Selection Criteria for Automatic Water Control valves

FOREWORD

The variety of control valves on the market is overwhelming, and when an engineer finds himself having to make crucial decisions on a subject where not many will agree upon, it becomes a frustrating exercise. It is further complicated by the fact that this decision making process takes place during advanced stages of the project planning roster when deadlines are looming.

This paper is designed to extract the benefits of a product effectively and ensure that it will suit the engineer's needs within the parameters of his pipeline design.

Acknowledgements

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WATER DISTRIBUTION NETWORK AUTOMATION

AUTOMATIC CONTROL VALVES AND PROCESS CONTROL VALVES

When considering automation of an existing water distribution network, a review should be made of existing system components and future system requirements. Many components such as pipe, isolation valves, hydrants, reservoirs, tanks or pump stations can be readily utilised in the new automated system. With the simple addition of control valves to a previously manually operated system, distribution can become completely automatic.

All types of manual valves used in water distribution networks can be automated by fitting electric, hydraulic or pneumatic actuators, and will be referred to as process control valves. These actuated valves, in conjunction with very costly instrumentation, can automate a network if the relative power sources are available. Generally, water distribution pipelines run through remote areas where the cost of providing such power sources will eliminate the selection of process control valves.

The only feasible alternative is found in automatic control valves, and when designing a new network, automatic control valves will be selected every time.

A better description for automatic control valves will be “hydraulically self-actuated, pilot operated control valves”. Generally manufacturers opted for “automatic control valves” as a shorter description which is more easily written into documents. The word automatic is defined as “having an inherent power or action” and as being “self-acting”. The word control is defined as “to keep within limits, to exercise directing, guiding or restraining power”. An automatic control valve certainly does conform to these definitions and it actually goes one step further, it replaces the human element. It performs without human assistance or supervision, those functions that otherwise would require regular or continuing physical attention.

Many distribution systems when automated rely on a constant pressure design concept. Typically, the water resources and the distribution network are engineered to provide maximum flow demand requirements at a constant pressure to a zone. Depending on the topography of the site, one or more zones are also created throughout the entire system network. Automatic control valves are used at various points in the system to help maintain constant pressure to the various zones and to help ensure adequate supply of water sources to the zones. By designating control parameters for the valves which control reservoir levels, operating pressures and flows, the network can be automated. As system requirements change, these control valve functions or settings can be easily changed on site to accommodate to the new requirements.

The automatic control valves selected should be capable of providing a variety of functions within the system. Reservoir level control, pressure control, flow control, and relief control are examples of functions needed.

SELECTION CRITERIA FOR AUTOMATIC CONTROL VALVES

WHICH ONE TO SELECT?

Terminology plays a big role in marketing styles, and can be very confusing during the selection process. Each manufacturer will carefully select terms in their papers, and use these terms to the advantage of their own design of valve. Not only can this be misleading, but often these terms lead to downright incorrect statements, or lies. This document is written with intent and will endeavour to shed light on such terminology. The reader is also reminded that the evaluation of these features and benefits of different designs, are made specifically for applications in water distribution networks.

Various designs have seen the light over the years, but essentially seven principle designs have proved successful and are still available

- Axial flow-type piston actuated
- Y-type piston actuated
- Globe-type piston actuated
- Axial flow-type sleeve actuated
- Axial flow-type liner actuated
- Y-type diaphragm actuated and
- Globe-type diaphragm actuated

All seven categories of designs are based on the principle of the relationship between pressure, force and area. Each of these valves are equipped with a control chamber, which will drive the valve seat towards the closed position when pressurized, and when de-pressurized, will allow the line pressure to drive the valve seat towards the open position. By using the medium in the pipeline as the only available power source, the valve inlet pressure is directed to the control chamber to effect closing of the valve. This presents the situation where the pressure at the valve inlet, acting on the valve seat, is equal to the pressure in the control chamber, acting in the opposite direction on the valve seat. The equation represents a static situation, as the two resulting forces are equal and opposite. To create motion, the cross-sectional areas on which the pressures are applied need to differ. This will create a resultant force, and motion will be achieved in the direction of the resultant force. All these valves are designed to have a larger cross-sectional area exposed to the line pressure within the control chamber, than that of the seat, which is exposed to the same line pressure (see figure 1 and 2)

