Section 3

Blenders and Auxiliary Equipment

Table of Contents

Introduction

Specialized equipment is necessary to properly add chemicals and sand into fracturing fluids. Proportioners (blenders) have been developed that have the needed equipment mounted on a single truck or trailer (Figure 3.1). The overall operation of the blender with its different systems is an extremely important phase of stimulation work.

Topic Areas

The section units are

- Hoses
- Centrifugal Pumps
- Tub Agitator
- Additive Systems
- Sand Screws
- Hydraulic Systems
- Instrumentation

Learning Objectives

Upon completion of this section, you will be familiar with

- Use and care of hoses
- Pumping systems used on blenders
- Use and care of additive systems
- Hydraulic systems introduction and safety
- Basic instrumentation used for job control
- Sand screw delivery rates and calculations
- Systems of the blender and how they relate to the overall job functionality

Figure 3.1

Unit A: Hoses

Flexible rubber hoses are key components in successful fracturing and stimulation jobs. The critical nature of hose applications requires careful selection, care and maintenance. Proper handling of these hoses will contribute to the successful completion of a stimulation job.

Suction Hose Selection

Frac hoses used for suction applications connect reservoirs of stimulation fluids (frac tanks) to the blender (Figure 3.2).

Figure 3.2 – Suction Hose

As you consider "rigging up" equipment for the stimulation jobs, ask yourself these questions to help select the best hose arrangement for a particular application:

1. Is the hose spiral reinforced with wire to prevent the hose from collapsing under suction?
2. What is the flow rate? Remember: higher flow rates and friction restriction require that more hoses be used.
3. What kind of treating fluid will be used? The viscosity of the fluid also affects the number of hoses selected for the stimulation fluid.

The first question asks if the hose is spiral reinforced with wire. Reinforcement will prevent the hose from collapsing under suction. What may not be so easily recognized is that the wire also serves as a conductor that grounds the equipment.

The second question asks about flow rate. In *Section 2: Calculations,* you learned the effect of flow rate on friction pressure (P_f) in steel tubular goods. Friction pressure also exists in suction hoses. There is a limit to the amount of fluid that can be transferred through one hose. Therefore, more hoses are required when the flow rate increases. The viscosity, which is a measure of a fluid's resistance to flow, will also affect the number of hoses required for a job.

Table 3.1 was developed to provide an easy guide for selecting the number of suction hoses to use on a given job based on the flow rate and viscosity of the fluid. Use it to gain experience in hose selection. However, before the chart can be properly used, some terms need to be defined:

- *Water:* Fresh water or salt water to which nothing has been added that could cause the water to develop viscosity. The water could also contain friction reducers.
- *Thin oil:* Thin oil is normally considered to be diesel or kerosene. While the higher API gravity oils and condensates are also very thin, they should be included with high vapor pressure fluids.
- *Low, moderate, and high viscosity fluids:* Low viscosity fluid is water with less than 30 pounds gel per 1000 gallons of gel added to it. A moderate gel would be 40 pounds gel per 1000 gallons of gel added. A high viscosity fluid would be 60 to 80 pounds per 1000 gallons of gel added.
- *High vapor pressure:* The higher the API gravity of an oil, the greater the amount of vapor given off by the oil. Gasoline is a

good example of a fluid with a high vapor pressure.

API gravity is the American Petroleum Institute's relative comparison of the specific gravity of oils. Water has an API gravity of 10. Most oils have a higher API gravity than water. The higher the gravity, the lighter the oil.

The value for API gravity is measured with a hydrometer. The temperature of the sample is also taken because temperature will affect the gravity of the oil. API gravity is reported as degrees API at 60°F. A correction needs to be made if the sample temperature is not 60°F. For each degree F above 60°, add 0.1° API to the reading. For each degree below 60°, subtract 0.1° API from the reading.

If the specific gravity is known, the API gravity can be calculated from the following formula:

$$\text{API gravity} = \frac{141.5}{\text{SpecGrav@60°F}} - 131.5$$

API gravity is an area that needs consideration in pumping oils. For example, very little difficulty would be experienced in pumping oil with an API gravity of 48°. However, it is very difficult to pump oil with an API gravity of 19°.

Minimum Number of Suction Hoses Recommended for High Viscosity Fluids or Fluids with High Vapor Pressures (20-ft lengths)		
Volume (bbl/min)	**No. of Lines**	**Size (in. ID)**
5	2	4
10	3	4
30	5	4
40	6	4
50	8	4

Table 3.1

Rule of Thumb: To determine the minimum number of 4 inch suction hoses required for water and moderate gels, calculate a 10 bbl/min capacity for each 20 feet of length. When pumping thick or gaseous fluids, add 50% more hoses to the result of your calculations.

Example 1:

The gel being Pumped is 70 lb/Mgal WG-18 at 60 bpm. Each suction hose is 20 ft. in length.

$$\#\,\text{Hoses} = \frac{60\ \text{BPM}}{10\ \text{BPM per hose}} = 6\ \text{hoses}$$

$$6\ \text{hoses} \times 1.5\ (\text{for thick fluid}) = \mathbf{9\ hoses}$$

Discharge Hoses

Discharge hoses are used to transfer combined liquids and additives from the blender to the high-pressure pumps. Since these hoses are usually supercharged when transferring the treating fluid from the blender, they will have a higher pressure rating than the suction hoses. Discharge hoses are normally about ten feet long. Like suction hoses, discharge hoses are also spiral reinforced with wire.

Figure 3.3

Since the discharge hoses are under pressure when transferring liquids and additives, they should be covered with hose covers to deflect fluid in case of leaks. This is especially true when pumping flammable fluids. Failure to cover the hose may cause a flammable liquid to be sprayed into the intake manifold on an engine and cause an equipment fire.

If using three inch discharge hoses, remember that a 4 inch hose has 12.6 square inches of area to flow through while a 3 inch hose has only 7.07 square inches of area. So, it will take two, 3 inch discharge hoses to equal the flow carrying capacity of one 4 inch hose.

Warning: Do not stand on or straddle any line or hose under pressure!

Hose Storage and Use

To increase hose life, follow these common-sense procedures while using and storing hoses:

- Never drag the hose or pull it by the coupling when moving a hose from the blender to the tanks.
- Do not drive vehicles over hoses or use hoses for wheel chocks.
- Do not drop hoses so the couplings receive undue shock.
- Because of the hose weight and the tremendous vibration associated with well stimulation operations, be extremely careful when connecting hoses with crossovers. Pay particular attention to any sharp edge that might cut the hose, such as a well-beaten hammer union lug.
- Be sure to allow enough free length in the hose to avoid a problem. Hoses could contract up two to three percent in length when pressurized during frac jobs. A hose that is too short for the application will be damaged at the coupling (Figure 3.3) and can lead to early hose failure.
- When the job is completed, flush and drain the frac hoses prior to placing them back on the blender. If it is not possible to flush the hoses then, flush them at the first opportunity. The hoses should be placed on the blender in a straight flat position.

