NASA BECOMES SERVICE PROVIDER FOR PRIVATE SPACE VENTURES

Ever since the space shuttle program was cancelled, NASA and the Kennedy Space Center have been rebranding themselves. While they will continue to build and launch spacecraft for exploration and other government projects, the earlier single-minded focus on the shuttle program has broadened. NASA has now taken their sprawling complex and is essentially leasing space and capabilities to tenants. While those tenants consist mostly of subsets of NASA working in different areas of aerospace, two are private companies -- SpaceX and United Launch Alliance.

SpaceX designs, manufactures, and launches advanced rockets and spacecraft. The company was founded in 2002 by Elon Musk of Pay Pal fame to revolutionize space transportation, with the ultimate goal of enabling people to live on other planets. Today, SpaceX is focused on space technology through its Falcon launch vehicles and Dragon spacecraft.

SpaceX is the only private company to successfully launch and return spacecraft from low earth orbit. Recently its Dragon spacecraft attached to the International Space Station, exchanged cargo payloads, and returned safely to Earth -- a technically challenging feat that led to a $1.6 billion contract with NASA to fly at least 11 more cargo supply missions to the ISS. In the near future, SpaceX plans to carry crew as well.

United Launch Alliance (ULA) is a 50-50 joint venture owned by Lockheed Martin and The Boeing Company. ULA brings together two of the launch industry's most experienced teams from the Atlas and Delta rocket programs. They provide space launch services for the U.S. government. U.S. government launch customers include the Department of Defense, NASA, and the National Reconnaissance Office among others.

Atlas and Delta expendable launch vehicles have supported America's presence in space for more than 50 years, carrying a variety of payloads including weather, telecommunications and national security satellites that protect and improve life on Earth, as well as deep space and interplanetary exploration missions that further our knowledge of the universe.

THE NEED FOR METERING

"It used to be that the only customer we had was the shuttle program," said Dan Tierney, sustaining systems engineer for URS Corporation, a contractor working with NASA at the Kennedy Space Center. "Since they were the sole user of everything that was supplied, there was no need to monitor usage. Now that the shuttle program has ended and NASA has various customers, we need to bill each one separately for everything we supply them. For liquids and gasses that meant that we had to install metering."

"For a variety of reasons, the two most difficult flows to measure are nitrogen and helium gas," said Tierney. "Both are vital in rocket and spacecraft use. Nitrogen is a propellant and helium has three uses. It is used to remove atmospheric moisture from clean room facilities. Because helium is an extremely small molecule and can find its way through the tiniest opening, it is valuable as a leak detector on spacecraft. Third, it is used in high volumes in launch support. Since helium will not freeze upon expansion as most gasses will it is used as a purge gas to sweep out combustible vapors from rocket engines and engine compartments. We call it 'safing'.

“The need for metering was also a means to encourage conservation. Helium very expensive -- 10 times the cost of nitrogen. Helium is a finite commodity so we must try to conserve it. Most recently it cost $120 per 1,000 cubic feet. We want to encourage our customers to not over use it.

Everyone is now doing accountability for how much they're using. They must transfer funds for commodity use. And they must rethink how much they're using for conservation reasons.”

SELECTING THE RIGHT METER

NASA is noted for their meticulous attention to detail, so when it was time to determine what metering they needed for their helium and nitrogen piping, they teamed Tierney with Michael Katz, a mechanical design engineer for URS Corporation, and tasked them with the job of identifying the ideal meter for the job. It had to be one that could measure the flow of liquid and gaseous helium and nitrogen at extreme pressures. It had to measure through extra thick XXS pipe. And it had to measure gas flow through piping less than an inch in diameter.

First, they established the goals of the study. The study would:

- Define primary requirements and determine industry manufacturer's capability to meet NASA standards through market survey.
- Determine technology types and/or methodologies for flow measurement.
- Perform technical literature survey to verify applicability and reliability of technology types.
- Assess through comparative analyses the differences of various technology types.
- Provide Rough Order of Magnitude (ROM) cost study of candidate flow meters under consideration.
- Recommend a flow meter selection as a fixed-installation for both pipeline transit to launch pads and for the fixed processing facilities.

The challenges were great. The meters tested would have to provide accurate measurements on a variety of tube and pipe sizes at a wide range of pressures and flow rates. The three sites to be used for testing were the old shuttle launch pad, the helium facility, and the nitrogen facility. All of them had different requirements and provided a range of challenges.

TESTING REQUIREMENTS

At LC-39 (The old shuttle launch pad) the meters would be tested on pipelines of gaseous nitrogen (GN2) and gaseous helium (GHe).

- Rated for 6000 psig maximum allowable operating pressure (MAWP).
- Measurement accuracy at 1.0% or better.
- Self-ranging scale for a flow range of 10 - 20,000 standard cubic feet per minute (SCFM).
- Capable of measurement of high-purity compressed gaseous nitrogen GN2 (2.5 in pipe) and gaseous helium GHe (1.5 in pipe).
- External meter, clamp-on types must be capable of reading through heavy wall pipe, Sch XXS.
- Must be capable for in-place calibration.

