

A Practical and Theoretical Evaluation Of Shale Shaker Screen

Successful Drilling of Oil and Gas Wells by Optimal Drilling-Fluid/Solids Control—A Practical and Theoretical Evaluation

Summary

Since the development of the drilling industry, the process for removing drill solids from the drilling fluid has culminated in the use of shaker screens as the primary or sole solution. It is, therefore, necessary to optimize both filtration efficiency and the screen life to hinder drilled solids from entering the drilling fluid. Optimum solids control can be obtained by using knowledge of how damage to the filtration cloth arises, of how to reduce it, and of how the particles in the circulation system influence the general picture of the drilling process. When this knowledge is accepted, established, and implemented in the drilling industry, it is possible to maintain efficient drilling.

This paper describes, in detail, the theory and field examples on how wear arises on the shaker-screen cloth. As will be shown, this knowledge has been used to increase the solids-control efficiency and to reduce the screen wear by more than 90% in several field cases where 17½-in. sections have been drilled with oil-based mud. This has been achieved by use of a different screen configuration, running with top screens with finer cut points than normal. This leads to removal of 90 to 95% of the solids from the fluid using the top deck, thereby minimizing the wear on the finer bottom-deck screens. The documentation is based on practical off-shore results from these drilling operations, including data from the drilling log, laboratory analyses of the drilling fluid, and of the particle-size distribution (PSD) of the drilling fluid. The particular focus of this article is the application of double-deck shakers.

Introduction

Correct use of solids-control equipment is essential to maintain drilling fluid within its desired properties and to avoid generation of unnecessary waste streams during drilling (Bouse and Carrasquero 1992). Since the early 1930s, the shale shaker has been the dominant device for primary solids removal (AADE 1999). Additional equipment such as desilters, desanders, and centrifuges were often used in the past to maintain proper solids control. Although it is dependent on the choice of correct shaker screens, most shakers at present perform sufficiently to be able to act as the sole solids-control device without the use of desanders and desilters.

The optimum solids-control design for a particular drilling fluid may not be generally valid for all fluid types (Lal and Hoberock 1988). For example, a combination of shaker and screens applicable for treating water-based drilling fluids may not be suitable for treating oil-based drilling fluids. Furthermore, the suitability of the screen and shaker combination may change during drilling because the drill-cuttings morphology changes.

During the last few decades, major shaker-design improvements have been made. The circular-motion shakers used up till the 1980s have been replaced by elliptical-motion and linear-motion shakers. Furthermore, double-deck, or even triple-deck, shakers have been implemented in the industry. Alternatives to shakers have been tested to improve occupational hygiene aspects

although this type of equipment has not yet reached the market (Saasen et al. 2003). Sinusoidal-formed screens have been implemented on some shakers to increase the flow capacity (Neidhardt 1995).

Shaker operation has also been automated (Scott 2006). Scott (2006) claims that use of this automated system leads to an increase in shaker-screen life. However, Scott (2006) does not reveal the screen selection for this case. Therefore, it is difficult to use this information in the present analysis.

Removal of solids with a particle diameter larger than 120 to 150 μm can be achieved without problems on most shakers today by the application of the correct screen size (Wollherr and Krobok 1998). There are many types of screens on the market. The following analysis is general and does not compare any products or designs.

Screen Opening and Mesh Sizes

Typically, a shaker screen may consist of a single metal cloth or be constructed as a series of superpositioned cloths. In some cases, these cloths are tensioned in all directions while being melted onto a frame; while in other cases, the cloths are melted onto frames without being tensioned. Some screens are tensioned onto the shakers directly without being attached to frames.

The screen cloths are woven with warp wires running along the cloth and weft wires running across the cloth as it is woven. The warp and weft wires can be equal or different, giving a large variation in possible screen-cloth designs.

Fig. 1 schematically shows the definitions of the terms aperture width, w , which is the length of the open area; the pitch, p , which is the length from the wire center to the next wire center; and the wire diameter, d . An example on varying the pitch differently on the warp and weft wires to produce square and oblong apertures is shown in **Fig. 2**.

Traditionally, the petroleum industry has used the mesh number to designate the screens and screen openings. The mesh number is the number of apertures per inch. Therefore, this number does not reflect the aperture width. This is clearly indicated by the example shown in **Fig. 3**, where on the left side it is illustrated how the aperture width changes with varying wire thickness. Similarly, it is shown on the right side of **Fig. 3** how the flow area is affected if the aperture width and mesh number are kept constant and the wire diameter is varied.

