SAND CONTROL MEASURES FOR PRODUCTIVITY ENHANCEMENT

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SAND CONTROL MEASURES FOR PRODUCTIVITY ENHANCEMENT

A thesis submitted in partial fulfillment of the requirements for the Degree of
Master of Technology
(Gas Engineering)

By
Akula Srinivas

Under the guidance of

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College of Engineering
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Whomsoever it may Concern

This is to certify that **Mr. Akula. Srinivas , a student of M. Tech. (Gas Engineering) College of Engineering, University of Petroleum & Energy Studies, Dehradun**, has successfully completed his summer training from 10th March 2008 to 30th April 2008 . During training he worked with dedication on the Project entitled, "Sand Control Measures for Productivity Enhancement". He took keen interest in learning the basic concepts of sand control as well as operational aspects of equipments used for experimental studies to complete the assigned project. I am pleased to state that he completed the project to the best of my satisfaction.

During his work he was found sincere, hard working, analytical and punctual. His behaviour and conduct was very good . I wish him a bright future in his academic endeavour and life.

US Prasad
21. 5. 08

CERTIFICATE

This is to certify that the work contained in this thesis titled "sand control measures for productivity enhancement" has been carried out by Akula.Srinivas under my/our supervision and has not been submitted elsewhere for a degree.

Prof.S.sahai,
Adjunct Professor (Exploration).

ABSTRACT

Sand production has been a world wide challenge for the petroleum industry for many decades and is a major problem in almost all fields of India. Every year the petroleum industry spends millions of dollars in carrying out work over jobs associated with sand production. In today's scenario gravel packing is the most widely used method of controlling sand production when properly designed and executed. The objective of this project is to design a gravel pack for oil and gas wells with sand problem during production. The design was done for an onshore gas well having high sand production and water cut. The gravel pack was selected based on the laboratory tests such as soxhalation and sieve analysis. This gravel pack design when implemented can improve the productivity of the well. This project will also be a guiding path for the junior students for carrying out their projects related to sand production and control.

Acknowledgement

First of all I would like to thank KDMIPE, Oil and Natural Gas Corporation for providing this project which helped me to explore my knowledge working with professionals in oil and gas industry and hence to enhance my practical skills.

At the very outset, I would like to thank **Dr.R.P.Badhoni**, Course Coordinator, M.Tech (Gas Engineering), for giving me the opportunity to undergo this major project

I would like to thank **Narender kumar Uppal**, chief manager (Reservoir), my guide with out whose help and encouragement the project would not been successful.

I cordially thank **Prof.S.sahai**, Adjunct professor (Exploration), for extending their full support in completing this project.

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INTRODUCTION ABOUT KDMIPE

The Keshava Deva Malaviya Institute of Petroleum Exploration (KDMIPE), located at Dehra Dun in the picturesque Doon valley, was set up in 1962 as a research and training institute. The institute continues to be the country's premier centre for basic and applied research in petroleum exploration. It caters to the research needs of ONGC's operating regions in the field of geosciences for petroleum exploration, and development of alternate sources of energy.

The objectives of the Institute are:

1. Synergistic geoscientific studies for understanding habitat of petroleum and identification of prospective petroliferous areas

2. Exploration efforts review for short term strategic and long term prospective plans

3. Harnessing of alternate energy resources

4. Management of centralized database and exploration informatics through countrywide E&P data network (EPINET)

Chapter-1

Introduction

1.1Introduction:

Objective: Stop sand movement and maintain maximum production.

The success of a sand control job is measured by three inter related parameters that are all important. These parameters are.

1. Stop sand movement
2. Maintain maximum production rate
3. Payout the job costs in a responsible time.

Sand flow from unconsolidated formations is controlled through chemical or mechanical means to prevent or correct various problems. The term meaning of unconsolidated is that sand grains are not cemented. This is lack of cementation.

- All produced solids smaller than the 90-percentile formation sand are probably interstitial fines
- Produced solids between the 90 and 75 percentile range probably represent some of the smaller load bearing solids.
- Produced solids between the 75 and 50 percentile range certainly represent load bearing solids.

Sand production has plagued the oil industry. With today's higher production rates and depletion of many older wells, sand control is becoming more essential. Production of formation sand with reservoir fluids can be costly and is potentially dangerous; therefore, it must be controlled. Other potentially serious and costly problems include production loss caused by sand bridging in casing, tubing, and flow lines, erosion problems, abrasion of down hole and surface equipment.

If production rates are high enough to carry produced sand to the surface. Severe erosion of both surface and subsurface equipment may occur. Also production of formation sand can create considerable disposal problems, especially on offshore locations. Continued production of formation sand can cause loss of a well from casing collapse.

1.2 Possible causes of sand production:

The sand production mechanism is complex and influenced by each operation from first bit penetration of the producing zone to start of production. It is not always possible to determine reasons for sand production in a given well. However these reasons can be any one or a combination of the following:

(I)Totally unconsolidated formations:

Some formations are thought to be totally unconsolidated, or in a fluid state. Any attempt to produce formation fluid can result in production of large amounts of sand with the fluid.

(ii) Production rates:

Some well produce sand if the production rate is high. These wells will produce sand-free if production is restricted. For many years restricting production was a primary means of sand control.

(iii) Onset of water production:

In some formations the cementatious material is clay minerals and silt, which may seriously affect by water. When water production starts the bond is weakened or destroyed, and formation sand may be produced.

(iv) Increase in water to oil ratio:

Generally, as water production increases, the total fluid production is increased to maintain maximum oil production. This increased production rate causes excessive stresses on weakly

Consolidated formations and may exceed the ability of the cementatious material to bound sand together.

(v) Reservoir depletion:

In some cases reservoir pressure is believed to aid in the support of overburden. Reduction of reservoir pressure may cause the overburden to crush a poorly consolidated formation and result in serious casing damage.

(vi) Improper well completion practices:

Misuse of acid for stimulation may remove the small amount of calcareous bonding material in certain weakly consolidated formations and may result in sand production. In some cases swabbing a well too hard or bringing the well up to desired production capacity to fast can cause excessive stress on weakly consolidated formations. Well completion practices such as these can cause premature sand production in wells that have produced sand-free for years.

1.3 Reasons for sand control:

1. Erosion damage to down – hole tubular and equipment including safety valves, chokes and artificial lift equipment:

Erosion damage due to sand production with oil and gas of down hole tubular and other equipment many necessitate replacing of the same by work over or wire line operations. This involves loss of production in edition to expenditure of replacement/ work over operations.

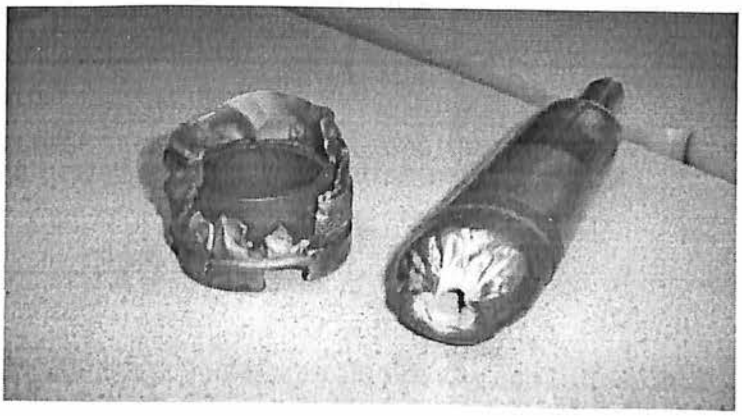

Figure 1.1 Erosion damage to chokes

2. Sand fill up and bridging inside the hole, casing or tubing:

Due to sand fill up or bridging of produced formation sand inside the hole, casing or tubing production is either reduced or sometimes completely stopped. To revive such wells, costly works over operations are often required.

Figure 1.2 Erosion damage to pipes

3. Sand accumulations in surface liens and equipment:

The produced sand carried to the surface by flow of oil and gas accumulates in surface and other equipment, which requires reservoir cleaning of the same.

4. Abrasive wear on surface controls, valves and pipes:

Flow of high velocity fluids contains formation sand has tendency to damage surface controls valves and pipes, causing loss of proper control over production severe cutting of chokes in wells producing sand is very common phenomenon.

