WOODWARD

Application Note 83410

Original Instructions

Gas Turbine Fuel Control on Sour Gas

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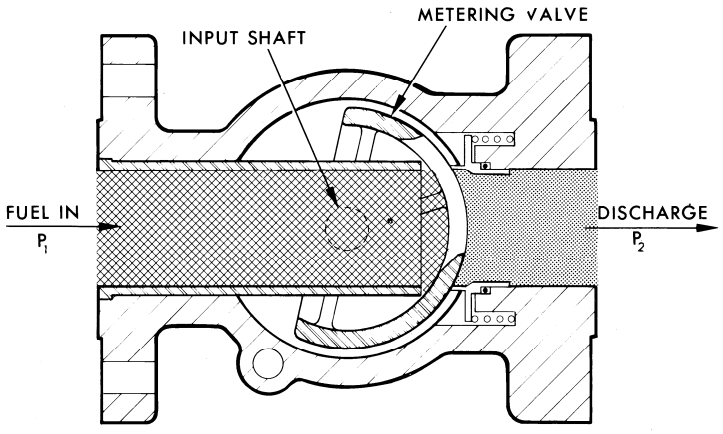
Hydrogen sulphide, gaseous organic acids, sand, rust, and water are some of the natural gas contaminants fed through gas turbine fuel metering systems in some parts of the world. Engines which drive generators and compressors in oil fields are often operated on heavily contaminated, unsweetened gas, and all components of the fuel system must withstand corrosion and erosion for periods up to 30 000 hours between overhauls. The fuel metering valve must do more than just survive this abuse. It must maintain the same accuracy and dynamic response through its life, protecting the engine from transient overtemperatures, compressor surge, and combustor flame-out. Accurate flow control is also essential for consistent starts and achievement of specified power output. Two decades of field experience has led Woodward to develop new concepts and components for industrial gas turbine control.

These include the 3103 gas valve with TM-55 electrohydraulic actuator, designed for engines in the 3730 to 37 300 kW (5000 to 50 000 hp) range. The combination of a self-cleaning valve concept, through hardened parts with hard surface coatings and high working force levels, is used to achieve good contaminant resistance. Maximum natural gas flow settings vary from 3405 to 22 700 kg/hr (7500 to 50 000 lbs/hr) while minimum flow settings may be as low as 22 kg/hr (50 lbs/hr). Flow turndown ratios of 500 to one are possible. Maximum inlet pressure is 45 bar (650 psig) and operating temperatures from –40 to +121 °C (–40 to +250 °F) are acceptable. The TM-55 actuator provides a minimum valve slew time of 100 milliseconds and a time constant of 25 milliseconds. Actuator rate limiting in the increase flow direction only, is available if required. Operating in conjunction with electronic control systems, the valve and actuator can be used to schedule flow for acceleration and deceleration control in addition to closed loop control of engine parameters such as shaft speed, torque, gas temperatures and pressures.



3103 GAS VALVE SCHEMATIC

The 3103 gas valve design consists of a rotating metering sleeve and seal shoe in a stainless steel housing. The metering port is cut through the sleeve and open port area is determined by sleeve position. Two standard ports are available with maximum flow areas of 645 and 1290 mm² (1 and 2 in²). Gas enters the valve through the guide tube which provides a smooth flow path and directs heavy contaminant particles through the metering port. Gas then enters the port from the inside of the metering sleeve which presents a converging flow path with no dead space or corners to collect contaminants. The gas exits the port through an area defined by the intersection of metering shoe bore and the port profile on the sleeve. The shoe is spring and pressure loaded against the sleeve to obtain a self-cleaning action. When gas expands through the port, condensates tend to form deposits on the down-stream side of the restriction.

