SPE 56591

The Nominal Sand Control Screen: A Critical Evaluation of Screen Performance

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This paper was prepared for presentation at the 1999 SPE Annual Technical Conference and Exhibition held in Houston, Texas, 3–6 October 1999.

Abstract

Over the past few years, several "premium" sand control screens have been introduced into the market. The proliferation of new screens has raised questions about how to choose the proper sand control screen for a particular formation. In order to address this concern, a project was initiated at Chevron to devise a method to evaluate sand control screens.

As a result of this program, a method has been standardized for the evaluation of sand control screens. The method known as the Screen Efficiency Test shows the relationship between the normalized sand control characteristics (i.e., Sand Control Factor) of the screens and the normalized length of time it takes a screen to plug under a certain set of conditions (i.e., the Performance Factor). The results of Screen Efficiency tests to evaluate several sand control screens for a North Sea and West Africa field are discussed in the paper.

The data in this paper also documents that the numerical rating given the screens by the manufacturers are generally not very useful in understanding the sand control rating of the particular screen, or comparing screens from different manufacturers. In addition, the effect of particle size distribution and sand concentration on the relative performance of sand control screens was demonstrated.

Introduction

Over the past couple of years there have been a large number of “premium” sand control screens introduced to the market. In general, these screens consist of a perforated base pipe, some type of woven metal material layered on to the base pipe, and a “protective shroud” around the woven metal material. As each of these premium screens hit the market, the manufacturers flood the potential buyers with data and literature about how much better the newest version of screen is over the competition.

There have been several papers written concerning sand control screens (1-6). However, the need for a standard method of evaluating sand control screens in the oil industry is very evident. The ever-increasing number of premium screens and reams of data generated by the manufacturers is, at best, very confusing. In addition, it is almost impossible to compare any of the data between manufacturers. Therefore, it is very difficult for the practicing engineer to decide which is the "best" sand control screen for a particular application.

The service companies are in good faith generating a great amount of data to support the performance of their particular product. In addition, the service companies are usually advertising the sand control screens with a numerical value which is supposed to represent some semblance of the "size" of the openings in the screen. However, when the service company is pinned down as the meaning of numerical value given to a particular screen, there is a lot of "hemming and hawwing" about what it actually means. Some service companies have gone to the extent of saying that the numerical value given the screen is a "nominal" rating of the screen, but that the screen actually as an "absolute" rating of something else. This is much like the same information the operators were given about nominal and absolute filters several years ago.

One of the biggest problems the potential buyer has is trying to relate data sets from the various screen supplier. This is because each of the screen manufactures have their own way of running tests to prove their product is superior to the competition. However, in most cases, the service company doing the tests does not have samples of the competition’s screen and the tests are not run the same from service company to service company. Therefore, it is left up to the operator to try to make educated decisions about the selection of a sand control screen for a particular formation based on unrelated data sets.

As part of an ongoing program, a method of evaluating sand control screens was developed by Chevron. Several screens were evaluated for application in the North Sea and Western Africa to help in the selection of a screen for the next round of completions. The results of the screen evaluations are discussed in this paper, along with a detailed description of testing methodology. As a result of this situation, it was decided at the Drilling Technology Center (DTC) to develop a “Chevron Standard” method of evaluating sand control screens.

The overall objective of the program discussed in this paper was to develop a standard method of evaluating sand control screens. The main criteria of the end user within Chevron focused on what is roughly defined as a screen which does not plug or plugged the slowest. The greatest amount of interest comes from the areas considering use of a stand-alone screen. In many cases, the amount of sand that which passes through the screen is a potential problem also due to facility or erosion concerns.

Discussion

North Sea Test Program. Several sand control screens were evaluated using the technique developed at the Drilling Technology Center, Houston, Texas to allow selection of a screen type for the next set of completions. The criteria for the screen selection centered on the two fore mentioned aspects of the screen performance: screen plugging and sand retention. The first criteria is obvious, it is desirable to have screens that last as long as possible before plugging. The second criteria is easy to understand, but difficult to achieve from the standpoint of filtration; i.e., screens that do not plug and do not pass a significant amount of sand.

Selection & Preparation of Test Samples. Two small samples of North Sea formation sand were sent to DTC to verify the paraticle size distribution of the sands. A portion of each sand sample was cleaned following a procedure provided by a local service company (See Appendix A). A portion of the sand was then analyzed using standard sieve analysis techniques. The result of this analysis is shown in Figure 1. A synthetic formation sand was then prepared to simulate the particle size distribution shown in Figure 1 for all the North Sea tests.

Screen Selection. The Screen Efficiency Test described in Appendix B was used to test the relative performance of several screen types for possible application in the completion of wells in the North Sea formation. The filter media used in this portion of the test program are described in Table I.

Figure 2 shows the pressure profiles of all the screens tested. Inspection of Figure 2 indicates three (3) apparent groupings of screens. Table 2 is a listing of the apparent three Groups.

TABLE I
SCREEN MEDIA USED IN
NORTH SEA SCREEN EFFICIENCY TEST

Screen	Manufacturer	Description
1	A	Woven metal fiber, "small openings"
2	A	Woven metal fiber, "large openings"
3	B	Sintered metal fiber, "small openings"
4	B	Sintered metal fiber, "large openings"
5	C	Sintered multi-layer woven metal fiber, "small openings"
6	C	Sintered multi-layer woven metal fiber, "large openings"
7	D	Sintered multi-layer woven metal fiber, "small openings"
8	D	Sintered multi-layer woven metal fiber, "medium openings"
9	D	Sintered multi-layer woven metal fiber, "large openings"

TABLE 2
APPARENT GROUPING OF SCREENS
NORTH SEA SCREEN EFFICIENCY TEST

Group I	Group II	Group III
Screen #5	Screen #7	Screen #9
Screen #1	Screen #3	
Screen #8	Screen #6	
	Screen #4	
	Screen #2	

Gravimetric Profiles. Even though the information presented in Figure 2 and in Table 2 appears to Group the various screens, additional information is critical in the determination of which screen is possible best for sand control in the North Sea completions. It is very important to know the relative amount of sand coming through each of the screens (i.e., the gravimetrics). Figure 3 shows the gravimetrics for each of the screens tested.

Evaluation of the pressure profile and the gravimetrics for all the screens provides a much more complete evaluation of the various screens. It appears that the Group III screen is eliminated as a choice due to the large amounts of solids which comes through the screen. The Group I screens appear to "plug" too quickly and therefore are probably not the screens for use in the North Sea completion.

The basic premise for the selection of a screen for sand control in the North Sea completions is to choose a screen which resists plugging and retains the most sand. Inspection of the Group II screens shows five screens with somewhat similar pressure profiles. Evaluation of the gravimetrics of this group of screens indicates that most have similar sand retention efficiencies, which the exception of one screen. Screen #6 appears to retain relatively more sand than the other screens in Group II.

One of the main justifications for running performance tests on screens is brought forth by the evaluation of the screens from screen manufacturer D. Manufacturer D initially supplied screens with only "small" and "large" openings. However the North Sea Business Unit also wanted a screen with an opening somewhere in between the "small" and "large" opening screen. It should be noted that there were numerical values associated with the name of each screen which implied the relative size of the openings in each screen sample. It was "assumed" from the numbers associated with each screen sample that the higher the number, the larger the average opening in the screen. Inspection of Figures 2 & 3 shows that the screen with the "medium" openings plugs much faster than the screen with the "smaller" openings and lets less solids through than the screen with the "smaller" openings. When confronted with this information, Manufacturer D owned up to the fact that to make the screen with the "medium" openings, and the screen with the "larger" openings was simple compressed, i.e., made thinner. This technique may have made a sample with an average opening "smaller" relative to the screen with the "larger" openings; however, it is speculated that the process of compressing the screen with the "larger" openings resulted in much less open area, which in turn caused the screen with the "medium" openings to plug faster than the screen with the "smaller" openings**.** ***The results of this analysis shows how important it is to run a performance tests on screens rather than take the numerical value assigned to the screen by a service company as having any relationship to the relative solids retention capability of the screen.***

Screen Efficiency Plot. In order to better understand the relationship between the pressure profiles and the gravimetric profiles, a methodology was developed called a SE Plot (Screen Efficiency Plot). The SE Plot shows the normalized relationship between the Performance Factor and the Sand Control Factor. The Performance Factor and the Sand Control Factor are related to the pressure profile and gravimetric analysis as follows:

$$\text{Performance Factor} = T/Ap$$

Where:

T = time for the pressure profile to reach 100 psi
Ap = total area under the curve of the pressure profile

$$\text{Sand Control Factor} = 1/\ Ag$$

Where:

Ag = total area under the gravimetric profile

The SE Plot for the screens tested for the North Sea sand are shown in Figure 4.

