TESTING OF AN IN-LINE ROTARY SEPARATOR (IRIS™) AT THE CHEVRON F. RAMIREZ GAS PRODUCTION FACILITY

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ABSTRACT
The In-line Rotary Separator (IRIS™) was tested from October 1999 to June 2000 at the Chevron F. Ramirez gas production facility in Laredo, Texas. The purpose of this test was to evaluate the flow and separation characteristics of this technology in an actual production system, as well as monitor the mechanical reliability. The unit logged 4,763 hours of operation and exhibited excellent mechanical performance over that time. The flow and separation characteristics varied with the production rate with a separation efficiency level greater than 99% was achieved at peak test conditions. Further testing was undertaken in November 2000 at the Colorado Engineering Experimental Station, Inc. (CEESI) to quantify the flow, pressure drop, and speed characteristics.

INTRODUCTION
The IRIS™, developed by Multiphase Power & Processing Technologies, is an ultra-compact in-line separation device designed to "scrub" liquids from a wet gas stream. The technology provides high quality separation at significantly smaller equipment size than current technology. A cross section of this device is shown in Figure 1. Separation is achieved by a free-spinning rotor wheel, which derives power from process pressure. Requirements are a 1-7% pressure drop for operation, depending on the liquid content. Maximum inlet liquid content that can be handled is 4% by volume.

It can operate equally well at the wellhead or pipeline, and will provide significant advantages in retrofit, debottlenecking, and new installations. The compact size produces the highest throughput-to-size ratio of any scrubbing equipment and greatly reduces liquid inventory hold-up over vessel based technology. In-line installation eliminates support skid and allows fast change-out. Envisioned applications for the IRIS™ include gas transmission and metering runs, compressor suction or discharge, absorber/contactor inlet or outlet, well testing and proving, or as a standard or secondary scrubber.

