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Bulk Containment and Transfer of Oil-Contaminated Drill Cuttings: Field Experience using Pneumatic Systems

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Abstract

Regulatory changes in the North Sea have reduced the allowable level of discharge of residual hydrocarbons on drilled cuttings to 1% by weight. This has resulted in cuttings either being injected in slurry form or transferred to shore for processing. Transporting drilled cuttings to shore has also increased in other areas of the world.

This transfer has largely been by the use of specially constructed cuttings boxes. Experiences arising from skip filling and handling operations identified a requirement for new bulk techniques for the safe containment and transport of drilled cuttings.

A bulk transfer and containment method for drilled cuttings based on the use of positive air pressure conveying has been under development since 1998. Initial onshore trials proved the capability to convey drill cuttings samples. A product development programme to adapt this technology to the specific demands of oilfield drilling was then undertaken. In autumn 2000, on-rig containment and rig-to-boat transfer trials were carried out on rigs drilling in UK waters. This paper describes the successful application of positive air pressure conveying for drill cuttings and resulted in further improvements to the technology.

The authors will detail how in 2001 full bulk containment and transfer systems were successfully deployed in the North Sea and in the Gulf of Mexico. The operating principles of the systems are described, along with the design of the principal components. The performance of the systems in practice and the operational experience gained are considered.

Introduction

After January 16, 2001, the offshore discharge of cuttings contaminated with greater than 1.0% residual hydrocarbons on cuttings was effectively prohibited in UK waters. Rules have been tightening worldwide, with similar discharge regimes implemented in all western European waters, the Caspian Sea and other areas. In the US, discharge regulations now require either containment of contaminated cuttings or drying below 6.9 % retention on cuttings for base fluids that meet the environmental performance criteria for IO 1618, and 9.4 % retention on cuttings for base fluids that meet the environmental performance criteria of esters. Improved methods for moving cuttings either to containment, to process before discharge, or to cuttings re-injection units are required.

While the established solution for containing cuttings offshore - ''skip and ship'' - is technically proven, it can be troublesome. Boxes are filled with material on the rig and transferred one at a time to an adjacent supply vessel. Very large numbers of crane lifts are required offshore, which requires a strong focus on safety management. The number of skips involved creates significant logistic management challenges. Operations may also be affected by weather.

A system that could move contaminated cuttings in a sealed system by bulk transfer from rig to boat would eliminate these risks. Several possible technology options exist for the bulk transfer of materials.

Mechanical systems such as augers, conveyor belts, and bucket conveyors are not suitable for rig-to-boat transfer because of the distances and relative motion involved, as well as the difficulty of ensuring total containment.

Slurry-pumping technology is capable of covering the distances involved, and has previously been utilized in the oilfield to convey cuttings short distances. The principle of slurry-based systems is adding fluid and mixing to suspend the solids in a liquid mixture that can be pumped. The addition of fluid obviously increases the size of the waste stream, and may complicate subsequent processing.

Vacuum-conveying technology, which uses an exhauster unit to create a pressure differential and sucks material along a hose or pipeline in a low material/air ratio, may be used successfully to convey cuttings short distances, but is not suitable for conveying drilled cuttings from rig to boat at a sufficient rate over the distances required.

Positive air pressure conveying, which uses compressed air to push granular materials through pipes or hoses with a high ratio of material to air, is widely used in industrial settings including coal-fired electricity generation, foundries, and iron and steel works. The potential to use positive air pressure conveying technology to move drilled cuttings was first identified in 1998.

Development of the System

The primary objective of the design and development programme was to develop a system that could fully contain and handle drill cuttings contaminated with invert emulsion mud all the way from the shaker ditch to the point of processing or final disposal onshore. The technology had to be safe, reliable, and able to handle untreated cuttings at the rate they were produced. Interim storage capability on rigs and supply vessels would be required, and bulk-transfer capability at rates acceptable to overall well logistics was necessary.

