CHAPTER 5

TANK ARRANGEMENT

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The purpose of a drilling rig surface fluid processing system is to provide a sufficient volume of properly treated drilling fluid for drilling operations. The active system should have enough volume of properly conditioned drilling fluid above the suction and equalization lines to keep the well bore full during wet trips.

The surface system needs to have the capability to keep up with the volume-building needs while drilling; otherwise, advanced planning and premixing of reserve mud should be considered. This should be planned for the worst case, which would be a bigger-diameter hole in which high penetration rates are common. For example for a 14¾-inch hole section drilling at an average rate of 200 ft/hr and with a solids-removal efficiency of 80%, the solids-removal system will be removing approximately 34 barrels of drilled solids per hour plus the associated drilling fluid coating these solids. More than likely, 2 barrels of drilling fluid would be discarded per barrel of solids. If this is the case, the volume of drilling fluid in the active system will decrease by 102 barrels per hour. If the rig cannot mix drilling fluid fast enough to keep up with these losses, reserve mud and or premixed drilling fluid should be available to blend into the active system to maintain the proper volume.

The surface system should consist of three clearly identifiable sections (Figure 5.1):

- Suction and testing section
- Additions section
- Removal section

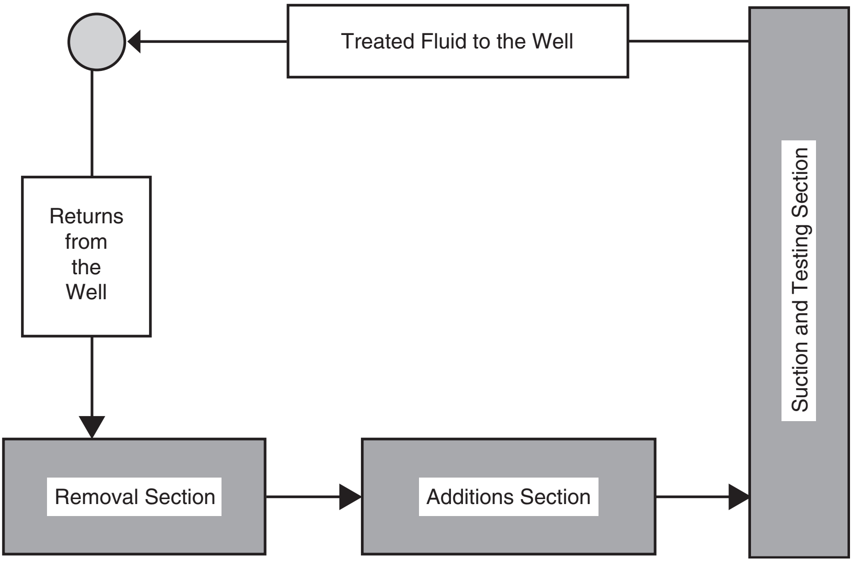

Figure 5.1. Surface circulation system.

5.1 ACTIVE SYSTEM

5.1.1 Suction and Testing Section

The suction and testing section is the last part of the surface system. Most of the usable surface volume should be available in this section. Processed and treated fluid is available for various evaluation and analysis procedures just prior to the fluid recirculating downhole. This section should be mixed, blended, and well stirred. Sufficient residence time should be allowed so that changes in drilling-fluid properties may be made before the fluid is pumped downhole. Vortex patterns from agitators should be inhibited to prevent entraining air in the drilling fluid.

In order to prevent the mud pumps from sucking air, vertical baffles can be added in the tank to break up the possible vortex patterns caused by the agitators. If the suction tank is ever operated at low volume levels, additional measures should be taken to prevent vortexing, such as adding a flat plate above the suction line to break up the vortex pattern.

Proper agitation is very important, so the drilling fluid is a homogeneous mixture in both the tank and the well bore. This is important because if a “kick” (entrance of formation fluid into the well bore due to a drop in hydrostatic pressure) occurs, an accurate bottom-hole pressure can be calculated. The well-control procedures are based on the required bottom-hole pressure needed to control the formation pressures. If this value is not calculated correctly, the well bore will see higher than necessary pressures during the well-control operation. With higher than required pressure, there is always the risk of fracturing the formation. This would bring about additional problems that would be best avoided whenever possible. For agitator sizing, see Chapter 10 on Agitation.