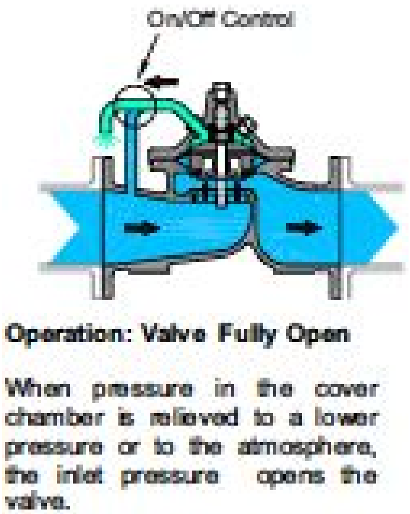


Fig 1

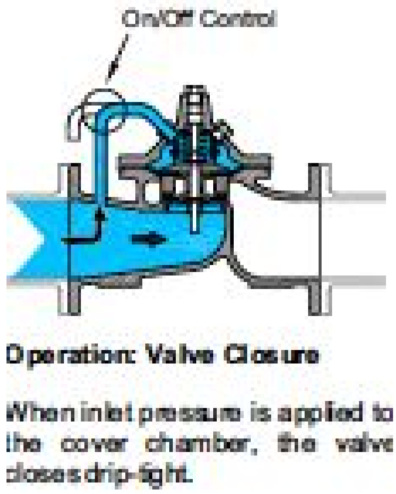
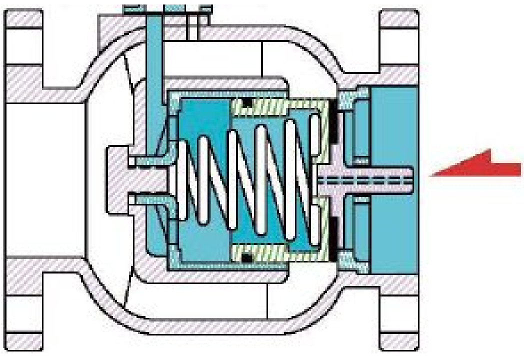


Fig 2

1. **Axial Flow-Type Piston Actuated Automatic Control Valves**

Fig 3 

The principle design of any axial flow-type valve lends itself to lesser friction loss across the valve as a result of the favourable pattern of flow through the valve. The design also supports the fact that a very short stroke of the stem is required to achieve the fully open position, and hence axial flow-type valves generally has favourable coefficients of flow (Cv). Combined with this, the flow characteristics of the design is excellent when comparing the percentage of flow with percentage of valve opening. This comparison produces an almost straight-line graph.

The pattern of flow produced by such a valve allows for the valve to have a very good resistance to damage as a result of cavitation, and hence can be subjected to high velocities of flow as well as high differential pressures.

The short distance of stem travel allows the valve to be quick acting, which is a requirement in many applications.

These features fulfil the requirements of most applications at first glance, but in having a closer look, several shortcomings are revealed as a result of these features.

The control chamber needs to be of a larger diameter internally than the inside diameter of the seat in order to create a difference in cross-sectional areas. The result is that the valve body, or casing, is of a bulky design, and has to be lengthened to achieve the required pattern of flow. This adds considerably to the manufacturing cost, not even mentioning the amount of close-tolerance machining required to produce the valve. Some manufacturers have resorted to reducing the bore of the design to reduce manufacturing cost, but this affects the coefficient of flow and thus removed the advantages of the design.

