PDHonline Course M163 (1 PDH)

The Function of Check Valves Used in the Oil & Gas Industry

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CHECK VALVES

FUNCTION OF CHECK VALVES

The prime function of a check valve is to protect mechanical equipment in a piping system by preventing reversal of flow by the fluid. This is particularly important in the case of pumps and compressors, where back flow could damage the internals of the equipment and cause an unnecessary shutdown of the system and in severe cases the complete plant.

Generally speaking check valves have no requirement for operators, and so the valve is operated automatically by flow reversal; however, in very special circumstances this uni-directional facility has to be overridden. Check valves either can be fitted with a device that allows the closure plate(s) to be locked open or alternatively can have the closure plate(s) removed. The latter alternative requires dismantling the valve, removing the plates, and re-installing the valve.

Check valves are automatic valves that open with forward flow and close against reverse flow.

This mode of flow regulation is required to prevent return flow, to maintain prime after the pump has stopped, to enable reciprocating pumps and compressors to function, and to prevent rotary pumps and compressors from driving standby units in reverse. Check valves may also be required in lines feeding a secondary system in which the pressure can rise above that of the primary system.

Grouping of Check Valves

Check valves may be grouped according to the way the closure member moves onto the seat. Four groups of check valves are then distinguished:

1. Lift check valves. The closure member travels in the direction normal to the plane of the seat, as in the valves shown in Figure 4-1 through Figure 4-7.
2. Swing check valves. The closure member swings about a hinge, which is mounted outside the seat, as in the valves shown in Figure 4-8 through Figure 4-10.
3. Tilting-disc check valves. The closure member tilts about a hinge, which is mounted near, but above, the center of the seat, as in the valve shown in Figure 4-11.
4. Diaphragm check valves. The closure member consists of a diaphragm, which deflects from or against the seat, as in the valves shown in Figure 4-12 through Figure 4-14.

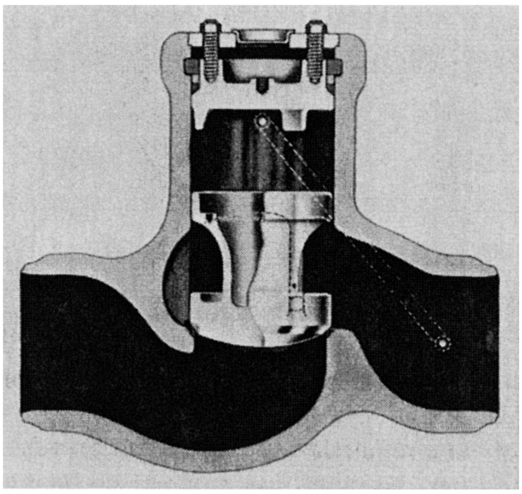

Figure 4-1. Lift Check Valve with Piston-Type Disc, Standard Pattern. (*Courtesy of Edward Valves Inc.*)

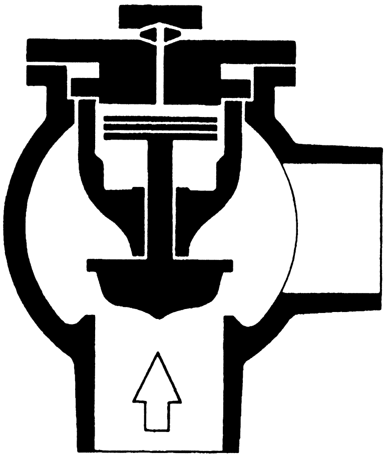

Figure 4-2. Lift Check Valve, Angle Pattern, with Built-in Dashpot, Which Comes Into Play During the Final Closing Movement. (*Courtesy of Sempell A.G.*)