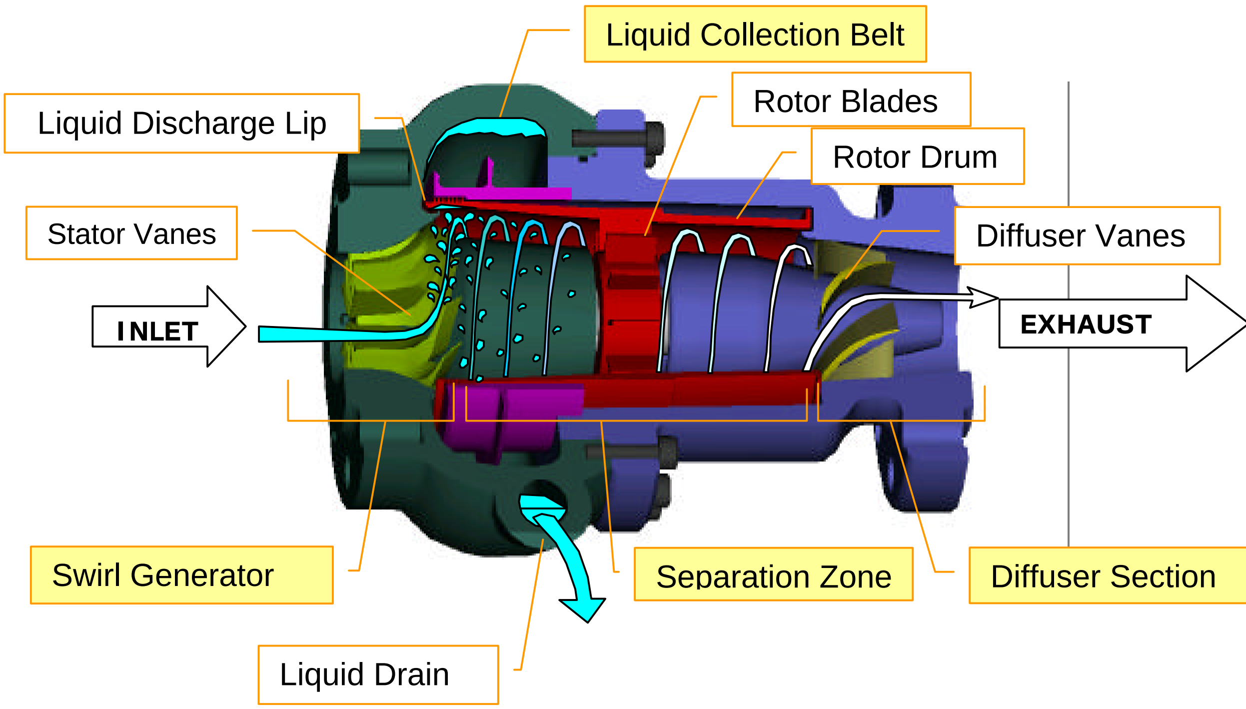

Figure 1 IRIS™ cross-section showing components and flow path.

OPERATION DESCRIPTION

The general layout of this device is similar to an axial flow cyclone. It has an axial arrangement consisting of a swirl generator, separation zone, diffuser section, and liquid collection belt, as shown in Figure 1.

The inlet gas/liquid stream travels through a set of stator vanes in the swirl generator that directs the flow to a larger radius while increasing the tangential velocity component. The stream then enters a separation zone, which is an annular region with a static inner wall, and a rotating outer wall formed by the inside of the rotor drum. The vortical flow subjects the fluid stream to a field of up to 3,000 "g", which centrifuges the liquids (or particles) to the outer wall.

The rotating outer wall provides several important benefits. The primary advantage is a radially outward force continually applied to the separated liquid forcing it to "stick" to the moving wall. Secondly, because the outer wall and fluid are moving at approximately the same rotational speed, no significant fluid shear boundary forms. This results in a more distinct and smooth liquid layer compared to static walled cyclones, and provides significantly improved separation. Finally, the moving wall actively forces the separated liquid to a drain location. A combination of viscous drag on the drum and momentum transfer from the fluid stream passing through axial spokes on the rotor provides the energy for rotation.

After traversing the separation zone, the dry gas exits through a vaned diffuser section to recover a portion of its kinetic energy and to minimize exit swirl. The separated liquid on the rotor drum moves to a collection ring. Liquid exits the collection ring through four radial holes. It jets radially outward into an annular collector band, which directs it toward a tangential drain opening.

FIELD TEST PROGRAM

A field trial of this technology in production operations took place from October 1999 to June 2000. The field test site selected is the Chevron F. Ramirez gas production facility, located 45 miles southeast of Laredo, TX. This site was selected due to its flow conditions, ease of installation, and interest in using this technology in Chevron. The total accumulated run time on the unit was 4,763 hours. The unit ran 132 days with 100% uptime after initial setup and debugging, which was end life of this well.

FIELD TEST LOCATION

The F. Ramirez site contains production wells, gathering manifolds, scrubber separator, liquid storage tanks, and gas custody transfer metering stations as shown in Figure 2. Gas, with associated water and condensate, are produced from various wells in the area, and gathered into a HP (ANSI Class 600) and LP (ANSI Class 150) manifold. The HP and LP gas each flow through a dedicated horizontal scrubber vessel (24" I.D. x 10' S/S) to remove associated liquids. Gas from each well can also be bypassed to a test separator for well tests. The gas flows to a dedicated HP or LP metering station and into sales line, while the removed liquids are mixed and sent to the storage tanks. The tanks are periodically gauged and liquids removed from the site via tanker truck.