The example shown in **Fig. 3** is for a relatively coarse screen, applicable mostly for top screens on double-deck shakers. The similar phenomenon on 200-mesh cloths is shown in **Fig. 4**. It is shown that the aperture width changes from the theoretical maximum of 127 μm to smaller values when realistic wire diameters are applied. The common belief is that the aperture of a 200-mesh cloth is approximately 75 μm . A cut point of 75 μm for a 200-mesh screen, however, is seldom found.

For multilayer screens or screens with oblong apertures, application of the mesh concept is even more difficult. There is no simple connection between cloth apertures and cut points. There are several reasons for the lack of relationship between cut points and mesh size. The different cloths are superpositioned in a manual operation, leading frequently to different appearances of wires if looked upon from above. There is no way other than true measurements to manage the effect of the tortuous flow paths through the complete screen. Discussions about the effect of screen-cloth

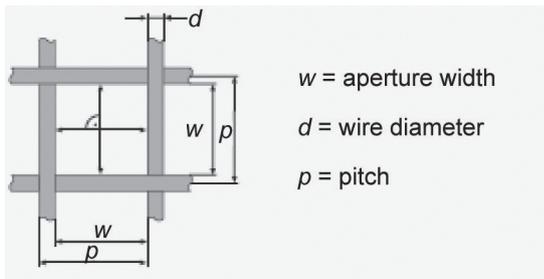


Fig. 1—Screen-cloth definitions.

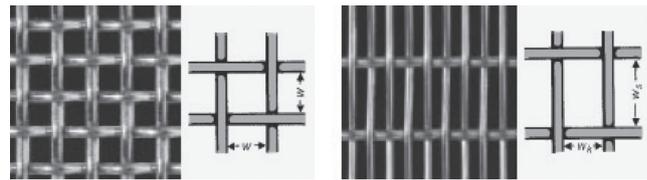


Fig. 2—Example of screen-cloth square aperture (left) and oblong aperture (right).

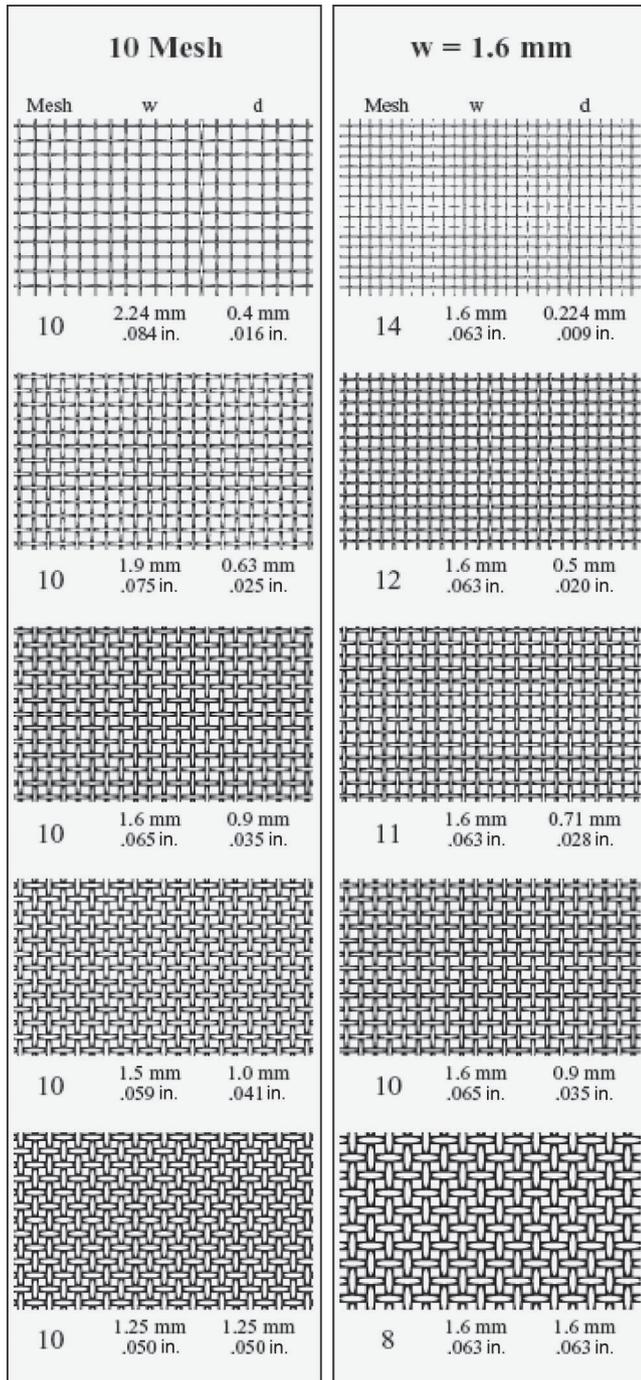


Fig. 3—Example of different aperture widths on a 10-mesh screen cloth as function of the wire diameter (left) and variations in the mesh number by varying the wire thickness for a constant aperture opening (right). *Figure reprinted with permission from Haver and Boecker, D-59302 Oelde, Germany.