At the helium facility the challenges were:

- Must be capable of measuring GHe supply and branch tubing, with pressures at 50–3300 psig.
- Must be capable of measurement with KC tubing less than 1-inch.

At the nitrogen facility, the meters would measure piping:

- Rated for 6000 psig operational pressure (MAWP).
- Typical pipe size at 1-1/2". Sch XXS.

The study investigated the feasibility of all potential flow meters, either as pipe insertable and non-intrusive types, based on the ability to meet the above criteria.

SELECTING THE METER

"We started our research on the internet," said Katz. "Some meters we already had knowledge of, but there are a lot flow meters out there. One thing that disqualified many of them was that they couldn't measure flow through thick pipe. And because we move nitrogen and helium at some very high pressures, we use thick pipe."

When their research was done, they invited those that seemed most qualified to perform the measurements described above. The velocity flow meters assessed by the team included electromagnetic, vortex, swirl, turbine, and ultrasonic.

"While many of the meters provided acceptable accuracies, operating and maintenance costs played a big factor," said Tierney. "All but one of the meter types was intrusive and had to be exposed directly to the flow. That meant an expensive installation. And then there was maintenance. Because the meters were exposed directly to the flow, they would experience wear. That meant that down the road, we would have to shut down, remove, the meter, clean or replace parts, and start up again. That added greatly to the long-term cost.

"The one type of meter left was ultrasonic and NASA had some bad experience with ultrasonics in the past so there was a negative mind set with NASA management. They had been intrigued by the clamp-on concept that ultrasonics offered and had some companies in, but none could get measurements on the thicker wall pipes."

"We did a lot of research on all the meters we reviewed. For ultrasonics we only invited one manufacturer because they were the only one who said on their web site that they produced accurate measurements on thick wall pipe," said Katz.

"The problem NASA had in its previous encounter with ultrasonic flow meters was that they failed to accurately measure flow on thick wall pipes," said John Van Nostrand, south east regional manager for FLEXIM Americas. "FLEXIM uses both Lamb wave and shear wave transducer technology. Lamb wave transducers create a wide beam of sound by vibrating at the harmonic of the pipe wall. This creates a very efficient signal which is needed for gas measurement at lower pressures. For gas measurement at very high pressure where the pipe wall is very thick, a shear wave narrow beam transducer is more effective. It is important to offer different transducer designs to cover the many flow application we encounter. Having both transducer types in our demonstration kit allowed us to operate well on all the pipes we encountered at NASA"

Nonetheless, there was still a reluctance on the part of NASA management because of their previous experience with ultrasonics.

"John did presentations for a variety of groups at NASA, mostly management, engineering, and particularly the fluid management department," said Tierney. "They included demonstrations with a portable meter that gave his claims credibility." NASA then purchased two portable ultrasonic flow meters and went around testing them on every line that needed a permanent meter. By taking this extra step, whatever doubt about the ability of clamp-on ultrasonic meters to measure the full range of NASA's applications.

HOW ULTRASONIC METERING WORKS

The technique most ultrasonic flow meters use is called transit-time difference. It exploits the fact that the transmission speed of an ultrasonic signal depends on the flow velocity of the carrier medium, kind of like a swimmer swimming against the current. The signal moves slower against the flow than with it.

When taking a measurement, the meter sends ultrasonic pulses through the medium, one in the flow direction and one against it. The transducers alternate as emitters and receivers. The transit time of the signal going with the flow is shorter than the one going against. The meter measures transit-time difference and determines the average flow velocity of the medium. Since ultrasonic signals propagate in solids, the meter can be mounted directly on the pipe and measure flow non-invasively, eliminating any need to cut the pipe.

ULTRASONIC METERING INSTALLED

"After we got the approval from NASA, FLEXIM worked very well," said Tierney. "We started with two fixed installations -- the helium pipeline and nitrogen pipeline at the old shuttle pad known as Launch Complex 39A. It is reserved for NASA's next rocket. Since the meters did not come in contact with the gasses, the installation was fast and easy with no need to shut the system down during installation.

"There was only one problem early on with measuring flow in the small diameter stainless tubing with the portable meters. We were testing smaller piping going into the leased buildings. We use a pressure vessel outside the leased facilities and run tubing into the building. Since these measurements are what we bill our clients by, the ultrasonic had to be successful on small tubing, it became the main focus. Even though they are big laboratories, clean rooms, and processing bays, they don't use the quantities of a launch pad, so we had to prove success with small tubing. FLEXIM's solution was just the opposite of the high pressure, thick walled pipe. They switched to the lamb wave transducers and that solved the problem."

FUTURE METERING NEEDS

"The accuracy of the ultrasonic meters was as good as or better than any of the other meters we tested and installation and maintenance costs are almost nil," said Katz. "NASA management and engineering are all on board. So, in coming months we will be installing an additional 22 permanent ultrasonic meters at the Kennedy Space Center and using the resulting data to bill our lease clients on gas usage."

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