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BLACK POINT GAS PIPELINE STORAGE PRESSURE LETDOWN CONTROL VALVES

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Abstract

A long 778 km high pressure, submarine pipeline supplying natural gas will serve multiple combined cycle gas turbine peaking units on the Pacific Rim. The gas supply flow into the pipeline is constant, but the power plant will primarily operate during daylight hours or in certain situations, operate in a two-shift mode. So the pipeline essentially serves as an increasing pressure, gas storage vessel during the night, and pressure falls off during the day as the gas is fired. Hence, the gas letdown receiving station presented many critical design challenges. Among these were the need for constant plant service pressure control, especially during individual power generator unit startup, shutdown, and upset conditions. In addition, there was a very severe noise attenuation requirement and high gas flow rangeability was required. This complex, integrated gas pressure, control valve letdown system and its operation is described in detail.

Introduction

Castle Peak Power Co. Ltd., (a joint undertaking of China Light & Power, Ltd. and Exxon Energy, Ltd.) are installing eight, 312-MW, combined cycle units at their new Black Point Power Station in Hong Kong. Natural gas will be supplied through a high pressure, 28 inch pipeline from Yacheng 13-1 gas field offshore wells near Hainan Island, 484 miles (778 km) to the southwest. These eight combined cycle units essentially operate as peaking units during the day time, or over a period of two shifts.

Letdown station design specified a maximum inlet gas pressure of 2190 psig (15.2 MPa); a constant outlet gas pressure to the power plant of 573 psig (4.1 MPa); with gas flows varying between zero and 720 MMSCFD.

Noise attenuation is extremely important in view of station location and its proximity to populated areas. This was specified to be 85 dBA from plant. Daily station startup and shutdown posed their own special requirements.

In addition, possible gas pressure spikes that could occur during upsets had to be prevented.

Pressure Letdown Reducing Station

To meet these stringent requirements, several basic pressure reducing valve and control arrangements were thoroughly investigated and found to be inadequate in one way or another.

One valving arrangement investigated involved three valves in parallel: a small fine control valve and two coarse control valves operating in a split range mode in parallel. However, due to a downstream, gas velocity limitation of 70 ft/sec (21 m/sec) a serious piping problem arose. It would have required the piping size for the first coarse control valve to have been 28 inch, which would negatively impact cost. Further, the first coarse control valve would have to handle a much higher pressure drop than the second coarse control valve as supply line pressure is reduced during the operating day. Thus, the two coarse control valves would have to be of different sizes, negatively impacting parts interchangeability.

As a result of these various studies to meet the stringent operating requirements, the basic letdown station valve arrangement shown in Figure 1 was selected. These requirements included: the 70 ft/sec (21 m/sec) downstream piping gas velocity limit, lowest installed system costs, and meeting all other operating requirements.

Absolute reliability was required, and to attain this goal, two entirely separate but duplicate and parallel, pressure letdown stations are being installed. Block valves are being installed around each duplicate letdown station for isolation purposes and to provide for letdown station maintenance during daily operation.

This arrangement shown in Figure 1 involves one, relatively small, multiple pressure reducing valve which serves sequential unit startup and shutdown gas needs. In addition, this valve will be used during the daily plant operation to assure accurate fine control of the gas flow. In parallel with this smaller valve, are two larger valves for coarse control of full gas flow to the eight combined cycle units. Two, rapid acting, monitor valves downstream from these valves provide immediate shutdown in case of emergency need. They also provide a backup control function in the event of coarse control valve inoperability.

Station Operation

During sequential unit startup, the 4 inch (100 mm) startup/shutdown/fine control valve will supply the gas needs of the initial units on startup in the morning and the last units shutdown in the evening. It controls gas flow up to about 80 percent of its maximum rated flow of 40 MMSCFD. At this point, both 14 inch (350 mm) coarse control valves begin to open in parallel, and the 4 inch valve drops back to about 50 percent of its rated flow, assuming its fine control function during the daily period of high gas flow. Thus, during the day with all units operational, the vast bulk of the needed gas flow will be handled by the large coarse control valves in parallel with the single, smaller fine control valve constantly maintaining the precisely needed gas pressure to the eight combined cycle generating units.