5.1.2 Additions Section

All commercial solids and chemicals are added to a well-agitated tank upstream from the suction and testing section. New drilling fluid mixed on location should be added to the system through this tank. Drilling fluid arriving on location from other sources should be added to the system through the shale shaker to remove unwanted solids.

To assist homogeneous blending, mud guns may be used in the additions section and the suction and testing section.

5.1.3 Removal Section

Undesirable drilled solids and gas are removed in this section before new additions are made to the fluid system. Drilled solids create poor fluid properties and cause many of the costly problems associated with drilling wells. Excessive drilled solids can cause stuck drill pipe, bad primary cement jobs, or high surge and swab pressures, which can result in lost circulation and/or well-control problems. Each well and each type of drilling fluid has a different tolerance for drilled solids.

Each piece of solids-control equipment is designed to remove solids within a certain size range. Solids-control equipment should be arranged to remove sequentially smaller and smaller solids. A general range of sizes is presented in Table 5.1 and in Figure 5.2.

The tanks should have adequate agitation to minimize settling of solids and to provide a uniform solids/liquid distribution to the hydrocyclones and centrifuges. Concerning the importance of proper agitation in the operation of hydrocyclones, efficiency can be cut in half when the suction tank is not agitated, versus one that is agitated. Unagitated suction tanks usually result in overloading of the hydrocyclone or plugged apexes. When a hydrocyclone is overloaded, its removal efficiency is reduced. If the apex becomes plugged, no solids removal

Table 5.1
Size of Solids Removed by Various Solids-control Equipment

Equipment	Size	Median Size of Removed Microns
Shale Shakers	API 80 screen	177
	API 120 screen	105
	API 200 screen	74
Hydrocyclones (diameter)	8-inch	70
	4-inch	25
	3-inch	20
Centrifuge		
Weighted mud		> 5
Unweighted mud		< 5

occurs and its efficiency then becomes zero. Agitation will also help in the removal of gas, if any is present, by moving the gaseous drilling fluid to the surface of the tank, providing an opportunity for the gas to break out.

Mud guns can be used to stir the tanks in the additions section provided careful attention is paid to the design and installation of the mud gun system. If mud guns are used in the removal section, each mud gun should have its own suction and stir only that particular pit. If manifolding is added to connect all the guns together, there is a high potential for incorrect use, which can result in defeating proper sequential separation of the drilled solids in an otherwise well-designed solids-removal setup. Manifolding should be avoided.

5.1.4 Piping and Equipment Arrangement

Drilling fluid should be processed through the solids-removal equipment in a sequential manner. The most common problem on drilling rigs is improper fluid routing, which causes some drilling fluid to bypass the sequential arrangement of solids-removal equipment. When a substantial amount of drilling fluid bypasses a piece or pieces of solids-removal equipment, many of the drilled solids cannot be removed. Factors that contribute to inadequate fluid routing include ill-advised manifolding of centrifugal pumps for hydrocyclone or mud cleaner operations, leaking valves, improper setup and use of mud guns in the removal section, and routing of drilling fluid incorrectly through mud ditches.