The objective of using the Screen Efficiency Plot (SE Plot) is to allow the practicing engineer to select a sand control screen based on the relative performance of all the screens under consideration for a particular application. In practice, the SE Plot shows the relationship between the normalized sand control characteristics (i.e., Sand Control Factor) of the screens and the normalized length of time it takes a screen to plug under a certain set of conditions (i.e., the Performance Factor). The "perfect" sand control screen would have values of 1 & 1 for both the Sand Control and Performance Factors. Based on this criteria, the best screen is Screen #7. However, inspection of Figure 4 shows that both Screen #1 and Screen #8 give much better relative sand control than Screen #7 while giving up only a small amount of relative performance. Therefore, just on the data from the SE Plot, Screen #1 and Screen #8 are ranked as good second choices.

In many cases, there are other factors that also effect the choice of the screen for an application. The obvious are cost and availability. In the case for North Sea, there is other information which caused careful consideration to using either Screen #1 or Screen #8. Screen #1 was initially used in the North Sea completions. However, the completions started to fail; i.e., started to make sand. Even though the cause is not known, the recent failures of Screen #1 resulted in the choice of Screen #7. Screen #8 was not chosen because of the information learned concerning the manufacturing process during the analysis of the SE Plot data.

Based on the SE Plot and additional information, Table 3 shows the rankings of the screens tested for the North Sea sand.

TABLE 3
SCREEN EFFICIENCY RATINGS
NORTH SEA FORMATION SAND

Screen	Ranking	Comments
Screen #7	1	Reasonably high Performance and Sand Control Factors
Screen #1	2	Good Sand Control Factor with slightly less Performance Factor than Purolator 125
Screen #8	2	Good Sand Control Factor with slightly less Performance Factor than Purolator 125
Screen #6	3	Average Performance and Sand Control Factor
Screen #4	4	Poor Performance and Sand Control Factors
Screen #3	5	Poor Performance and Sand Control Factors
Screen #2	6	Poor Performance and Sand Control Factors
Screen #9	7	Very good Performance and very poor Sand Control Factors

It is important to note that the rankings in Table 3 are subjective, based on the SE Plot , and cost and availability of the screen are not taken into consideration in this ranking.

Close inspection of the raw data shown in Figure 5 indicates that in some cases, the gravimetric curves do not go all the way to zero percent solids. This implies that the screen is still passing solids even at a 100 psi differential. In support of this, inspection of the raw data plots used to generate the gravimetric data indicates the screens are indeed passing solids up to a 100 psi differential. Figure 6 is a copy of a raw data plot of psi vs. time for a screen tested in the North Sea program. These traces show downward "spikes" as the pressure differential reaches higher values. These downward pressure "spikes" are thought to represent events where by some mechanism the filter cake on the screen sample breaks down an allows flow through the screen. During this event, it is very possible that solids are flowing through the screen, which in turn results in the presence of sand in the gravimetric sample during that time period. This type of behavior is cause for concern when considering the sand retention capability of any screen type. Ideally, the screen will promote the formation of a stable filter cake that will eventually prevent the production of all sand through the screen. Not enough testing has been done to determine if the pressure "spikes" are a function of the relationship between the opening size of the screen and the mean particle size distribution of the test sand, or is a function of the way the filter media of the screen if manufactured. Some consideration has been given to the possibility that the pressure "spikes" are a function of the ability of the filter media to "flex" at higher pressure differentials. If this is the case, filter media which is sintered or by some other method stabilized enough to prevent the "flexing" is required. Additional testing is needed to address this issue.

There was some concern about the reproducibility of the Screen Efficiency test data from one lab to another. To address this issue, Chevron worked with manufacturer D to set up a test stand in the manufacturing center of manufacturer D similar to the Screen Efficiency test stand at Chevron. A set of test parameters was given to manufacturer D and a Screen Efficiency Test was run on screen #7. Figure 7 shows a comparison of the data sets generated by DTC and manufacturer D on the same size screen. As shown, the two data sets are within experimental error of one another. This exercise shows that if screen "plugging" tests are run exactly the same by two different companies, the test procedures produce very similar results.

West Africa Test Program

Selection & Preparation of Test Samples. A similar test program was done for the West Africa Business Unit. The Screen Efficiency Test program used a synthetic sand with a particle size distribution (PSD) similar to the PSD shown in Figure 8 from one of the representative wells in the field in West Africa. The sand was cleaned using the service company procedure described in the discussion of the North Sea test program.

Screen Selection. The screens tested in the West Africa program are listed in Table 4

TABLE 4
SCREENS USED IN
WEST AFRICIA SCREEN EFFICIENCY TESTS

Manufacturer	Screen Description*
A	1
A	2
D	7
C	5
C	6
B	3

* from Table I

Pressure Profiles. The results of the individual pressure profiles are shown in Figure 9. A comparison of the data in Figure 9 indicates that the Screen #1 plugs much quicker relative to the other screens tested. The next grouping of screens appears to include the Screen #7 and Screen #3. The last grouping includes Screen #5, Screen #2 and Screen #6.

As with the screen evaluation for the North Sea, using only the pressure profile plot data is potentially very misleading when comparing the relative performance of the screens. It is always desirable to use a screen which never plugs or takes a very long time to plug. However, another criteria for selection of a screen depends on the amount of sand the operation can stand to produce. If a large amount of produced sand is acceptable and the main purpose of the screen is to provide some protection against complete loss of the wellbore in the event of a catastrophic collapse failure of the wellbore, almost any screen with very large gravimetric profile will suffice. Or, if a moderate amount of sand production is acceptable, a screen with a middle of the road pressure profile and a moderate gravimetric profile is best suited. The decision of which screen to choose is very dependent on the parameters under which the field must operate.

Gravimetric Profiles. To better understand the performance of the screens tested for this portion of the project, gravimetric profiles were done for each of the screens. Figure 10 is a composite of the gravimetric data obtained for the screens tested in this program. Inspection of Figure 10 shows some very interesting trends. If one of the basis for selection of a screen is to minimize the amount of solids which passes through the screen, then Screen #2 is <u>not</u> the screen of choice.

Screen Efficiency Plot. The SE Plot for the screens tested for the West Africa sand is shown in Figure 11. Inspection of the SE Plot indicates that Screen #1 screen is one of the best screens for the sand tested. It is important to note that the point representing the Screen #5 is missing from the plot. Inspection of the Pressure Profiles (Figure 9) and the Gravimetric Profiles (Figure 10) shows that Screen #5 appears to be far and away the best screen because of the long sloping Pressure Profile, and perhaps the most striking factor is the extremely low Gravimetric Profile. It should be noted that the pressure profile and the gravimetric profiles were re-run to double check the results. The results were within experimental error of being the same. Assuming these profiles are real as indicated, then the best screen for this particular sand is Screen #5.

The SE Plot shown in Figure 11 is an abbreviated version of a SE Plot, which does not include Screen #5 data. Inclusion of the Screen #5 profiles in the normalization process makes the comparison of the other screens difficult. This points out that it is still necessary to use some engineering judgement in the analysis of the data generated by the SE Plot method described in this paper.

Based on the information presented in the abbreviated SE Plot, and the Pressure & Gravimetric Profiles, the relative rankings of the screens tested with the simulated West Africia sand are given in Table 5.

TABLE 5
RANKINGS OF SCREENS FOR
WEST AFRICIA

Screen	Ranking	Comments
Screen #5	1	<u>Extremely</u> high Sand Control and Performance Factors
Screen #1	2	Very good relative Sand Control and Performance Factors*
Screen #3	3	Good relative Sand Control Factor with slight lower Performance Factor than Baker Excluder 110*
Screen #7	4	Slightly above average Sand Control Factor and good Performance Factor*
Screen #6	5	Slightly above average Performance and Sand Control Factors*
Screen #2	6	Poor Sand Control Factor and good Performance Factor*

Effect of Particle Size Distribution

It is intuitive that one of the factors governing the potential for screen plugging is the particle size distribution of the formation sand the screen is designed to retain. This is proved out by comparing the combined pressure profile / gravimetric plots for the North Sea and West Africa sands. Figures 1 & 8 show the particle size distributions of these two sands. Inspection of these figures shows that the West Africa sand contains more fine material than the North Sea sand.

Figure 12 shows a comparison of the combined pressure profiles / gravimetric plots for a the West Africa and the North Sea sand for Screen #7.. As expected the sand with the greater amount of fines; i.e., the West Africa sand, plugs first.

Effect of Flux

Another important factor in the plugging tendency of any sand control screen is the concentration of solids per unit volume of fluid passing through the screen; i.e., the flux challenging the screen. Figure 13 shows the results of tests using the North Sea sand where the flow rate of the fluid through the screen was kept constant, but the concentration of the solids was increased. Inspection of Figure shows that as the solids concentration is increased, the time to "plug" decreased. Therefore, in order to know the relative life of a screen in any particular environment, it is important to know (or quess-a-mate) the flux the screen will experience in the well.

It is very important to know that all the results obtained using the Screen Efficiency tests are "relative". It is not practical to run the Screen Efficiency tests at the actual flux seen in the field. The tests would take too long. However, the Screen Efficiency test does provide a measure of the relative performance of screens. How long a screen will actually perform satisfactorily in the field is best determined in the field.