In order to maintain the valve, not only does it have to be removed from the pipeline, but it also becomes a workshop procedure. Generally they are returned to the respective manufacturers for repairs

2. Y-type Piston Actuated Automatic Control Valves

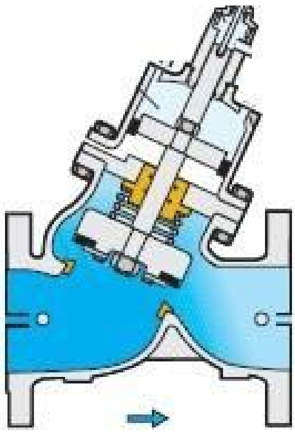


Fig 4

As far as can be ascertained, only one manufacturer is associated with this design, which was developed from one of their existing designs, the Y-type diaphragm actuated automatic control valve. In essence, this is a copy of an existing globe-type piston actuated valve, adapted to be a y-type valve. The marketing of this design is targeted at high pressure control applications, which puts it in the same niche market as the axial flow- type and globe type piston actuated valves. The manufacturer claims the same features and benefits for their design when compared with axial flow- type piston actuated valves.

This is obviously not true, and an extract from the catalogue reveals that they do not have much experience when it comes to high-pressure control. I quote: "The valve has a superior, smooth, quiet and accurate control even on extreme pressure and flow conditions." None of these terms are defined in any of their literature, hence the reader is influenced that the valve is superior. Let us look at a few of these features.

One fails to see just how smooth an quiet the flow will be when the direction of flow is changed three times through the valve (thirty degrees up from parallel, then ninety degrees down over the seat, and again thirty degrees up to return to parallel). Over and above that the flow is forced through a "cavitation" cage, which accelerates the velocity of flow through small ports. This results in the vena-contracta being within the confines of the outlet chamber, where all the working parts of the valve are situated. Because of the shape of the outlet chamber, the working components as well as the walls of the outlet chamber will suffer from damage as a result of cavitation. Is that why the manufacturer refers to it as a "cavitation cage"?

Elsewhere in the same manufacturer's catalogue, in promoting their own diaphragm actuated valve, they refer to disadvantages of using piston-actuated valves:

- Wear in moving parts
- Leakage as a result of dirt
- Sensitivity to sediment
- Seals need regular replacement and
- Lubrication required in some instances

Whilst these disadvantages are in fact a reality, diaphragm actuated valves are limited to the extent of the differential pressures across them, and one is forced to select piston actuated valves for those applications. The two designs do not compete with each other for market share.

Without analysing the design any further, the simple fact that only one manufacturer considers this design, and that their statements do not make engineering sense, creates scepticism and suggest that it is not an advanced product.

3. Globe-Type Piston Actuated Automatic Control Valves

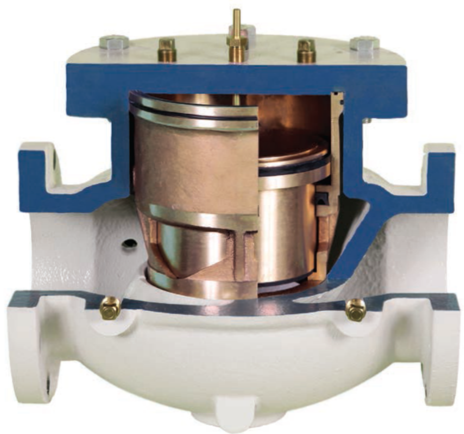


Fig 5

In having had some insight on piston actuated designs above, one could safely say that the target market for these products lies in high-pressure applications. The main function of control valves for such applications will be pressure reducing. In other words, one will require a throttling or modulating valve, which creates friction as a result of the pattern of flow of the design. This is where the globe-type control valve comes into its own.

The flow changes direction twice through a globe design, once at 90 degrees upward from parallel towards the seat, and a second time at 90 degrees downward over the seat back to parallel. The drastic changes in direction of flow creates friction losses in the system which is exactly what is required. A globe valves does not have to throttle excessively to reduce pressure or flow, while an axial flow valve will have to.