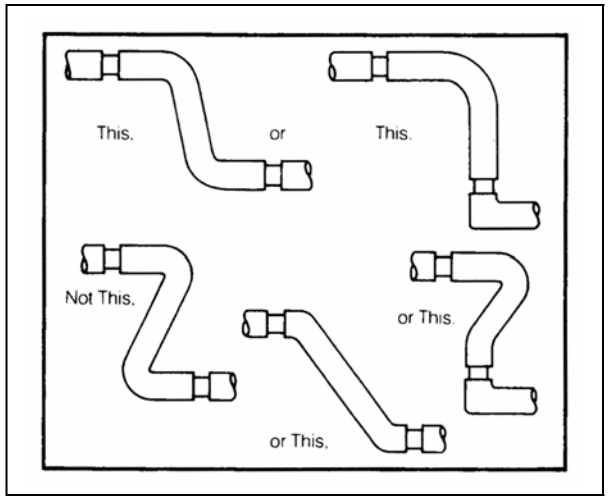

Figure 3.4

Figure 3.5

Hose Inspection

The key to efficient maintenance is constant awareness of the hose condition. Frac crew members should inspect a hose for the following signs of wear and tear each time the hose is loaded or unloaded:

- Couplings - Check for cracks, signs of slippage, kinks, and hose condition at the coupling. The abrasive action of sand laden fluids will wear the hose faster if it is kinked.

- Hose cover - Be on the lookout for cuts, exposure of the reinforcement, a kink (flat spot) or blister.
- Hose tube - Shine a flashlight into one end of the frac hose and look into the other end for obstructions, cracks, tube pulling away and blisters.

An investment in hose inspection time and procedures can pay dividends in hose service life and create safer working conditions. No one wants a hose that is transporting frac fluid to burst under high pressure.

Be aware of the safety hazard of flying pieces of metal when making up hoses. Wing ends that have become too worn (pointed) should be replaced. (Figure 3.6) Always wear safety glasses with side shields when making up hoses or iron or if you are in the vicinity.

Figure 3.6 Worn Wing End

Basic Do's and Don'ts

Frac hoses used in the well servicing business are very rugged and dependable, but they can fail if excessively abused. Following are some helpful tips developed over the years that can help increase hose life:

- DO use the proper hose for each particular well servicing application – i.e., suction hose for suction application and the proper hose for the materials being pumped.
- DON'T stretch a hose to reach a connection. The stress added to the internal pressure could lead to shortened hose life.
- DO inspect hose as often as practical. Look for signs of leakage, blistering or loose covers. Cuts, gouges and abrasions can lead to weakened hose reinforcement.
- DON'T drag the hose over especially abrasive or sharp surfaces. Never pull it by the coupling assembly.
- DO match hose pressure ratings with job specifications.
- DON'T recouple a failed hose.
- DO protect threaded ends of a coupling to enhance a leak-proof seal.

The last thing needed at a frac job is a premature failure because the wrong hose was used on the job or the hose was not properly maintained. It is good business to follow a few simple common-sense practices in the selection, care and maintenance of a frac hose to help perform a safe, efficient and profitable operation.

Unit A Quiz

Fill in the blanks with one or more works to check your progress in Unit A.

1. The proper handling of suction hoses helps in the successful completion of a stimulation job. Each time a hose is loaded or unloaded, these three areas should be inspected for wear and tear:

    1. ________________________________
    2. ________________________________
    3. ________________________________

2. To prevent the hose from collapsing under suction, the hose is __________ __________ with ___________.

3. The number of suction hoses selected for use on a stimulation job is determined by the ________________________ and the ____________________ of the treating fluid used.

4. The higher the API gravity of an oil, the greater the amount of _________________ given off by the oil, and the ___________________ the oil.

5. A fracturing job requires a 40 bbl/min injection rate. The base gel is 60 lb/1000 gal WG-11. Each suction line will be 20 ft in length. Using Table 3.1, how many 20-ft suction hoses will be required for the job?

6. When transferring high-vapor pressure fluids from the blender to the high pressure pumps, the discharge hoses should be ________________ to deflect __________________ in case of leaks.

7. Discharge hoses could contract when pressurized during frac jobs. Allow enough ______________ in the hose to avoid a problem.

8. After a job, __________________ and _________________ frac hoses before storing them back on the blender.

9. Frac hose should be stored in a _______________, flat position.

10. Obstructions, cracks, tube pulling away, and blisters can be located on the inside of a frac hose by shining a _____________________ into one end of the frac hose and ____________________ into the other end.

Now, look up the suggested answers in the Answer Key.

Unit B: Centrifugal Pumps

Centrifugal pumps are used on blenders to draw fluids out of storage tanks and convey sand laden fluids to high pressure pumps. Understanding centrifugal pump operation and performance is vital if blenders are to be operated correctly.

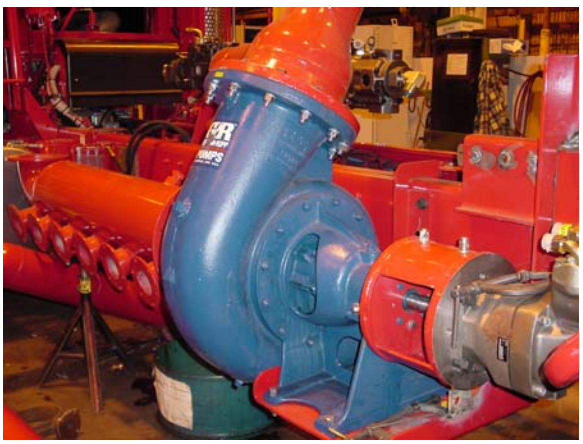

Figure 3.7 - Gorman Rupp

Centrifugal pumps are used because they are more tolerant of abrasive fluids than gear or vane pumps. This tolerance causes less wear on the pumps, therefore increasing pump life. However, they are much less tolerant of air.

In this unit, you will learn about how centrifugal pumps operate.

Principles of Operation

A centrifugal pump consists essentially of one or more impellers equipped with vanes. The impeller is mounted on a rotating shaft and enclosed by a casing. Fluid enters the pump at the center of the impeller. The fluid is then directed radially toward the case by the vanes (Figure 3.8). As the fluid leaves the impeller, it is collected in a volute or series of diffusing passages. This causes the fluid rate to drop and the pressure to increase.

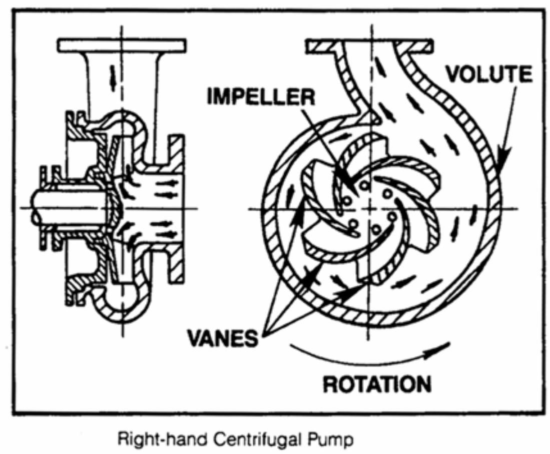

Figure 3.8 – Right-hand centrifugal pump.

The head or pressure developed by the centrifugal pump is entirely the result of the fluid rate caused by the impeller rotation. This pressure is not created by any type of positive displacement methods (plungers).

Figure 3.9

Definitions of Terms

Before centrifugal pump principles and operations can be fully understood, there are certain terms that must be defined. Centrifugal pumps are classified according to suction and discharge manifold diameters, impeller diameters, number of vanes, direction of discharge, and many other characteristics.

An important distinguishing feature is whether the pump is a right-hand or left-hand pump. To determine this, use Figure 3.8 as a reference. As you look into the impeller from the suction side of the pump, note on which side of the case the discharge manifold starts. In Figure 3.8 the discharge starts on the right. Therefore, it is called a right-hand pump. A left-hand pump has the discharge starting on the left.

