We Solve Control Valve Problems®

Duke Energy Catawba Nuclear Station Solving Cavitation Problems

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Presented at AUG January 8-12, 2007

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Catawba Nuclear Station is a two unit 1,145 MWe each PWR nuclear plant located in Clover, South Carolina. The plant design employs forced air Cooling Towers taking make-up service water from Lake Wylie. Cooling Tower basin water level is monitored with a sensor to signal valve position to maintain basin water level. The original plant configuration had make-up water tied from the Low Pressure service water system to Cooling Tower basins through a 2000 ft. long sub-grade 30 in. pipe using two electro-hydraulic operated butterfly valves for isolation and throttling service.

Since the 1985 initial start-up, Catawba Unit 1 and subsequently Unit 2 experienced severe cavitation and erosion damage of two each Cooling Tower basin level butterfly control valves when used for make-up flow throttling. These valves trended to produce the highest level of corrective work orders of all valves located in the raw water system and exhibited excessive cost for repair.

Cavitation in the butterfly control valves was severe enough to cause easily detected ground vibration. Cavitation induced valve oscillation resulted in mechanical damage of linkage between the valve and actuator which required repair or replacement every outage. Unsuccessful attempts were made to reinforce actuator to valve connection to tolerate vibration.

As part of a year 2001 plant design enhancement to address biological formation and fouling in the subject Cooling Tower basin level make-up line, Duke Energy elected to abandon in place, the make-up line and establish a replacement cross tie connection. The new cross tie connection was decided to be located between the existing Condenser Circulating Water system and Low Pressure service water system for Cooling Tower basin level make-up purposes. This new configuration eliminated the high cost of repairing or replacing 2000 ft. of sub-grade level pipe and allowed reduction of basin water level control valve quantity from two to one for each Unit.

Existing electro-hydraulic actuated butterfly valves were located adjacent to the Cooling Towers. Relocation of the upgrade motor operated control valves to a convenient, remote area where a new cross tie connection would be established was considered and approved.

Raw water supplied from Lake Wylie has above average dissolved solids measuring 53 ppm and suspended solids ranging from 8-175 ppm. Service water pump discharge screens are designed limit particulate by-pass size to less than 1/8 in. A motor operated control valve specifically designed to tolerate Catawba raw water conditions to mitigate clogging and seat damage, and to prevent development of micro biological growth through design elimination of stagnant flow regions was required. Pressure differential across the two systems to be connected, tight shut off and improved system response to compensate for anticipated thermal lag from valve relocation of 1,500 ft. greater distance was also carefully considered.

ROOT CAUSE ANALYSIS

The service conditions for this application (Table 1) shows that the pressure drop across the valve to be in the range of 25-35 psid, which was not considered too severe. However, the Cavitation Index "σ" in the range of 2.16 to 1.74 for a butterfly valve is severe enough to cause cavitation. Another cause was the excessive trim exit velocity that peaks at a value of 73 ft/sec, which is quite high in a large service water line.

Also, the amount of horsepower available in the exit jet was computed and found to be over 300. This is an enormous energy available to excite the valve and other pipeline components.

The solution to this problem is to reduce the amount of trim exit velocity and the available horsepower in the jet exit by an order of magnitude.

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Table 1: Service Conditions

Fluid	Water			
Critical Pressure	psi G	3194		
Critical Temperature	deg F	705.5		
Condition		Max Normal	Max X-Conn	Min
Fluid State		Water	Water	Water
Liquid Vol Flow Rate	gpm(US)	22000	22000	15000
Mass Flow Rate	W, lbm/hr	10,959,951	10,959,951	7,472,694
Inlet Pressure	psi G	39.6	32.6	47.8
Outlet Pressure	psi G	14.8	14.8	12.3
Pressure Differential	psi	24.8	17.8	35.5
Inlet Temperature	deg F	90.0	90.0	90.0
Density	lbm/ft3	62.12	62.12	62.12
Vapor Pressure	psi G	-14.0	-14.0	-14.0
Service Cavitation Index	$\sigma_1 = \frac{P_1 - P_V}{P_1 - P_2}$	2.16	2.62	1.74
Required Flow Capacity	Cv	6354.4	6814.6	4035.1
Trim Exit Velocity of BFV	V, ft/sec	60.8	51.5	72.8
Power in Jet Exit $P = W \frac{V^2}{2g_c(1.98\times10^6)}$	hp	318.0	228.2	310.8
With 4 stage DRAG	V, ft/sec	19.8	16.8	23.7
Power in Jet Exit $P = W \frac{V^2}{2g_c(1.98\times10^6)}$	hp	33.7	24.3	32.9

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SOLUTION

After lengthy evaluation of alternative solutions, Duke selected CCI's DRAG® control valve with Limitorque brand modulating motor operator to address valve cavitation wear and system response anomalies. To correct conditions of cavitation and erosion, the new control valve was specified as a 24 x 24 angle type with four pressure let down stages in multi-path, radial configuration (Figure 1).

