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UTILIZATION OF AN INLINE ROTARY SEPARATOR AS A WET GAS METER

V. C. Ting
Chevron Petroleum Technology Company
Houston, Texas, USA

ABSTRACT

Chevron Petroleum Technology Company evaluated the performance of an inline rotary separator in 2000 and during the evaluation tests, we discovered that the inline rotary separator could also be used as a wet gas meter to measure gas and liquid flow rates. The inline rotary separator, IRIS™, is a commercial gas-liquid separation device manufactured by Multiphase Power and Processing Technologies, LLC. It is a compact, high quality, separation device that can be used in wellhead or pipeline applications.

The inline rotary separator removes gas and liquid phases from a wet gas stream and the gas flow rate can be interpreted by measuring the rotor speed at wet conditions. Hence, it can be used as a wet gas meter by measuring the separated liquid phase and the rotor speed. Test results indicated that low liquid loading, up to 3% liquid/gas mass ratio (LGMR), has minimal affect on rotor speed. Natural gas flow rates can be measured within ±5% accuracy using the dry gas speed curve at high gas velocity. For LGMR greater than 3%, meter flow calibration and gas flow rate interoperation are required.

This paper consists of the following topics:

- Review inline rotary separator operation principle.
- Present field trail and flow loop test results.
- Use inline rotary separator as a wet gas meter.
- Measure gas flow rates at low and high liquid loading.
- Conclusions and recommendations.

INTRODUCTION

Accurate and reliable wet gas metering technology is an important component of the natural gas production system. More gas will be produced in the future from remote and subsea fields where production, capital investment, and operating costs must be optimized. For example, real time measurement of gas and liquid flow rate in a subsea production system will improve well allocation, optimize reservoir production, and enhance flow assurance. Most commercial multiphase meters have a higher measurement uncertainty in high gas void fraction (GVF) range, which is not suitable for wet gas applications. Therefore, wet gas metering technology has received more attention by the industry and, consequently, several wet gas-metering systems have been developed. In addition, joint industry projects have been formed to evaluate wet gas meter performance.

The wet gas metering technology available generally falls into three categories:

- Commercial Gas Meters—Several studies[(1-7)] were conducted recently to determine the effect of liquid on gas flow measurement accuracy in orifice, venturi, v-cone, vortex, ultrasonic, coriolis, and turbine meters. When these types of meters are used for wet gas flow measurement, the liquid flow rate is required as a known input parameter for gas flow rate corrections and calculations. The liquid flow rate can generally be determined or estimated by using well tests, tracers or reservoir PVT predication methods. These methods will provide a constant liquid flow rate estimate over a test period. The uncertainty of the gas flow rate measurement, therefore, depends on the uncertainty of the liquid flow rate input value over that measuring period. If the liquid flow rates vary significantly, the gas flow rate measurement uncertainty will be large.

- Wet Gas Meters—There are commercial metering products for wet gas flow measurement, such as Venturi Dualstream, Agar, VEGA, Ultrasonic wet gas meter, and in-line multiphase meters,[(8-12)] where gas and liquid flow rates are measured simultaneously. However, there are limited third-party published performance evaluations on these new devices at this time.

- Separation/Metering—This method utilizes a gas/liquid separation device to produce a low GVF multiphase stream and a gas stream. A multiphase meter is used to measure the low GVF multiphase steam with better measurement uncertainty while a commercial gas meter is used to measure the gas stream.[(13)]

Chevron recently evaluated a compact 75 mm (3-inch) in-line gas-liquid rotary separator, IRIS™, at Chevron's Laredo Gas Field and at the Colorado Engineering Experiment Station, Inc., (CEESI) Wet Gas Flow Facility. IRIS™ is a commercial gas-liquid separation device manufactured by Multiphase Power and Processing Technologies, LLC. The unit is 10% of the size and weight of a conventional static separator.[(14)] During performance evaluation tests, we discovered it could be used as a wet gas meter to measure gas and liquid flow rates.

