

# Turbine Bypass Valve Technology and Applications



# Design Considerations

The turbine bypass system is a very important component of power stations, and of a difficult service too. Although it does not operate continuously, when it is required to operate it has to be fast and reliable. Its main job is called steam conditioning. It means pressure reduction and desuperheating of steam that has been produced by the boiler but, due to transient or unexpected conditions, can not flow through the turbine.

The percentage of total steam handled by the turbine bypass system depends on plant design philosophy. Capacity usually ranges between 30% up to 100% of the maximum continuous rating (MCR) boiler steam flow.

The high pressure turbine bypass system provides an alternate flow path at the high pressure side of the turbine, taking the steam from the turbine inlet to the reheater inlet section. This bypass system permits stable operation of the boiler when the turbine trips off line or during start-up operations. Steam flowing through the high pressure bypass control valve is throttled and cooled to a temperature slightly above the HP turbine exhaust temperature, by spraying feed water at the outlet of the bypass control valve. This flow is then combined with high pressure exhaust steam and passes through the reheater.

The low pressure turbine bypass system presents a flow path around the LP turbine, taking steam from the reheater outlet and conditioning it to be fed into the condenser. For condenser protection, high pressure and temperature drops are taken by valve throttling and by addition of large amounts of desuperheating spray water, preventing that superheated steam reaches the condenser.

