



**OTC 24724-MS**

## **Stop Erosion at the Well Head on Fractured Wells**

Trina Dreher, Alex Biley, Phillip Tuckett, Process Group Pty. Ltd.

Copyright 2014, Offshore Technology Conference

This paper was prepared for presentation at the Offshore Technology Conference Asia held in Kuala Lumpur, Malaysia, 25–28 March 2014.

This paper was selected for presentation by an OTC program committee following review of information contained in an abstract submitted by the author(s). Contents of the paper have not been reviewed by the Offshore Technology Conference and are subject to correction by the author(s). The material does not necessarily reflect any position of the Offshore Technology Conference, its officers, or members. Electronic reproduction, distribution, or storage of any part of this paper without the written consent of the Offshore Technology Conference is prohibited. Permission to reproduce in print is restricted to an abstract of not more than 300 words; illustrations may not be copied. The abstract must contain conspicuous acknowledgment of OTC copyright.

### **Abstract**

Shale gas and other wells commonly suffer from severe erosion caused by frac sand and other residual solids that routinely appear at the well head and due to their abrasiveness can cause severe erosion in well-head equipment. In particular, it is not uncommon for well head let-down valves (flow line chokes) to require replacement after only a few months of service. In addition to erosion issues, the solids accumulate in downstream flow-lines and process equipment and cause blockages and other operation problems until the solids are removed.

This paper describes how Todd Energy stopped their well head sand accumulation and potential choke and pipework erosion by installing a custom designed Well Head Desander directly at the well head. Before installation Todd Energy had a duplex sand filter that required significant manual intervention to switch filters and empty.

Todd Energy approached Process Group for a long-term solution. Process Group custom designed a Well Head Desander to withstand the highly abrasive environment experienced at the well head so that the solids could be removed from the well fluids upstream of the flow-line choke valve. The custom designed package included a solids accumulation vessel to allow the captured solids to be collected and stored for batch dumping for disposal at regular intervals without stopping the gas flow from the well.

Plant data shows that the Well Head Desander Unit consistently removes frac sand (typically > 50 micron diameter) and other solids that are produced from the well. The Desander remains in continuous operation and biannual maintenance inspections confirm no erosion issues either in the Desander or with downstream equipment.

### **Introduction**

Well head equipment is often subjected to severe service in terms of pressure, erosion and corrosion. High fluid velocities, slugging, sand production and multiphase flow of oil, gas and water mean the equipment needs to be specifically designed to withstand these conditions and still maintain a very high turndown capability. In particular, the presence of sand or other particles in production fluids exposes well head components and downstream equipment to the risk of erosion damage. Severe material loss due to erosion could result in equipment failure and blowout risk, which can have a severe impact on the safety of personnel and on the environment, not to mention the potential loss of production.

The technical and commercial threats posed by solids produced from a reservoir formation are well known<sup>1-4</sup>. Management of these solids is essential and requires proactive strategies to manage the impact of solids on production to maximise the flow and profitability of a well. Solids production can reduce well productivity and also cause significant damage including mechanical damage and/or erosion of choke valves, pipework erosion and accelerated corrosion, reduction of corrosion inhibitor performance, settlement of sand in separators and solids disposal issues. To protect equipment solids need to be removed as soon as possible downstream of the Christmas Tree. Ideally this is upstream of the well head choke valve meaning the solids separator needs to be able to withstand high well head pressures. In addition, early removal of solids prior to contamination with oil is advantageous as it results in a cleaner and easier to dispose of solid waste and eliminates sludge formation and solids accumulation problems. It also avoids sand accumulation and blockage in downstream equipment and avoids the need for sand jetting systems.

A common sand removal method is via a screen filter. The sand is usually collected in the lower part of the filter housing vessel and needs to be manually removed. Trapped sand and debris also requires periodic back-flushing to clean the filter screens. As such, two filter units in a duty/standby mode are required to enable sand to be manually removed from the offline filter. A range of screen sizes is used, typically down to 50 micron. Where the solids volume is very high or where manual cleaning is impractical, for example in remote areas, a well head desander cyclone is preferable; either installed on its own or upstream of a filter. Depending on cyclone design there may be single or multiple cyclones housed inside a pressure vessel.

Desander cyclones are pressure-driven separators and therefore, require a controlled pressure drop to be applied across the cyclone liners to cause flow to occur, which results in separation of the solids from the gas (or liquid) stream. Gas and entrained solids enter the desander cyclone at system pressure via a tangential inlet. The tangential inlet and cyclone liner shape forces the gas/solids mixture to spin in a vortex flow profile. The tapered cyclone shape causes increased rotational acceleration as the internal diameter is reduced over the length of the liner, causing the increasing centrifugal forces to force the separation of the two phases. The heavier solids are forced outwards toward the wall of the liner, displacing the lighter gas phase towards the centre axis of the liner where it forms a core and travels in the opposite direction to the solids before exiting the liner via an outlet nozzle at the top of the cyclone. The heavier solids flow out of the liner through the tailpipe into a solids accumulator vessel. The accumulator vessel can be isolated for emptying without taking the cyclone offline as a certain amount of solids can settle in the base of the cyclone without affecting performance. The solids removal performance of a desander cyclone is most influenced by the density and particle size distribution of the solids, as well as the well head stream properties. Typically up to 99% solids removal (by weight) is achieved with 50-300 kPa (7-43 PSI) pressure drop, although this is dependent on the solids size distribution.