Several additional extremely important factors in this complex startup and shutdown operating mode required special valve design attention:

1. That the bulk gas flow transfer from the small startup/shutdown/fine control valve to the parallel, coarse control valves be "bumpless," i.e. that it occurs smoothly and without creating a downstream gas pressure spike.

2. In view of the high level of gas flow control required, valve actuator response times from fully open to closed were specified at less than 5 seconds in the smaller, fine control valves and less than 7 seconds in the larger, coarse control valves.

3. High rangeability was required: 150:1 for the fine control valves and 75:1 for the parallel, coarse control valves.

Multiple Pressure Reducing Valves

In both redundant strings of letdown valves, the fine control valve and the two parallel coarse control valves, Figure 2, are of the multiple pressure reduction, tortuous path design. That is, pressure energy is dissipated at a controlled velocity head through multiple, right angle turns in a stack of electric discharge machined individual disks.

The stacks of these disks surround the valve plugs throughout their stroke, Figure 3. Exit velocity head ($\rho V^2/2$) from a stack of disks is limited to 70 psi (0.48 MPa) to minimize noise and vibration. Since it takes into account fluid density, it has been established that velocity head is a better criterion than just pure velocity for judging design adequacy in pressure reducing valves. It is very useful in eliminating the destructive effects of high fluid velocity in noise/vibration problems.

This tortuous path, velocity control design limits noise levels to below the 85 dBA specified for this pressure letdown station. These multiple pressure reducing valves are ANSI Class 1500 with an ANSI Class V plug/seat design and materials to assure tight valve closure at shutoff.

In addition, the disk stack incorporates a pressure equalizing ring (PER) on its inside diameter. This ensures equal pressure acting radially on the valve plug at all times. This eliminates the vibration that could occur because of rapid plug radial movement and pressure forces on the plug which could cause plug guide galling.

Discrete groups of tortuous path disks within the valve disk stacks were used to "characterize" the stack trim for inherent linearity. The characterization of the two valves also assures overlap in the capacity rate change at the transfer of control between the fine and coarse valves. This produces a valve plug travel directly proportional to valve flow requirements. The number of right angle turns for each disk group ranges from 8 to 20 in the smaller fine control valve and 4 to 20 in the parallel, coarse control valves.

Characterization permits precise velocity control over the total valve plug stroke range and results in good control at all flows. Figure 4 shows the characterization curve for the fine control valve; Figure 5 shows the characterization curve for each coarse control valve.

The 14 inch monitor valves were also characterized although their trim is not of the tortuous path design. Rather, these valves have drilled hole, single stage, cage type trim. Characterization is achieved by varying the diameters of these drilled holes in three groups throughout valve plug travel. Because these normally on/off monitor valves are also characterized, they can take over gas flow control in the event of a corresponding coarse control valve failure. Since they operate so infrequently, strict noise attenuation was not a requirement.

As previously mentioned, smooth gas flow load transfer between valves during startup and shutdown operations had to be closely coordinated to provide a "bumpless" load transfer, i.e. producing no pressure spikes. Figure 6 depicts how this was achieved.

Note that while Figures 4 and 5 plotted percent C_v vs. percent valve stroke, Figure 6 shows actual C_v vs. valve stroke in absolute travel.

On increasing demand, the load transfer is initiated when the fine control valve reaches 80 percent of its stroke. At this point, the system demand results in a total capacity (C_v) of 76. As the coarse control valves open, the smaller fine control valve backs down to a 50 percent open position where this valve has a C_v of 26. Coincident with the fine control valve reducing its capacity, each large coarse control valve opens to a capacity (C_v) of 25 (total C_v equals 50 for the two valves). Thus, the three valves operating in parallel produce the required system capacity of 76.

To assure that this transfer takes place without system perturbation, the rate of change in capacity of the small and large valves must be nearly equal. The rate of change in capacity is the slope of the C_v versus stroke curves shown on Figure 6. At transfer, the fine control valve changes at a rate of 26 C_v per inch of travel. This is essentially equal to the rate of change for the combined coarse control valves. This change occurs between shutoff and slightly over 8 percent of the coarse control valves travel. Small differences between the rate of change of capacity and stroke speed are compensated for by the valve control system. A "bumpless" transfer of load is therefore easily achieved.

