## Introduction

Dynomax performed shop testing on our 475 Regulator™, proving the tool operation, and getting high speed data to show the real time response.

## Background

The Regulator functions by using a spring loaded valve to open and close a set of bypass ports, based on the flow rate going across an orifice. By varying the size of the orifice, the tool can be set to open at any desired flow rate. Once open, the through flow (or Bit flow) will remain constant, while any excess flow is vented out the side of the tool.

This allows for several benefits to the operator, including allowing increased flow rates for optimal hole cleaning while maintaining optimal motor performance and bit rpm.

## Apparatus

Rather than testing in Isolation, Dynomax tested our 475 Regulator in combination with a 5" - 7/8 Lobe 3.7 Stage HR Series 2 Motor. The test was conducted on a third-party Dyno Beam.

In order to capture the Regulator behaviour, Ultrasonic Flow Meters and Pressure Transducers were mounted both directly uphole and downhole of the Regulator in order to exactly capture the tool behaviour.

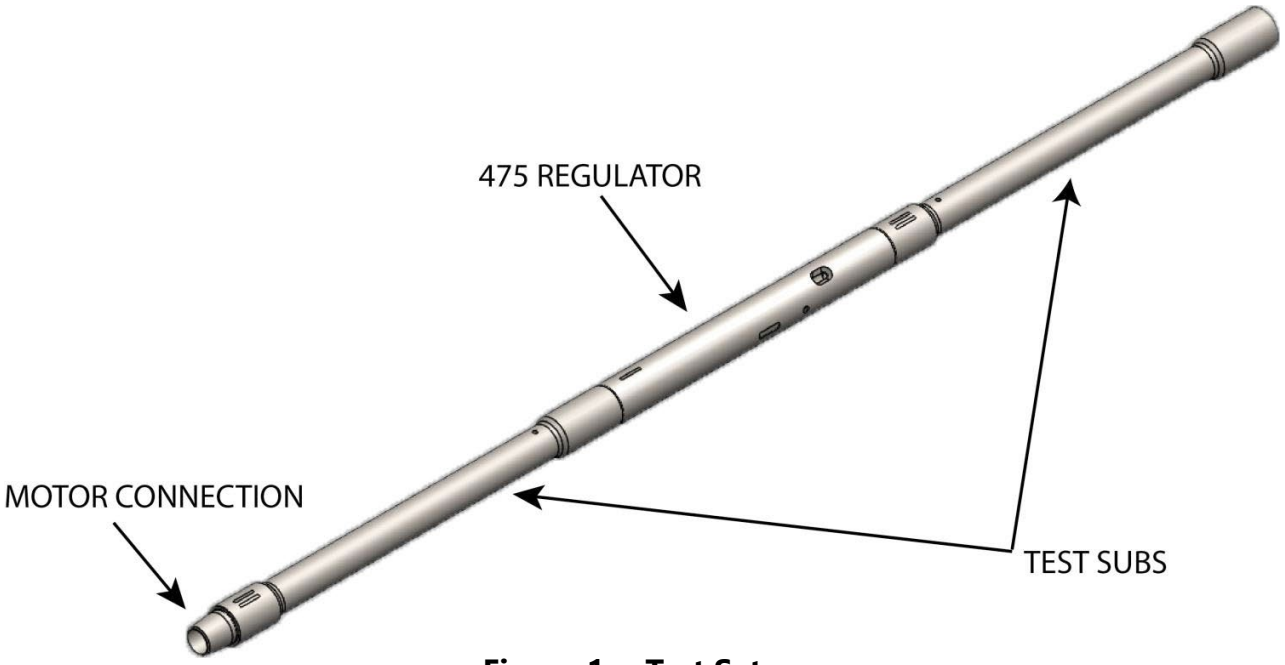


**Figure 1: Test Setup**

The Dyno Beam was set up to flow through the Regulator, then Motor, then choke (representing the bit). The Regulator was held stationary, and a 1" Orifice was installed.

## Results

The Regulator was expected to open at ~1205 lpm when flowing with water (1000 kg/m$^3$ mud weight).

The Resulting Opening Rate was found to be 1230 lpm, which represents a 2% Variation from the predicted rate.

