Yesterday's ideas are today's hardware

GE OIL & GAS MEETING SHOWCASES THE NEW 15 PPM COMBUSTOR

ERIC JEFFS AND
KALYAN KALYANARAMAN

New Technology Frontiers was the title of GE Energy Oil & Gas customer meeting held in Florence, Italy, from Jan. 31-Feb. 1. The focus was on the technological challenges in developing oil and gas resources in remote parts of the world. "The challenges include production from non-traditional resources, drastically increased unit train size to leverage economies of scale, and operation with respect for the environment," said Claudi Santiago, president of GE Energy's Oil & Gas group.

Last year's meeting was mainly about new technologies for Liquified Natural Gas (LNG) and Gas-To-Liquids production, and the growing pressures on gas turbine operators to meet environmental standards set a decade earlier for the electric power industry. This year GE announced the commercialization of the 12 MW GE 10-2 gas turbine fitted with a new dry low NO_x combustor. The twin-shaft turbine will be used predominantly as a mechanical drive. The new combustor will be adapted at the end of 2005 to the single-shaft GE 10-1 turbine used for generator drive.

For the GE 10-2 fitted with the new combustor, GE is guaranteeing the following emission limits for a load range of 50 to 100% of baseload in a wide ambient temperature range from -20 to +100 °F:

- 15 ppmvd (15% O_2) for NO_x
- 25 ppmvd (15% O_2) for CO
- 15 ppmvd for unburned hydrocarbons

The NO_x limit for the old K-1 combustor was 25 ppmvd. And GE is offering the new combustor as a retrofit on existing PGT 10/A and GE 10-2 machines so that these units can meet new and future emission regulations.

Reducing NO_x

A significant part of the NO_x in modern gas turbines is produced when nitrogen and oxygen in the combustion air react with each other above temperatures of 1,450 ºC. Designers of combustors try to lower this "thermal NO_x" by adding more air in the primary combustion zone (lean combustion), thus lowering the flame temperature, and reducing the time the fuel-air mixture spends in the combustion primary zone (called the residence time). But all these actions increase CO and unburned hydrocarbons, and therefore designers try to achieve a balance in the levels of these pollutants.

To promote efficient combustion at "lean" conditions, the fuel is "premixed" with air to produce an intimate mixture before it enters the combustion chamber. This also helps to avoid local hot spots that may produce thermal NO_x. But this NO_x reduction technique increases the chances of flame blow-out and combustion pressure dynamics, particularly at part-load and transient conditions. The premixed flames then need stabilizing solutions in the combustor.

Around the world, new gas turbine installations are normally guaranteed at 25 ppm NO_x. However, power generating plants generally function at constant frequency and hence constant speed, and at a steady output as determined by the system dispatcher.

To achieve low-NO_x operation over the wider operating range of the mechanical drive, GE has retained in the new combustor the variable geometry construction that was there in the older version.

A valve in the air path to the combustor controls the fuel-air mixture by regulating the air flow to the primary zone. At high load, large quantities of air are employed to minimize NO_x formation; at low loads the primary air flow is partially blanked off. This optimizes the fuel/air ratio and reduces the velocity to give high combustion efficiency and low CO and unburned hydrocarbons.

The air valve has two concentric rings with slots in the walls (Figure 1). The air flow out to the cooling path is controlled by the relative rotation of the rings which makes the slots overlap by a variable amount. Air which is not used for combustion is passed into the space between the inner liner and the outer wall of the can, to reduce metal temperatures and cool the combustion products before they enter the turbine.

In the old K-1 combustor, the main premixed fuel was stabilized by pilot fuel that came in through 32 holes distributed circumferentially on the combustor throat. The non-premixed pilot flames were diffusive, which means that the pilot fuel first came in contact with the air only inside the combustion chamber. These flames have hot spots and produce more thermal NO_x.

GE engineers estimated that about 90% of the total NO_x in the old K-1 came from the diffusive pilot flame. The engineers added four premixed pilot burners and stabilized the pilot flame with a lean and diffusive sub-pilot flame (Figure 2). The result is that only a small fraction burns in a non-premixed mode as sub-pilot.

The GE 10-2 has a single combustor which can be mounted either vertically or horizontally.

