

# SWAGED CONNECTION SYSTEM FOR STRUCTURAL & PRESSURE TIGHT APPLICATIONS

Providing Total Solutions Through Swaging Technology



  
OIL STATES MCS LTD.

# Worldwide Leaders In Tubular Expansion Technology

---

**Hydra-Lok® Pile Connection Technique .....Page 2**

---

**Hydra-Lok Lite™ for Subsea Structures .....Page 5**

---

**Hydra-Lok® DH for Downhole Connections .....Page 7**

---



Jacket



Wind Turbine Jacket



Tripod



Monotower

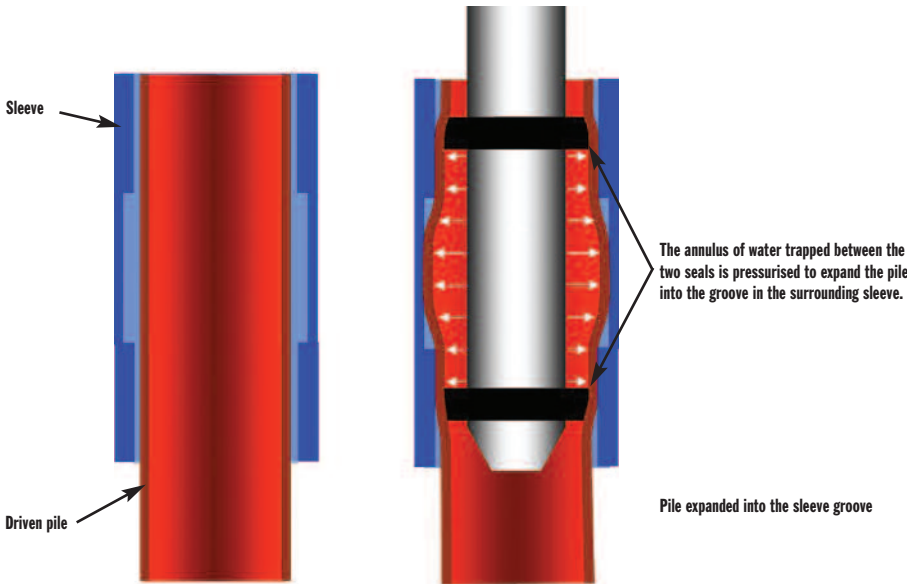


Downhole



Subsea Structure

# Hydra-Lok® Pile Connection Technique

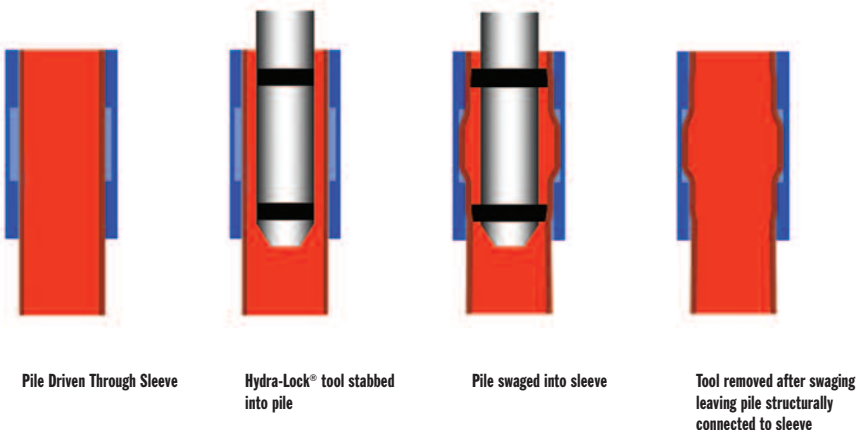


## Hydra-Lok® Principle

The unique Hydra-Lok® system forms connections between concentric tubes by expanding an inner tubular to connect with the outer tubular by means of hydraulic pressure. Hydra-Lok® was developed during the 1980's to make structural connections between offshore jackets and their driven foundation piles. It has since been used to anchor all types of offshore structures including small and large jackets, wind turbine jackets, tripod and monotower jackets and many types of subsea structures such as drilling templates, wellhead protection structures and manifolds.

The operation to form the connection starts by inserting the Hydra-Lok® tool inside the inner of the two concentric tubulars, in this case the driven pile. It is positioned within the pile so that the tool seals span a grooved region in the outer tubular, in this case the sleeve. The seals are then inflated to contact the pile wall trapping an annulus of water between them that is subsequently pressurised to expand the pile into the groove(s) of the outer sleeve. Once the connection has been formed the tool is removed and the process repeated on adjacent piles, leaving each pile structurally connected to the sleeve as shown in the diagram below.