Additionally, the leakage rate of the Regulator was checked just prior to opening, and it was found that 15-20 lpm were being bypassed when the Regulator was closed. This represents a leakage rate of less than 2% the total flow.

| REGULATOR OPENING FLOW RATE** (lpm) | | | | | | Tool Pressure Drop [kPa] |
|---|---|---|---|---|---|---|
| ORIFICE SIZE [in] | Mud Weight (kg/m^3) | | | | | |
| | 1000 | 1100 | 1200 | 1300 | 1400 | |
| 0.90 | 937 | 895 | 853 | 821 | 792 | 651 |
| 0.95 | 1064 | 1016 | 969 | 932 | 900 | 659 |
| 1.00 | 1205 | 1151 | 1098 | 1056 | 1019 | 669 |
| 1.05 | 1363 | 1302 | 1242 | 1195 | 1153 | 678 |
| 1.10 | 1541 | 1472 | 1404 | 1351 | 1304 | 689 |
| 1.15 | 1744 | 1665 | 1589 | 1529 | 1475 | 700 |
| 1.20 | 1978 | 1889 | 1802 | 1734 | 1673 | 713 |
| 1.25 | 2252 | 2151 | 2052 | 1974 | 1905 | 726 |
| 1.30 | 2581 | 2465 | 2351 | 2263 | 2183 | 740 |

**Figure 2: Orifice Chart**

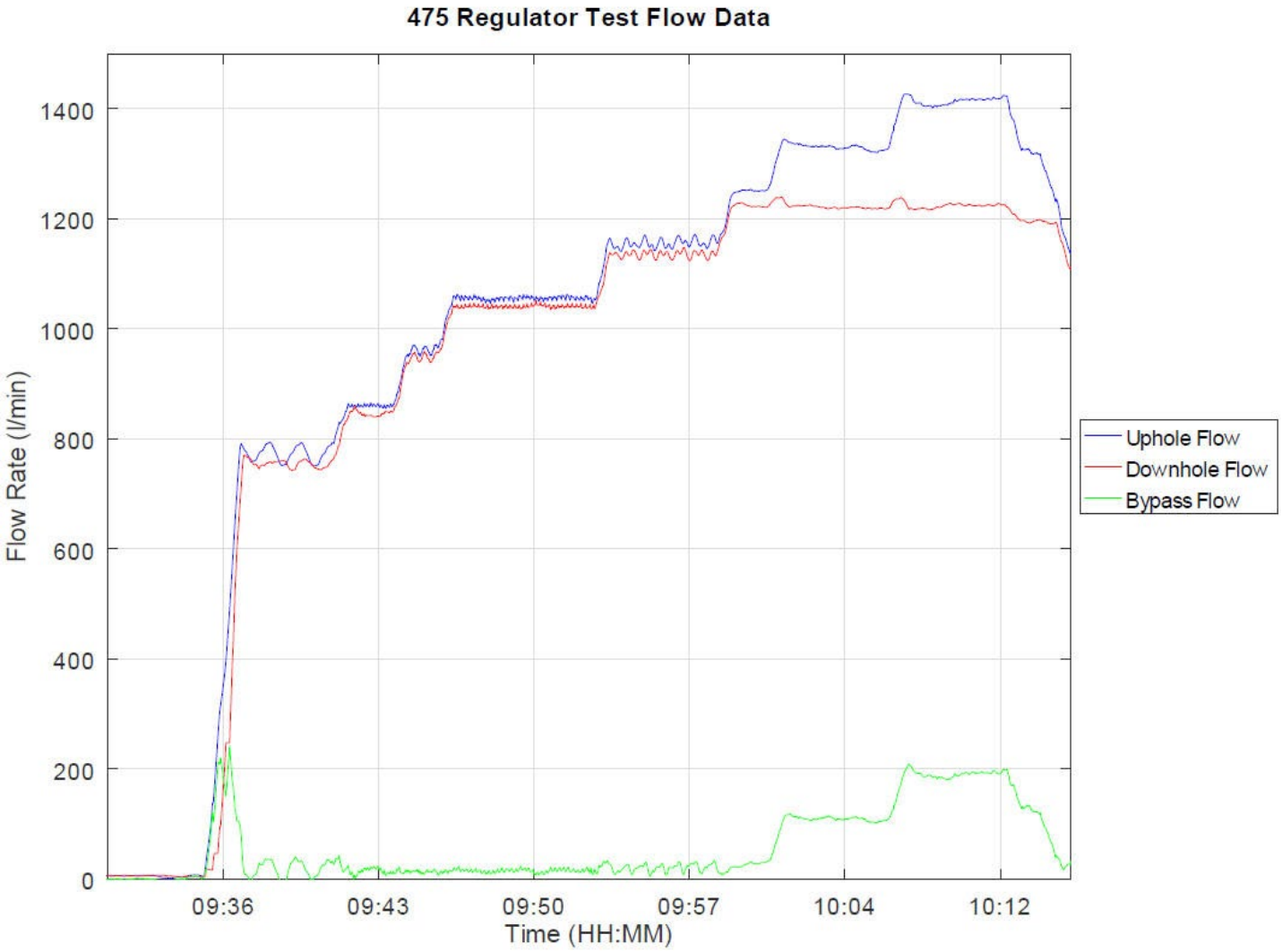


**Figure 3: Opening Flow Rate**

Additionally the data shows that there is very little change in the through flow of the Regulator even during the dynamic opening/closing events.