configuration on cut point are considered outside the scope of this paper and will not be addressed further. This topic is thoroughly covered elsewhere (Datta et al. 2007; Robinson and Morgan 2005).

Flow conductance is strongly dependent on the aperture opening. A first-order approximation is that the conductance is directly proportional to the area. The solid line in Fig. 5 shows how the relative conductance changes with wire diameter for a 200-mesh screen cloth. This relative conductance is the flow area of the cloth, given by the wire diameter divided by the flow area with an aperture of $75 \mu\text{m}$. Conductance is, of course, not directly related to the flow area. However, its dependency with geometrical factors is dominated by the dependency on drilling-fluid viscosity. Therefore, a more accurate treatment here would be of less use. The flow through screens and screen cloths is controlled by the drilling-fluid viscosity and, even more, by the extensional viscosity of the drilling fluid. The latter is the reason that conductance can be significantly different for water- and oil-based drilling fluids.

A first-order approximation of the wear strength of the cloth is also shown in Fig. 5. The very crude estimate is based on the strength being proportional to the wire cross-sectional area. Shown in the figure is the cross-sectional area of the wire divided by the wire diameter, giving an aperture of $75 \mu\text{m}$ for a 200-mesh screen cloth.

Screen suppliers have aimed for many years to produce screens with conductivity that is as good as possible. From the data shown in Fig. 5, it is shown that doubling the conductivity from that of the $75\text{-}\mu\text{m}$ aperture width leads to using a wire diameter with a strength of only approximately 15% of the strength of the wire for the $75\text{-}\mu\text{m}$ aperture width. Currently, most shale shakers are good enough to handle large flow rates even though the conductance of the screens is not optimized. Therefore, selection of a screen cloth with a wire that is too thin should no longer be necessary.

Screen Wear

The normal way to look at screen wear is related to the role of friction between the drill solids and the screen cloth in the separation process. Traditionally, it has been anticipated that the wear develops from the topside of the threads in the cloth; and, in some

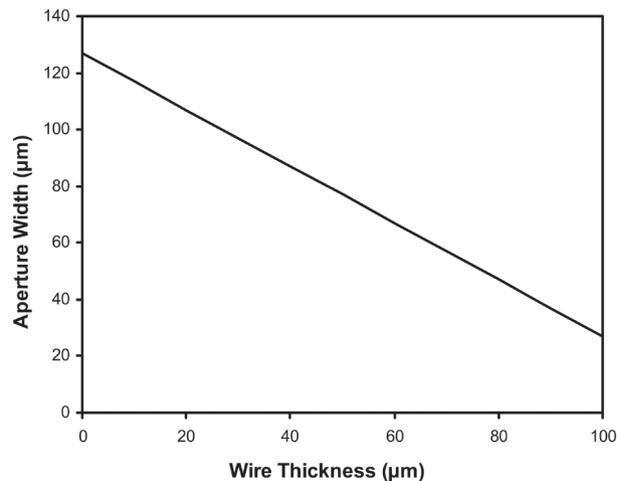


Fig. 4—Aperture width for 200-mesh cloth as function of the wire diameter.

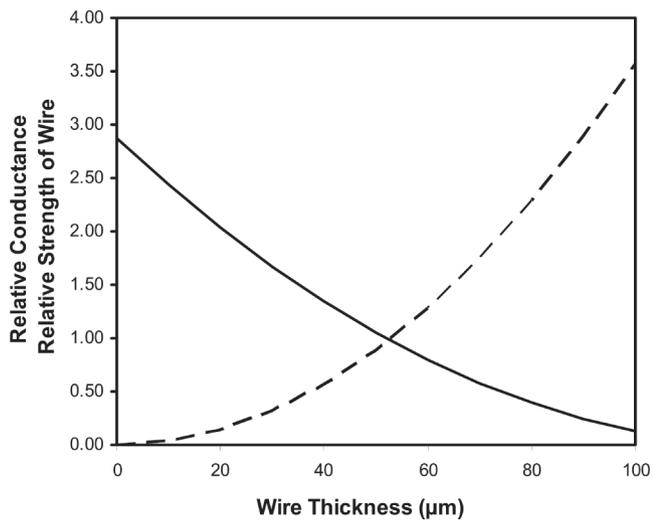


Fig. 5—Solid line is approximate relative conductance of 200-mesh screen cloth as function of wire diameter. Dashed line is an approximation to relative strength of wire. Unity represents 53-µm wire with aperture width equal to 75 µm.