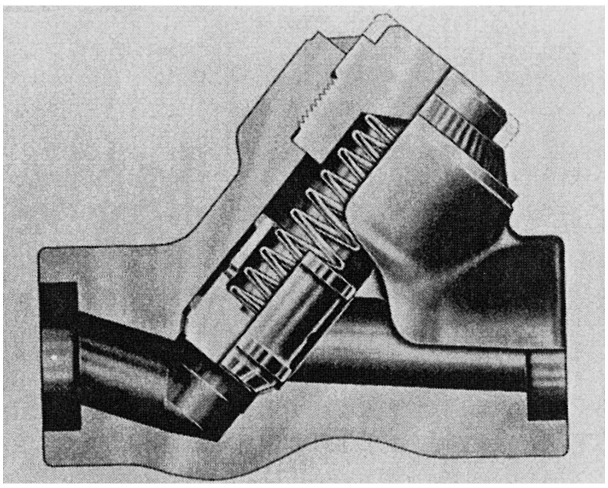

Figure 4-3. Lift Check Valve with Piston-Type Disc, Oblique Pattern. (*Courtesy of Edward Valves Inc.*)

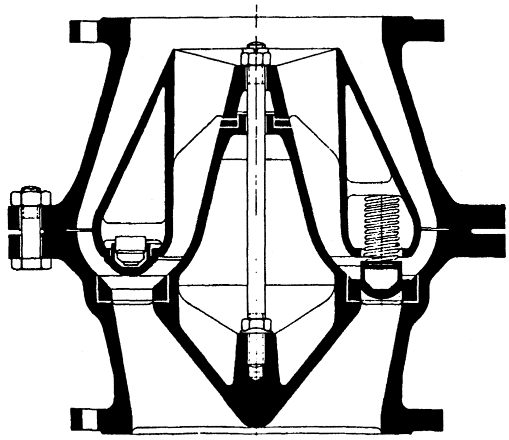

Figure 4-4. Lift Check Valve with Spring-Loaded Ring-Shaped Disc. (*Courtesy of Mannesmann-Meer AG.*)

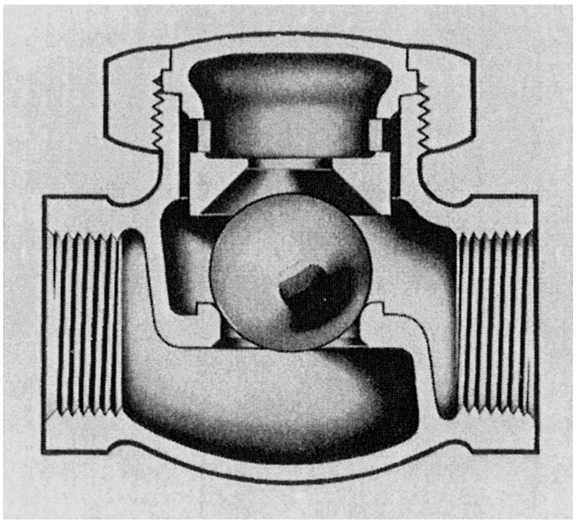

Figure 4-5. Lift Check Valve with Ball-Type Disc, Standard Pattern. (*Courtesy of Crane Co.*)

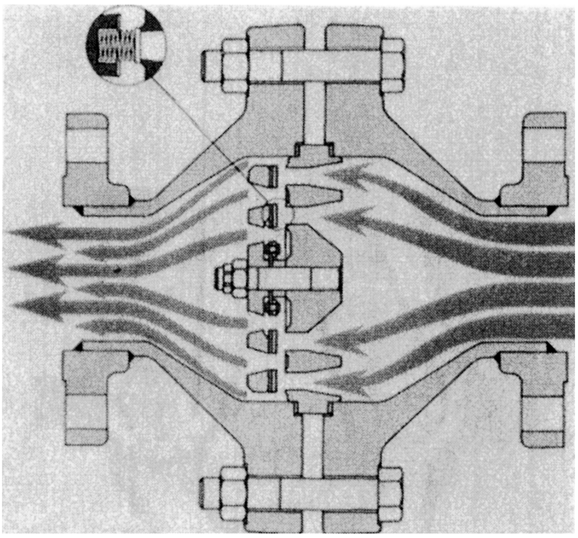

Figure 4-6. Lift Check Valve for Pulsating Gas Flow Characterized by Minimum Valve Lift, and Low Inertia and Frictionless Guiding of Closure Member. (*Courtesy of Hoerbiger Corporation of America.*)