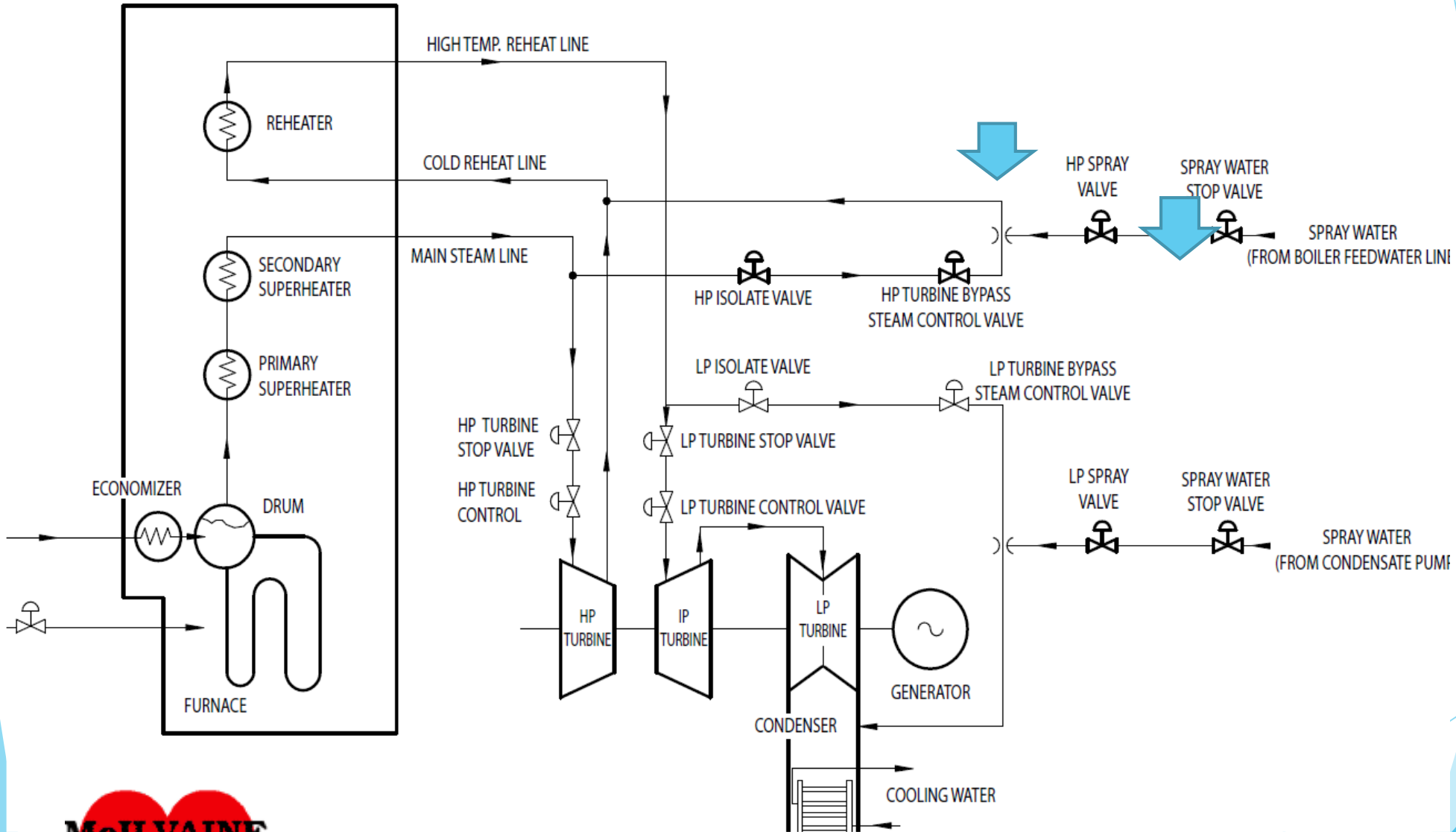


# Siemens 2 x 50% for HP and 1 x 60% for LP

Turbine Bypass System Valves: The purpose of the turbine bypass system is to rapidly dump steam to the condenser in the event of a turbine trip, or to bypass the turbine during startup or commissioning. Multiple, staged valves are used to provide controlled bypass functionality.

Various turbine bypass valving schemes are used, depending on the system design. The bypass system is designed to operate before the pressure safety valves lift off their seats and dump steam to the atmosphere with consequent substantial loss of boiler water. This sometimes is reflected in a bypass system capable of dumping 100% of full-load steam; however, in some designs, a 100% bypass capability is used for the HP turbine and a lower rated capacity in the range of 50% to 70% for the LP turbines. Bypass capacities below 40% of full-load capacity are not recommended. The Siemens Reference Power Plant includes 2 X 50% bypass valve stations for the HP Turbine Bypass, and 1 X 60% bypass valve station for the LP Turbine Bypass.

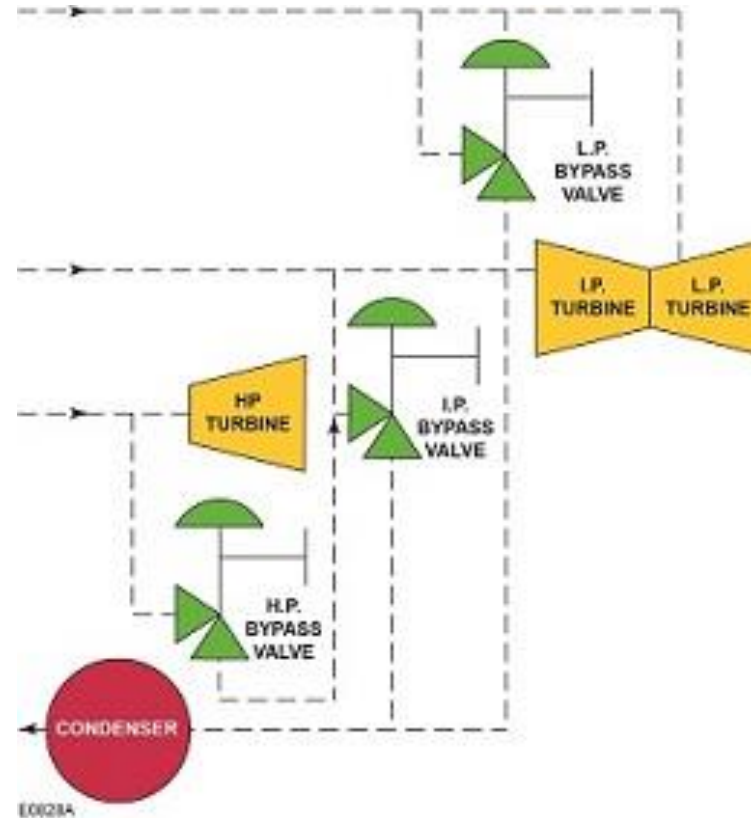




## More Spent on Actuators

As often as four times a year during winter months, a power plant in Wisconsin would miss a scheduled start of its 620 MW combined cycle power plant (Figure 1) due to malfunctions of the turbine bypass valves.

