OTC 8096

Fast Response System for Large-Volume Acid Stimulation

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This paper was prepared for presentation at the Offshore Technology Conference held in Houston, Texas, 6-9 May 1996.

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Abstract

Historically, the conventional approach to large-volume offshore acid stimulation has been to use a vessel dedicated to offshore stimulation services or to use a semi-permanent installation on the rig or platform. This approach often results in long-term commitment to an offshore vessel restricted to stimulation work or a great reduction of the valuable space on the rig or platform for an extended time. Both of these options usually require continuous, large capital outlays with periods of little or no use.

The fast response stimulation package (FRSP) described in this paper provides a 25-bbl/min, centrally controlled, modular, acid-stimulation system with 50,000-gal acid storage capacity, 25-bbl/min, computer-operated blending equipment, acid-resistant manifold modules, and high-pressure pumping units. All processes are monitored and operated from a central control cabin. The FRSP can be quickly installed on an offshore work vessel or drilling rig of sufficient size to perform matrix acidizing and acid frac, and then be removed between jobs. The equipment has recently completed acid-stimulation services in a five-well program in 30 days, delivering up to 41,000 gal of blended acid at rates of 0.5 to 17 bbl/min from two different drilling rigs. This equipment has provided for greater versatility and better use of operator assets while providing specified requirements for stimulation services.

Introduction

When the operator requested an acid-stimulation package for the project in West Africa, there were numerous requirements. Some of the more important requirements are listed below:

- Perform acid-stimulation services from either of two offshore rigs or on an offshore workboat.
- Be able to set up at the jobsite in less than 2 days and demobilize in 1 day.
- Do not exceed 15 MT lift for any one piece of equipment when used on one of the rigs offshore.
- Provide 40,000 gal of raw HCl.
- Establish a pumping rate of 25 bbl/min with no less than 1,800 hhp.
- Be able to batch-mix all the acid before the job to include up to 40,000 gal of flush and 10,000 gal of pad acid, allowing for additional additives during delivery to the well, such as gelling agents.
- Accomplish all these tasks without sacrificing dependability, safety, or versatility, or increasing adverse affects to the environment.

The service company responded with the FRPS, which provides a 25-bbl/min centrally controlled, modular, acid-stimulation system with 41,000-gal raw acid storage capacity, 25-bbl/min computer-operated blending equipment, acid-resistant manifold modules, and high-pressure pumping units. Figure 1 is a photograph of one of the early jobs taken from one of the semisubmersible drill rigs just before completing hookup.

The FRSP Equipment Package

The FRSP equipment design had to be compatible with the vessel and rig, or the crew had to modify the rig or vessel to meet equipment requirements. Major considerations included the following:

- deck space
- deck structural integrity
- vessel or rig trim and stability
- sufficient volume and delivery rates for fresh water, salt water, diesel, air, and electricity.

Existing equipment designs did not meet parameters needed for the specialized acid-stimulation services requested and the fast-setup, multi-location requirements. New equipment was designed and built, structural studies of supporting deck areas on the rig and proposed vessel were performed, and information was furnished to the vessel and rig owners to review for trim and stability, all within 5 months. Figure 2 shows the equipment layout in the various required locations.

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Quick-Response Deck Grid. The equipment had to be arranged to fit the spaces available and maintain proper vessel trim and stability and to properly transmit the loads, including the dynamic loads caused by the anticipated sea conditions back to the hull structure. Dynamic loads on rigs are nearly non-existent, but on the vessel(s), three force conditions are considered:

- 2 g straight down
- 1 g down with a 0.8-g transverse load (athwart ships)
- 1 g down and 0.4g longitudinal (fore and aft)

A deck grid was developed to provide a means of exactly locating and securing each piece of equipment and to better distribute the concentrated equipment loads to the hull(s). This arrangement enables the vessel's deck to be virtually clear for other uses when the FRSP is removed. To quickly secure the individual equipment to the beams, the service company incorporated the ISO lock system, which has been used in the container-shipping industry for quick and efficient movement of equipment for many years. Lighter equipment is secured directly to the decks with ISO locks. See Figure 3 for examples of the various locking systems incorporated.

Blender/Liquid Transfer Skid. The blender occupies one 20-ft ISO frame to provide the easy-securing feature. The blender can mix acids at rates up to 25 bbl/min or deliver preblended acids up to 20 bbl/min. This system has five liquid-additive pumps: two can deliver 1.8 to 5 gal/min, and three can deliver 3.6 to 25 bbl/min. Two Acrison feeders are manually fed from the top of the blender, and each feeder can meter up to 1.6 ft^3/min of dry additives.

The blender resists the effects of HCl acid corrosion with a polyethylene blender tub, a polyethylene, raw-acid transfer pump, Teflon-lined raw acid transfer piping with all system valves fitted with acid/xylene resistant trim. The entire external area of the unit is carefully coated with acid-resistant paint.

The redundancies built into the controls provide for total operation from the control cabin with a prejob programmed computer or pneumatic/electronic override of any single function or group of functions or full manual operation of selected functions from the control stand on the blender itself.