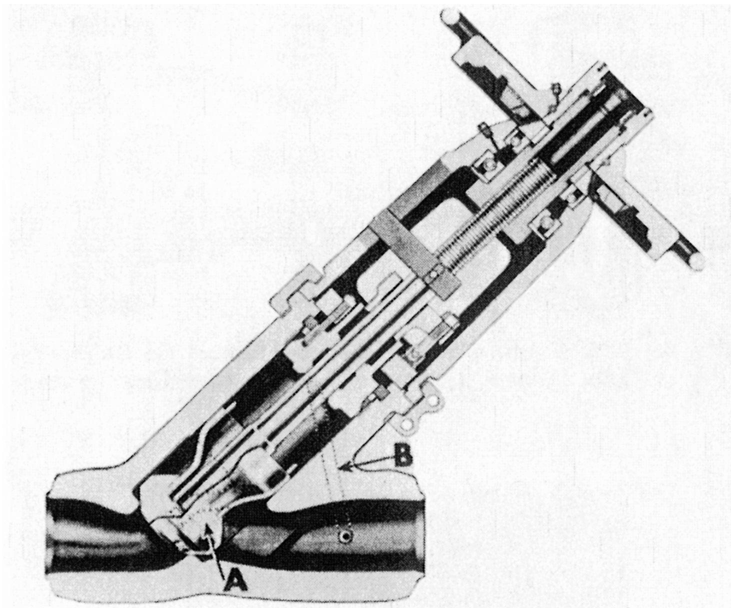

Figure 4-7. Combined Lift Check and Stop Valve with Piston-Type Disc, Oblique Pattern. (*Courtesy of Edward Valves Inc.*)

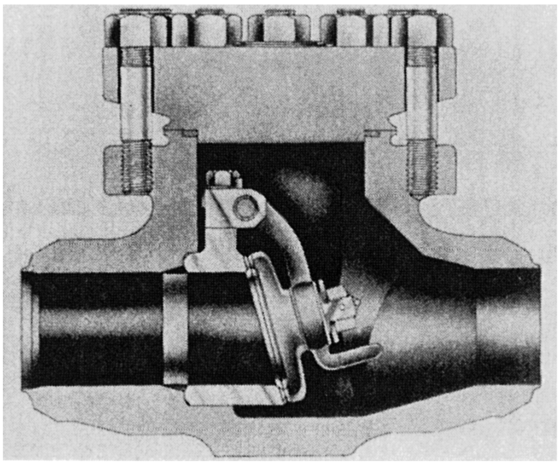

Figure 4-8. Swing Check Valve. (*Courtesy of Velan Engineering, Limited.*)

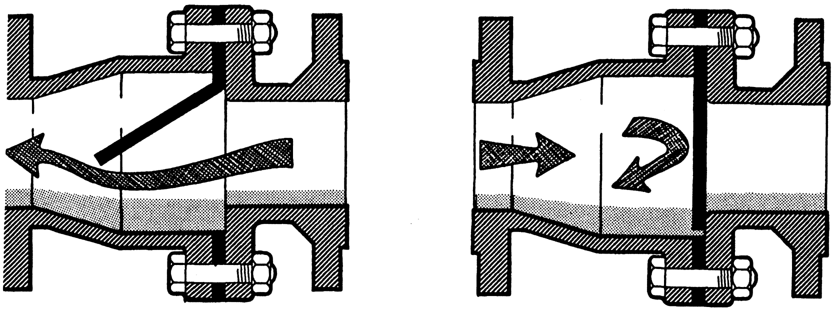

Figure 4-9. Swing Check Valve with Steel Reinforced Rubber Disc, the Disc Being an Integral Part of the Body Gasket. (*Courtesy of Saunders Valve Company Limited.*)

Operation of Check Valves

Check valves operate in a manner that avoids:

1. The formation of an excessively high surge pressure as a result of the valve closing.
2. Rapid fluctuating movements of the valve closure member.

