ARTICLE REPRINT

Inflatable Seat Valves

by Michael F. Crawley
Macawber Engineering
Maryville, Tennessee

Published in:
Powder Handling & Processing
June 1993

SUMMARY
Inflatable seat valve design overcomes longstanding deficiencies in traditional valve design. Particle entrapment at the seat minimzes wear and the inflatable seal automatically compensates for the accumulative wear that occurs. Consequently, 1,000,000 cycles between inspections can be obtained in approved applications. Where abrasive materials need to be conveyed reliably and pressure differentials are crucial to performance, Macawber's Dome Valve® have proven to perform where tradi-tonal valve designs fail.

Inflatable Seat Valves

DOME VALVE

Macawber Engineering, Incorporated

Maryville, Tennessee USA

Reprinted from **powder handling & processing**

Michael F. Crawley, *Chief Executive of Dome Valve Company, presents a new concept in valve design for operating reliability.*

The Dome Valve's® unique seat sealing method heralds a new concept in valve design. A flexible, inflatable seat which is designed to entrap particles at the seat completely overcomes the main source of the valve seat wear.

The valve was designed and patented in the late '70's, and since then has seen diverse application in many industries with a present day valve installation population of some 7,000 valves. In recent time, the valve has been applied to retrofit and to new system designs in the chemical processing industry where conventional valve designs have not met operational or reliability requirements.

The unique inflatable sealing action has been developed to satisfy applications in which

a) Abrasive materials such as sand, coke breeze and ground glass can be handled without coat wear.

Pressure differentials with abrasive materials in fluid media may be sealed with up to 18 bar pressure differential and with full vacuum service.

c) Perform upon applications with media temperatures up to 660°F.

d) Perform in applications comprising combinations of the above conditions.

In addition, in most applications, the valve may close and seal through a static column of powder or granular material in one action.

The paper describes the valve design and its performance in a wide range of duties, and sets out to challenge the concepts of future valve designs utilizing the innovative principle of inflatable valve seats.

Introduction

This paper describes a unique valve concept which has been proven to demonstrate remarkable characteristics of reliability and wear resistance operating with abrasive bulk materials and pressure differentials.

The device, known as the Dome Valve® was developed in the 70's and registered at the United States patent office. It incorporates a unique seat sealing method. The valve seat is a flexible and inflatable heavy membrane which is designed to entrap particles at the seat, to prevent their movement under the influence of a pressure differential, and therefore overcome the main cause of wear in valves handling bulk materials or dirty gases containing particulate.

Although the valve introduces a new concept in seat sealing technique, it has been widely applied in many industries. The manufacturer claims 7,000 installations throughout the world since its introduction to North America in 1978 in diverse applications such as controlling filling of pressure vessels with hot bottom ash at 1200°F and supporting a pressure differential of 6 bar, to controlling filling of a pressure/vacuum chamber with magnesium powder.

Many applications of the Dome Valve® are in retrofit situations where conventional valves have failed to provide reliable operation in pressure differential applications. This is typical of situations in which closing member design or seat design allows particulate movement across the seat face to cause accelerated wear. This is a situation common to conventional valves applied beyond their application ability normally for reasons of *first cost* economy.

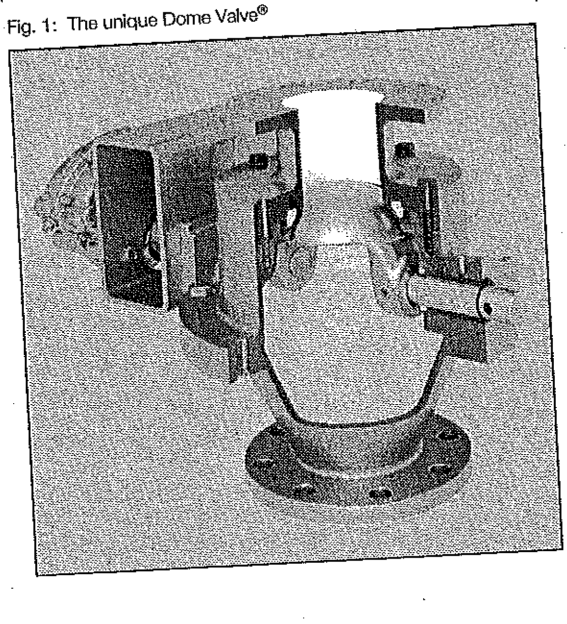
Valve Design Objectives

The valve was designed to achieve two main objectives:

a) To provide minimal or no seat wear when handling abrasive bulk materials, and a closing action to support a pressure differential.