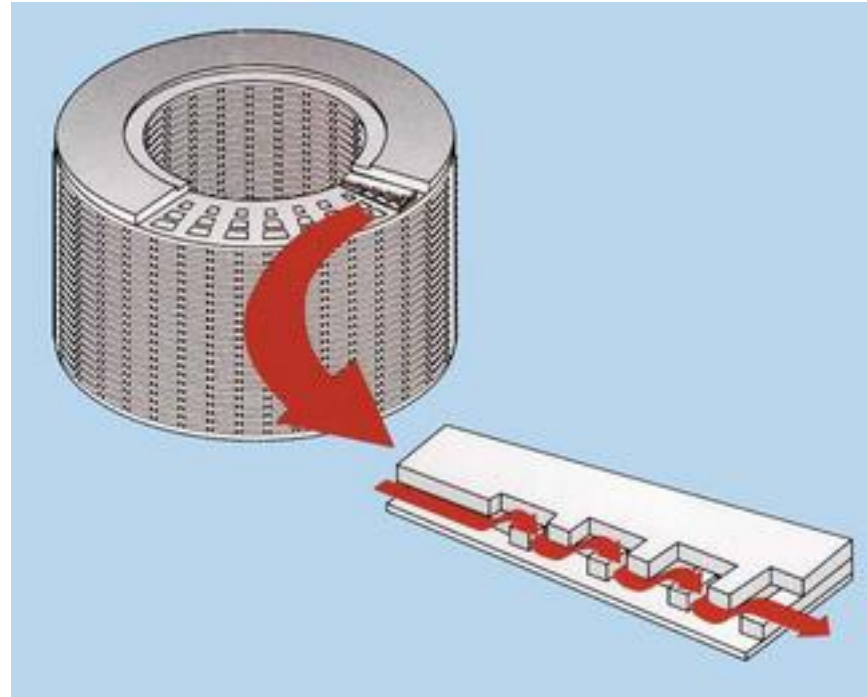
The valves that gave them the most frequent problems were the hot reheat turbine bypass valves. Over time, the plant identified that many of the accessories—including volume boosters, trip valves and solenoid valves—on the original actuator packages were not rated for use in cold weather.



The plant installed six Fisher Type 585C/685 piston actuators (Figure 4) with yoke adapters, remote-mounted type DVC6200 positioners with optimized digital valve (ODV) diagnostics, Fisher SS-263 Volume Boosters, and Model 377 trip valves. <https://www.power-eng.com/2018/08/13/cold-start-improving-turbine-bypass-valve-reliability/#gref>

# Improved Trim Design

A few years ago, the high pressure (HP) feedwater control valves and manually operated HP and reheat superheater drain valves with maximum  $\Delta P$ s of 115 bar failed at AES's 688 MW Medway Power Ltd., plant in the UK. The failure of these drilled-hole, cage-guided control valves was due to excessive trim exit kinetic energy (or velocity head - Hv). The replacement valve trim used takes full advantage of multistage-pressure reduction technology to severely limit this Hv.