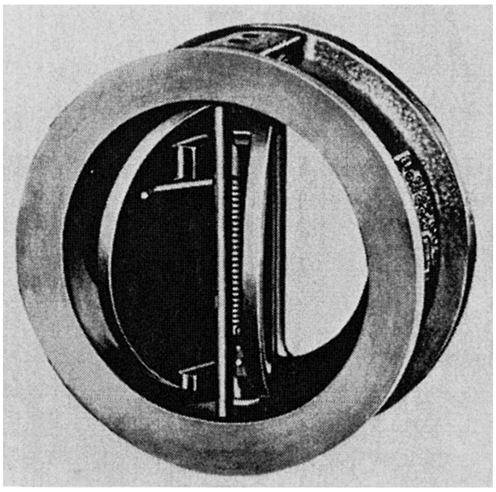

Figure 4-10. Double-Disc Swing Check Valve. (*Courtesy of Mission Manufacturing Co.*)

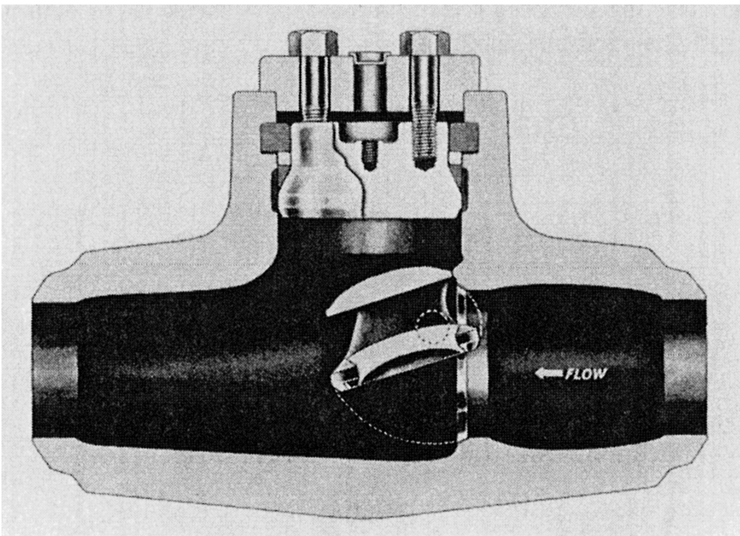

Figure 4-11. Tilting-Disc Check Valve. (*Courtesy of Edward Valves Inc.*)

To avoid the formation of an excessively high surge pressure as a result of the valve closing, the valve must close fast enough to prevent the development of a significant reverse flow velocity that on sudden shut-off is the source of the surge pressure.

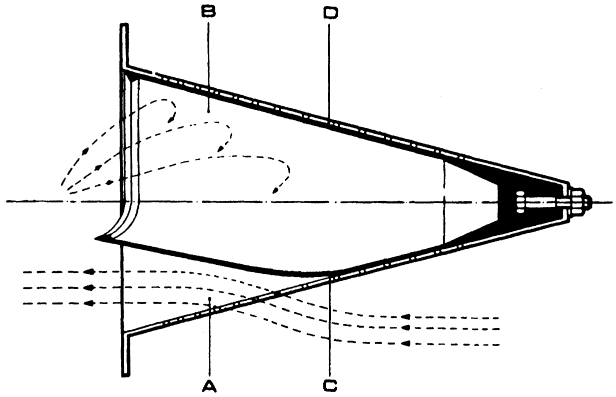

Figure 4-12. Diaphragm Check Valve with Cone-Shaped Diaphragm. (*Courtesy of Northvale Engineering.*)

