FACTS ABOUT "QUALITY" CONTROL VALVE DESIGN
Edward J. Johnson
Vice President
C. M. Lovsted, Inc.
Seattle, Washington

In much the same way we dig for facts about people, we can dig for facts about valve design. In much the same way we talk about how people behave, we can talk about how valves behave.

Back about 1850 the new coal industry challenged the mind of man to provide a device to control pressure. The answer to the challenge was a gas regulator with a single ported, quick opening valve plug. This inaugurated the "Regulator Age" when automatic control began to emerge.

The valve plug in this single ported regulator was guided as it approached its seat, but, by present day standards, the guiding was inadequate and flimsy. The guiding was done a long way from where the seating took place. For one thing, the fit between the stem and its guide was sloppy. For still another thing, the total area of guide in contact with the steam was skimpy. The most immediate problem, however, was the unbalance across the single ported valve. High inlet pressure on the underside of the valve produced a greater force than low outlet pressure on the top side.

Here was a challenge which was met by the invention of the double ported valve. In this design, the higher inlet pressure pushes up on one part of the valve and down on the other to balance itself out. Likewise, the low outlet pressure balances itself out. This time, the answer was to guide in the ports by means of wings on the valve plug.

This was developed about the time of the American Civil War, and from then on until 1930--which heralded the "Control Valve Age"--there were but minor refinements in valve design. At that time, the valve designer met with three new challenges. He was faced with an emerging control concept and two new mechanical devices.

The control concept recognized the need to replace the on-off mode common in process industries of the time with the same proportional type control characteristic of existing gas, water and steam pressure regulators. One of the mechanical devices was an early form of what we now call an instrument. The output of this device was a pressure which was proportional to the input signal. The other device was a spring return diaphragm actuator, which could receive that proportional output pressure and produce a stem travel greater than before available.

Challenge was linked to opportunity in this increased stem travel. The first step in meeting the challenge was to increase the distance between the ports of the double-ported body, so that increased valve plug travel now available could be utilized. The first step in grasping the opportunity was to modify the wing guides on the valve plug into skirts. This did improve the port guiding, but the real purpose was to change the character of the flow. Now flow took place through the V-notches in the skirts, rather than almost all the way around, as in the quick opening valve. While the early valve plug was quick to add capacity as it traveled away from its seat, the major capacity of the V-ported plug was not reached until advantage had been taken of the increased stem travel now available. The change from slender wing guides to skirts made it possible to endow the plug with a variety of flow characteristics. The increased valve plug travel in combination with special flow characteristics which could be effectively utilized by a proportional controller-instrument was not the final answer.

Only a few years into the Control Valve Age brought ever higher pressure drops, more severe temperatures, and greater flow demands, all coupled with erosive and corrosive materials. Simple port guiding just couldn't cope with the severe impact and erosive forces which were buffeting the control valve. The answer to the challenge was top and bottom guiding. Released from the task of guiding, the plug could be contoured to provide various flow characteristics. This top and bottom guided design of valve has been an excellent answer in many cases. In the past, it has been the only answer in certain cases. In recent years, it has become more
and more apparent that it is not necessarily the best answer. But where and how could improvements be made?

As it has turned out, there were several places where improvement was needed in the top and bottom guided valve. For all its size and weight, it had been obvious for some time that it does not possess the internal configuration for most efficient movement of material from inlet to outlet. Capacity is one "where." Top and bottom guiding is better than port guiding, but its advantages could not be fully utilized without making the design ever bigger and heavier. The guiding needed to be bigger around, it needed greater contact surface, and it needed to be closer to the place where the valve plug contacted the seat ring. Guiding is another "where." Many applications called for an ability to shut off tightly, which the conventional double port valve did not and could not possess. The corresponding single port valve would shut off, but re-introduced the unbalance which often demanded an oversize actuator. Needed was a design with a combination of low seat flow and minimum stem force. Balance is another "where." Seat rings in this design are screwed and sometimes welded into place. Guide bushings are pressed into place. This makes trim replacement an awkward and often difficult job. Trim replacement is another "where." Attempts to modify this design to meet an increasing variety of demands and to meet intensification of those demands led to a variety of materials, shapes and alternative parts. Standardization is another "where."

Now let us recap the "where" points where improvement was needed: One--Capacity; Two--Guiding; Three--Balance; Four--Trim Replacement; Five--Standardization.

As a way to accomplish improvements, valve designers have looked long and longingly at a valve body with a single port. It had possibilities. At the same time, it had apparent impossibilities. These apparent impossibilities centered around two things. The first was the old bogey of unbalance across the single ported valve. The second was the reduction in capacity which would have to be accepted.

