MOVING YOUR WORLD
IDEAS IN MOTION CONTROL FROM MOOG INDUSTRIAL
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MOOG

MOOG 6 DOF TEST SYSTEM KEEPS HAZARDOUS CARGO SAFE DURING OCEAN VOYAGES

Moog 6 DOF Test System for Liquefied Natural Gas (LNG) Tank Structure Research in Marine Design and Research Institute of China (MARIC)

By Jason Yang, Test Application Manager
Moog China

Natural gas is viewed as the cleanest fuel when compared to other fossil fuels due to the reason that it contains very little sulfur content. Today natural gas constitutes 25% of the total fuel consumed over the world and the percentage is increasing every day. When you turn on a gas stove, you can recognize that you are burning natural gas from its pure blue flare. However you might not know that the natural gas you are using could be transported with a Liquefied Natural Gas (LNG) carrier from the other side of the world.

LNG tanker transporting natural gas

Natural gas from offshore oil/gas wells is typically very difficult to be directly utilized and then transported and pumped into urban gas networks. The LNG carrier plays a key role between the producer and consumer. Natural gas needs to be cooled down to a super low temperature -162 °C (-260 °F), and its volume will be reduced to 1/600th of its original gaseous state. It will then become Liquefied Natural Gas (LNG) – now small enough to be transported and stored.

Huge tanks in LNG carriers need to be kept at a super low temperature for weeks or months during its transportation journey. The tanks, which are typically 125,000 m^3 (4,414,000 ft^3) each in volume, are difficult to build due to their extreme volume and "super cool" requirements. Also the thin [0.7 mm-1.5 mm (0.028-.059 in)] welded Invar stainless alloy membrane structure which holds the LNG has to have the right properties including reliability in -162 °C (-260 °F) temperatures, and no leakage over the carrier's lifetime of 40 years.

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Dr. Sam Fan, structural research lab director of Marine Design and Research Institute of China (MARIC) was assigned the challenging assignment of investigating the structural strength and properties for the LNG tank to give help to the ship building industry. He needed a system to perform "slosh testing" on LNG tanks which simulates the motion of the carrier and allows researchers to study the impact of the slosh on the structure of the scaled LNG tank model.

Dr. Fan had difficulty finding a workable solution for this test challenge but in late 2009 he contacted Moog. Yuan Bai, the Simulation Sales Manager for Moog in China, immediately visited MARIC to introduce Moog's 6 Degree-of-Freedom (DOF) 4.5 Ton motion base.

Standard Moog MB-EP-6DOF/36/4500kg Specifications

DOF	Excursion Limits Maximum	Velocity	Acceleration
Surge	-0.69/+0.85 m	+/-0.9 m/s	+/-8 m/s^2
Sway	+/-0.69 m	+/-0.9 m/s	+/-8 m/s^2
Heave	+/-0.59 m	+/-0.7 m/s	+/-10 m/s^2
Roll	+/-23.9 deg	+/-33 deg/s	>150 deg/s^2
Pitch	+/-23.9 deg	+/-33 deg/s	>150 deg/s^2
Yaw	+/-23.9 deg	+/-33 deg/s	>150 deg/s^2

It was clear that the requirements and specifications for this application required a modification to the motion system.

MARIC Application Key Specification Highlights

Key Specs	Items	Unit	Descriptions	Moog Standard MB-EP-6DOF/36/4500kg
Speed	Max Surge	m/s	+/-1.3	+/-0.9
	Max Sway	m/s	+/-1.3	+/-0.9
	Max Heave	m/s	+/-1.0	+/-0.7
Acceleration	Max Surge	m/s^2	+/-8.8	+/-8.0
	Max Sway	m/s^2	+/-8.5	+/-8.0
	Max Heave	m/s^2	+/-15	+/-10.0
	Max Roll	deg/s^2	+/-219	+/-150
	Max Pitch	deg/s^2	+/-245	+/-150
	Max Yaw	deg/s^2	+/-420	+/-150

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The major challenges that required addressing with this solution included:

- MARIC slosh test needed a faster speed – 1.3 m/s in Surge and Sway
- MARIC slosh test needed a higher acceleration – 15 m/s^2 in heave and also very high rotary acceleration in roll/pitch/yaw
- The motion system for testing required a GUI and testing software that can replicate the data captured in a real ship to simulate the excursion, velocity and accelerations
- The pressure vessel used in the pneumatic support system has to meet Chinese regulations

