International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 4, No. 1, January 2015

Research Paper

SEVER SERVICE VALVE WITH IMPROVED EFFICIENCY

Sachin Jadhav[1]* and Sandip B Patil[2]

*Corresponding Author: Sachin Jadhav, ✉ Sach_jadhav1@rediffmail.com

Designing of control valves of the tortuous path employing at right angles turns and multiple paths are presented here with improved efficiency with additional features and with past experiences and on field. The main feed pump recirculation valve is the most difficult and severe service application in a central power station. The valve must provide a controlled letdown of the pressure without excessive noise, cavitations or erosion while maintaining leak-free service when shut off. A valve design and its performance in the field is described. The design has evolved from many years of application feedback. The result is a valve which has provided trouble free and economical performance for periods in excess of two years. This compares with some plant experiences which require valve rebuilding every three to six months. The tortuous flow path takes the energy out of the fluid or gas and reduces its velocity in a controlled way, ensuring that velocities never exceeds the threshold that could impair system performance or damage valve components.

Keywords: Cavitations, Tortuous path, Shut off valve, Feed pump

INTRODUCTION

This paper describes a valve design which has evolved from field experience. The design has been proven in applications with trim life in service for nearly ten years and with time between maintenance exceeding five years.

The high pressure pump recirculation application is one of the most difficult and severe duty control valve installations demanded by the power industry. There are two significant features that make this valid. First, flow must be controlled during a very high pressure drop and second, when not controlling flow a tight leak proof shut off is required. Failure to achieve either of diesel functions will quickly result in a plant shutdown or valuable loss of energy over an extended period.

The feed pump recirculation valve application has been discussed many times

[1] M. E. Student, Mechanical Engineering Department, MET's IOE, BKC, Nashik, India.
[2] Associate Professor, Mechanical Engineering Department, MET's IOE, BKC, Nashik, India.

in the literature; Mortt (1985) gives a general description, discussing the merits of on-off versus modulating service. The on-off versus modulation issue is also discussed in Power Magazine (1982) in terms of its economic impact. The study shows that as much as one-quarter million dollars is lost by using on-off control for a 450 MW oil-fired unit. The economic losses due to a leaking recirculation valve or an unplanned shutdown can also be determined from Hughes (1985), which provides the savings (or loss) due to a change in efficiency, capacity factor, or heat rate, Fuel costs and unit size are also considered.

The hope was expressed. That a valve could be designed for a five year trim life, this article presented an excellent summary of the state of the art and a description of the relationship between liquid pressure and velocity during die throttling process. The author describes the "...recirculation valve service to be die most difficult of any in the station... The recirculation valve is the highest-technology valve in the central station today." Unfortunately, the state of the art has not changed much in me intervening years. Improvements have been slowed by the time necessary to receive feedback from the field.

The main reason for a feed water recirculation loop is to protect the pump under reduced flow conditions. For some pumps this is as low as 20% of the design flow but for nuclear plant pumps this can be as high as a 50% flow rate. Many difficult schemes have been used to try to control the pressure letdown. For example, Van Blarcon and Schmitt (1980) mentions six different methods for just avoiding flashing in the downstream piping, although flashing may not be the worst effect of the pressure letdown. Many of these schemes are tried because a good recirculation valve has not been available.

There are many different types' tortuous path valves which differ in the manner in which pressure drop stages are achieved and the amount of division of the main flow stream.

In multi stage valves with single flow paths, the pressure drop stages are formed by a non uniform cage shape with corresponding plugs of varying cross section and the flow is parallel to the axis of the plug.

Within the area of the valve design numerous options have been attempted. One of these has been to solve the cavitations damage problem by brute force, that is, to use harder and harder materials. Material selection guidelines and valve designs are presented in Schumacher and Gossett (1983) for the classical treatments of erosion and corrosion in recirculation valves.

The design to be discussed has evolved from many trials and tests conducted over an extensive period. Many different designs features were tried and feedback from either good or bad performance integrated into an evolving solution.

The features of the design and installation experience are presented below. The design is indifferent as to whether the application is for an on-off or modulation service.

