Safety and Relief Valves

Learning Outcome

When you complete this module you will be able to:

Discuss boiler safety valves for power boilers and heating boilers.

Learning Objectives

Here is what you will be able to do when you complete each objective:

1. State the ASME Code requirement for safety valves.
2. Describe the construction and operation of high pressure safety valves.
3. Describe the construction and operation of low pressure heating boiler safety valves and safety relief valves.
4. Describe the testing and repair of safety valves.
5. Describe the construction and operation of a temperature relief device.

INTRODUCTION

Each boiler is designed to operate below a specific maximum pressure. The basic function of safety valves is to protect boilers against overpressure.

Certain conditions, such as sudden loss of load or failure of automatic controls, can cause the boiler pressure to rapidly exceed the operating pressure. To prevent bursting of the boiler drum or other pressure parts due to this excessive pressure, at least one pressure operated safety valve must be installed on each boiler. When the pressure in the boiler approaches its maximum allowable value, the safety valve will open and release steam to the atmosphere, thus preventing any further increase in pressure.

CODE REQUIREMENTS

The ASME Code states that each steam boiler shall have at least one safety valve, and if the boiler has over 46.4 m^2 (500 sq. ft.) of water heating surface, then two or more safety valves shall be installed.

All boilers must be fitted with an approved type of pop safety valve of sufficient capacity to discharge all the steam that the boiler can evaporate, without permitting the pressure to rise more than 6% above the allowable working pressure. (See ASME Section I).

This module contains extensive references to ASME Section I, ASME Section IV, and ASME Section VII. The specified sections of these codes should be read while doing this module. The regulations governing safety valves are covered in detail in the ASME Code Section I, paragraphs PG-67 to PG-73.5.

CONSTRUCTION

A safety valve is held shut by means of a spring which holds the safety valve disc tightly against its seat. When the boiler pressure reaches the pressure at which the valve is set (popping pressure), the disc will be raised slightly from its seat and steam will begin to escape.

Fig. 1 shows a safety valve of an approved design, which has a cast steel body and flange connections.

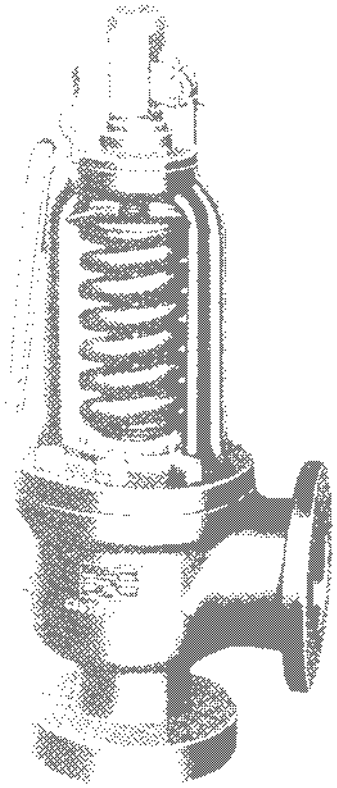

Figure 1
Cast Steel Safety Valve

Fig. 2 illustrates the construction of a safety valve. Referring to Fig. 2, the safety valve is attached to the drum at the top of the steam space. The valve disc “D” is held firmly on its seat by the pressure of the heavy coil spring “J”. The point at which the valve will lift and relieve the pressure is adjusted by screwing the nut “L” up or down, and so decreasing or increasing the compression of the spring “J”. The nut “L” is prevented from shifting after adjustment, by the lock nut “N”. When the valve has been set by adjusting nuts “L” and “N”, the cap “B” is put in place and the Inspector attaches his seal to a wire passing through the hole “O”, thus preventing access to the adjusting nut “L”.

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The valve can be manually lifted by the lever, which raises the valve spindle connected to the valve disc. (ASME Code Section I).

In order to ensure consistent operation, tightness, and proper seating of the disc, the valve disc is equipped with guides at the bottom and top to allow the valve disc to move up and down only in a vertical direction.

