The DepthStar™
A Solution to an Industry Dilemma

The Problem:
How Can the Industry Continue to Meet the Equipment Demands Imposed by the New Areas into which Development is Venturing?

The Answer:
Be proactive! How? Develop new concepts instead of trying to stretch the limits of the old ones!

This idea has recently been used to solve the problems that have plagued the industry with tubing-retrievable safety valve (TRSV) performance as development has ventured into deep-water environments. The DepthStar™ is an example of this approach.

Although TRSV performance has been improved drastically over the last decade, development into deeper and more corrosive offshore environments has continued to push TRSVs to their limits. An example of the additional concerns that have surfaced for deep-set applications is the higher valve opening pressures required. Conventional solutions have focused on balancing the piston area, which called for additional seals and/or gas-charged chambers. To maintain reliability, these solutions depend heavily on elastomeric seals and/or the permanent, long-term containment of a dome charge or pressure counterbalance. Unfortunately, when designing for life-of-the-well reliability, dynamic elastomeric seals pose a major limitation.

In a revolutionary TRSV design, a floating-magnetic-coupler mechanism is used to position the hydraulic actuator in a dedicated chamber isolated from contact with well fluids and pressure. By separating the hydraulic actuator from the tubing wellbore, this valve

- is the first in the industry to have 100% metal-to-metal (MTM) sealing with no moving seals within the tubing wellbore,
- does not need high-pressure operating equipment since the low hydraulic operating pressure of the valve simplifies the complexity of the pressure source equipment,
- could completely eliminate high-pressure equipment and associated umbilical line, (often more expensive than the TRSV),
- increases the life of the well and environmental and personnel safety while reducing system costs and sealing requirements.

Introduction
Deepwater activity has become a critical part of the oil and gas industry to the extent that deepwater prospects have become the primary driver of capital expenditures with both majors and independents. However, these new environments have subjected the equipment to more corrosive high pressure/high temperature (HPHT) conditions.

In addition to deepwater development, 3D seismic tools have turned up other areas to explore. These deeper targets promise superior production capabilities, but will further challenge technology. New equipment will be required to drill and complete these potential “super” wells with reservoir depths as deep as 40,000 ft., bottomhole temperatures above 400°F, and bottomhole pressures approaching 30,000 psi. These conditions would place further challenges on Surface-Controlled Subsurface Safety Valve (SCSSV) design. The knowledge that the industry would require equipment that would outperform present SCSSV designs encouraged a major oilfield engineering and manufacturing company to partner with a major magnetic technology company to explore a completely new concept in safety valve design.

Dexter at a Glance:

> ISO: 9001:2015

> AS9100D

> Clean Room Class 10000 (ISO7)

> Patented Magnetic Technology

> Flexible Manufacturing

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About Dexter

Dexter Magnetic Technologies is the global leader in specification, design and fabrication of magnetic products and assemblies. Since its founding in 1951, solutions designed by Dexter have and continue to positively impact our world daily – from life-saving medical devices to intelligent optics.

As the essential magnetic system partner, our teams of engineers and support staff are dedicated to delivering innovative technological solutions and services through a powerful combination of engineering and manufacturing expertise.

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General DeepWater SCSSV Application

Using conventional SCSSV technology, the valve's setting depth and the internal wellbore pressure work together to create the operating pressure required to maintain the SCSSV in the full-open operating position. So, as the setting depth of the SCSSV increases by 100 ft., an increase of 100 psi is needed to operate the SCSSV. Therefore, a one-to-one increase in operating pressure as the internal wellbore pressure at the SCSSV increases is also necessary. (See Figure 1)

Current DeepWater SCSSV Technology

The current solutions for higher valve-opening pressures associated with deep-set applications have focused on balancing the wellbore and its influence on the hydraulic operating piston. By balancing the wellbore's reaction on the piston, internal wellbore pressure at the SCSSV no longer directly affects the operating pressure.
But, this type of solution typically requires additional seals and/or gas-charged chambers, which are heavily dependent on elastomeric seals and/or the permanent, long-term containment of a dome charge, to maintain reliability. Because SCSSVs are critical to overall well safety, reliability is a primary issue. Advances in design and enhanced validation testing have played roles in increasing the reliability of SCSSVs. However, validation testing has been limited due to the difficulty in simulating conditions that could prove long-term reliability for elastomeric seals and gas containment. A simplified design that eliminates seals and uses non-elastomeric and MTM sealing technology has contributed to the increase in SCSSV dependability.