True Micron Rating

The issue of "true micron rating" of the various screens is a topic of many debates between screen manufactures and the end user. The bottom line is that the numerical value provided by the manufacturer for a particular screen is not the true micron rating of the screen. The number if more related to some nominal rating which is not related to the true opening size of the media. There is no straightforward method for determining the "true micron rating" of a screen. A discussion about how one service company determines the size of the openings in their produce will serve as a very good example of why determination of a "true micron rating" is not practical or simple. A good example is how manufacturer A rates the "small" and "large" opening screens. At first glance, these numbers would probably be thought to represent the respective micron ratings of the screens. In reality, the numbers do not. It is true that the screens with the larger numerical value probably have bigger openings in the woven steel mesh than the screens with the smaller numerical value. However, once questioned closely about how the numbers were obtained, there are serious concerns about the validity of the number. It was found out that one way manufacturer A determined the size of the screen openings was by looking at the openings under a microscope and measuring the "openings" with a vernier. This technique is very difficult and not very precise, considering the shape of the openings. Another technique used by Baker was to flow a solids laden fluid through the screen and measure the size of the particle passing through the screen. This technique too is very subjective, because of when the sample is taken. If the sample is the very first one, there might be a chance of determining the largest particle the screen will allow to pass. However, once a filter cake of any type is formed, the size of the particles coming through the screen will decrease.

The preceding example represents an attempt to determine the "true micron rating" of a screen material with a very uniform opening. The problem is even worse with a material like that used by manufacturer B, which is a sintered metal fiber with a random pore throat size opening. Therefore, Chevron has concluded that is it **not** practical to put much stock in the numerical rating provided by the respective service companies for their screens. The only true measure of the effectiveness of a screen for a particular formation is by a Screen Efficiency performance test.

General Comments

It is obvious from the data generated from the North Sea and West Africa fields that comparison of sand control screens for a particular application is not straight forward. Sand control sand performance criteria are important factors which the engineers deciding on which screen to select must decide weigh in choosing a screen for a particular application. However, the SE Plot method is a good tool to aid the engineer in making that decision.

The ultimate aim of the screen evaluation program discussed in this report is to generate enough data sets from different formations and screens to generate a correlation between the particle size analysis of the formation and relative screen performance. This type of correlation would then allow the engineer to decide on a screen for a formation based on the particle size distribution of the formation. Until enough data sets are generated, it is necessary to continue to use the SE Plot technique to evaluate the relative performance of screens for each formation.

Future Work

As stated previously, the objective of this type of approach is to generate enough data sets to ultimately provide an algorithm which will allow an engineer select a sand control screen based on the particle size distribution and flux expected for a particular completion. It is hoped that the work described in this report will generate enough interest in the operating units to result in additional requests for screen performance evaluations, which in turn will provide the data necessary to generate the desired algorithm.

All the tests discussed in this report were done using disks of the "filter media" representative of each of the premium screens. A couple of other types of "filter media" have come to the market since the completion of the lab portion of this work. These include a metal fiber mesh somewhat like steel wool, and the other is a woven ceramic fiber. The steel wool type media definitely has its place in the market, but probably not for the North Sea. The advertised median openings are approximately 250 microns. However, the ceramic fiber media may have application.

Another concern raised by more than one of the screen manufacturers is the contention that the total configuration of the sand control screen contributes to the overall performance of the screen. By the total configuration, the screen suppliers mean the combination of inner drainage layer, sand control layer, outer drainage layer and protective shroud. As mentioned, the tests do date at DTC only include the sand control layer. It might be worthwhile to do a short series of tests with the "total configuration" of a couple of screens from a short list of screens to determine the validity of these claims.

Conclusions and Observations

The following conclusions and observations are based on the data presented in this paper:

1. Test results indicate that the best way to evaluate a screen for a particular application is a performance test with a sand representative of the formation of interest.
2. The relative ranking of screens based on plugging tendency and sand retention vary as a function of particle size distribution of the formation.
3. The advertised number associated with most screens is not very useful when comparing screens.
4. Screens with similar pressure response profiles can have markedly different solids retention curves for the same sand.

5. Results show that with the sands tested, screen plugging is a function of flux; i.e., the amount of sand challenging a screen per volume fluid per unit time.

Acknowledgements

The authors of this paper would like to thank Chevron Production Technology Company for permission to publish this paper.

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7. ANSI / NFPA T3.10.8.8 R1-1990

Appendix A

1. Mix 10.0 gms formation sand with 50 mL methylene chloride in 250 mL beaker
2. Stir gently for 30 minutes at room temperature with magnetic stirrer
3. Remove stir bar and let mixture set quiescent for 1 - 2 hours
4. Decant supernate gently into 100 mL graduated cylinder
5. Dry wet solids in 250 mL beaker @ 125°F for 1 - 2 hours
6. Inspect 100 mL graduated cylinder for residual solids; if solids present, decant off supernate and recombine solids from graduated cylinder into 250 mL beaker and re-dry solids @ 125°F

Appendix B - Test Procedure

The Screen Efficiency Test uses a cell and procedure adopted from the University of Oklahoma originally developed for filter industry called the “F-2 Test” (7). During the modification of the F2 Test procedure for the evaluation of gravel pack screens, several of the service companies were consulted. Pall and Baker were directly involved in the design of the apparatus; and the test procedures were discussed with Pall, Baker, Halliburton and Johnson at some point in the development of the current program. The test procedure currently used by DTC is, in general, the same type of test used by all the service companies. The major difference is the level of accuracy and precision of the data.

The basis of the test is that a sample of screen is exposed (challenged) with an oil containing a set amount of solids at a constant flow rate (i.e, flux) . The solids have a particle size distribution characteristic of the formation the business unit is interested in controlling. During the test, the pressure differential as a function of time is measured; as well as, the amount of solids passing through the screen. For a particular formation and set of potential screens, data sets are used to generate a family of curves of pressure vs time, and sand retention vs time. Even though it is not possible to predict the actual life of a particular screen in a well using this technique, the procedure does provide a relative comparison of time to plug and sand retention for each screen based on the business unit's formation characteristics.

The experimental apparatus used in the Screen Evaluation tests is shown in Figures 14 & 15. Figure14 shows the overall equipment set up, and Figure 15 shows the cell used to hold the screen samples.

