

## *Effect of Constant-G Control on Shale Shaker Performance*

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### **Abstract**

One of the limitations of current shale shakers is that their performance varies as the feed changes. Standard shakers operate with vibratory motors running at a constant speed and with a constant force output. This results in a nominal acceleration on the basket. As soon as mud is added to the system (i.e. more mass), the acceleration (g-force) decreases.

Standard shakers typically have a higher than necessary acceleration when they are lightly loaded just to be able to have adequate acceleration when heavily loaded. Thus, screen life is not optimized when the shaker is lightly loaded, and throughput is not maximized when heavily loaded.

A significant improvement for shale shakers has been achieved with the introduction of the Constant-G Control Technology. This new development measures basket acceleration and sends a signal to a VFD\* to maintain constant g-force even under varying loads. This results in the same performance in top hole as bottom hole. Field testing indicates that a Constant-G Control shaker is capable of screening finer than a similar standard shaker while maintaining a similar fluid end point. Use of this technology should allow for improved solids removal efficiency at the shaker.

Presented will be results, observations and testing methods from twenty four months of testing. This paper will cover the effect and relationship between the change in g-force on the shaker basket and critical performance parameters such as capacity, conveyance, cuttings dryness and screen life. This paper will also focus on the difference between linear and elliptical motion at different g-force settings as well as provide a brief note on testing philosophy and methodology.

### **Introduction**

A Shale Shaker's basket acceleration is a result of two variables: force and mass. Newton's Second Law of Motion states that " $F = ma$ ." Therefore, the mass and the acceleration are inversely proportional given the same excitation force.

As the drilling fluid (mud) fills the shaker's basket, the total system mass increases, which decreases the acceleration at a constant force. The shaker's vibrators usually run at a constant frequency, thereby generating a constant force.

The deceleration of the basket affects critical performance parameters such as flow capacity, conveyance and cuttings

dryness. Mud is lost due to the inability to handle the flow during the top sections of the well, and conveyance drops because of the high accumulation of solids near the discharge end of the shaker.

The opposite is also true when the flow decreases during the bottom sections of the well. When the flow decreases, the basket acceleration increases, sometimes higher than necessary, leading to a higher surface area of non-lubricated screens which causes premature screen failure.

One way of reducing these issues is to vary the force as the mass changes to keep the basket acceleration constant throughout the operation. To do that, a standard shaker is retrofitted with a vibration sensor and a VFD controller. The sensor is mounted on the side of the shaker and connected to the VFD controller (Figures 1A and 1B). Figure 1C shows the controller. The controller can be mounted remotely or on the shaker. The sensor sends a 4-20 mA signal that is proportional to the basket acceleration back to the VFD. The VFD interprets the signal as a percentage and changes the frequency of the vibrators with a PID\* control loop. The VFD is programmed such that it would run the shaker at 60 Hz if the sensor signal is lost. The VFD also checks every 8 minutes if the sensor is reconnected, and if connected, would resume running the PID loop. This protection function was implemented after field testing. Field operators often noticed that the shaker ran at a higher g-force without the sensor, so they removed the sensor from the housing. A shaker running without the sensor would operate constantly at maximum frequency. This would significantly shorten the life of the vibrators and the screens. This mechanism was designed to protect the shaker in case such events were to happen or the sensor is damaged.

The control system has up to three set points where operators can chose to change the g-force depending on operating conditions. The VFD can increase the speed up to a certain frequency, and then the g-force will go down as the load increases. The maximum frequency varies with each vibrator.

The sensor has been tested for oil field reliability. Usually the sensor housing has a cover to protect the sensor. But, during the field tests, the cover was purposely removed to expose the sensor to hot oil based mud. The sensor continued to operate throughout the entire test (3 weeks). Since the

sensor is a critical component of the design, it is important to trust its reliability under the toughest conditions.

The system is robust such that a retrofit kit can be placed on any type of shaker. By changing the VFD parameters, the control system can operate different shakers according to their capacity.

### Testing

To measure the value added by the control system, pilot plant and field tests have been conducted since December, 2007. Capacity, conveyance, cuttings' dryness, screen life and motion comparison were tested to determine their relationship to changes in the g-force.

Pilot plant testing ensures control over certain variables that are difficult to control in the field. Flow, screen selection, basket angle, and all mud properties are controlled in a pilot plant environment. Results from the pilot plant show the various relationships between the change in g-force and the tested variables. Field test results confirm the data obtained from the pilot plant.

