Actively Cooled Fuel Controls: Enhancing Liquid Fuel System Reliability

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2500% improvement in transfer reliability rates. Successful transfer rate improved from 4% to 100% during the test period, August 2004 to September 2005.

1998 - 2004
August 2004 - September 2005

8000+ hours of operation with WCLFCV’s during 2005
96,000 cumulative hours of check valve operation without a failure
History of Check Valve Failures
1950- 1998

1. Different variations of Ball & Spring Check Valve designs utilized: All failed within 2 years of operation requiring fleet wide replacements for in-warranty units.

2. Soft seat check valves: seal melts due to high temperatures, valves stick shut

3. excessive leaks when particulates are trapped between ball and seat during fired shutdowns,

4. ball and/or seat damaged by particles traveling through valve at high velocity,

5. Flow Instability: High frequency oscillation at various pressures and flows; resulted in premature wear of valve internal components, hydraulic hammer caused cycle fatigue failures (breakage) of fuel tubing, resulting in turbine compartment leaks
JASC check valve design features

1. Flow stability addressed by incorporating Hem Holtz resonator circuit. This feature will dampen flow divider generated pressure signature of 90 psi pk-pk to 5 psi pk-pk for the entire flow range. Eliminates high frequency oscillation, hydraulic hammer and fatigue related tubing failures.

2. Vespel seal material rated for continuous service of 575 degrees “F”, can withstand short intervals of 700 degrees. Abnormal conditions which expose material to 1000+ degrees will only result in charring and cause material to crack. There is no risk of disintegration or material moving downstream to block nozzle orifices.

3. Contamination tolerant design: Multiple injections of 480 grams of Arizona road dust failed to impact the check valve functionality. Feature allows valve to function properly in spite of catastrophic filter failure.

4. Knife edge seat decreases risk of particles being trapped between the poppet and seat. As little 5 psi of backpressure will embed particulate into the seat and allow the valve to close.
Current liquid fuel system issues in dual fuel applications

1. Transfer reliability impacted
2. Multiple start attempts required when firing on distillate
3. Excessive exhaust temperature spreads
4. Liquid fuel system pressurized by purge air/CPD
5. Check valve or 3-way purge valve refurbishment or replacement required after gas operation due to coking
6. Contamination related failures during commissioning
7. Coking of fuel lines
8. Liquid Fuel Thermal Expansion during gas operation
9. Complete evacuation of liquid fuel lines back to flow divider or beyond
10. Trips at load during transfer attempts
Standard Liquid Fuel Check Valve Installation

![Image of a fuel check valve installation]

- Conventional Liquid Fuel Check Valve
- Note Check Valve Proximity to High Temperature Surfaces
When operating a dual fuel turbine on gaseous fuel the liquid fuel system is idle. Stationary fuel in close proximity to the combustor is exposed to high temperatures, above 250 degrees “F”, which oxidize the fuel and turn it into a hard substance which coats the internal surfaces of the check valve components, restricting their movement. Once this occurs the check valve will not open and close properly.

Lower the temperature and eliminate coke formation!
Example of coking in ball & spring check valve design
Coking – Primary Cause for Failed Transfer

A standard Liquid Fuel Check Valve showing the realized coking potential.
Water Cooling of Flame Detector

Extending Concept to Liquid Fuel Check Valves
Installed in 6FA

- **Design Benefits and Expectations**
  - Low cost and ease of installation.
    - Added connections to cooling water supply and return.
    - Installed tubing distribution supply and return ring in turbine compartment.
    - Cooling requirement is .25 to 1 GPM per check valve.
    - 40 to 80 psi of water pressure.
    - No controls modifications needed.
  - Improved fuel transfer ability.
  - Improved start up reliability on diesel fuel.
  - Check valve life of 20 years or more
Water Cooled Liquid Fuel Check Valve

Developmental Water Cooled LFCV with a welded sleeve

Production Water Cooled LFCV using a cast sleeve

All variants of the Water Cooled LFCV use the same internal components as the standard LFCV
Water lines rated to 1500 psi, operating pressure 40 to 80 psi
Uncooled vs. Cooled Check Valves

Uncooled Check Valve

Water Cooled Check Valve

Less than 100 fired hours

1,300 fired hours
Failed Transfers - Trips

Most Common Trip During Transfer – High Exhaust Spread Temp.
Cause – Stuck Liquid Fuel Check Valves due to coking.
Actively Cooled Fuel Controls: Enhancing Liquid Fuel System Reliability

1. JASC water cooled liquid fuel check valves addresses all previous failure modes and the most recent, coking.
2. Eliminate high exhaust temperature related trips due to sticking check valves.
3. Refurbish and perform maintenance on liquid fuel check valves every 4 or 5 years during scheduled major outages.
4. Eliminate the need for multiple starts in order to purge air from your liquid fuel system.
5. Low installation costs, readily applied to all frame sizes.
6. No controls modifications required.
7. Simple to assemble or disassemble before and after scheduled maintenance.
8. Ability to exercise your liquid fuel system regularly without worrying about the condition of your fuel controls.
The future of Actively Cooled Fuel Controls: Enhancing Liquid Fuel System Reliability

- Water Cooled Combining valve design features
  - Replaces liquid fuel check valve
  - Replaces purge air valves
  - Replaces fuel distributor valve
  - Integral strainer to eliminate contamination failures
  - Eliminate coking and leak related issues on all 3 major components
3-Way Purge Valve Overview:
Replaces Liquid Fuel & Purge Air Check Valves
Over 3000 Units in Field Operation
No Active Water Cooling (currently) - Units in High-Temperature Locations are Prone to Internal Coke Formation
No Particle Trap - Seals are Typically Damaged During Initial Firings Due to Large Particulate Contamination of the Fuel

The Water-Cooled Combining Valve:
Valve is Designed to Emulate Functions of Current OEM Fuel Distributor Valve
Addresses Specific Issues of Current Valves to Improve Overall Liquid Fuel System Reliability:
- Effective Water-Cooling Design
- Staged Fuel Delivery
- Small Quiescent Internal Fuel Volume
- Removable Fuel Inlet Screen
- Pilot Air Actuation can be Incorporated (if required)
Valve / Bracket Assembly

Bracket Only

Fuel Inlet

Water Inlet

Fuel Distribution Ports

Mounting Surfaces

Purge Air Inlet

Cradle
Water Cooling has arrived!

- Combining Valve design used for DLN applications
- Bolt-on configuration
- Technology can be readily applied to all dual fuel gas turbine applications
RESULTS

Max. Temp. Spool “Balloon” Surface: **187 °F**

Avg. Temp. Water at Discharge Port: **152 °F**

Note that max. temp occurs **away from** spool seal region

Max. fuel temp is sufficiently **below** coking temperature

Static fuel in cavity

Max. Temp. Fuel: **210 °F**
Cost Analysis Considerations

- Installation of both systems is relatively simple
- Tap into existing water system
- Maintenance only required during major outages
- Significantly improved Transfer reliability
- Elimination of coking related failures
- Elimination of contamination related failures
- Enhanced start capability on liquid fuel
- Elimination of trips associated with high exhaust temperature spreads
JASC has had great success developing complete systems or integral components which resolve process control problems in a variety of industries and applications.

Continuous improvement of existing designs provides our customers with products which exceed all expectations.

Our goal is to provide our customers with a level of service which is unparalleled.

We actively seek opportunities to apply our problem solving ability to your issues.
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