cases, this is true. However, most often the main wear is a result of the friction between the wires of different cloths of multilayer screens. The wear is generated by the weight of the solid material in the drilling fluid or by the drilling fluid itself pressing the upper cloth down onto the coarser backing cloths. Friction between the different cloths is then generated because of the relative motion between the cloths and because of the strain of the upper cloth giving a relative motion between the cloths. Most of the wear is, thus, taking place on the finest threads in the upper cloth or middle cloth where the wear is acting from underneath.

Single-layer cloths are often used as scalping screens, meaning screens for the upper deck on multideck shakers. In this case, the wear is truly a function of the friction between the drill solids and the threads in the cloth. An example of wear experienced from a field operation is shown in Fig. 6.

The wear on the single-layer screens results from the impacts of cuttings particles hitting the screen and from the continuous bend-

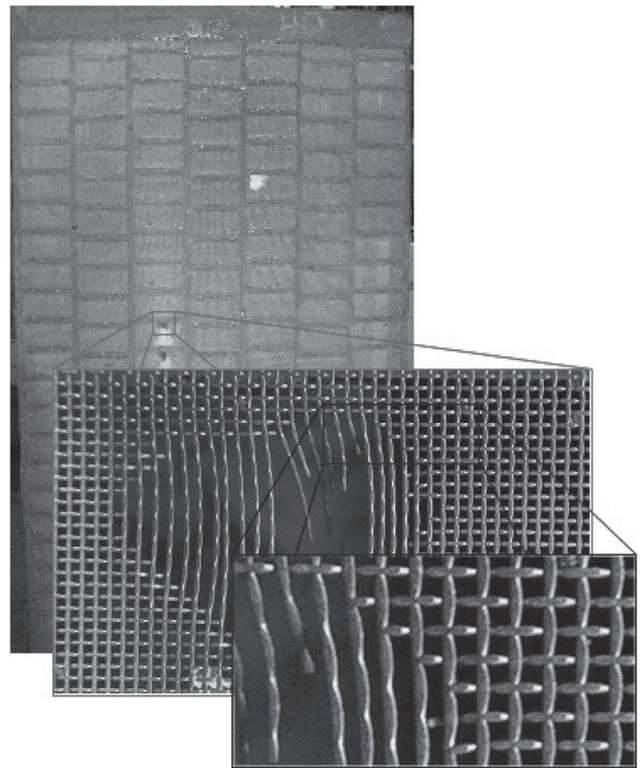


Fig. 6—Example of wear on a single-layer scalping screen.

ing action of the screen-cloth wires because of the shaker vibration. Furthermore, there is wear arising from the scratching of the cloth by the movement of the particles along the screen, as shown in Fig. 6. In the large magnification in the bottom right of this figure, it is seen that the threads are flat on the top where the solids have travelled past.

Double- and triple-layer screens are often used as primary screens (i.e., the screens used for the final filtration of the drilling fluid at the bottom deck of the shakers). Part of the wear for single-layer screens is a function of the friction between the cuttings particles and the cloth. However, the major contribution for the wear may no longer be from this friction. Dissimilar thickness of the threads in the filtration cloths and the coarser backing cloths cause different stiffness of the cloths as indicated in Figs. 7 and 8. Therefore, the load of the cuttings onto the fine upper cloth presses the upper cloth down onto the lower and coarser cloths in the screen. These cloths do not deflect equally with the upper cloth,

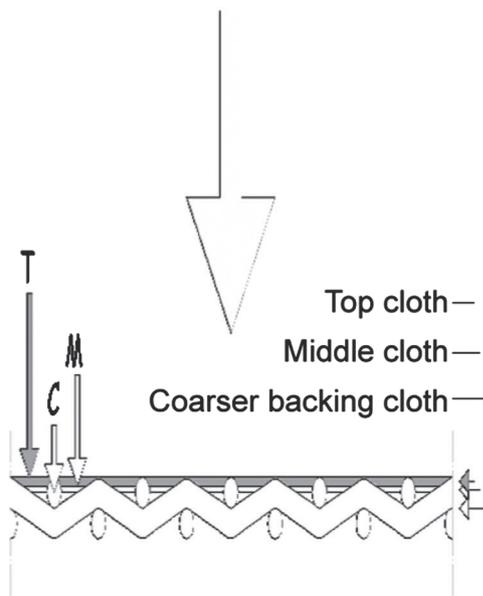


Fig. 7—Cut view of a triple-layer shaker screen illustrates the different wear on the top and middle cloths. The large arrow symbolizes the direction of gravity forces. The three arrows to the left illustrate the difference in strain during a load of the top (T), middle (M), and backing (C) cloths in this screen.

