Valves – and the viable alternatives to asbestos

Vinod C Bhasin: "a good substitute for asbestos did not exist"

Asbestos used to be cheap and effective in hazardous situations – now valve designers are turning to new designs and first-class monitoring systems for safety's sake.

Over the past decade, there have been significant and exciting developments in industrial valving requirements in: hazardous materials involving asbestos valve packings and flange gaskets; valve operability in fire-hazard locations; and advance diagnostics of valve/actuator problems in order to avoid costly plant shutdowns. Though valve and actuator manufacturers trumpet significant breakthroughs in these areas, the users need to know exactly what to expect so that they can seriously consider specifying special features where they provide the most value.

Non-asbestos Sustitutes

Asbestos has been the unchallenged material (and still is) for valve stem packing and gasketing applications involving high temperatures (above 500°F) for the last 50 years or so. Its excellent sealing ability combined with an extremely low cost, relative chemical inertness, and ability to resist extrusion under extremely high valve stuffing box bolt loads, particularly at high temperatures, went unmatched. Only in the last decade, when the environmental health hazards associated with mining, processing, fabrication and user handling of asbestos were publicised, did engineers realise that a good substitute for asbestos did not exist.

Many experiments with natural and synthetic materials have been tried and the initial results seem promising. However, each of these new alternatives has its own limitations and each must be evaluated separately for specific applications.

Pure asbestos with an Inconel[R] wire insert around a resilient asbestos core, and impregnated with graphite, has been the choice for valve stem packing in temperatures up to 1200°F and pressures up to 2000 psi. The almost chemically inert (better than asbestos) and modestly expensive TFE-filled, braided TFE yarn packing has performed extremely well in most chemical applications requiring pressures up to 2500 psi and temperatures up to 500°F. For temperatures approaching those acceptable with asbestos, packing manufacturers have been supplying carbon and graphite based packings in woven square shapes with or without Inconel[R] wire inserts.

They are now experimenting with other graphite shapes such as 'chevron', 'sootblower', and 'wedge' in an attempt to reduce mechanical packing stress (gland pressure). Tests conducted jointly by Foster-Miller Inc and A W Chesterton Company on the three new shapes have resulted in sealing at much lower gland pressures. The wedge-shaped graphite rings, sandwiched between two braided graphite rings, provide superior performance with a minimum need for periodic stuffing box adjustment.

Graphite packing rings offer all the desired properties of an ideal packing: chemical inertness, high resilience, reduced stuffing box height, rapid heat dissipation (necessary for temperature cycling of the line medium), self-lubrication with a much lower coefficient of friction than asbestos, resistance to caking, shrinking, or hardening, and the ability to withstand nuclear radiation (desirable for nuclear plants).

There is, however, one serious drawback to using graphite rings. Since they are extremely pliable, they tend to extrude from the stuffing box at high packing loads. To overcome this deficiency, the most common packing arrangement consists of three extremely pliable rings made by die-forming graphite ribbon tape, which are sandwiched between a set of rings made of braided, extremely strong carbon fibres. The carbon fibre rings have been very effective in preventing extrusion even under extreme valve cycling at high packing loads.

In addition to a very high price, usually three to four times that of asbestos, the graphite rings have two other shortcomings. The first is that, unlike asbestos rings, these rings can not be split easily; the rings can not be replaced in the field without removing the actuator or the valve handle assembly. Furthermore, there are problems with the galvanic corrosion of the valve stem in contact with the graphite rings. Stainless steel (especially the 400 series) stem pits even after a period as short as six months. This pitting not only starts a leak but also makes replacing the stem an expensive necessity.

To alleviate this problem, the packing manufacturers have been coating the graphite rings with a dusting of zinc or supplying companion zinc rings so that the zinc will act as a sacrificial material. However, it is only a guess as to how long it will take for the zinc to corrode or be consumed by the line medium.

Other passive corrosion inhibitive coatings, such as barium molybdate or phosphorous have also been tried but they have a finite life before they start leaching out of the packing. Other alternatives would be to use nobler stem materials or electroless nickel plating of the stem to inhibit stem corrosion.