b) To provide a closing and sealing action in one motion through a static or moving column of bulk materials.

Fig. 1: The unique Dome Valve®



Subsequent development of the valve allowed additional objectives to be achieved which were:

c) Achieve the above objectives when operating in applications at a constant temperature of 660°F.

d) Achieve the above objectives when operating with both pressure and vacuum differentials in the same operating cycle.

e) Provide a snap-open characteristic to the closing member of the valve for high gas pressure exhaust applications.

f) Flow regulation with auto-positioning capability in addition to flow stop requirements.

Additional design objectives relating to valve performance and practical considerations were incorporated:

g) Unrestricted flow through the valve when in the open position.

h) Easy inspection and maintenance.

i) Open choice of valve operators for any valve application.

j) Wide range of construction materials for media compatibility.

k) Wide range of seal membrane materials for media compatibility.

l) Very low maintenance costs. The main components of the valve, i.e., dome, casing, top plate, do not require replacement or repair for several years. The inflatable seal is often only replaced once per year, or every two years, and is a low cost item.

The history of valve design objectives implemented by the manufacturer was influenced by the initial application duty of the Dome Valve®.

During its first years of introduction, the Dome Valve® was exclusively applied to high pressure pneumatic conveying systems in which the majority of materials handled were abrasive,such as coke breeze, lump coal or sand, and in which pressure differentials were up to 7 bar. Recently the valve began to see application opportunities within the general valve market where the evident superior ability of the sealing technique became noticed.

General applications in the chemical processing industry has subsequently caused the latter design objectives to be adopted with consequent strengthening of application capability.

powder handling & processing Volume 5, No. 2, June 1993

Valve Design

The valve design is a masterpiece of simplicity. The closing member is a segment of a sphere (dome) with extended arms mounted to shafts (see Fig. 2). The shaft is driven 90° by an actuator which allows the crank-mounted dome to rotate entirely away from the inlet port of the valve body. Passage through the valve is therefore totally unobstructed.

In the closed position, the dome sits concentrically beneath the inlet port beneath which the inflatable seal assembly is positioned. The inflatable seal, which is a complete ring of an elastomer or rubber approximately 3/4" to 1" wide, covers the periphery of the dome. A controlled gap of about 1 mm between the face of the dome and the face of the inflatable seal (seat) allows the dome to rotate into and away from the closed position. Particles from the media entering the valve are allowed to pass or remain between the seal and the surface of the dome.