After verifying the Regulator openeing flow rate, the total flow was increased for multiple acivations of the Regulator. The "Bit" RPM (or Motor output speed) was monitored by the Dyno-Beam apparatus, and is plotted below versus the theoretical motor output at the total flow rate.

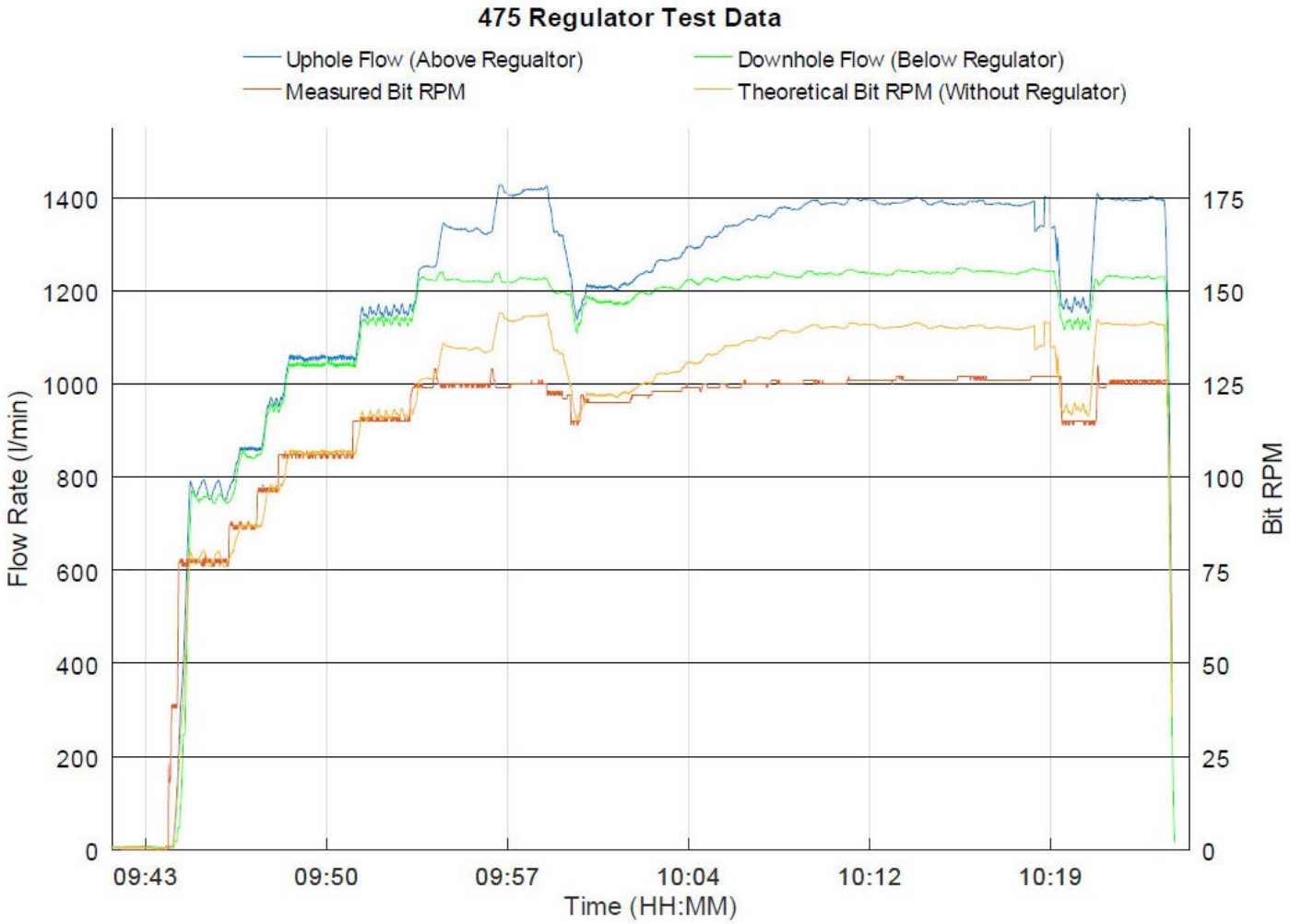


**Figure 4: Motor RPM**

It can be seen that the measured bit RPM holds nearly perfectly steady at any flow rate greater than the opening flow of the Regualtor. In fact we see less than 5 rpm variation in the bit speed across all cases where the Regulator is open.

Next the flow was increased further, up to a total flow rate of over 2000 lpm, with a resulting bypass flow of over 800 lpm. Due to limitations in the ultrasonic flow meters, they could not be used to measure the total flow as the velocity exceeded the rated values. Instead the less accurate Dyno-beam flow meter was used to measure total flow for the increased flow rates.