Two discharge pumps from the blender provide system backup or enable operation of two functions at one time. All liquid handled flows through the blender. Figure 4 shows the manifolding used for the variety of blending and liquid transfer tasks. Three mixing procedures were required to meet the requested stimulation programs.

1. The first procedure is strictly a batch-mixing process used primarily for pad acids containing xylene. Proper blending of this particular acid is not done well by mixing on-the-fly because certain chemicals must be thoroughly mixed before the introduction of the next chemical(s) to the solution. The flush acids are premixed and stored in the ISO tanks that originally held the raw acid until actually delivering it to the well. This required a complete recirculation system back to the ISO acid-storage tanks and the ability to draw raw acid from one tank while delivering blended products back to another tank. These preblended acids are then supplied directly to the high-pressure pumps.
2. The second procedure is to pass the premixed acid through the blender a second time to have additional chemical packages, such as gelling the preblended acid, added on-the-fly. The pre-mix can also provide an acid blend that requires more additives (five liquid and two dry) than are available during a single pass through the blender.
3. The third method is to completely mix the acid on-the-fly, which can be pumped directly to high-pressure pumps or through one-half of the 250-bbl blend tank to provide a buffer that helps ensure an uninterrupted flow during the entire job.

Liquid-Additive Module. A 20-ft, ISO-framed, 3,934-gal liquid-additive storage module is located directly next to the blender. The module has six 549-gal and four 160-gal stainless steel chemical storage tanks. The tanks are manifolded to a central discharge point directly across from the blender liquid-additive pumping system. To meet the 15 MT weight requirements, the module can only be lifted into place with about 75% of the tanks loaded and the remainder filled on the rig.

Two-Compartment, 250-bbl Blend Tank. An unlined, two-compartment (125 bbl each), cylindrical batch-blend tank is primarily used to blend and store the pad acids but also can be used as a safety buffer for the flush acids when blending on-the-fly. the blender tank has a remotely controlled manifold to allow for suction from and discharge into any tank with any pump. A lined connection to each side of the tank provides for the addition of acid and xylene.

ISO Acid Storage Tanks. Eight glass-reinforced, tnemec-lined, 5,400-gal tanks installed in 20-ft ISO frames are used to provide the 4,000 gal of 22 Ba HCl acid storage. The tanks are top discharge as required by most regulatory bodies and are pressurized to between 20 and 30 psi when unloading. They are certified for HCl transportation on cargo/container ships anywhere in the world. They can be lifted to the rig with no more than about 1,800 gal of HCl acid and stay under the 15 MT weight limit. Rubber-lined, 2,500-gal marine portable tanks are used to supply the additional acid to complete filling the ISO storage tanks. On the vessel at dockside, these tanks can be loaded to capacity.

Control Cabin. FRSP remote-control and data acquisition are performed from the control cabin, which is a sound- and heat-insulated, climate-controlled ISO container, mounted on a 4-ft spacer above the liquid-additive module to provide a view of the equipment spread. Most of the control functions can be operated in several ways:

- the prejob computer program in the control cabin
- the remote semi-automatic pneumatic/electronic control from the control cabin
- the equipment manually
- a combination of the first two methods (most common operation)

As shown in Figure 5, the pneumatic manifold control console, the manual blender function selection panel, and high-

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pressure pump operation are located on one wall. The single control handle "discharge all" feature shown in Figure 5 simplifies emptying all the tanks in one bank without an interruption in flow by manifolding the tanks in series. On the wall above this console is the emergency systems activation panel, semi-automatic ball injector control, and the acid storage level monitor. Emergency systems in this panel are "all to neutral," "emergency kill," "emergency disconnect," and "fixed fire system activation."

Figure 6 shows one end of the control cabin with the electronics power feed panels, including twin uninterruptible power source (UPS), 12- and 24-volt power supplies, and the computers for (1) programming and monitoring the blending processes, (2) controlling the sequence of job stages, and (3) monitoring and recording well data during the entire stimulation program. If a power failure occurs, the UPS allows for several hours of operation without interruption of the computer and electronic control system. The blending and downhole monitoring system is equipped with two printers that can record the progress of the stimulation program being performed in realtime and provide jobsite reports at job completion.

The other end of the control cabin (Figure 7) has additional blending control indication function set points and system readouts with electronic manual override for each of the individual blend functions. A panel provides single-switch control for stage changes, overriding the computer or transferring operation of the stage flow change totally to the pneumatic console.

FRSP control hookup is accomplished quickly by centrally locating all connections for all functions to be remotely controlled at one point on each piece of equipment, which enables the use of multi-signal connectors between these single points. Figure 8 shows the bank of 19-tube connectors at the control house that provided the control signals to each piece of equipment. Multiconductor connectors are used in the same way to provide electronic control. Only the blender requires more than one pneumatic and one electronic connection to the control house.