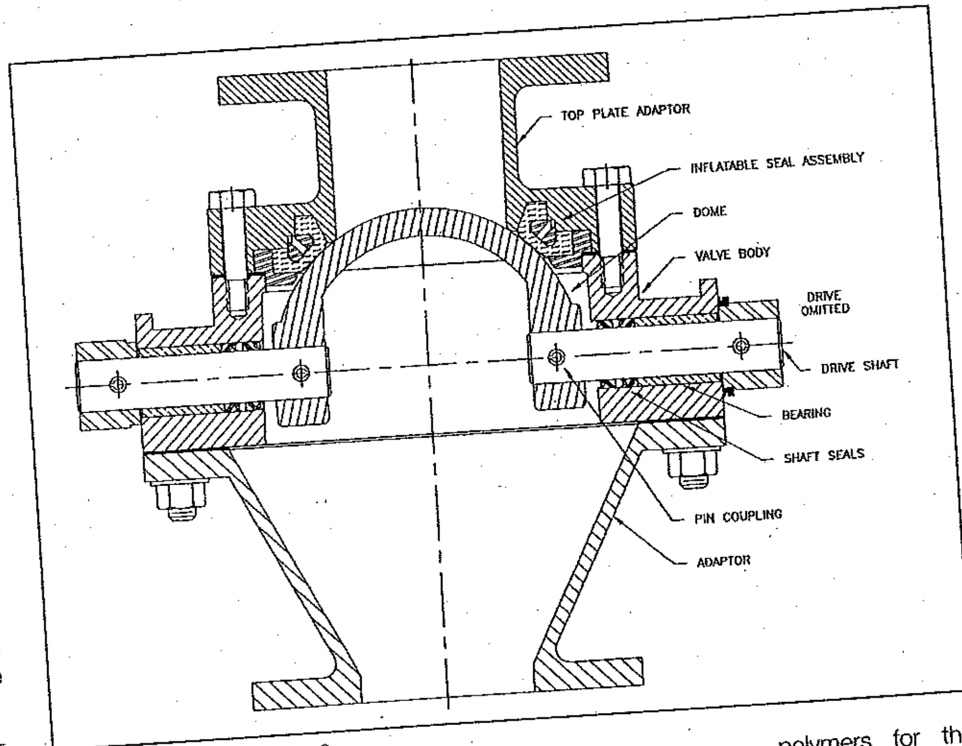


Fig. 2: 4' inline PHO Dome Valve®

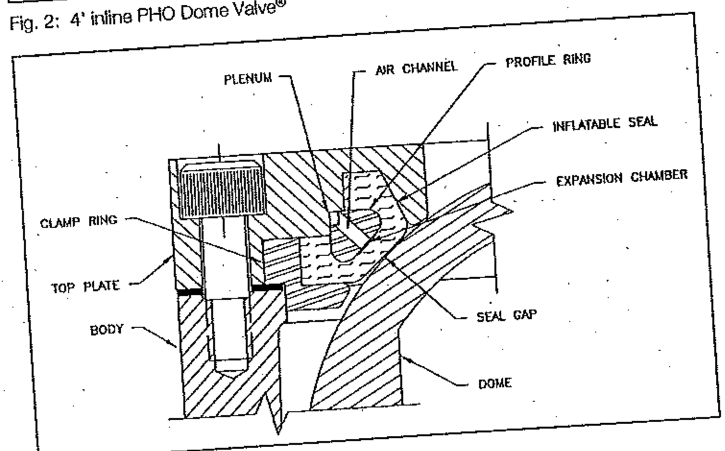


Fig. 3: Inflatable seal assembly of a Dome Valve®

Closing the Dome Valve® automatically sequences the seal to inflate by initiating a limit switch when the dome drive shaft completes a 90° rotation to the closed position. Seal inflation is achieved by introducing compressed air or other gas through a small plenum behind the sealing ring. With sealing air pressures of 25 psi or 20% higher than the pressure differential across the valve closing member are applied, the seal inflates and engages the periphery of the dome component. Small particles that enter the gap between the seal face and the dome surface are entrapped by the expanding face of the rubber seal to prevent their movement and subsequent wear to the seat (see Fig. 3).

This technique of entrapping particles between the seat has been proven to considerably reduce valve seat wear even when performing with the fine abrasive powders such as ground glass and coke breeze.

The pneumatic seal and its operating action provides an additional benefit: As wear does occur on the seal face or the dome component, the expanding seal provides wear compensation automatically until a wear limit is reached. The wear limit is considerably greater than any other valve design.

So confident are the manufacturers of this unusual feature that they provide a 1 million cycle frequency between seal inspections on approved applications.

The pneumatic seal or inflatable seat is a masterpiece of simple mechanical design. The seal component is a continuous ring with a special profile that provides both correct location and effective anchoring. There are no special fasteners or adhesives to complicate the process of assembly or replacement. The seal ring is beneath the top plate of the valve so that when the valve is used in its preferred direction of flow mode, the seal is completely protected from the flow of media through the valve. The manufacturer has developed an impressive array of seal materials utilizing various rubber compounds and elastomers to insure temperature and chemical compatibility with media passing through the valve (Table 1).