Here are some other key terms:

- *Head* is generally used with centrifugal pumps rather than pressure. It refers to the height (in feet of water) that a pump can discharge. This is important because the heavier the fluid (ie. Sand concentration) the lower the head the pump will have or the less boost pressure the pump will have.
- *Horsepower* is the power required by the pump, not the hydraulic horsepower delivered. Unless otherwise noted on the curves, these values are based on a specific gravity of 1.0. If the fluid being pumped has a different density than water, multiply the horsepower by its specific gravity.
- *Net Positive Suction Head (NPSH)* is divided into two categories. Required NPSH is the amount of pressure that must be supplied to the suction of the pump for the pump to operate properly. It is shown on performance curves. The Available NPSH varies with suction conditions and must be equal to or greater than the Required NPSH. Both are measured in feet of liquid.

Halliburton field personnel will not be expected to calculate Available NPSH, but it is important to understand this characteristic of centrifugal pumps to avoid possible problems when laying temporary suction manifolds.

Although all factors of Available NPSH can be controlled to some extent, the friction loss can be altered more easily than the others. This is usually done by varying the number and/or length of the suction lines. The maximum volume that should be pulled through one 20 ft, 4 in. suction hose is 420 gal/min (10 bbl/min). This is only a rule of thumb, and there will be times when the volume per hose must be lower.

The higher the flow rate, the higher the friction loss, which can result in air or vapor separation. This is further complicated when elbows or tees are used close to the pump or the hose length is increased beyond 20 ft. Uneven flow patterns, vapor separation, or both, can keep the liquid from evenly filling the impeller. This upsets the hydraulic balance and can lead to cavitation, vibration and excessive shaft deflection. Shaft breakage or premature bearing failure may result.

Suction lines should be as short and as straight as possible. They also should not have intermediate in-line high places to create air pockets. O-rings should be in good condition and should be in place to prevent air intake at the connections.

Performance Characteristics

The centrifugal pump will adjust its rate depending on the input and output pressures. If an adequate head of fluid (input pressure) is available, the pump rate will adjust to match the output pressure. If an adequate head of fluid is not present, then vapor pockets can form in the center of the impeller and cause cavitations. This can also cause serious structural damage to the pump. Cavitations can be eliminated by down-throttling (partially closing) a valve in the discharge line to reduce the output rate to a point where the input head is adequate.

Faster speeds produce more pressure or head and demand more horsepower. Slower speeds have the opposite effect.

Water Hammer

Some centrifugal pump cases have been split by water hammer. Water hammer occurs when a valve in the discharge line of the pump is closed too quickly. This brings the fluid to a sudden stop and exerts very high pressure throughout the system upstream from the valve. Normally, the pump case is the weakest part of the system and is the part that fails.

A typical water hammer break is characterized by a crack running around the centerline of the case. This may not happen the first time a water hammer occurs, but it definitely weakens the case and increases the probability of future failure.

A surge chamber can be installed in the discharge line to reduce the hammer, but won't eliminate it. If possible, pump speeds should be reduced and valves closed gradually.

Parallel and Series Operation

Sometimes it is necessary to operate two or more pumps at the same time. Depending on the arrangement of the pumps, the operation will be either parallel or series.

Parallel

Parallel centrifugal pump operation is illustrated in Figure 3.10. An example of a parallel operation would be connecting two centrifugals to separate frac tanks and discharging them both into a third tank.

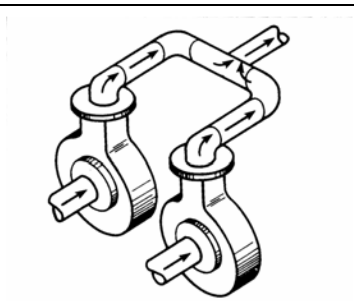

Figure 3.10 - An example of a parallel operation.

In parallel operation:

- The discharge head is equal to that of one pump.
- The volume is equal to the total of the two pumps.
- Use care with the suction manifold so that one pump does not starve.
- Be sure the discharge capabilities of the pumps are fairly equal.
- Do not operate the pumps at relatively high heads and low capacities to avoid the possibility of one pump moving fluid back through the second pump.

Series

The result of a series operation is the opposite of parallel systems (Figure 3.11):

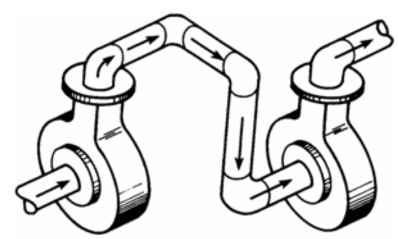

Figure 3.11 – An example of series pump system.

An example of a series operation would be in using a booster pump trailer to feed the suction side centrifugal of the blender.

In series operation:

- The volume is limited to the capacity of one pump.
- The head is equal to the sum of the two pumps (the second pump will add its head to the head supplied to its suction by the first pump).
- You must know the maximum case working pressure of the pump to avoid bursting the second pump.

- You must take care to not part the lines with dresser sleeve connections.
- At high rates, leakage may occur at the stuffing box seals or packing of the second pump.

Example:

Two pumps, each having the capacity of 500 gal/min @ 120 ft of head, are to be operated together. What is the output for parallel and series operations?

Solution:

Parallel Operation:

Volume = 500 + 500 = 1,000 gal/min

Head = 120 ft

Series Operation:

Volume = 500 gal/min

Head = 120 + 120 = 240 ft

Although the theoretical head for series operation is 240 feet, the actual head will be lower. This is due to the friction loss in the manifold between pumps and will vary with volumes and manifold arrangement.

Unit B Quiz

Fill in the blanks to check your progress in Unit B.

1. Centrifugal pumps on blenders draw fluid out of _______________ _______________ and convey sand-laden fluids to ___________ ___________ ___________.
2. Centrifugal pumps have been selected for use on blenders because centrifugal pumps are more tolerant of ____________________ ______________________.
3. The disadvantage of the centrifugal pump is that it is less tolerant of _______________.
4. Instead of pressure, the term _______________ is generally used with centrifugal pumps.
5. If an adequate head is not present, vapor pockets can form and cause _______________, which can be eliminated by partially closing a valve in the discharge line.
6. Water hammer occurs when a _______________ in the discharge line is closed too quickly.
7. In a parallel operation of two pumps, the head is equal to that of _______________ pump(s), and the volume is equal to that of _______________ pump(s).
8. Fluid enters a centrifugal at the _______________ of the impeller.
9. As the fluid leaves the impeller, it is collected in a volute or series of diffusing passages. This causes the fluid rate to ________ and the pressure to __________.

Now, look up the suggested answers in the Answer Key.

Unit C: Tub Agitators

The tub agitator consists of two sets of blades on a shaft. The bottom blades are set just off bottom of the mixing tub (Figure 3.12). The purpose of the agitator is to help keep the proppant suspended in the fluid without entraining air. If the agitator speed is too low, the proppant can build up on the bottom of the tub and suddenly get picked up as a slug and sent to the pumps. If the agitator speed is set too high it can whip or entrain air in the fluid causing the booster pump to pick up air, which will cause a decrease in boost pressure.

The agitator's speed (revolutions per minute-rpm) is computer controlled. In the computer, the agitator is given a set speed without proppant. When proppant is added to the fluid in the tub, computer will increase the agitator's rpm as the proppant concentration is increased. A default setting is 40 rpm without proppant and adding 4 rpm per pound of proppant added.