Increasing emphasis on MTM sealing also provides significant improvements. In today's SCSSVs, MTM body connections are standard and with the use of "ball type" sealing, full MTM flapper systems are also available. Simplified construction techniques and non-elastomeric sealing have greatly advanced the hydraulic actuation system. However, conventional SCSSV design positions the hydraulic piston within the wellbore and requires wellbore pressure containment using moving seals, adding to design complexity. Wellbore pressure connectivity with dynamic hydraulic seals presents issues:

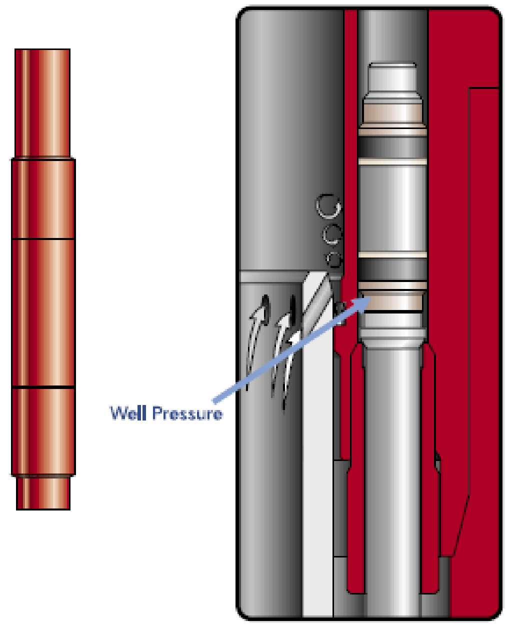

Figure 1, Conventional SCSSV Operating Piston Design

- Direct connectivity requires seals be compatible with the well fluids and any fluids that might be injected into the wellbore.
- Seals are often subjected to high differential pressures. It is not uncommon for gas or hydrocarbons to escape into the hydraulic system over time. Gas migration can be very costly and cause operational risks like higher operation pressures.
- When using a fixed pressure balance system (dome-charged valves), the dome charge must be primed for the wellbore pressure. Current conditions and predicted conditions over well life must be determined. Over time, operational pressure demand can change with varying well conditions. When multiple wells are on a single-control system, one well change can affect the entire system design.

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The ideal solution is to completely isolate the piston from the wellbore, allowing the SCSSV to operate at a low pressure, independent of wellbore conditions. This is a difficult solution since the piston provides the means of actuation in conventional SCSSV designs, and therefore, must remain connected to the closure mechanism for proper SCSSV operation.

Magnetic Coupler Technology Offers a Solution

Incorporating a floating-magnetic coupler mechanism positioned the hydraulic actuator in a dedicated chamber isolated from the well environment and provided the desired actuation of the SCSSV without the piston being physically attached to the operating mechanism.

When designing a floating magnetic coupler, two basic questions had to be answered: How much force could be achieved? and What amount of coupling force would be required to ensure reliable valve operation? To determine the amount of coupling force needed, SCSSV technology can establish a benchmark target. A 150-lbf benchmark was chosen as a minimum coupling force for the magnetic coupler since conventional platform SCSSVs use a minimum spring force of 150-lbf. This provides the necessary mechanical closing forces when operating in debris-laden environments. A rare earth permanent magnetic material called Samarium Cobalt (SmCo) was selected. A 250-lbf coupling force was achieved using a 4½-in., 10,000 psi prototype.

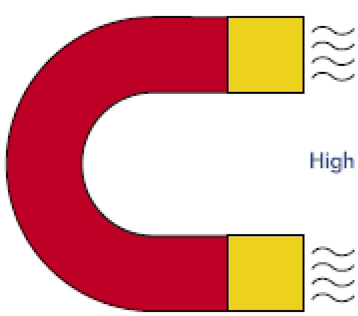

Figure 2, Examples of the Forces in the Coupler

Using a sophisticated computer software design package and working closely with the magnet suppliers, several magnet

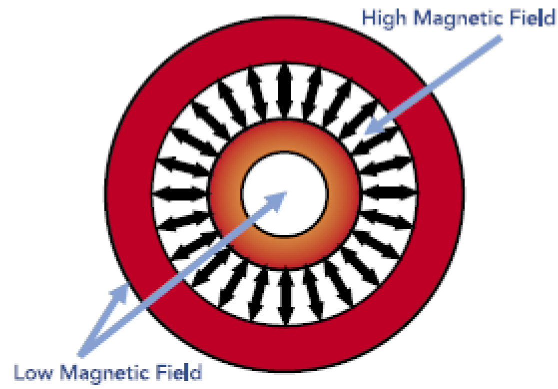

Figure 3, Magnetic Coupler Design

configurations were reviewed and evaluated until one was chosen that would provide 900 pounds of connectivity, which was six times the targeted bench mark—a salient pole configuration. A salient pole configuration provides good axial coupling stiffness, needed for propagating positional changes of the two components. Since the magnetic coupler must last the life of the well, SmCo was selected as it is the premium of the "permanent" magnetic materials. For over 30 years, SmCo magnet material has had a proven track record in the magnet industry. SmCo features a high resistance to corrosion and good temperature stability. The effects of temperature are reversible. When temperature is present, there is a slight loss of force, and when the temperature is removed, there is a return back to the original state.

When designing the magnetic coupler, the effects of the magnetic forces on associated well equipment that might be run on the outside or through the SCSSV was considered. The magnetic coupling field is directed into the interface region between the two coupler components through the provision of a magnetic "back-bone"

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material and selective use of nickel-alloy materials. This optimizes connectivity and minimizes magnetic fields in the region outside. This is best explained by a horseshoe magnet where there is large force on one end and almost no force on the opposite end. Figure 2 shows the horseshoe concept and Figure 3 shows a simplified configuration of the magnetic coupler.