5. Handling and disposal of produced formation sand:

Production of large amount of sand at the surface may cause handling and disposal problems. This is specially difficult and costly in offshore areas.

Chapter-2

Geological and Petrophysical properties

2.1 Geological sands are classified as

Marine deposited sands

1. Cemented with calcareous or siliceous material.
2. Well consolidated.

Erosion deposited sands

1. Cemented with soft clay/silt.
2. Partly consolidated.
3. Unconsolidated

Table -2.1 Classification of sands and their failure tendencies

Term	BHN (Brinell hardness)	Sonic Transit Time (μs/ft)	Remarks
Unconsolidated	<2	>130	No cementing material
Partially	2-5	100-130	Can Crush with fingers
Friable	5-10	90-130	Crushed when rubbed
Hard	>30	60-80	Can not be broken with forceps
Medium hard	30-50		
Hard	50-125		
Very hard	>125		

Serious sand production is predominantly associated with the unconsolidated, partially consolidated, and friable sands.

2.2 Formation sand description:

A good concept of what the formation sand looks like and how it behaves down hole is important. There are such a wide variety of sands that correctly identifying the type of sand that is present will help determine how to deal with them. It is useful to categorize incompetent sands into three broad categories relative to strengths.

(i) **Quick sand:**

Quick sand is a term often applied to completely "unconsolidated" formation sands. This type of sand has no effective cementing agent and is held together only by small cohesive forces and compaction. It is difficult to drill through this type of formation as it readily collapses in to the well bore and sticks the bit. Sand production begins immediately with fluid production if some means of sand control is not used. Sand flows readily with oil, water and gas.

As the formation pressure depletes and production rates are lower, the sand cannot be carried to surface. It begins to accumulate more frequently in the wellbore. Causing more frequent clean out operations.

(ii) **Friable sand:**

The second type of potentially trouble-some sand is a friable or semi competent sand which is well cemented and easily cored cores of this type of sand appear strong enough that they don't look like they would allow sand to produce. However, under the combination of increasing grain-to-grain stress, erosion, and changes in saturation, the cementation may break down and permit sand production to occur. However, produced fluid or gas readily erodes the sand from the face of the formation as it flows in to the perforations.

It is common for this type of formation to produce sand for a few days or weeks after completion, and then for sand production to diminish to only a trace, or cease. With significantly reduce pore pressure or water influx into the well, sand production may recur, especially at high production rates, where turbulence becomes significant in the near well bore area.

(iii) **Partially consolidated sand:**

A third type of formation sand is partially consolidated sand. It has some cementing agents but is only weakly consolidated and unconfined compressive strengths. A core can usually be taken from this type of formation with a conventional core barrel, but the core crumbles easily. An open hole completion is possible with this type of sand, but without some means of sand control the hole would collapse. Behind casing this type of formation crumbles and spalls, forming small cavities or pockets that cave in frequently. This causes slugs or clumps of sand to come into the wellbore which readily fill the rat hole and form bridges in the tubing.

2.3 Chemistry of sands and clays:

Sand can be defined strictly as a granular material of a size range of 0.0625 to 2 mm diameter particles. Chemically it is usually quartz, but carbonate sands also occur in nature. Commonly both types of sands occur as a mixture. Quartz (sio2) is the most common mineral in sandstone as it is the most stable under sedimentary conditions. However sands are accumulations of many chemicals as shown in table below which gives a typical sand analysis.

Typical sand composition

Sio2	78.66
Al2o3	4.78
Fe2o3	1.08
Feo	0.30
Mgo	1.17
Cao	5.52
Na2o	0.45
K2o	0.45

Sands are predominately midly hydrophilic, often mixed with strongly hydrophilic clay minerals; clays have strong chemical and mechanical effect on permeability out of proportion to their volume due to their platy or fibrous shapes and large surface areas.

2.5 Petro physical properties:

i) Porosity

This is a measure of the non-solid space within sandstone where liquids or gases accumulate. Porosities of sand decreases with poorer sorting (wider sand grain size distribution), tighter packing, and more cementing. Porosities of sands are unchanged by differing grain sizes. Porosity is often related to permeability but this is not a valid relationship as the manner in which cementing agents are distributed in the pores may affect the permeability strongly but have little effect on porosity. Shale, for instance, commonly has extremely low permeability but high porosity and water saturation.

ii) Permeability

This is a measure of the capacity of a porous media to transmit fluid. Permeabilities of sands decreases with poorer sorting (wider sand grain size distribution), tighter packing, more cementing, and smaller sand grains. Permeability is often directional in sandstones due to their depositional modes. The permeability of sand is highest along a bedding plane and in the direction of the depositional flow. Horizontal permeability is commonly much greater than vertical permeability. This is often due to permeability barriers caused by bedding planes, shale or clay streaks. Thicker beds tend to have higher permeability.

iii) oil-water wet

Due to the hydrophilic nature of quartz and clays, sands tend to be water wet. It is extremely difficult to drive all of the water from a quartz surface by heating. Sands can be oil wet from the surface active nature of some crude oils in the reservoir. Minimum water saturations of producing sands are seldom less than 10% and commonly 15 to 40%.small amounts of clays can greatly increase these figures. Shaley sands can produce water free oil water saturations as high as 65%.

iv) Relative permeability

Because of the natural tendency for sands to be water wet, the permeability of sand to the flow of oil is higher than the permeability to the flow of water. It is normally easier for oil to flow through sand than it is for water.

These statements assume that the water saturation of the sand is constant. The simple reason for this is that oil is repelled by the water that coats the sand grain surfaces. Thus, oil tends to stay in the center of the pore spaces and flows with little resistance or friction. Water is attracted to sand grain surfaces and a frictional force resists its flow. The opposite phenomenon is true when the sand is oil wet.

2.5 Sand Failure Modeling:

Detailed work seeking to quantify the risk of a given well to produce sand has been ongoing for over twenty years. The techniques have ranged from those based strictly upon field observations, laboratory-based sand production studies, and theoretical models. Until recently, the majority of these models assumed very simplified rock failure criteria, did not consider changes in rock strength as down hole conditions change, and were primarily suited to predict if sand production would occur _ not how much or how fast the sand would be produced. Veeken et. al.2 stated in 1991 that all three approaches (field observations, laboratory evaluations and theoretical modeling) should be used in combination to achieve realistic results.

In general, these different models have been used to determine if gravel packing could be avoided. This approach assumes that at certain times, gravel packing may be a necessary evil, but its use should be avoided whenever possible. The motivation for these assumptions are based upon an increased initial completion cost for gravel packed wells, and for the belief that by definition a gravel packed well will lose productivity.

Chapter -3

Causes and Prevention of Sand production

3.1 Factors affecting sand production:

The following factors are responsible for sand ingress in oil and gas wells:

1. Over burden, friction, differential stresses
2. Cementing material, degree of consolidation
3. Fluid viscosity, production velocity, drags forces
4. Capillary forces, water production

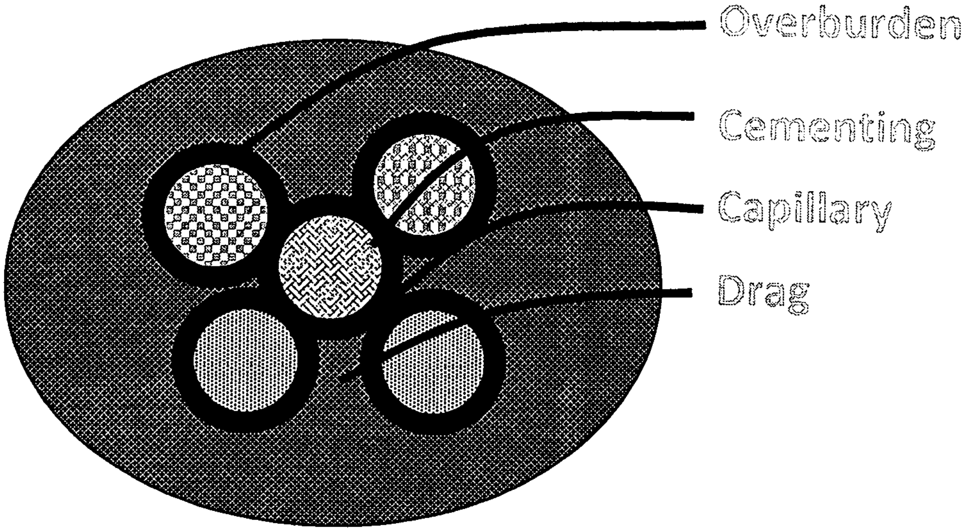

Figure 3.1 Factors affecting sand production

a) Sand production associated with oil and gas wells is one of the oldest problems facing the petroleum industry.