## Discussion

Process Group's CYCLONIXX<sup>®</sup> range of desander cyclones is regularly used to efficiently remove solids from produced water systems. A request in 2001 came from Todd Energy to provide a permanent solution to solids removal for their first Mangahewa natural gas well. The well, located in Taranaki, New Zealand, had been in operation intermittently for about four years with initial testing commenced by its previous owners. This initial testing indicated that significant amounts of frac and formation sand were produced following fracking. Therefore, at the well head a down-hole sand screen filter was installed in a simple housing and although sand production ceased after a relatively short period of time the device was retained during long-term production tests with temporary facilities. The production tests were successful over a 12 month period with no sand production so permanent facilities were installed. The locally made sand screen was retained as insurance against sand production however, the increase in production made possible by the new permanent facilities significantly increased the reservoir drawdown which resulted in production of both frac and formation sand that overloaded the screen filter. This resulted in the screen quickly wearing out and providing inadequate protection for downstream equipment. In particular the choke valves suffered severe erosion and needed to be replaced regularly. Due to the ANSI class 2500 rating of the well head, manual cleaning of the sand screen filter required a complete well head shut down for a period of approximately six hours, which was not sustainable. As such, a temporary duty/stand-by drilling type sand filter was installed and site manning increased to allow for frequent sand removal as an interim measure to maintain gas production while a permanent, low maintenance sand removal system was sought.

Shell Todd Oil Services, the then operator of the well, investigated options and approached Process Group to design a continuous online sand removal system with a conservative fine cut and high recovery as the well was the only well in production so risks had to be minimised. In addition, the system had to;

- Be suitable for use at remote sites,
- Be fully automated, simple to operate, and relatively inexpensive,
- Operate over a wide range of flow conditions and solids loadings, and
- Be easily moved from well head to well head.

Process Group's desander cyclone system easily met these requirements however, the package design conditions of 345 Barg and 100°C and the highly abrasive well head environment caused by the high sand content and large particle size presented significant challenges in the design and construction of the desander cyclone and pressure vessels.

A major challenge was to reduce the abrasiveness of the sand particles entering the desander cyclone, which was achieved by modifying the flow path into the cyclone. In a well head separation process the separation is usually of gas and solids rather than water and solids, the latter which is typical of produced water applications. The larger density difference between the phases means that the length to diameter ratio of the well head cyclone can be reduced, which allows the use of a single, large diameter cyclone rather than multiple small diameter cyclones as is typically used for produced water applications. The use of a single, large diameter cyclone allowed more accurate control of the flow path into the cyclone liner. To control the inlet flow, Process Group custom designed an inlet sleeve piece to guide the multiphase sand flow from the desander cyclone inlet nozzle into the cyclone liner tangential inlet. The design of the inlet sleeve ensured a shallow angle of impact on the desander cyclone interior wall of the entering fluids thereby minimising their erosive power.

Due to the very high pressure rating manufacture of the pressure vessels required an unusual approach. Pressure vessels are typically manufactured from rolled steel plate or pipe material however, steel plate of the required thickness could not be rolled to the small diameters required to house the cyclone while pipe material is not commercially available with the wall thickness required to meet code requirements. Therefore, both the Desander pressure vessel and the Accumulator pressure vessel were custom designed to be fabricated from machined steel billets. The machined vessel parts were specifically designed to incorporate the required nozzles into the vessel heads and shell which could then be bolted together to minimise welding. Essentially, a solid steel cylinder was bored out to create a hollow middle where the desander cyclone liner could be installed and a second solid cylinder bored out to create the accumulator vessel. Figure 1 shows the desander cyclone liner being lowered into its pressure vessel machined from a solid steel billet. Extensive Finite Element Analysis (FEA) was performed to determine the stress profiles of the vessels and the required wall thickness and shape of each portion of each vessel; an example is given in Figure 2. An additional challenge was attaching the vessels to each other and to the process lines as methods such as standard flanges and clamp locks were deemed unsuitable due to material, weight, mechanical, and/or cost constraints. Therefore, Process Group designed custom flanges to fit within the aforementioned constraints as well as meet all process and mechanical specifications. The final design involved the unusual design of bolts being directly screwed into the vessel shell wall to minimise welding.



Figure 1: Desander cyclone being lowered into containment vessel.