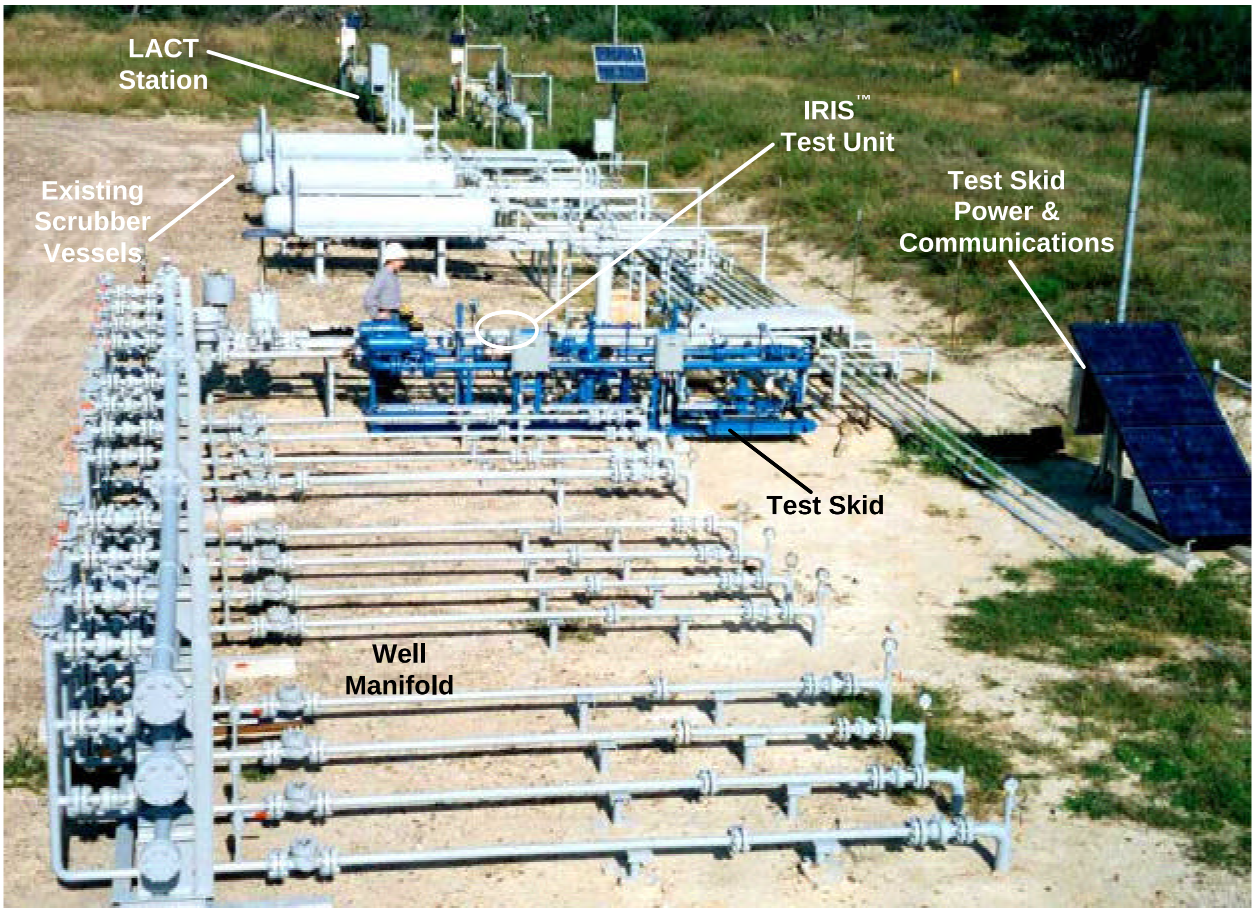

Figure 2 Test skid (in blue) installed at the Chevron F. Ramirez gas production facility.

The field evaluation unit was installed upstream of the HP scrubber vessel, directly on the outlet of the manifold. The produced fluid flow through the unit, where the liquids are separated, metered, and to the storage tanks. The scrubbed gas is metered and flows to the HP test separator to capture carryover.

IRISä AND SKID DESIGN

All components of the IRIS™, except the shaft and bearings, are made from 316 SS. The shaft is made from 17-4 PH stainless steel to provide a harder material running on the face of the bearings. Dry running graphite bearings are used because they do not require an active lubrication system.

The skid is designed to prevent interference with production at the F. Ramirez site under all circumstances. The inlet, outlet, and bypass piping are 3" to match the production header line size as shown in Figure 3.

