POWER
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BT valve adapts plant for sliding-pressure operation

Boiler throttle valve installations result in excellent plant operation. A special computer program shows good correlation between design and operating parameters

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In 1989, Louisiana Power & Light Co. retrofitted Unit 4 of its Ninemile Point power plant from base load into a sliding-pressure mode that permits operation at 10% maximum control rating load. This was the first such retrofit of a Combustion Engineering combined-circulation, once-through steam generator in the U.S. The retrofit was dictated by current and future operational requirements.

System demand basis is determined by the dispatcher. Therefore, this unit could be called upon for frequent and drastic load changes. Other goals included a faster load-change capability and maintaining relatively constant turbine first-stage temperature throughout sliding-pressure operation in order to minimize thermal stresses in the turbine.

Ninemile's Unit 4 retrofit

Unit 4 is rated at 748 MW net (762 MW gross) and has a supercritical, combined-circulation, once-through steam generator rated at 3850 psig/1010 F/1005 F (270 kg/cm2/543 C/540 C). Many modifications were implemented during the fall 1989 outage to effect these alterations in desired operating mode. In addition to boiler-throttle (BT) valve replacements, modifications included the addition of a new 10,000-hp (7457 kW), motor-driven boiler feed pump for start-up and low load service, main boiler feed pump turbine control replacement, steam generator control replacement, auxiliary turbine-generator board modification, and related instrumentation changes.

BT valve operation

As originally designed for base load operation (from full to 25% load), the boiler throttle bypass (BTB) and boiler throttle (BT) complex contained three smaller BTB valves and five larger BT valves between the steam generator and the primary superheater. These were replaced with five identical 14-in. tortuous-path, pressurized-seat BT valves specifically designed for sliding-pressure operation. They are used to slide the load from the optimum turbine valve control point of 540 MW gross (70% load) down to approximately 75 MW gross (10% load).

Figure 1 is a partial schematic of Unit 4's cycle showing the five new BT valves. Figure 2 shows BT valve operation within a 10%-70% load range and beyond. Throughout this load change, 75% of the turbine governor valves (six of the eight valves) are maintained at a point where the other two valves begin to open for loads above 540 MW gross. A waterwall pressure of 3500 psi (246 kg/cm²) is maintained by the BT valves.

Below 10% load, turbine steam is provided from the separator tank. Between 10% and 40% load, the BT2 and BT4 valves control flow to the primary superheater. At 40% load, the BT1, BT3, and BT5 valves begin to open and modulate

Right: Louisiana Power & Light Co. Ninemile Point power plant. Unit 4 (inset) is second from left.

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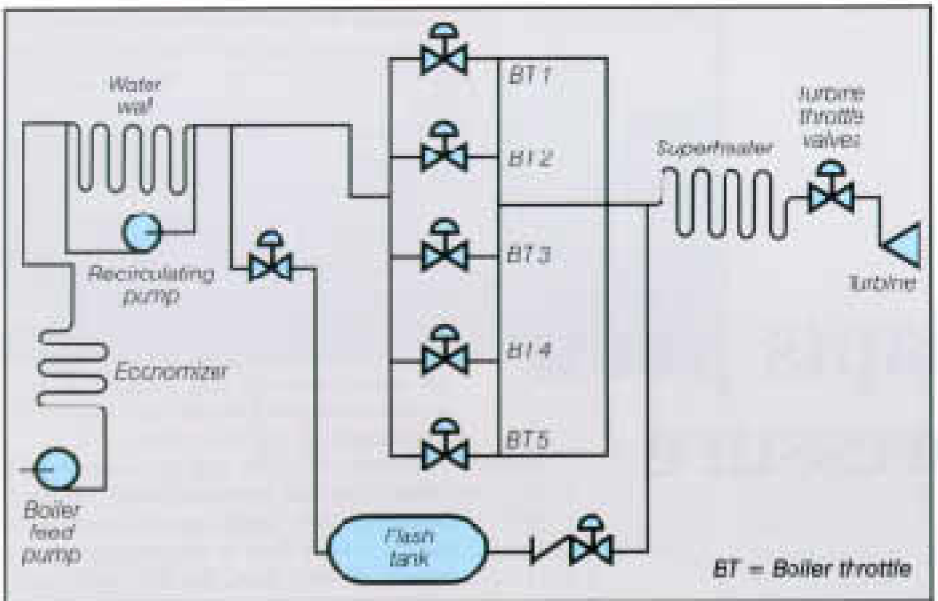

Figure 1. Partial cycle schematic with valve locations.