Manifold Modules. The several manifold modules are a unique feature that allows for the rapid installation of the FRSP. The modules provide a complex manifold arrangement with relatively simple external hookup. Some valve control functions were moved to the manifold to reduce the number of remote signal connections required from the control cabin.

Four ISO tanks are manifolded together with Teflon-lined pipe so that they can be emptied or filled independently or emptied with the "discharge all" control. A similarly constructed manifold ties the two banks of tanks together into a common manifold to supply the blender.

A manifold module is used for supply and discharge of treatment fluids to and from the high-pressure pumping skids. It also contains a high-pressure remote disconnect, two perforation ball injectors, and the junction box for the two pump skid controls. This allows one connection between the control cabin and the pump area instead of two. An air-driven power supply on the skid operates the ball injector and the remote disconnect.

High-Pressure Pumping Skids. Two Quintiplex 950 hhp, high-pressure pumps are provided with the initial package. A quick installation locking system is integrated with the pump suction/discharge manifold module to provide an integrated unit, fixing the equipment locations relative to each other.

Quick-Response Hookup Features

Co-flexip hoses both on the rig and from the vessel are used to expedite the high-pressure hookup to the wellhead. Bronze Cam-Lock fittings are used on all 4-in. and smaller Teflon-lined hoses used for fluids flow between modules. As previously mentioned, many of the control functions are at least partially performed on the equipment to reduce the number of signals between the control cabin and the function required. Use of the multi-connection hookup system reduced (to seven) the number of pneumatic connections between the control cabin and the equipment to provide pathways for 133 signals. The electronic connections are similar.

Safety/Environmental Protection Features

Safety and environmental considerations are high on the list of priorities in the FRSP. Safety practices used with the FRSP include protective clothing, eye wash, and showers in the work area. The chances of accident from miscommunication are tremendously reduced by having complete control of the processes from one central location. Because several very flammable substances, including xylene, are handled, fire protection is essential. The blender, liquid-additive module, and the xylene tank all have a fixed foam fire system that can be activated from the control cabin.

The spread has seven portable fire extinguishers strategically located about the spread. Two fire hoses from the vessel or rig are pressurized at all times during the stimulation program. Other special fire-fighting equipment is furnished, including a fire suit, fire axes, and two full-breathing apparatus. A remote, high-pressure hose release is installed to allow for fast disconnect of the workboat from the rig in emergency situations. Safety relief valves are installed on all pressure vessels and on the high-pressure discharge to prevent rupture. Clear escape routes are designed into the package.

Environmental issues were considered in the installation of containment walls or drip pans in all major equipment and manifold modules. Drip pans are also installed under the ISO acid storage tanks and in the route of the hoses among system equipment. Fume scrubbers are on the vents from the ISO acid storage tanks and the blender tub. The scrubbers neutralize the acid fumes before they reach the atmosphere. To reduce fumes above the blender tub, especially at the dry additive feeders, a fume eductor provides a fresh-air flow into the tub and directs fumes through the scrubber.

Performance History

Four stimulation jobs were completed between July 1994 and early December 1995. These first four jobs were far apart and

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were less than perfect, although the stimulation programs were successful. The long periods between jobs did not allow the operators to develop the familiarity with this new equipment necessary to learn the limitations or the steps to overcome them. It extended the time to ensure solutions to any problems were effective. After Job 4, six acid jobs were completed between late December 1995 and the first week in February 1996 with good results. Table 1 provides basic information on the those six wells.

The first 10 jobs were performed on the two semi-submersible drilling rigs. The entire FRSP was disassembled on one rig, and then was moved and made ready to operate on the second rig in 3 days.

Conclusions

- The FRSP provides optimum use of operator-furnished marine vessels, which adds value to operator's floating assets and provides a savings in the overall costs for stimulation services.
- The mobile FRSP equipment does provide stimulation services without sacrificing quality or safety.
- Future FRSP equipment will allow for much greater versatility and expanded services from dedicated stimulation vessels and from operator-furnished floating equipment. Much of this wider range of well service equipment is already available.

Acknowledgments

The author acknowledges the contribution of Remy Caulier, who furnished critical field operations and equipment performance data.

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Table 1—Information on Six Wells with Acid Jobs

Job No.	5	6	7	8	9	10
Date	Dec. '95	Jan. '96	Jan. '96	Jan. '96	Jan. '96	Feb. '96
Volume Acid, m^3	95	125	125	156	140	145
Average Rate, bbl/min	5	14	16	5	17	16
On-the-Fly	*	Y	Y	Y	Y	Y
Operator Satisfied with equipment	Y	Y	Y	Y	Y	Y

* Acid was premixed and TLC80 acid gelling agent added on-the-fly.