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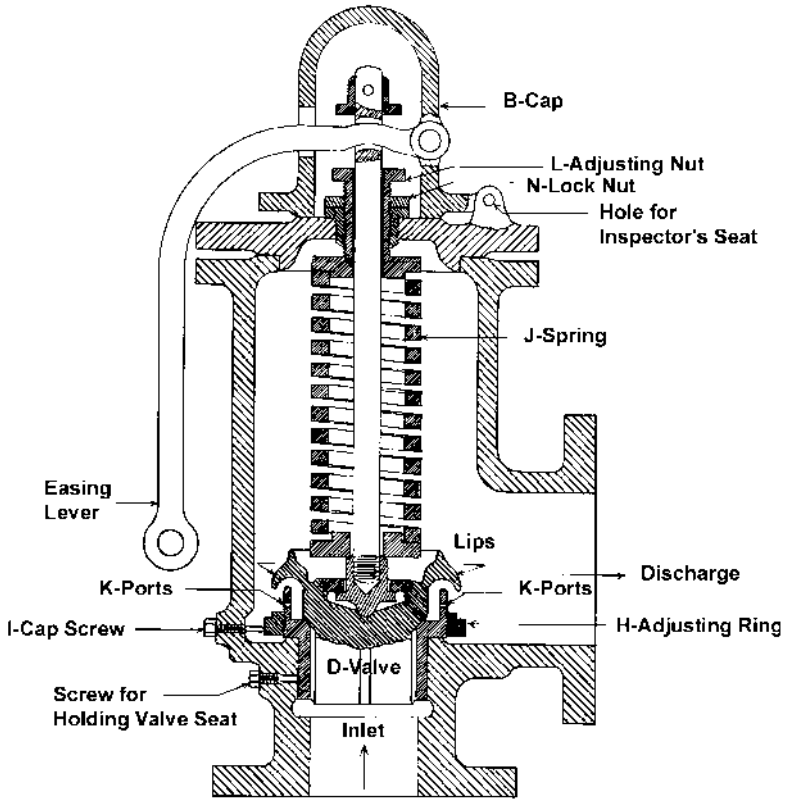

Figure 2
Safety Valve Construction

OPERATION OF SAFETY VALVES

The pop valve is provided with a lip or skirt “E” shown in Fig. 3, which becomes filled with steam when the valve starts to open, so that the effective area of the disc is increased. As illustrated in Fig. 3, the safety valve disc is slightly off its seat and steam is entering this chamber below the valve lip or skirt.

As soon as the valve lifts, the pressure of the steam acts on this increased area of the disc, resulting in a greater force applied against the spring, causing the valve to pop wide open. Once open, the valve will remain open until the pressure drops below the popping pressure.

Fig. 4 indicates that as the valve begins to lift, steam rushes into the pop chamber, acts on an increased area as indicated by the shaded ring and causes the valve to suddenly lift or “pop” to its full opening.