The first phase of the development programme was onshore testing, which began in 1998. Initial material tests were carried out in the controlled environment of the manufacturer's in-house testing facility, enabling development of the design concepts. The basic concepts were then tested and proven at an onshore cuttings processing site in Lowestoft, England. Two major oil companies were invited to participate and all equipment was tested successfully onshore before commencement of offshore trials. Various samples of drill cuttings from different wells were used in these onshore tests, which took place in 1999 and 2000.

The cuttings-handling system begins when drilled cuttings contaminated with hydrocarbons exit the shaker ditch and are fed into a hopper above a cuttings blower unit. When the hopper reaches a preset level, the material enters the cuttings blower and is dispatched to combined storage and conveying units located elsewhere on the rig. Each of these units, referred to as ISO-Pumps, can store 20 – 25 m of cuttings, depending on bulk density. The combined storage and conveying units are used for on-rig storage of cuttings until the supply vessel comes alongside.

The units are then discharged through a flexible hose to identical units mounted on the deck of the supply vessel. When the supply vessel returns to harbour, the loaded units on board may be discharged to onshore vehicles, to storage, or discharged directly into a harbour-side processing facility. Alternatively, the units may be lifted directly from the vessel for road transport to a cuttings-processing facility.

Manpower requirements to operate the on-rig equipment consist of one to two dedicated men per shift, depending on the phase of the well. Other than the crane lifts for the hose, there no requirement for the use of the rig crew in operating the system.

The principal equipment used in the system is as follows.

The cuttings blower (Fig. 1) is a totally enclosed device capable of conveying material up to 300 m (1000 ft). It is automated in operation and fed by gravity on a batch basis. The cycle frequency of the cuttings blower is dynamic, automatically adjusting to fluctuations in produced rates of cuttings, whilst maintaining optimal cycle efficiency. An inlet valve, controlled by a level probe, opens under a feed hopper to allow cuttings to enter the unit. Once the inlet valve has closed mechanically, an inflatable seal expands to seal the valve against pressure. Cuttings are then conveyed using positive air pressure, at a design rate of up to 25 m/hr. The preferred location for installation of the cuttings blower is directly under the shaker ditch outlet.

The ISO-Pump (Fig. 2) is a combined storage and conveying unit based on dimensions of a standard 20-ft ISO frame container. It has a nominal capacity of 15 m^3 (100 bbl) and can comfortably discharge material pneumatically at a rate of up to 40 t/hr (136 bbl/hr). It can be operated manually or automatically, and is completely sealed for storage and transport. The design is approved by DNV and suitable for use on the rig, on supply vessels and on any form of land transport.

On the rig, the ISO-Pump is positioned on a weigh frame that is fitted with a load cell and gauge to indicate the weight of cuttings loaded into the unit. Weigh frames are not required for boat installation, as each rig ISO-Pump discharges to an identically sized unit on the boat, eliminating the possibility of overloading. The number of ISO-Pumps required will vary depending on the characteristics of the drilling and logistics programs for the rig. The ISO-Pumps provide significant storage volume for the cuttings whilst the well is drilled ahead.

Specially designed full-bore material-diverter valves (Fig. 3) with one inlet and two outlets are used to direct the flow of cuttings into particular ISO-Pumps. One outlet is selected, and the other bypassed outlet is sealed against the conveying pressure.

Offshore testing commenced in 2000 on a semi-submersible rig west of Shetland. On this rig a cuttings blower unit successfully conveyed cuttings at rates of up to 25 m/hour over distances of 240 ft and to heights of 40 ft. An ISO-Pump unit was successfully filled and discharged after 24 hours settling, and conventional cuttings boxes were filled without difficulty. The equipment operated safely, with no reported incidents and no health and safety concerns noted.

Further trials took place later that year on another semi-submersible with a second operator. The most significant of these was the world's first pneumatic transfer of drill cuttings from a rig to a supply vessel. In this September 23, 2000 trial, a cuttings blower filled an ISO-Pump on the rig with 18 mt of cuttings. This ISO-Pump was then discharged via a flexible hose at a distance of over 61 m (200 ft) to an ISO-Pump on a supply boat alongside the rig. The material was discharged at a rate of 40 t/hr without any problems.