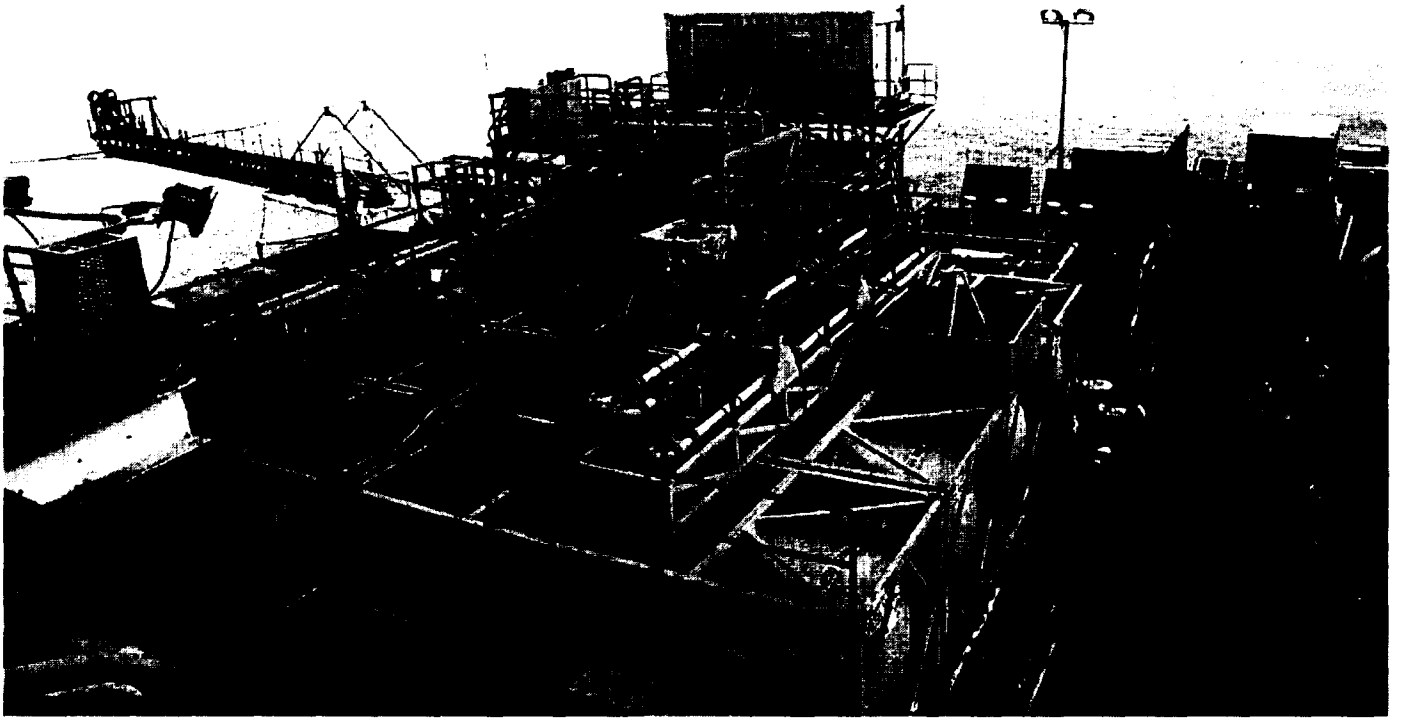

Fig. 1—Job on semisubmersible drill rig just before completing hookup

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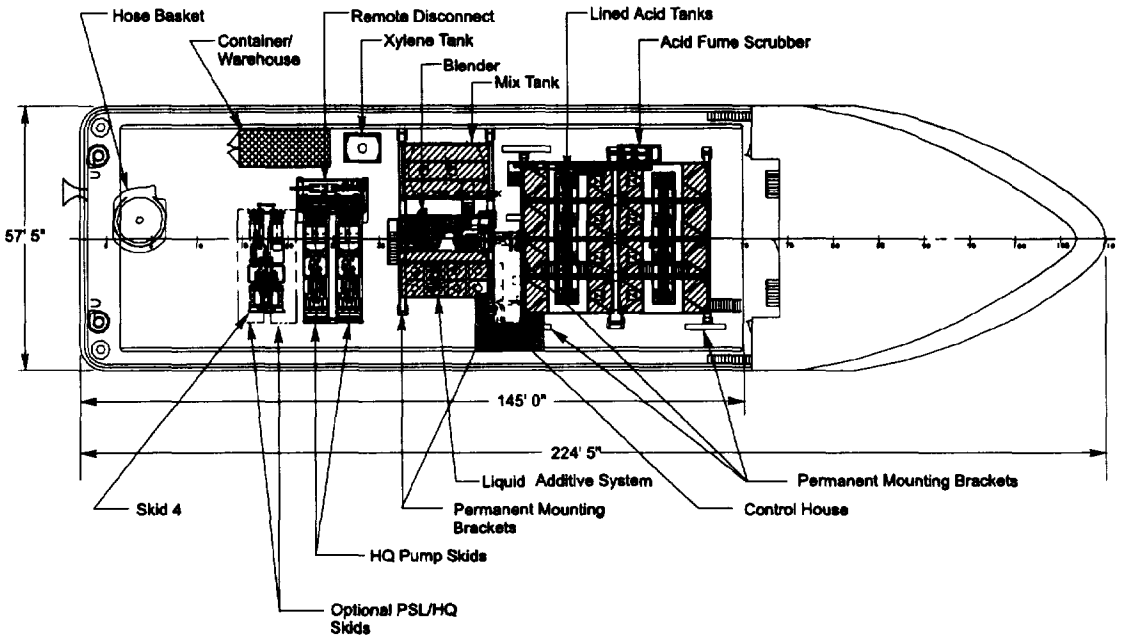