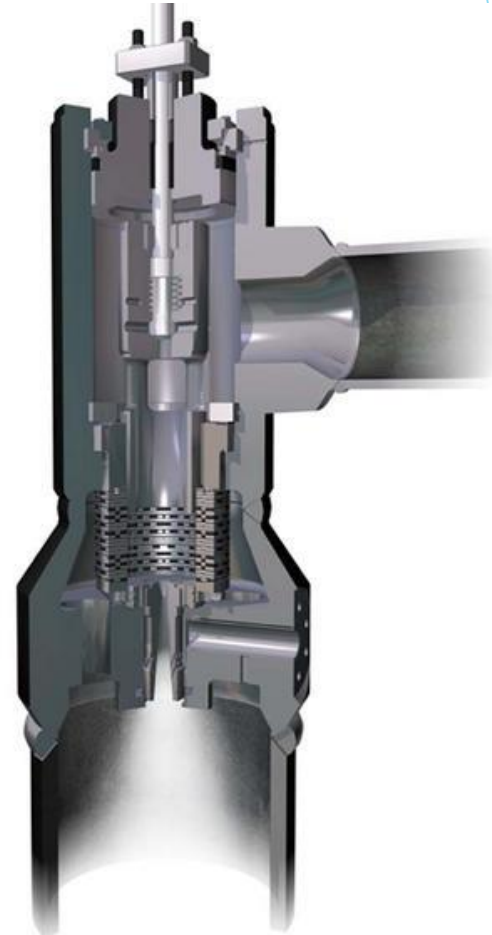


Since then, AES has used this design technology in critical combined cycle, turbine bypass systems in most of its new power plants. In fact in the last five years or so, this critical-service, multistage pressure-reduction technology with severely limited Hv has been utilized internationally in five AES combined cycle plants ranging from the 230 MW AES Barry Power Plant in Wales up to this 705 MW AES Ironwood power plant in Pennsylvania.

# Specific Valve Specifications

The turbine-bypass system at AES Ironwood consists of two, 100 x 250 mm HP steam-bypass-to-cold-reheat valves, two 400 x 400 mm low pressure (LP) steam-bypass-to-condenser, and two 640 x 889 mm hot-reheat-steam-bypass valves to the condenser, with an associated desuperheating spraywater control valve for each steam bypass valve.

The HP bypass-to-cold-reheat valves are designed for steam flows up to 70 kg/s at maximum inlet pressures of 130 bar[a] and  $\Delta P$ s of 115 bar at 570°C. The LP bypass-to-condenser valves are designed for steam flows up to 11 kg/s at maximum inlet pressures of 4 bar[a] and  $\Delta P$ s of 3 bar at 27°C. The hot reheat bypass-to-condenser valves are designed for flows up to 95 kg/s at maximum inlet pressures of 30 bar[a] and  $\Delta P$ s of 29 bar at 570°C





# Specific Issues and Options for steam valves

## Factors creating issues

- Higher temperatures
- Higher pressures
- Fast and frequent cycling
- Entrained water drops

## Resulting issues

- Valve trim wear
- Cavitation
- 'flashing
- Vibration
- Seal damage
- *Is flow accelerated corrosion a problem with valves as it is with other components*

## Options

- Follow ISA guidelines for control valves
- Buy severe service valves (*need definition*)
- Consider special materials and coatings
  - Prevent stellite liberation
  - Fuse coating to base material
- Separate small start up valve for low loads
- Change inspection, operations, and maintenance procedures
- Specify valve after you know pump feed pressure
- Faster response and reliable actuators
- Repair rather than replace
- Buy all HP valves from one vendor
- Do not oversize feedwater valve
- Require tight shut off ( better tolerances)
- Hydraulic actuators for fast response
- Electric actuator increases reliability



# CCGT Severe Service Valve Requirements Relative To Coal Fired Power

- Valve requirements for CCGT power generation are similar in many respects to conventional coal-fired power plants
  - Many of the same valve types are required including pressure relief valves, turbine bypass valves, turbine drain valves, attemperator spray valves, recirculation valves, and others
  - Severe service conditions will apply involving high temperatures, high pressures, high delta P's, and other severe service conditions
  - More “**cycling**” of valves may be expected in CCGT plants due to load variations for plants that are not purely base-load plants, or for plants that serve as peaking plants or backup for renewable power including solar and wind. This creates a special set of thermal and mechanical issues unique to CCGT power plants.