b) This is due to insufficient cementing materials and geo pressured environments, reducing the effects of inter granular friction and over burden stress.

c) These unconsolidated formations demonstrate similar characteristics and problems throughout the entire reservoir.

d) This is usually due to varying amounts of calcareous materials mixed with the silts and clays.

e) From a geological view point marine – deposited sands are usually cemented with calcareous or siliceous minerals and are generally well consolidated.

f) Erosion – deposited sands will often be weak and either partly consolidated by a soft clay or slit or completely unconsolidated.

g) In weakly consolidated formation the stresses caused by fluid flowing into the well bore are often sufficient to cause fine particles to be agitated.

h) In turn the throttling effect caused by these particles lodging in ore throat near to the well bore redirects the fluid flow pattern there by altering the direction and magnitude of the stress fields. This leads to additional particles being dislodged.

3.2 Sand control mechanisms:

The possible sand control techniques are:

3.2.1 **Production rate control:**

Where the following rate is maintained below the critical rate for sand production.

3.2.2 **Gravel packing:**

Where sized gravel is placed around a screen set across the perforations. Mechanical methods of sand control involve use of gravel to hold formation sand in place with a screen to retain the gravel. Screen to retain the formation sand with no gravel.

1. Gravel packing is the most widely used method of controlling sand production when properly designed and executed this method is also the most effective for controlling sand, especially in initial completions Gravel pack implies, properly sized gravel is placed around a screen to prevent formation sand from being transported into the well bore along with the formation fluids.

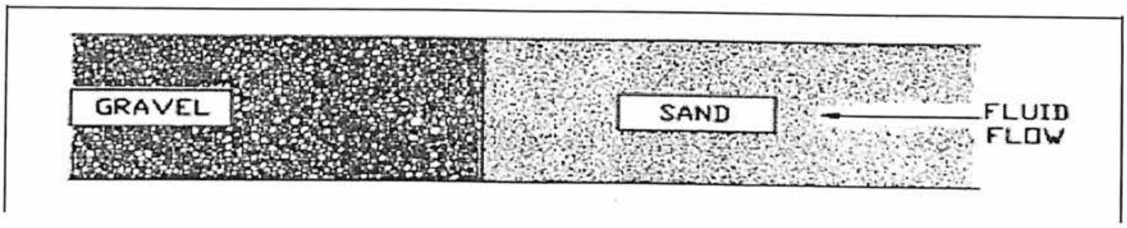

Figure 3.2 sand control through gravel packing

2. Gravel is sized to stop sand production, while the function of the screen is to hold the gravel in place. This method is an evolution from the practice of simply installing the screen to slotted liner opposite the formation

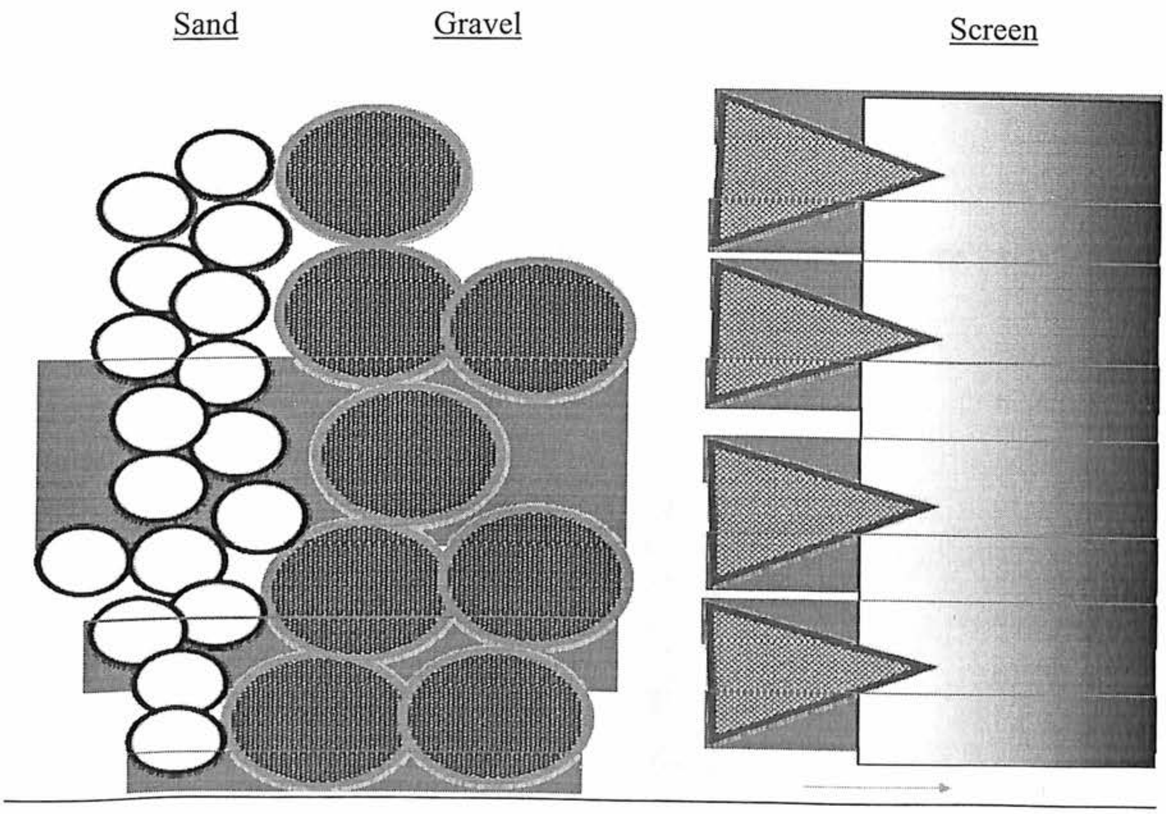

Figure 3.3 Gravel pack arrangement in well bore

4. Essential a gravel pack entails placing a granular filter in the annular space between an unconsolidated formation and centralized slotted liner or wire- wrapped screen.

5. Most gravel pack treatments are performed in cased hole completions for situations in which extremely high productivity is required.

6. They are also performed in open hole and under reamed completions. When first applied in oil wells, it was recognized that guidelines were needed for selecting the correct slot and gravel size.

Gravel packing is now the most successful method of sand control and can be used in greater variety of wells than any other techniques. It is used in most wells, including wells with long completion interval and slit for shale zones.

The basic problem is how to control formation sand without an excessive reduction in well productivity.

3.2.2.1 **Basic design parameters include:**

- Optimum gravel size in relation to formation sand size.
- Optimum screen slot width to retain the gravel, or if no gravel, the formation sand.
- An effective placement technique-perhaps most important.

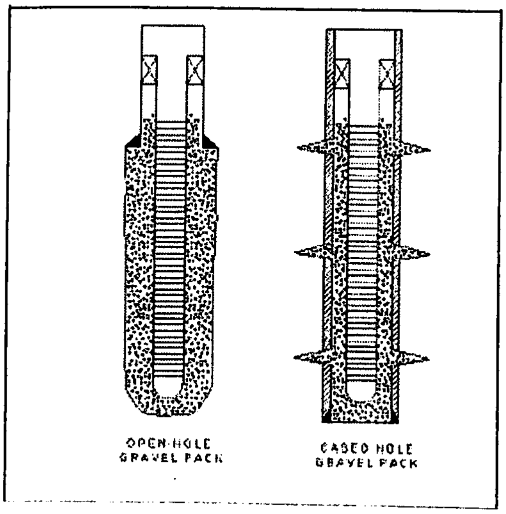

Figure 3.4 open and cased hole gravel pack arrangement

There are two basic types of gravel pack:

1. The external or open hole gravel pack
2. The internal or cased hole gravel pack.

3.2.3 <u>Open hole completion:</u>

1. A method of preparing a well for production in which no production casing or liner is set opposite the producing formation

2. Reservoir fluids flow unrestricted in to the open wellbore

3.2.3.1 Open hole gravel pack sequence:

Step-1 under reaming:

The hole is often under reamed in order to provide the necessary gravel thickness.