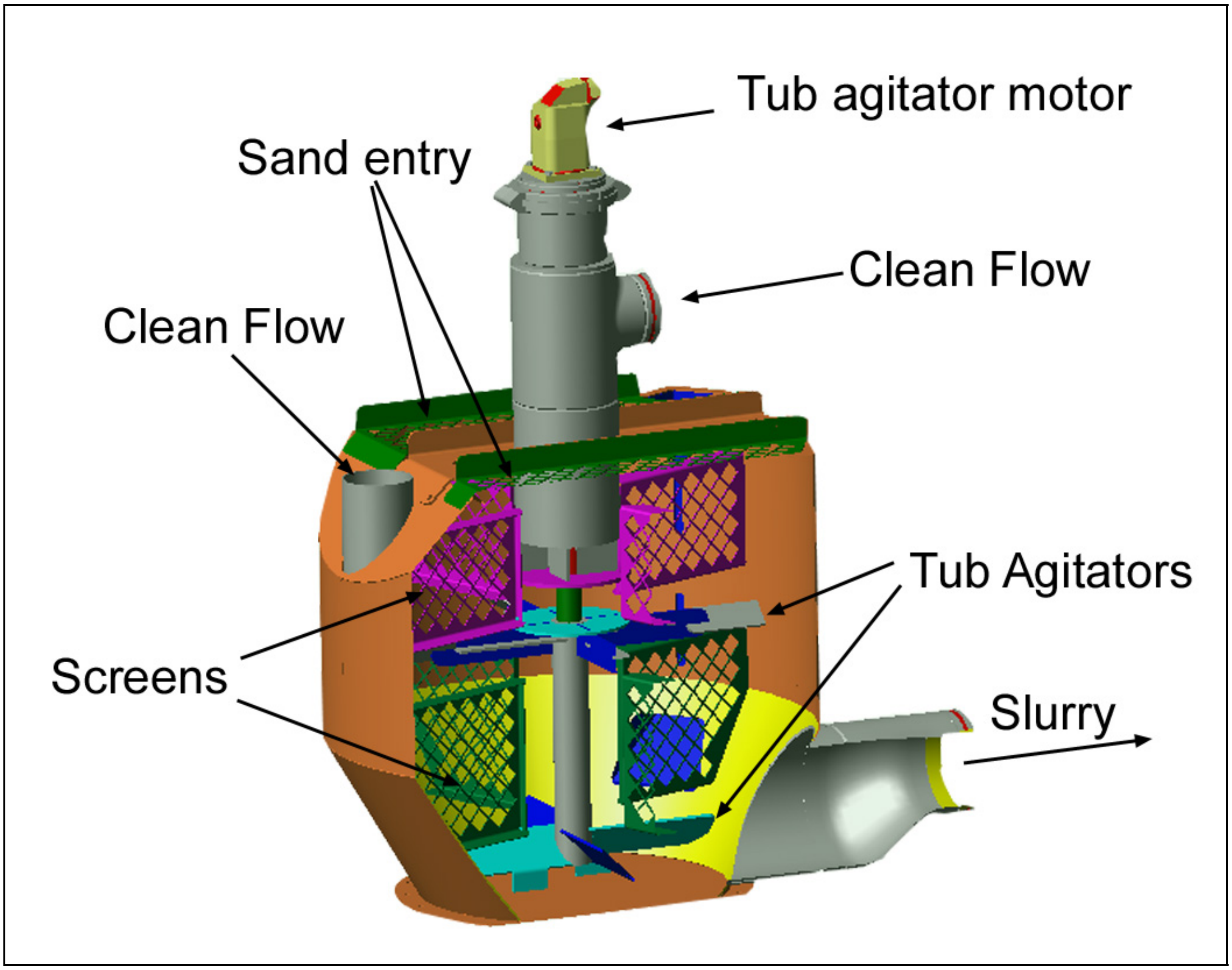

Figure 3.12 - Blender Tub (High Rate Blender) - Sectional view

Unit D: Additive Systems

Due to the nature of stimulation fluids, some additives can only be added "on-the-fly" (while pumping). These additives are in liquid or solid form. Various pumps and hoppers mounted on the blender allow accurate measuring and addition of these additives. Equipment for both liquid and dry additives will be discussed in this unit.

Liquid Additive System

Halliburton has many fracturing fluids that require a large number of chemical additives for proper performance. Many of these additives are liquid. Some of the liquid chemical additives are crosslinkers, surfactants, breakers and oil gelling agents. The liquid additive systems on blenders are designed to blend the liquid chemicals into the fracturing fluids.

Injection points on the blender will be dependent on the liquid additive type. Some chemicals are split into two pumps. This split is not because of the amount of chemical added, but due to the fact that the viscosity of the fracturing fluid may get so high that it will not leave the tub or the proppant may just stack on top of the slurry. So, some will be injected into the tub slurry and the rest of the chemical will be injected into the slurry at a point after it leaves the tub. Injection points are in the suction side, in the tub, in the eye of the discharge booster pump or in the discharge manifold. There is one chemical (sand wedge) that is commonly injected into the sand screw at various distances in the sand screw housing. The exact placement is area specific.

Liquid Additive Equipment

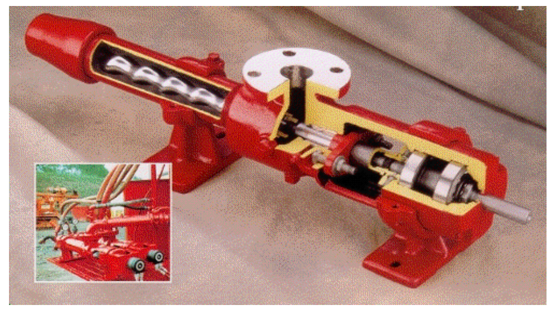

Figure 3.13 Roper Progressive Cavity Pump

With the advent of today's fluid systems, the liquid additive equipment has to be capable of a high level of precision. The blenders come equipped with from 3 to 7 liquid additive systems. These additive systems consist of a pump, typically a Roper Progressive Cavity (Figure 3.13) and a Micro-Motion Flow Meter.

Figure 3.14

Progressive pumps are used mainly because they are more tolerant of trash and the most accurately controlled. These pumps have to be sized for the amount of fluid you wish to pump. The minimum rate they will pump is typically one tenth of the maximum volume they will pump. The most common problem with these pumps is that when they are run dry, it destroys the stator (pump liner). The pumps can be purchased with different stators, Buana N, Viton and Butyl Rubber. The type of Stator to be used will depend on the chemical to be pumped. The accuracy and the life of this pump is dependent on the operator using the appropriate stator material and taking care not to run the pump dry. The Roper pump has a very poor suction capability. The chemical tanks should always be above the suction of the pump. Slurry hoses to the suction side of the pump should be large enough to free flow the amount of chemicals you intend to pump.

Stainless steel liquid additive tanks are mounted on the blender (Figure 3.15). All of the stainless steel tanks have a bottom suction connection. They also have sight tubes for visually checking levels along with electronic fluid level sensors. They have the capability to be tied to another holding tank that will be able to keep the tank on the blender filled when it gets to a certain level. Care must be taken to only put chemicals inside that are compatible with stainless steel. Vicon HT breaker is one chemical that is ***not*** compatible with stainless steel.

Figure 3.15

MicroMotion flow meters are installed on the liquid additive pumps because of their accuracy (Figure 3.16). MicroMotions provide feedback to the computer on the blender that allows it to accurately control the addition of chemicals to the treatment slurry.