The following illustrations show a typical full system design with a cuttings blower and 10 ISO-Pumps on the rig, and 10 ISO-Pumps on the supply vessel. Fig. 4 shows typical rig equipment, Fig. 5 shows typical boat equipment, and Fig. 6 illustrates a complete system in service.

Full-Scale Bulk Trial: June 2001

Trial Design

The first full-scale bulk transfer trial took place in June 2001. The aim of the trial was to clearly demonstrate the capability of the technology to convey drilled cuttings from their production at the shale shakers through three stages of handling and finally resulting in the transfer of the cuttings from a Platform Supply Vessel (PSV) to a storage/processing facility onshore at Lerwick, Shetland.

Consequently, the total trial was a combination of three separate material handling stages:

- Collection and conveying of the drilled cuttings from the shale shakers, by a cuttings blower to ISO-Pump vessels located on the rig, which provided intermediate storage.
- Conveying of the drilled cuttings from the rig ISO-Pumps to an equal number of ISO-Pumps onboard a PSV.
- Discharge of the PSV-located ISO-Pumps into storage containers on the quayside for subsequent processing.

The rig utilized for the trials was a deepwater semi-submersible operating West of Shetland. The conveying equipment onboard the rig included a cuttings blower, five ISO-Pumps, four material valves and associated conveying pipe.

The cuttings blower was the primary mover, transporting the cuttings in a closed 5-in. nominal bore conveying pipeline through to the storage ISO-Pumps located on the starboard riser deck. A total conveying distance of 131 ft was recorded between the cuttings blower and rig ISO-Pumps.

All of the conveying pipe was 5-in. nominal bore pipe galvanized to reduce corrosion and maintain a uniform internal surface finish.

The five ISO-Pumps were all mounted on weigh frames to enable monitoring of the actual weight of cuttings produced and hence handled by the system

The conveying distance from rig to PSV ISO-Pumps was 394 ft, with 177 ft of this being made of 5-in. hard walled, high-pressure hose, and the balance being flexible hose with the same nominal bore. The hose was made up from 60-ft lengths connected with wing union fittings.

The first stage in installation of ISO-Pumps on the PSV was marine engineering design approval. In conjunction with the vessel owners and marine certifying authorities, a design analysis process was undertaken to ensure stability and security under maximum environmental loading criteria.

The PSV ISO-Pumps were mounted on a load-spreading frame with sea fastenings designed to accommodate the corner blocks of the individual ISO-Pumps. In turn the load-spreading frame was secured to the boat by bolt-down plates, attached to doubling plates welded directly to the PSV deck and aligned with the main PSV load-bearing deck beams. Once the initial work was done to install the doubling plates, installation of the equipment was carried out in under 12 hours.

Five ISO-Pumps were installed onto the PSV together with four R-Valves and appropriate air and material manifolds.

With the PSV ISO-Pumps full of drilled cuttings from the transfer down from the rig, the hose was disconnected. The Platform Supply Vessel is then sailed to land to conduct the final phase of the handling process.

Once back to port at Lerwick, the PSV ISO-Pumps were to be connected to a conveying pipeline on the quayside and the contaminated drilled cuttings conveyed from PSV to quayside storage tanks. In this particular case, the conveying distance was approximately 197 ft terminating, via a deflector hood, into 20-ft x 7½ -ft x 7½-ft tanks. In order to mitigate any chance of drilled cuttings escaping from the system other than at the intended terminal location, the conveying pipe from the PSV to storage tanks was to be run on or within a temporary bunding constructed from plastic sheets and tarpaulins. This precaution was primarily to satisfy local permission requirements, as the chance of the hose breaking is negligible and the material being conveyed was principally solid rather than liquid. Monitoring of atmospheric VOCs during the discharge process took place to ensure safety and compliance with environmental regulations.