Pilot plant tests demonstrate the advantages of a new design, but they hardly expose a design's weakness.

Field tests expose products' weaknesses and test newly developed products for safety, durability and reliability in the oilfield.

### Capacity

Testing for capacity in the pilot plant revealed that a higher g-force increases the shaker capacity. However, the relationship is not linear. The law of diminishing returns applies to capacity as the g-force increases. As the g-force increases, the rate of increase in capacity decreases to eventually a flat line when the g-force reaches a threshold point. Figure 2 shows this relationship. Notice the upwards shift in the curve for elliptical motion compared to linear motion. For the shaker used during the tests, the curve begins to flatten between 7 and 7.5 g's in both linear and elliptical motions. This graph is most likely related to each shaker and the type of screen used. A change in screen will most likely change the curves, but the relationship between capacity response and the screen used is beyond the scope of this paper.

Each data point reported on Figure 2 is the average of several data points observed at different g-force set points. Figure 3 and Figure 4 show the raw data collected before averages were computed for elliptical and linear motions. Notice the similarity in pattern and shape between Figure 2 and Figures 3 and 4.

To measure capacity in the pilot plant, a constant fluid end point was selected for all g-forces and the flow was measured to determine the capacity at the selected g-force. The flow was measured after the fluid end point and the g-force were stable for 10 minutes.

Field testing confirmed the results of the pilot plant. As Figure 5 shows, the rate of change in the fluid end point decreases as the g-force increases. Since controlling and measuring the flow in the field is difficult, measuring the fluid end point is a reliable measure of change in capacity assuming no major change in flow. Therefore, most data collection was

accumulated in a short time frame to ensure consistency in the flow.

Like Figure 2, Figure 5 represents the average of the raw data in Figure 6 obtained in the field. Notice that the same pattern exists between the raw data points and the averages from Figure 5.

### Conveyance

Conveyance is measured by dropping a ping pong ball (or a similar shaped item) at the fluid end point and measuring the time it travels to the end of the screen. Knowing the distance (inches) and the time (seconds) it took the object to travel, we can calculate the conveyance in inches/second. Testing was conducted over linear and elliptical motion in the pilot plant and only in linear motion in field tests. Figures 7 and 8 show the conveyance response to the change in g-force in linear and elliptical motion from the pilot plant. Notice, as is the case with the capacity tests, that elliptical motion had higher conveyance rates than linear motion at the same g-force.

Unlike capacity's response to increasing the g-force, there is a linear relationship between g-force and conveyance. If a linear regression equation is applied to the pilot plant results, the following formulas are generated:

$Conveyance = 0.7075 * (g - force) - 1.1485$  for linear motion with a  $R^2$  of 83% and:

$Conveyance = 0.7108 * (g - force) - 0.9551$  for elliptical motion with a  $R^2$  of 85%.

Field tests confirm the pilot plant results and a linear regression equation can be written as:

$Conveyance = 0.3468 * (g - force) + 0.402$  with a  $R^2$  of 82%.

There is evidence to conclude that there is a linear relationship between the increase in g-force and the conveyance. Notice that the slope is almost halved between the pilot plant test and the field test. This is likely due to the difference in mud properties and the screens used. In the pilot plant, API 100 screens were used, and in the field, API 120 screens were used. Figure 9 shows the raw data along with the fitted regression line for the field test. Pilot plant tests used water based mud while the field test used oil based mud, which shows that the linear relationship still holds regardless of the mud type.

Further testing can be conducted to study the effects of different variables (screens, mud type, shaker design, etc.) with the change in the g-force and the conveyance, but this is beyond the scope of this paper.

### Dryness

Measuring the dryness in the pilot plant was performed by collecting the cuttings from the discharge end of the shaker. The cuttings collected were weighed and then dried. The dried cuttings were re-weighed and the new mass was divided by the old mass to get the percent dried solids. The sample wet cuttings were placed in a drying oven held at 355 °F until they were dried. Figure 10 shows the relationship between the change in g-force and dryness. The dryness samples were

collected during the capacity tests, so the fluid end point was similar for all g-force set points. Figure 10 shows the dryness at almost 84% for all set points. The dryness was the same for linear and elliptical motions.

Field test data was inconsistent with the pilot plant primarily because the fluid end points could not be controlled. As Table 1 shows, the dryness was higher for 9 g's and 7 g's than it was at 5 g's. Although the fluid end point was different between 7 g's and 9 g's, the dryness remained similar as Table 1 indicates.