Fig. 2a—Equipment installation on offshore workboat

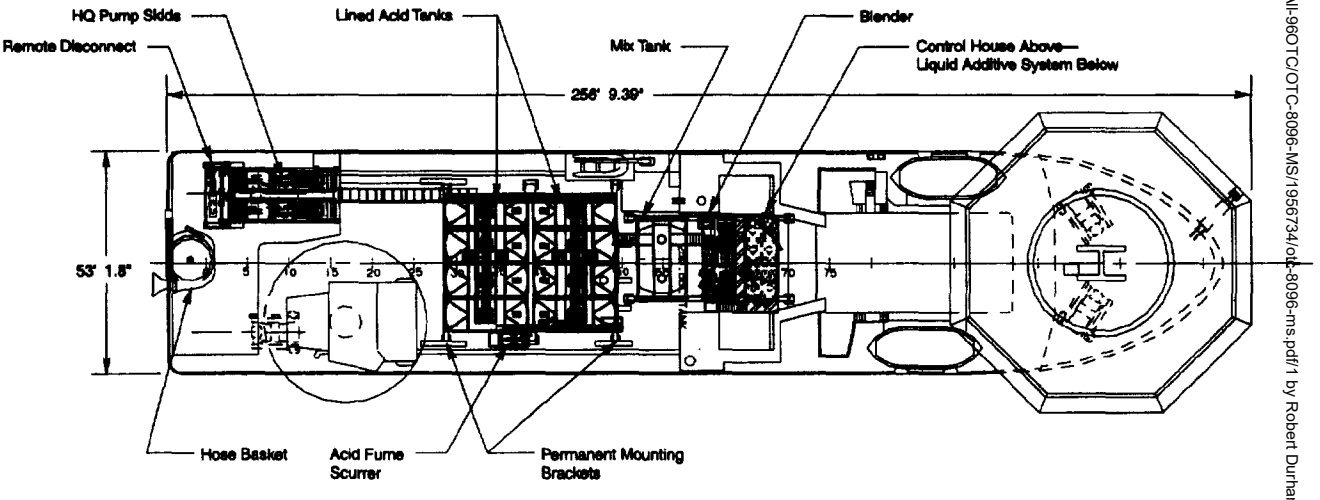

Fig. 2b—Equipment layout for vessel originally proposed by operator

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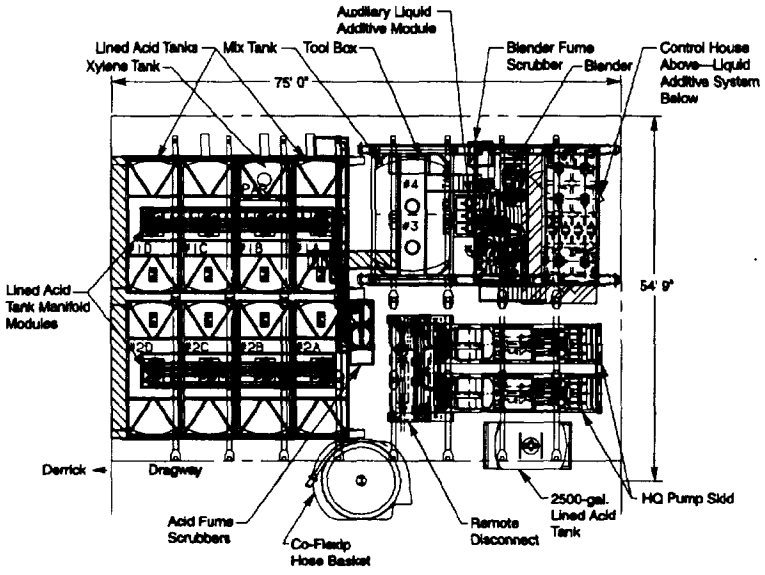

Fig. 2c—Equipment layout on two semisubmersible rigs, where the first 10 jobs were performed