# Who should specify HP valves?

- L&T is supplied a complete solution for HP valves requirements for the UMPP Mundra Project. The innovative packaging concept facilitated in economics of scale, spares and service
- **Mundra Ultra Mega Power Project (Mundra UMPP)** is a [subbituminous coal](#)-fired power plant in Tunda village at [Mundra, Kutch district](#), in [Gujarat](#), India. The coal for the power plant is imported primarily from [Indonesia](#). The source of water for the power plant is seawater from [Gulf of Kutch](#).
- There is the option for complete supply of high pressure valves for either coal plants or combined cycle gas turbine plants.
- L&T is a group within Larsen Toubro who furnishes complete plants and also supplies its own design HRSG.
- So the options are
  - Owner buys all high pressure valves from one supplier
  - Owner buys a high pressure valves from several suppliers and can pick the best from each
  - HRSG supplier provides valves associated with this process
  - Plant supplier specifies and buys valves rather than the owner

# Overview of CCGT Major Systems

(Boiler Feed, HRSG, Turbine, Condenser, Flue gas, other systems)

## Hot reheat bypass valve selection

HRH valve requirements are complex from a mechanical design standpoint. The ANSI 600-lb-rated valves range from 12 to 24 inches in diameter. They must tightly shut off and be able to be throttled (conflicting requirements for such difficult service), and their body and trim materials must deal with rapid thermal transients. Noise control and extended trim life also have become very important design requirements.

Unbalanced HRH valves are typically not used in this application because the actuation forces required for valves of this size would be too large for conventional pneumatic actuators. However, because tight shutoff is a design requirement, pilot-balanced trim is common. This design allows for the use of relatively low actuator thrust at full differential pressure (balanced when open), while enabling full unbalanced forces on the valve seat in the closed position (installed in the flow-to-close direction) to ensure tight shutoff.

Special materials, tolerances, body/trim/bonnet arrangements, and flow paths (warming lines, for example) are used to address the thermal cycling issues that HRH valves must deal with, such as weld fatigue and internal reliability. Many designs have forsaken pneumatic actuators fitted with standard positioners and volume boosters to meet stroking speed requirements in favor of smart positioners with boosters that improve diagnostic capabilities and reduce overshoot.

# Specific Issues and Evaluation Considerations

(Repair/Replace)

By Arvo Eilau, Pentair Valves & Controls

Current global power generation market conditions, driven by an abundance of natural gas fuel, recent advances in gas turbine technologies and more efficient combined-cycle component operation, have placed enormous demands on critical valves within thermal generation systems.

Pentair proceeded to review valve products designed for combined-cycle power facilities in these small to medium bore drain and vent applications. Applications were selected for their severe duty cycles (temperature and flow), directly related to cycling of the combustion turbine/heat recovery steam generator, and their strict boiler and piping code design requirements. Our project objective, beyond continuous product improvement, was to evaluate the products' overall contribution to the customer's corporate strategy objectives as previously outlined. **This research would also compare a repairable product to a replacement product to determine which offered superior benefits.**

## Application

Boiler Feed

Turbine Bypass

Turbine Control

Hazardous Fluid Handling

Two-Seated Valves

**Inlet Air**

**Repair/Replace**



# Specific Issues and Evaluation Considerations

## (Repair/Replace)

### Conclusions

This study revealed that the cost to repair this type of critical thermal valve is significantly lower than the cost to replace it after every cycle. The fact that Pentair's Yarway Welbond repairable valves can be repaired inline is an additional benefit. Repairing is also a more sustainable solution, as it reduces the total process cycle.

Initial Capital Cost		3	
Valve	\$1,600.00		
Insulation	\$225.00		
Craft Labor (Welding)	\$1,050.00		
Non Destructive Examination	\$150.00		
<b>Total</b>	<b>\$3,025.00</b>		
<b>Repair Cycle 1</b>	<b>\$380.00</b>	<b>Replacement Cycle 1</b>	<b>\$3,025.00</b>
<b>Repair Cycle 2</b>	<b>\$380.00</b>	<b>Replacement Cycle 2</b>	<b>\$3,025.00</b>
<b>Repair Cycle 3</b>	<b>\$380.00</b>	<b>Replacement Cycle 3</b>	<b>\$3,025.00</b>
*Tooling	\$2,700.00		
<b>Total</b>	<b>\$3,840.00</b>	<b>Total</b>	<b>\$9,075.00</b>

### Application

Boiler Feed

Turbine Bypass

Turbine Control

Hazardous Fluid Handling

Two-Seated Valves

Inlet Air

**Repair/Replace**



# Valve Life is Shorter than Anticipated

There are have been lots of problems in GTCC plants due to the frequent cycling. Therefore the forecast of valve life for GTCC plants is shorter than for other fuel type.