Although this design is subject to the same disadvantages pointed out for other piston actuated valves, it holds an edge over the others because of the pattern of flow, as well as the fact that maintenance can be effected without removing the valve from the pipeline. By selecting a reputed brand or manufacturer, new parts will be interchangeable even though machining has to be done under close-tolerance requirements.

Other advantages of globe-type designs are pointed out under “Globe-type diaphragm actuated automatic control valves”.

4. Axial Flow-Type Sleeve Actuated Automatic Control Valves

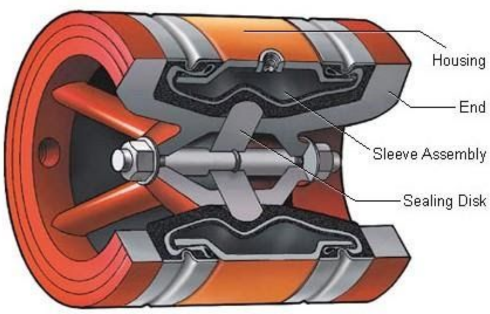


Fig 6

All the features of an axial flow-type piston actuated valve can be built into a sleeve actuated valve if well designed. The operating mechanism, being a rubber sleeve, is the pinnacle of the design. Since this is the only working part, the valve not only has excellent features, but also is very easily maintained even though it has to be removed from the pipeline for this purpose. The sleeve can be replaced in the field and although specialised tools are required, general repairs do not have to be a workshop procedure. Very little close-tolerance machining is required to manufacture this design.

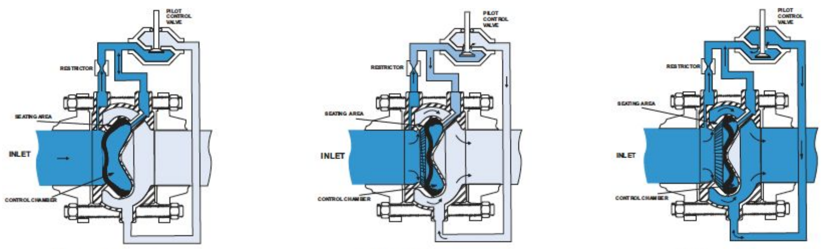
Again, at first glance the design is ideal, but only manufacturers with the necessary resources and the rubber technology can develop suitable sleeves.   This however, at a cost that is carried with the production cost of the valve for many years to come.

Generally the sleeves available produce good results when used in on-off (open or closed) applications, but modulating functions such as pressure reducing, causes the sleeve to “creep” creating instability of control and excessive wear. (“Creep” occurs as a result of the elasticity of the sleeve having to resist the friction of flow produced by a throttled valve. The inlet part of the sleeve is stretched and the outlet portion is bundled up.) The valve starts leaking prematurely, and the life of the sleeve becomes short-lived.

High-Pressure sleeves are also available, but the friction loss across the valve is excessive and the advantages of the design disappear

Sleeve actuated automatic control valves do have good features and benefits when used in gas line

5) **Axial Flow-Type Liner-Actuated Automatic Control Valves**



Model 100-42 Valve in Closed Position | Model 100-42 Valve in Partially Open Position | Model 100-42 Valve in Fully Open Position

Fig 7

This design is a definite improvement when compared with all other axial flow-type automatic control valves. Again, all the features and benefits are built into this design with the added advantage that the short length achieved by utilising a liner instead of a sleeve, improves the flow characteristics dramatically. This makes the design ideal for throttling or modulating applications. (Unfortunately it is not a good on-off control valve, since prolonged periods of operation in the fully open position, can cause failure to close. As the control chamber cannot be equipped with a spring, the only initiative to close is produced by the "memory" of elasticity of the rubber liner. Prolonged operation in the fully open position could result in a loss of "memory" as the liner is not under tensile stress as is the case with sleeve actuated valves.)

This design is not sensitive to low-flow conditions, and is quoted to have one hundred percent rangeability. This feature makes the design suitable for "pressure management" applications where night flows are minimal compared to maximum demand conditions. (Pressure management applications are covered under the "Control of Pressure" section later on.)