INLINE ROTARY SEPARATOR OPERATING PRINCIPLES

The IRIS™ is an inline rotary gas-scrubbing device, which is compact in size with acceptable separation features. It can operate at the wellhead or pipeline where space or accessibility is limited. Its assembly consists of three major components: an inlet housing, an exhaust housing, and a rotor/bearing system, as shown in Figure 1. The inlet housing contains the swirl generating passages, liquid collection belt, inlet pipe flange, and bearing housing. The exhaust housing contains the diffuser/flow straightening section, the exit end bearing housing, and the exhaust pipe flange. The rotor assembly contains a rotor drum/wheel pressed onto the shaft. The thrust and journal bearings are ceramic ball bearings. The inlet and exhaust housings are bolted together to form a pressure containment vessel.

The general layout of IRIS™ is similar to an axial flow cyclone as show in Figure 2. It has an axial arrangement consisting of a swirl generator, separation zone, diffuser section, and liquid collection belt. 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.

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 rotational flow field subjects the fluid stream to a high gravity "g" field, which centrifuges the liquids to the outer wall forcing them to attach to the moving wall. 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.

After traversing the separation zone, dry gas exit through a vane diffuser section to recover a portion of its kinetic energy and to minimize exit swirl. The separated liquid on the rotor drum moves axially upstream due to the conical shape of the drum. Liquid exits the rotor off a lip at the inlet end of the drum. It spills outward in the radial direction into an annular collector band, which directs it toward a tangential drain opening.

SEPARATION PERFORMANCE EVALUATION

Prototype Unit Field Trail

A prototype In-Line Rotary Separator was tested from October 1999 to June 2000 at the Chevron F. Ramirez Gas Production Facility in Laredo, Texas, USA. The purpose of this test was to evaluate the mechanical reliability and separation characteristics in an actual production system. A skid was designed to handle a capacity of 340,000 Sm^3/day (12 MMSCFD) of gas and 32 m^3/day (200 BPD) liquids at 9,928 kPa (1,440 psig). The skid includes a 7.6 cm (3-inch) prototype unit, gas and liquid metering system, and the bypass piping as shown in Figure 3.

The facility contains production wells, gathering manifolds, scrubber separator, liquid storage tanks, and gas custody transfer metering stations. Gas, water, and condensate are produced from various wells in the area, and gathered into a manifold. High pressure and low pressure streams each flow through dedicated horizontal scrubber vessels. Individual wells can also be bypassed to a test separator for well tests. Natural gas flows to sales lines while the removed liquids are sent to the storage tanks. The tanks are periodically gauged to measure water and condensate content.

The evaluation system was set up so that the test skid was installed upstream of the high-pressure scrubber vessel, directly on the outlet of the manifold. IRIS™ separates the multiphase fluid whereas the liquid flow is metered. The scrubbed gas was also metered and flows to the test separator to capture any liquid carryover. The amount of liquid carryover from the test separator was used to determine the separation efficiency. Separation efficiency is defined as the ratio of liquid removed from the IRIS™ over the total liquid input.

The unit operated at 76 bar (1,100 psig) inlet pressure and ambient temperature conditions with flow rate up to 11,800 Sm^3/hr (10 MMSCFD). The liquid load is 0.33-0.66 m^3/hr (50-100 bbl/day) with 75% water cut. The unit operating speed ranges from 5,000 to 8,000 rpm with a pressure drop between 1-1.4 bar (15-20 psi). The flow and separation characteristics varied with the production rate with greater than 99% separation efficiency at near design conditions. Figure 4 shows IRIS™ speed and separation efficiency history plots. The field test was concluded when the gas flow rate was reduced to 20% of the design flow rate. A total of 4,763 hours of operation was logged and no mechanical failure was detected over that time.

Commercial Unit Performance Tests

Further testing of a 7.6 cm (3-inch) commercial unit, shown in Figure 5, was undertaken at the Colorado Engineering Experimental Station, Inc., (CEESI) Wet Gas Flow Loop to quantify the flow, pressure drop, and speed characteristics of the rotary separator. The wet gas flow facility is constructed as a re-circulating flow loop where processed natural gas and liquid decane are selected as flowing fluid for the tests. The flow loop is designed to flow at pressures between 5.9 and 82.7 bar (100 and 1200 psia) and temperature 2.7 to 27ºC (5 to 50ºF) above the ambient temperature. The overall uncertainty of CEESI's wet gas flow system is estimated at 1%. A gas turbine flow meter is selected as the dry gas flow reference meter and a coriolis meter is also used to measure the liquid flow rate before it is injected into the gas stream. After liquid is injected into the gas stream, wet gas with known liquid gas mass ratio (LGMR= m_{liquid}/m_{gas}) flows through a test section. In the performance evaluation tests, a mist removal vessel downstream of the rotary separator was installed, as shown in Figure 6, to measure liquid carryover by IRIS™.