The Moog in China team immediately discussed the requirements for this specialized motion system with the R&D center in Moog, Nieuw Vennep, Netherlands (NV). Olivier Voinot, Test System Engineering Manager, performed an analysis and determined that the Moog motion base's performance could be extended with certain system reinforcements and modifications:

- A high power transformer could be introduced to raise the DC bus voltage within the AC Servo Drive up to 600 V to boost the velocity and acceleration up to the required level
- The upper joints could be enhanced with steel bushings, rather than the original plastic ones, which would improve the stiffness of the system and to help provide additional stability under higher velocity and acceleration
- Moog Replication and Runner Software could be integrated to communicate with the motion base and provide MARIC with an All-In-One testing environment to execute the slosh testing from generating cyclic waveforms (such as sine wave etc.) to replicating a real 6 DOF spectrum data acquired from the LNG carrier
- Moog in China would integrate GB-150 pressure vessel into the system to meet Chinese pressure vessel standards

A working team between Moog in The Netherlands, Moog in China and Dr. Fan's team has been collaborating throughout the whole project. Karlijne van Leibergen and Jason Guan, Project Managers from the two Moog sites worked closely to ensure the system was designed and built per specifications and to achieve Dr. Fan's requirements for slosh testing. The system was delivered in July 2010 and SAT was completed successfully on 4 July 2010.

A few factors that contributed to the success of this project include:

- Seamless team work, not only within Moog but also with our customer
- Flexibility, willingness to customize and a "Can-Do" attitude are all part of Moog's DNA and each site contributed to a solution which goes beyond just satisfying requirements to delighting the customer
- Localization efforts to guarantee the system not only meets performance requirements, but also complies with safety regulations in different countries around the world

"The slosh testing motion system provides us with a powerful simulation tool to deeply understand the structure strength and nature of the LNG tanks. Our research will definitely provide a solid foundation to the LNG ship building in China", Dr. Fan commented.

In light of the success of the slosh test system, MARIC continues its cooperation with Moog. A second motion system is on its way and we all are looking forward to the next exciting project with MARIC. "Success is the mother of success" – this is what we believe now.

Author

Jason has been Test Application Manager since 2008. He joined Moog Singapore in 2000 as an application engineer in plastic machinery. Jason was heavily involved in Electro- Mechanical actuation development from 2002 to 2004 in Moog in the US engineering and EM Business Development in China from 2004 to 2006. Jason also assumed the Automotive Sales Manager position from 2006 to 2008 in China. Jason holds an Electronics and Applied Control Theory Master Degree from China and also an MBA degree from St. Bonaventure University, USA. Jason has been in application engineering for more than 10 years in Moog.