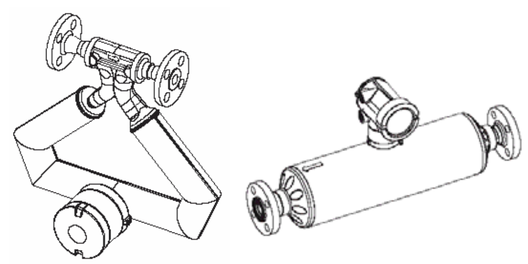

Figure 3.16 – MicroMotion Flow Meters

Typically, they are accurate to within 1% of the volume actually pumped. A problem that may be encountered with the MicroMotion meter is that air in the fluid causes an erroneous flow rate. Thick or viscous fluid is not recommended. The MicroMotion flow meters must also be sized for the rate of the fluid that is to be pumped through them.

Dry Additive Equipment

In addition to the liquid additives required to make up the different fracturing fluids, there are also many dry additives that must be used. A dry additive system improves the blending of dry additives into a fracturing fluid. The mechanical equipment on the dry additive system usually includes two Acrison-Feeders. Tube diameter size depends on the area that the blender is used in. The sizes can run from 1-3/8 inches to 4-1/2 inches. Blenders typically come equipped with two Acrisons, a 4 inch and a 1 3/8 inch.

Dry additives are sack-fed into the hopper and dispensed by a screw feeder through eductors or by gravity into the blender mixing tub. The eductor should be used with caution on high pump rate jobs as air entrainment into the slurry can cause the boost pressure to decrease. Proper calibration of the dry additive screws is imperative for correct additive dispersal. This requires the operator to have a set point value for the amount of pounds of dry additive that will be dispersed for each revolution of the Acrison Screw for each dry additive to be used.

At the end of the job, the hopper and screw should be cleaned of material. Material left inside can harden and prevent them from turning.

Figure 3.17

Unit D Quiz

Fill in the blanks with one or more words to check your progress in Unit D.

1. The minimum rate a Roper pump will pump is typically _____________ of the maximum rate.
2. A Roper Progressive cavity pump should never be pumped without _______________ in it as this will _______________ the stator.
3. Micro motion flow meters are accurate to within ________ of the volume pumped.
4. Dry additives are __________-__________ into the hopper and dispersed by the __________ __________ through an eductor into the blender tub.
5. Dry additives remaining in the feeder after a job will __________ and prevent the feeder from ____________.
6. The hoses to the Roper pump should ____________ ____________ enough fluid to supply the pump during the job.

Now, look up the suggested answers in the Answer Key.

Unit E: Sand Screws

Fracturing jobs normally require the addition of propping agents into the fluid. Sand screws convey those propping agents from bulk equipment to the blender tub. The propping agent may be sand, lightweight ceramics, intermediate or high strength bauxite, or a resin coated version of any one of these types. See Section 9 for more details on proppants.

Each sand screw on the blender is operated independently through computer controlled hydraulic throttling.

Sand Screws

Most of the blender sand screws on newly manufactured blenders are 12 inch and 14 inch diameter screws, with 11 inch and 13 inch screw flights. These sand screws may have been modified to be able to run a chemical additive called SandWedge NT.

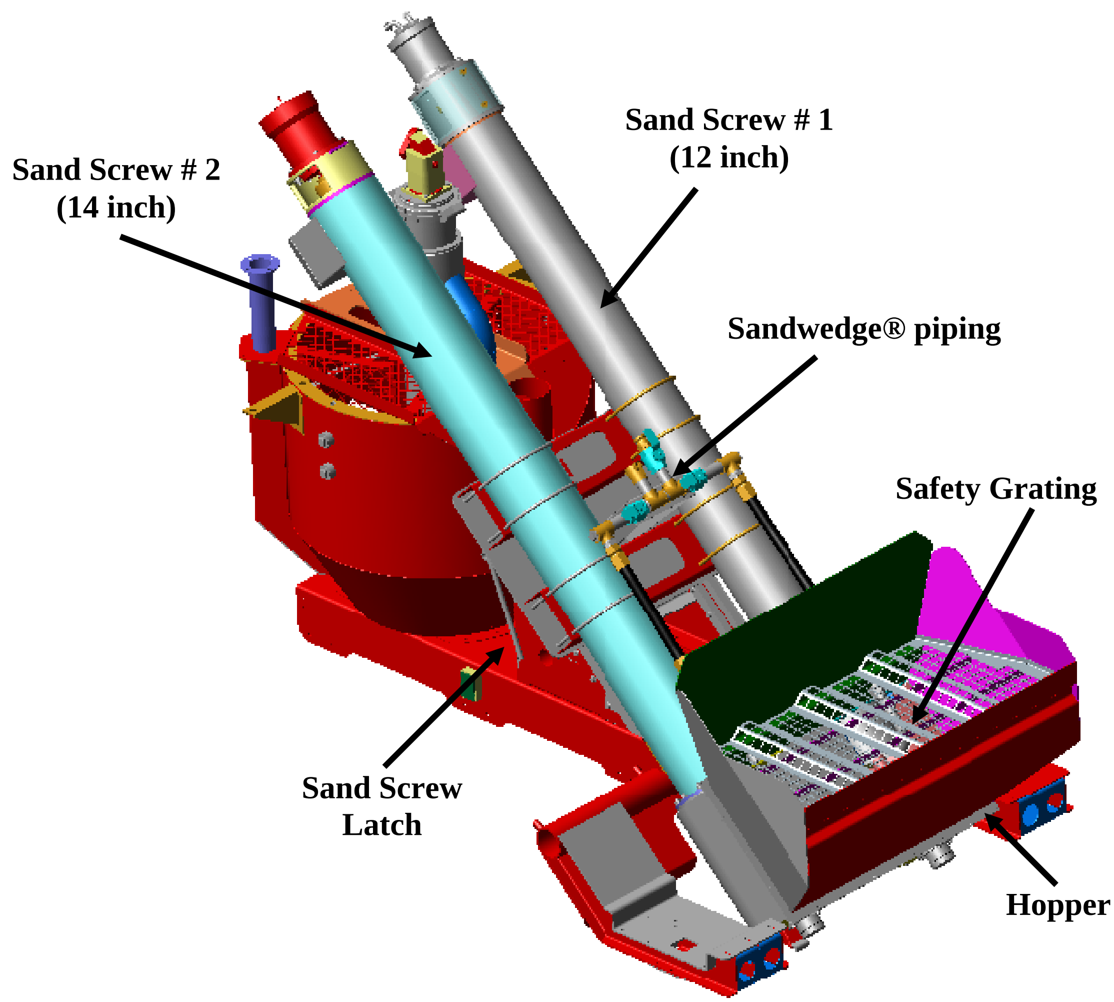

Figure 3.18 – High Rate Blender tub and sand screws

The maximum output for a 12 inch screw is about 100 sacks per minute and, for a 14 inch screw, 130 sacks per minute at a maximum speed of 350 – 360 rpm. Proppant delivery for Ottawa sand is about 30 – 31 pounds per revolution (lbs/rev) for the 12 inch sand screw and 48 – 49 pounds per revolution (lbs/rev) for the 14 inch sand screw.