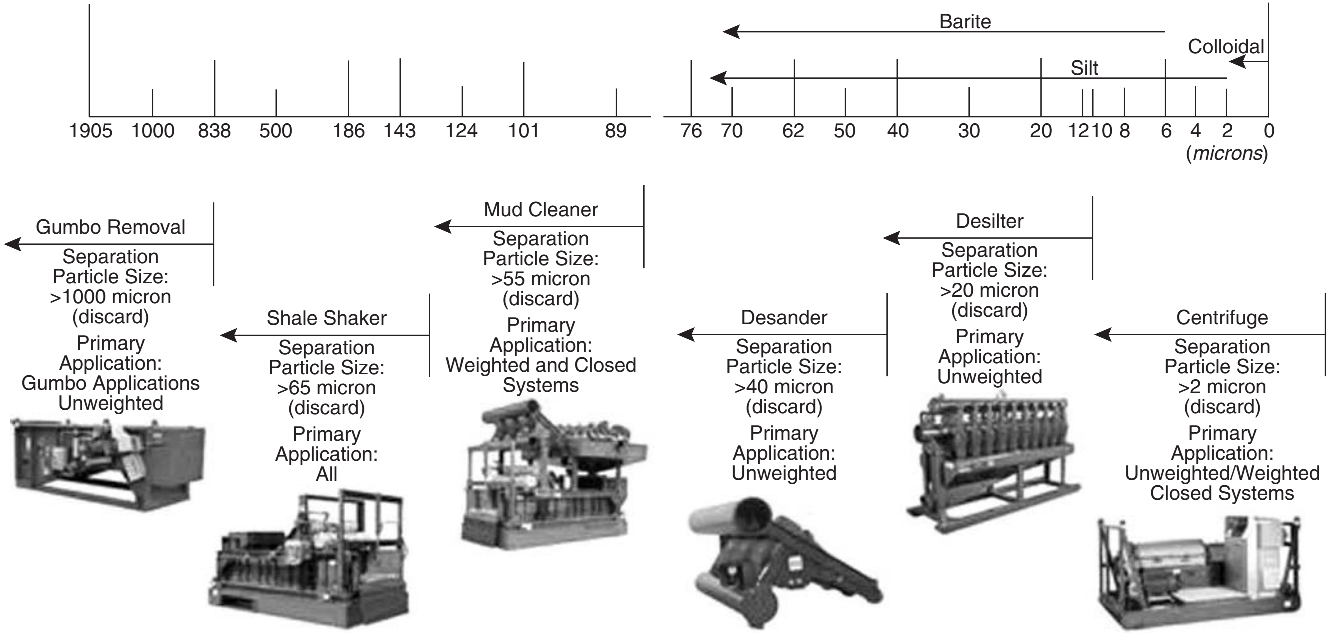

Figure 5.2. General solids control equipment removal capabilities.

Each piece of solids-control equipment should be fed with a dedicated, single-purpose pump, with no routing options. Hydrocyclones and mud cleaners have only one correct location in tank arrangements and therefore should have only one suction location. Routing errors should be corrected and equipment color-coded to eliminate alignment errors. If worry about an inoperable pump suggests manifolding, it would be cost saving to allow easy access to the pumps and have a standby pump in storage. A common and oft-heard justification for manifolding the pumps is, "I want to manifold my pumps so that when my pump goes down, I can use the desander pump to run the desilter." What many drilling professionals do not realize is that improper manifolding and centrifugal-pump operation is what fails the pumps by inducing cavitation. Having a dedicated pump properly sized and set up with no opportunity for improper operation will give surprisingly long pump life as well as process the drilling fluid properly.

Suction and discharge lines on drilling rigs should be as short and straight as possible. Sizes should be such that the flow velocity within the pipe is between 5 and 10 ft/sec. Lower velocities will cause settling problems, and higher velocities may induce cavitation on the suction side or cause erosion on the discharge side where the pipe changes direction. The flow velocity may be calculated with the equation:

$$\text{Velocity, ft/sec} = \frac{\text{Flow rate, gpm}}{2.48(\text{insided diameter in})^2} \tag{1}$$

Pump cavitation may result from improper suction line design, such as inadequate suction line diameter, lines that are too long, or too many bends in the pipe. The suction line should have no elbows or tees within three pipe diameters of the pump section flange, and their total number should be kept to a minimum. It is important to realize that an 8-inch, 90° welded ell has the same frictional pressure loss as 55 feet of straight 8-inch pipe. So, keep the plumbing fixtures to a minimum.