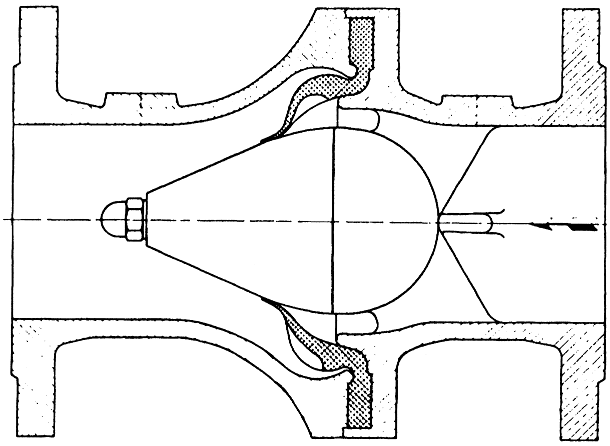

Figure 4-13. Diaphragm Check Valve with Ring-Shaped Pleated Diaphragm. (*Courtesy of VAG-Armaturen GmbH.*)

However, the speed with which forward flow retards can vary greatly between fluid systems. If, for example, the fluid system incorporates a number of pumps in parallel and one fails suddenly, the check valve at the outlet of the pump that failed must close almost instantaneously. On the other hand, if the fluid system contains only one pump that suddenly fails, and if the delivery line is long and the back pressure at the outlet of the

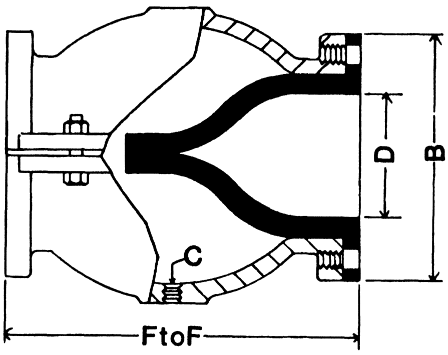

Figure 4-14. Diaphragm Check Valve, Incorporating Flattened Rubber Sleeve Closure Member. (*Courtesy of Red Valve Company Inc.*)

pipe and the pumping elevation are low, a check valve with a slow closing characteristic is satisfactory.

Rapid fluctuating movements of the closure member must be avoided to prevent excessive wear of the moving valve parts, which could result in early failure of the valve. Such movements can be avoided by sizing the valve for a flow velocity that forces the closure member firmly against a stop. If flow pulsates, check valves should be mounted as far away as practical from the source of flow pulsations. Rapid fluctuations of the closure member may also be caused by violent flow disturbances. When this situation exists, the valve should be located at a point where flow disturbances are at a minimum.

The first step in the selection of check valves, therefore, is to recognize the conditions under which the valve operates.

Assessment of Check Valves for Fast Closing[43]

In most practical applications, check valves can be assessed only qualitatively for fast closing speed. The following criteria may serve as a guide:

1. Travel of the closure member from the fully open to the closed position should be as short as possible. Thus, from the point of speed of closing, a smaller valve is potentially faster closing than a larger valve of otherwise the same design.

2. The inertia of the closure member should be as low as possible, but the closing force should be appropriately high to ensure maximum response to declining forward flow. From the point of low inertia, the closure member should be of light construction. To combine lightweight construction with a high closing force, the closing force from the weight of the closure member may have to be augmented by a spring force.
3. Restrictions around the moving closure member that retard the free closing movement of the closure member should be avoided.