Improved Additional Features

The recirculation valve must perform two important functions. It must control the fluid during the large pressure letdown when open at all plug positions and it must assure no leakage when the valve is closed. There is little room for error in performing these functions as any erosion or cavitations damage cascades rapidly, resulting in a very short trim life. The controlled pressure letdown features are discussed first.

A sketch of the recirculation valve is shown in Figure 1 where the flow direction and path are shown. The flow enters the tortuous path trim and flows inwardly to the plug, then past the seat ring and out. Although an angle valve configuration is shown in Figure 1 a globe body configuration is also applicable.

The tortuous path trim consists of a number of disks brazed together to form a stack as shown in Figure 2. Each of the disk outlet openings are staggered circumferentially from the disk above and below so as to develop a uniform exiting from the disk. The inside diameter of the disk stack is ground to a tight tolerance so that a minimum annular gap is

Figure 1: Valve Schematic

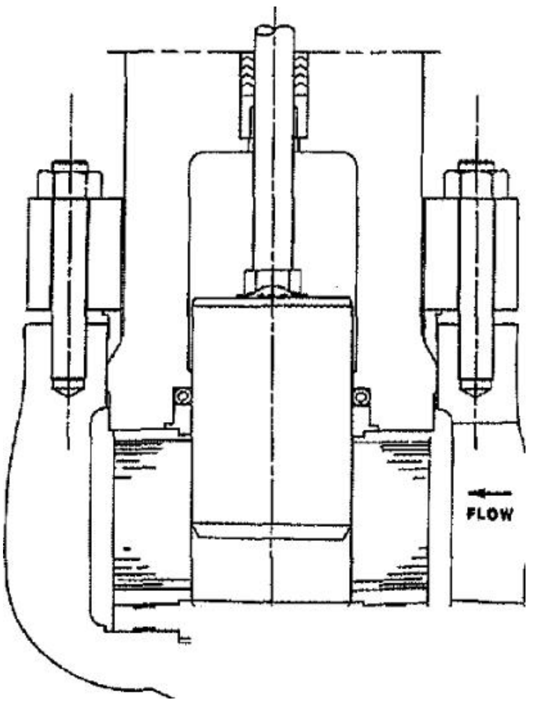
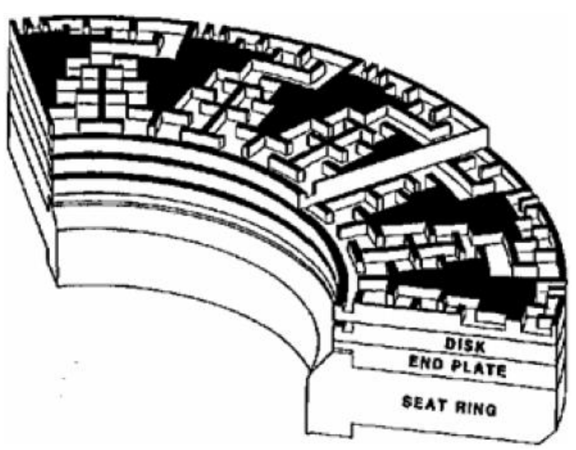


Figure 2: Disc Section



available for fluid flow between the stack and the valve plug.

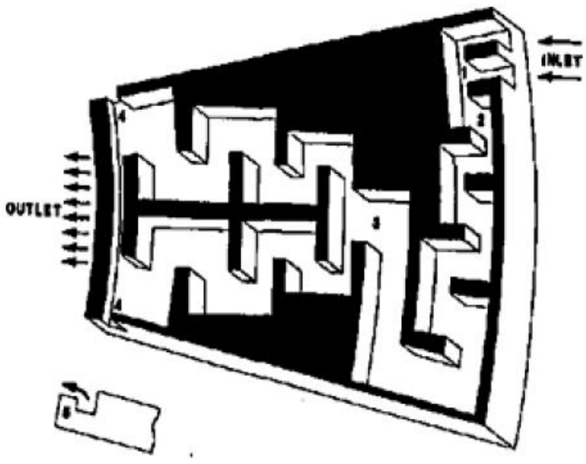
Each disk in the stack has a multitude of tortuous flow channels electric discharge machined into the metal. Each disk channel is independent of adjacent channels or disks. Thus each disk's flow remains constant regardless of the position of the plug once the opening is uncovered.