In this design, the through-hardened stainless steel shoe scrapes these deposits off the sleeve as it rotates. The TM-55 actuator provides over 1334 N (300 lb) of shearing force at the sleeve outer diameter to remove deposits and cut through light debris such as pipe scale. The metering sleeve is supported on two sealed ball bearings which are located outboard of the primary gas seals on the sleeve shaft. A second set of seals is located outboard of the bearings and the interseal cavity is vented via an external tubing connection. A torsion return spring is provided at one end of the metering sleeve to eliminate linkage backlash between the valve and actuator. Other features include maximum and minimum flow stops, a light-off flow gauge screw for field set-up, minimum position indicator switch and valve position indicator scale. The actuator and adapter mount directly on the valve and no external linkage is required. The gas valve complies with ANSI B16.5 Class 600 specifications and has in-line, 51 mm (2 in) flanged connections. All materials meet the recommendations of the National Association of Corrosion Engineers Standard MR-01-75, "Sulphide Stress Cracking Resistant Material for Oil Field Equipment." The TM-55 actuator, described in *Diesel & Gas Turbine Progress*, January 1977, is now UL listed for Class I, Division 1, Groups B, C, and D type operation. The complete assembly meets the requirements of AP1616 specification for equipment on gas turbines for refinery services.

Natural gas metering methods for gas turbines may be classified broadly into flow scheduling and parameter feedback types. In the flow scheduling approach, the required gas flow rate is determined electronically or mechanically, and the metering system is then controlled as precisely as possible to deliver that flow. In parameter feedback systems, the metering valve is always modulated to achieve closed loop control of some engine parameter such as a shaft speed, gas pressure or temperature. This approach substantially reduces the accuracy requirements of the metering system, but does not provide the best possible starting times and acceleration rates from the engine. Its use also implies the use of accurate, stable, fast, and ultra-reliable transducers on the engine. The 3103 valve may be used in either type of system, but the flow scheduling approach has been used successfully in the majority of applications.

Most systems feature an upstream pressure regulator set 1.4 bar (20 psi) or more above the maximum valve discharge pressure. Heat flow schedules for acceleration and deceleration are converted into valve position schedules using calculations based on user specified gas properties and pressure data. The schedules are then implemented in the electronic engine control system. The 3103 differs from previous Woodward gas valves in that the port profile is not customized for each application. Previous designs featured plungers or ports contoured to achieve a specific flow vs. position schedule. This allowed the plunger to be positioned proportionally to engine compressor discharge pressure for acceleration fuel limiting, but resulted in an endless succession of valve part numbers, material lists and test specifications.

Whenever a change occurred in flow schedule, gas properties or conditions, a new valve had to be created. Today's more complex engine controls necessitate electronic fuel scheduling and it makes more sense to include valve non-linearities in the electronic schedules rather than contour the valve port for flow linearity. This approach allows the same valve assembly to be applied in many diverse applications. A second benefit is that it is much easier to predict the flow characteristics of a valve with fixed internal geometry. Every time a port contour is changed the discharge coefficients change, making the design of new versions an iterative process.

Over 200 of these valve and actuator assemblies are in use worldwide on engines ranging in size from 3730 to 37 300 kW. One unit at a pipeline compressor station in Michigan, USA, has operated over 20 000 hours on clean, dry gas. Another has accumulated more than 16 000 hours on exceptionally sour, heavily contaminated gas at an oil field power station in the United Arab Emirates. At this site, a previous valve type survived only 50 to 500 hours of operation. Failure modes included sticking due to condensate accumulation, erosion of metering plungers by sand and flow schedule changes due to buildup of iron sulphide deposits.

Gas metering systems will become more complex as engine pressure ratios increase and multi-fuel operation with on-line changeover capability becomes a more common requirement. Simple, constant pressure supply systems are not adequate in these situations and are not economically desirable. Systems where operating pressures are measured and compensated for electronically have already been installed. Other approaches have been proposed in which the 3103 is used in electronic pressure control loops for absolute and differential control. For larger engines, Woodward offers the 3130 gas valve and TM-300 actuator, a package with seven square inches of port area, and 152 mm (6 in) flange size. The valve offers the same performance capabilities as the 3103 unit with three times the flow capacity.

[Written by Paul Avery.]

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