Different types of proppants have different lbs per revolution calibration settings for each screw. The reason for this can be seen in the different bulk density and absolute volume values for each proppant in Table 3.2. Each proppant type will have a different volume of space it will occupy for a given weight. Proper calibration of the sand screw is imperative for correct proppant dispersal. This requires the operator to have a calibration value for the number of pounds the screw will discharge each revolution. Usually a good reference is the absolute volume of Ottawa sand (0.0452) divided by the absolute volume of the new proppant times the lbs/rev cal factor for sand equals the new lbs/rev cal factor for the proppant.

$$\frac{\text{Absolute vol of sand}}{\text{Absolute vol of proppant}} \times \text{lb/rev of sand}$$
$$= \text{New cal factor}$$

Example:

We are going to pump 20/40 Econoprop. Its absolute volume factor is 0.0444. The screw calibration set point is 30 lb/rev for Ottawa sand in a 12 inch screw. What is the New Cal Factor?

$$\frac{0.0452\,\frac{\text{gal}}{\text{lb}}}{0.0444\,\frac{\text{gal}}{\text{lb}}} \times 30\,\frac{\text{lb}}{\text{rev}} = 30.541\,\frac{\text{lb}}{\text{rev}}$$

Absolute Volume Factors			
PROPPANT TYPE	**Bulk Density (lb/ft3)**	**Specific Gravity (g/cc)**	**Absolute Volume (gal/lb)**
20/40 Ottawa	95.9	2.65	0.0452
20/40 AcFRAC BLACK	102	2.55	0.0470
20/40 SUPER HS	95.5	2.55	0.0470
20/40 ECONO-PROP	96	2.70	0.0444
20/40 CARBO-LITE	97	2.71	0.0442
20/40 CARBO-PROP	117	3.27	0.0366
20/40 INTER-PROP	120	3.13	0.0383
12/18 CARBO HSP 2000	128	3.56	0.3366

Table 3.2

Unit E Quiz

Fill in the blanks with one or more words to check your progress in Unit D.

1. Each sand screw on the blender is operated ________________ of the other(s).
2. Currently, most blenders being manufactured have _____ and _____ inch sand screws.
3. Different types of __________ have different __________ ______ ________________for calibration.
4. A 12 inch sand screw has a maximum delivery of about __________ sacks per minute.

Now, look up the suggested answers in the Answer Key.

Unit F: Hydraulic Systems

The hydraulic system powers the sand screws, centrifugal pumps, liquid additive pumps, tub agitator, and the lift mechanism for the sand screws on all Halliburton blenders.

The components making up the hydraulic system are the

- Prime movers (engines)

  A prime mover, or engine, supplies mechanical energy to drive hydraulic pumps. The prime mover may not be the same on all benders. Late model blenders are equipped with either Detroit or Caterpillar engines.

Figure 3.19 – Caterpillar C-16 diesel engine

  Refer to the blender operation and maintenance manuals for proper maintenance procedures for these engines.

- Oil Coolers

  Modern blenders rely heavily on hydraulically driven components and a large amount of heat is created. The hydraulic fluid needs to be kept below 180°F to be safe and effective. Hydraulic oil coolers work on the same basic principle as the radiator on a car engine. Hot hydraulic fluid enters an oil cooler heat exchanger where air or water is forced past the oil to help cool it.

Figure 3.20 – Hydraulic oil cooler

- Tanks (reservoirs)

  The tank, or reservoir, is the first storehouse for the fluid until it is required by the system. The tank provides a place for air to separate from the fluid and permits contaminants to settle. It also helps dissipate heat that is generated by the system.

Figure 3.21 – Hydraulic reservoir and filters

- Filters and strainers

  Filters and strainers keep the hydraulic fluid clean by trapping contaminants as fluid flows through them. Strainers are simply coarse filters.

- Pumps

Hydraulic pumps convert mechanical energy to hydraulic energy by pushing the hydraulic fluid through the system. Almost every component on a blender, from control valves to the centrifugal pumps, use this energy to operate.

Figure 3.22 - Sundstrand series 90 hydraulic pump

- Accumulators

An accumulator stores incompressible hydraulic fluids under pressure. As the fluid enters the accumulator chamber, it does one of three things: compresses a spring, compresses a gas, or raises a weight.

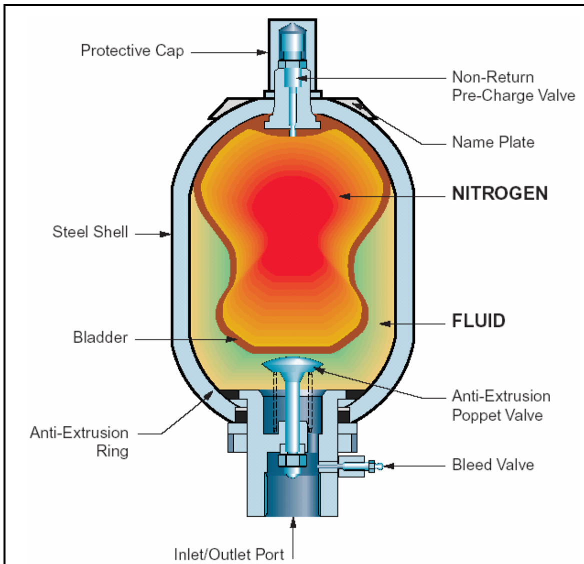

Figure 3.23 - Gas type hydraulic accumulator

A drop in pressure at the outlet causes the element (spring, gas, or weight) to react and force the fluid back out. Accumulators absorb shocks or pressure surges due to the sudden stopping or reversing of oil flow.

- Valves

Directional valves are used to control the direction of flow. A check valve's function is to only permit fluid flow in one direction.

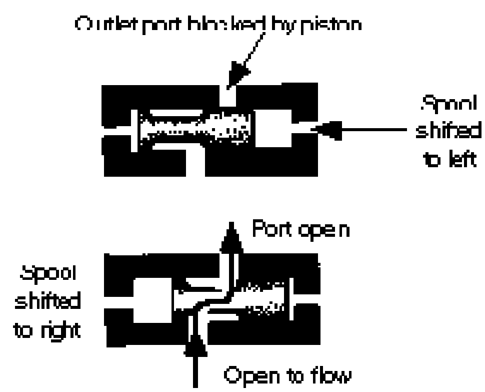

Figure 3.24 - Spool type directional valve

- Cylinders

Cylinders are linear actuators. Linear means that the ouput of a cylinder is a straight-line motion and/or force.

Figure 3.25 – Linear actuator

Cylinders are used for remote operations which require back and forth motion such as sand screw lift.

- Hydraulic Motors

Motor usually refers to a rotary hydraulic actuator. Motors look very much like pumps in construction, but instead of pushing the fluid, motors are pushed by the fluid.

Figure 3.26 – Sauer Series 90 hydraulic motor

This produces torque and rotating motion with drives the sand screws, chemical additive pumps, centrifugal pumps, etc.

The main thing to understand about the hydraulic system is that the hydraulic fluid needs to be kept clean. When filling the hydraulic tank, make sure the container you are transferring the hydraulic fluid from is clean. Also, the hydraulic fluid's temperature can and does run above 180°F. The recommended heat range is below 180°F. So the fluid and thus the hoses and connections are very hot. If the hydraulic oil temperature is above 180°F, contact your local mechanic.

When you see a leak, DO NOT PUT YOUR HAND ON IT. Hydraulic fluid is under pressure and can be injected through your skin. This injection of hydraulic fluid into your system can require the injected portion to be removed.

Most of the hydraulic components on a blender are under computer control.

Unit F Quiz

Fill in the blanks with one or more words to check your progress in Unit G.