Manufacturers that have opted for investment cast methods, can produce the design from virtually any material, making the product suitable for a wide range of applications. The combination of options of materials of construction and excellent characteristics of flow, results in the valves being highly resistant to damage as a result of cavitation. This compact design allows for it to be available in "wafer" patterns, and the size of valve chambers can be reduced drastically. As for sleeve actuated valves ,the only working part is the liner, and although the valve also needs to be removed from the pipeline, the liner is easily replaced in the field without the need for specialized tools.

6) Y-Type Diaphragm Actuated Automatic Control Valves

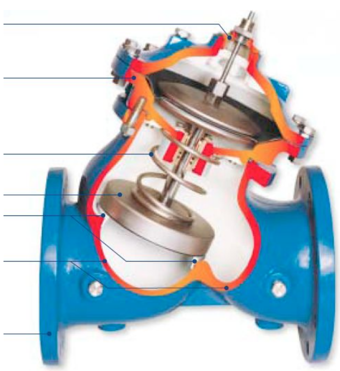


Fig 8

Again, as for the Y-type piston actuated valve, only that manufacturer is associated with this design. By looking into the history of this design, one will find that the strength of this manufacturer is predominantly in products for the irrigation market. They have produced control valves for this market successfully for many years. (A diaphragm actuated valve with no stem or guide or seat, but instead the mere sealing of the diaphragm against the walls of the valve inner-body. It is a very cost-effective construction, and is good for irrigation purposes where low pressures and low velocity of flow requirements exists. The primary function is that of small-bore on-off control.)

Their Y-type diaphragm actuated valve was added later, when the other automatic control valves were already established in the water distribution markets. For this product to enter the market, it had to have specifiable features, and hence was to be different from others. In essence, this is a copy of existing globe-type diaphragm actuated valves, adapted to be a y-type valve.

Their marketing strategy is to incorporate terminology that makes their design unique, and hence once specified by the project engineer, the opposition products are illuminated by the specification. This style of marketing should prompt the project engineer to look closely at features and benefits promoted before selecting the product.

The design is described as "the advanced hydrodynamic, wide y-pattern valve body design", and often referred to as the "wye-type". This description is unique to this design, and hence to this manufacturer. The first question is simple: Why did other manufacturers not consider these features in their designs?
The answer lies in the analysis of the features.

The main feature of this design is the favourable pattern of flow, with low friction loss characteristics. This is true, but the feature is marketed as follows: "25% more flow than existing types of globe valves." When comparing the Cv of this valve with that of globe valves, one will find a difference between the two, and only marginal …not nearly as much as 25%. It is also striking that they size their valves to suit a pipe velocity of five metres per second maximum:- the same parameter used by globe valve manufacturers. (Some globe designs will even tolerate 7,5 metres per second pipe velocity) The truth is that the design cannot allow a higher rate of flow, because it will suffer from damage as a result of cavitation. The lower head-loss feature is only an advantage in applications such as pump control, where the running cost of the pump should be limited. Interestingly enough, most pump control applications require the valve to throttle in order to keep the effective pumping head under control. More than ninety percent of applications in water distribution networks are for pressure and flow-control. These are throttling requirements, and the more friction provided by the valve, the more advantageous to the system.

The design features a throttling V-port plug, which is promoted to improve the regulating characteristic, and to stabilise control during low-flow periods.   This too is true, but in reality the V-port plug is used for different reasons altogether:

- This design is the worst performer of all designs under low flow conditions. The principle of operation of all automatic control valves requires a differential pressure to be created across the valve in order to have stability
- The design includes for a centre bearing only, and under higher differential pressures, the stem is subjected to bending movements, causing wear on the bearing, the O-ring seal, and the stem. To overcome this, the V-port plug is used as a secondary bearing, to support the stem

By using the V-port plug, many of the disadvantages that apply to piston actuated valves, will apply to this design as the V-port is nothing but a piston profiled as a V-port. Just as the y-type piston actuated valve with the cavitation cage will cause damage to components and the walls within the outlet chamber, so does this design. By inserting the V-port plug, the low head-loss feature of the design disappears.

