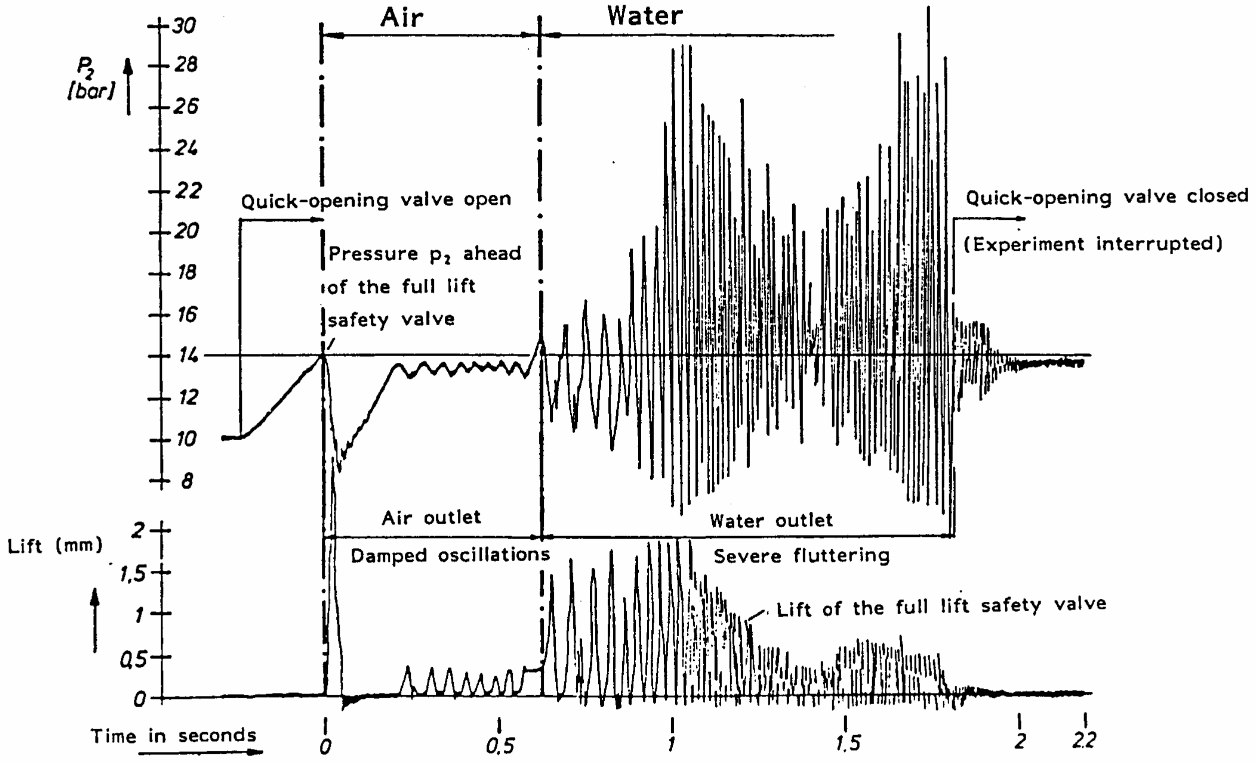
Experiment setup



Functional experiment on a proportional valve without air lock



Functional experiment on a proportional valve



Functional experiment on a full lift valve