Application of Mathematics to the Operation of Check Valves

The application of mathematics to the operation of check valves is of relatively recent origin. Pool, Porwit, and Carlton[40] describe a calculation method for check valves with a hinged disc that involves setting up the equation of motion for the disc and applying to that the deceleration characteristic of the flowing fluid within the system. Before the equation of motion for the disc can be written, certain physical constants of the valve must be known. The calculation determines the reverse flow velocity at the instant of sudden shut-off. The surge pressure due to the sudden shut-off of the reverse flow can then be calculated as described in Chapter 2.

It is important for the valve user to know that valve manufacturers can use mathematics in designing check valves for given critical applications and predicting surge pressure.

DESIGN OF CHECK VALVES

Lift Check Valves

The check valves shown in Figure 4-1 through Figure 4-7 represent a cross section of the family of lift check valves.

Lift check valves have an advantage over most other types of check valves in that they need only a relatively short lift to obtain full valve opening. This lift is a minimum in lift check valves in which the flow passage at the seat is ring-shaped, as in the valves shown in Figure 4-4 and Figure 4-6. Lift check valves are, therefore, potentially fast closing.

In the majority of lift check valves, the closure member moves in a guide to ensure that the seatings mate on closing. However, such guiding also has a disadvantage in that dirt entering the guide can hang up the closure member, and viscous liquids will cause lazy valve operation or even cause the closure member to hang up. These types of lift check valves are therefore suitable for low viscosity fluids only, which are essentially free of solids. Some designs overcome this disadvantage, as in the valve shown in Figure 4-5, in which the closure member is ball-shaped and allowed to travel without being closely guided. When the valve closes, the ball-shaped closure member rolls into the seat to achieve the required alignment of the seatings.

The check valve shown in Figure 4-2 is specifically designed for applications in which a low surge pressure is critical. This is achieved in two ways, first, by providing the closure member with a conical extension that progressively throttles the flow as the valve closes, and second, by combining the closure member with a dashpot that comes into play in the last closing moments. A spring to assist closing of the valve has been purposely omitted, as breakage of the spring was considered a hazard for the service for which the valve is intended.

The check valve shown in Figure 4-6 is designed for gas service only. Depending on flow conditions, the valve may serve either as a constant-flow check valve in which the valve remains fully open in service irrespective of minor flow fluctuations, or as a pulsating-flow check valve in which the valve opens and closes with each pulse of the flowing gas.

Constant-flow check valves are used after centrifugal, lobe-type, and screw compressors, or after reciprocating compressors if the flow pulsations are low enough not to cause plate flutter. Pulsating-flow check valves are used after reciprocating compressors if the flow pulsations cause the valve to open and close with each pulsation. The valves are designed on the same principles as compressor valves and, therefore, are capable of withstanding the repeated impacts between the seatings. The manufacturer will advise whether a constant-flow or pulsating-flow check valve may be used for a given application.

The valves owe their operational characteristics to their design principle, based on minimum valve lift in conjunction with multiple ring-shaped seat orifices, low inertia of the plate-like closure member, frictionless guiding of the closure member, and the selection of a spring that is appropriate for the operating conditions.

The valve shown in Figure 4-7 is a combined lift check and stop valve. The valve resembles an oblique pattern globe valve in which the closure member is disconnected from the stem. When the stem is raised, the valve acts as a lift check valve. When the valve is lowered and firmly pressed against the closure member, the valve acts as a stop valve.

Lift check valves must be mounted in a position in which the weight of the closure member acts in the closing direction. Exceptions are some spring-loaded low-lift check valves in which the spring force is the predominant closing force. For this reason, the valves shown in Figure 4-1 and Figure 4-5 may be mounted in the horizontal flow position only, while the valve shown in Figure 4-2 may be mounted in the vertical upflow position only. The valves shown in Figure 4-3, Figure 4-4, and Figure 4-7 may be mounted in the horizontal and vertical upflow positions, while the valve shown in Figure 4-6 may be mounted in any flow position, including vertical downflow.