Comprehensive analysis of potential safety hazards and failures was undertaken in advance of the trial, with emphasis on ‘engineering out’ any potential risks.

Hose Connection Method

In order to make the hook-up between PSV and rig without the need for any manual lifting of the 5-in. hose, a purpose-designed assembly was manufactured and installed on the PSV. The assembly, known as a tilt table (Fig. 7), offers a simple, quick and safe solution to this challenge.

The following describes the fundamental operations of the tilt table as it is used offshore.

The PSV is located on the port side of the rig. The flexible hose, fitted with lace-on flotation collars, is lowered to the PSV from the main rig crane. The tilt table is lowered to the horizontal-landing position. The PSV deck crew guides the hose onto the tilt-table assembly. The hose is landed and is latched into the unit. The crane lowers off, ensuring all weight is removed from the crane irrespective of PSV- induced wave movement, and the strops connecting the hose to the crane are released. With the crane disconnected and clear of the

PSV, and the hose securely latched in position, an hydraulic hand pump is used to elevate the tilt table from the horizontal landing position to its working angle. The hose is mated with the rigid pipe on the boat and the wing union is hammered closed. At this point the connection procedure is completed. Less than 2 minutes was recorded to complete this entire process.

On June 22, 2001, several days before the actual drilling activities began, a trial was held to demonstrate the functionality of the tilt table. For this the PSV was brought along side the port side of the rig and the hose lowered. The tilt table was used to engage the hose and then disengage. Both stages were realised in direct accordance to the operating procedure to the complete satisfaction of all involved parties. The PSV then sailed back to the stand-off area.

Trial Performance

The cuttings blower was started up as drilling commenced on an 8½ -in sidetrack. Whilst drilling through the whipstock, the cuttings were conveyed from the cuttings blower to a ‘skip filling station’, where three standard cuttings boxes can be filled via a series of diverter valves. During this period, a level probe was used for the first time with the cuttings blower to provide fully automatic control. This level probe ensures the cuttings blower only cycles when sufficient material is available in the vibratory feed chute and therefore direct modulates the cycle frequency of the system to correspond to actual drilled cuttings production rates.

The drilled cuttings were directed to the five ISO-Pumps. This manual change over (rotation of a 90º-bend) took in the order of seven to eight minutes to complete. Filling of the ISO-Pump then commenced.

At this stage in the trial, concerns from the Lerwick processing facility regarding their available storage capacity necessitated a change to the original ISO-Pump filling plans. Due to the limited reception capacity available, a total volume of only 250 bbl was planned to be shipped to shore. The eventual fill weights of the ISO-Pump were recorded as shown in Table 1.

When the first ISO-Pump was filled to the 20½-tonnes (approximately 70-bbl) level, the status of the first diverter valve on the ISO-Pump filling manifold was changed to “through” from the previous “divert” position. The drilled cuttings being produced were now conveyed into the second ISO-Pump without interruption to the cuttings blower operation.

Whilst the second ISO-Pump was filling, the first ISO-Pump was discharged down to the PSV. With the hose connected to the PSV via the tilt table, a conveying airflow was established and the integrity of the pipe and hose verified. With both line and tank airflow confirmed at the ISO-Pump, the outlet valve on the pump was opened. With the standard ISO-Pump discharge characteristics, the cuttings were discharged when the tank pressure reached approximately 60 psi.

During the discharge cycle of the ISO-Pump, the overboard hose was observed to be relatively stable as it lay on the water level, with the aid of floatation collars. A small degree of flexing of the hose was evident particularly at the lift onto the PSV.

During the discharge of the first ISO-Pump, the cuttings blower continued to fill the second ISO-Pump with no difficulty. This demonstrated the capability to simultaneously fill and discharge ISO-Pumps.

During the discharge phase of this ISO-Pump the average discharge rate was 20 metric tons per hour (68 bbl/hr).

ISO-Pumps 2, 3 and 4 were then filled to the weights, shown in Table 1 with each tank containing approximately eight hours of cuttings production.