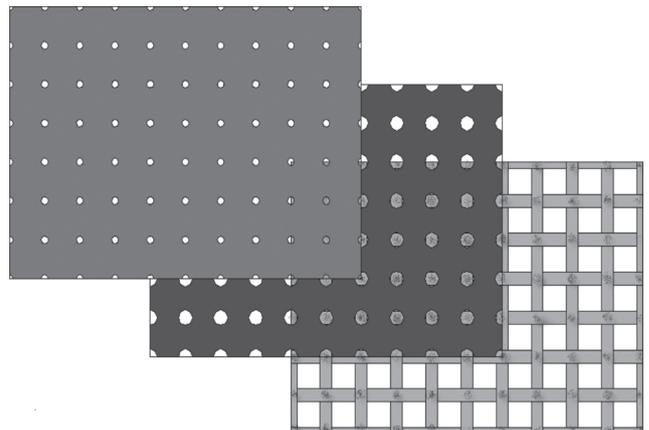


Fig. 8—A section of a triple-layer shaker screen: the fine top, the middle, and the coarser backing cloth, where the wear from each point of intersection to the coarser backing cloth punctures the finer cloth above.

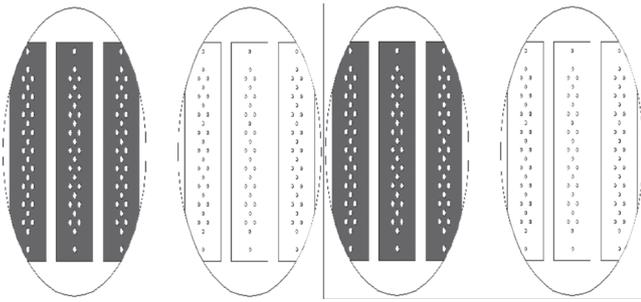


Fig. 9—Illustration of wear details from the middle cloth (left) and from the top cloth (right). The wear appears in the center of the cells.

leading to friction forces between the different layers. Because of this, the wear arises first from underneath onto the middle and upper layers.

On double-layer screens, the wear will first be observed on the top cloth. On triple-layer screens, the wear may appear in the middle cloth first. The junction points of the warp and weft wires on the coarse backing cloth often appear like spikes where the wear will first arise because of the direct contact with the finer middle cloth. These spikes are illustrated as the top points of the bottom wire in Fig. 7. As illustrated in Fig. 9, the wear appears first in the middle of the different cells. Furthermore, Fig. 9 also illustrates that the wear may be more severe in the middle cloth than in the top cloth.

An example of a cell where the wear has removed most of the top and middle cloth is shown in Fig. 10. The backing cloth is the cloth that is undamaged throughout the complete cell. While investigating the lower right part of Fig. 10, it is possible to see the top cloth as the light-gray cloth on the left side and the middle cloth as the somewhat darker-gray cloth in the middle and on the right side. This part of Fig. 10 is magnified in Fig. 11, and the top and middle cloth are, therefore, more distinct in this picture. It can be seen that the spikes from the bottom-cloth wire junctions have penetrated the middle cloth. The top cloth is sufficiently transparent to indicate that the middle cloth is penetrated also in the area where the top cloth to some degree is intact.

Especially when drilling through sand sections, there is a possibility that sand may be trapped between the top cloth and the underlying cloths during a shorter or longer period of time. These sand particles will contribute to wear in two ways. First, the sand