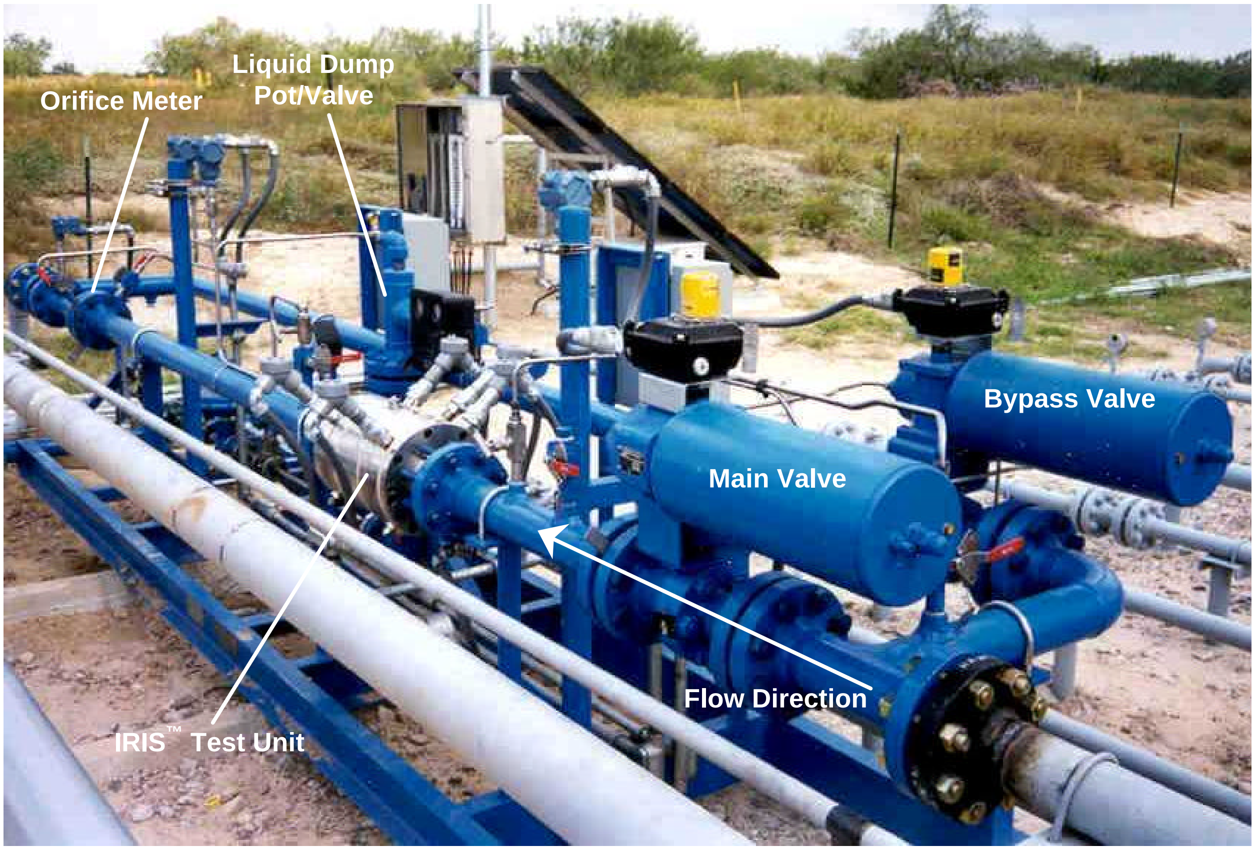

Figure 3 Close-up of test skid layout.

The skid is designed to 600# ANSI operation, at a capacity of 12 MMSCFD of gas and 200 BPD liquids. Due to the remote nature of the site, power and communications are provided within the skid package. Electric power for the PLC, transmitters, and phone system is provided by a solar panel with battery backup. Area classification for all equipment is Class 1, Division 2, Group D, and the control panel is rated to NEMA 4X. On-line operation can be viewed through cellular phone dial-up system, which is also used to download logged data.