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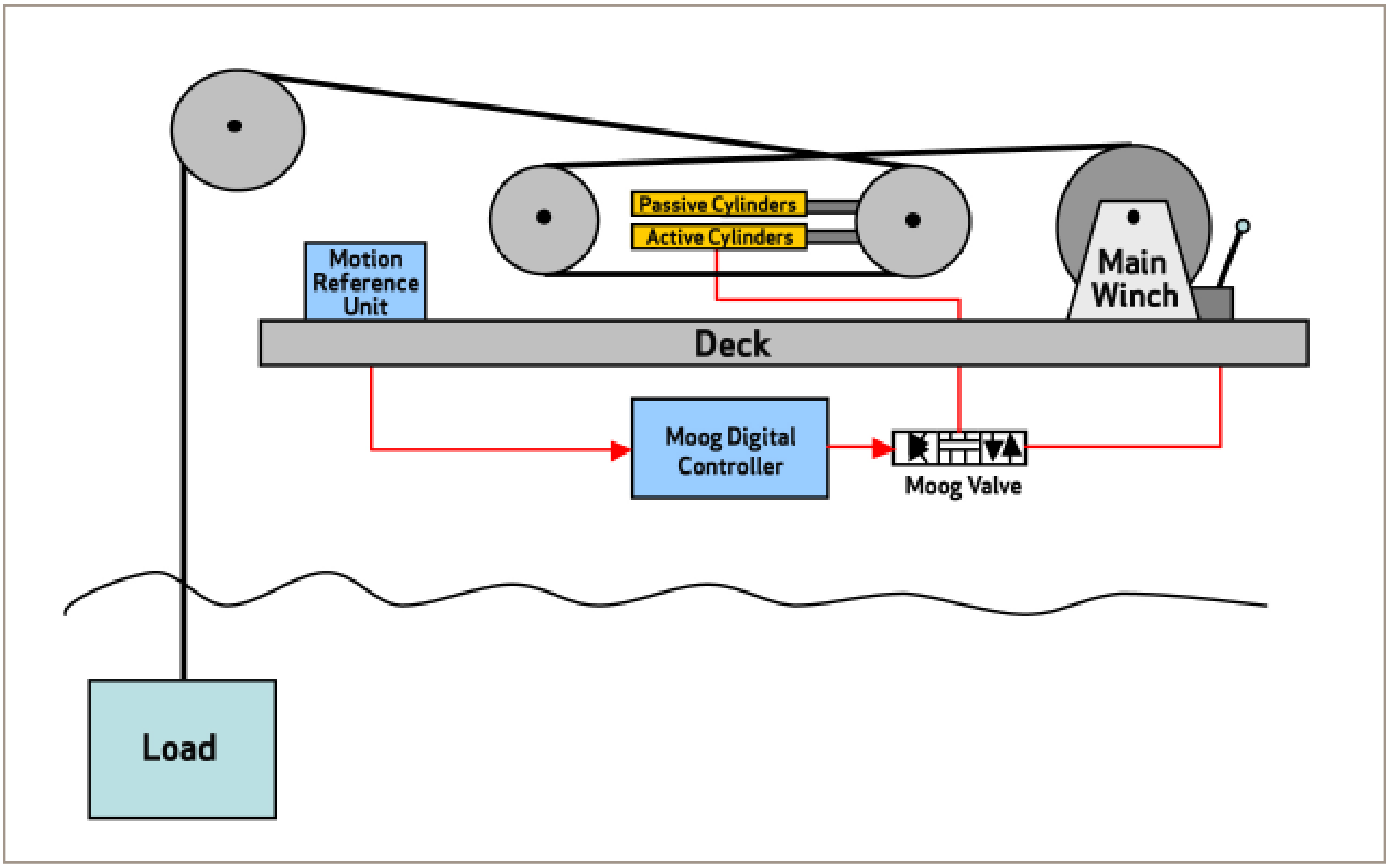
STEADY UNDER PRESSURE: UNDERSEA EXPLORATION BENEFITS FROM MOOG INNOVATION

By Martin S. Jones, Manager, Niche and Emerging Markets

One recent trend in the industry is the installation of increasingly complex and sophisticated equipment on the sea bed, for oil and gas exploration and production. This requirement presents a unique challenge, as extremely heavy mechanical structures have to be lowered to the seabed by winches or cranes from floating vessels which are subject to wave motion.

A key technique to achieve this is 'Heave Compensation' where the vertical movement of the vessel is electronically monitored and the crane/winch is automatically controlled to compensate for this. Effectively the crane cable is continuously paid out or reeled in to allow the load to "hover" above the sea bed. The operator of the winch can then generate command signals to the winch drum which are superimposed on the automatic compensation function. This permits the operator to precisely control slow and accurate movements -relative to the sea bed.



Functional Schematic

The Edda Fjord

A good example of this technology is the heave compensation actuation system supplied 4 years ago to TTS who specializes in marine winches. This was a system retrofitted to the crane on the vessel "Edda Fjord," operated by Østensjø in Haugesund.

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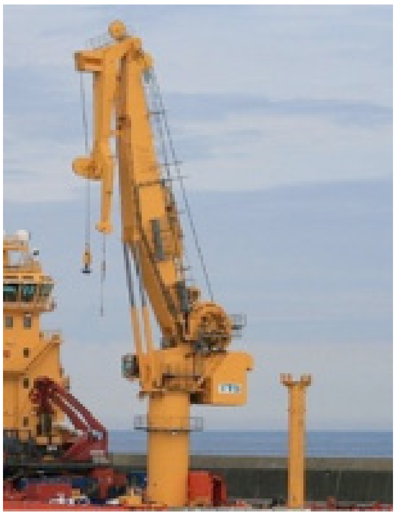
The Control System

In this application a Sheave or 'Jigger Winch' was added to the original crane hoist winch system. This utilizes a hydraulic cylinder and pulley system to actively vary the effective cable length between the winch drum and the payload being deployed. With this arrangement the winch operator controls the movement of the winch drum in the normal way and the supplementary Sheave system automatically compensates for the rise and fall of the ship.