Actuators

In all cases, pneumatic actuators operate the pressure reducing and monitor valves. The control schematic for the smaller, and the larger, coarse control valves is shown in Figure 7. The fine control valves and the coarse control valves automatically fail closed. A minimum flow function in the software control scheme will not allow the coarse control valves to operate below a minimum, controllable flow. This also precludes plug/seat erosion due to high gas velocity under very low flow conditions.

Conclusion

This pressure letdown arrangement of valves and controls will successfully met all the noise level, "bumpless" gas flow transfer, and rangeability requirements needed by the Black Point Power Station.

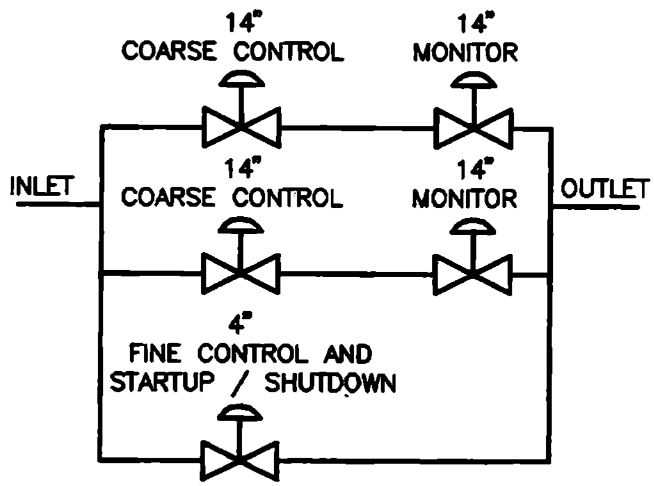

Figure 1. Letdown Valve Arrangement

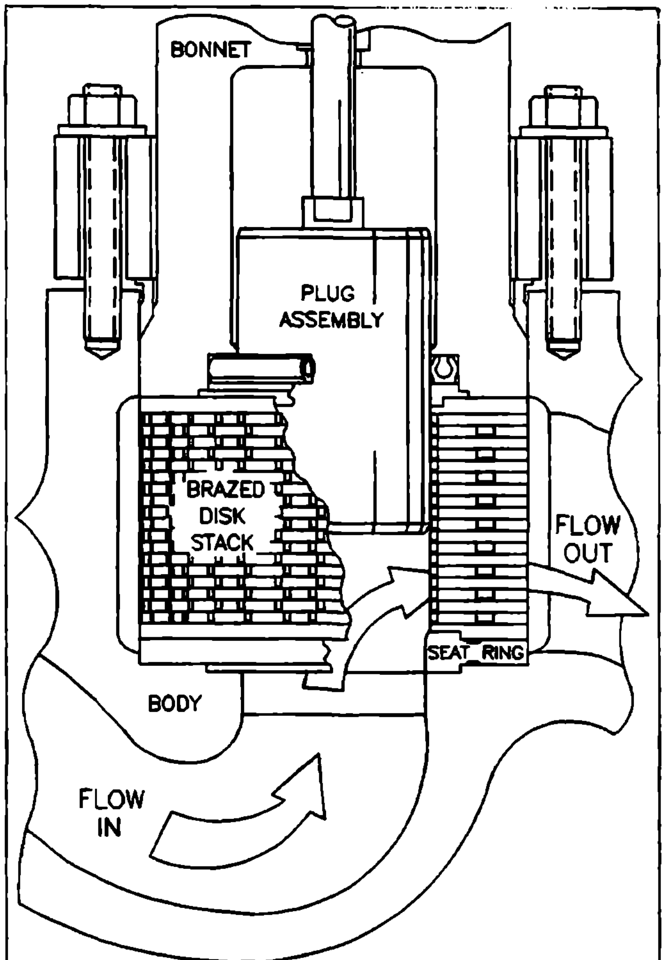

Figure 2. Multi-stage, Pressure reducing Valve Sectional

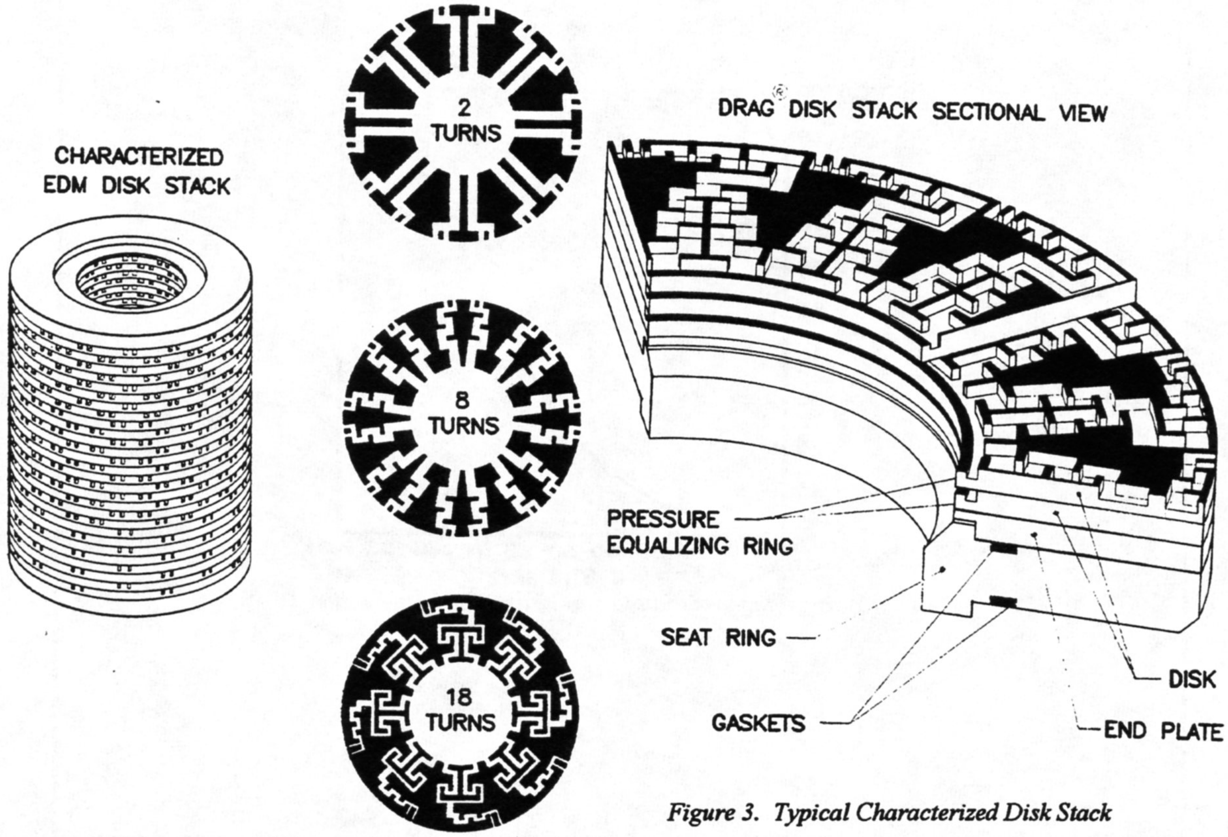

Figure 3. Typical Characterized Disk Stack

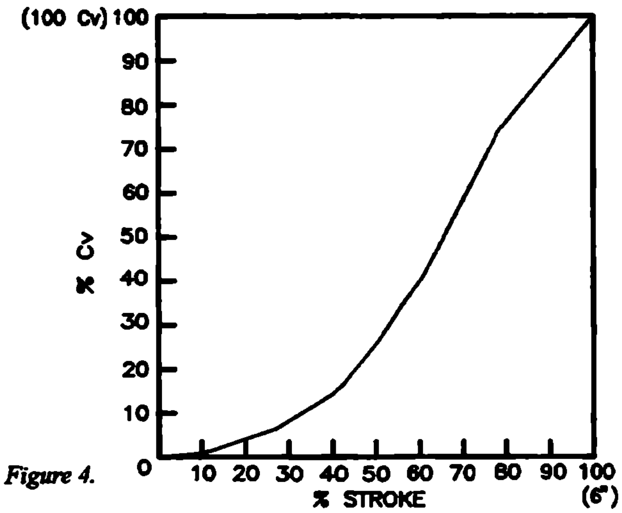

Figure 4.