One of the most impressive innovations of this remarkable valve is the use of water for cooling purposes in high-temperature application. It was originally regarded by the valve designers to be a disadvantage to require an additional utility to the valve to enable its operation for high temperature duties. However, the choice between exotic materials of construction with experimental polymers for the seal over the addition of cooling channels and additional utility connections was not difficult. Water cooling has proven to be a wise and effective choice enabling a simple, effective and low-cost valve solution for some of the most demanding applications in the industry.

Two temperature zone design steps are offered to insure economic targeting of the product (see Fig. 4). Up to 355°F, the valve is provided with a water-cooling channel around the pneumatic seal area within the top plate. Up to 660°F temperature duty, the addition of a water-cooled dome component is provided. The water is introduced through a water channel in one shaft axis to the supporting leg of the dome, through the dome in which a chamber is provided, and exiting the valve in the same way through the other shaft, an unusual but simple and effective solution. The Dome Valve® is widely used in such high-temperature applications as ash handling for utilities and industrial coal-fired boiler plants, as well as many high-temperature chemical processes.

The simplicity and robustness of the valve and its shaft drive configuration allows any kind and type of valve operator to be applied. This versatility has allowed the valve

Volume 5, No. 2, June 1993 powder handling & processing

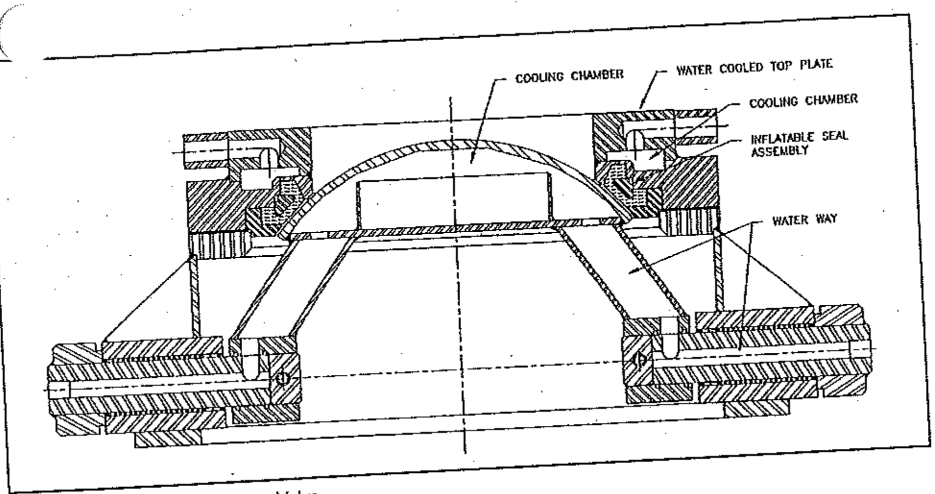


Fig. 4: 16" PH2 bulkhead Dome Valve

to be used in applications to solve special problems such as:

- Flow regulation by positioning the dome closing member as required by modulated signal from down-stream processes, added to the standard function of closing and sealing against substantial pressure differentials.
- Snap-open action to minimize gas velocities through the valve when operating with high-pressure exhaust applications, again added to the standard function of closing and sealing against substantial pressure differentials. This application has been satisfied for high-temperature dust laden gases in which water cooling has been applied to both the valve sealing chamber and the dome component.

The manufacturer has taken an unusual approach to the valve market with their unique design. They have resisted packaging the features into a range of standard specifications with standardized variations in an attempt to seek out a volume market. They have taken the position of valve problem solvers with much of their market arising from retrofit situations and newly-designed applications in which "conventional" valves appear to be inadequate for reasons of temperature duty, abrasive media, or high pressure differential, or all three.