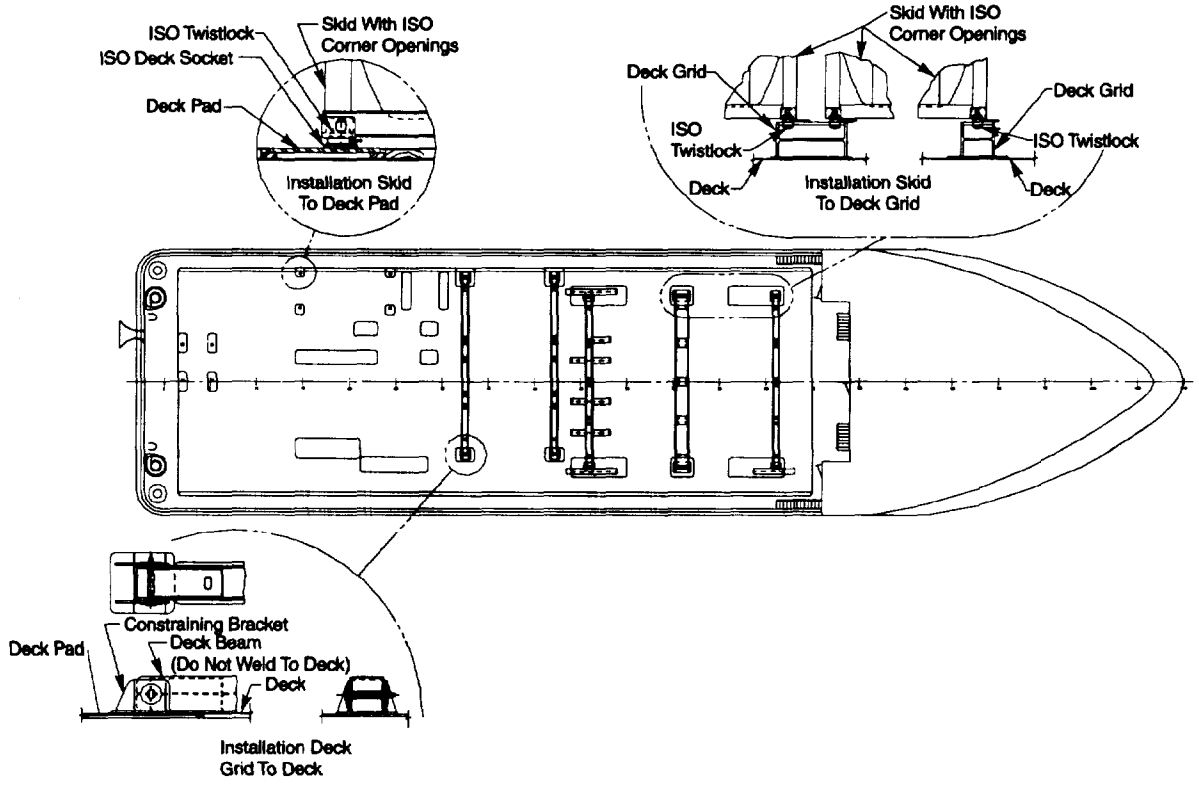

Fig. 3—Methods to secure deck grid and equipment

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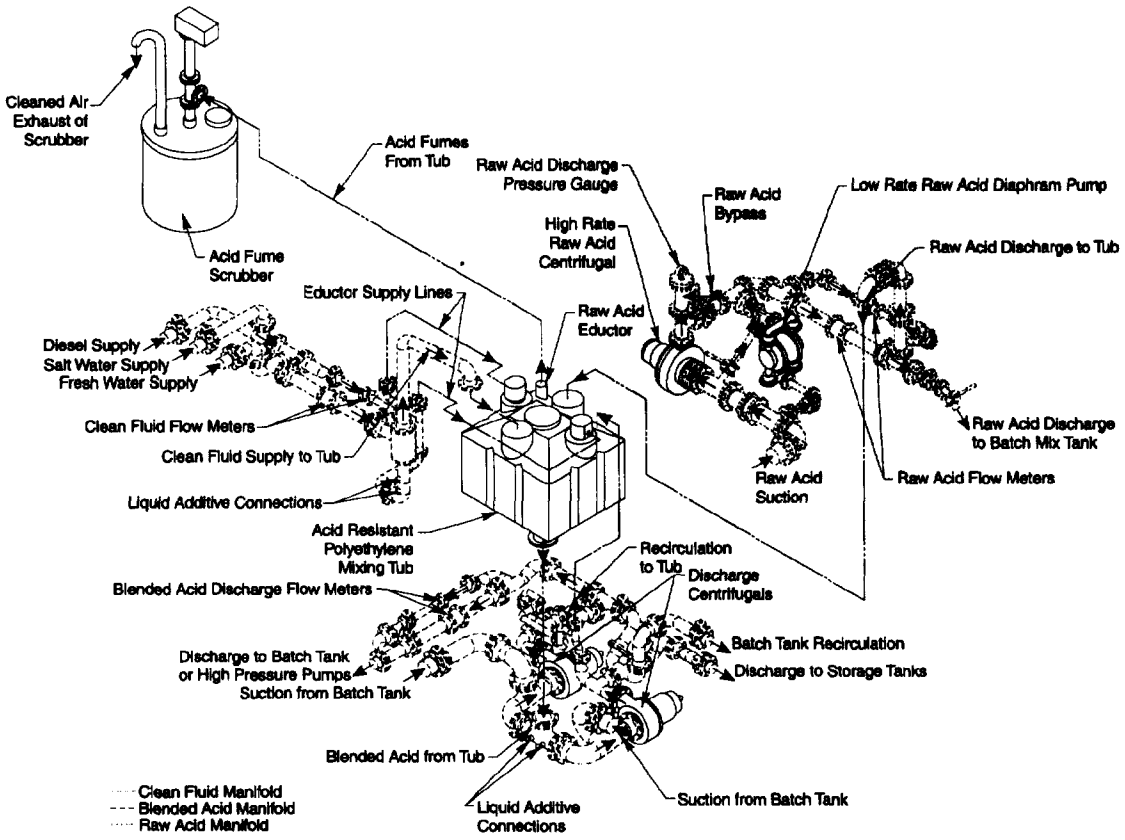