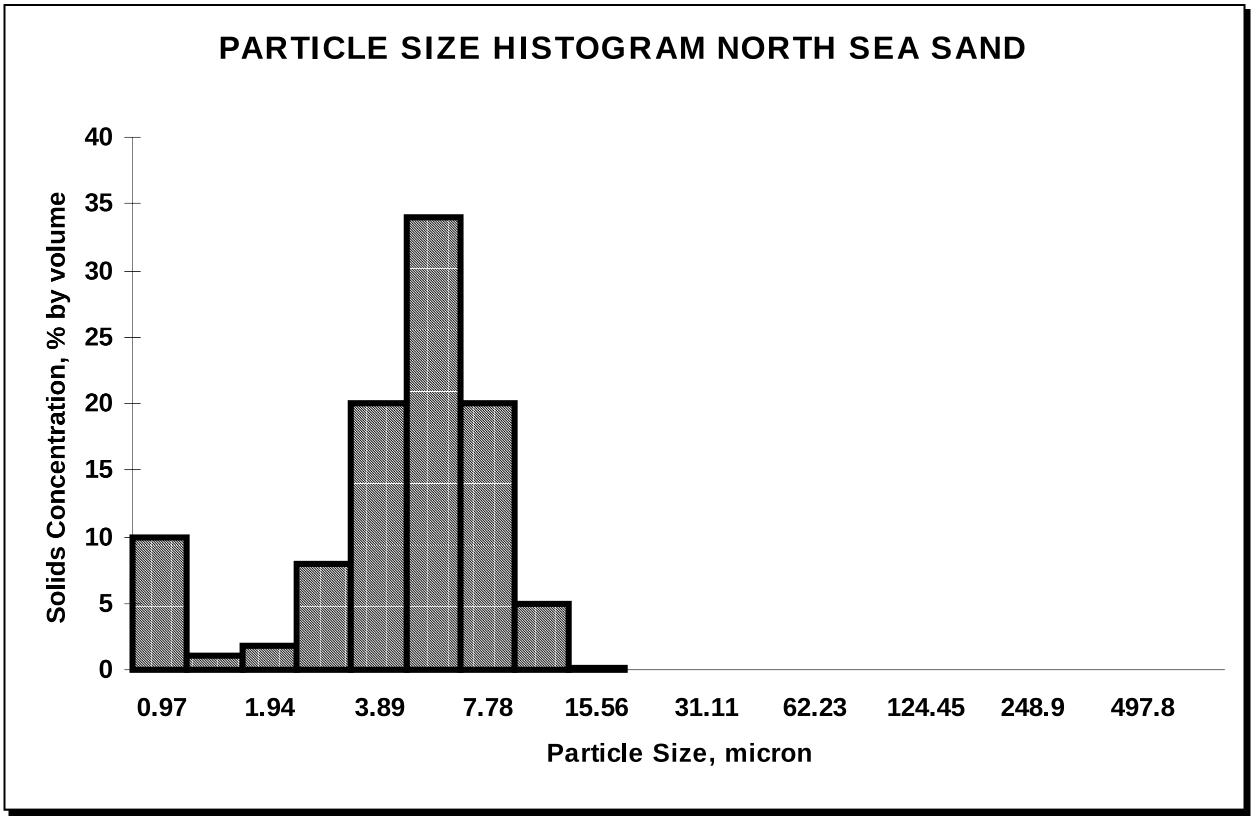

Figure 1 – Particle Size Distribution – North Sea Sand

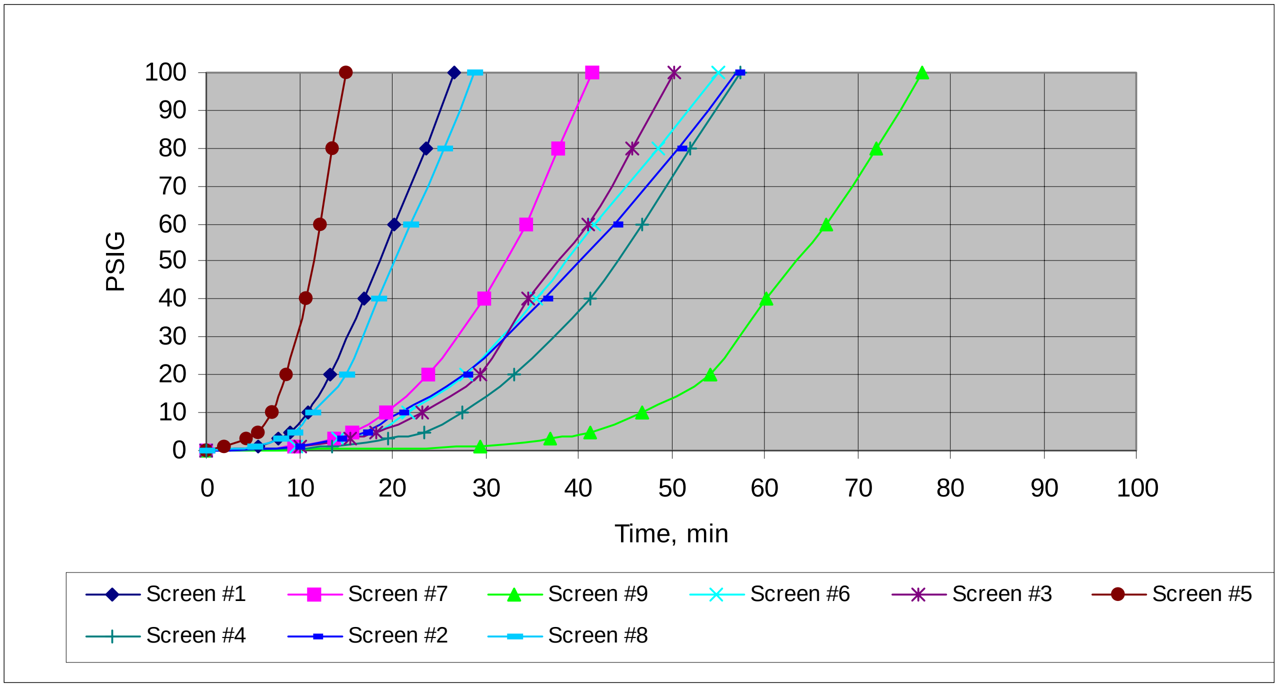

Figure 2 – Pressure Profile – North Sea Sand

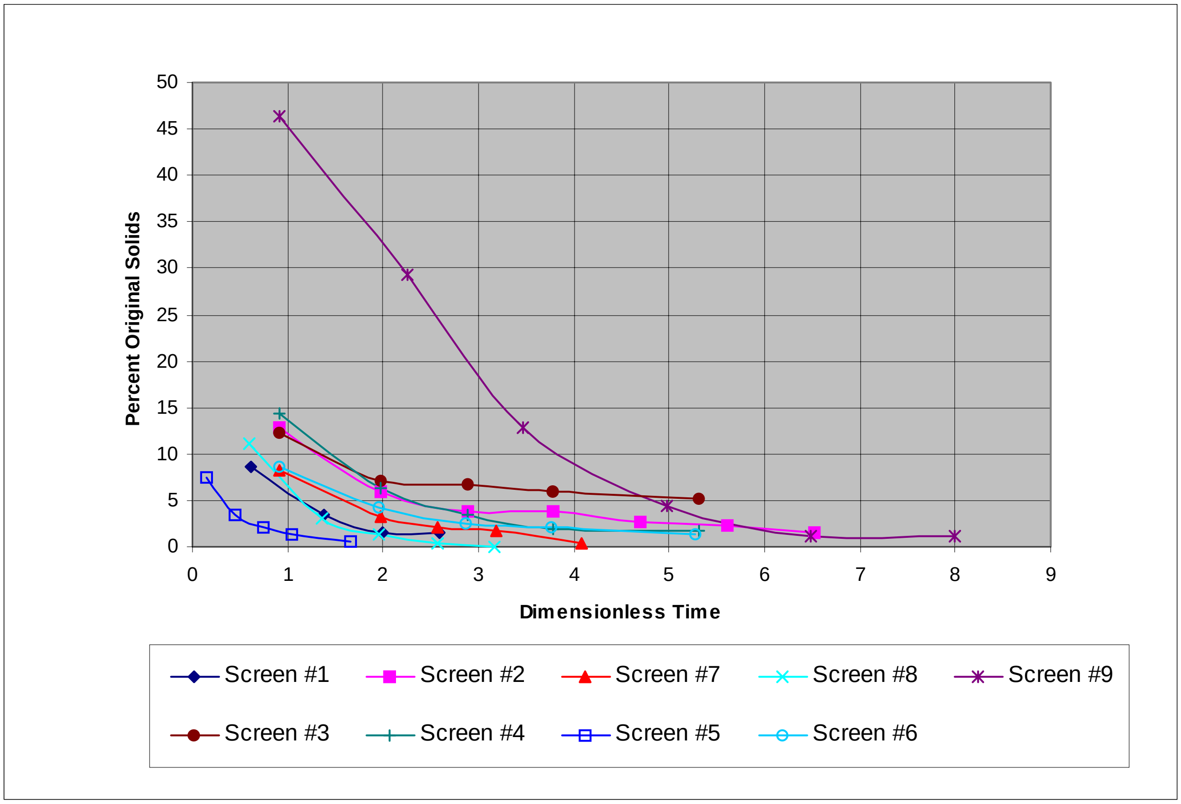

Figure 3 – Gravimetric Profile – North Sea Sand