Compression sheet gaskets (as well as spiral wound gaskets involving high pressure and high temperatures), made from both natural and synthetic materials, have been tried successfully and are now available as substitutes for asbestos gaskets. One problem with the sheet gaskets is that they cannot be readily substituted in every application where asbestos is specified. The

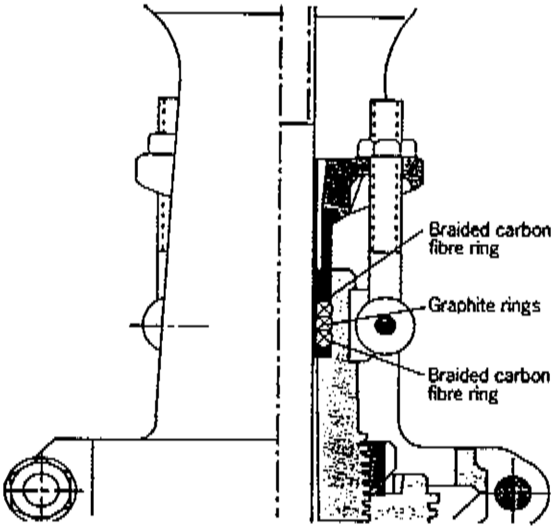


Figure 1: typical high-temperature valve packing

chemical inertness of these synthetic gasket materials may vary from one line medium to another. And the flange bolt loads required to seal these gaskets may vary considerably from one application to another.

To achieve a satisfactory flange seal, three conditions must be met. Firstly, regardless of the line operating pressure, the flange gasket must be squeezed sufficiently to make the gasket material flow into the tiny surface imperfections of the mating flanges to initiate a gasket seal. Thus, flange bolts must exert enough load (Wm_2) to squeeze the gasket. Secondly, a sufficient residual gasket stress must be maintained to ensure that the gasket will not separate from the flange sealing surfaces under operating line pressure, and the flange bolts must be stressed accordingly in order to maintain a suitable load on the gasket (Wm_1). And finally, the gasket material must be capable of withstanding the compressive loads of these first two conditions.

The ASME Unified Pressure Vessel Code, Section VIII, Division I, establishes the minimum gasket load using the following formulae (*Figure 2*):

$$Wm_2 = 3.14bGy, \text{ and}$$
$$Wm_1 = (3.14/4)G^2p + 2b\,(3.14)\,GPm,$$

where b is the effective sealing gasket width, P the design pressure, and G the diameter at location of gasket load reaction. Both the m and y factors vary considerably with the gasket material, thickness, and construction; and the sealing medium (liquid or gas). The flange bolts must be stressed to generate a load which is greater than both Wm_1 or Wm_2.

From the above formulae, it can be seen that the flange bolt loads could vary dramatically with each application for various gasket materials and thicknesses. For example, for a 1/8-inch thick gasket involving liquid applications, the y factor for a compressed synthetic gasket could be as much as three times that of an asbestos gasket, while the m factor could be half as much. This would triple the value of Wm_2, but may not substantially lower Wm_1. With synthetic gaskets, under most situations, a substantial increase in flange bolt load would occur, and thus could necessitate high strength flange bolting.

The last consideration is that the synthetic gasket material may itself not be strong enough to resist increased flange bolt loads. Synthetic and asbestos gasket materials are somewhat comparable in strength at room temperature, but synthetics loose their strength rapidly at temperatures above 700°F.

Fortunately, most chemical plant applications involve either a low temperature at high pressure or a high temperature at low pressure, and many synthetic compression gaskets would seal nicely. For applications involving both high temperatures and high pressures, stainless steel spiral wound gaskets filled with graphite laminations provide a reliable alternative. They are rather expensive, however, and spiral wound gaskets of alternative synthetic materials are being studied.

Fire-safe Valves & Actuators

Every chemical engineer dreams of being able to specify critical piping components in fire-hazardous locations, and having them perform flawlesly if fire starts in a chemical plant! Well, the manufacturers of industrial valves and actuators claim they offer fire-safe valves and actuators (there are at least two dozen such manufacturers in the US alone) to meet such demanding applications. The word 'fire-safe' was coined to classify speciality valves which would not only be leaktight during normal operating temperatures, but also during and after the valve being subjected to a fire. Similarly, the fire-safe actuators would remain operational under such conditions.