5.1.5 Equalization

Most compartments should have an equalizing line, or opening, at the bottom. Only the first compartment, if it is used as a settling pit (sand trap), and the degasser suction tank (typically the second compartment) should have a high overflow (weir) to the compartment downstream.

The size of the equalizing pipes can be determined by the following formula:

$$\text{Pipe diameter} = \sqrt{\frac{\text{Max. Circulation Rate, gpm}}{15}} \qquad (2)$$

A pipe of larger diameter can be used, since solids will settle and fill the pipe until the flow velocity in the pipe is adequate to prevent additional settling (5 ft/sec).

An adjustable equalizer is preferred between the solids-removal and additions sections. The lower end of an L-shaped, adjustable equalizer, usually field fabricated from 13-inch casing, is connected to the bottom of the last compartment in the removal section. The upper end discharges fluid into the additions section and can be moved up or down. This controls the liquid level in the removal section and still permits most of the fluid in the suction section to be used.

5.1.6 Surface Tanks

Most steel pits for drilling fluid are square or rectangular with flat bottoms. Each tank should have adequate agitation except for settling tanks. Additionally, each tank should have enough surface area to allow entrained air to leave the drilling fluid. A rule of thumb for calculating the minimum active surface pit area is:

$$\text{Area, ft}^2 = \frac{\text{Flow rate (gpm)}}{40} \qquad (3)$$

For example, if the active circulating rate is 650 gpm, the surface area of each active compartment should be about 16 square feet. The depth of a tank is a function of the volume needed and ease of stirring. Tanks that are roughly cubical are most efficient for stirring. If this is not convenient, the depth should be greater than the length or width. If circular tanks are used, a conical bottom is recommended and centrifugal pump suction and/or a dump valve should be located there. Another consideration is that the tanks need to be deep enough to eliminate the possibility of vortexing at the centrifugal pump suction. The depth required is a function of the velocity of the drilling fluid entering the suction lines (Figures 5.3, 5.4, 5.5, and 5.6).

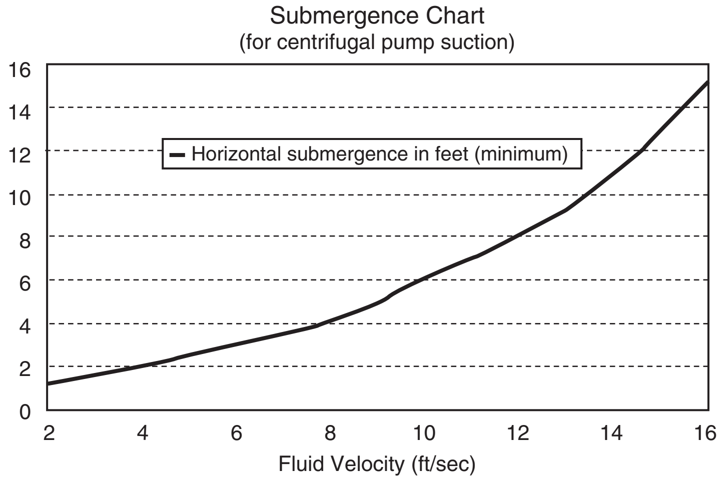

Figure 5.3. Submergence chart for centrifugal pump section.