When the required quantity of cuttings was collected, the cuttings blower was once more connected to the skip filling station to complete the interval whilst the ISO-Pumps were discharged down to the PSV.

During discharge of ISO-Pump 2, the vent pipe on the PSV flexed free of the vent container. Conveying was stopped, the vent hose was secured, and subsequently conveying resumed. This unplanned “emergency-style” shutdown demonstrated the capacity of the system to be stopped suddenly in mid-cycle with conveying lines heavily loaded with material and then successfully restarted.

The average discharge rate recorded was 20 tonnes per hour (60 bbl/hr).

Once the ISO-Pumps were empty, the line airflows were stopped and ISO-Pump pressure reduced to atmospheric. At this stage, the hose was disengaged and capped before being lifted off the PSV. No material was released during the hose-disconnection operation.

Discharge of the ISO-Pumps At Lerwick

Conveying Route

The discharge from the ISO-Pumps rose about 6 ft turning through 90º into the diverter valves and into a common return line. At the edge of the boat, this was attached to a 60-ft flexible hose that joined into the fixed landline for conveying into the storage containers.

At the end of the fixed landline was a short flexible hose feeding into two 90º bends rising about 7 ft and leading over the reception tank to the deflector box.

The total length of conveying line was about 200 ft from the first discharge from the nearest ISO-Pump to the nearest reception tank, and 260 ft for the last discharge from the furthest ISO-Pump to the furthest reception tank.

Unloading

After connecting the shipboard system to the land-based system, the conveying line was sealed at the reception end and the complete system was pressure tested to 105 psi.

ISO-Pump 1 was connected to the system and airflow established down the line. Afterwards, the airflow was switched on to the vessel and the outlet valve opened.

The emptying of ISO-Pump 1 took 28 minutes.

The system was shut down and ISO-Pump 2 was prepared for emptying, while the discharge was changed to the second reception container. Discharge time was similar to ISO-Pump 1.

ISO-Pump 4 was discharged next. Partway through the discharge, the reception tank became full and discharge was suspended by closing the outlet valve and isolating the line air.

The changeover took about 20 minutes and, when complete, the air line was re-established and the outlet valve opened. Material flow started immediately with no problems.

The discharge of ISO-Pump 5 was similar to that of ISO-Pump 2.

After all ISO-Pumps were discharged, they were re-pressurized and a small amount of additional material was conveyed.

After conveying, the system was stripped down. Very little material was found in the conveying lines, although the outlets of three of the systems had a small amount of material left in the outlet valve area.

Analysis of the discharge data showed an average mass flow rate of 35 tonnes/ hour (120 bbl/hr). This rate approached the design transfer rate of 40 tonnes/ hour, conveying the same material that conveyed at 20 tonnes/hour from rig to boat. The principal explanation for the difference between these two rates is the conveying-pipework route, which on the semi-submersible rig was relatively complex and included a length of sloping pipe at a descent angle known to adversely affect conveying performance, whereas the boat to shore discharge route was relatively simple and nearer to the design ideal.

Conclusions from the June Trial

All parties involved judged the loading and discharge of the rig ISO-Pumps as very successful. The average discharge rate of 20 tonnes/ hour from rig to boat (68 bbl/hr) was below the anticipated level. Potential pipe route modifications were identified to improve on this value for subsequent projects. The tilt-table operations demonstrated the capability to make hose connections to the PSV without the need for manual handling.

The discharge of the four boat ISO-Pumps to shore reception was successfully conducted with no operational or HSE concerns. The ISO-Pumps were successfully operated in stop/start mode to enable the discharge hood to be repositioned over empty containers as the discharge progressed.

An average discharge rate of 35 tonnes/r hour was recorded for a volume of drilled cuttings that was analyzed as having an oil-on-cuttings value of 7%.

The cuttings had an angle of repose of 60 – 70º. Consequently, the cuttings built up in the onshore reception container beneath the discharge hood resulting in poor distribution along the container's full 20-ft length. The need was identified for an improved discharge arrangement to achieve a larger working capacity from each container.