Practically speaking, a fire-safe valve should seal bubbletight at its normal operating temperature but allow a small amount

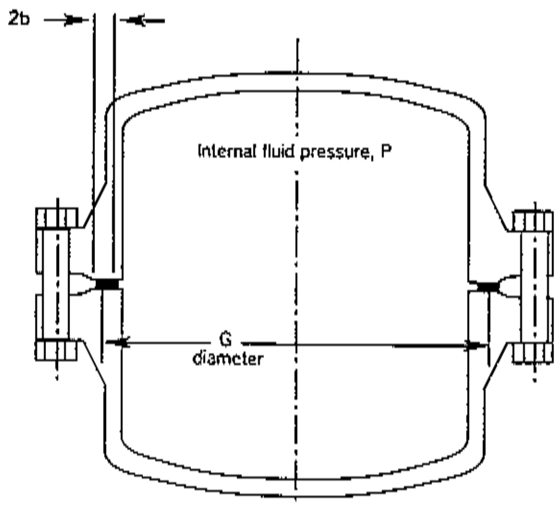


Figure 2: typical gasket installation

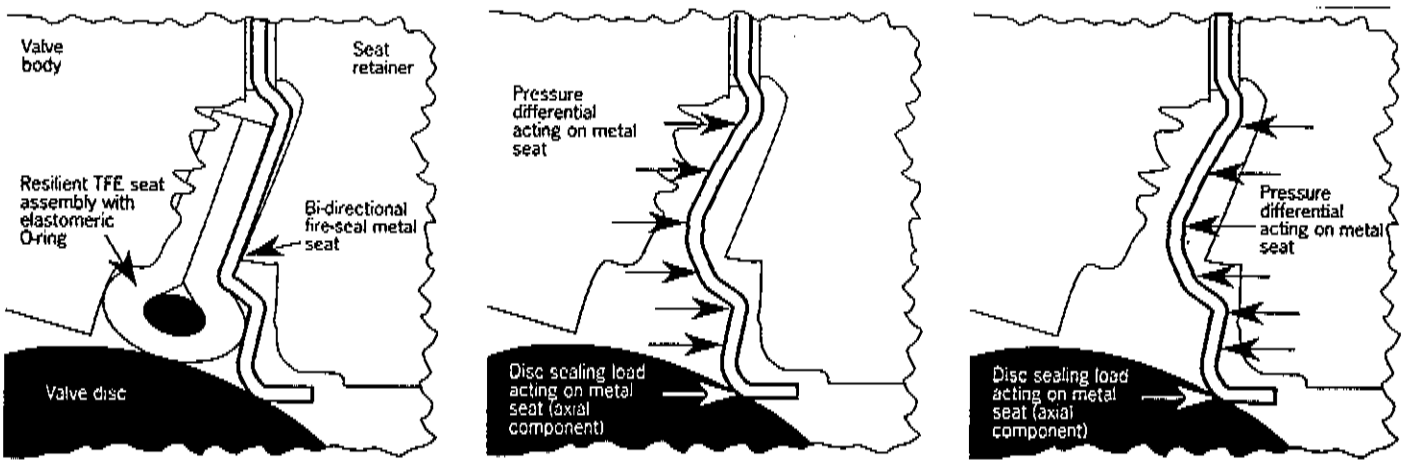


Figure 3: The typical McCannaseal Fire-Seal bidirectional fire seat assembly provides seal with seat retainer upstream and downstream

of internal and external leak when subjected to a fire. This small amount of leak should be sufficient to contain the fire and not feed it.

The term fire-safe, as applied to actuators, is somewhat ambiguous. It may mean one of two things. When subjected to a fire, the actuator may be able to open or close a valve without power; or, upon demand, it should be capable of providing a few cycles of manual valve actuations even after a fire.

There is no single, universally accepted definition of fire-safe valves. Typically, valves judged as fire-safe are subjected to fire tests prescribed by various industrial societies (such as BS, API, Exxon, Factory Mutual, and UL). The choice of a particular fire test usually rests with the valve manufacturer (sometimes the valve user may dictate the test if he is sufficiently knowledgeable).

The fire tests vary greatly among the societies in features such as stem position (open or closed), test medium (water or kerosene), burn duration, heat flux input, and acceptable leak rates (internal or external). For this reason, a particular fire-safe valve design may pass one test yet fail another. It should be noted, however, that although there are significant differences between the fire tests, all of them are used to predict valve behaviour when subjected to extremely high temperatures.