Step-2 caliper survey:

A caliper survey is run to provide an estimation of the amount of gravel

Step-3 gravel placement:

The gravel is placed around the screen using a high viscosity fluid to prevent the gravel bridging before the complete fill-up of the formation screen annulus.

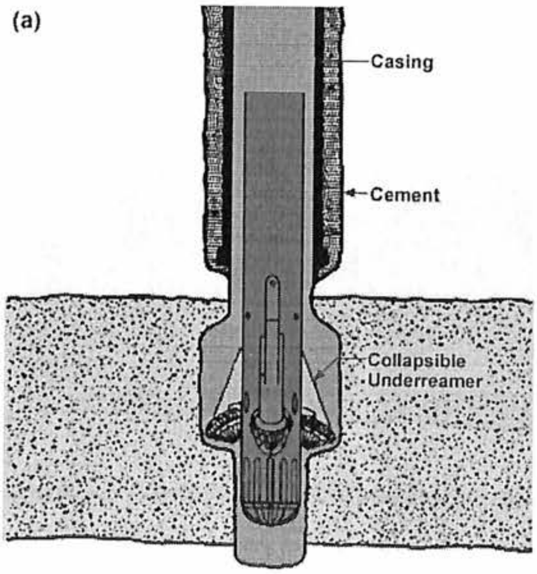

Fig-3.5 Open hole gravel pack

The gravel is placed in the annular gap between a liner screen and the formation. The hole is usually under reamed to remove drilling damage and to reduce flow restriction by enlarging the wellbore radius of sand/gravel interface. In external gravel pack the casing is set above the top of the pay zone and the completion interval is then under reamed to remove drilling damage and maximize the inflow area.

The gravel pack screen is hang as an uncemented liner and the space between the screen and the formation face is packed with properly sized gravel.

In theory external gravel packs result in better productivity than internal gravel packs, especially at high rates and/or with viscous crudes. In practice, they are often more difficulty to plan and install effectively. Thus the external gravel pack provides potentially higher productivity due to the absence of perforations.

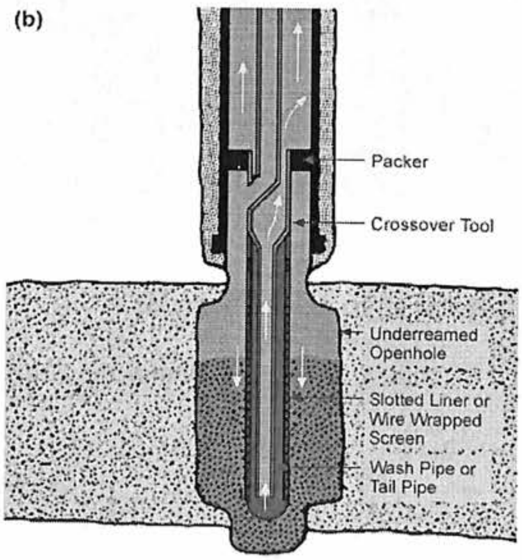

Figure 3.6 Arrangement of open hole gravel pack

3.2.4 Cased hole completions:

1. Steel pipe placed in an oil and gas well as drilling progresses to prevent the wall of the hole from caving in during drilling.

2. A method of preparing a well for production in which production casing or liner is set opposite the producing formation

As in the cased hole gravel pack the produced fluid must flow through the gravel and through the screen to reach the wellbore. Unlike the internal pack however the fluid flow with the external gravel pack is purely radial.

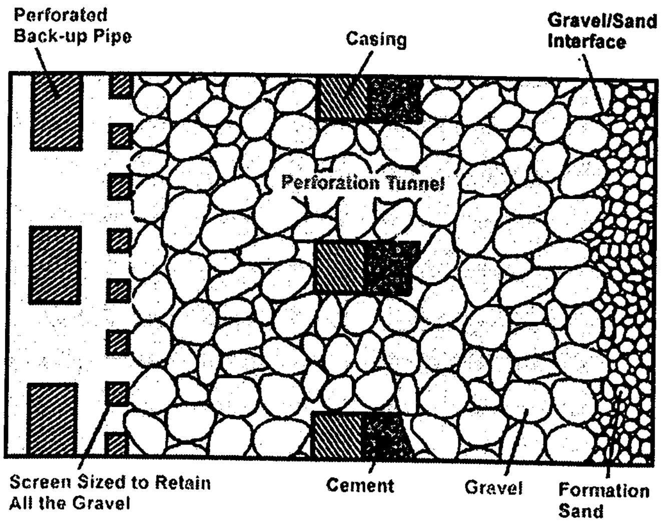

Figure-3.7 A schematic view of an internal gravel pack

3.2.4. Cased hole gravel pack sequence:

Step-1 perforating

Step-2 perforation cleaning

Step-3gravel squeeze

Step-4 gravel placement

The produced fluid must flow through the gravel-filled perforations, through the gravel pack and screen, to reach the well-bore. Hence the productivity is governed by the flow resistance through each of these sections. The greatest potential for flow restriction is at the perforations, where the flow pattern becomes linear instead of radial.

Moreover flow must converge and diverge in the vicinity of the perforations. The major challenge of the packing operations is to transport gravel through the perforation to pack the entire area around the perforation tunnel with very high permeability gravel.

The gravel size is optimized to achieve the maximum permeability that can completely stop the formation material at the formation-gravel interface. Gravel should be placed with out incurring mixing of gravel with formation solids. Gravel should be tightly packed in the liner-casing annulus and in the perforation tunnels; with out any voids (i.e., a packing efficiency of 100%). All completion fluids should be very clean and not create formation damage.

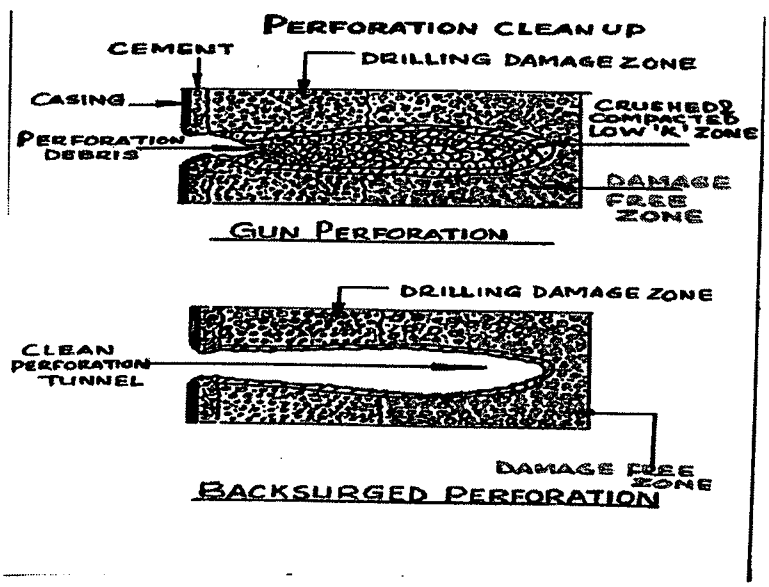

Figure 3.8 Perforation cleaning

The perforations are the sources of the greatest number of problems, since they are the most critical areas. Opening up the perforations and packing gravel efficiently inside the tunnels without mixing gravel with formation solids is a challenge, especially in heavily depleted zones, in deviated wells, and in shallow, poorly consolidated formation sand, where sloughing and cave-ins often occur.