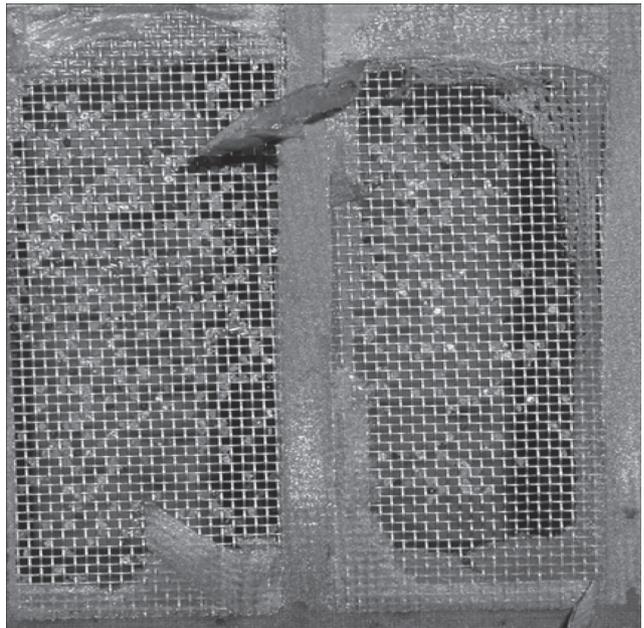


Fig. 10—A field example of nearly complete wear on the top and middle cloths of a three-layer screen.

particles may hammer onto the two cloths and, thereby, create wear. Second, the sand (with sharp edges) may be sandwiched between the two upper cloths, increasing the friction between the cloths and, thereby, increasing the wear from inside of the screen.

Field experience using triple-layer-shaker screens, prefabricated onto frames and divided up into smaller cells, indicates that the wear very often starts in the center of the cells. As discussed in previous paragraphs, the wear on overloaded screens evolves from below the fine-filtration cloth. For this reason, it can be difficult to determine how far the wear has come until suddenly all the filtration-cloth wires tear off.

If a fine-mesh screen with damages from wear, like holes, is allowed to be used for a long period, it will, in the long term, act like a significantly coarser screen. Therefore, if there is a possibility that the fine-mesh screen may be used a “long” time without being changed, it is generally better to use a slightly coarser, but stronger, screen.

To reduce the high wear and tear on the primary screen, it is necessary to reduce the weight load from the drilled solids before it reaches the fine-filtration cloth. The scalping deck should be used to reduce the weight load by removing most (90 to 95%) of the formation solids on this deck. To achieve this, the scalping deck should be used generally with screens much finer than 10-mesh. Preferably, screens in the range of 60- to 100-mesh should be used, dependent on the viscosity of the drilling fluid. When performed correctly, it is possible to reduce the wear on the primary screens by more than 90%.

Field Experience

On the basis of experience from the Norwegian sector of the North Sea, running a coarse scalping screen over a very fine primary screen has been practiced for a long time. The majority of the 17½-in. sections have been drilled with a screen configuration consisting of a 10-mesh scalping screen over lower-deck primary screens ranging from 200-mesh to 300-mesh. Rectangular and square cloths have sometimes been used. In such cases, the shaker-screen consumption, or wear, has been extremely high. Only 1.2 m³ of drilled formation solids has been removed per screen used.

The overall shaker-screen consumption, based on information from the drilling-fluid and shaker-screen suppliers and supported by internal data, shows that an average of 2.7 m³ of drilled formation solids has been removed per used screen. This is with a “trash limit” of 20% “damaged” cloth. Here damaged means either damaged or repaired with plugs or sealing compound. Optimized

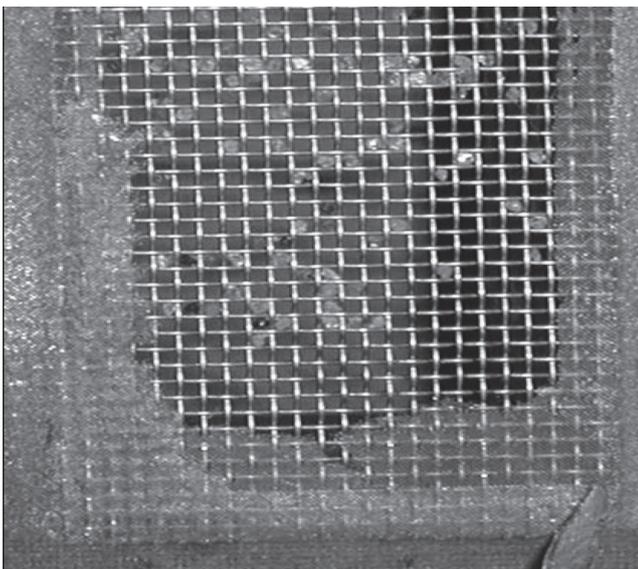


Fig. 11—A field example of wear on the top and middle cloths of a three-layer screen—magnification of lower-right part of Fig. 10.