For the recirculation valve each disk is the same so that each disk is working equally for all flows, another way to say this is that the total valve flow is directly proportional to the plug position as the disk stack has a linear characteristic.

If it is necessary that the flow resistance of the trim change with increasing stroke then each disk, or grouping of disks, would have different channels machined into their surface. A fully customized flow versus stroke stack can be characterized to meet a unique set of flow conditions.

A typical disk channel is shown on Figure 3. Each flow channel consists of several right angle turns (stages), each of which account

Figure 3: Flow Channels



for more than one velocity head of pressure drop. This large number of stages is packaged into a radial wall as small as 11/8 inches (28 mm). Therefore a pressure drop of 3000 to 4000 psi (200 to 300 kg/cm^2) is achieved by each channel in a very tight space.

Figure 3 shows five significant features of each disk channel. These are:

1. Strategic inlets (Section 1): Which are the smallest flow channels in the path, but are significantly larger than the required flow channel after the entrance. The purpose of the dual inlets and their size is to prohibit any foreign matter such as weld rod or other trash from passing through the valve and damaging the seating surface. Particles small enough to pass through the inlets will also flow through the channel because the flow area is continually increasing. The extra flow area at the inlet will permit almost a 50% blocking before the flow versus pressure drop characteristic of the valve is impacted.
2. Increasing passage size (Section 2): The flow area is continually increasing as the fluid pressure decreases. Thus the velocity is continuously reducing to a very low level, at-the disk outlet. As the pressure drop takes place the, velocity, is controlled by the flow area design. There are no local pressure recovery points for cavitations to take place in the trim, such-as occurs with a drilled hole type trim.
3. Increased number of stages (Section 3): Because there are 24 stages the pressure drop takes place at much. Lower velocities than for designs in which there are only. Three to four stages. Liquid velocities as high as180 m/s are common in most recirculation valve designs. In this the maximum liquid liquid velocity is limited to around feet per second (60 m/sec) and this only occurs for a short period as the first expanding channel reduces the Velocity.
4. Ring (Section 4): A flow channel around the inside diameter of the disk equalizes any unbalanced pressures which may be induced by uneven velocity distribution. This pressure equalization assures that there are no unbalanced forces on the plug to cause noisy mechanical vibration.
5. Pressure reducing weir (Section 5): At the exit of the channel the fluid is forced over a weir. This assures a uniform sheet flow of fluid entering the plug cavity and a reduced average velocity at the weir exit. This eliminates any chance for high local velocity to cause damage. The weir exit in combination with a tight tolerance between the disk ID and the plug forms an effective labyrinth seal.
6. This minimizes any annular flow that may pass through this area and cause damage

to the seat ring. The sheet flow out of the disk also intercepts any annular flow to divert it away from the sealing surfaces.

The second essential function mentioned above is to maintain a leak free valve. If a leak is allowed to develop, the high pressure, high velocity fluid quickly causes a combination of wire draw and cavitations damage to the sealing surfaces and trim. In some cases the valve body wall or downstream piping pressure integrity can be lost due to erosion or cavitations damage.

To prevent a leak from starting, the design uses a 300 series stainless steel seat and a hardened 400 series stainless steel plug. The seating angles on die plug and a seat ring differ by 3 degrees to assure a circumferential line contact. A very high actuator closing force of about 1000 pounds per inch (18 kg/mm) of mating plug/seat line is used. This assures a good line contact on every closure because the 300 series seat material deforms to mate perfectly with the plug.

The seat design evolved from many tests on installed recirculation valves, Variables were seat angles, actuator force per seal length, and material combinations. One very surprising result was that the use of stellited mating surfaces had the shortest seal life, which is contrary to normal perceptions. The reason for failure is believed to be the lack of accommodation of imperfections by the very hard surfaces. Small deviations in part roundness and/or alignment due to varying assembly care cannot be tolerated. The 300/400 series combinations are much more forgiving in the real industrial plant world.

Two other design features are incorporated to extend die sealing life. The first of these is the over-the-plug flow direction. This feature prohibits significant trash from passing through and causing damage to the seat or getting lodged between the seat ring and plug.