The liner screen should be designed to achieve minimum flow resistance while still preventing any gravel from entering the tubing string. The annular space between the liner and casing should be adequate to prevent gravel bridging during placement and to permit wash over operations. The screen need be no larger than the production tubing in a conventional single-zone completion. The screen should be centralized and constructed from a material that will resist corrosion, erosion, and collapse.

3.2.5 Gravel quality:

A high quality gravel is necessary is necessary to obtain a high success ratio. It is therefore recommended to inspect the gravel prior to it's delivery on the well site. This inspection made in the laboratory, will cover all in the API standards. The guidelines are as follows. A Krumbein roundness and sphericity of 0.6 or better is often recommended.

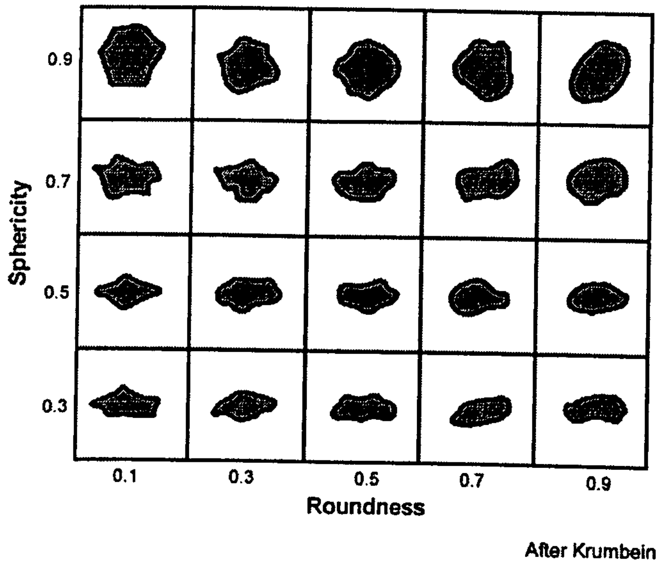

Figure 3.9 Krumbein scale for roundness and sphericity

The above figure shows the various classifications of roundness.

1. Angularity and size distribution (krumbein roundness>.6) in order to obtain a tighter pack.
2. Solubility: this gravel should have an insolubility of 98% or more to avoid possible pack deterioration during acidizing(HCL)
3. Clay or silt content should be nil

4. Size control: to ensure the proper formation sand/gravel ratio.

3.2.6 Practical considerations in gravel packing:

The keys to successful gravel packing are

- Selecting gravel of proper size and quality.
- Placing the gravel without contamination, at the proper location, as tightly as possible. Then holding it in place for the life of the well.

The crux of the problem is to control the load bearing solids without excessive loss of productivity. Where reservoir conditions are such that high production rates can be sustained, every trick must be employed to maximize productivity and reduce flow velocity per unit area.

3.2.7 Sand consolidation:

Where a resin or high sand content resin slurry or plastic is injected into the formation. This resin act as a cementing material for the formation sand or injected sand.

Plastic consolidation involves the injection of plastic resins, which are attracted to the formation sand grains. The resin hardens and forms a consolidated mass, binding the sand grains together at their contact points. Excess plastic is over flushed from the grains to re-establish permeability.

Three types of resins are commercially available: epoxies, furans (including furan/phenolic blends), and pure phenolics. The resins are in a liquid form when they enter the formation and a catalyst or curing agent is required for hardening. Some systems use "internal" catalysts that are mixed into the resin solution at the surface and require time and/or temperature to harden the resin. Other systems use "external" catalysts that are injected after the resin is in place. The internal catalysts have the advantage of positive placement since all resin will be in contact with the catalyst required for efficient curing. A disadvantage associated with internal catalysts is the possibility of premature hardening in the work string. The amounts of both resin and catalyst must be carefully chosen and controlled for the specific well conditions. Epoxy and phenolics can be placed with either internal or external catalysts; however, the rapid curing times of the furans (and furan/phenolic blends) require that external catalysts be used.

All plastic consolidation systems require a good primary cement job to prevent the resin from channeling behind the casing. Shaley zones should not be perforated. A clean system is essential for plastic consolidation treatments because all solids which are in the system at the time of treatment will be "glued" in place. The perforations should be washed or surged, work over rig tanks should be scrubbed and fluids should be filtered to 2 microns. Work strings should be cleaned with a dilute HCl acid containing sequestering agents, and pipe dope should be used sparingly on the pin only. A matrix acid treatment, which includes HF and HCl, is recommended for dirty sandstones.

Advantages:

The main advantage of plastic consolidation is that it leaves the wellbore fully open. This becomes important where large OD down hole completion equipment is required. Also, plastic consolidation is suitable for through tubing applications, and may be applied in wells with small diameter casing. For many applications, the problems associated with plastic consolidation outweigh the possible advantages. The permeability of a formation is always decreased by plastic consolidation. Even in successful treatments, the permeability to oil is reduced because the resin occupies a portion of the original pore space, and because the resin is oil wet. The amount of Resin used is based on uniform coverage of all perforations.

Difficulties:

The primary difficulty in using resin systems is complete and even placement of the chemicals in the formation. For this reason plastic consolidation is only suitable for interval lengths less than 10-15 feet. Longer intervals can be treated using packers to isolate and treat small sections of the zone at a time, but such operations are difficult and time consuming. However, perforation plugging or Permeability variations will often cause some perforations to take more plastic than others. The Perforations which received excess plastic may be plugged, and little, if any, strengthening will occur in the perforations not receiving resin. In systems which utilize an external catalyst, there will be no sand control in areas which are not contacted by both resin and catalyst.

Plastic consolidation treatments also do not perform well in formations with permeabilities less than about 50 millidarcies and/or bottom hole temperatures in excess of 225°F. However, this technique currently represents less than about 1% of all sand control completions worldwide. The reasons for decreased usage include the placement difficulties described above, as well as tight regulations on the handling of the chemicals, which are generally quite toxic (with the furans being the least toxic of the three). In addition, these treatments tend to have a high cost.

3.2.8. **Combination sand control techniques:**

These techniques of sand control combine the advantages of gravel packing and consolidation and are becoming more widely used in oil industry. There are widely used in oil industry

1. Resin-coated gravel packs

Introduction:

Resin coated gravel is high permeability gravel pack sand coated with a thin layer of resin. When exposed to heat, the resin is cured resulting in a consolidated sand mass. The use of resin coated Gravel as a sand control technique involves pumping the gravel into the well to completely fill the Perforations and casing. The bottom hole temperature of the well or injection of steam causes the resin to cure into a consolidated pack. After curing, the consolidated gravel pack sand can be drilled out of the casing leaving an unobstructed wellbore. The remaining consolidated gravel in the perforations acts as a permeable filter to prevent the production of formation sand.

First, and most important, a successful job requires that all perforations be completely filled with the resin coated gravel and the gravel must cure. Complete filling of the perforations becomes increasingly difficult as zone length and deviation increase. Secondly, the resin coated gravel must cure with sufficient compressive strength. The compressive strength of the resin coated gravel is dependent on temperature and time. Currently available systems will cure at temperatures exceeding 180°F after about 14 days; however, compressive strength is poor.

To achieve high compressive strengths, temperatures in excess of 300°F are required for several hours. Such temperatures are difficult to achieve down hole unless the well is in a field utilizing thermal recovery techniques.

1. Plastic resin is first applied to the gravel and then the gravel is made into a slurry and pressure packed against the formation. When the plastic has cured, the gravel is bonded together to form a consolidated gravel that requires no screen to retain the pack.

2.Resin coated gravel pack completion has been found to be particularly as a primary sand control method in wells with relatively short intervals(less than 20 ft) in formations with high clay contents(more than 20%), and in multiple completions where the interval spacing preclude the use of screen. And to wells with a formation temperature of less than 120°c.

3. Compare to plastic consolidation jobs, this method is less expensive because less plastic (about 10 to 30%) is used when the gravel is pre-coated. The savings may be partially offset by increased rig time spent waiting on the plastic to cure and in drilling out the gravel in the casing.

4.resin coated gravel can be used for liner less(behind the casing), open hole and between casing and screen gravel packs, since it has the desirable properties of a gravel porous media, yet has no tendency to move or change position. If required, acid treatment can be performed, because resin is unaffected by acid.