1. Prime movers, or _______________, drive hydraulic _______________, which provide hydraulic pressure to the system.
2. Hydraulic leaks should never be covered by ________________________.
3. Hydraulic lines can be very ____________.
4. Above ______°F hydraulic oil temp, you should contact your local mechanic.

Now, look up the suggested answers in the Answer Key.

Unit G: Instrumentation

Because of the complexity of today's stimulation chemicals and job procedures, and the development of new, more critical processes, accurate instrumentation on the blender is extremely important for the success of a stimulation treatment. The four most widely used measuring instruments in stimulation are:

- Flow meters
- Pressure transducers
- Radioactive densometers
- pH probes

Flow Meters

The most widely used flow meter for stimulation is the turbine flow meter (Figure 3.27). It has a rotor with vanes that spin when a fluid is pumped past the rotor. A magnetic pickup on the outside of the flow meter counts each vane of the rotor as it passes. Each vane creates one pulse that is translated into a frequency. The frequency reading from a flow meter is converted into a rate. The flow meters have been calibrated in Duncan with fresh water and have a different calibration factor given in pulses per gallon. This factor is accurate for fresh water only.

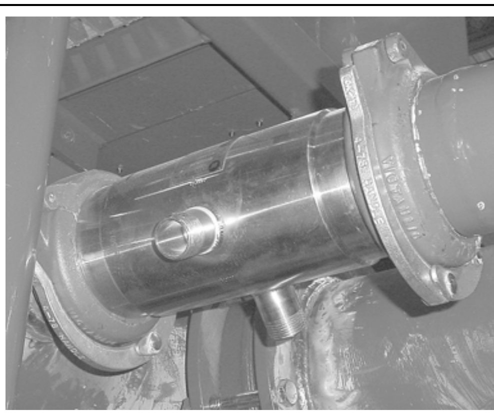

Figure 3.27 – 4" Blender Turbine Flow Meter.

NOTE: Gelled fluids and oils affect the movement of the rotor and a turbine flow meter may give inaccurate readings at certain flow rates. Each fluid has a different effect on the flow meter.

Turbine flow meters range in size from ½ inch to 8 inches in diameter. The blender comes equipped with two "clean side" flow meters installed. The fluid can be pumped through either of these flow meters by opening and closing valves. The choice will be determined by the clean flow rate going through the meter.

It is very important for blender operations to choose the correct size flow meter for the expected rate on the clean side of the blender. For rates less than 20 bpm, use the 4 inch flow meter. For rates greater than 20 bpm use the six or eight inch flow meter depending on what is installed on the blender.

Figure 3.28 – 8" Blender Turbine Flow Meter

Blenders can also use an optional magnometer type of flow meter. "Mag" flow meters have an advantage over turbine flow meters in that they do not have any moving parts and are less likely to be damaged by debris traveling through them. "Mag" flow meters work by measuring the magnetic field created by fluid moving through them. However, this also creates a severe disadvantage in that they are not able to measure non-conductive fluids such as diesel. Most blenders do not have “Mag” flowmeters installed.

Pressure Transducers

Pressure transducers take a fluid pressure and convert it into an electrical signal that can be recorded or used to control a piece of equipment (Figure 3.29). There are two 0 – 300 psi pressure transducers on the blender. The suction and discharge side each have a transducer. These transducers are used to control the centrifugal pumps on the blender.

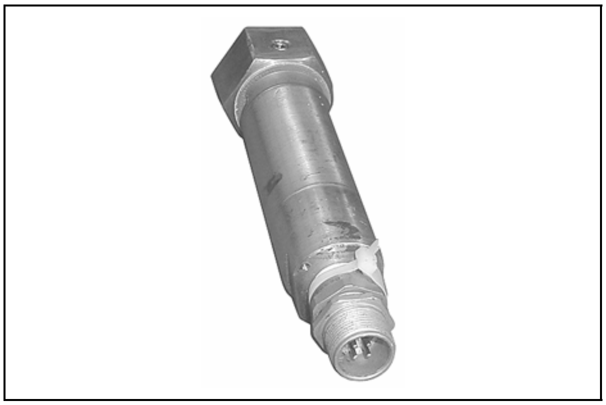

Figure 3.29 – Blender 0-300 psi Transducer.

Radioactive Densometers

Radioactive Densometers (Figure 3.30) are used for measuring stimulation fluid density. From this density, the computer calculates the proppant concentrations. Densometers consist of a lead shielded source material (Cesium-137), a flow chamber, and a photomultiplier tube (PM tube). These densometers work on the principle of absorption of radioactive particles. The source and PM tube are on opposite sides of the flow chamber. Radioactive emissions are directed across the flow channel and are detected and amplified by the PM tube. As fluid passes in front of the source, it absorbs some of the radiation. The denser the fluid, the less radiation is picked up by the PM tube. This can then be converted into a fluid density or sand concentration.

Figure 3.30 - Radioactive Densometer.

Densometers range in size from 2 inches up to 8 inches. 6 inch and 8 inch densometers are used on the blender. Digital densometers make up the majority of densometers in use today. A digital densometer can be calibrated no matter what fluid is in the flow chamber, but is more accurate when calibrated using the Low Cal value with the flow chamber empty of fluid.

The PM Tube should always be removed prior to hammering up or loosening the connections.

pH Probe

A pH probe on the blender is used to help monitor the pH of the fluids that are being pumped. This probe must be taken off the blender after every job and place in a carrier. An electrode on the pH probe contains a solution that must never dry out, so extreme care in handling a probe is necessary. The pH probe is accurate in the pH range of 1 to 14.

The calibration of the pH probe requires two or three known pH fluids. The pH probe should be calibrated before every job to maintain accurate measurement of the pH of the fluid.

The pH probe has a specific direction it should be placed into the stream. The protective hood should be placed upstream of the probe to keep the slurry stream from coming into direct contact with the pH probe end.

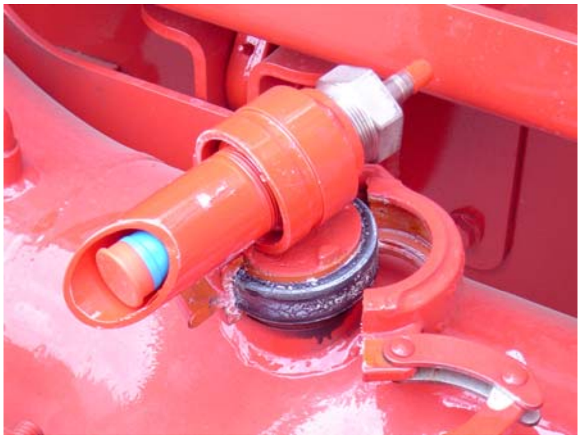

Figure 3.31 – In-line pH probe

The Graphical User Interface (GUI)

On the ARC and ACE blenders, software is used to control the blenders' operation. An electrical signal from the various sensors (pressure, rate, pH, viscosity), referred to as feedback, is constantly being returned to the controlling computer. Feedback is an important element in the operation of the blender. The computer must make adjustments to each device it is monitoring until each gives feedback that equals the "set point" that has been entered. Figures 3.32 And 3.33 are the ARC and ACE control screens. ARC (Automatic Remote Control) blender software is controlled with two-handed, push-button function keys through an OIP (operator interface panel)

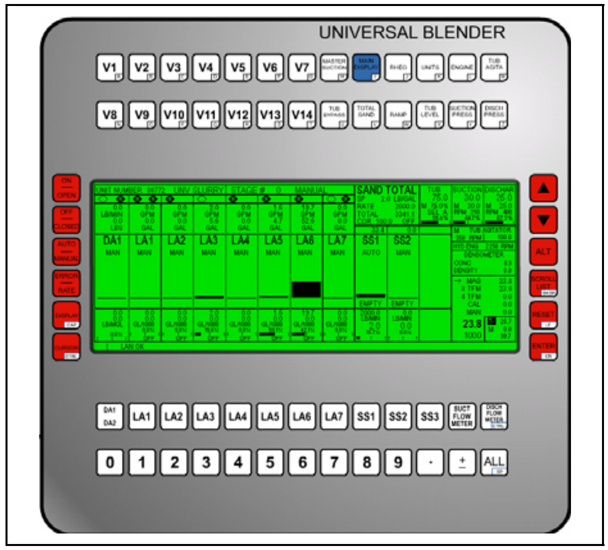

Figure 3.32 – ARC Operator Interface Panel

Factory Link ACE (Automatic Controlled Equipment) blender software runs on Windows NT operating system. ACE software is a later generation of control software that employs the use of touch screens as well as keyboard input.