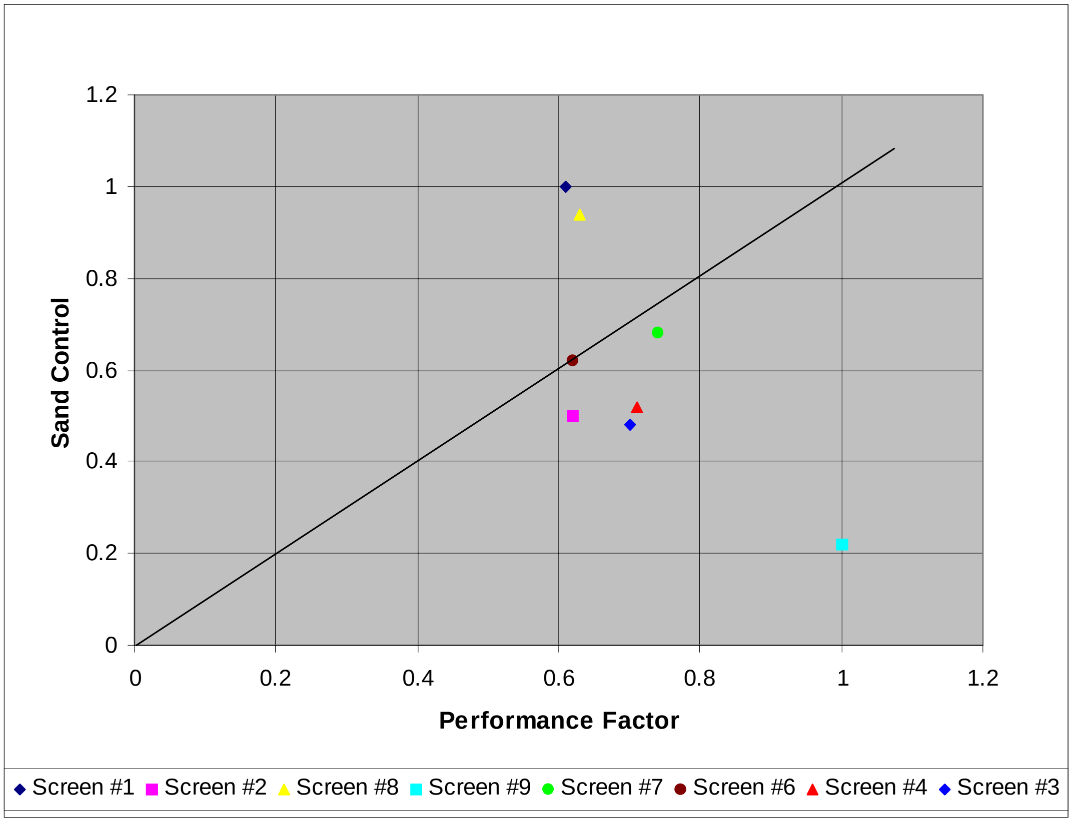

Figure 4 – SE Plot – North Sea Sand

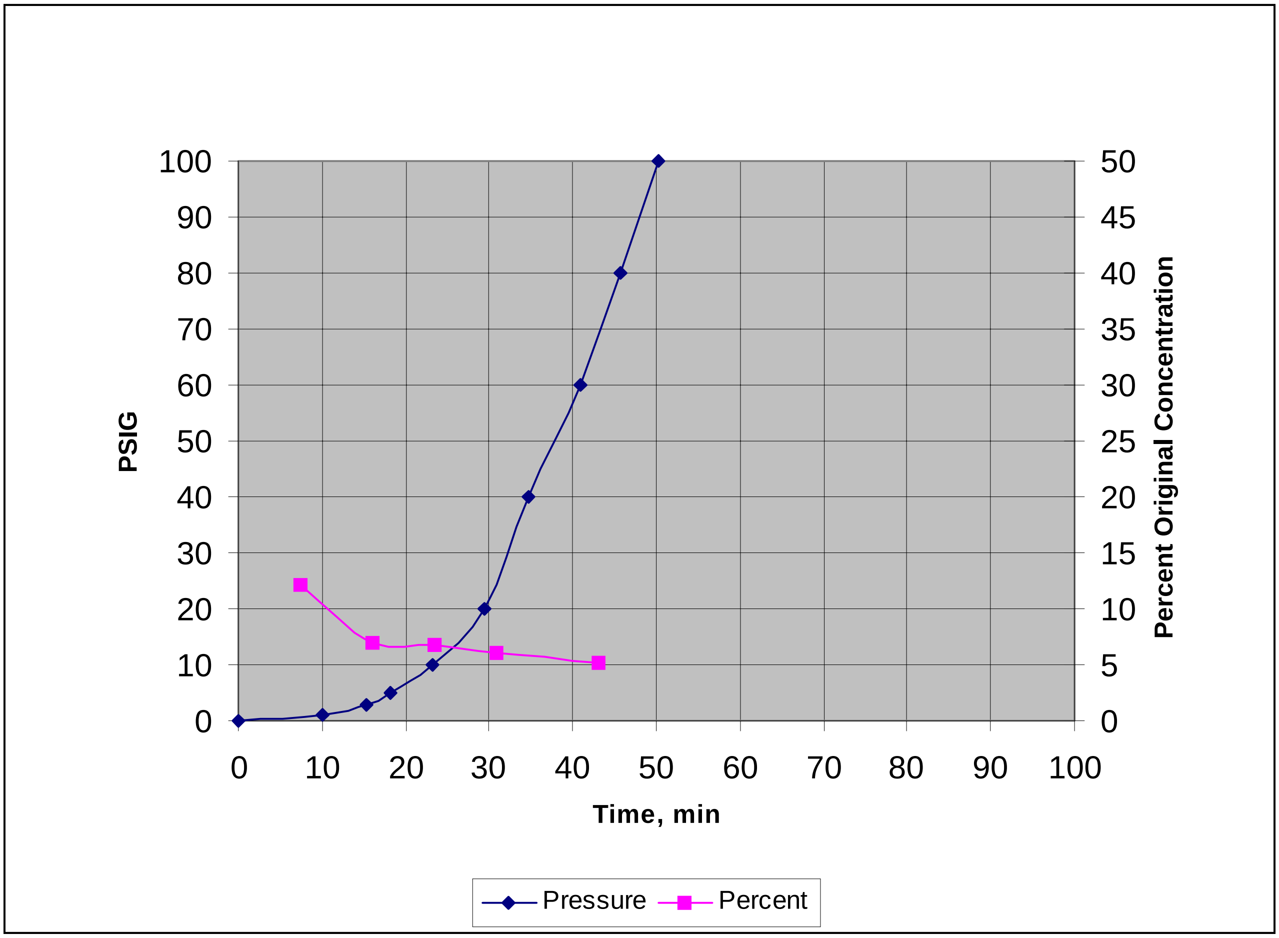

Figure 5 – Plot of Lab Data

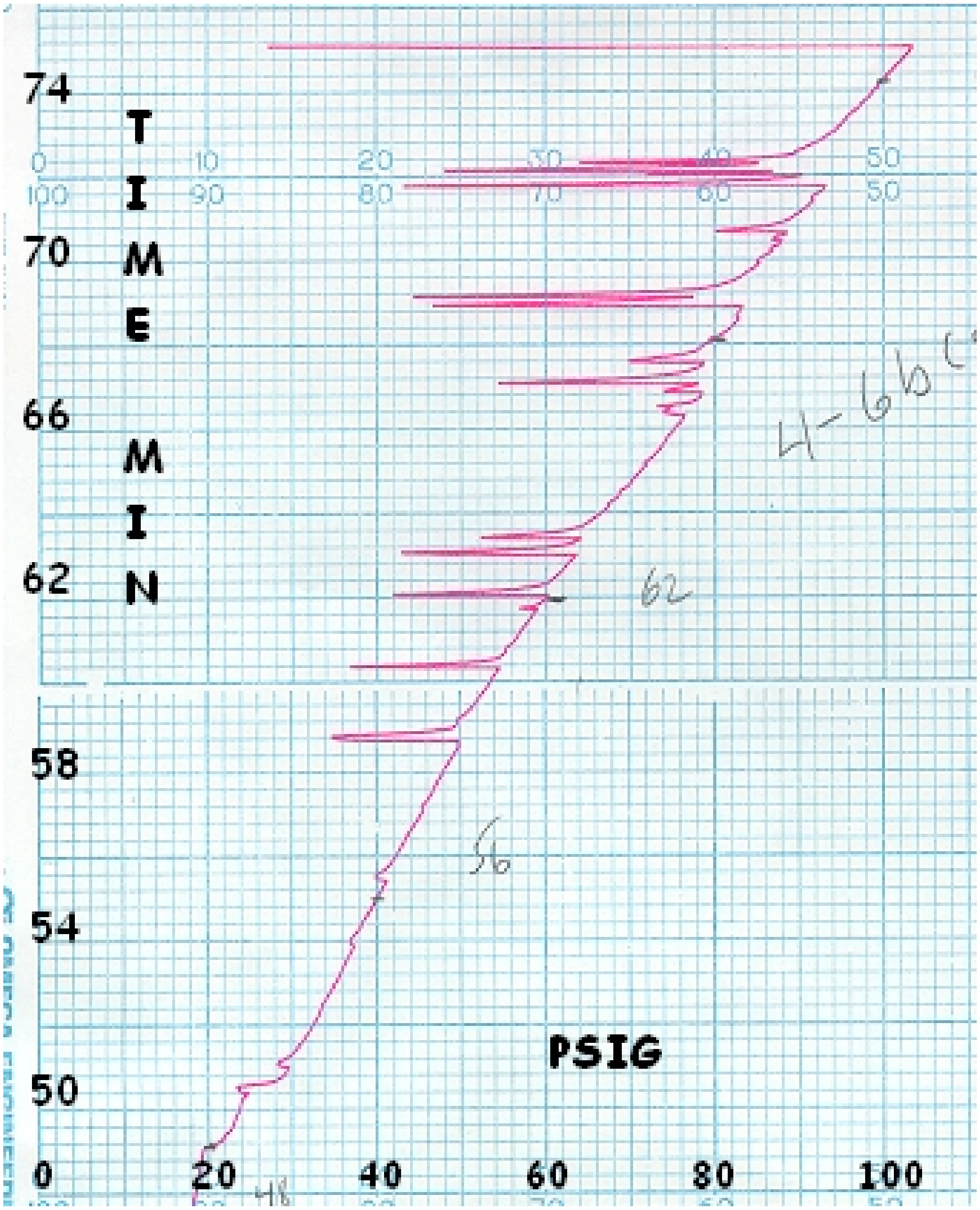

Figure 6 – Raw Lab Data