The 4½-in. 10,000 psi TRSV design using the magnetic coupler has been extensively tested. This design has a high degree of repeatability. While a conventional SCSSV has repeatability between cycles of 50 to 100 psi, this magnetic coupler design resulted in repeatability within 13 psi. The magnetic coupler is easy to operate, and the couplers basically are suspended magnetically (floating), straddling the housing, which creates a virtually frictionless mechanism. The friction reduction improves repeatability, reduces wear, and increases life.

Application

Using the floating-magnetic-coupler-technology will provide multiple advantages for deepwater applications. There are significant benefits to removing the physical connectivity between the wellbore fluids and hydraulic system pressure to the SCSSV piston actuator.

1. The SCSSV can be operated at an extremely low pressure irrespective of the valve's setting depth and/or internal wellbore pressure.
2. Subsea umbilicals are usually limited to a 10,000 psi rating, and the magnetic coupling design allows for safe effective operation within this pressure limitation.
3. Two hydraulic systems operate in many of today's subsea operating systems—a high pressure line that operates the SCSSV, and a lower pressure line, typically rated to 5,000 psi, to operate the wellhead equipment. By adjusting the operating requirements for the magnetic coupler design, the dedicated high-pressure line can be eliminated
4. Eliminating the dedicated line in subsea wells with long offsets can provide significant cost savings.
5. Isolating the operating piston actuation from wellbore effects means a new SCSSV design with no moving seals exposed to the well environment and 100% MTM sealing within the tubing wellbore.
6. There is no longer concern of contaminating the hydraulic operating system with gas or hydrocarbons.

Future Applications

The floating-magnetic-coupler was specifically designed for deepwater and HPHT applications. As discussed earlier, operating pressures can exceed 15,000 psi. Standard practice for in-house testing does not permit pressures above 5,000 psi. Using the floating magnetic coupler removes the associated safety hazard by providing SCSSVs that operate below 5,000 psi regardless of setting depth or internal bore pressure.

By eliminating the restriction on the SCSSV setting depth, downhole shut-in capability at the packer depth can be established. Closing the SCSSV at the downhole pressure gauge (DHPG) and allowing the pressure to build up can yield significant results. This capability could be combined with sensing technology such as running downhole fiber optics within the hydraulic control line to eliminate running an additional line.

In the Gulf of Mexico, operations include drilling to hit reservoir targets out beyond 30,000 ft. Large-bore HPHT completions in conditions approaching 30,000 psi will be necessary. Since the SCSSV can safely operate at a pressure below 5,000 psi without any concerns of well fluids entering the hydraulic system, the SCSSV can operate safely in these harsh environments.

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Downhole electronics can also utilize the magnetic coupler. An all-electric SCSSV will facilitate a complete electric safety system. Like isolating the hydraulic piston with current deepwater SCSSVs, downhole electronics are much more adverse to well fluids and pressure. The magnetic-coupler concept will encase the actuator in a dedicated chamber completely isolated from well fluids while using an electric actuator.

Summary

The SCSSV floating-magnetic-coupler design focuses on deepwater and HPHT applications. Since the SCSSV can now be operated with pressures of less than 5,000 psi, new safety standards relating to operating pressures will likely be established. As the industry moves into higher pressures and deeper reservoir depth, this will prove to be extremely valuable. The 100% MTM sealing design uses no moving seals within the tubing wellbore. By isolating the SCSSV piston actuator from the wellbore fluids and pressure, two main goals are reached: (1) overall reliability is enhanced, and (2) the potential for contamination of the hydraulic operating system by well fluids is eliminated.

Conclusions

Operators of deep subsea wells can benefit from the magnetic coupling technology in this new industry recognized valve design.

- Simple operation and elimination of potential leak paths enhances system reliability.
- Seals isolated from contact with wellbore fluids.
- Installation depth constraints found in current SCSSV equipment eliminated
- Lower operating pressures provide safer conditions and allow simplified, lower pressure valve control systems and related hardware.
- Downhole monitoring and control technology adaptations ready for future use.

This paper is a synopsis of SPE 90721,:"A Unique Design for Deep-Set Tubing-Retrievable Safety Valves Increases Their Integrity in Ultra Deepwater Applications," by Mike Vinzant and James Vick, Halliburton Energy Services, Inc., and Anthony Parakka, Dexter Magnetic Technologies, Inc. The original paper was presented at the SPE Annual Technical Conference and Exhibition held in Houston, Texas, U.S.A., 26–29 September 2004.

Further information on this new technology can also be obtained by a review of OTC 17455, (Copyright 2005 to Offshore Technology Conference), entitled "Unique Safety Valve Design Using a Floating Magnetic Coupler and Metal-to-Metal Sealing Capability to Provide Step-Change Improvements in Reliability, Safety, and Cost," prepared for presentation at the 2005 Offshore Technology Conference, Houston, TX, U.S.A., 2–5 May 2005.