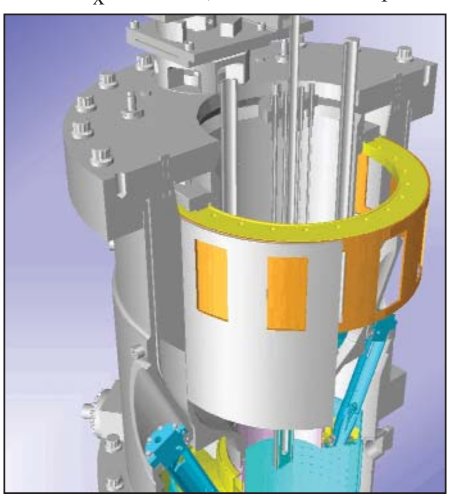

Figure 1: The air valve is formed by two perforated rings which rotate relative to each other to open and close the air path

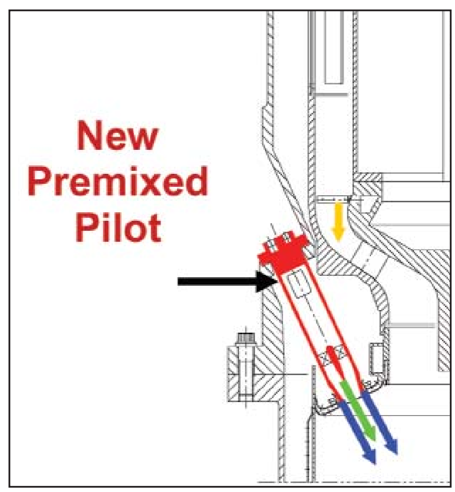

Figure 2: Blue indicates the premixed pilot flame; green refers to the diffusive sub-pilot; yellow shows the premixed main flame

UPDATE ON IRAQ

The first invited speaker at the Oil and Gas customer meeting was Ahmed Barifcani, the Deputy Oil Minister of Iraq. He gave an update on the Iraqi oil and gas industry

Dr. Barifcani started his presentation with three pictures of sabotage of oil pipelines which has substantially thwarted attempts to raise Iraqi oil output. When the coalition forces entered Baghdad in March 2003, oil production was about 1 million bbl/d. It was planned to get it up to 3.8 million bbl/d by the end of 2004, but production is still only 2.8 million bbl/d.

Sabotage is but one problem. All the oil installations were built before 1980 and are in a poor condition, Barifcani says. The UN Oil for Food program had severely restricted development of an industry which had been deliberately starved of funds during the previous decade. Much of the work in the last two years has been the repair and refurbishment of the best of the existing installations and installing some new processes.

The National Oil Company has three operating divisions: North, centred on Kirkuk; Midland, based in Baghdad; and Southern, located at Basrah. Proven oil reserves are 115 billion bbl, and of gas 3,450 billion m^3. The aim is to get oil production up to 6 million bbl/d by 2010 and lay the foundation for an international trade in natural gas to Europe and Asia.

Natural gas, says Dr Barifcani, is required first for power generation inside Iraq up to about 10,000 MW. But the infrastructure for exploiting gas for power is not fully developed and therefore there is a potential to export by pipeline through Turkey to Europe, and to Asia through a new LNG terminal at the gulf port of Um Qasr. The other big project at the planning stage is a new refinery, with a capacity of about 300,000 t/year, which is to be built on a greenfield site between Basrah and Nassariya.

The combustor cap houses the four premixed pilot nozzles.

The turbine has been developed from the original PGT10 design of Nuovo Pignone which was introduced as a single-shaft version in 1986. The first application was a cogeneration unit for a paper mill at Lucca, about 50 km west of Florence, Italy.

The controls system includes the Inlet Guide Vane (IGV) on the axial compressor, which controls the power output in conjunction with the fuel flow. The variable nozzles on the turbine control the speed of the power turbine. The IGV and the variable nozzles together control the air flow through the gas turbine and the exhaust gas temperature. The combustor air valve maintains a constant fuel/air ratio as the load changes.

The control system provides an easily programmable sequence to balance the air flow to achieve complete combustion and stabilize the premix flame at low loads. The combustion system hardware and software have been extensively tested in the U.S. at GE's Energy Laboratory in Greenville, SC. This had been followed by full scale operability tests in Florence to verify performance over the operating range. During testing of the new configuration, GE engineers validated the system's ability to maintain the NO_x, as well as the CO and unburned hydrocarbon emissions, below the target limits.

In the Amazon forest

Along with emission constraints, last year's meeting also focussed on the 100 MW gas turbine drivers in LNG plants in Qatar. GE received a contract for the supply of three modified Frame 9Es, and these units were assembled at its plant in Belfort, in eastern France. Two have already been sent to the Massa test site near Florence, and the third was shipped there at the end of January. These will be packaged in Italy and set up for string tests later this year. Belfort has received orders for three more Frame 9E mechanical drivers for another LNG plant.

The development of new gas fields in the Amazon rain forest in Peru is an environment challenge of a different kind. The gas will need to be piped over the Andes mountains to the cities in the Pacific coast.

A consortium consisting of Pluspetrol, Argentina; Hunt Oil Company, USA; SK Corporation, Korea; Hidrocarburos Andinos, Argentina, is developing the Camisea project in the rain forest which will bring bring gas over the mountains to Lima. Alberto Moonz, the international director of Pluspetrol, of Argentina, says that the field that was discovered in 1983 contains 1,022 billion m^3 of gas and 600 million bbl of condensate. It is situated in the Malvinas district, 450 km east of Lima on the Urubamba River, a tributary of the Amazon.