Edda Fjord/crane

Crane Hoist Winch

A special feature of this system is to use auxiliary cylinders and hydraulic accumulators to support the weight of the load. This increases the performance envelope of the active compensation system as it does not waste energy supporting the load. Essential to this application is the sensing component - the MRU [Motion Reference Unit] which senses the rise and fall of the ship by means of gyros and inertial reference transducers.

The Moog and PMC Servi Solution

Moog in Norway and their technical partner PMC Servi in Norway have a long track record of cooperating to provide innovative solutions for the Oil and Gas Industry. These solutions are focussed on precision hydraulic and electric actuation of high loads, in conjunction with intelligent electronic controllers.

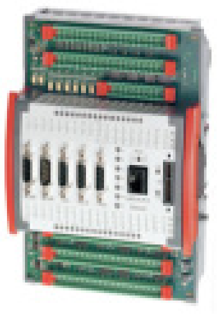
PMC Servi designed and manufactured the hydraulic actuation system comprising of a large hydraulic power pack, hydraulic manifold cylinders and electronic controls including the operator interface.

The hydraulic section incorporates a Moog D665 Proportional Valve capable of flows of 3600 l/min (950 gpm) required to give the maximum cylinder velocity of 2.4 m/sec (94 in/sec). This valve is also able to achieve the extremely sensitive position control required, as it is can modulate these large flows with an accuracy of 0.2 %.

The Moog D665 Proportional Valve

Key to the electronic control system is the Moog Digital Servo Controller, the latest evolution of which the Moog Motion Controller is pictured below.

Moog Motion Controller



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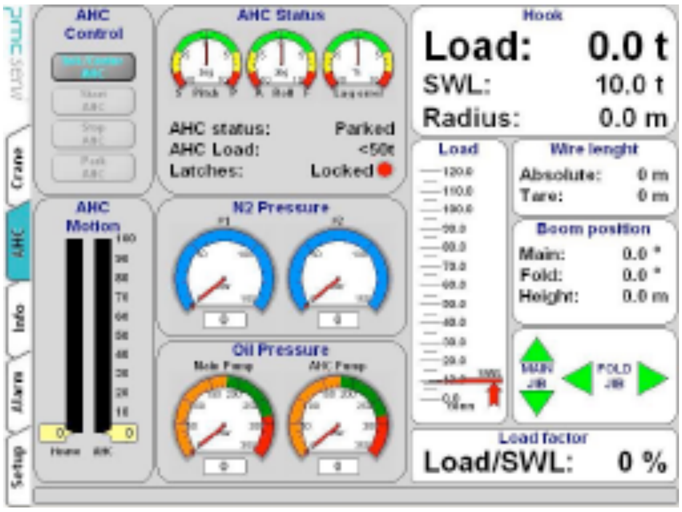
The key role of the Moog Controller is to compare signals from the Motion Reference Unit and cylinder position sensor and calculate the required correction signals which are sent to the D665 valve at a rate of 250 hz.

In addition to controlling the heave compensation function the Moog Motion Controller also monitors the correct function of the system and in the event of a system failure initiates alarms and a “fail-safe” procedure to safeguard the load.



Operator Interface Screen

The Benefits of the System

The system installed on the Edda Fjord has now been in use for 4 years working in diverse locations including the North Sea, the Baltic and the west coast of Africa.

The system is capable of handling loads of up to 200 tonnes (220 tons) with ±1.5 m (4.9 ft) wave heights or 100 tonnes (110 tons) with wave heights of ±3 m (9.8 ft).

In practice, the performance of the system has easily exceeded the original specification of achieving a 95% attenuation of the wave motion during operation. Typically it has proved possible to make the load “hover” with movements of less than 10 cm relative to the sea bed.

To the operator, this sophisticated control system brings a variety of cost and time saving benefits. Subsea assemblies can be installed without the risk of damage to both the assembly itself and other remotely controlled handling equipment such as ROVs (Remotely Operated Vehicles). In addition the operator is able to continue working in more extreme sea conditions saving waiting time and the significant cost of these complex operations.

Author

Martin S. Jones is responsible for the Motorsport business around the world and is also the Market Manager for Niche and Emerging Markets in Europe. He has worked for Moog for 30 years in sales and applications engineering for a range of industries including mobile equipment, marine and offshore, blow molding and rolling mills. He studied Physics and Economics at the University of East Anglia.