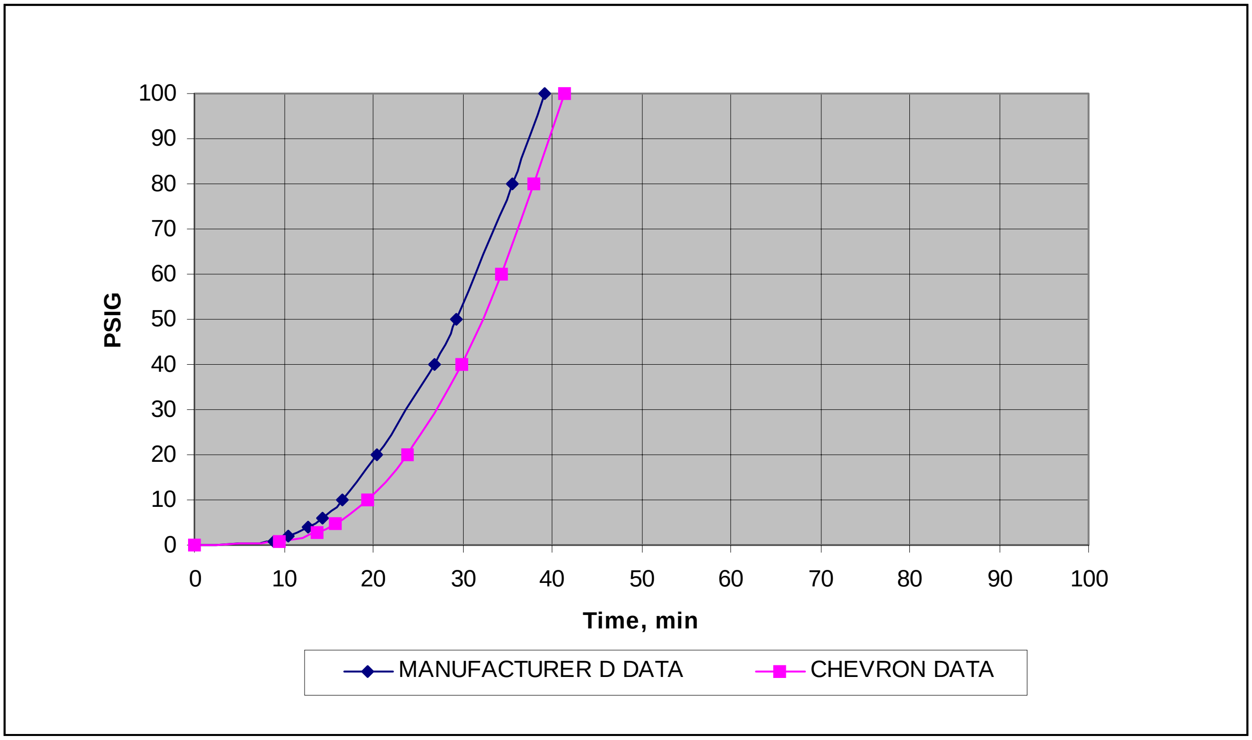

Figure 7 – Comparison of Test Data

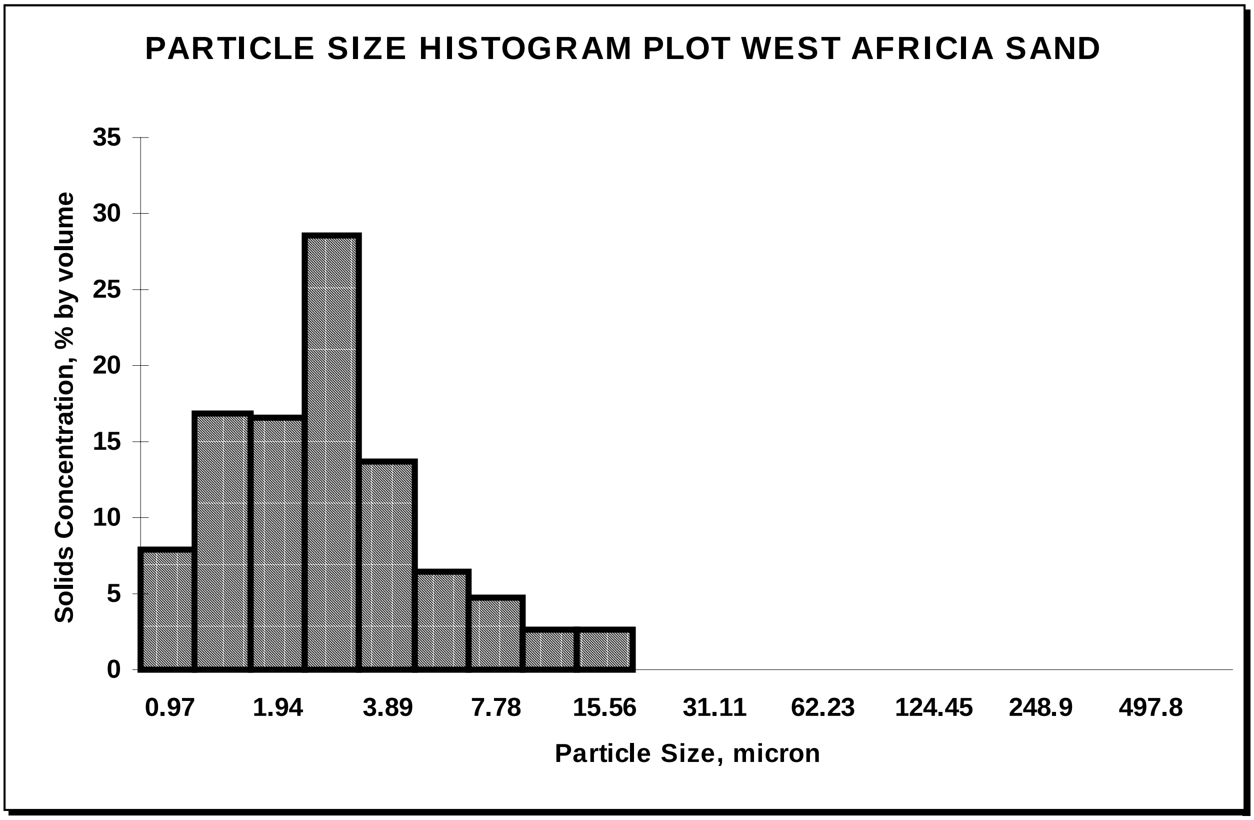

Figure 8 – Particle Size Distributions – West Africa Sand

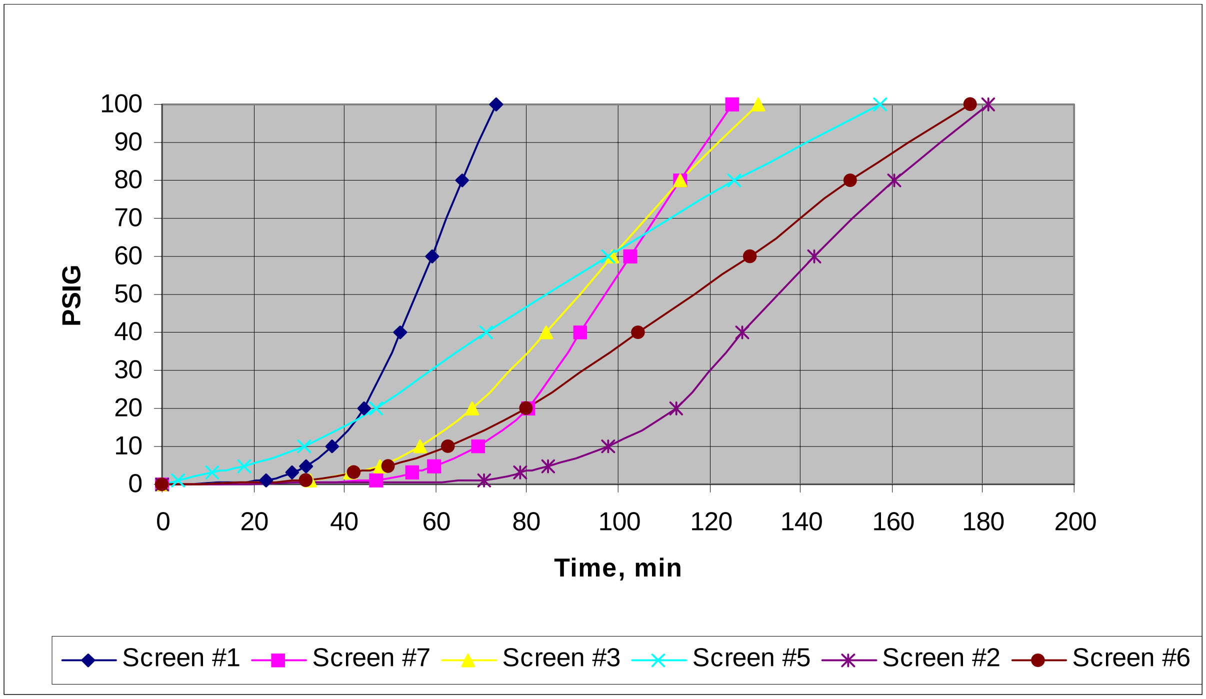

Figure 9 – Pressure Profile – West Africa Sand