Monitoring of the air in the discharge area for VOCs found there to be no measurable emissions.

Full System Deployment: August 2001

In August 2001 the quantity of equipment was increased to include a total of nine ISO-Pumps on the rig and 10 on the PSV, along with an increased number of R-Valves and the existing cuttings blower on the rig. Minor additional hookup pipework was required. The capacity of the system was increased to enable a full 12¼-in. section to be contained. In practice, the figure of nine ISO-Pumps was determined by space limitations on the starboard riser deck.

Three boat trips were made to transfer the material from the rig to the reception facility at Lerwick. Average conveying rate from rig to boat was 34.6 mt/hr, and from boat to shore 43.0 mt/hr.

The average conveying rates achieved for both the rig-to-boat and boat-to-shore transfers were higher than those in the June trial. This was partly a result of modifications to the pipework arrangements, and partly a result of variation in materials conveyed. Since variation in material condition is the norm in drilled cuttings, it is concluded that variations in conveying rate must also be considered to be the norm.

Gulf of Mexico Bulk Trial: October/November 2001

A cuttings-blower unit was installed on a drillship operating in Florida waters. It was required to fully contain and transfer to shore all cuttings from the 17½-in. section and subsequent sections.

It was possible to tie the PSV alongside the drillship and a means was devised to transfer the cuttings directly into skips mounted on the deck of the PSV without intermediate storage on the rig. Fifty standard cuttings boxes were laid out on the deck of the PSV in ten transverse rows of five. Diverter valves were used to direct cuttings along pipework to the set of 10 boxes, and a length of flexible hose was used to connect the pipework to a discharge hood placed over one of those 10 boxes. Once a box was filled, the diverter valves were used to direct cuttings to another set of boxes while the discharge hood and hose were transferred to another box. The conveying distance from the cuttings blower to the last box in the furthest row was 250 ft.

On the drillship, cuttings were fed into the vibratory hopper above the cuttings-blower unit by means of an auger. The available surge volume was minimal above the vibratory feed hopper. The hopper did not fill completely as the feed arrangement was a flat top to the hopper with an 18-in. pipe entering at one edge. The angle of repose of the cuttings prevented the far side of the hopper coming into contact with the cuttings. As a result, the blower unit was run approximately 70% full.

A couple of line blockages were caused by over-filling boxes. These were easily cleared by stopping the blower unit, switching to another box closer in the line to the blower unit and clearing the remaining material into the selected box. At the same time, the cuttings in the full box were spread away from the lid to leave some room in the box. The blower unit was routed back to the full box, and an empty blow cycle performed. This cleared the remaining material from the last section of line and hence the blockage. Then conveying was switched to the next box.

For most of the 17½-in. section, the lithology was the same (shale), with occasionally a higher percentage of marl (a clay-type material). The last 250 ft of hole was siltstone, sand, and shale.

During a couple of well sweeps, the timer was overridden and the blower unit was manually run as fast as possible. This was continued until the surge of returns from the well was past, at which point automatic cycling was reinstated.

The total cuttings production for the 17½-in. section was 933 bbl to the PSV, for 1,693 ft drilled. In addition, 150 bbl of cuttings were transferred to boxes in the moon pool area by backup systems resulting from the first well sweep. During this section the ROP started at 40 ft/hr (for 320 ft) then increased to 80 ft/hr (1170 ft) with peaks to approximately 120 ft/hr. Drilling of the 17½-in. section was never interrupted until it was completed.

Drilling of the subsequent well sections was beset by downhole problems and as a result required conveying rates were very low.

Overall, the operator’s personnel were very pleased with the performance of the blower unit, and drilling was never stopped or slowed down as a result of its operation.