4 Inch Startup/Shutdown/Fine Control Valve Characterization

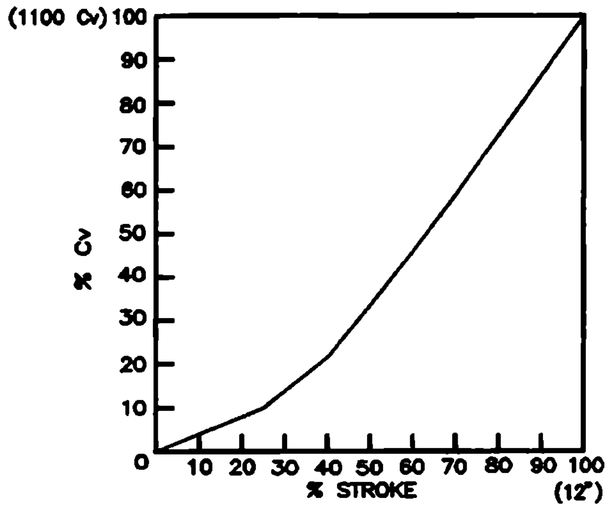

Figure 5. 14 Inch Coarse Control Valve Characterization

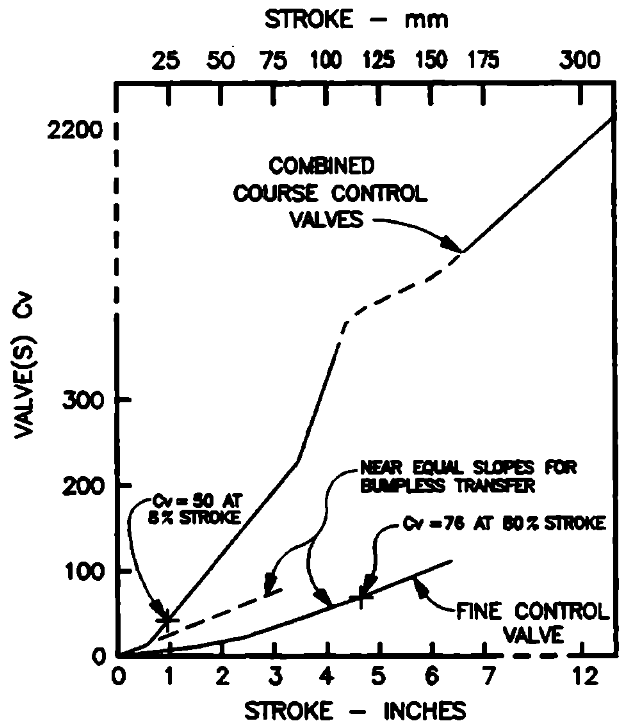

Figure 6. Valve Capacity and Rate Change Versus Stroke

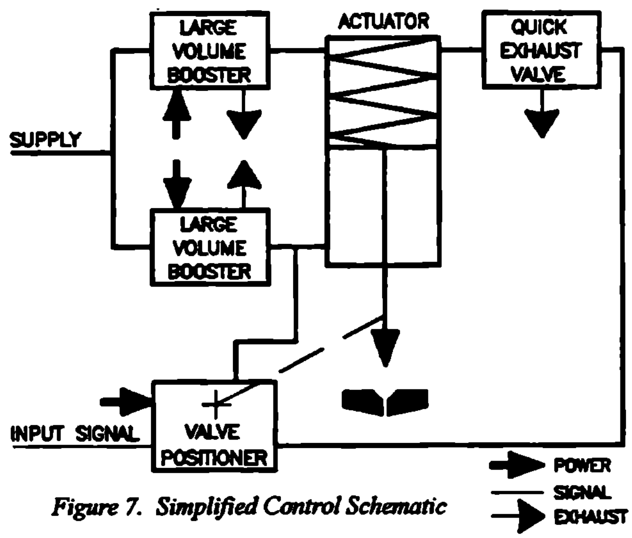

Figure 7. Simplified Control Schematic