PUMPING UP FUEL PERFORMANCE IN GAS TURBINES

By Martin S. Jones, Manager, Niche and Emerging Markets and Geoff Carson, Sales Engineer, Moog Tewkesbury

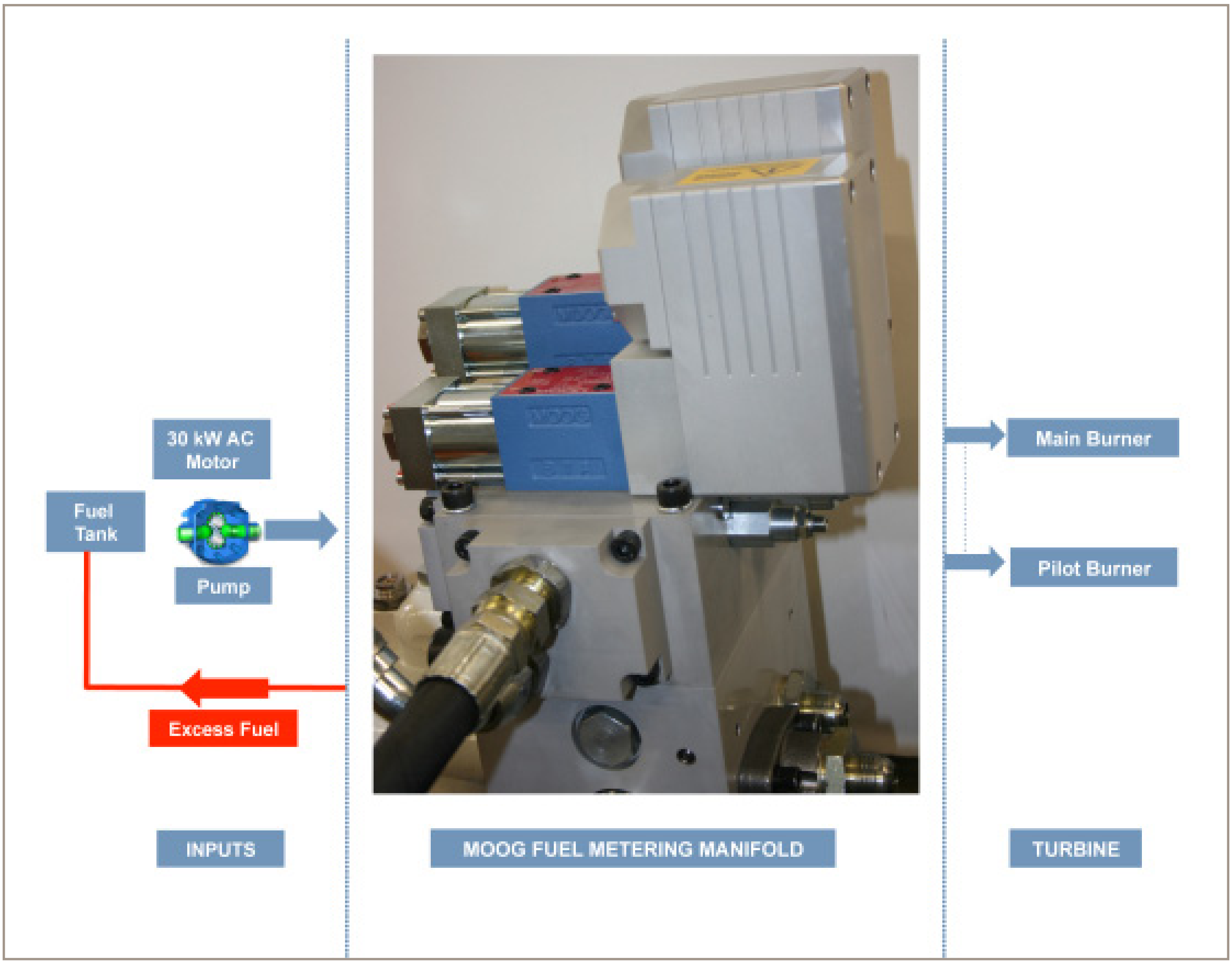
With today's escalating energy costs, the manufacturers of Dual Fan Gas Turbines are constantly looking for ways to improve efficiency, and meet ever more stringent emissions requirements. Key to these needs is the Liquid Fuel Metering function, which directly controls the supply of liquid fuel to the turbine burners (e.g. comparable to diesel). Moog has been working on fuel metering technology to improve performance for over 20 years. Before we examine Moog's latest development, let's take a look at how this latest solution has evolved.