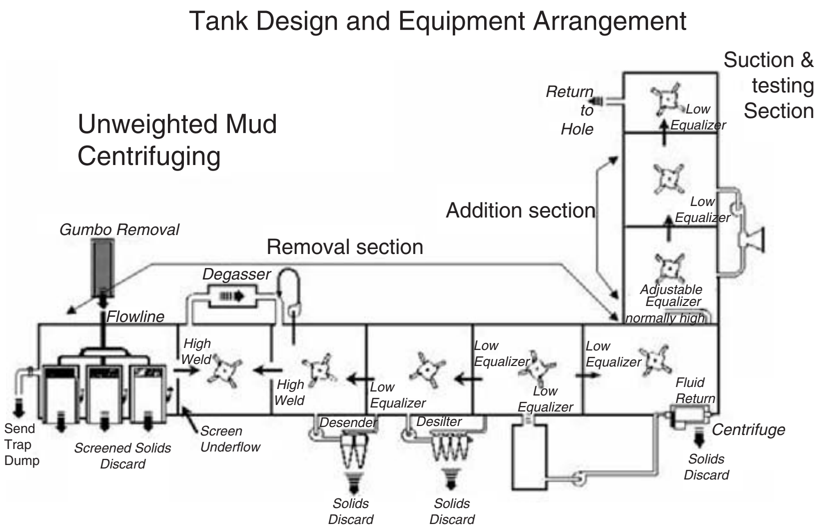

Figure 5.4. Tank design and equipment arrangement.

5.1.7 Sand Traps

After the drilling fluid passes through the main shaker, it enters the mud pit system. When screens 80-mesh and coarser were routinely used, the sand trap performed a very useful function. Large, sand-size particles would settle and could be dumped overboard. The bottom of a sand trap

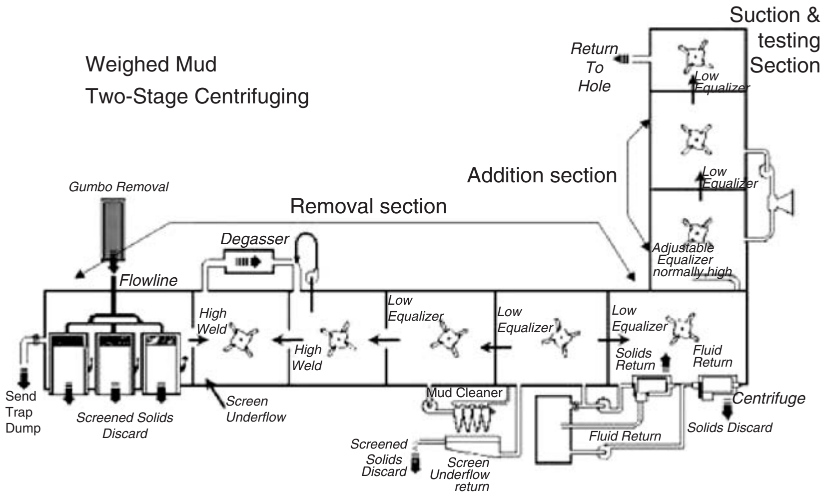

Figure 5.5. Weighted mud two-stage centrifuging.

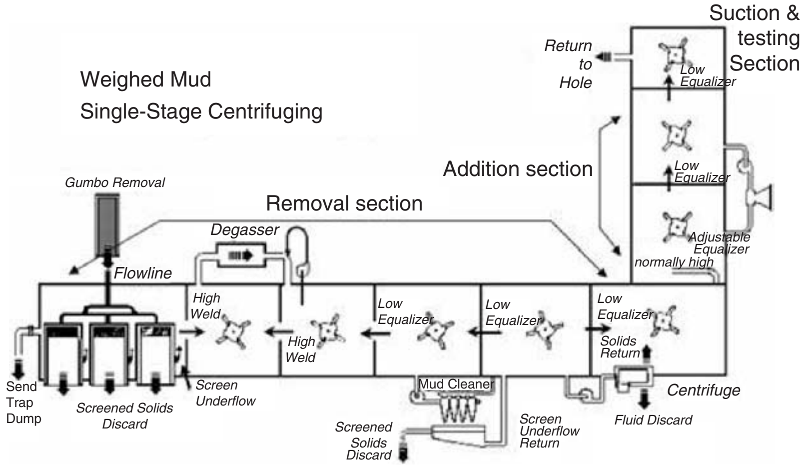

Figure 5.6. Weighted mud single-stage centrifuging.

should be sloped at about 45° to facilitate quick dumping. A sloped bottom 45° or greater will self-clean when dumped. The sand trap should not be agitated and should overflow into the next compartment. Linear and balanced elliptical motion shale shakers have all but eliminated this technique. Small drilled solids generally do not have sufficient residence time to settle. When inexpensive drilling fluid was used, sand traps were dumped once or twice per hour. Today, in the era of fine-mesh screens, expensive waste disposal, and environmental concerns, such dumping is either not allowed or is cost prohibitive.