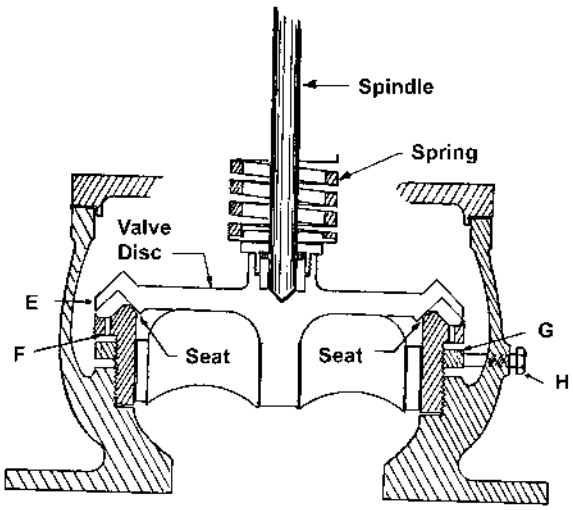

Figure 3
Pop Type Safety Valve

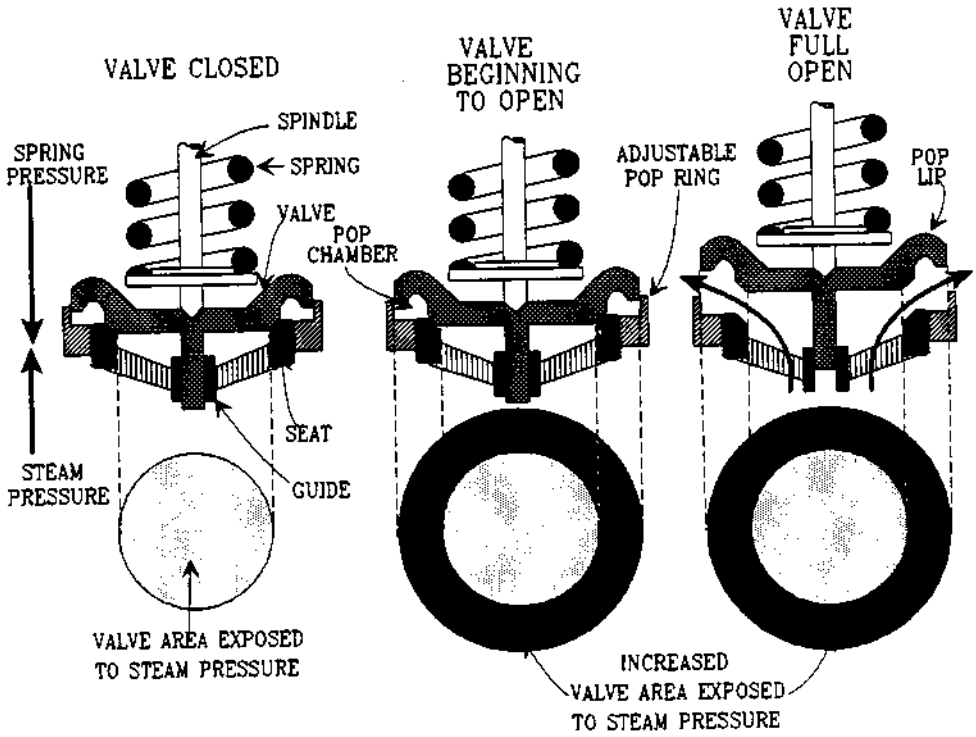

Figure 4
Construction and Operation of a Pop Valve

The lifting force exerted on the disc, by the boiler pressure, is dependent on the area of the disc exposed to the pressure and on the freedom with which the steam can escape from under the skirt or lip.

Referring to Figs. 3 and 5, the “huddling chamber” or “pop chamber” is provided with adjustable outlet ports, ports “F”, to allow steam to escape from under the skirt or lip. If the huddling chamber outlet is closed, the pressure under the skirt or lip will be greater and the boiler pressure must drop quite low before the spring can close the valve. On the other hand, if the huddling or pop chamber outlet is wide open, the pressure in it and therefore under the skirt or lip, will be small and the valve will close with very little drop of boiler pressure.

It was previously explained how the effect of the skirt “E” or lip, will cause the valve to open wide very soon after starting to open. In closing this action is reversed. When the boiler pressure drops sufficiently to allow the spring to begin closing the valve, the pressure under the skirt (lip) drops and allows the spring to close the valve faster. Because these valves open and close quickly, they are called “pop” valves.

REGULATING THE BLOWDOWN

The differences between the pressure at which the valve opens and the pressure at which the valve closes is called the blowdown of the safety valve. The blowdown, according to ASME Section I, PG-72.1, must be a minimum of 14 kPa (2 psi), and the maximum blowdown will allow the safety valve to close at a pressure not lower than 96% of the set pressure of the safety valve.

A threaded adjustable angular ring “G” may be screwed up or down to vary the amount of port opening “F”, as shown in Fig. 3.

If the angular ring is screwed up toward the port holes, the blowdown will be longer. The raising of the adjusting ring decreases the area of the escape ports and therefore more steam is directed against the skirt or lip. The resulting increase in the lifting force acting on the disc, causes the valve to stay open longer and to close at a lower steam pressure.