DATA GATHERING

Performance data is gathered both electronically and manually. The skid control system is designed with a data logger to capture process and mechanical operating conditions. All data points are logged every 20 minutes and stored in a 386-based data module. The data is retrieved by a cellular phone dial-up system. In addition, up time monitoring and control of the unit is done through the remote dial-up interface screen. The data collected includes time, temperature, pressure, instantaneous flow rate, totalized flow rate, vibration, speed, inlet & outlet valve location, and trip alarm. Process data for the F. Ramirez site was collected and distributed by Chevron. The metering station measured totalized gas flow. Totalized flow rate for the separated liquid was measured by level measurement in the storage tanks. Totalized flow rate for liquid carryover was measured by a positive displacement flow meter on the liquid outlet of the test separator. Table 1 shows the range of data recorded over the duration of the test program.

Table 1 Range of process and mechanical data.

Data Point	Unit	Min. Value	Max. Value	Mean Value
- Inlet Pressure	psig	1054	1119	1095
- Pressure Drop	psi	1.4	30.1	13.2
- Rotor Speed	RPM	1939	7200	4609
- Inlet Vibration	mils	0.5	2.4	0.7
- Outlet Vibration	mils	0.1	1.6	0.3
- Water Flow	BPD	33	117	61
- Condensate Flow	BPD	0	27	9
- Gas Flow	MMSCFD	4.33	7.94	6.23
- Inlet Liquid Mass Fraction	%	1.79%	11.71%	5.95%

RESULTS

The pressure drop exhibited qualitatively predictable results as shown in Figure 4. Variation of the pressure drop with changes in gas flow rate and liquid content followed expected trends. Increases in gas flow resulted in proportional changes in pressure drop. All test data collected was used in validation of the design model and to improve the commercial unit.