5. It can be used in injection and effluent disposable wells. In injection wells, advantage of using the pre-coated gravel is that it remains in place around the screen so that it is available to prevent sand from entering the screen when the wells are back flushed.

6. Another advantage of resin coated sand is that it can be used as proppant for hydrofrac jobs. Resin coated sand has comparatively more crushing strength as compare to uncoated sand and hence can bear more overburden load and will generate less fines.

Chapter-4

Procedure for gravel pack design

LABORATORY INVESTIGATION:

Efforts were made to produce the core samples from the perforated zones. In case of non availability of the same the cores available from the nearest interval were collected.

4.1 Formation sand sampling:

Improper formation sand sampling techniques can lead to gravel packs which fail due to plugging of the gravel pack or the production of sand. Because the formation sand size is so important, the technique used to obtain a formation sample is also important. With knowledge of the different sampling techniques, compensations can be made in the gravel pack sand size selection if necessary.

4.1.1 Produced Samples: In well producing sand, a sample of the formation sand is easily obtained at the surface. Although such a sample can be analyzed and used for gravel pack sand size determination, produced samples will probably indicate a smaller median grain size than the formation sand.

- The well's flow rate produced fluid characteristics and completion tubular design will influence whether a particular size of formation sand grain is produced to surface or settles to the bottom of the well. In many cases, the larger sand grains settle to the bottom, so that a sample that is produced to the surface has a higher proportion of the smaller size of sand grains.
- This means that the surface sample probably is not a good representation of the various sizes of formation sand which are present Also, the transport of a sand grain through the production tubing and surface flow lines may result in small corners being broken from the sand grains, causing the presence of more fines and smaller grains. This is sometimes called grain shattering.
- Grain shattering also reduces the quantity of larger formation sand grains, giving the impression of a smaller median grain size than the formation sand actually has. The use of produced sand samples may result in the use of smaller gravel pack sand than required.

- The permeability of sand can change by an order of magnitude from one inch to the next and the sand grain size distribution can change as rapidly. These factors also change laterally in a reservoir. So samples of sand are required from each well. Even though different wells are completed in the same reservoir, it can not be assumed that the sand will have the same characteristics in each well.

4.1.2 Techniques of obtaining samples are

1. Rubber sleeve cores
2. Conventional cores
3. Sidewall cores
4. Bailed samples
5. Produced samples collected from the wellhead, flow lines, separators, and treater or stock tanks.

1. Rubber sleeve cores:

A rubber sleeve core barrel is the only technique available for recovering good samples of "quick sand" type formations. This type of sand usually falls out of conventional core barrels and the softer, totally unconsolidated sands are not recovered. A rubber sleeve core barrel holds the sand together during the coring operations and the trip to the surface. As a core is cut, a rubber sleeve is pulled from the external housing of the tool and stretches to from a tight skin over the core. These barrels are designed to core as much as 20 feet in one run. When the core is retrieve from the tool at the surface, it is only necessary to install rubber and caps and it is ready to be shipped to the laboratory for analysis.

2. Conventional Core Samples:

The most representative formation sample is obtained from conventional cores. In the case of unconsolidated formations, rubber sleeve conventional cores may be required to assure sample recovery. Although conventional cores are the most desirable formation sample, they are not readily available in most cases due to the cost of coring operations. This may be used for obtaining samples of more consolidated sands. However, if very much core loss is observed, this indicates the possibility of totally unconsolidated sands. If available, small plugs can be taken

Under controlled circumstances at various sections of the core for a complete and accurate median formation grain size and grain size distribution determination.

3. **Sidewall Core Samples:** Side wall cores are the most frequently available samples of formation sands as they are the least expensive. For wells that are to be worked over this type of core is commonly the best sample available. Sidewall core samples are obtained by shooting hollow projectiles from a gun lowered into the well on an electric line to the desired depth. The projectiles remain attached to the gun via steel cables, so that when pulling the gun out of the well, the projectiles are retrieved with a small formation sample inside. Taking sidewall core samples is generally included in the evaluation stages of wells in unconsolidated formations and these are the most widely used sample type for gravel pack sand design. Although more representative than produced or bailed samples, sidewall core samples can also give misleading results. When the projectiles strike the face of the formation, localized crushing of the sand grains occurs, producing broken sand grains and generating more fine particles. The core sample may also contain drilling mud solids that can be mistaken for formation material. Experienced lab analysts can separate the effects of crushing and mud solids to some degree prior to evaluating the sample, thus improving the quality of the results.

4. **Bailed and surface Samples:** These samples are usually not much better than guessing at the formation sand characteristics. Samples collected from the bottom of a well using wire line bailers are also relatively easy to obtain, but these also are probably not representative of the actual formation sand. Bailed samples will generally consist of the larger size sand grains, assuming that more of the smaller grains are produced to surface. Bailed samples may also be misleading in terms of grain size distribution. When closing the well in to obtain a sample, the larger sand grains will settle to the bottom of the well first, and the smaller sand grains will fall on top of the larger ones. This results in a sorting of the formation sand grains into a sample which does not representative the formation sand. The use of bailed samples may result in the design of larger than required gravel pack sand which can result in sand production (small formation particles passing through the gravel pack) or plugging of the gravel pack (small

formation particles filling the spaces between the gravel pack sand grains).

- For laboratory investigations the core samples were selected for analysis based on visual inspection in the following priority:
- Quick/unconsolidated sand
- Partially unconsolidated
- Consolidated sand

4.2 Soxhelation process for removal of organic matter:

Core sample contains oil, water, wax, paraffin etc. In order to remove the wax and paraffin Soxhelation is carried out. Core sample with identification mark is rapped in filter paper and put into a soxilate. In the round flask, organic solvents are put. The flask is then heated. The fumes of the solvent go up and come in contact with the condenser. The vapour gets converted into liquid and the solvents fall on the cores. All the organic matter comes out of the core. This converts the liquid into different colors. There after the sand was washed thoroughly with the mixture of benzene, toluene and xylene to remove oil. After the soxilate gets filled it is recycled to the bottom flask. This cycle is repeated until requirement is achieved.

4.3 Ultrasonic vibrator for separation of grains:

Further more, the cores packed is soaked in distilled water to check the binding. If binding is less then its good but in case a tight bond is established then the cores are placed in ultrasonic vibrator for separation of grains. The wet powder is kept in electric oven and the marked samples are ready.

Each core was ground using rubber paddle so that each grain is separated. The sample was then examined to ascertain that all sand grains are separated and no grain clusters are present.

The studies conducted on the core samples are particle size distribution analysis, static acidisation studies and mineralogical studies.

4.4 Particle size distribution analysis:

The sand samples were analyzed as per API standard using 3-D sieving machine. A set of 18 sieves ranging from 10 US mesh to 325 US mesh were used for sieving the samples.100gms of sample was sieved and portion of particles retained on each sieve was collected and weighed. The cumulative weight retained and percent cumulative weight retained on each sieve was computed. Particle size distribution curves were plotted between cumulative weight percentage and corresponding size of sand particles on semi log paper.

4.4.1 Sieve analysis:

Sieve analysis is the typical laboratory routine performed on a formation sand sample for the Selection of the proper size gravel pack sand. Sieve analysis consist of placing a formation Sample at the top of a series of screens which have progressively smaller mesh sizes. The sand Grains in the original well sample will fall through the screens until encountering a screen through which that grains size cannot pass because the openings in the screen are too small. By weighing. The screens before and after sieving, the weight of formation sample retained by each size screen Can be determined. The cumulative weight percent of each sample retained can be plotted as a Comparison of screen mesh size on semi-log coordinates to obtain a sand size distribution plot.