Conversely, if the ring is screwed downwards, the blowdown will be shorter because the ring increases the area of the ports causing less steam to contact the lip and the valve closes sooner.

The adjustment of the blowdown ring can be made by removing the cap screw, inserting a screwdriver that will catch in notches or ribs on the outside of the adjusting ring, and turning the adjusting ring in the desired direction. When the adjusting ring is set in the desired position, it is locked in place by the set screw, “H”.

To prevent unauthorized persons from tampering with this adjustment, a cap screw is installed and held in place by a seal which is installed by the Boiler Inspector to prevent any further adjustments. The cap screw and seal are visible in Fig. 5 and Fig. 6, respectively. Refer to ASME Section I.

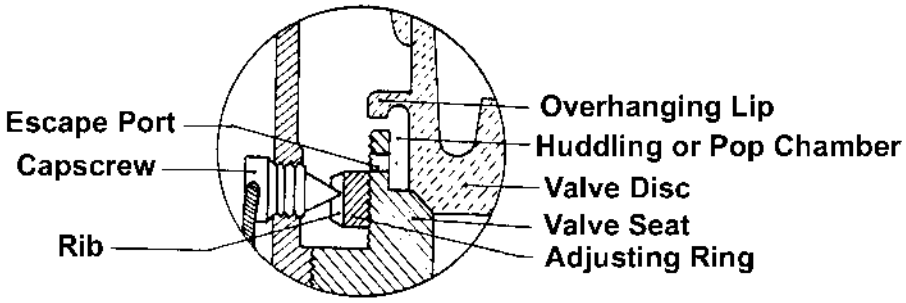

Figure 5
Disc and Seat Details of Pop Safety Valve

ADJUSTMENT OF POPPING PRESSURE

The safety valve springs are designed for a certain opening pressure or "popping" pressure. This popping pressure may be increased or decreased by five percent (5%) by changing the compression of the spring, as per ASME Code Section I.

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Before adjusting the pressure at which the safety valve opens, the lock nut, on the adjusting nut screwed on the spindle above the spring, must be backed off. To increase the blowoff pressure; screw the adjusting nut down, thus compressing the spring. To decrease the blowoff pressure; screw the adjusting nut upwards, releasing some of the pressure on the spring.

Note: Adjustment of the safety valve setting may only be done with the permission of an authorized Boiler Inspector.

The regulations governing safety valve design, material selection, capacity, testing, adjustments, and sealing is covered in the ASME Code Section I, PG-73.

Fig. 6 shows a cast-iron safety valve suitable for boilers operating at pressures up to 1720 kPa, and steam temperatures up to 232 C. Cast-iron valves are not used on superheaters.