Development of this project is important for Peru which relies heavily on diesel and coal-fired plant for electricity generation. Replacing this with gas-fired capacity has the potential to save $120 million/year in energy costs. The project calls for the construction of a 750 km gas pipeline over the mountains to Lima with a capacity of 12.5 million $m^{3/}$day, and another for condensates.

The problems are in the location and development of the gas field. It is a biodiverse site on the edge of the Amazon rain forest. No roads can be built into the site, all wastes must be removed to an approved landfill site. The culture and customs of the native peoples of the surrounding jungle must be respected.

The Urubamba exhibits a high seasonal variation in flow, which means that only during three months of the rainy season there is sufficient depth of water to enable barges to bring the heavy equipment items up to site. Equipment manufactured in Europe and the U.S. had to be shipped to Brazil and then transferred to barges for the journey up river to site, and everything was timed to reach it at high water in the rainy season.

An airstrip enabled personnel to reach the site which is 400 m above sea level. Helicopters carriied men and material to the construction sites along the pipe route with a total of 10,000 flying hours logged. More than half a million seedlings were planted around the finished sites.

Arctic LNG plan

An equally challenging project at the other climatic extreme is Statoil's Snøvhit project to develop a gas field in the Barents Sea and an LNG terminal to send the gas to market. Roy Scott Hiorsted, director of the project, described how Statoil's expertise in developing subsea systems had been applied to designing sub-sea wellhead structures which would lie unattended in 350 m of water 150 km offshore.

The fields at about 75° north are roughly on the same latitude as the North Slope of Alaska. Snøvhit is the first development in the high European Arctic. Being so far away from the market, LNG is the only practical way to get large quantities of gas to markets in Europe and the U.S.

Hiorsted pointed out, despite the remote location, that the capital expenditure of the project was only 30% that of a conventional offshore field such as Draugen, off southern Norway, which came into production in 1980. There are no platforms or manned items off-

All pumps and compressors in the Snøvhit offshore gas field near Norway are electrically driven

shore, and all pumps and compressors are electrically driven. The LNG plant and the associated 200 MW gas turbine power station is being built on an island, 3 km from the centre of Hammerfest. All the subsea equipment has been streamlined so as not to interfere with trawlers, since the area is the world's largest pelagic fishery.

The power plant consists of five LM6000 gas turbines in a Combined Heat and Power (CHP) scheme with a 50 MW back-up from the Norwegian National Grid. The HRSGs are single pressure units with oil as the working fluid instead of water. The power plant is supplying all the subsea equipment and the process compressors for the liquefaction plant and lighing. The hot oil system provides for intake deicing in the depths of winter and for space heating around the site. The efficiency is 41% as a generating plant and 71% in CHP mode.

Gas will come ashore in 2006 and shipments will begin in 2007. 1.8 million t/year will go to the Cove Point, MD, terminal in the U.S., with other shipments to Spain and France. Total LNG output will be 4.8 million t/year.

Trinidad expansion

At the end of this year Atlantic LNG is scheduled to complete its fourth LNG train at Fortin Point in Trinidad. Train 4 will be the largest LNG unit in the world with a capacity of 5.3 million t/year.

Richard Cape, Atlantic LNG's president, traced the development of the company from the commissioning of the first process train in 1999. This train has an output of 3 million t/year of LNG and 6,000 bbl/d of stabilized natural gas liquids. 60% of the output goes to Tractabel at the Everett, MA, terminal near Boston, and 40% goes to Repsol in Spain.

Trains 2 and 3 were completed in the second quarter of 2003. At 3.3 million t/year each, the trains tripled output from the site. 62% of the output goes to Spain and 38% to the U.S. through the Elba Island terminal near Savannah, GA.

Completion of Train 4 will bring the total capacity at the site to 15 million t/year. The four trains between them have 26 Frame 5D gas turbines and 48 process compressors. Cape says that the company reconfigured the Frame 5D as part of a project to reduce down time for maintenance, particularly of the gas turbines. The turbines have a four-year maintenance cycle of combustion inspection, hot gas path inspection, combustion inspection, and major overhaul.

The reconfigured Frame 5Ds can now be separated into modules, which allow them to be dismantled for maintenance and reassembled in a similar manner to aero engines. The three modules are compressor, combustion system and power turbine. A complete module can be lifted out and sent to a maintenance shop to be taken apart, cleaned, repaired and reassembled. The advantage is that less work has to be done on the turbine deck, and gas turbine parts can be repaired in Trinidad. Cape says that experience with the modular system shows that the total maintenance time can be reduced by two days for the hot gas path inspection and by 11 days for a major overhaul. Holding a spare set of gas turbine modules would further shorten down-time. TI