### Screen Life

Screen life tests in the pilot plant consisted of comparing two different sets of 4 screens. The 2 g-force set points were 7.5 g's maintained and 6.1 g's nominal. Nominal g-force means that the shaker runs at a constant frequency resulting in 6.1 g's. As mass (screens and mud) is added to basket, the g-force drops because the force from the motors is constant. One set of 4 screens was tested using the 7.5g's, and the second set of 4 screens was tested using the 6.1 nominal g's. All tests were conducted in linear motion. The purpose of this test was to compare a regular shaker operation against the increase in g-force and observe the effects on screen life. The screens and the g-force set points were changed every 2 hours to insure that both test conditions were exposed to similar mud properties. After running both sets of the screens, it took a similar time frame to damage similar amounts of screen area on both sets. Figures 11-14 show the comparison between both sets of screens. Each graph compares the two g-force set points for one screen out of the 4 total screens, according to their positions in the basket. As the graphs indicate, the numbers are very similar over the period of time tested. The mud properties are attached in Table 2. The mud was designed to expedite screen failure. The screens were also exposed to two different types of mud properties as indicated in Table 2. This was done to test if the screens would react in the same way and have the same cell damage rate under various mud conditions. As figures 11-14 indicate, the cell damage was identical in both cases.

It should be noted that the fluid end point was held constant during the pilot plant test. This means that the set of screens running at 7.5 g's handled more flow than the set of screens running at 6.1 g's continuously.

Field testing validated the pilot plant results that increased g-force does not affect the screen mesh or reduce its life. Test shakers located offshore have been on the same rig for 9 months (and running) and have not reported any significant change in screen life.

The increased g-force acts as a quick check for proper screen installation. If the screens are not installed properly, a loud vibration noise occurs at the higher g-force set point (7.5 g's and above) in contrast to the regular operation without a VFD starter.

### Conclusions

Testing conducted on a shale shaker showed the relationship between the change in g-force and capacity,

conveyance, dryness and screen life. A study of constant g effects on performance revealed that capacity increases but at a decreasing rate after a threshold point. The conveyance's relationship with the change in g-force is linear. Elliptical motion showed higher throughput and conveyance than linear motion holding all other variables constant. Changes in g-force did not change the dryness of the discharge as long as the fluid end point was held constant in the pilot plant and didn't show any patterns in the field.

These performance measures are only the results of one shaker tested. These results open the door for many questions. Will the same performance patterns hold for different shakers with different designs? Will changing a screen on the shaker tested change the capacity threshold point? Will the conveyance change with different screens? Does elliptical motion outperform linear motion on other shakers? If so, then why? Will all these results change with change in the basket angle? What happens when the same g-force is reached but at different frequencies?

In search of better methods to design and operate shale shakers, having reliable answers backed up by solid data is the only way to find out. The chances of finding one "optimal" method are small because of all the variables associated with operating shakers. But, continuing to research and learn about shakers' performance will open the door for improvements.

### Acknowledgments

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### Nomenclature

VFD = Variable Frequency Drive  
PID = Proportional, Integral and Derivative

### References

1. Scott, Eric. "Automation Shaker Control." IADC/SPE SPE-99035-PP (February 2006).

## Tables

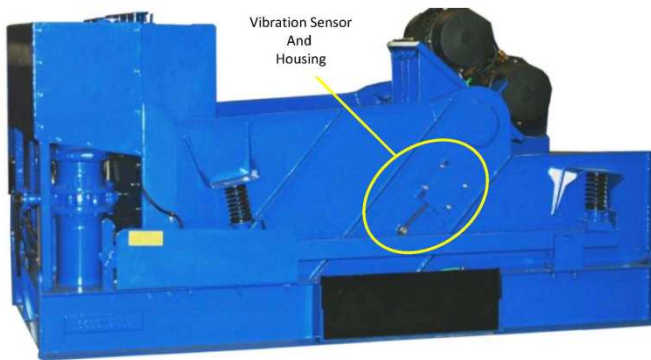
*Table 1 – Dryness by Percent Mass as the g-force changes – Field Test Results.*

Set Point	9 Gs	7 Gs	5 Gs
Sample % Solids T1	65%	65%	N/A
Sample % Solids T2	70.0%	71.0%	65.0%

*Table 2 – Mud Properties for pilot plant screen life test*

Mud Density	Funnel Viscosity	Sand Content
10 ppg	45-60 sec	3-5.5 %
12 ppg	80-85 sec	6-9%