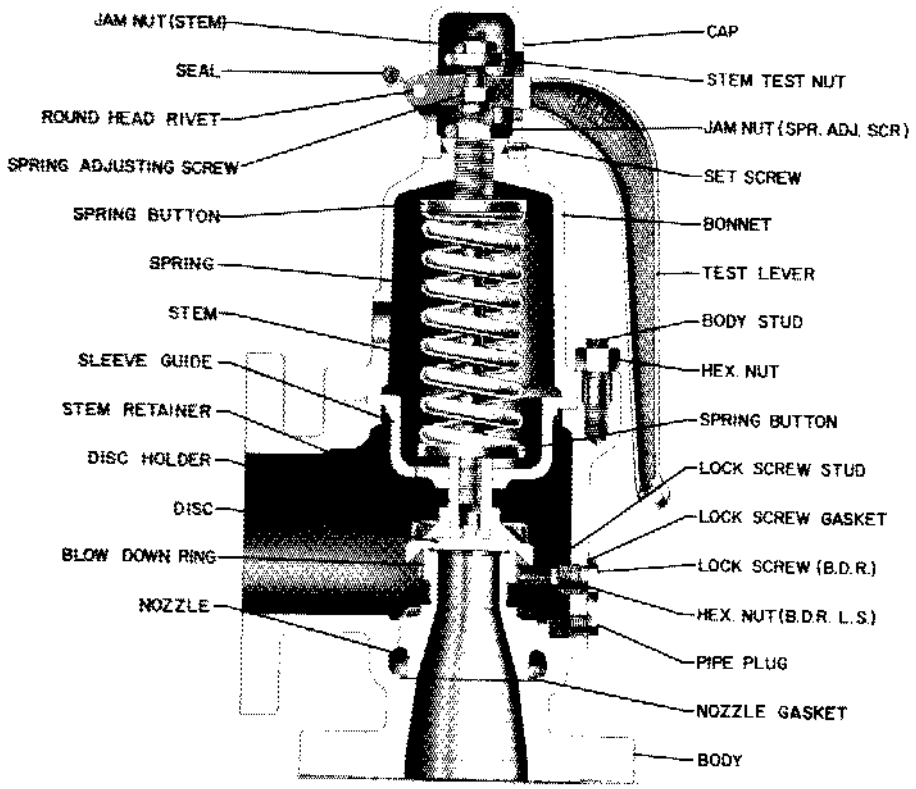

Figure 6
Pop Safety Valve - with Adjustable Popping Pressure

THE SAFETY VALVE DISCHARGE PIPING

The safety valves on the drum, superheater, and reheater inlet and outlet headers should be placed in an upright position with the spindle vertical. They must be connected to the boiler independent of any other steam connection and as close as possible to the boiler without any unnecessary intervening pipe or fitting, as stated in ASME Code Section I. The discharge pipe should be provided for safety valve outlets as stated in ASME Code Section I, PG-71. The discharge pipe should be separately supported, leaving ample room for expansion so that no force is exerted on the valve.

Fig. 7 shows the discharge piping arrangement and dimensions for a typical safety valve per ASME Code Section I.

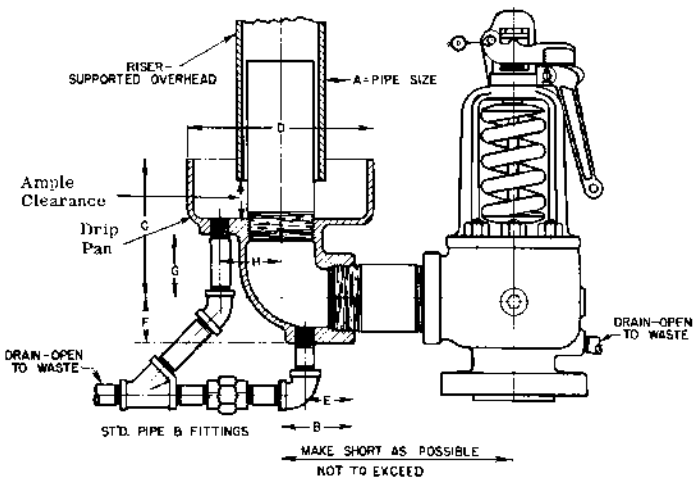

Figure 7
Discharge Piping Details

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The superheater safety valve shown in Fig. 1, has an exposed spring to prevent the high temperature of the superheated steam from destroying the mechanical properties of the spring.

The superheater and reheater safety valves are set to pop open before, and to close after, the drum safety valves. In this way overheating of the superheater and reheater is avoided as there will be a flow of steam maintained through the tubes until the fires can be shut down, or the pressure reduced. ASME Code Section I, paragraph PG-68 states the rules governing superheater and reheater safety valves.

Recommended Rules

The ASME Code Section VII, Subsection C4, from paragraph C4.100 to C4.130 should be thoroughly read by the student at this time. ASME Section VII provides recommendations for the testing, operation, and maintenance of safety valves.

Torsion Bar Safety Valve

The torsion bar safety valve pictured in Fig. 8 is designed for use on boilers operating at 8000 kPa or over. Its operation is similar to the conventional types of safety valves except that torsion bars are used to hold the valve closed instead of a heavy spring. Its main advantage is that the torsion bars can be machined to much finer specifications than can a coil type spring.