The preceding illustrations show the solids-removal system with a sand trap. Rigs currently operating may or may not have sand traps. If a rig does not have a sand trap, then the shakers would have their underflow directed to the degasser suction pit and all other functions would remain as illustrated.

5.1.8 Degasser Suction and Discharge Pit

For proper operation of a vacuum-type degasser, the suction pit should be the first pit after the sand trap, or if no sand trap is present, then the first pit. This pit should typically be agitated in order to help roll the drilling fluid and break out as much gas, if present, as possible. The processed fluid flows into the next pit downstream. There needs to be a high equalizer or weir between these two tanks.

The degasser discharge pit is also the suction pit for the centrifugal pump used to pump drilling fluid through the eductor on the degasser. This is commonly called *power mud*. Pumping power mud through the eductor actually pulls the fluid out of the degasser vessel from the degasser suction pit and out to the discharge line due to the Bernoulli effect, causing a low-pressure zone in the eductor. The discharge from the eductor goes back into the same tank used for the suction for the power mud.

The reason that mud is sucked into the vacuum degasser and through the degasser vessel is that a centrifugal pump will not pump gaseous mud; therefore it cannot be pumped through the vessel and has to be sucked into it. (For complete information on operation of degassers, refer to Chapter 9 (Gas Busters, Separators, and Degassers) in this book.)

5.1.9 Desander Suction and Discharge Pits

The degasser discharge pit is also the suction pit for the desander. The desander, as well as the desilter, needs to be downstream of the degasser operation. If the hydrocyclone suction is upstream of the degasser operation and gas is present in the mud, the efficiency of the centrifugal pump will be reduced, or the pump will become gas locked and simply not pump any mud. Additionally, induced cavitation can occur and cause premature wear to the centrifugal pump. This wear can be rapid and severe.

The desander discharge (cone overs) should flow into the next pit downstream, and a low equalizer between these tanks should be opened. This allows backflow through the equalizer when the cone manifold is processing a greater volume than is entering the tank (recommended). This ensures that all of the drilling fluid is processed through the desander manifold.

Desander operation is typically recommended only for unweighted drilling fluids. If operated with weighted drilling fluid, the desander will discard a lot of drilling fluid away, including a lot of weight material.

5.1.10 Desilter Suction and Discharge Pits (Mud Cleaner/Conditioner)

The desilter suction pit is the desander discharge pit. The desilter will remove smaller particles than the desander, so its operation is downstream of the desander. Setup and operation of desilters are the same as with desanders. The manifold discharge is downstream of the suction, with a low equalizer between the two tanks. It is recommended that the desilter process more volume than the rig is pumping so that there is a backflow through the equalizer, ensuring that all of the drilling fluid is processed.

If drilling fluid is being pumped through mud guns from the suction compartment downstream, this fluid must also be processed through the hydrocyclones. For weighted drilling fluids, the underflow of the desilter cones is processed by a shaker. Ideally this shaker will have screens installed that allow the weight material to pass through while rejecting any drilled solids larger than the weight material.

5.1.11 Centrifuge Suction and Discharge Pits

Centrifuge suction is taken from the pit that the desilter manifold discharges into (for unweighted drilling fluids). The drilled solids removed by the centrifuge are discarded, and the cleaned drilling fluid is returned to the active system in the next pit downstream.

For a weighted aqueous drilling fluid, the solids separated by a centrifuge are composed largely of weight material (assuming upsteam processing has been performed correctly) used to increase the density of the drilling. This solids discharge (centrate or cake) is returned to the active system and the effluent or liquid discharge is discarded. The effluent contains the fine particles (colloidal or clay size) that will cause rheological problems with the drilling fluid if allowed to accumulate to a high enough concentration.