## Decision orchard [\(Click here for hyperlink to documents\)](#)

- **Resource Title:** EPRI Valve Maintenance Guides Developed for Combustion Turbine Combined Cycle Plants
- **Location:** GdPS for CCGT Valve Selection
- **Keyword:** Valve-Maintenance
- **Discussion:** As U.S. utilities curtail operation of older coal-fired plants, CTCC plants are increasingly being run at higher capacity factors, putting new stresses and pressures on plant equipment. This trend, in turn, requires crews to re-evaluate their inspection and maintenance practices. At the same time, advanced new equipment is finding its way into plants, adding greater complexity to the maintenance process

### Valve maintenance guides developed for combustion-turbine combined-cycle plants

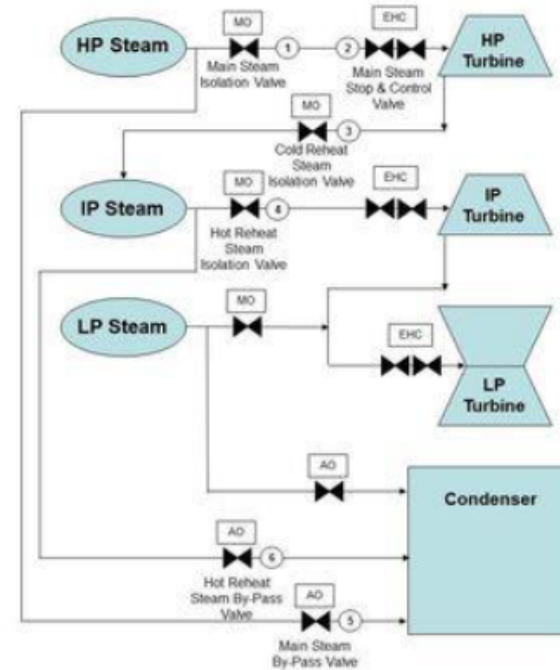


Figure 1.

# Specific Issues and Evaluation Considerations

Application	Issues	Discussion
Boiler Feed	Single Valve or Dual Valve	Achieving the most economical and effective solution to boiler feed valving while avoiding cavitation and retaining startup and variable load performance
Turbine Bypass	Stellite Delamination	Mostly affecting steam valves in high pressure (hp) turbine bypass or hot reheat (hrh) lines; can result in valve damage/seat leakage or damage to turbine
Turbine Control	Cycling	More prevalent in CCGT plants than base-load coal-fired plants, and can require special valve capabilities for the increased thermal and mechanical stress
Hazardous Fluid Handling	Double Block & Bleed (Ammonia)	Hazardous fluids sometimes require double block & bleed compliant valves for maximum safety. Ammonia handling is one application in CCGT power plants.
Two-Seated Valves	Center cavity over-pressurization (CCOP)	Center cavity over-pressurization can be an issue with two seated valves, including double block & bleed valves
SCR	Anhydrous, aqueous, or urea	Ammonia for SCR NO <sub>x</sub> removal can be accomplished with anhydrous ammonia, aqueous ammonia, or urea with onsite ammonia production.
Inlet Air	Fogging Control	Generally advantageous in hot, dry climates to increase inlet air density and increase power output.
Vent & Drain	Repair/Replace	The economics of repairing or replacing worn valves

# Turbine Bypass Valve Life in GTCC Plants is less than in Coal Fired Plants due to Cycling and Flow Accelerated Corrosion and Other Problems

Barry Dooley, [Structural Integrity Associates Inc](#), and  
Bob Anderson, [Competitive Power Resources Corp  
\(CPR\)](#).