Figure 4.1 Different types of sieves

Table 4.1 Standard sieve openings

U.S. Series Mesh Size	Sieve Opening (in.)	Sieve Opening (mm)	U.S. Series Mesh Size	Sieve Opening (in.)	Sieve Opening (mm)
2.5	0.315	8.000	35	0.0197	0.500
3	0.265	6.730	40	0.0165	0.420
3.5	0.223	5.660	45	0.0138	0.351
4	0.187	4.760	50	0.0117	0.297
5	0.157	4.000	60	0.0098	0.250
6	0.132	3.360	70	0.0083	0.210
7	0.111	2.830	80	0.0070	0.177
8	0.0937	2.380	100	0.0059	0.149
10	0.0787	2.000	120	0.0049	0.124
12	0.0661	1.680	140	0.0041	0.104
14	0.0555	1.410	170	0.0035	0.088
16	0.0469	1.190	200	0.0029	0.074
18	0.0394	1.000	230	0.0024	0.062
20	0.0331	0.840	270	0.0021	0.053
25	0.0280	0.710	325	0.0017	0.044
30	0.0232	0.589	400	0.0015	0.037

Reading the graph at the 50 percent cumulative weight gives the median formation grain size diameter. This grain size, often referred to as D_{50}, is the basis of gravel pack sand size selection procedures.

Sieve analysis provides grain size distribution on percentile basis. Sieve analysis is reported in inches or millimeters. However in some areas Tyler mesh designations are used. Ten percentile sand size is defined as the point on the distribution scale where 10%by weight of the sand is of larger size and 90% of smaller size.

The samples used for sieve analysis must be representative of the formation if the analysis data is Expected to provide accurate gravel packing information. If possible, a sample should be taken Every 2 to 3 feet within the formation or at every lithology change.

Figure 4.2 Sieve analysis

Sieving can be performed either wet or dry. In dry sieving (the most common technique), the sample is prepared by removing the fines (i.e., clays) and drying the sample in an oven. If necessary, the sample is ground with a mortar and pestle to insure individual grains are sieved rather than conglomerate grains. The sample is then placed in the sieving apparatus, which uses mechanical vibration to assist the particles in moving through and on to the various mesh screens. Wet sieving is used when the formation sample has extremely small grain sizes. In wet sieving, water is poured over the samples while sieving to ensure the particles do not cling together

4.5 SELECTION CRITERIA FOR GRAVAL PACK JOBS

4.5.1 Statistical parameters:

Statistical parameters like mean, median, standard deviation, coefficient of variation, skewness and kurtosis have been computed using a computer package. The package has been developed by using moment formulae for computation of statistical parameters. The information generated from these statistical parameters would be helpful in understanding the mechanisms operative during transportation and deposition of sedimentary environment. In addition they are helpful in determination of single-phase permeability and there by prediction of well productivity for better reservoir characterization.

4.5.2Uniformity coefficient:

Uniformity coefficient is the ratio of particle size at 40-percentile point and 90-percentile point as computed from sieve analysis curves on semi log paper .the value of uniformity coefficient varying between 1 to 3 indicates that the sand is uniform in character. A value between 3 to 5 indicates that the sand is non-uniform in character. And uniformity coefficient greater than 5 is indicative of highly non-uniform nature of the sand.

4.5.3 Sorting range (D 10/D 95)

This ratio has the ability to see distinct variation between the size and sorting ranges of formation sands. This ratio increases sharply with finer size of sand at the D95 position. For this reason it is a good indicator of potential problems with ultra wide range of particle size. This ratio having value greater than 10 are considered high.

4.5.4 Fines percentage (sub 325 mesh):

The difference of percent cumulative mass retained on the pan and the last sieve i.e. 325 US mesh sieve is taken as sub 325 mesh. It is a measure of fines and clays, which are the main culprits in reducing the gravel pack permeability.

4.5.5 Selection of gravel size:

The gravel size has been selected based on diameter of formation sand grains at 50-percentile point. This value is then multiplied by a factor of 4 to obtain the smallest size of gravels and by a factor of 8 to obtain the largest size of gravels. The commercially available gravel size nearer to the computed gravel size is then selected. In cases, where the sand is non-uniform or highly non-uniform, the next smaller commercially available gravels are selected for gravel packing.

4.5.6 Gravel pack sand:

Gravel pack well productivity is sensitive to the permeability of the gravel pack sand. To ensure maximum well productivity only high quality gravel pack sand should be used. The API RP58 establishes rigid specifications for acceptable properties of sands used for gravel packing. These Specifications focus on ensuring the maximum permeability and longevity of the sand under typical Well production and treatment conditions. The specifications define minimum acceptable Standards for the size and shape of the grains, the amount of fines and impurities, acid solubility, and crush resistance. A summary of the API gravel test procedures and specifications are given in below table. Only a few naturally occurring sands are capable of meeting the API specifications without excessive processing. These sands are characterized by their high quartz content and consistency in grain size. A majority of the gravel pack sand used in the world is mined from the Ottawa formation in the Northern United States.

4.5.7 API Specifications for Gravel-Pack Sand:

1. Sphericity and Roundness:

Gravel pack sand should have an average sphericity of 0.6 or greater and an average roundness of 0.6 or greater as determined by visual analysis using the chart developed by Krumbein.

Table 4.2. Permeability of gravel pack sands

U.S. Mesh Range	Permeability (Darcy's)[4]	Permeability (Darcy's)[5]	Permeability (Darcy's)[6]
6/10	2703	-	-
8/12	1969	-	-
10/20	652	500	-
12/20	-	-	668
16/30	-	250	415
20/40	171	119	225
40/60	69	40	69
50/70	-	-	45

2. **Acid Solubility:**

A 5 gram sand sample is added to 100 ml of 12%-3% HCl-HF acid and allowed to sit for one hour at 72°F to allow dissolution of contaminates (carbonates, feldspars, iron oxides, clays, silica fines etc.). The sand is then removed and dried. The before and after weights are compared to determine acid solubility. The acid soluble material in gravel pack sand should not exceed 1.0% by weight

3. Silt and Clay Content:

A 20 ml sample of dry sand is mixed with 100 ml of demineralized water and allowed to sit for 30 minutes. The sample is then shaken vigorously for 30 seconds and allowed to sit for 5 minutes. A 25 ml sample of the water-silt suspension is removed and the turbidity is measured. The resulting turbidity of tested gravel pack sand should be 250 NTU's or less.

4. Crush Resistance:

A sand sample is sieved to remove all fines and weighed. The sample is then exposed to 2,000 psi confining stress for two minutes. The sample is resieved to determine the weight of fines generated. Gravel pack sand subjected to this test should not produce more than 2% by weight fines. For large sand sizes, 12/20 U.S. Mesh and 8/12 U.S. Mesh, the amount of fines produced should not exceed 4% and 8% respectively.

4.6 NEW CRITERA FOR SELECTION OF GRAVEL&SCREEN:

Current gravel pack completion design generally does a good job at preventing reservoir sand invasion with formation sand that has a normal distribution pattern. For the reservoir sand distributions that are skewed towards finer sand and\or where large amounts of fines predominates, skin from traditional gravel pack and screen completion can be high and failure can occur.

The principle fines suspected are sub 325 mesh grains (clay-sized fines) from the formation. The scale 325 mesh is selected because the average pore size of the 40/60-mesh gravel is about 45 microns. This size and smaller particles in this size range can plug the formation/gravel pack interface, causing significant damage skins.

Based on the field experience and laboratory investigation D.L.Tiffin et al. has proposed the following solution to the problem,

1. Identify the formation by particle sorting criteria, based on size range and quantity.
2. Use the completion mechanism that will either pass the fines or confine them so far away from the wellbore that the conductivity damage they cause has a minimum effect on production.
3. Additionally when the fines are absent or the formation is well sorted, conventional design based only on 50%number may be too restrictive, creating condition that leads to high pressure drop and rate limiting turbulence. The proposed criteria is a conditional method of gravel and screen selection that is still based upon the 50 percentile point but takes into account the sorting and sub 325 mesh fines content of the formation to help, determine the relationship of the "fit" of the gravel to the formation sand.

For a typical formation, fines greater than 5% or so would provide a sufficient quantity to bridge and seal against the medium and coarse particles at the interface of the gravel pack. Levels of D40/D90 of 5 above are warning signs of fines size that could plug the screen.

The D10/D95 criterion was selected based on the ability to see distinct variation between the size and sorting ranges of formation sands. For the D10/D95 ratio, levels above 10 are considered high.