Figure 7 presents typical performance results showing the separation efficiency for LGMR ranging from 0 to 1.0, and superficial gas velocity from 3-15 m/s (10-50 ft/sec) at 41 bar (600 psia). The separation efficiency varies from 96% to 100% depending on the superficial gas velocity and LGMR. As shown in the figure, the tested unit performed best at 15-m/s. Performance curves such as these can be used to understand the rotary flow characteristics and improve future separation design. Pressure drop across the rotary separator measured up to 3% of the inlet pressure.

IRIS SEPARATOR AS WET GAS METER

During the evaluation tests conducted at CEESI, it was discovered that the inline rotary separator could be used as a wet gas meter to measure gas flow rates. For low liquid injection tests, the rotor speed is less sensitive to the liquid flowing rate which is shown in Figure 8. In this figure, superficial gas velocity is plotted over the rotary speed for dry gas at LGMR<3%. The dry gas speed data points (■) are bounded by the ±5% accuracy dotted lines. The test data also show that wet gas rotor speed date points (◆) lie within the ±5% bounds at low LGMR and higher gas velocity. This implies that the wet gas flow rate can be measured directly by using the dry gas speed curve at higher gas velocity conditions. Combining with the liquid flow rate measured separately, the IRIS™ can be used as a wet gas meter.

At low LGMR, gas flow measurement accuracy can be improved further by using the wet gas speed calibration curve at operating conditions. For example, a calibrated LGMR vs. Speed plot, shown in Figure 9, can be used to iterate gas flow rate calculations to improve gas flow measurement accuracy. Similarly, the liquid flow rate accuracy can be improved by considering the separation efficiency in flow rate calculations.

As the LGMR increases, the rotor begins reducing its speed due to additional loading and increasing fluid drag. For a constant gas flow rate, the rotor speed reduction is proportional to the liquid loading, shown in Figures 10-12, at 6.6, 41.1, and 75.8 bar (100, 600, and 1100 psia) operating pressure respectively. In these figures, liquid loading (kg/hr) is plotted against rotor speed. At higher liquid loading up to 100% LGMR, the gas flow rate can be estimated directly by using liquid load and speed calibration curves. For a given set of liquid flow rates and rotor speeds, the gas velocity can be interpolated from the family curves of various pressures as shown in the figures. The gas flow measurement uncertainty depends on the accuracy of the liner curve regression and the interpolation techniques. Because there were limited sample points in these tests, the measurement uncertainty could be improved if additional test points were conducted and an accurate gas flow rate measurement model were developed.

CONCLUSIONS AND RECOMMENDATIONS

1. The rotary separator is a compact device, which is best for space- and accessibility-limited applications. In addition to compact separation applications, IRIS™ can be used as a wet gas meter and/or well test allocation measurement system in a remote location, offshore platform, or subsea. An inline rotary separator was tested as a wet gas meter at liquid loading, LGMR, up to 100%.

2. For low LGMR up to 3%, the rotor dry gas speed curve is used to estimate gas flow rate within ±5% accuracy at higher gas velocity.

3. For higher LGMR, up to 100%, the rotary separator should be calibrated at flowing liquid/gas conditions to develop the wet gas speed curve. The wet gas speed curves are used to interpolate gas flow rates.

4. A commercial wet gas metering flow computer algorithm using the rotary separator for wet gas metering applications is not available and should be developed.