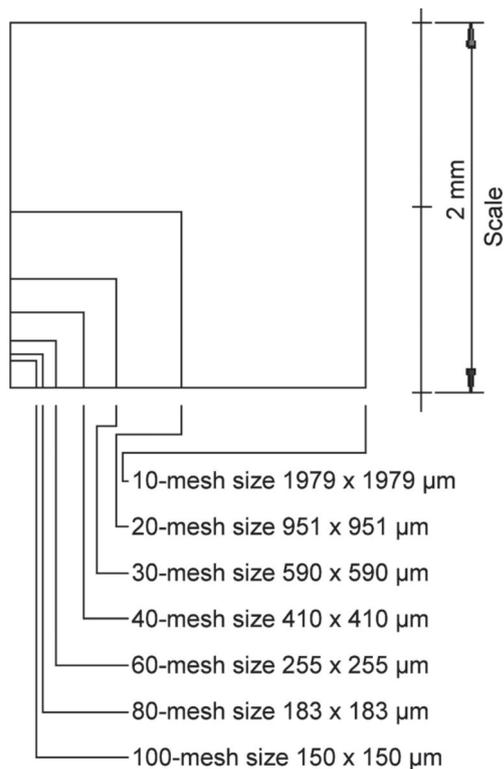


Fig. 12—Shaker scalping screen: Visual presentation for the proportion between mesh sizes and open areas, measured in μm , for square cloth.

solids control implies that more than 50% of the screening area can be blanked off and the screen can still have sufficient filtration ability as long as total-flow capacity is sufficient to handle the well flow. Field experience demonstrates that removal of 800 to 1000 m^3 of drilled formation solids is readily achievable before a screen needs to be disposed of, even if a more restrictive trash limit is used.

Good work practice, which also removes exposure to drilling-fluid dampness and mist, includes changing all the screens on a shaker with a different batch of screens at regular inspection intervals. These screens are then investigated, the damages are repaired, and these screens are changed back into the shakers at next inspection. In this way, work time at the shaker is reduced, interference with the drilling operation is minimized, and shaker-screen maintenance is optimized.

As described in the Screen Opening and Mesh Sizes section, the mesh definition is the number of wires per 1 in. of a cloth. Therefore the cut point will be influenced by the wire diameter and does not follow the same scale as the different mesh sizes do. As shown in **Fig. 12**, the open areas for each mesh size do not

Mesh	Cut Point							
10	1979	1 :						
20	951	2.1	1 :					
30	590	3.4	1.6	1 :				
40	410	4.8	2.3	1.4	1 :			
60	255	7.8	3.7	2.3	1.6	1 :		
80	183	10.8	5.2	3.2	2.2	1.4	1 :	
100	150	13.2	6.3	3.9	2.7	1.7	1.2	

* Each column shows size of cut point for each mesh number compared to the cut point of the upper mesh size in each column.

follow the same scale as the mesh description does. Using mesh as an exact definition of a filtration quality for a cloth is not sufficient and can be confusing for the daily handling on the rigs. Cut point and the particle sizes where 16 and 84% of the particles go through the screen are actually the parameters necessary to optimize solids control.

Tables 1 through 3 show examples of cut points and mask area, respectively. A reduction in cut point and the affiliated reduction in the area of one mask for the change from 10- to 60-mesh screen give a reduction in area of 1/60.2 and a reduction of particle volume and mass of 1/467.4. Note that this number can change differently if another type of screen had been evaluated in the examples.

As described earlier, the weight of drilled-solid particles hammering on the primary filtration cloth determines the rate of wear. The weight of single particles passing through examples of scalping screens and the ratio between these are shown in **Table 3**. A comparison of data for the 10- and 60-mesh screens shows that the mass of one particle is reduced to less than 1/450 by changing from 10-mesh to 60-mesh on the scalping screens. This change is illustrated in **Fig. 13** where the size of two spheres, one having the maximum size for a 10-mesh mask and the other having the maximum size for a 60-mesh size, is illustrated.

With this knowledge in place, field experiences from several drilled sections the shaker-screen consumption has been reduced and 680 m^3 of drilled formation solids has been removed for each shaker screen used. This is 250 times more material that is being removed per screen before they are worn out.

During the drilling operation, the rig personnel manually measure the size of punctured area in the cloth with an "open-area" template. The average open or punctured area in the cloth for each m^3 of drilled formation solids was close to 1.25 cm^2 . With a trash limit for the shaker screen of 20% damaged area, this will, in this case, be approximately 850 cm^2 of filtration-cloth open/punctured area. This method does not measure the repaired-screen area.