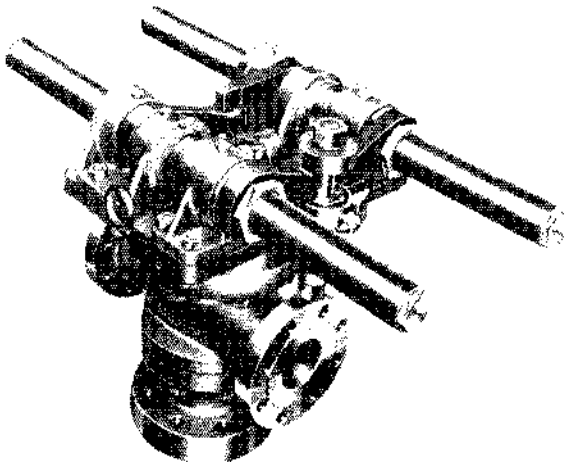

Figure 8
Torsion Bar Safety Valve
(Hopkinsons Ltd.)

HEATING BOILER SAFETY AND SAFETY RELIEF VALVES

Code Requirements

The ASME Code states that each steam heating boiler shall have one or more officially rated safety valves of the spring pop type, adjusted and sealed to discharge at a pressure not to exceed 103 kPa (15 psi). The safety valve must not be smaller than 13 mm (1/2 in) or larger than 110 mm (4 1/2 in) seat diameter.

The safety valve capacity shall be such that, with the fuel burning equipment installed and operated at maximum capacity, the pressure cannot rise more than 34 kPa (5 psi) above the maximum allowable working pressure when all steam outlets are closed.

The safety valve shall be equipped with a body drain connection below the seat level which shall not be plugged after installation of the boiler. This will prevent the collection of condensate around valve and seat which could result in sticking of the valve due to corrosion.

Mounting the Safety Valve

ASME Code, Section IV, sets the following requirements for the mounting of safety valves on heating boilers:

1. The safety valve shall be installed in a vertical position and located in the highest practicable part of the boiler proper.

2. They shall be connected directly to a tapped or flanged opening in the boiler, to a fitting connected to the boiler by a short nipple, to a Y base, or to a valveless header connecting steam or water outlets on the same boiler.

   The opening or connection between boiler and safety valve shall have at least the same area as the valve inlet and no shut off valve may be installed between valve and boiler.

   The safety valve shall not be connected to an internal pipe in the boiler.

3. The discharge pipe of the safety valve shall be as short and straight as possible to avoid undue stress on the valve. Its internal cross-sectional area shall not be less than the full area of the valve outlet. No shut-off valve shall be placed in the discharge. The discharge piping shall be properly drained to prevent collection of water. The discharge shall be so arranged that there will be no danger of scalding the operator.

   Should a long vertical discharge pipe be required, then it may be necessary to install a flexible joint near the safety valve so that the expansion of the pipe will not place any stresses on the safety valve.

TESTING THE SAFETY VALVE

Safety valves should be kept in good working condition at all times. To assure oneself of their proper operation, the operator can employ one of the following methods:

1. Try Lever Test

Pull the try lever on the safety valve to the wide open position and allow the steam to escape for 5 to 10 seconds. Release the lever allowing the spring to snap the disc to the closed position. This test determines whether or not the valve is free to operate, however, it does not determine whether or not the valve will open at its set pressure.

On low pressure boilers, this test should not be used unless the pressure is up to at least 35 kPa (5 psi). This is to ensure that any loose deposits or foreign material will be blown away when the valve opens and will not lodge between valve and seat. Should the valve simmer after the test, operate the try lever two or three times to allow the disc to seat properly. If the valve continues to simmer, it must be replaced or repaired. The ASME Code recommends that this test be performed on a monthly basis and then be recorded in the boiler log.

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2. Pop Test

By raising the steam pressure in the boiler to the value at which the safety valve is set to open, the operation of the safety valve and the exact pressure at which it opens can be checked. This is called the "pop test".

In order to perform this test the steam discharge and feedwater supply valves should be closed and the accuracy of the steam gage should be checked before the test. On automatically fired boilers it will also be necessary to bypass the operating control as well as the high limit control which normally shut the boiler down well before the popping pressure is reached.