Maintenance can be affected with the valve in position in the pipeline. Because of the angle of the stem assembly, and the mass, it becomes very awkward to remove components from larger sizes of valves. A further complication is that the standard construction is assembled by means of electroless nickel-plated bolts and screws. An experienced field technician once said that the only means of disassembly was with the help of an angle grinder

7) Globe-Type Diaphragm Actuated Automatic Control Valves

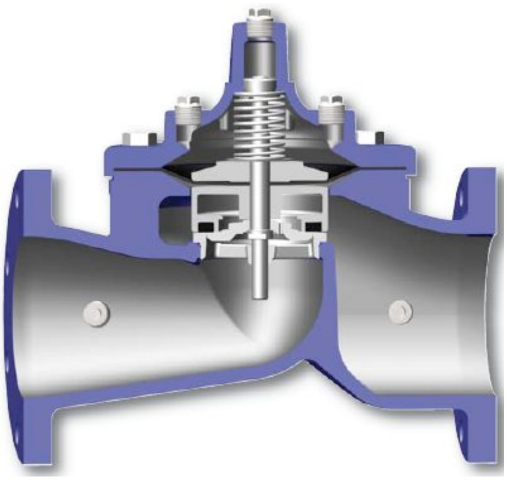


Fig 9

This design is by far the most suitable for use in water distribution networks. The statement is supported by the fact that at least twenty independent brands are available internationally, have been manufactured successfully since the early 1930's, and have been the market leader since its inception.

It is by no means insinuated that it is a perfect design, on the contrary, as for all other designs, its features and benefits should also be critically analysed

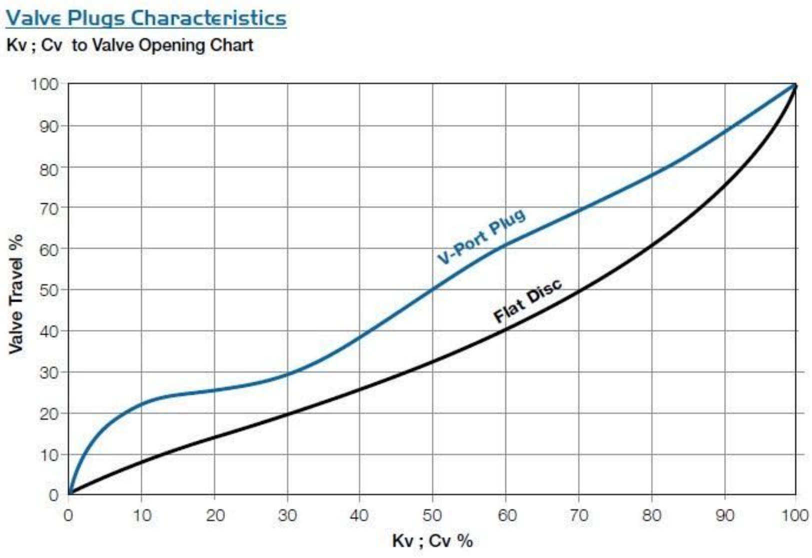
The following statements are extracts from one of the manufacturers catalogues"

Linear Flow Characteristic

Requirements	The Globe Valve design of Cla-Val is the most suitable for water distribution networks
Low Flow conditions	Model 600 Cla-Val Hytrols feature a reduced port design to cope with low flow conditions. No reducing pieces are required to install smaller valves and no V-Notches are required
High Differential Pressure	The Cla-Val non-magnetic stem is fully guided through its stroke by 2 replaceable bearings. No centre giudes or V-notches are required
Resistance to damage caused by cavitation	The enlarged flow area around the seat of the model 600 Cla-Val allows for vapour bubbles to slow up before disposing against walls in the valve housing, and reduces the effective damage. A ratio of 4:1 reductions pressure can be maintained without damage. Cla-Val does not utilise V-notch seats at it increases potential cavitation damage.
Critical Flow and pressure setpoints	The 2-way modulating control systems by Cla-Val are designed to minimise set point fluctuations. The stem movement of these controls is limited to 1mm, hence the spring is

compressed by 1mm and the modulus of the spring does not change over this distance of compression. The result is that the set-point does not change like in the case of 3-way controls utlised by other manufactuers.