## Figures



*Figure 1A\**

*A shale shaker retrofitted with sensor housing*



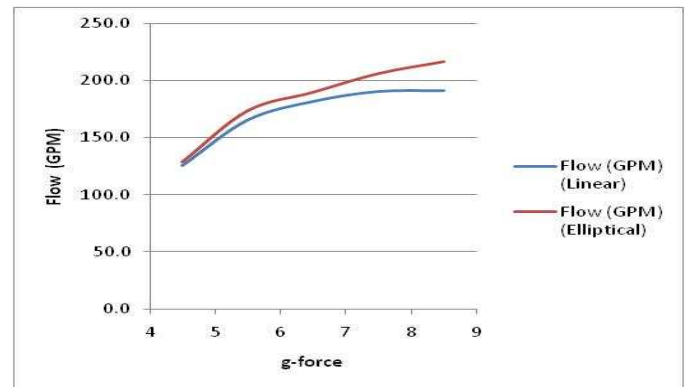
*Figure 1B\**

*Up close picture of the sensor with the housing cover removed*



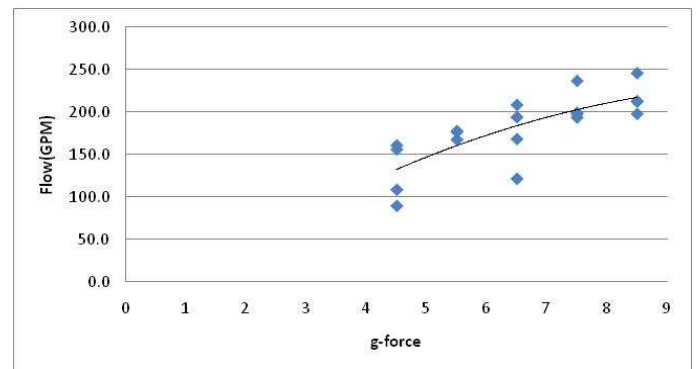
*Figure 1C\**

*A VFD controller that mounts remotely or on the shaker*



*Figure 2*

*Capacity vs. change in g-force  
Pilot Plant*



*Figure 3*

*Capacity vs. Change in g-Force raw data with fitted line  
Elliptical Motion – Pilot Plant  
Pilot Plant*

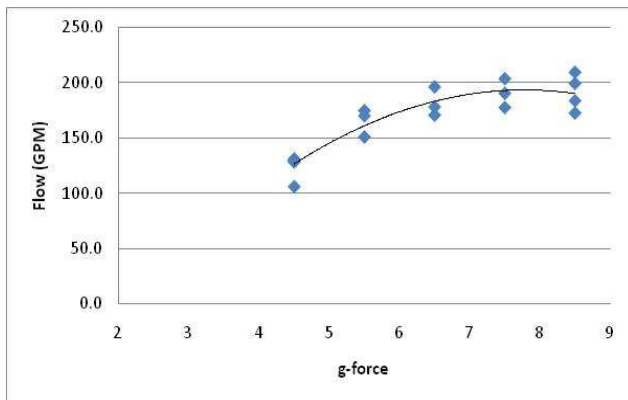


Figure 4  
Capacity vs. Change in g-Force raw data with fitted line  
Linear Motion - Pilot Plant