Established Technology

The established Moog fuel metering solution comprises a custom made manifold system, which used in conjunction with a fixed displacement pump, controls the fuel flow to a single or multi stage burner system. The key control elements of the system are high accuracy Moog Direct Drive Valves (DDVs), controlling the flow to the burners, whilst hydro-mechanical valves regulate the spilling of surplus fuel back to the reservoir.

The integration of all the control devices into a single pre-tested, calibrated manifold, provides a compact solution completely eliminating interconnecting pipe-work, giving improved reliability.

While this approach gives extremely high accuracy of fuel metering (1% of maximum), it has the inherent characteristic of generating heat in the spilled fuel with a consequential energy loss.



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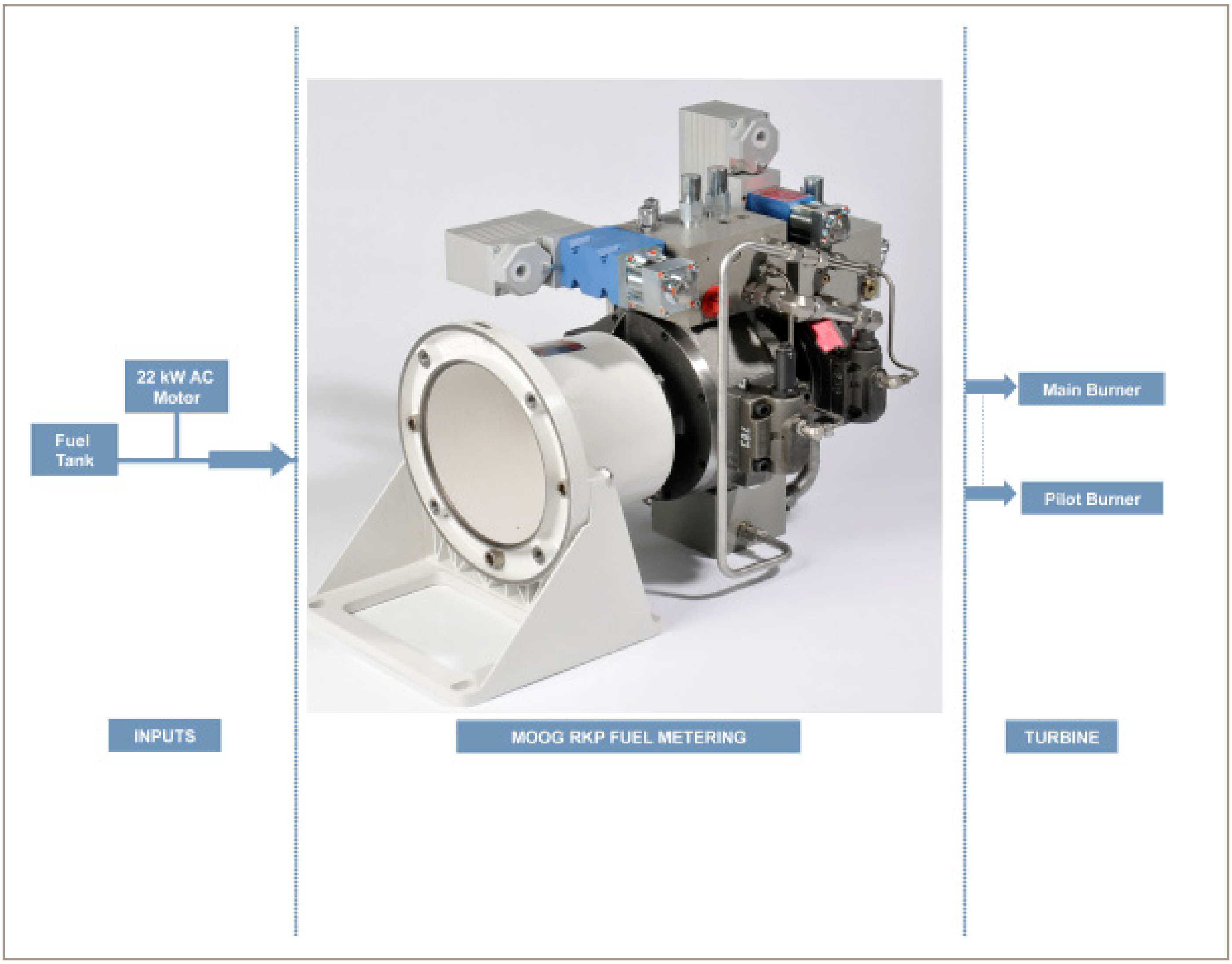
The New Moog RKP Pump Approach

This new approach combines a simplified fuel metering manifold and variable displacement pump in a single assembly. The accurate Moog DDV control elements are retained, but there is no requirement to spill excess fuel as the intelligent pump delivers only the fuel demanded by the system.