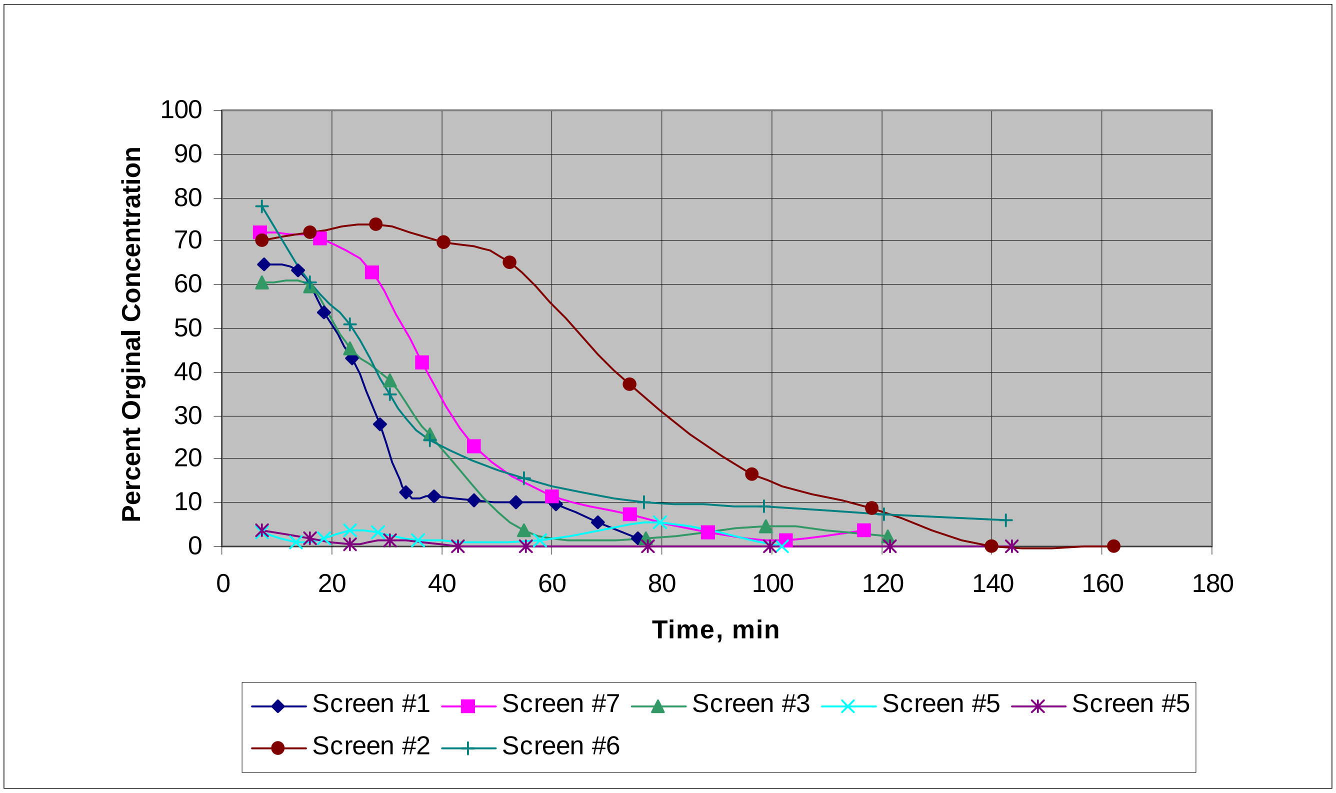

Figure 10 – Gravimetric profile – West Africa Sand

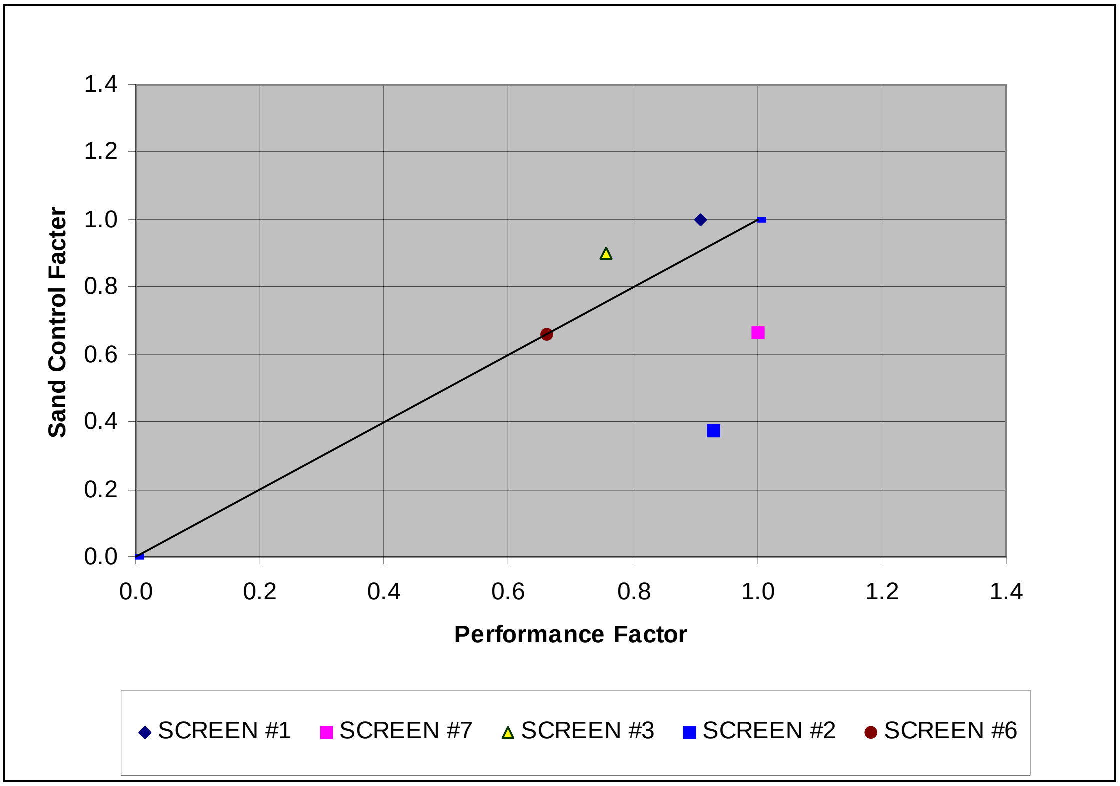

Figure 11 – SE Plot – West Africa Sand

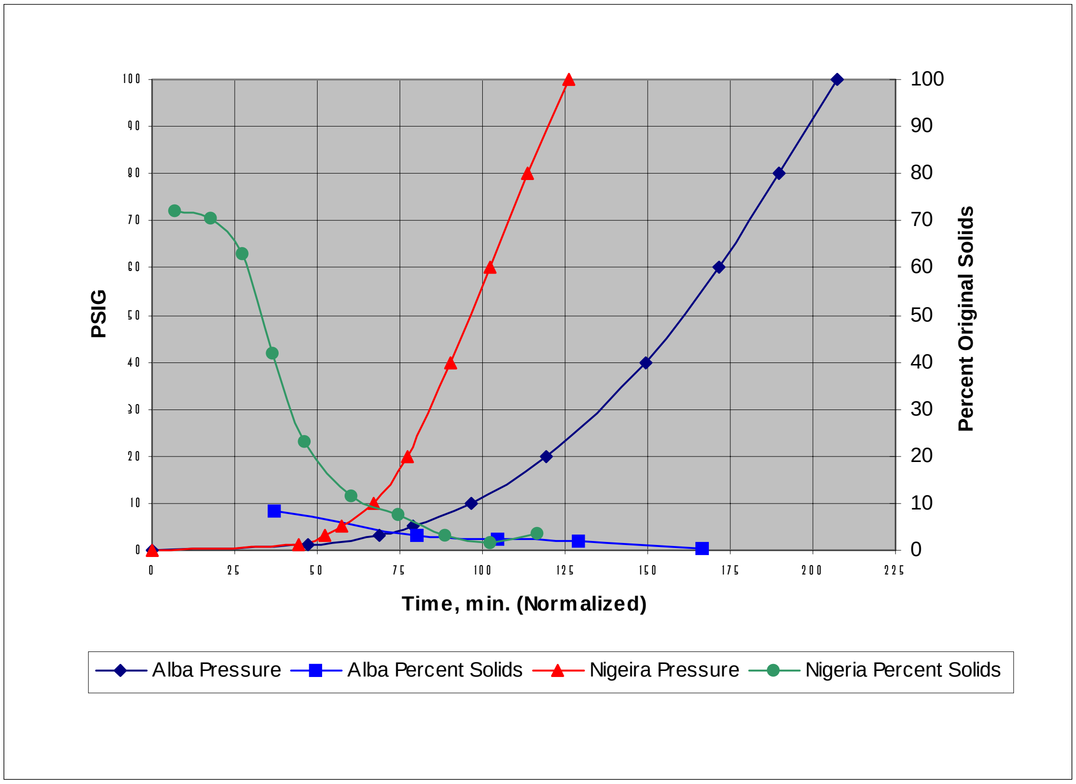

Figure 12 – Comparison of North Sea and West Africa Plot