As long as the measuring of the open area is another way of measuring screen wear, these numbers cannot be compared di-

Mesh	Cut Point							
10	3916.4	1 :						
20	904.4	4.3	1 :					
30	348.1	11.3	2.6	1 :				
40	168.1	23.3	5.4	2.1	1 :			
60	65.0	60.2	13.9	5.4	2.6	1 :		
80	33.5	116.9	27.0	10.4	5.0	1.9	1 :	
100	22.5	174.1	40.2	15.5	7.5	2.9	1.5	

* Area is given in 1000 μm^2 . Each column shows size of area for each mesh number compared to the area of the upper mesh size in each column.

Mesh	Cut Point							
10	1 :							
20	9.0	1 :						
30	37.7	4.2	1 :					
40	112.5	12.5	3.0	1 :				
60	467.4	51.9	12.4	4.2	1 :			
80	1,264.7	140.3	33.5	11.2	2.7	1 :		
100	2,296.5	254.8	60.9	20.4	4.9	1.8		

* Each column shows particle weight for each mesh number compared to the particle weight of the upper mesh size in each column.

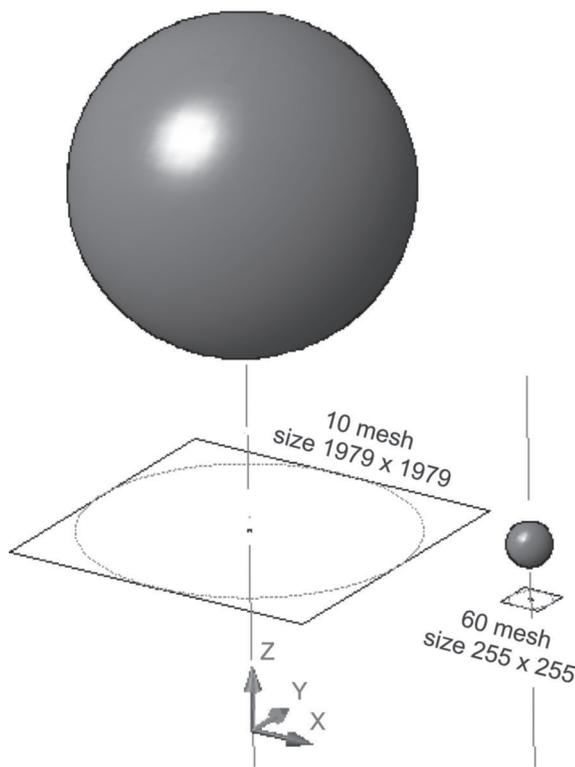


Fig. 13—Visual presentation of volume and weight of particles passing through one mask in the filtration cloth and the proportion between 10- and 60-mesh.

rectly to the historical numbers (2.7 m³/screen). However, it clearly illustrates the potential that lies within optimizing the running of solids-control equipment.

Understanding the mechanisms of wear has changed the operating procedures of the solids-control system and, thereby, has reduced screen consumption while simultaneously improving the quality of the drilling fluid. In this case, the rig personnel repaired the shaker screen continuously as the tendency to wear arose. In the overall picture, this had also another positive effect for the rig personnel. The work load for operating the solids-control equipment was reduced because most of the drilled formation solids were separated out on the first circulation. This also led to positive effects on the whole drilling operation by reducing the equivalent circulating density, reducing pump pressures, and lowering the fluid consumption compared to similar sections drilled.

A final comment, which has to be added to the discussion in this paper, is that finer cloths on the scalping deck is not the sole solution for obtaining optimum drilling-fluid/solids control in the different drilling operations. In some cases, it is desirable to have a more continuous PSD in the drilling fluid, potentially avoiding downhole losses (Aston et al. 2004). It is essential, however, to have full control of the particles in the system, which can only be achieved by optimal operation of the solids-control equipment.

Conclusion

The mechanisms for wear on shaker screens are outlined. Furthermore, it is explained how double-deck shakers should be operated to minimize wear on the primary screens at the same time that solids removal from the drilling fluids is optimized. Particularly, it is shown how important the following is:

- The screen-cloth aperture should be used for determining screening potential and not the mesh number.
- As many solids as possible should be removed on the top shaker deck.
- Finest possible screens, such as 60- to 100-mesh, should be on the top shaker deck.
- Screen selection on the bottom deck should be one that ensures no or minimal wear. This often means use of coarser screens on the bottom deck than is common practice.

It is shown how the use of this knowledge has improved field operations by increasing significantly the amount of formation material being removed from the drilling fluid in the first circulation.

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SI Metric Conversion Factors

$$\text{in.} \times 2.54^* = \text{cm}$$

*Conversion factor is exact.

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