Have compiled in an extensive report, “Trends in HRSG Reliability—a 10-Year Review,” as of 2019

A new phenomenon appeared in the HP steam-turbine bypass circuit: Erosion of the pressure control valve cage, disc, and seat by wet steam and water. *HP bypass-valve erosion*. Abnormal seat, plug, and cage erosion in bypass pressure control valves has become common regardless of valve manufacturer, “caused by passing wet steam and/or water through the PCV. As damage progresses, superheated steam can leak through and overheat the downstream carbon steel pipe.”

## High-delta-p Investigation Identifies HRH Piping Cracks

### Tenaska Central Alabama Generating Station

Tenaska Alabama II Partners LP

885-MW, gas-fired, 3 × 1 combined cycle located in Billingsley, Ala

Plant manager: Robert Threlkeld

**Key project participants:** Brian Pillittere, plant engineer; Alan Foether, LCRO; Cecil Boatwright, operations manager

### Challenge.

Plant personnel found that the steam turbine experiencing higher than normal exhaust backpressure. The operators noticed that the backpressure dropped whenever the hot reheat (HRH) bypass valves were opened.

### Solution.

The LCRO came up with the idea to perform a test to determine the relationship between the HRH bypass-valve operation and the turbine-exhaust backpressure. During a plant startup, the steam pressure was increased in the HRH piping and steam was observed coming through the insulation downstream of the Unit 3 HRH bypass valve. The pipe insulation was removed and it was determined that the steam was coming from a crack in the weld that connects the HRH bypass valve to the downstream P91 piping. The valve was closed and the sound of air being sucked into the crack was heard.

A plant outage was taken to grind out the cracks and make weld repairs. The repaired areas will be inspected during future scheduled outages. In addition, manual block valves will be installed downstream of the HRH bypass valves in 2011 to allow repairs to the valves and piping to be made without requiring a full plant outage.

### Results.

Steam-turbine backpressure has since returned to normal. Backpressure is monitored regularly during plant operation using an Excel® model that compares the actual backpressure to the condenser manufacturer's design backpressure curves based on the circulating-water temperature and condenser heat load.

**Table 4: Analysis of avoidable causes of thermal-transient-induced damage/failures**

Thermal-transient category	Combined cycle/HRSG plants, %*
Routine attemperator hardware inspections conducted	18↑
Leaking attemperator spray evident in DCS data	82↑
Attemperator spray master control/martyr block-valve logic used	95↑
HPSH attemperator overspray evident in DCS data	31↑
RH attemperator overspray evident in DCS data	12↑
Inappropriate attemperator operation permitted	39↑
HPSH or RH drain pipes too small	65↓
HPSH/RH drain pipes sloped downward	29↑
Blowdown-tank elevation higher than lower HPSH/RH headers	47↓
Poor HPSH draining evident in DCS data	63↓
Poor RH draining evident in DCS data	68↑
HPSH/RH drains open during purge	58↑
Prudent HP drum ramp rate exceeded during startup	25↑
Exhaust-temperature matching used during cold, warm, or hot starts	16↓

\*Percentage of the 54 plants in this sample where the stated thermal-transient category was identified; arrows indicate the trend over the last five years

A workshop on optimization of steam-turbine bypass systems at the 2018 meeting of the Australasian Boiler and HRSG Users Group, led by Bob Anderson, Competitive Power Resources Corp, [covered the arrangement, purpose, and methods for operating and maintaining this equipment.](#)

Vibrant discussion followed presentations by Anderson, Justin Goodwin of [Emerson/Fisher](#), Ory Selzer of [IMI CCI](#), and Sanjay Sherikar of [Nihon Koso Co Ltd.](#)

Although many OEMs are using more-erosion-resistant designs and materials, presenters representing leading valve manufacturers stressed that “no PCV design can tolerate wet steam.” Newer materials and designs will only slow the wet-steam erosion process. Severe damage can result within one year in cycling units. Mechanisms of damage by wet steam were explained in detail, with visual examples and specific case studies (both existing and new units).