Fig. 4—Multi-task blender manifold

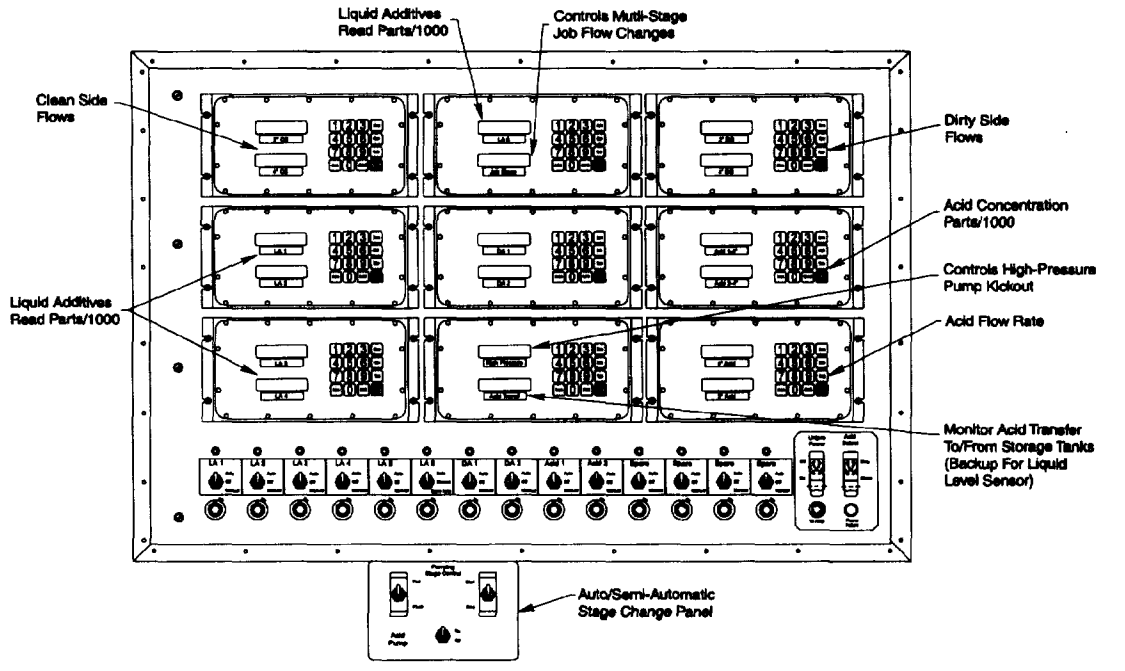

Fig. 5—Control cabin console for electronic function selection and function

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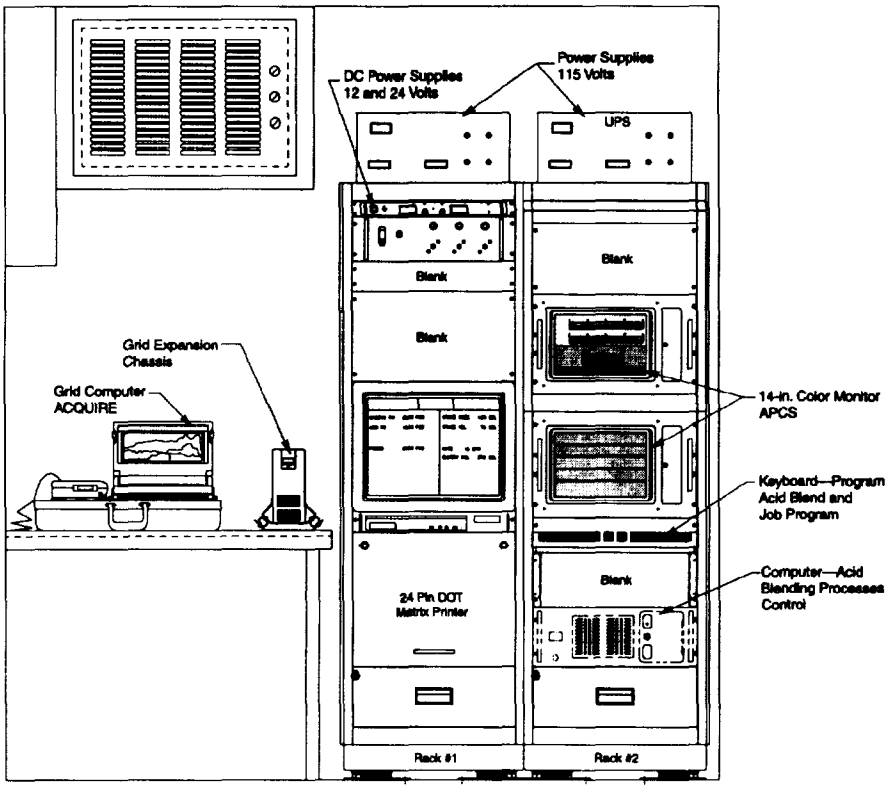