Axial flow-type designs produce better flow characteristics than the globe-type valve, but one has to define the term “flow characteristic”. This term is used to compare the percentage valve opening with the corresponding Cv value. Some manufacturers will compare the percentage opening with the corresponding flow. When this information is plotted in a graph form the flow characteristic is considered to be better if the graph develops a straight line, rather than a curve of any form. Manufacturers use this as a marketing tool extensively.



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This information is important when selecting control valves. A gate valve for instance will have a flat curve, which is only transformed over the first thirty percent of valve opening. This implies that by the time the valve is thirty-percent open, full flow is already achieved. This is not a good control valve. When considering the flow characteristics of ball-or butterfly type valves, one will come to a similar conclusion. A good control valve will produce a reasonably straight-line graph over the complete stroke of the valve as indicated above.

However, the flow characteristic of a design is not the be and end all for selection purposes and the engineer needs to consider many other factors before concluding his specification.

The attention to detail like the performance under low flow conditions may be crucial in certain applications. Most water distribution networks are subjected to maximum and minimum demand situations, such as very low night flow compared to peak demands during business hours. This situation will require of the valve to operate under extremely throttled position, added to which the differential pressure across the valve will be higher than during peak demand periods. Most manufacturers will promote V-port plugs or V-notch components, but experienced globe-type valve manufacturers will refuse to install such components in their valves. V-ports only add to the problem, as damage as a result of cavitation is the net result. The more experienced manufacturers will select a globe valve (often referred to as a “cavitation fighter”) with a reduced bore, which not only stabilises control under low flow, but also is more resistant to damage as a result of cavitation.

Globe-type valves are easily maintained in position in the pipeline, as they are designed to have a “diaphragm assembly” which contains all the working parts and be replaced as a single component. This assembly is removed by lifting it vertically, so that the mass of the larger diameter assemblies does not become a factor as lifting equipment can be utilised. The stem of this assembly is fully guided throughout its stroke by an integral bearing in the replaceable valve seat, and a replaceable bearing in the valve cover. These bearings do not have to form a seal, which can wear and start leaking, as is the case with some designs.

Some manufacturers will make use of “O” ring seals, but experience has shown that a resilient synthetic rubber disc of a rectangular cross section that can be held in place on three and one-half sides, forms a reliable seal which cannot be dislodged. This disc seal is held in place and guided by a contoured type disc guide which ensures a smooth transition of flow when the valve is extremely throttled

CONCLUSION

Globe-type diaphragm actuated automatic control valves have not only been the market leader ever since the inception of the design but will remain so for some time to come. Admittedly, one has to consider the limitations of the design, and make the selection accordingly, but in general it will be a case of having to decide on which manufacturer of this design to choose.

Be sure to select a reliable manufacturer who provide after sales services through their field technicians, and companies with sufficient experience backed up by research and development programmes. To start off with, such a company must be able to provide services such as cavitation analysis, life cycle costing, valve sizing, pressure management programmes, leak detection and surge analysis. Such organised companies will inevitably have associated products within their range to provide the user with solutions rather than just being another valve company. Be alert to companies manufacturing the “or similar” valves, as many reliable brand names have been copied over the years. In such cases spares are not interchangeable and these companies cannot provide design data on a professional basis.In the next paper different applications will be analysed, and compared with specific case studies. This in itself sheds a lot of light on the subject of selection criteria.

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