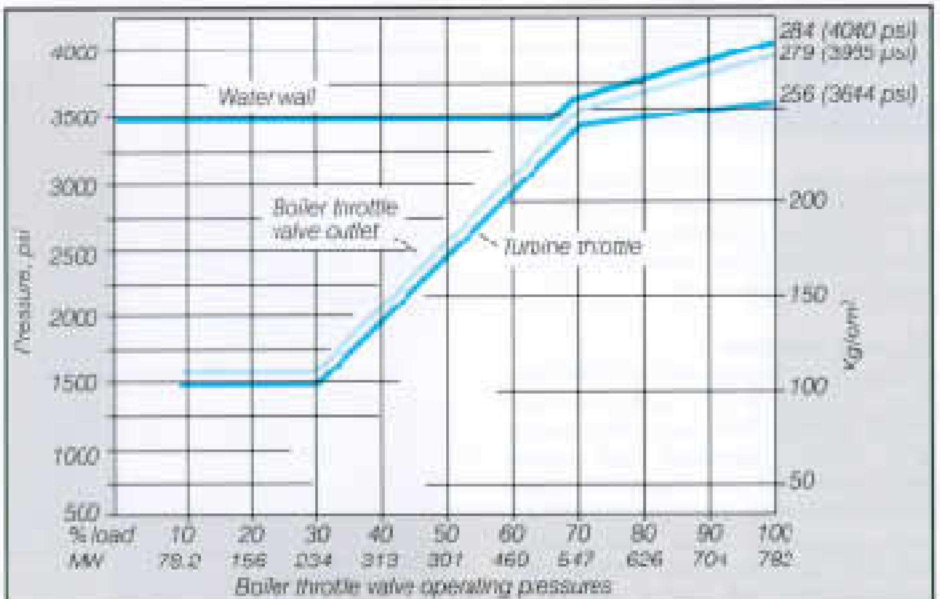

Figure 2. Boiler throttle valve operating pressures.

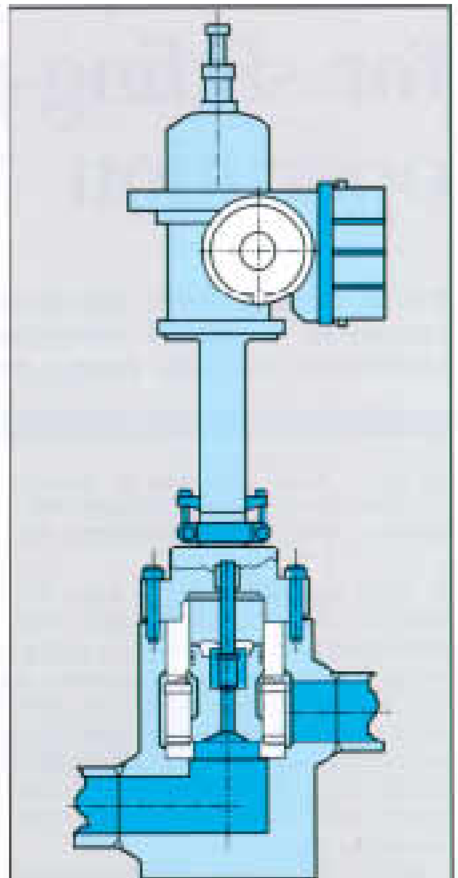
Figure 3. Pressurized seat boiler throttle valve.

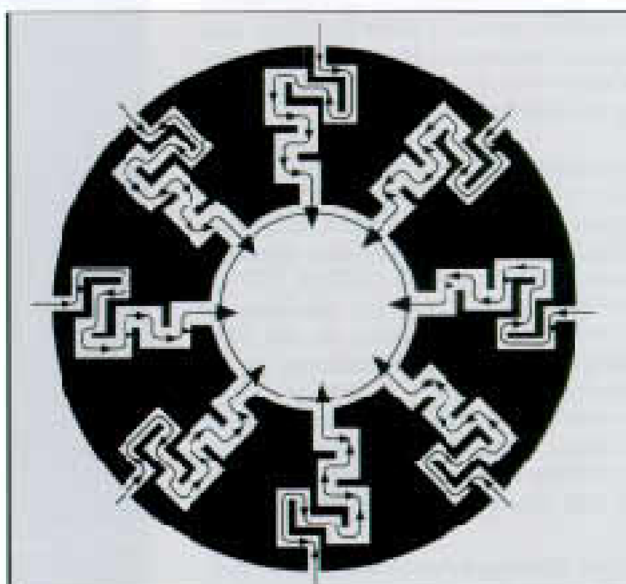
Figure 4. Multistage, tortuous path disk.