Due to the severe thermal cycling over operation, a fatigue failure can occur in the valve body of the bypass valve. So, it is necessary to estimate the fatigue life of the given bypass valve for the operating conditions like cold start, warm start & hot start. What are the operating conditions of these valves. Usually three generic operating conditions are found for a power plant 1. Cold start (>72hrs of plant shutdown) 2. Warm start (<=45hrs of shutdown) 3. Hot start (<=8hrs of shutdown) Among these three conditions, hot start is the most prevalent & necessary operating condition. Fatigue life requirements can be from 5000 cycles to 15000 cycles & varies for different plants

Essential characteristics of bypass valve

- Resistance to thermal shock and fatigue: The Bypass Valve will be subject to severe thermal shock (>200degC). Valve body and trim must be designed to assure reliable operation.
- Maximizing Power Output and reduced Maintenance: Repeatable seat tightness is required to prevent steam leakage that can otherwise be used to generate electricity and therefore revenue. Excessive seat leakage also results in excessive maintenance and plant shutdown
- <https://www.irjet.net/archives/V5/i3/IRJET-V5I3806.pdf>

The gas turbine (GT) at a 1 × 1 single-shaft combined-cycle plant designed for flexible operation has a staged combustion system that permits emissions compliance and a relatively good heat rate down to low loads. The HRSG is a three-pressure, reheat, horizontal-gas-flow unit equipped with only HP (high pressure, main steam) and RH (reheat steam) terminal attemperators. There is no duct burner or SCR.

Repeated severe water erosion damage to the HP bypass pressure control valve (PCV) caused the PVC to leak in combined-cycle service, requiring multiple repairs at significant unbudgeted costs and involving long forced outages.

**Corrective actions:**

Delay opening the HP-bypass PCV until the main-steam temperature measured downstream of the bypass tee increases to 20-deg-C above  $T_{sat}$ .

Repair the leaking HP attemperator spray and block valves.

Leave the main-steam-pipe warming drain open during open-cycle operation. This may require modulating the drain valve's position to limit steam flow while avoiding condensation in the deadheaded section of pipe.

# Specific Issues and Options for Steam Valves

## Factors Creating Issues

- ▶ Higher temperatures
- ▶ Higher pressures
- ▶ Fast and frequent cycling
- ▶ Entrained water drops

## Resulting Issues

- ▶ Valve trim wear
- ▶ Cavitation
- ▶ Flashing
- ▶ Vibration
- ▶ Seal damage

## Options

- ▶ Follow ISA guidelines for control valves
- ▶ Buy severe service valves (need definition)
- ▶ Consider special materials and coatings
  - ▶ Prevent stellite liberation
  - ▶ Fuse coating to base material
- ▶ Separate small start up valve for low loads
- ▶ Change inspection, operations, and maintenance procedures
- ▶ Specify valve after you know pump feed pressure
- ▶ Faster response and reliable actuators
- ▶ Repair rather than replace
- ▶ Buy all HP valves from one vendor
- ▶ Do not oversize feedwater valve
- ▶ Require tight shut off (better tolerances)
- ▶ Hydraulic actuators for fast response
- ▶ Electric actuator increases reliability<sup>23</sup>

# Background Documents in Intelligence System



## Vector and Wellheads Engineering Turbine Bypass System

This paper has a good flow diagram with valve locations. The turbine bypass system is a very important component in power stations, and of a difficult service too **Revision Date:** 9/9/2019

## Valvtechnologies Turbine Bypass System

The steam turbine bypass system will allow the operator to keep the gas turbine and the heat recovery system generator (HRSG) on-line in the event of a steam turbine trip or to facilitate faster start-ups of the CT and HRSG.

**Revision Date:** 9/9/2019

## Proper Steam Bypass System Design Avoids Steam Turbine Overheating

The steam bypass system is generally used during the following modes of operation: start-up and shutdown, steam turbine trip, steam turbine no-load or low-load operation, and simple-cycle operation. On start-up, the isolation of the CTG/HRSG from the STG allows the CTG to be placed on load without delay and well before the heat-up and roll-off of the STG. In addition, a faster start-up of the STG is possible since the bypass system provides the capability of close temperature matching between the steam inlet temperature and the steam turbine metal temperature.

**Revision Date:** 9/9/2019