The marketing philosophy appears to have worked well considering a first year sales volume of $1 million in 1992 without any sales promotion, and in a relatively depressed economy. Undoubtedly this good result was somewhat attributed to the vast installation reference list available to the manufacturer before they launched into the semi-special valve market with a new and independent product.

The company offers a comprehensive range of sizes from 2" to 20", with all international connection standards available. The valves are manufactured at a facility possessing an ASME National Board license for pressure vessels. Considering the duty performance of the Dome Valves®, the manufacturing skills for pressure vessels are appropriate for the quality requirement of this new valve.

Application Diversity

The application capability of the basic valve design is unusually wide for many reasons stated earlier which are summarized as follows:

Abrasive Media: Abrasive slurries, bulk powders, granules and dust laden gases cause rapid seat erosion and ineffective closure in conventional valve designs. The inflatable seal and its automatic wear compensation feature appears to overcome the wear problems associated with abrasive media.

Pressure Differential: Also causes accelerated seat wear in conventional valve designs, even though hardened seats may be used. Pressure differential causes untrapped particles in hard seat valves to move across the seat at high velocity which erodes hard seats and commences the wear process. The inflatable seal effectively entraps the particles and prevents particle movement and therefore wear.

Table 1: Seal materials and temperature applications

Abbreviation	Technical Nomenclature	Common Name	Service Temp. °F min	°F max	°C min	°C max
CR	Chloroprene Rubber	Rubber	-65	230	-54	110
NBR	Nitrile Butadiene Rubber	Buna N/Nitrile	-65	240	-54	116
*NR	Natural Rubber	Rubber	-65	180	-54	82
*PGR	Natural Rubber	Pure Gum Rubber	-65	180	-54	82
CIIR	Chloro-Isobutylene Isoprene Rubber	Chlorobutyl	-65	250	-54	120
CSM	Chloro-Sulfonyl Polyethylene	Hypalon™	-65	250	-54	120
EPDM	Ethylene Propylene Diene Monomer	Ethylene Propylene Rubber (Nordel™, Royalene™)	-65	300	-54	149
FPM/ FKM	Fluorocarbon Elastomer	Viton™, Fluorel™	-40	400	-40	204
AFMU	Tetrafluoro-ethylene Resin	Teflon™	-120	450	-85	232
SI	Dimethyl Polysiloxane	Silicon	-160	500	-107	260

Table 2: Comparison with conventional valves and the Dome Valve for applications ability and general performance

	Butterfly Valve	Cone Valve	Knife Gate	Vee Ball	Ball Valve	Dome Valve
Close and seal through static head of bulk materials	No	No	No	No	No	Yes
Support pressure differential up to 1 bar	Yes	Yes	No	Yes	Yes	Yes
Support pressure differential up to 14 bar	No	No	No	No	Yes	Yes
Temperature capable to 660°F	No	No	No	No	Yes	Yes
Good performance with abrasive materials	No	No	No	No	No	Yes
Automatic compensation for wear	No	No	No	No	No	Yes
Unobstructed flow through valve	No	No	Yes	Yes	Yes	Yes

High Temperature: Thermal expansion prevents consistent valve seat action in hard seat valves. The inflatable seal provides seal action compensation throughout the temperature range. Valve performance on media temperature up to 700°F has been achieved.

Close and Seal: The displacement action of the dome component and its spherical shape rotating within the valve housing allows closure through a solid column of bulk materials, followed by the seat sealing action of the inflatable seal.

A New Challenge to Valve Design Philosophy

With an impressive array of 7,000 tough installations, we should seriously consider the new philosophy of valve seat design represented by the Dome Valve®.

Metal seats have always suffered from varying rates of wear, depending upon application and duty. The inevitable conventional wisdom concerning solutions to high-wear rates has been to provide tougher or harder seat materials, or exotic designer materials to tackle abrasion, temperature and pressure differential. The philosophy has been to treat the symptom of the problem which is erosion from particulate movement across the seat.