flow up to 70% load, maintaining waterwall pressure. At this point, all BT valves are opened (from approximately 85% of stroke to 100% of stroke), the turbine governor valves are indexed to take over control, and turbine throttle pressure ramps from 3500 psig (246 kg/cm2) to 3675 psig (258 kg/cm'). Below 540 MW gross, the turbine throttle pressure is ramped between 3500 psig (246 kg/cm2) and 1500 psig (105 kg/cm2) and is maintained by the unit's steam-generator controls.

BT valve design

These five BT valves (Figure 3) are of the tortuous-path design for long life and optimum operation. Designed for severe service, they contain eight disks (3.2 mm disk thickness) per inch of stroke. The disks (Figure 4) dissipate pressure energy internally through abrupt right-angle turns. Because the flow paths are fixed in each disk in the stack, individual disk flow is constant at any degree of modulation through the valve. Thus, fluid velocities are limited. Close velocity control is especially important in steam and two-phase steam/water flow to keep energy levels manageable and to limit noise and vibration potentials.

An overriding design consideration in this BT valve service is to ensure absolute velocity control, repeatability , and resolution for high differential pressure at all variable flows. The typical disk can be varied by changing the number of right-angle turns to produce different pressure drops. Figure 5 shows the sequence of valve operation and valve position as a function of steam flow.

Discrete groups of tortuous-path disks within each stack can be designed (characterized) to produce the varying pressure-drop characteristics required at specific valve-stroke positions. Thus, the BT valves can be designed to maintain proper control throughout their range of operation.

Figure 6 shows the three zones (or disk

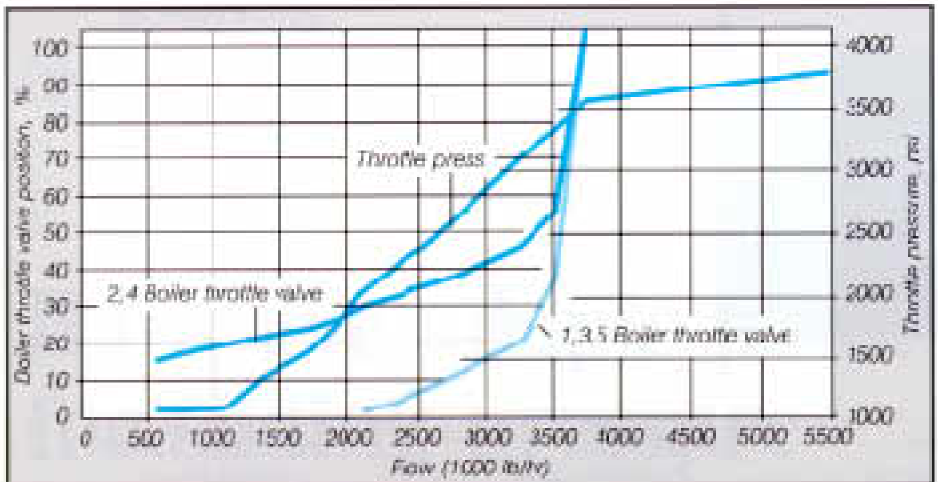

Figure 5. Boiler throttle valve positions.

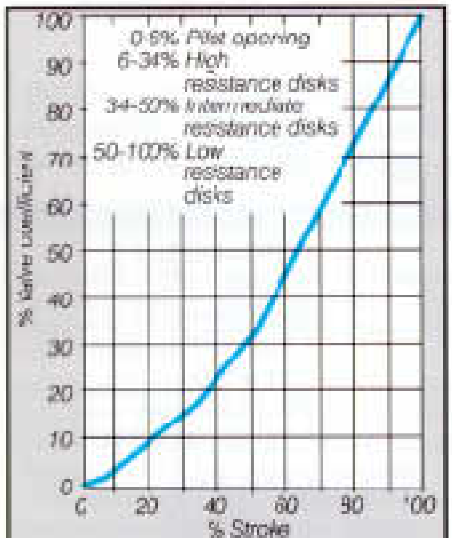

Figure 6. Disk stack characterization.