Again a very small variation in actual motor rpm was seen, with the measured bit rpm remaining constant at the expected 1230 lpm, even at a total flow of 2000 lpm.

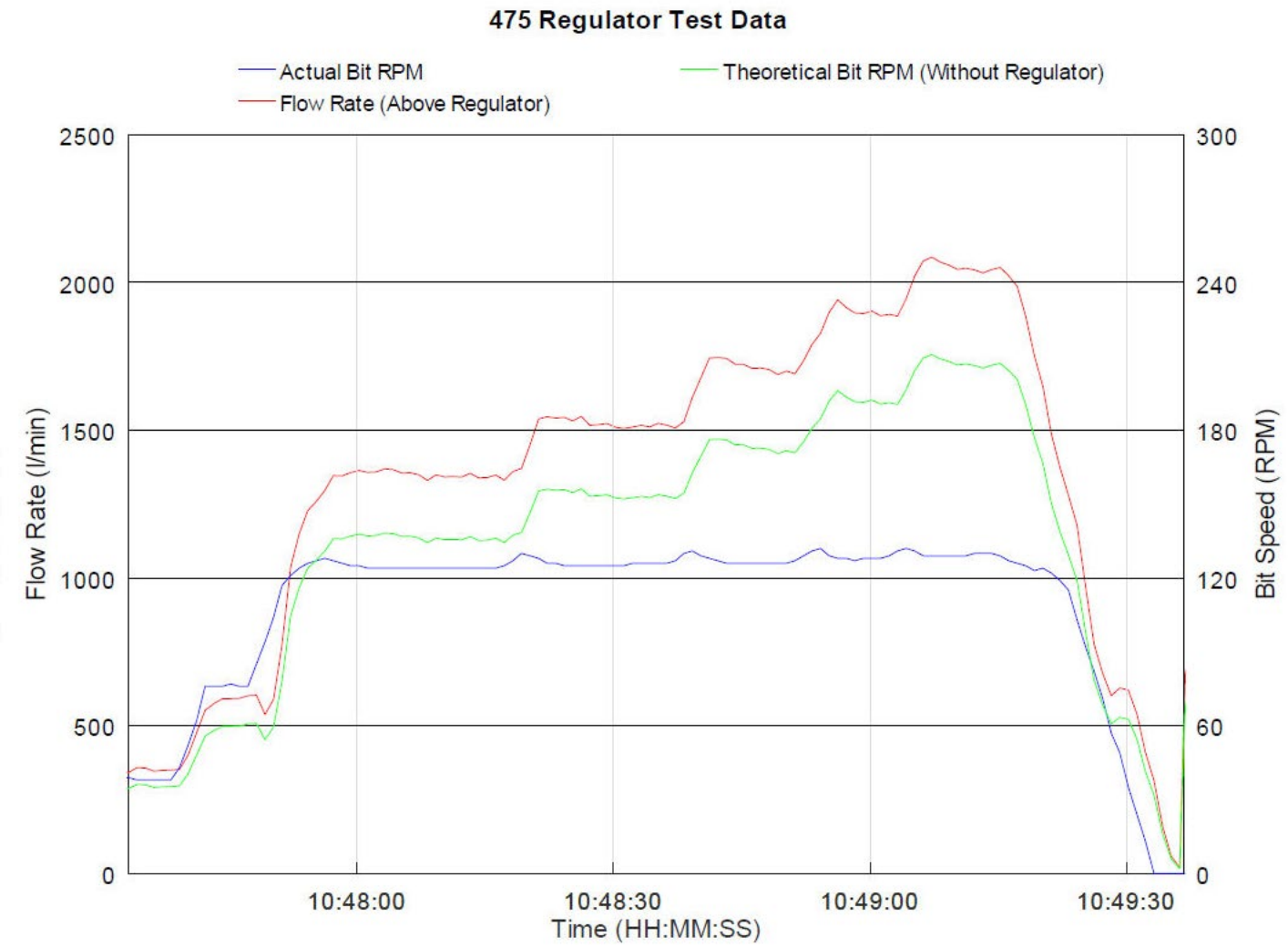


**Figure 5: Motor RPM at Increased Bypass Rate**

Throughout the testing the pressure drop across the tool varied from 675 - 693 kPa, which is a 1-3.5% variation from the expected tool pressure drop of 669 kPa.

## Conclusion:

The Regulator operated as expected, with a sub 2% leakage rate, an actual opening flow rate within 2% of the predicted value, and constand motor rpm for any flow exceeding the opening range.

The Regulator allows the operator to have greatly increased flow rates, resulting in enhanced hole cleaning, all the while protecting the motor from overflow, and having optimum rpm and torque to the bit throughout the run.