The Dome Valve® is the first valve that treats the cause of the problem. Entrapping particles at the seat and preventing their movement under the influence of a pressure differential is a unique approach to the problem. Evidence suggests that this philosophy is not only here to stay, but if we are to judge by the Dome Valve's® success, a technique we are likely to see a lot more of in valves and other mechanisms.

Comparison with Conventional Valve Designs

To place the Dome Valve® into the general family of valves now available, a comparison with conventional class valves is useful (see Table 2). The comparison is non-specific in terms of any single application study, but it does serve to provide a general representative comparison using general industry experience with all valve types. The Dome Valve® appears to provide application superiority against all conventional classes of valves.

Add to this the manufacturer's aggressive, but apparently well-timed guarantee of one million cycles between inspections, and we have a new approach to valving that needs careful attention. The special advantages of the Dome Valve® are, however, available with an apparent disadvantage, and that is price. The conventional valve classes are lower in price, or as we say "first cost". However, if we adopt modern accounting philosophies for plant and equipment investment requirements, and consider life cycle cost, the low wearing and problem solving reputation of the Dome Valve® may well place this new and exciting product at the top of the list on all counts.

Dome Valve Company
1829 Clydesdale Street,
Maryville, TN 37801, USA
Contact: Mr. Brian Patterson
Tel.: +1 615 984 52 86
Fax: +1 615 977 4131

For more information circle Reader Service Card No. 208

Appendix:

Examples of Dome Valve® Installations

Valve Size	Media Name	Temp. °F	Press. Diff. psig	Oper. Freq. cycle/h	Owner	Date of Installation	Process
4"	Sand	150	40	30	Harrison Steel	1980	Pneumatic Conveyor
8"	Ash	660	60	60	Delco Remy	1978	Pneumatic Conveyor
8"	TiO_2	160	50	60	Ace Hardware	1983	Pneumatic Conveyor
8"	Fructose	212	40	60	Pfizer	1988	Pressure/ Vacuum Let Down
8"	Rice Ash	335	30	90	Argi Electric	1985	Pneumatic Conveyor
4"	Flyash	396	40	60	Reeves Bros.	1983	Pneumatic Conveyor
4",6", 8",10" 12"	Alumina	180	60	30-120	Alcoa	1980	Retrofit Pneumatic Conveyor
8"	Sugar/ Dextrose	112	40	60	Allen Sugar	1991	Pneumatic Conveyor
8"	Resin Powder	180	50	60	B.F. Goodrich	1984	Pneumatic Conveyor
8" SS	Ultranox Crystal	200	50	60	General Electric	1987	Pneumatic Conveyor
8",12"	Lead Concentr.	396	60	15	Boliden Metals	1988	Pneumatic Conveyor
4"	Ilmenite	396	60	60	Nord Rutile	1986	Pneumatic Conveyor
8"	Litharge	200	50	60	Ferro Ind.	1990	Pneumatic Conveyor
8"	Pebble Lime	180	40	60	First Miss Steel	1990	Pneumatic Conveyor
8"	Bottom Ash	396	30	60	Ford Motor Co.	1985	Pneumatic Conveyor
8"	Coke Breeze	212	40	30	General Motors	1981	Pneumatic Conveyor
8"	Paper Ash	535	30	60	Herman Bogot	1982	Pneumatic Conveyor
8"	Bottom Ash	535	40	60	Galaxy Carpets	1982	Pneumatic Conveyor
8"	Coke Breeze	200	50	60	J. I. Case	1980	Pneumatic Conveyor
8"	Dolomite	212	35	120	Latrobe Steel	1991	Pneumatic Conveyor
8"	Carbon	200	40	60	L.T.V. Steel	1987	Pneumatic Conveyor
8"	Bottom & Flyash	535	40	100	Mallinckrodt	1983	Pneumatic Conveyor
8"	Bottom Ash	396	50	120	Minnesota Corn	1983	Pneumatic Conveyor
8"	Copper Concentrate	212	60	60	P.T. Inco	1990	Pneumatic Conveyor Retrofit
8"	Bottom &	535	50	90	State of Illinois	1981	Pneumatic