Swing Check Valves

Conventional swing check valves are provided with a disc-like closure member that swings about a hinge outside the seat, as in the valves shown in Figure 4-8 and Figure 4-9. Travel of the disc from the fully open to the closed position is greater than in most lift check valves. On the other hand, dirt and viscous fluids cannot easily hinder the rotation of the disc around the hinge. In the valve shown in Figure 4-9, the closure member is an integral part of the rubber gasket between the valve body halves. It is steel-reinforced, and opens and closes by bending a rubber strip connecting the closure member and the gasket.

As the size of swing check valves increases, weight and travel of the disc eventually become excessive for satisfactory valve operation. For this reason, swing check valves larger than about DN600 (NPS 24) are frequently designed as multi-disc swing check valves, and have a number of conventional swing discs mounted on a multi-seat diaphragm across the flow passage in the valve.

Swing check valves should be mounted in the horizontal position, but may also be mounted in the vertical position, provided the disc is prevented from reaching the stalling position. In the latter case, however, the closing moment of the disc, due to its weight, is very small in the fully open position, so the valve will tend to close late. To overcome slow response to retarding flow, the disc may be provided with a lever-mounted weight or spring loaded.

The check valve shown in Figure 4-10 is a double-disc swing check valve with two spring-loaded D-shaped discs mounted on a rib across the valve bore. This design reduces the length of the path along which the center of gravity of the disc travels; it also reduces the weight of such a disc by about 50%, compared with single-disc swing check valves of the same size. Coupled with spring loading, the response of the valve to retarding flow is therefore very fast.

Tilting-Disc Check Valves

Tilting-disc check valves such as the one shown in Figure 4-11 have a disc-like closure member that rotates about a pivot point between the center and edge of the disc and is offset from the plane of the seat. The disc drops thereby into the seat on closing, and lifts out of the seat on opening. Because the center of gravity of the disc halves describes only a short path between the fully open and the closed positions, tilting-disc check valves are potentially fast closing. This particular valve is, in addition, spring-loaded to ensure quick response to retarding forward flow.

Reference may be made also to the valve shown in Figure 3-77 that can serve as a butterfly valve, a tilting-disc check valve, or a combined tilting-disc check and stop valve, depending on the design of the drive.

Tilting-disc check valves have the disadvantage of being more expensive and also more difficult to repair than swing check valves. The use of tilting-disc check valves is therefore normally restricted to applications that cannot be met by swing check valves.

Diaphragm Check Valves

Diaphragm check valves such as those shown in Figure 4-12 through Figure 4-15 are not as well-known as other check valves, but they deserve attention.

The check valve shown in Figure 4-12 consists of a perforated cone-shaped basket that supports a matching diaphragm. This assembly is mounted in the pipeline between two flanges or clamped between pipe unions. Flow passing through the cone lifts the diaphragm off its seat and lets the fluid pass. When forward flow ceases, the diaphragm regains its original shape and closure is fast. One application worth mentioning is