Long known methods of improving gravel permeability are:

1. Using rounder gravels(present a more constant pore size and higher permeability)
2. Using gravels that contain less initial out of range particles
3. Using gravels that produce less fines during handling and placement (stronger).

4.6.1. USING GRAVELS WITH NARROWER SIZE RANGE:

The synthetic gravel offer much rounder profiles and greater strength for only a small increase in cost over regular gravels. Selecting narrow size graves may offer tremendous advantages in either the case of abundant fines or low fines content. Cost increase is minimal in comparison to benefit, especially in synthetic gravels.

4.6.2 Suggested criteria for gravel and screen selection for the wells with high fine content and wide distribution of grain size:

New criteria for gravel and screen selection for sand control, based on field experience and laboratory investigation, the following criteria is suggested.

1. D10/D95<10, D40/D90<3, sub325 mesh<2%, the lowest sorting values with low fines content may be bare screen completion candidates.
2. D10/D95<10,D40/D90<5,sub 325 mesh<5%,low to medium sorting ranges or with fines just out of range may be served by bare screen completion with new technology woven mesh screen/strata pack.
3. D10/D95<20, D40/D90<5, sub 325 mesh<5%medium ratio ranges may be served by larger gravels (7*or 8*D50), placed in high rate water pack.
4. D10/D95<20, D40/D90<5, sub 325 mesh<10%, medium ratio ranges with too many fines may use a combination of larger gravels and a fines-passing screen.
5. D10/D95>20, D40/D90>5, sub 325mesh>10%, the highest ratio, particularly those coupled with large amounts of fines. Signal a critical need for enlarging the wellbore through fracturing, horizontal or multilateral well technology, under reaming or large volume prepackages to minimize serve permeability damage at the gravel sand interface due to flow.

Based on the data of uniformity coefficient, sorting range &fines content computed from particle size distribution analysis, the selection of best fit gravel size &screen and suitable sand control measures have been determined for all the conventional core samples of different wells of sample.

Chapter-5

Case study and calculations

5.1 Introduction:

The Tatipaka is the main gas producing fields of Rajahmundry asset. Through most of the wells are producing sand free production but four of the wells are facing the problem of sand production. It has been observed that there was gradual reduction in the productivity followed by closure of the wells. These sands are hydrocarbon bearing and the average porosity of the reservoir sands is 14.22% and permeability ranges from 2 to 25 md. The current gas production is 6.1 LCMD.

5.1.1 Analysis of the problem:

Sand cut is most likely to occur in the fields of Tatipaka (onshore). The main reason for sand cut in these fields is the presence of clay coating in the entire reservoir facies in the field, poorly consolidated formation, low shot density and high water cut. The clay coated reservoir rocks generally lack other cementing materials and make it most susceptible to damage. Also due to low salinity of formation water, these clays tend to swell and grain to grain bond is weakened/ destroyed and formation sand may be produced.

The other factor influencing sand cut mostly in the wells of Tatipaka field is attributed to high water cut. The onset of water production seriously affects the cementing material and increase in water to oil ratio causes excessive stresses on weakly consolidated formations which in turn may exceed the ability of the cementing material to bound sand together.

Table 5.2 GUIDELINES SELECTION OF SAND CONTROL TECHNIQUE

Condition	Rate control or screen	Gravel pack	Gravel pack	Sand consolidation	Sand consolidation
		Open hole	Internal casing	Resin	Sand content resin slurry
Fine to silty sand	Not recommended	Average	Good	Average	Average
Rough sand	Good	Very good	Good	Very good	Good
Thin layer	Good	Very good	Good	Good	Good
Thick layer	Good	Good	Good	Not recommended	
Multi layer	Average	Average	Good	Not recommended	Good
Close water-oil (or) Gas-oil	Not recommended	Not recommended	Good	Good	Good
Permeability variation	Average	Good	Good	Average	Good
Clay content	Not recommended	Poor	average	Poor	Average to poor
Water sensitive sand	Poor	Good	Good	Average	Average to poor
High desired flow rate	Poor	Very good	average	Average	Good
Small dia hole	Not recommended	Not recommended	Not recommended	Good	Good
High viscosity oil	Not recommended	Very Good	Good	Not recommended	average
Deviated hole	Good	Good	Good	Good	Good
No rig availability	Not applicable	Not applicable	Not applicable	Good	Not applicable
Old well	Not recommended	Good	Good	Not recommended	Good

Stability of the technique with time	Poor	Good to very good	Good	Average	Avg

5.3 Laboratory calculations

Soxhelation process: In this process sand was washed thoroughly with the mixture of benzene, toluene and xylene to remove any traces of hydrocarbons.

Sieve analysis:

Table-5.2 **Sieve analysis:**

s.no	US mesh	Mesh size(mm)	Weight retained(gms)W	Cum.wt retained(gms)	%Cum.wt retained
1	10	2	0.7381	0.7381	0.7485
2	14	1.4	1.8446	2.5827	2.6192
3	20	0.85	1.6036	4.1863	4.2455
4	30	0.6	3.8397	8.0260	8.1395
5	40	0.425	6.949	14.9750	15.1868
6	50	0.3	12.1454	27.1204	27.5040
7	60	0.25	5.1173	32.2377	32.6937
8	70	0.212	5.5407	37.7784	38.3128
9	80	0.18	3.97	41.7484	42.3389
10	100	0.15	15.5067	57.2551	58.0650
11	120	0.125	15.1621	72.4172	73.4416
12	140	0.106	6.4056	78.8228	79.9378
13	170	0.09	13.5022	92.3250	93.6310
14	200	0.075	2.3079	94.6329	95.9715
15	230	0.063	2.596	97.2289	98.6042
16	270	0.053	1.0469	98.2758	99.6659
17	325	0.044	0.3124	98.5882	99.9828
18	PAN	0.031	0.017	98.6052	100.00

The sand samples were analyzed using 3-D sieving machine. A set of 16 sieves ranging from 10 US mesh to 325 US mesh were used for sieving the samples. 100 gms of sample was sieved and particles retained on each sieve was collected and weighed. The cumulative weight retained and percent cumulative retained on each sieve was computed.

From the graph

Gravel selection:

1. At 50 percentile point = 0.1597 mm.

2. Smallest gravel size = 4* (50 percentile point)

= 4*(0.1597)

= 0.6388 mm

3. Largest gravel size = 8*(50 percentile point)

= 8*(0.1597)

= 1.2776 mm

Selected gravel size = 14/30 US mesh

Commercially available gravel size =16/30 US mesh

Screen selection:

4. Uniformity coefficient = D40/D 90

= 0.2/ 0.099

Uniformity coefficient = 2.02 (sand is uniform)

Uniformity coefficient varying between:

- 1 to 3 indicates "sand is uniform"
- 3 to 5 indicates "sand is non-uniform in character"
- >5 "highly non-uniform nature of sand".

5. Sorting range = D10/D95

= 6.49

6. Fines percentage:

The difference of percent cumulative mass retained on the pan and the last sieve. It is a measure of fines and clays.

Mass retained on the pan = 100gms

Mass retained on the last sieve = 99.9828 gms.

Fines percentage = 100- 99.9828

= 0.0172 gms.

- **From new criteria for gravel and screen selection for sand control:**

D40/D90 <3, D10/D95< 10, sub 325 mesh< 2%,

The lowest sorting values with low fines content, "bare screen completion"

Conclusion and Recommendations

Gravel packing is now, the most successful method of sand control and can be used in greater variety of wells than any other techniques. It is used in most wells, including wells with slit for shale zones.

The gravel and screen selection of above sample is

- D40/D90 between 2 to 2.46 and sub 325 US mesh is negligible to 0.06%
- From new criteria for gravel and screen selection for sand control, gravels of 16/30 US mesh and suggestive of bare screen completion

The successful gravel packing is depend on following factors:

1. Selecting gravel of proper size in relation to formation sand size.
2. Optimum screen slot width to retain the gravel
3. Placing the gravel without contamination. An effective placement technique-perhaps most important.

Nomenclature

B.H.N = Brinell hardness

K = permeability

Φ = porosity

K = permeability

U.C = uniformity coefficient

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