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Internal View of Rotary Separator IRIS™

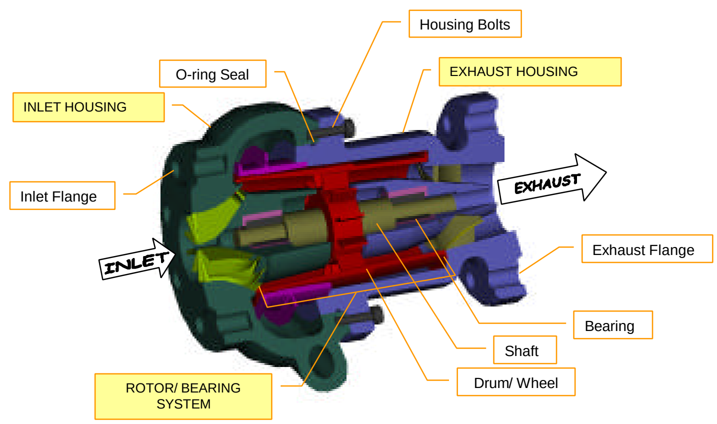

Figure 1

Rotary Separator IRIS™ Flow Path

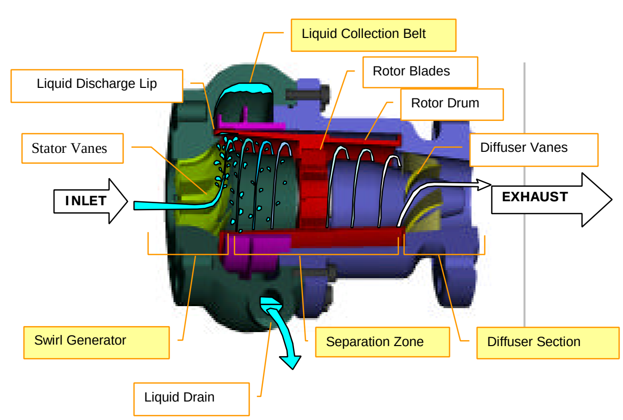

Figure 2

Field Trial at Chevron Laredo Gas Field

Figure 3

Rotary Separator Speed and Separation Efficiency-- Chevron Field Trial