Generally tandem variable displacement pumps are used for independently supplying the pilot and the main burner. This eliminates any unwanted interaction between fuel streams associated with the more established single pump solution.

The custom designed Moog RKP pump incorporates a hydro-mechanical compensator which senses the burner pressure and delivers only the exact flow required.



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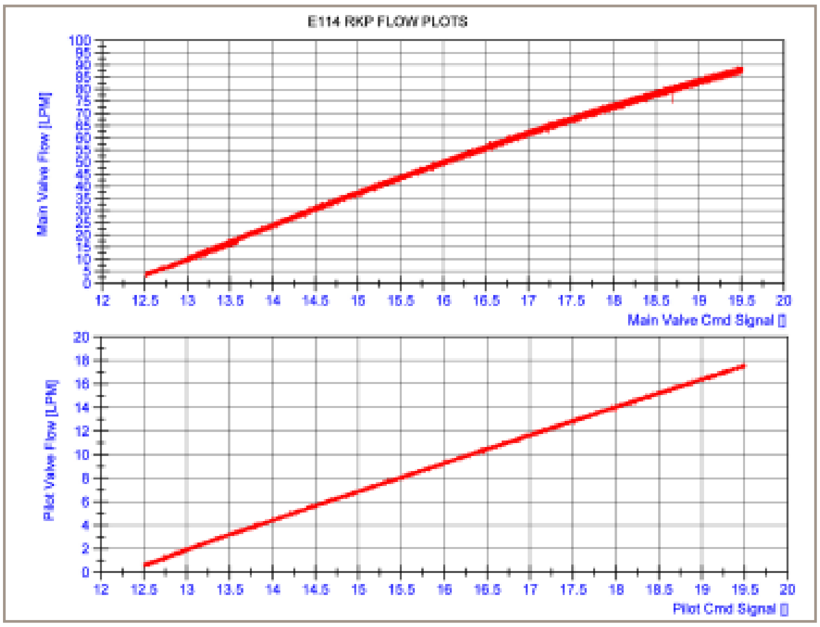
An example of the in-house acceptance test flow versus command demonstrating the exceptional repeatability.



A key feature of this compensator is its ability to respond very quickly to changes in fuel requirements, allowing it to respond to sudden changes in turbine power demand.

This technology has already been applied to turbines of power levels of up to 15 MW corresponding to fuel flow rates of up to 100 lpm (28 gpm) at 100 bar (1450 psi). Typical fuel types that have been accommodated include diesel and diesel derivatives. The system is ATEX certified for use in Group 2, Category 3 hazardous areas.

Key Customer Benefits

The benefits of the Moog RKP Fuel Metering System for a Gas Turbine user are:

- Improved reliability due to integrated construction
- Reduced fuel consumption due to improved fuel metering accuracy
- Reduced energy costs due to improved pumping efficiency
- Simplified installation due to integrated construction
- Modular range with single standardised package
- Improved start-up performance due to independent fuel metering streams

The new metering system is now fully developed for production, and is currently being used by a major Power Generation OEM for five sizes of turbine.

Future (and planned) enhancements include increasing the size of the pumps and further optimization of the manifold to accommodate larger flows required by medium sized turbines.

Authors

Geoff Carson is a Sales Engineer at Moog in Tewkesbury. Geoff recently moved from engineering where he focused on pumps in the Power Generation market. This role included the implementation of the RKP-II in relation to fuel metering. Geoff has been with Moog for 15 years.

Martin S. Jones is responsible for the Motorsport business around the world and is also the Market Manager for Niche and Emerging Markets in Europe. He has worked for Moog for 30 years in sales and applications engineering for a range of industries including mobile equipment, marine and offshore, blow molding and rolling mills. He studied Physics and Economics at the University of East Anglia.

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