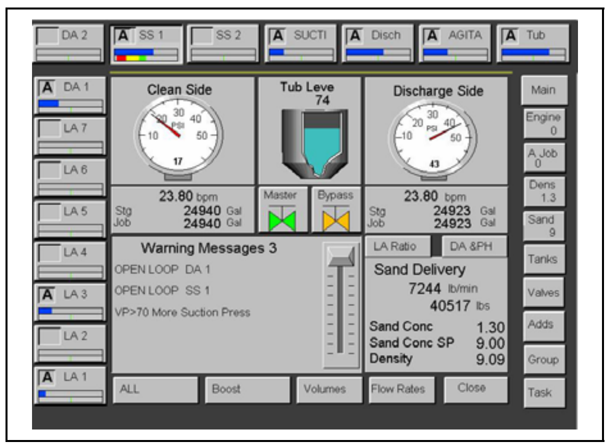

Figure 3.33 – Factory Link ACE Graphical User Interface

The current version of ACE software operates on Windows NT, 2000 and XP software. Improvements include: Built in error check for operator inputs of chemical set-points as well as automated bucket test for Liquid and dry additives.

One great feature of this software is it's ability to be configured as a Blender, a Pump or a Mountain Mover. Another feature is the ability to download the software from Halworld and install on a laptop computer for training purposes. In "model mode" you can set up pumps and pull slurry from the blender, simulating a "virtual job."

Figure 3.34 – ACE Blender Graphical User Interface

The current version of ACE is replacing PCI-2 (Pump Controller Interface) inside our TCC's (Tech Command Centers). Using the same GUI's both on the equipment and insider the control van, and individual has an easier transition onto a job supervisor's role.

Electronic Failures from welding EMI

During the process of welding, both conducted and radiated electromagnetic interference (EMI) can occur. EMI can range from tens to hundreds of volts. EMI can cause electronic malfunction and failure of components such as external sensors, actuators and computers. Never weld on any piece of Halliburton equipment without following HMS guidelines and discussing with your supervisor both safety precautions and what EMI could do to attached electronics. Additional information can be found in Technology Bulletin GST- 03-005.

Unit G Quiz

Fill in the blanks with one or more words to check your progress in Unit G.

1. The Turbine Flow Meter has a movable ________________ with _________________ that turn as fluid passes.
2. The magnetic pickup on a Turbine Flow Meter counts each _________________ as it passes and creates a _________________ that is translated into a _________________.
3. Turbine Flow Meters have a calibration factor that is determined using _________________________.
4. Each fluid has a different ___________ on the flow meter.
5. The pressure transducers on the blender are used to control the _____________ pumps.
6. Radioactive Densometers work by measuring the amount of _________________ _________________ which passes through a fluid.
7. A Digital Densometer can be calibrated with _________________ fluid in the fluid chamber, but is more accurate when calibrated using the ___________ ___________ value.
8. The two Graphical User Interfaces used on the blenders for operation are ____________ and ___________.

Now, look up the suggested answers in the Answer Key.

Self Check Test for Section 3: Blenders & Auxiliary Equipment

Mark the single best answer to the following questions.

1. API gravity is:

______ A) the force of gravity

______ B) surface tension

______ C) the specific gravity of a fluid

______ D) a relative comparison of fluid specific gravity of oils.

2. A job requires the blender to pump a 58° API oil (high vapor pressure condensate) at 70 bbl/min. How many suction hoses are required? (show work)

3. Which of the following will help increase the life of a hose?

______ A) Never drag the hose or pull it by the coupling when moving a hose from the blender to the job.

______ B) Do not drive vehicles over hoses or use hoses for wheel chocks.

______ C) Do not allow any free length in the hose.

______ D) Do not drop hoses so the couplings receive undue shock.

______ E) All of the above.

4. When looking at the suction side of a centrifugal pump, the discharge is on the left side. What type of centrifugal pump is this?

______ A) right-hand

______ B) left-hand

______ C) neutral

______ D) back-hand

5. In parallel operation of two centrifugal pumps, the ___________________ is equal to that of one pump and the _____________________ is equal to the total of both pumps.

6. ______ True ________ False: If the pumps in #5 were in series operation, the system output would be the same.

7. Sand screws deliver proppant to the blender. Sand screws are calibrated to deliver a specific number of _______________ of proppant for each ______________ of the screw.

8. The hydraulic system on a blender is used to power

______ A) Sand screws

______ B) Liquid-additive pumps

______ C) Centrifugal booster pumps

______ D) Tub agitator

______ E) A, B, C and D

9. ______ True ______ False: Turbine Flow Meters are accurate for all fluids without any corrections necessary.

10. ______ True ______ False: Radioactive Densometers are used to determine the density of a fluid.

Now, look up the suggested answers in the Answer Key.

Answers Keys

Refer to the pages provided as references if you answered any of these items incorrectly, or if you were unsure of your answers.

Items from Unit A Quiz

1. couplings / hose cover / hose tube
2. spiral reinforced / wire
3. flow rate / viscosity
4. vapor / lighter
5. 40 bpm $\div$ 10 bpm/hose = 4 hoses

   4 hoses $\times$ 1.5 (for high vis fluids) = 6 hoses
6. covered / fluid
7. free length
8. flush / drain
9. straight
10. flashlight / looking

Items from Unit B Quiz

1. storage tanks / high pressure pumps
2. abrasive fluids
3. air
4. head
5. cavitation
6. valve
7. one / two
8. center (eye)
9. drop / increase

Items from Unit D Quiz

1. one tenth (1/10)
2. fluid / destroy
3. one percent (1%)
4. sack-fed / screw feeder
5. harden / turning
6. free flow

Items from Unit E Quiz

1. independent
2. 12 / 14
3. proppant / lbs per revolution2. proppant / lbs per revolution
4. 100

Items from Unit F Quiz

1. engines / pumps
2. your hand
3. hot
4. 180

Items from Unit G Quiz

1. rotor / vanes
2. vane / pulse / frequencyvane
3. fresh water
4. effect
5. centrifugal
6. radioactive particles
7. any / any / emptylow cal
8. ARC / ACE

Self Check Test

1. D
2. 70 bpm ÷ 10 bpm per hose = 7 hoses
   7 hoses × 1.5 (for high vapor pressure fluid) = 3.5 round up to 4
   7 hoses + 4 hoses = 11 hoses
3. E
4. B
5. head/rate
6. F
7. lbs per revolution pounds / revolution
8. A, B, C, D
9. F
10. T