At the maximum ROP of 80 ft/hr, the blower unit cycled once every 100 to 120 seconds at 70% full. It is estimated that at the furthest box an ROP of 114 to 135 ft/min could have been handled successfully by this installation. An improved installation design enabling complete filling of the feed hopper and therefore full loading of the cuttings-blower unit would have enabled a still higher capacity to be achieved. It would be quite possible to use the same cuttings blower to feed a cuttings dryer or cuttings re-injection unit located on the rig, or to fill skips on the rig if required.

Conclusion

Positive air pressure bulk-transfer technology has been applied to solve the problem of bulk transfer of drill cuttings. Full-scale bulk-transfer systems have been successfully fitted to rig and to PSV. OBM cuttings with varying characteristics have been safely and successfully transported to shore reception facilities. Average transfer rates of between 20 tonnes/hour (68 bbl/hr) and 43 tonnes/hour (146 bbl/hr) were recorded

For the UK installation in particular, fewer rig personnel were required to operate the equipment, crane operations were reduced to a handful of hose lifts, and the contaminated materials were kept within a sealed system until discharged into onshore reception tanks. Health and safety and environmental risks were much reduced.

The Gulf of Mexico installation demonstrated the flexibility of the conveying technology in transferring cuttings from the shaker ditch to a series of different locations on the PSV, successfully keeping pace with a 17½-in. section. The potential to use the cuttings blower to feed cuttings dryers, re-injection units, or other containment units was identified.

It can be concluded that this technology is a significant advance in drill cuttings handling, and will assist significantly in the quest to minimize the environmental impact of offshore drilling operations.

Table 1 - Fill Weights for June Trial

ISO-Pump No	Weight of Stored Drilled Cuttings (Metric Tons)	Approximate volume equivalent (bbl)
1	20.5	70
2	15.6	53
3	14.2	48
4	17.6	60

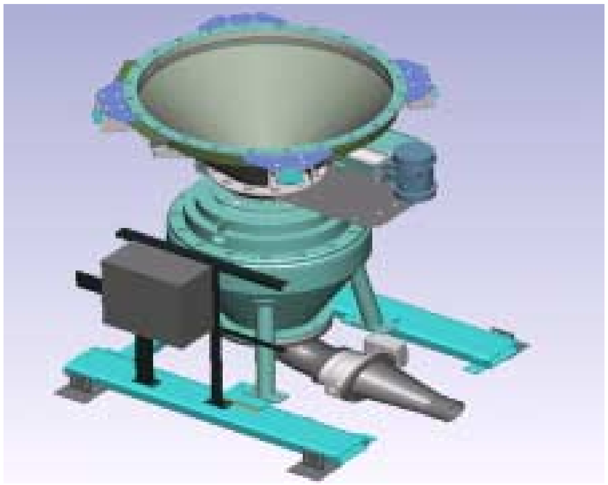

Fig. 1 – CCB.

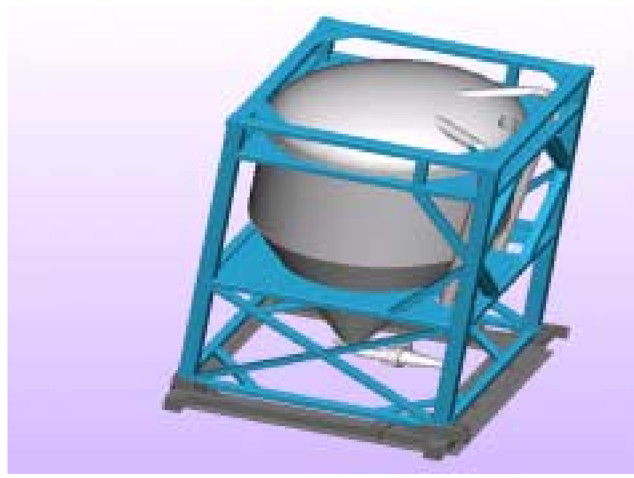

Fig. 2 - ISO Pump.

Fig. 3 - R Valve.