The second feature is applicable only to the modulation valves versus the on-off version. A snap action relay is used on the actuator to cause the valve to close when operating within 5 percent of the seat ring. This amounts to one percent of the pump rated flow. Thus operation of the plug this close to the seat is prohibited. If very low openings are permitted, velocities can be very high as die total pressure drop is absorbed in the small gap between die sealing surfaces. These velocities can cause local cavitations and seat damage thus leading to quick failure.

All of the above features for controlling the fluid velocity and maintaining a tight shut-off are necessary. There is very little room for compromise. If any of the features are not present the life of the valve will be reduced. If die sealing features are not implemented, valve life will be drastically reduced.

Velocity, Pressure Profiles

The pressure drop across a restriction is proportional to the square of the average velocity. The proportionality constant is a function of the fluid density and the nature of the restriction. Ignoring the minor differences between various restrictions the influence of the number of pressure loss stages on velocity can be established for comparative purposes. This comparison is shown in Table 1 for 175 °C water at 3800 psi and for equal pressure drop stages. Since the pressure drop per

Table 1: % Water Velocity for a 3800 psi Drop

(Equal Pressure Drop Stages)	
No. of Stages	**m/sec**
1	240
2	170
3	140
4	120
6	100
8	75

stage is seldom equal, actual water velocities are much greater than the averages shown in Table 1.

The high velocities in Table 1 illustrate the potential for erosion damage and imply the reasons for cavitations. The cavitations damage occurs when the high velocity fluid must de-accelerate to a more reasonable pipe velocity, usually less than 30 m/sec. The pressure recovery that results in this slowing process is significant and any vapor bubbles that are present collapse.

This causes the cavitations damage that is so prevalent in most feed water recirculation valve designs.

In the design discussed here the fluid is permitted accelerate to an initial velocity, which is much less than the velocity for even an eight-stage trim. A large pressure drop per stage then takes place at the highest fluid pressures. A gentle letdown of the pressure then progresses with decreasing velocity to the outlet of the last stage. There is no pressure recovery throughout the trim nor does the pressure drop pass the vapor pressure to cause bubble formation or collapse.

SUMMARY

An unique feature of this valve is that the flow passage through the control section is broken up into numerous smaller passages. Each flow passages is also continuously increasing in flow area so that the velocities are continuously reducing thus minimizing the potential for damaging pressure recovery. Improved sever service valve design has been described. The valve performs the necessary dual functions of controlling fluid velocities during the pressure letdown and provides tight shutoff when closed. The fluid velocity is controlled via a 24 stage tortuous trim disk stack. The trim has additional features to eliminate trash damage, local velocity damage and has an effective plug/stack seal. The tight shutoff is achieved by a combination of high actuator force amplified by the plug/seat interface geometry and a combination of materials for the plug and seat ring.

REFERENCES

1. Afnor N F (1998), "Industrial Process Control Valves", *Flow Capacity Test Procedures*, EN60534-2-3.
2. Hammitt F G (1980), "Cavitation and Liquid Impact Erosion", *Wear Control Handbook*, ASME Press, New York.
3. Hughes M (1985), "Nomogran Estimates Saving from Efficiency Improvements", *Power Engineering*, September, p. 58.
4. ISA-RP75.23 (1995), "Consideration for Evaluating Control Valve Cavitations", ISA Press, Research Triangle Park, North Carolina.

5. Keefe O William (1979), “New Ideas Help Feed Pump Recirculation Valves”, pp. 72-76.

6. Miller H L and Sterud C G (1987), “A High Pressure Recirculation Valve”, August, Presented at Electric Power Research Institutes Power Plant Symposium, Kansas City.

7. Mortt M W (1985), “Control Philosophy and Valve Requirements for Feed Pump Recirculation System”, International Conference on Developments in Valves and Actuations for Fluid Control, September 10-12.

8. Power Magazine (1982), “Compare Feed Pump Recirculation Losses: On/Off versus Modulating Controlling” , November, p. 284.

9. Schumacher M and Gossett (1983), “Selecting Material for Recirculation’s Valves Used in Secondary Recovery System”, *Oil and Gas Journal*, February 28.

10. Van Blarcon P P and Schmitt R D (1980), “Avoiding Vapor Flashings in High Temperature Fluids’ in Tech”, February, pp. 75-76.