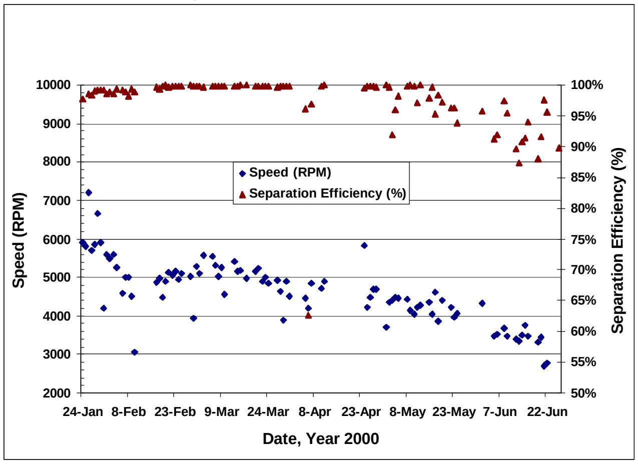

Figure 4

In Line Rotary Separator IRIS™ Testing
at CEESI

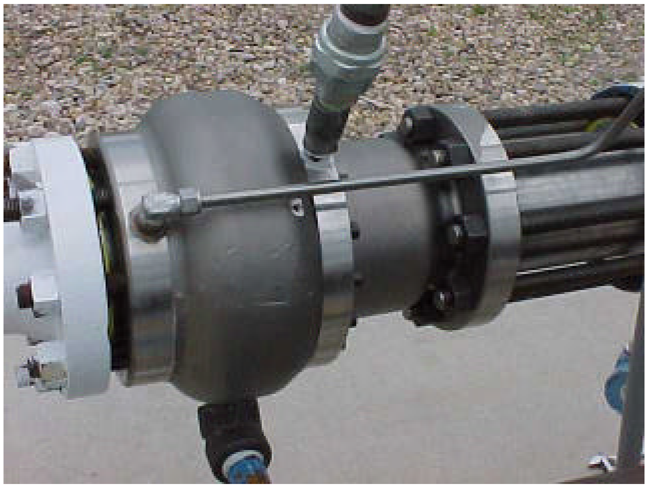

Figure 5

Rotary
Separator
Test Set Up
at CEESI

Figure 6

IRIS™ Separation Efficiency

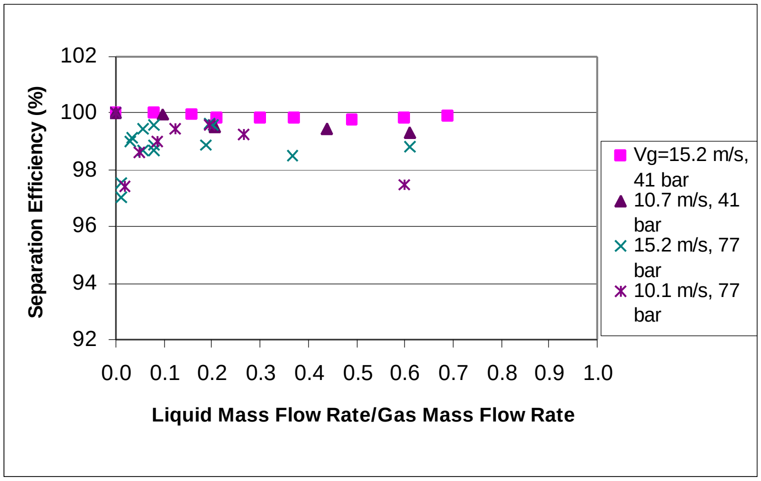

Figure 7

Effect of Low Liquid Gas Mass Ratio (<0.03) on Rotor Speed at 41.4 Bar