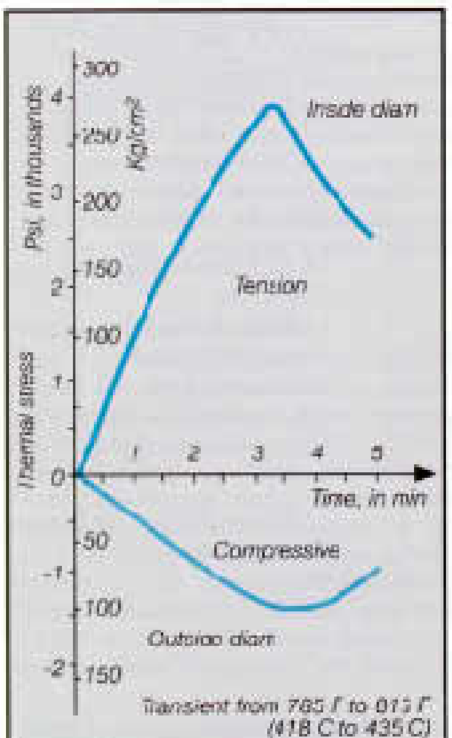

Figure 7. Typical thermal stress transient.

groups) of characterization used at Nine-mile Point. The disks in zone 1 are characterized to produce linearity from initial valve opening to approximately 3.3 Mlb/hr (1.6 Mkg/hr). Disk characterization in zone 2 produces the needed linearity between 3.3 Mlb/hr (1.6 Mkg/hr) and 3.5 Mlb/hr (1.58 Mkg/hr) for all BT valves. Zone 3 produces linearity from where the turbine throttle valves take over at 3.5 Mlb/hr (1.58 Mkg/hr) to 100% valve stroke.

Pressurized valve seating

Valve-seat design is another important consideration. It must ensure tight closure under high pressure differentials to eliminate the erosive effect of leakage. For this reason, all five BT valves are of the pressurized-seat design. This avoids the need for oversized actuators. In this design, an internal pilot valve loads and unloads the closing force on the plug. When the valve is closed, full upstream pressure behind the plug exerts about 100,000 lb (450 N) of downward closing force. When the actuator is called upon to open the valve, the internal pilot opens first and bleeds off high pressure downstream through ports in the plug. This balances the forces acting on the plug and permits normal actuator loadings to control valve flow modulation.

Valve actuation

Unit 4's BT valve actuators are electrically driven and use ball-screw drives. Although these valves are not sensitive to electrical, pneumatic, or hydraulic actuator design, good actuator resolution is required to prevent excessive valve/feed pump interaction during sliding-pressure operation. LP&L achieved 1/4% resolution. However, other experience shows that these characterized, tortuous-path valves operate successfully in sliding-pressure, cyclic service with only 1% resolution.

Several studies were done during the design of these new BT valves for Unit 4. These include fatigue-life studies conducted in accordance with the methodology of Appendix 5 of the ASME Code, Section VIII, Division 2. They treated critical valve components individually-inlet nozzle, gallery wall, outlet nozzle, and disk stack. Table 1 shows the most severe conditions to be encountered.

Table 1. The most severe conditions encountered at valves.

Component	Combined thermal and pressure stresses - psi (kg per cm²)
F-22 inlet nozzle	7938 (558) +/-3912 (275)
F-22 gallery wall	7938 (558) +/-5700 (401)
F-22 outlet nozzle	9430 (663) +/-766 (54)
Inconel disk stack	30,158 (2121) +/-7915 (557)

Results of fatigue-life studies

Figure 7 shows a typical thermal stress vs time curve during the most severe temperature transient imposed throughout a fast load change. The thermal stresses are combined with the pressure stresses to arrive at the stress oscillations shown in Table 1. The fatigue-life study indicated that allowable operating cycles can exceed [illegible] against the fewer than 10,000 cycles contemplated during the power plant's life.

Conclusions

Plant operation has been satisfactory since the installation of these new BT valves. Their actual operation was checked against design using a special computer program. It showed good correlation between design and operation parameters. There is, however, a 40-psi (2.8 kg/cm2) turbine throttle pressure swing between 10% and approximately 30% load while the BT valves maintain water-wall pressure between 5 and 10 psi (0.35 to 0.70 kg/cm2) of 3500 psig (246 kg/cm2). This currently is being minimized through revised BT valve control strategy and several suggested solutions are now being studied to further minimize the effects of the pressure swings. END

AUTHORS

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