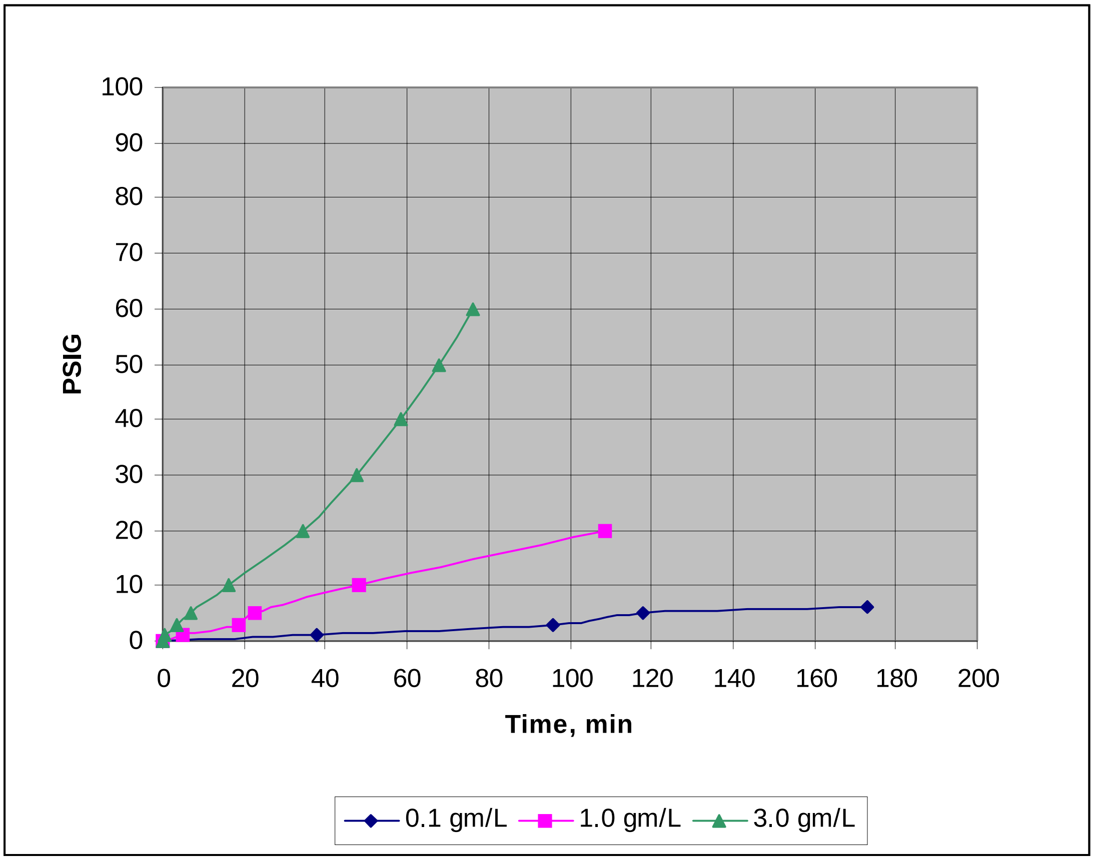

Figure 13 – Effect of Flux

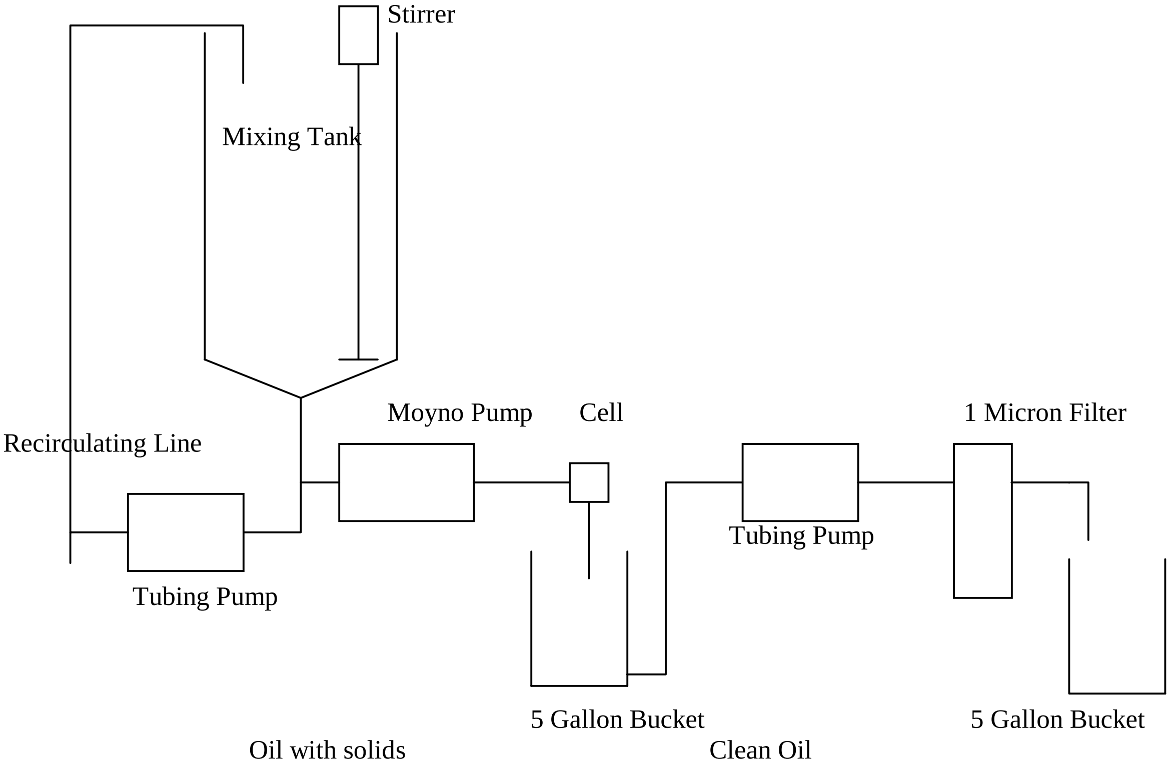

Figure 14 – Schematic of Test Appactus

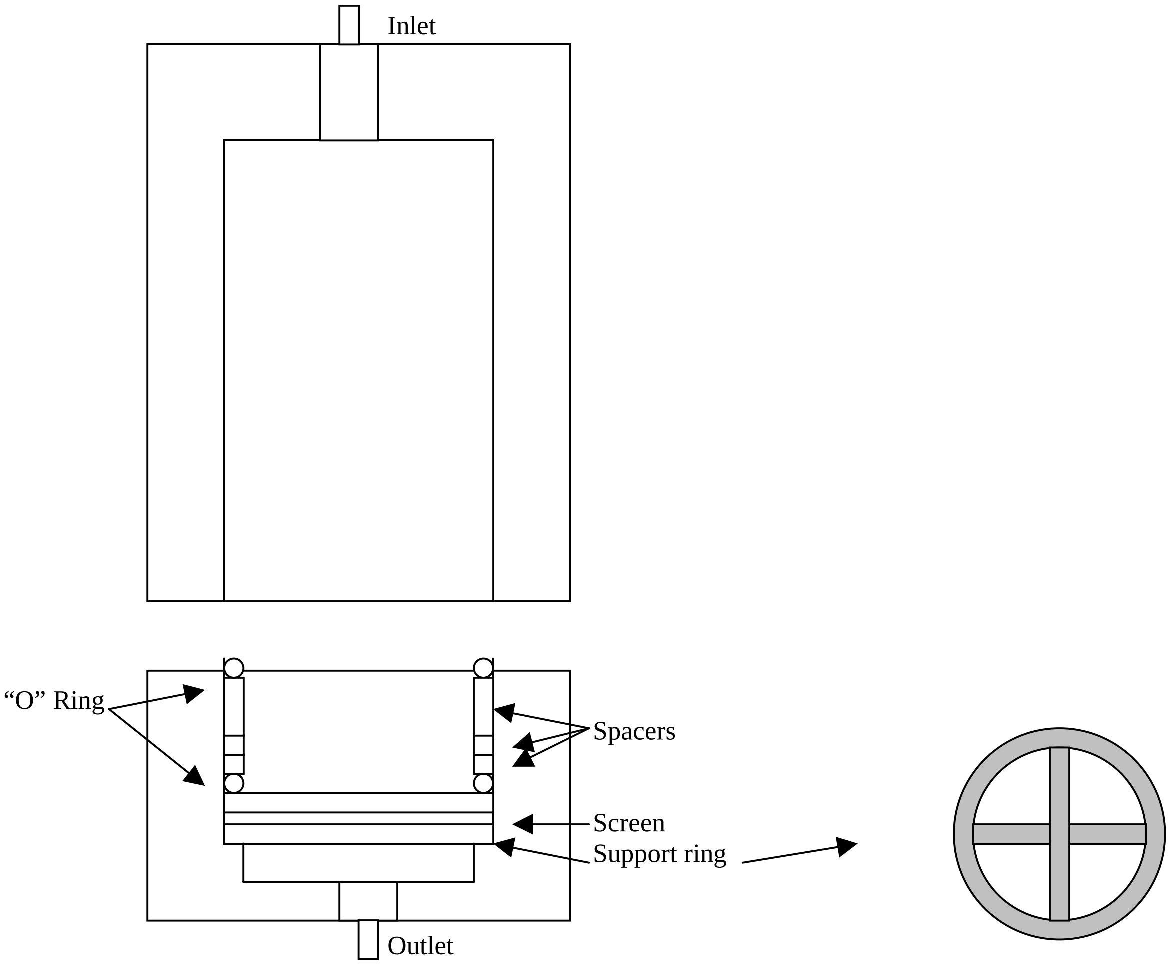

Figure 15 – Schematic of Test Cell