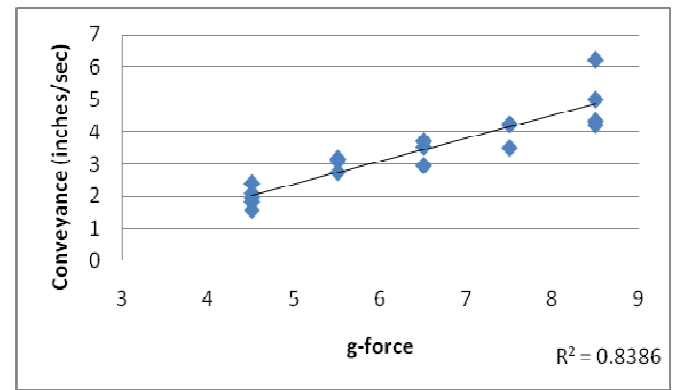


Figure 7  
Conveyance vs. change in g-force  
Linear Motion - Pilot Plant

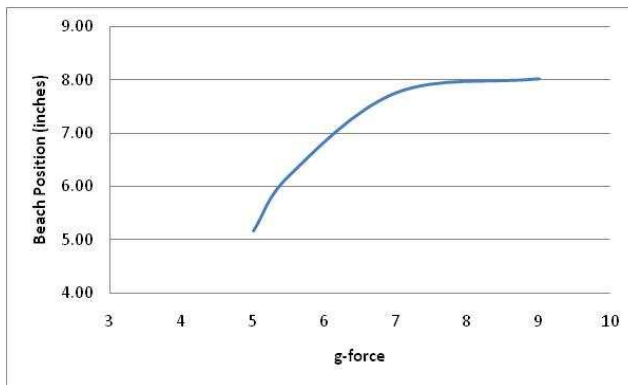


Figure 5  
Capacity vs. Change in g-force  
Linear Motion - Field Test

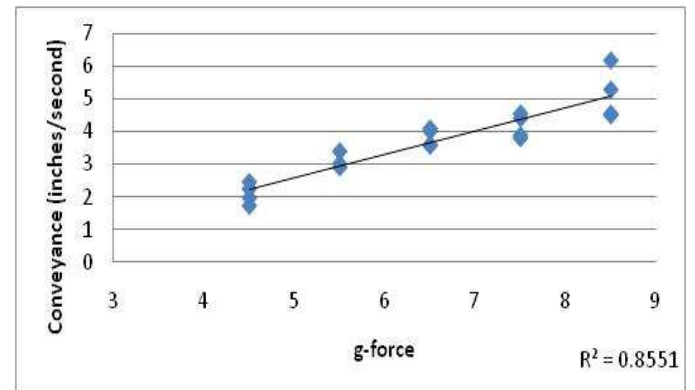


Figure 8  
Conveyance vs. change in g-force  
Elliptical Motion - Pilot Plant

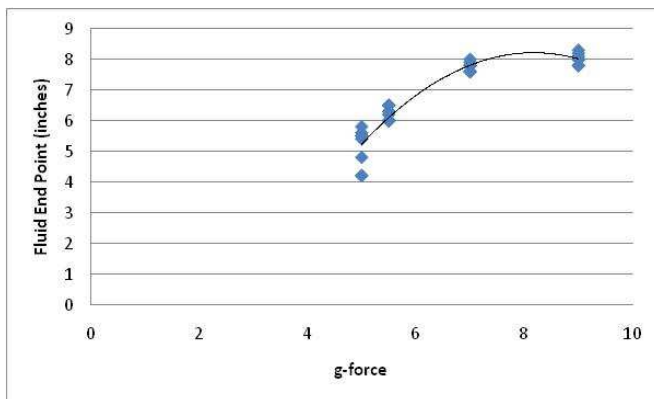


Figure 6  
Capacity vs. change in g-force raw data with fitted line  
Linear Motion - Field Test

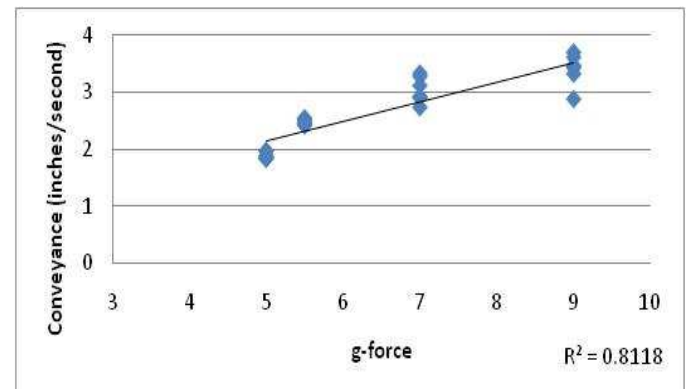
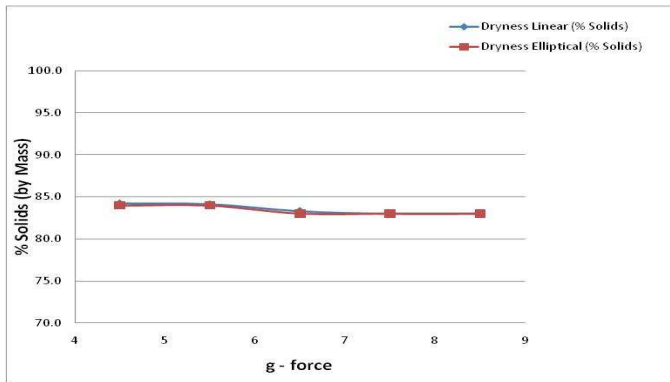
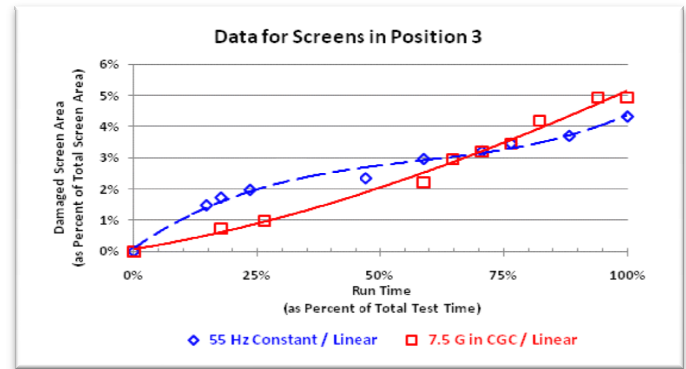