Fig. 6—Control cabin electronic power feed panels and computers

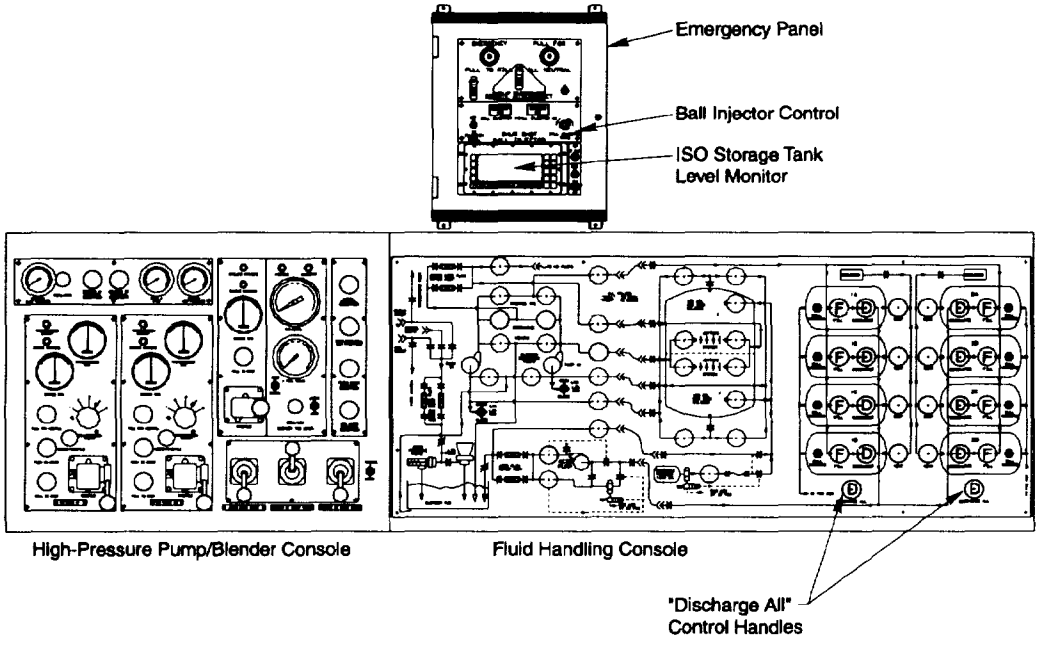

Fig. 7—Control console with "discharge all" control handles

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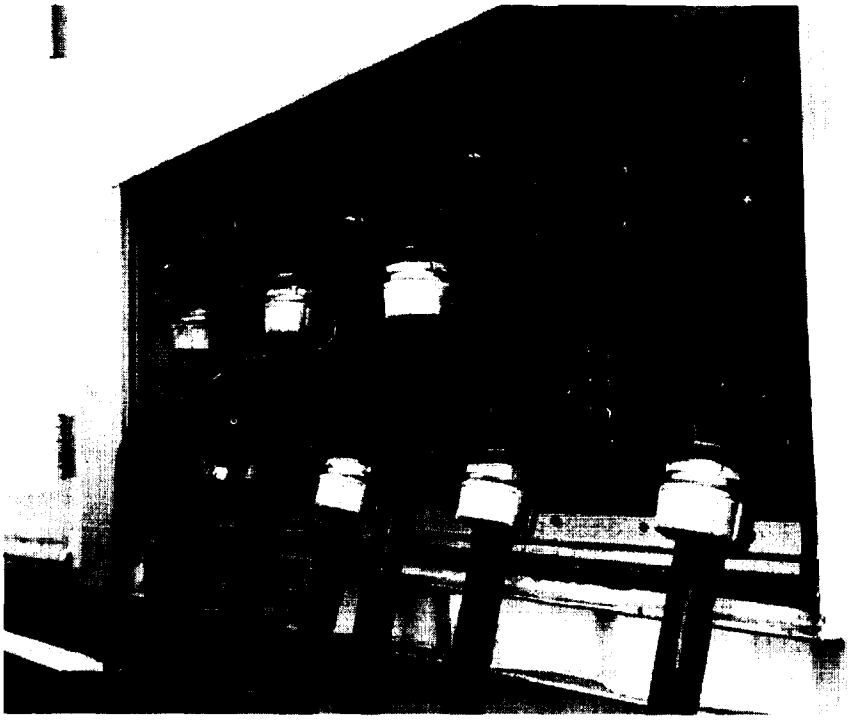

Figure 8—Bank of 19-tube connectors at the control house

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