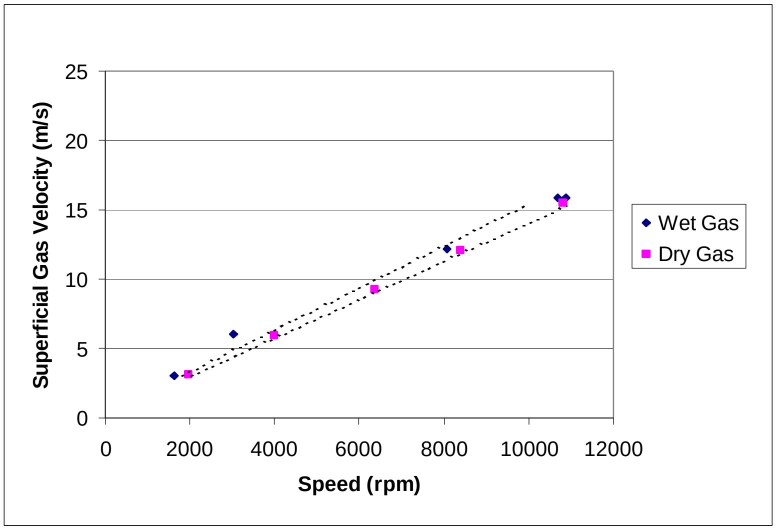

Figure 8

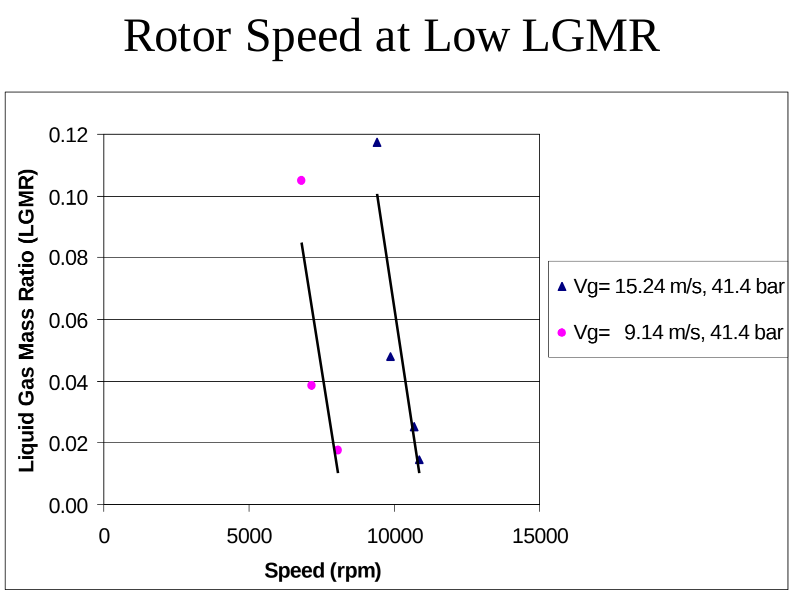

Figure 9

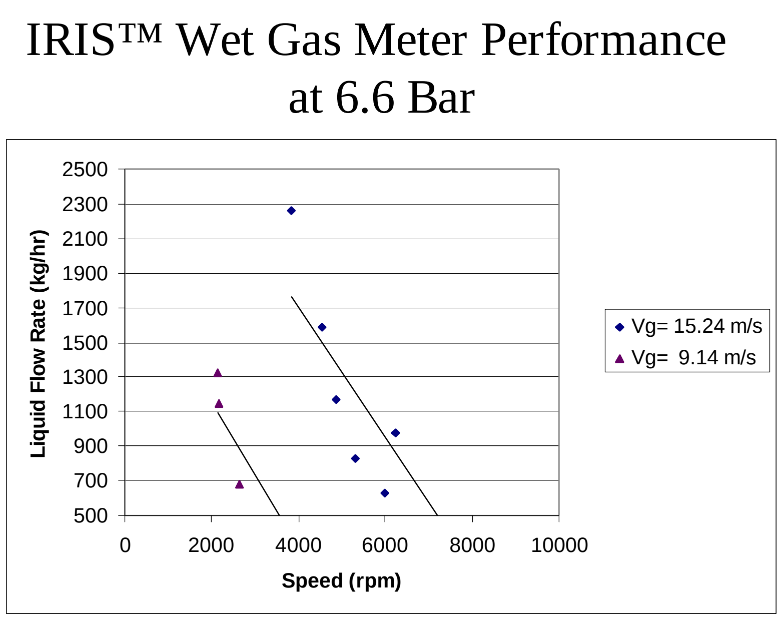

Figure 10

IRIS™ Wet Gas Meter Performance at 41.4 Bar

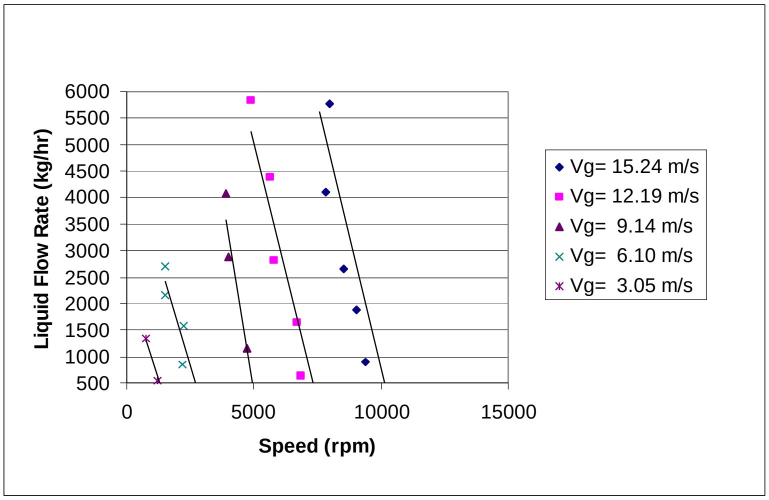

Figure 11

IRIS™ Wet Gas Meter Performance at 75.8 Bar

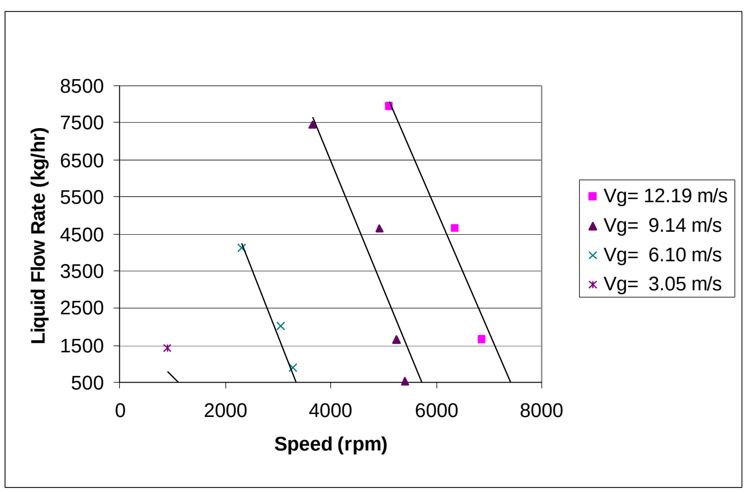

Figure 12