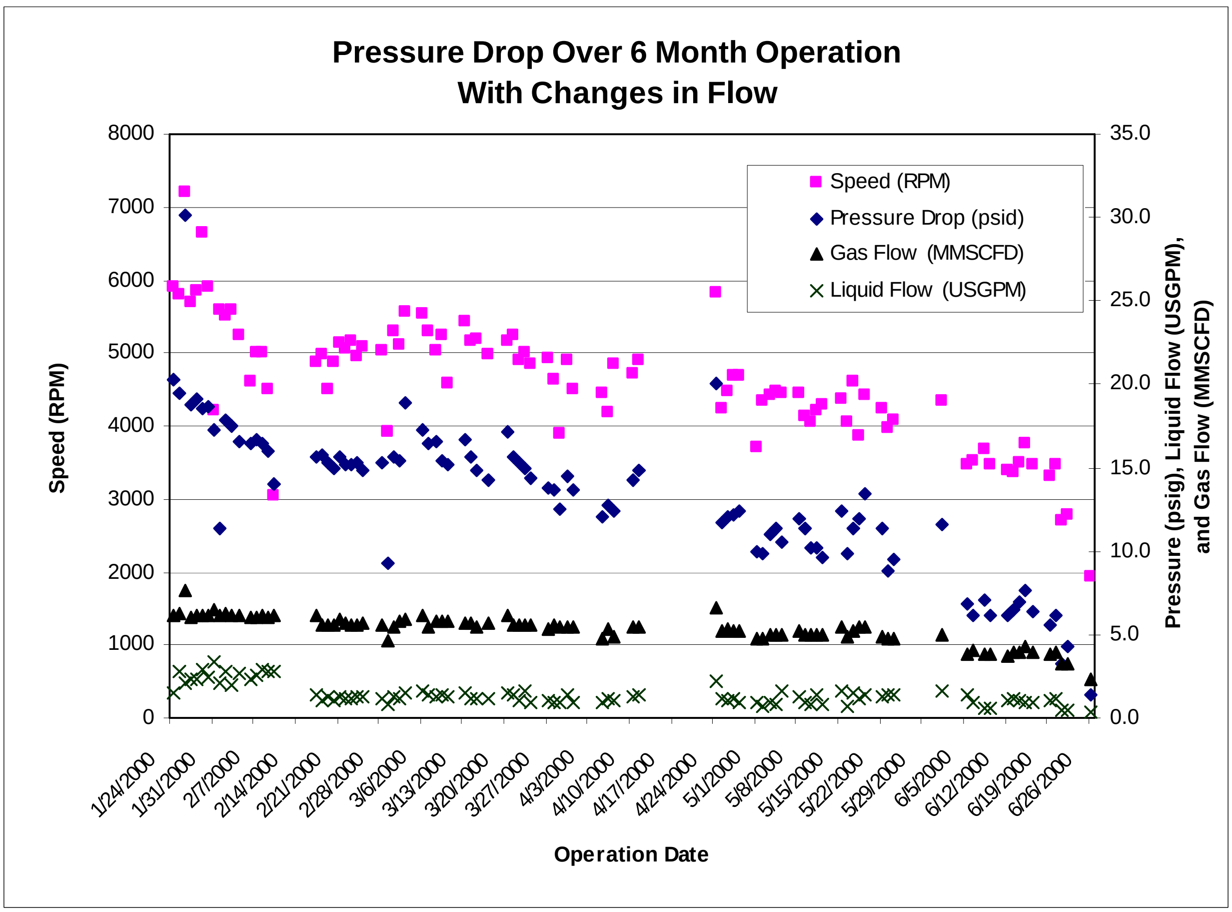

Figure 4 Six months of operating data at F. Ramirez site.

From January through May, the separation efficiency (defined as the percent of liquid removed from the inlet stream) averaged greater than 99.0%. In June, the well production started to show significant decline, which reduced the separation efficiency as shown in Figure 5. By this time, the test unit was running at 15-20% the design capacity. Qualitatively the performance was sufficient to validate the technology concept and to proceed with refinements in the design.