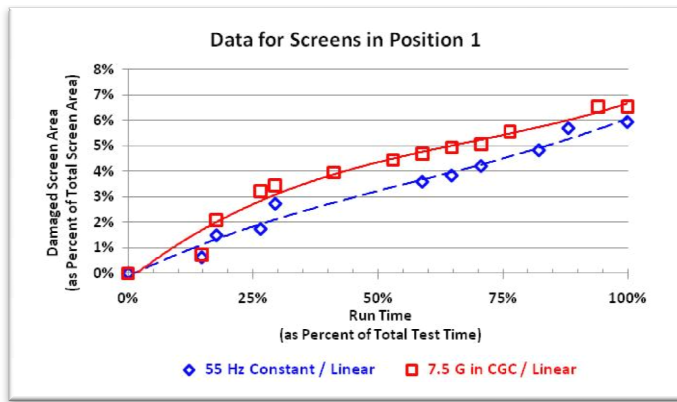
Figure 9  
Conveyance vs. Change in g-force  
Linear Motion - Field Test



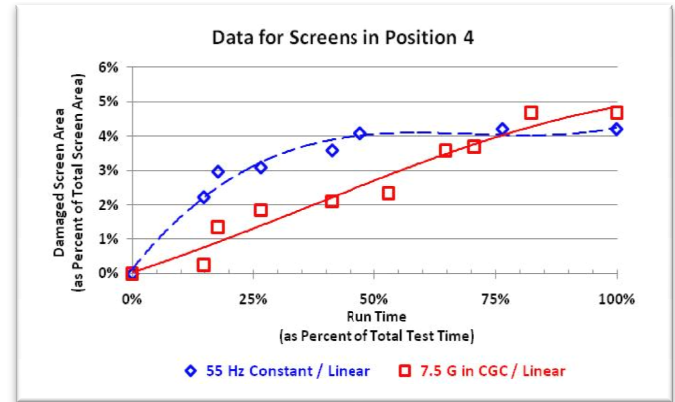
*Figure 10*  
Dryness vs. Change in g-force  
Pilot Plant



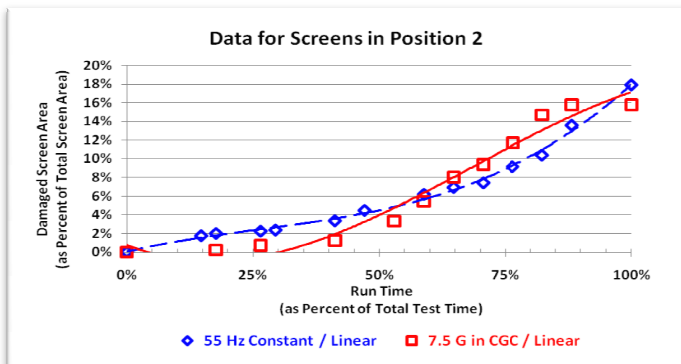
*\*Figure 13*  
Screen # 3 Life Testing Comparison  
Linear Motion - Pilot Plant



*\*Figure 11*  
Screen # 1 Life Testing Comparison  
Linear Motion - Pilot Plant



*\*Figure 14*  
Screen # 4 Life Testing Comparison  
Linear Motion - Pilot Plant



*\*Figure 12*  
Screen # 2 Life Testing Comparison  
Linear Motion - Pilot Plant

\*Figures 11-14 are courtesy of Tom Larson.  
Figures 1A-1C are courtesy of Sue Reneau.  
Constant-G Control is patent pending.