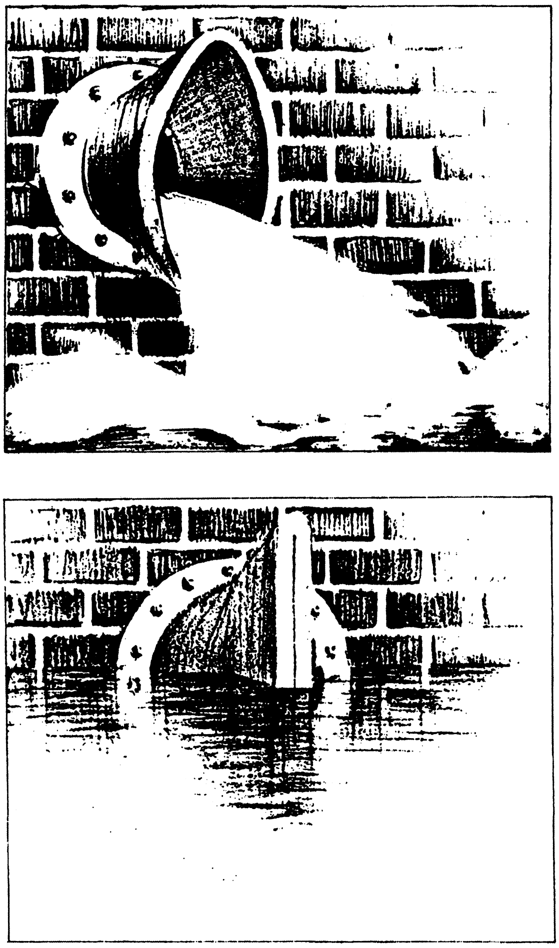

Figure 4-15. Diaphragm Check Valve Incorporating Flattened Rubber Sleeve Closure Member, Used as Tide Gate. (*Courtesy of Red Valve Company, Inc.*)

in purge-gas lines, which feed into lines, handling slurry or gluey substances. Under these conditions, diaphragm valves tend to operate with great reliability, while other valves hang up very quickly.

The check valve shown in Figure 4-13 uses a closure member in the form of a pleated annular rubber diaphragm. When the valve is closed, a lip of the diaphragm rests with the pleats closed against a core in the flow passage. Forward flow opens the pleats, and the lip retracts from the seat. Because the diaphragm is elastically strained in the open position, and travel of the lip from the fully open to the closed position is short, the diaphragm check valve closes extremely fast. This valve is well-suited for applications in which the flow varies within wide limits. However, the pressure differential for which the valve may be used is limited to 10 bar (145 lb/in^2), and the operating temperature is limited to about 74°C (158°F).

The closure member of the diaphragm check valve shown in Figure 4-14 consists of a flexible sleeve that is flattened at one end. The flattened end of the sleeve opens on forward flow and recloses against reverse flow.

The sleeve is made in a large variety of elastomers, and is externally reinforced with plies of nylon fabric similar in construction to an automobile tire. The inside of the sleeve is soft and capable of embedding trapped solids. The valve is therefore particularly suitable for services in which the fluid carries solids in suspension or consists of a slurry.

Figure 4-15 shows an interesting application of this check valve as a tidal gate.

The valve is available in sizes as small as DN 3 (NPS 1/8) and as large as DN 3000 (NPS 120) for tidal gates.

Dashpots

The purpose of dashpots is to dampen the movement of the closure member.

The most important application of dashpots is in systems in which flow reverses very fast. If the check valve is unable to close fast enough to prevent a substantial reverse-flow buildup before sudden closure, a dashpot, designed to come into play during the last closing movements, can considerably reduce the formation of surge pressure.

SELECTION OF CHECK VALVES

Most check valves are selected qualitatively by comparing the required closing speed with the closing characteristic of the valve. This selection method leads to good results in the majority of applications. However, sizing is also a critical component of valve selection, as discussed in the following. If the application is critical, a reputable manufacturer should be consulted.

Check Valves for incompressible Fluids

These are selected primarily for their ability to close without introducing an unacceptably high surge pressure due to the sudden shut-off of reverse flow. Selecting these for a low pressure drop across the valve is normally only a secondary consideration.

The first step is qualitative assessment of the required closing speed for the check valve. Examples of how to assess the required closing speed in pumping installations are given in Chapter 2, page 41.

The second step is the selection of the type of check valve likely to meet the required closing speed, as deduced from page 151.

Check Valves for Compressible Fluids

Check valves for compressible fluids may be selected on a basis similar to that described for incompressible fluids. However, valve flutter can be a problem for high lift check valves in gas service, and the addition of a dashpot may be required.

Where rapidly fluctuating gas flow is encountered, compressor-type check valves such as that shown in Figure 4-6 are a good choice.

Standards Pertaining to Check Valves

Appendix C provides a list of USA and British standards pertaining to check valves.