The controls are bypassed by putting jumper wires on their electrical terminals. Operators not familiar with or unsure of this procedure are strongly advised to call in a qualified tradesman to assist them.

When the boiler is set up for the test, start the burner and raise the steam pressure. The safety valve should open at 103 kPa (15 psi) but a variation of 14 kPa (2 psi) plus or minus is acceptable. Just before the valve pops open, a simmering action will be noticed. When the safety valve opens, shut off the burner. Observe the pressure gage to note the pressure at which the valve opens and the pressure at which it closes again. Record these pressures in your boiler log book.

Should the valve fail to open at 117 kPa (17 psi), shut the burner off and release the pressure slowly either to atmosphere through the vent valve or into the steam header. When the pressure has fallen below the popping pressure, apply the try lever test a few times to ensure that the valve is free to move, then repeat the pop test. If the valve still fails to open, it must be repaired or replaced.

Note: Never try to free a stuck safety valve by hammering or striking the valve body.

It is recommended that the pop test be conducted at least once a year, preferably at the beginning of the heating season if the boiler is used only for space heating purposes.

REPAIR OF A SAFETY VALVE

The ASME Code recommends that the repair of safety and safety relief valves be done by the manufacturer or their authorized repair representative. In Canada, provincial regulations allow a boiler operator to repair safety valves but only if fully qualified to do so and authorization in writing from the chief inspector has been obtained.

Low pressure steam heating boilers are designed to operate at a pressure not higher than 103 kPa (15 psi). A safety valve especially designed for a low pressure steam heating boiler is shown in Fig. 9, while Fig. 10 illustrates a cross section of this valve showing its construction.

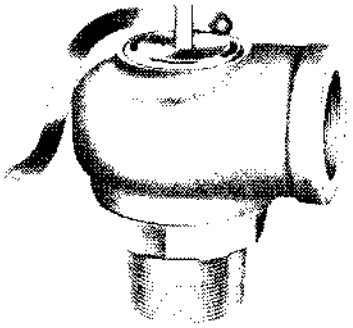

Figure 9
Safety Valve

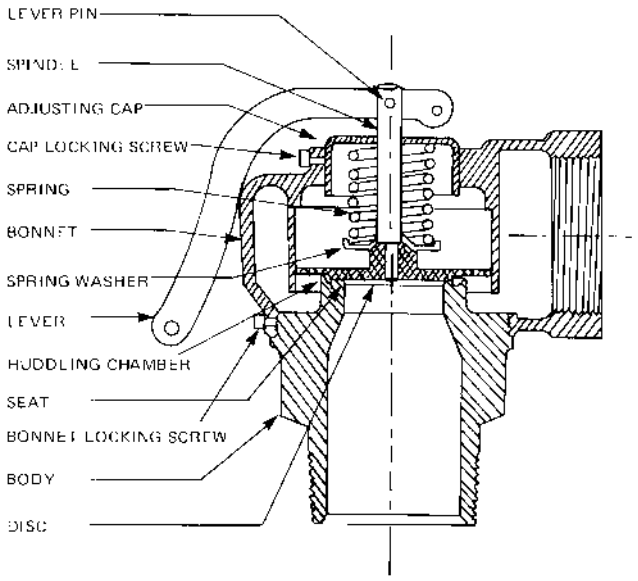

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Figure 10
Cross-Section of Safety Valve

The valve housing consists of two main parts: he valve body, directly connected to the boiler, and the bonnet threaded and locked onto the valve body. The bonnet has an outlet opening to atmosphere. A valve disc closes the opening in the upper part of the valve body and is tightly held down upon its seat by a heavy spring. The adjusting cap in the upper part of the bonnet compresses the spring and is held in position by a locking screw.

Safety Relief Valve

ASME Section IV, states that each hot water heating boiler shall have at least one officially rated pressure relief valve set to relieve at or below the maximum allowable working pressure of the boiler. The valve shall have pop action when tested by steam.