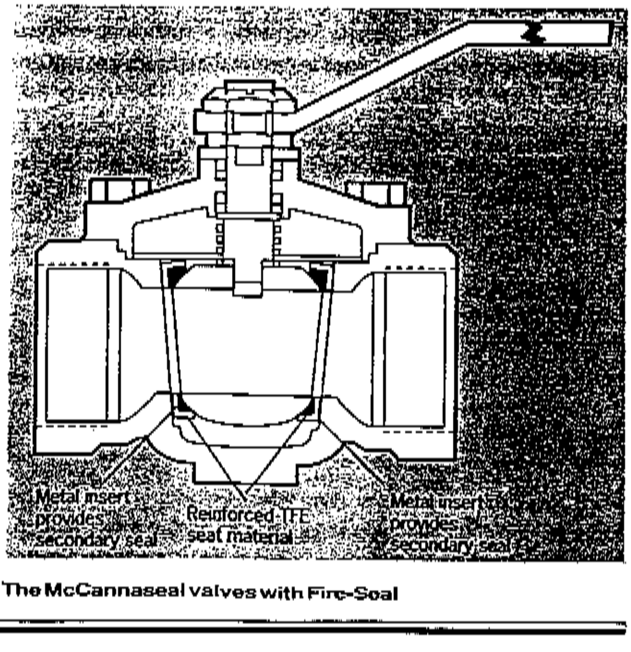
Because a fire-safe valve must shut off bubbletight during normal service temperature (usually below 400°F), and yet provide extremely low leak at elevated temperatures encountered in a fire, it must employ two separate seats in parallel (see *Figure 3*). The primary plastic seat (usually TFE or Delrin) provides a bubbletight shut-off before a fire, and the secondary metal seat (usually stainless steel or Inconel[R]) permits a small amount of leak at elevated temperatures, when the primary seat is destroyed in a fire.

Almost all fire-safe valves on the market today are of quarter-turn design such as ball and butterfly valves. Two distinct designs for the secondary metal seat exist, each with its own desirable and undesirable features.

The first design employs a metal secondary seat which, along with the primary plastic seat, is in constant contact with a hard-coated (usually electroless nickel or chromium plated) valve closure member (ball or disc). The metal seat will contain the through-seat leak to an acceptable limit during and after a fire.

This design requires a large valve-operating torque since the actuator must overcome the frictional torques caused by both seats. Moreover, this design tends to have a low valve cycle-life since the constant rubbing of the metal seat with the valve closing member (contact between the metal seat and the valve closure member is not required during pre-fire operation since the plastic seat will seal) tends to scratch or could even badly gall the hard coatings on the seating surfaces. Once the closure member is scratched, it cuts into the primary plastic seat, starting a leak path. For this reason, this design is suitable when the valve does not need frequent cycling.

The second design is similar to the first design except that its secondary seat does not contact the valve closure member during its normal operational life. Only when the valve is subjected to a fire, and only when the primary seat is destroyed, does the



The McCannaseal valves with Fire-Seal

secondary seat contact the valve closure member.

Obviously, this design would overcome the drawbacks of the first design, but it suffers from its own major drawback. It usually requires an almost complete destruction of the primary plastic seat (Exxon fire-test mandates the plastic seat to be completely destroyed during the fire test) before the secondary metal seat will provide a full 360-degree contact with the valve closure member. This can result in an unacceptably large leak during and after a fire. In the real world, a fire may actually last only a short time, and it is highly unlikely that the plastic seat will be completely destroyed.

There are some other factors that must be considered when fire-safe valves are specified. Fire-safe valves are very sensitive to machining tolerances. Unlike the extremely flexible plastic seat, the secondary metal seat and its location in the valve body must meet rigorous tolerances. The actuator and the valve/actuator interface must provide very accurate positioning of the primary and secondary seats on the valve closure member. The two seats share a narrow band of space on the valve closure member; a slight misalignment of the stem position may be enough to loosen contact between the metal seat and the valve closure member. In addition, most fire-safe butterfly valves demand significantly high operating torques (up to two to three times the torque of non-fire safe valves) and they may not seal bi-directionally during and after a fire.

Although a number of standards have been written to test fire-safe valves, none exist to test the actuators mounted on these valves. Standard actuators mounted on today's fire-safe valves will not operate because their designs and materials of construction will not function properly under high temperatures.

Because of this, actuator manufacturers have recently introduced fire-resistant actuators. These actuators have steel internals and housing (as opposed to bronze, cast iron, and aluminium) and special high temperature seals, metallic bearings, and lubricants which would remain functional when subjected to fire temperatures. Additionally, the housings may be either encapsulated in a fire-box or thermal blanket, or even be coated with thick intumescent epoxy material which, when exposed to fire, swells to form an insulating char under a glazed surface. Some actuators also have a fail-safe mechanism which consists of a compression spring and a fusible link between the valve/actuator interface. When the fusible link melts during fire temperatures, the valve is actuated when the energy stored in the spring (during the previous actuator stroke) is released.