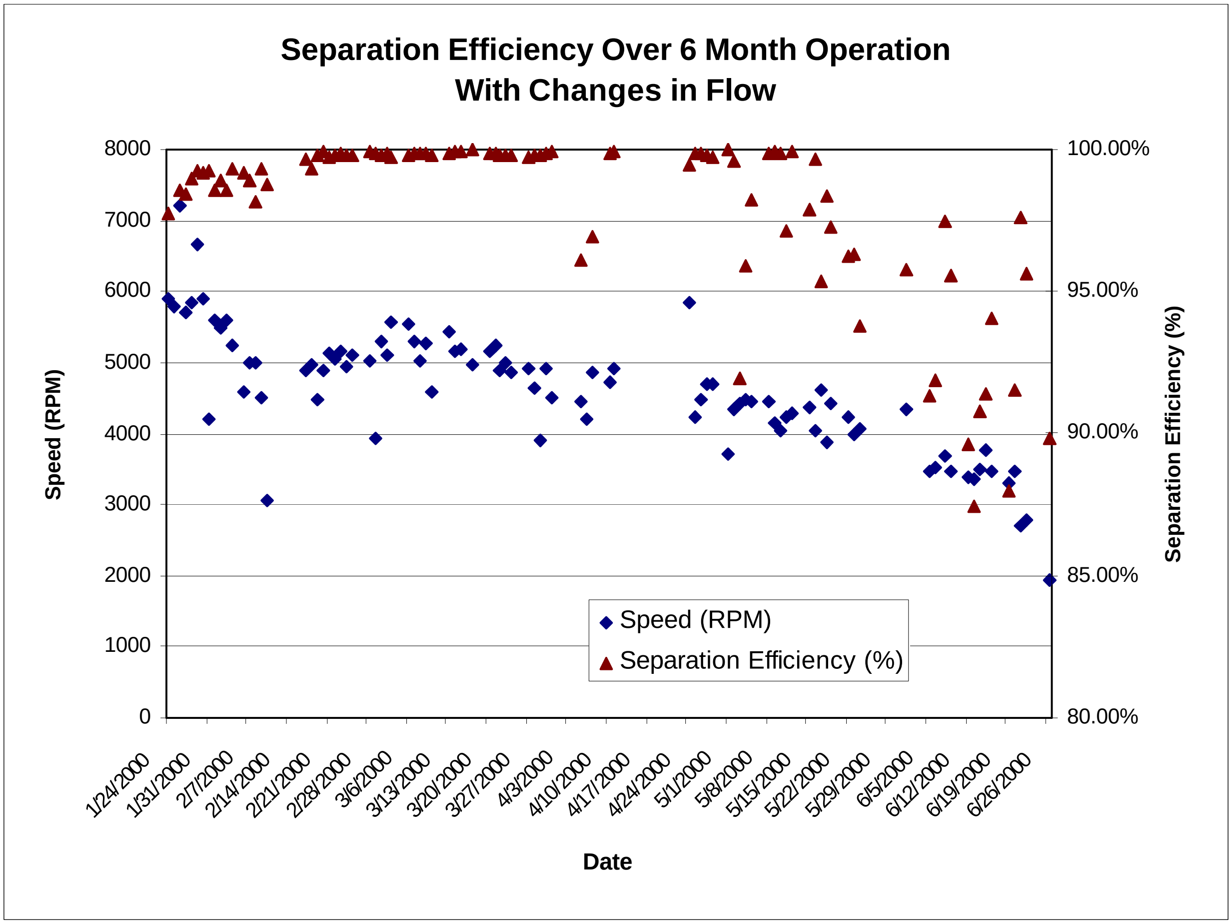

Figure 5 Separation efficiency results from F. Ramirez site.

The bearing vibration levels remained below the shutdown threshold of 2.5 mils throughout the duration of the test. The inlet and outlet bearings averaged 0.7 and 0.3 mils respectively. This includes multiple startups, liquid backup, liquid slugs, and transient flow conditions. In all cases, the bearing vibrations resumed to a constant level, well below the shutdown threshold. These levels are deemed acceptable for long-term operation.

FLOW STREAM CONTAMINANTS

The test unit was subjected to various flow stream contaminants that were present in the fluid flow. Of particular note were foam and solids. The wells at the F. Ramirez site were soaped every day to remove the liquid buildup from the well bore. The soaping process occurs daily and generates a slug of liquid/foam for 30-45 minutes within an hour after it is started. The liquid/foam slug was noted in the logged data by a spike increase in separated liquid flow rate, and a spike decrease in rotating speed. The foam slug clears itself immediately, and the unit resumes normal speed and separation. The overall effect of the slug is minimal to the separation performance and negligible to the mechanical integrity.

During two separate visual inspections, solid particulates were discovered throughout the test unit and skid piping internals. Samples of these solids were removed during the first inspection in November 1999 and inspected for visual microscope analysis. The samples contained rust (50-1000 microns), silica quartz sand (250 microns), and clay (<37 microns). The liquid discharge holes were not plugged with solids during any inspection. The upstream 1/8" cone strainer was also checked and no solids were observed. From the visual inspection for wear marks and the clearing of the solids from the rotor that the IRIS™ can suitable handle normal produced solids production from a gas well, and is self clearing of these solids. An upstream strainer is always recommended to prevent large foreign material from blocking the inlet or outlet orifices.

CEESI WORK

As an extension of the field test program, the prototype unit was tested at the Colorado Engineering Experiment Station, Inc (CEESI) Wet Gas Flow Loop in November 2000. The purpose of this test was to quantitatively define the flow and separation characteristics of the IRIS™. CEESI test work was performed with dry processed natural gas and decane. Quantifiable trending results were obtained for the gas and liquid flow versus speed. These results produced several equations that can be used to predict speed under a wide range of conditions. The trends obtained for gas and liquid flow rate versus separation efficiency are shown in Figure 6. The separation efficiency range determined at F. Ramirez field trail was also verified at CEESI.