For a weighted nonaqueous drilling fluid, it is not feasible to discharge the effluent from a centrifuge, due to environmental and/or economic concerns. In this situation, a dual centrifuge setup is utilized in which the first centrifuge operates at a lower *g* setting (usually 600–900 *g*) and the weight material (which is easy to separate due to its higher specific gravity) is returned to the active system. The effluent from the first centrifuge typically flows to a holding tank, and this fluid is not processed by a second centrifuge operating at a higher *g* force in order to separate finer solids, which are discarded. The solids from the second centrifuge typically are not in the size range that would cause rheological problems, but given time they will degrade into smaller particles that could start causing problems. Therefore, they need to be removed while the equipment can still remove them. The effluent from the second centrifuge is then returned to the active system.

5.2 AUXILIARY TANK SYSTEM

5.2.1 Trip Tank

A trip tank should also be a component of the tank system. This tank should have a well-calibrated, liquid-level gauge to measure the volume of drilling fluid entering or leaving the tank. The volume of fluid that replaces the volume of drill string is normally monitored on trips to make certain that formation fluids are not entering the well bore. When one barrel of steel (drill string) is removed from the borehole, one barrel of drilling fluid should replace it to maintain a constant liquid level in the well bore. If the drill string volume is not replaced, the liquid level may drop low enough to permit formation fluid to enter the well bore due to the drop in hydrostatic pressure. This is known as a kick. Fluid may be returned to the trip tank during the trip into the well. The excess fluid from the trip tank should be returned to the active system across the shale shakers. Large solids can come out of the well and plug the hydrocyclones if this drilling fluid bypasses the shakers.

The addition of trip tanks to drilling rigs significantly reduces the number of induced well kicks. The obsolete or old-system drillers filled the hole with drilling fluid with the rig pumps by counting the mud pump strokes (the volume was calculated for the displacement of the drill pipe pulled). The problem here was that a certain pump efficiency was estimated in these calculations. If the mud pump was not as efficient as estimated, slowly but surely the height of the column of drilling fluid filling the hole decreased. This caused a decrease in hydrostatic head, and if formation pressures were greater than the hydrostatic head of the drilling fluid, a kick would occur.

Another common way to induce a kick was to continue filling the hole with the same number of strokes used for the drill pipe even when reaching the heavy-weight drill pipe or drill collars were pulled. Both the heavy-weight drill pipe and the drill collars have more displacement per stand than the drill pipe; therefore a reduction in the height of the column of drilling fluid in the well bore would occur and problems would result.

5.3 SLUG TANK

A slug tank or pit is typically a small 20- to 50-barrel compartment within the suction section. This compartment is isolated from the active system and is available for small volumes of specialized fluid. Some drilling-fluid systems may have more than one of these small compartments. They are manifolded to a mixing hopper so that solids and chemicals may be added and are used to create heavier slurry to be displaced partway down the drill pipe before trips. This prevents drilling fluid inside the pipe from splashing on the rig floor during trips. These compartments are also used to mix and spot various pills, or slurries, in a well bore. The main pump suction must be manifolded to the slug pit(s).

Proper agitation is needed for this tank because there will be many different types of slurries mixed during drilling operations. Some will be easy to mix, while others will take a lot of energy to mix properly. The addition of a mud gun or guns would be beneficial in mixing various pills as well as keeping solids from settling in the bottom or corners of this tank.

5.4 RESERVE TANK(S)

The reserve tank(s) are for storage of excess drilling fluid, base fluids, or premixed drilling fluid for future mixing/additions. It could even be a completely different type of mud system for displacing the existing drilling fluid.

Land drilling rigs do not have reserve tanks in their systems. Extra tanks are rented as needed for their operation. These tanks are typically called fractionalization (frac) tanks.

Marine drilling rigs incorporate reserve or storage tanks in their design. The volume and number of these tanks depend on the space available and the available deck load capabilities of the rig. If more storage volume is required for marine drilling rigs, extra storage tanks can sometimes be installed on deck depending on space and deck load availability.

The type of drilling fluid stored in the reserve tanks will dictate whether it needs to be agitated. Since the type of fluids stored will vary, adequate agitation should be available if required.