The velocity in the jet exit was reduced to a maximum of 24 ft/sec and the jet exit horsepower to 34 which is less by a factor of 10 (Table 1). Valve plug size is 22 in. with large 26 in. stroke that optimizes mechanical rangeability and thus provides fine loop response to compensate for increased distance in control element location.

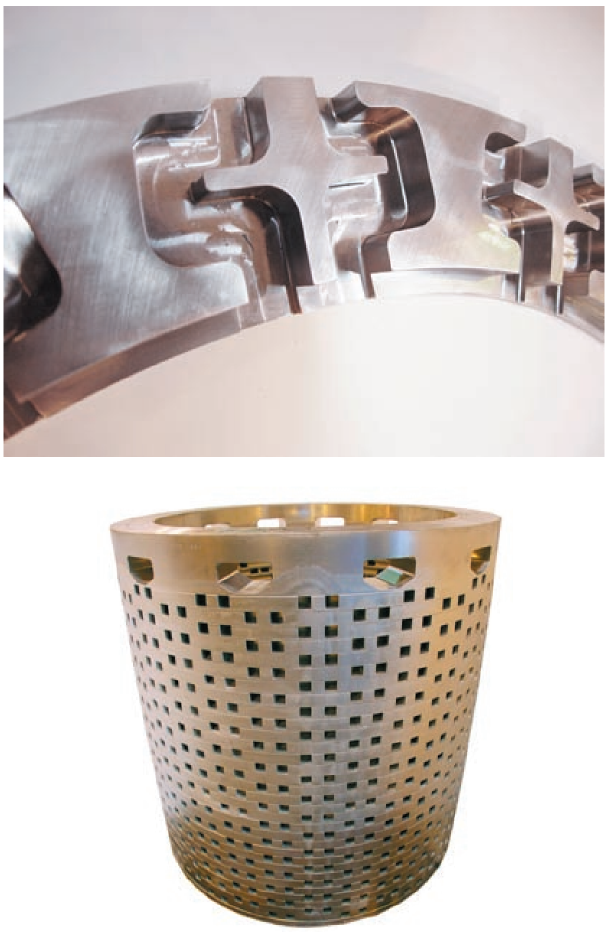

Figure 1: 4 Stage DRAG® trim with large passages, complete disk stack

CCI's control valve passages were specifically engineered to accommodate Catawba NPP raw water solids and conditions without clogging. The passages were carefully designed so that any encrustation may be mechanically removed by a rotary tool (Figure 2). All stainless steel construction was specified by the plant for improved environmental compatibility and elimination of coating repair costs (Figure 3).

CONCLUSION

Since the 2001 installation of DRAG® control valves in Catawba NPP's raw water system, no valve related failures or clogging have occurred, dispelling concern that a radial path control valve may not accommodate debris particles suspended in medium. The new configuration has proven to eliminate vibration. Valve life extension is attributed to a decrease in trim exit flow velocities and resulting reduction in jet exit horsepower acting as an aging mechanism on the original valve.

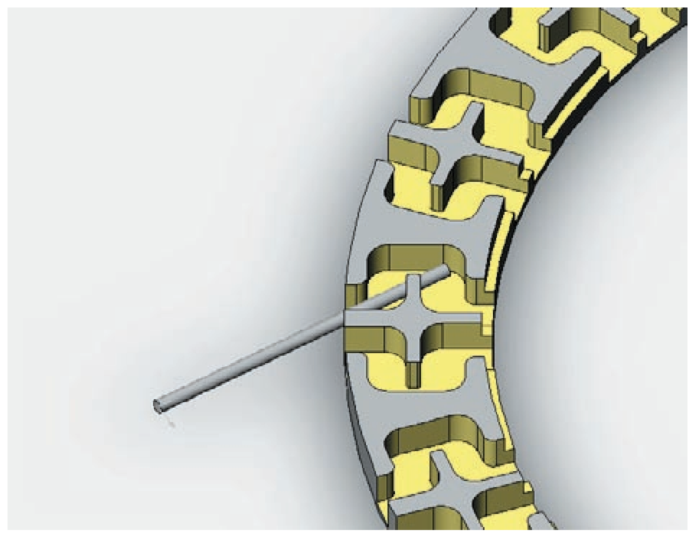

Figure 2: Simulated Rotary tool cleaning of disk passages

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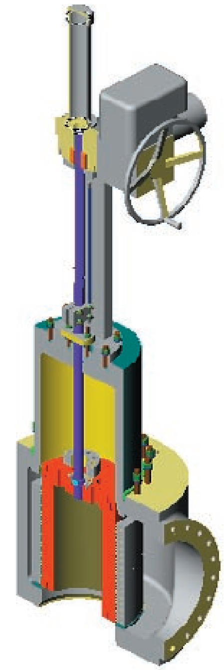

Figure 3: Complete valve undergoing shop test, section view of valve. Note all stainless steel construction.

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