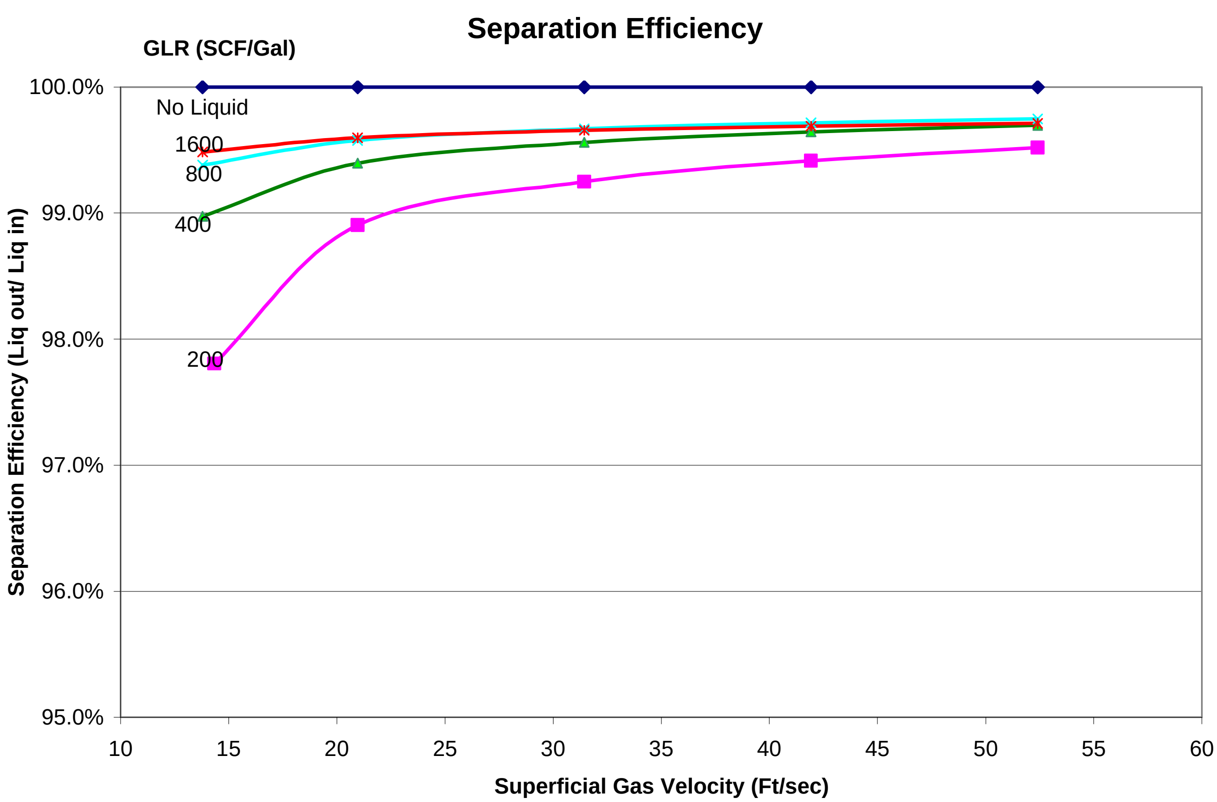

Figure 6 Separation efficiency results from CEESI.

CONCLUSIONS AND FUTURE WORK

The following general conclusions are drawn from the data, charts, and recorded observations.

1. The field test unit accumulated 4,763 installed run hours. The mechanical and vibration performance exhibited by the IRIS™ was excellent for the duration of this test, and gives sufficient confidence to implement the graphite bearings into the commercial design.
2. Flow and speed exhibited qualitatively predictable results during the field trial. The CEESI wet gas loop offered controlled test conditions to collect a wide range of performance data and develop accurate

empirical design equations. The commercial design unit will include refinements in the flow path to minimize the overall pressure drop.

3. The gas flow versus separation efficiency followed the general design trend. Qualitatively the performance data collected at the field trial was sufficient to validate the technology concept. Furthermore, CEESI test results provided further refinements for future design.

Future test work includes field evaluation on compressor suction and flow loop evaluation as a wet gas meter.

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