One approach, which offered several attractive features, was the split body valve. This design, normally held together by four bolts, could be parted at the seat ring. It offered economy when special body materials were demanded, since the flanges were removable and could be of standard material. The advantage of a gasketed-in, rather than a screwed-in, seat ring for easy trim replacement was off-set by the need to take at least half the body out of the line. Furthermore, a balanced valve version presented difficulties. These factors, and capacity considerations, dictated a fresh, new approach.

It was basic research into internal body configuration which brought surprising and gratifying results. These results confirmed the theory that the tortuous internal configurations of the top and bottom guided body acted like a pair of choking hands. Careful, patient shaping of flow channels, charted by laboratory testing, developed a single ported body with a capacity 40% greater than many previous single ported bodies. In popular sizes, even the capacity of the double port body was substantially exceeded--sometimes by as much as 20%. Research-guided flow passage sculpturing paid handsome dividends.

This is the "how" of one improvement. (Figure 1) The approach to guiding improvement was to relocate the guiding down close to where the plug contacts the seat ring. This is where the action is. The valve plug moves up and down inside a cage. The cage extends all the way down to the seat ring. This massive guiding is ideal in overcoming the buffeting forces of high velocity, high pressure drop applications. This is the "how" of another improvement.

How about getting the old trim out and putting a new set in? This design represents a genuine advance in this respect. The valve body can be flanged or welded in the line and left right there. The trim lifts up and out for replacement of conversion to restricted trim, conversion to a different flow characteristic, or a simple change in materials. The seat ring and valve cage must be sealed in place. Gasketing replaces sealing by means of threads and pressed-in bushings. The old bug-a-boo of thermal shock loosening of screwed-in seat rings is no longer a threat. Welding of screwed-in seat rings is no longer a required technique. Since the valve plug, valve cage, seat ring and gaskets are all removed and inserted through the bonnet flange, the bottom flange can be deleted from the design. An improved, simplified valve is the result.
Thus far, we have spoken only of valves which are held open by the actuator spring and closed by application of air loading pressure. Just as available is the construction in which the spring holds the valve closed and air loading pressure is used to open. The choice of actuator determines whether the control valve is normally open or normally closed.

Our new design made bold, effective approaches to problems of capacity, guiding and trim replacement. It seems, however, to have avoided the matter of balance and to have left standardization to the last. How about that balance problem? A considerable amount of work had already been done on piston balancing of single ported valves. (Figure 2) This had proved to be a very effective way of cancelling out stem forces which would overload the valve actuator. Static unbalance changes and flow introduces dynamic unbalance. Each valve size demanded individual attention, but there had to be design continuity to make manufacturing a feasible process. This continuity was achieved by going to a body design with flow downward at the port. A push down to close valve plug was employed.

Now, this construction has often been referred to as "flow closing" and has been cursed with a slamming action as the valve plug approached the seat. Slamming is not acceptable valve behavior. Something had to be done to keep from jumping from the frying pan into the fire. Two things were done. Pressures below the valve plug were communicated to the top through special passages. This balancing, in combination with a concave shaping of the underside of the valve plug produces—at all valve positions—a highly desirable equanimity of valve behavior. The balance achieved makes a standard valve actuator the effective master of residual stem forces.

Now, how about ability to shut off? If we are to secure a minimum flow when the valve is on its seat, we must contain the higher upstream pressure at two places. At the place where the valve contacts the seat and at the place where a piston ring seals against blowby. Established designs and materials provide a containment which limits shut-off flow of less than one-half of one per cent of wide open flow. This is not what is often called "tight shut-off"—it nevertheless represents excellent performance.

What about situations in which you want both balance and shut-off? This also is available. Double seating is employed. Both seats utilize resilient material against metal to secure the desired tight shut-off. Balance has been retained and shut-off has been added.

We have remaining the matter of material standardization. This is no longer a problem. This is an opportunity. With simple, flexible construction meeting the needs of so many varied applications, the decision to go to hardened stainless steel trim as a standard for wear resistance and long life became an economical one to make. To the user this means relief from the necessity of laying special hard surfacing alloys on conventional valve materials.

Another recap would seem to be in order. Looking first at capacity—it is better than many conventional double ported valves. The guiding is massive and where the action is. The balance is better than that of double port valves. Trim replacement is fast and flexible—truly quick change. Standardization is an economic reality. Standardization has not been achieved at the expense of versatility. Quite the contrary. The same valve body is used for an application demanding any one of three basic designs:

1. Single ported metal-to-metal seating.
2. Balanced valve with low seat leakage.