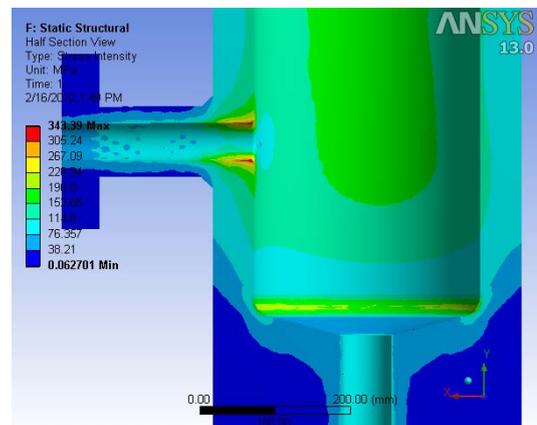


Figure 2: Finite element analysis image from desander accumulator vessel

To facilitate online removal of accumulated sand, a separate accumulator vessel, where separated sand settles, was installed below the desander vessel. The accumulator vessel can be isolated from the well head desander, depressurised and safely emptied while the desander vessel remains online. A small sand accumulation area is retained in the lower portion of the desander vessel so that sand removal can continue while the accumulator vessel is isolated. A water flushing system is also incorporated in the accumulator vessel to aid sand removal from this vessel.

For highly abrasive applications, such as those experienced at a well head, Process Group manufactures its CYCLONIXX range of desander cyclones in a range of highly wear resistant materials such as tungsten carbide and reaction bonded silicon carbide as they provide excellent wear resistance while not being too brittle. For large well head desander cyclones reaction bonded silicon carbide is the more economical choice and to provide additional mechanical strength the desander cyclone cone is enclosed in a duplex stainless steel sleeve.

In order to maximise package simplicity and minimise cost, a single 200 mm diameter cyclone was required for this project. However, at this diameter the cyclone was four times larger than Process Group had typically manufactured which presented significant mechanical design issues. Specifically, the larger sized cyclone liner led to an increase in the thermal expansion of the material that rendered the adhesive used to join the individual ceramic pieces that make up the silicon carbide desander

cyclone prone to cracking, as well as an increased risk of explosive decompression due to the very high operating pressures. Explosive decompression occurs when gas is allowed to ingress into the pores of the adhesive during operation and upon decompression of the system this gas expands very rapidly causing an explosion. It was essential to eliminate this occurring in the desander cyclone as it would cause catastrophic failure of the cyclone, as well as present significant safety risks. Therefore, Process Group extensively tested a wide range of adhesives before settling on a single-part, heat cured Epoxy adhesive. This adhesive is tolerant to thermal expansion and does not permit the ingress of gas into the pores of the adhesive, thereby ensuring the integrity of the large diameter desander cyclone at well head conditions.

The completed well head desander cyclone system is shown in Figure 3. Due to the compact nature of the desander cyclone package and its low maintenance requirements, it is equally applicable for offshore or onshore applications. The desander system was installed on the original well and as it performed so successfully it was also installed on additional wells in the Mangahewa field. The original system has been in operation for over ten years and has not required any substantial maintenance nor suffered any significant erosion during this time. In addition, few solid materials have been observed in downstream equipment. The desander systems installed on subsequent wells have been in operation for over a year and have also shown no signs of erosion confirming the efficiency and integrity of the process and mechanical design.



Figure 3: Completed well head desander package

## Conclusion

Shale gas and other wells commonly suffer from severe erosion caused by frac sand and other residual solids that routinely appear at the well head, particularly during the early and late production life of a well. Due to the abrasiveness of the solids they can cause severe erosion in well head and downstream equipment and hence proactive management of solids is essential to ensure the integrity and continuing operation of the well.

To remove frac sand from the mixed gas/liquid feed for the protection of downstream equipment at well sites sand filters are often installed, which required significant manual intervention to switch filters and empty. A more robust solution is the installation of a desander cyclone system to continuously remove solids from fluid streams and automatically dump accumulated solids into an appropriate receptor. Desander cyclone systems have the advantage of having very high turn down and very low maintenance requirements.

Very high well head pressures present significant design challenges for desander cyclone systems however, Process Group has overcome these challenges via the development of customised manufacturing techniques to ensure the mechanical integrity of its desander cyclones. Process Group's custom designed well head desander systems have proved to be highly durable, reliable and require little maintenance, as illustrated by the unit that has for over 10 years withstood the highly erosive environment at one of Todd Energy's Mangahewa wells with no erosion or maintenance issues. These desander systems are highly suited to test, early production and old or deteriorating wells where sand production rates are high or variable, or where a conservative approach is required to ensure no solids pass to downstream equipment. Due to the compact nature of the desander cyclone package and its low maintenance requirements, it is equally applicable for offshore or onshore applications.

### **Acknowledgements**

The authors gratefully acknowledge the assistance of Todd Energy in the preparation of this paper.

### **References**

1. Barton, N.A., Erosion in elbows in hydrocarbon production systems: Review Document. Report RR115 prepared by TUV NEL limited for the Health and Safety Executive, 2003.
2. Venkatesh, E.S.. Erosion damage in oil and gas wells. Proc. Rocky Mountain Meeting of SPE, Billings, MT, May 19-21, 1986, pp 489-497.
3. Andrews, J., Kjørholt, H., and Jøranson, H., Production enhancement from sand management philosophy. A case study from Statfjord and Gullfaks. Paper 94511 presented at the SPE 6th European Formation Damage Conference, Scheveningen, The Netherlands, 25-27 May, 2005.
4. Enform Safety alert - #08-2009, Casing erosion causes uncontrolled well release, release date June 15, 2009