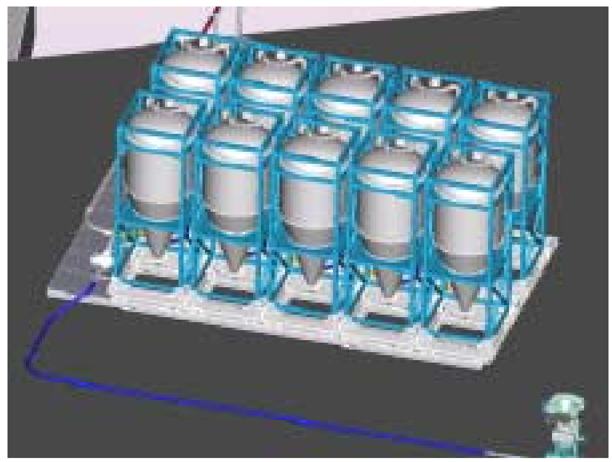

Fig. 4 – Rig-ISO Pump Storage.

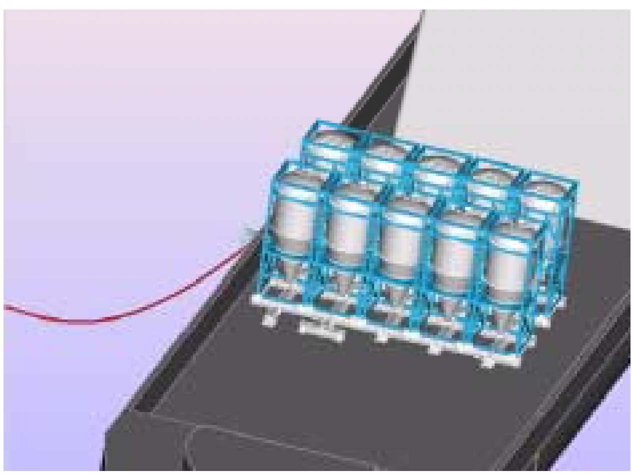

Fig. 5 - Boat ISO Pump Storage.

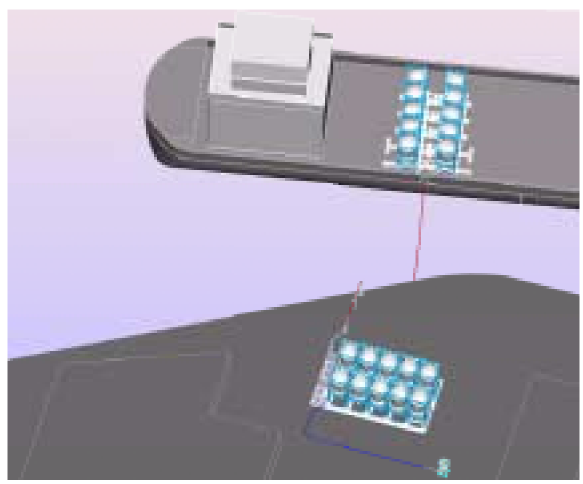

Fig. 6 – Rig-to-Boat Transfer.

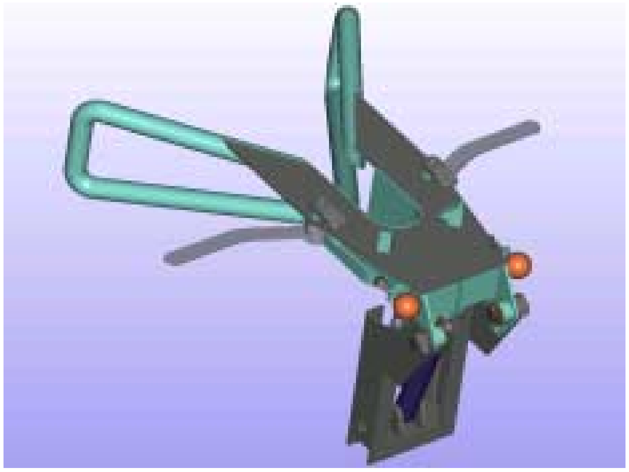

Fig. 7 - Tilt Table.