Just imagine how many things can go wrong in automated valves including jamming of the valve disk from seat wear and variations in system pressure and temperature, stem binding in bearing, bent stem caused by excessive actuator torque output, and packing freeze-up due to misadjusted stem packing or to drying of packing lubrication. The electric actuator failures could be due to misadjustment, calibration, or mechanical damage to torque switch and limit switch, shorted or open circuit electric motor, misadjustment/damage to declutch tripper assembly, ageing or failure of spring pack, drying of lubricant, or a worn stem nut. The electric motor output, which normally runs at high speeds, must be slowed significantly by large gear reductions to magnify its torque output. This also results in magnification of the rotational inertia of the motor assembly which could potentially damage the valve disk/seat when the valve disk strikes the seat in a gate or globe valve. The pneumatic actuators fail due to similar problems plus wear of pneumatic components such as piston seals, diaphragms, o-rings and other pipe fittings where a loss of air power could result from both internal as well as external leaks.

Monitoring Valves & Actuators

Would you like to know, well ahead of time, when a particular critical valve or its actuator might fail and need maintenance? Not only would this knowledge prevent unexpected costly plant shutdowns, but it would make preventative repair much easier.

Well, help is on the way. There are now at least half a dozen US companies (including Westinghouse/Movats Inc; Liberty Technology Center Inc; Fisher Controls International Inc; ABB Combustion Engineering; and Foster-Miller Inc) offering performance and diagnostic systems which, when installed on valves and actuators [rising stem as well as rotary motor operated valves (MOVs) and air operated valves (AOVs)], provide an inside look at the otherwise invisible valve and actuator internals.

Non-intrusive equipment mounted on a valve/actuator assembly (most often no dismantling of valve or actuator is required), provides the pulse or the 'signatures' of the valve and its actuator in real time. The signatures consist of sets of key operating parameters plotted against either the valve stem position or real time. Valve monitoring systems for both remote on-line and portable diagnostics are available, with each system employing a rational data base to store valve specification and test data.

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There are several methods employed to collect the stem thrust or torque data. In each method, linear, diametric or torsional distortion in the stem under load is measured by strain guages mounted either directly on the valve stem or on the valve yoke (the stem forces are mirrored in an equal and opposite manner in the yoke). Since strain is directly proportional to the applied stress or the load, the computer then converts the strain into stem load. Load cells are also available which will measure the stem loads such as: C-clamp, capacitance type stem-load sensors which measure the barrelling of the stem under load or the load cells which are attached at the valve yoke to actuator interface. Monitoring test data on swing-check-valves which are totally enclosed, is proving much harder than expected since there is no external operator to indicate their internal position or disk movement. Diagnosis using the valve acoustic emission signals is under way with some degree of success.

Considered experimental and often unreliable only a few years ago, these systems are now becoming standard in nuclear power plants where loss of a critical valve or its mating actuator can threaten the safety of plant personnel in addition to causing extensive damage to equipment. Although still considered very expensive (could be at $100,000 plus), valve monitoring systems have recently been given a big push by the US Nuclear Regulatory Commission (NRC) in letter 89–10, which mandates regular testing of all safety related MOVs by the electric utilities. As such, manufacturers of monitoring systems have started honing their equipment.

Automated gate valves are the most common valves currently being monitored, with globe, butterfly, check, and safety relief valves being the next in line. The latest monitoring systems are microprocessor-based diagnostic systems in which a number of desired signals are constantly being monitored and compared with predetermined setpoints as the valve is stroked from the full open to full closed positions or vice versa. Sensors typically monitor and evaluate actuator signatures (motor current, voltage, motor load, actuator stem position) and valve signatures (valve stem position, seating loads, valve packing load, valve bearing load, through-seat leak and many more desired readings), and provide control decisions based on these evaluations.

The microprocessor-based software continually checks for abnormalities (known as signature analysis) in certain important parameters such as disk position, stem thrust, and actuator output torque. When a particular abnormality (a particular setpoint has been reached or is about to be reached) is detected, the programmed software alerts a plant operator. The methods employed in sensing key operating parameters accurately and inexpensively, and the computer software used to automatically extract pertinent information which will provide reliable warnings with the least false alarms are of paramount concern. In the not so very distant future, as more hands-on experience is gained from the nuclear power industry, and as the cost of monitoring drops, these systems are bound to find their way into chemical plants. ●

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