The design of the safety relief valve is basically the same as that of the pop safety valve used for steam boilers except that it is not fitted with a blowdown adjustment ring and bottom guides are not permitted.

The relief valve opens partially when boiler pressure exceeds the valve setting slightly, however, the slight flow of the escaping water does not have the same lifting effect on the valve lip as the steam has so there is no immediate popping action. On further pressure rise the valve pops wide open.

The pressure relief valve may be installed anywhere in the hot water system reasonably close to the heater or tank. Frequently the relief valve is installed in the cold water supply line or in the hot water discharge line. There must not be any valve (shut-off, check or any other type) installed between the relief valve and the heater or tank.

The drain or drip line from the relief valve should be piped to some point over a fixture or floor drain and kept above the top rim of such a fixture. It must never be connected directly to any drain or vent pipe.

Frequent opening or spilling of the relief valve may be due to the following causes:

1. Scale has accumulated on the valve seat and the valve cannot close tightly. If the water is hard then scale will form if the temperature of the heater is carried above 65 C (150 F).

2. Pressure in the supply line varies and at times exceeds the setting of the valve.

3. The relief valve is defective or designed for the wrong pressure range.

If the relief valve does open frequently then the cause must be found and remedied. Never, under any condition, attempt to plug the outlet of the relief valve.

Temperature Relief Device

The temperature relief device protects the domestic hot water system from dangerously high water temperatures. It does this by opening when the water temperature rises to about 99 C. This allows hot water to escape from the system and cold water from the supply then enters thus reducing the temperature.

Various types of temperature relief devices are used. One type employs a fusible plug which melts at 99 C and allows the hot water to escape. The water continues to flow until the device is replaced. Another type uses the expansion and contraction of a rod and tube arrangement to open the device at 99 C and close it at 71 C.

Fig. 11 shows a combination pressure and temperature relief valve which will open due to either high pressure or high temperature.

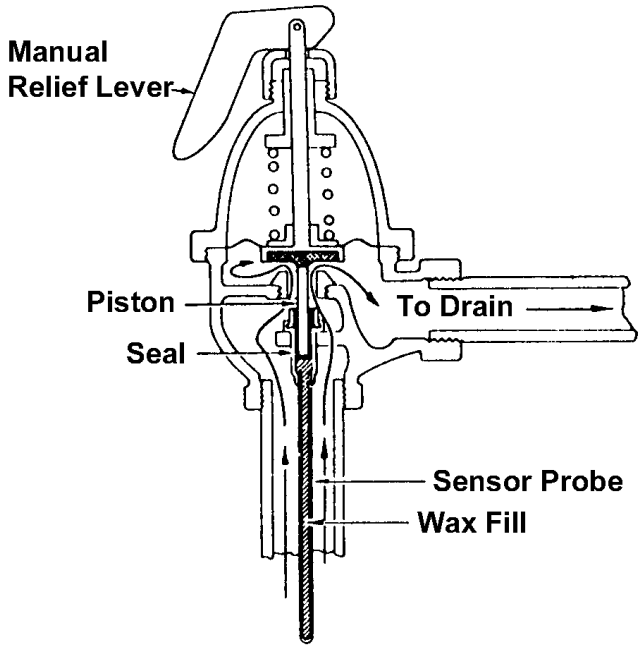

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Figure 11
Combination Pressure-Temperature Relief Valve

With this type (Fig. 11), if the pressure in the system rises, it will open the valve at the preset spring pressure. In addition, if the pressure remains normal but the water temperature rises, then the wax filled sensor probe will expand and open the valve by means of the piston at approximately 99 C (210 F).

Reference Material

For more information on this topic, the following are recommended:

1. ASME. *Rules for Construction of Power Boilers* - Section I. New York: The American Society of Mechanical Engineers; 1986.

2. ASME. *Recommended Rules for Care of Power Boilers* - Section VII. New York: The American Society of Mechanical Engineers; 1986.

3. Salisbury, J. Kenneth. *Kent's Mechanical Engineers' Handbook - Power*. 12th ed. New York: John Wiley & Sons.