## Hydra-Lok® Swaging Technique



## Features

- Rapid connections - 1 hr
- Immediate full strength
- Certifying authority approved
- 24" - 84" capability
- 100's of piles swaged worldwide
- Integrated levelling system available

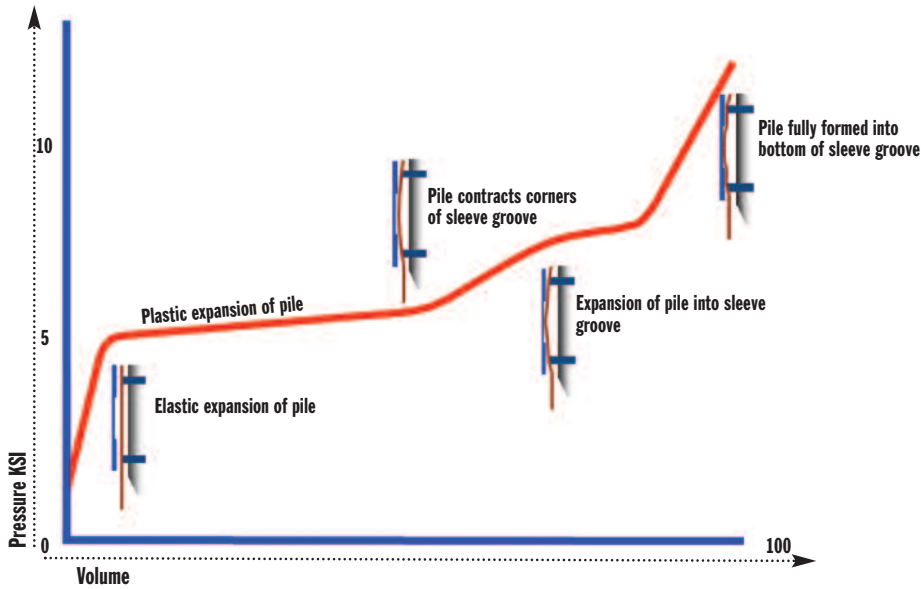


Marathon Brae template



Beatrice wind turbine jacket

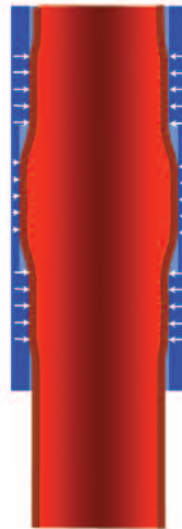
# Hydra-Lok® Pile Connection Technique



Pressure/Volume (P/V) Control Plot

## Operational Control

The swaging process starts with the inflation of the two axially displaced seals on the swaging tool, which seal against the inside of the pile thereby creating a pressure-tight annular chamber of water around the tool. Pressurisation of this captive “annulus” by pumping in water causes the pile to expand outwards, rather like inflating a balloon. As the tool and seals have a rigid construction and water is considered to be virtually incompressible, the swaging process is accurately and simply monitored by measurement of the pressure and volume of the water pumped into the annulus. At regular intervals during the swaging process, the pressure and volume are measured and the progress is plotted as a Pressure versus Volume graph (P/V) as shown above. This enables the operator to visualise the process in real time. The P/V plot shows the distinctive stages of the expansion process, first the initial elastic expansion of the pile, followed by its yield and plastic expansion to contact the internal diameter of the sleeve. Expansion continues with the pressure increase as the pile is forged into the bottom of the groove whilst expanding the sleeve elastically. When the final pressure is reached the process is complete and the connection is made. Upon releasing the pressure the sleeve contracts elastically onto the pile creating an interference fit, as shown right.



Forces acting on the connection after swaging

## Operational Control

- Accurate monitoring of operation
- Follows predicted path
- Simple parameters
- Easy to understand

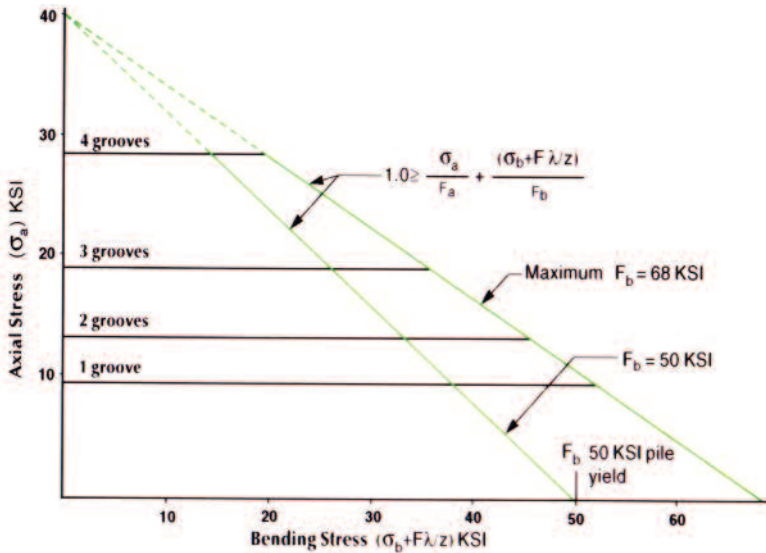


Swaged pile on pre-drilling template



Cirrus M7-A monotower platform

# Hydra-Lok<sup>®</sup> Connection Capacities



## Hydra-Lok<sup>®</sup> Bending and Axial Load Interaction

A firm and fixed connection between pile and structure sleeve is essential for structural platforms and is necessary for approval by certifying authorities. In order to achieve Lloyds 'Type Approval' extensive testing of the Hydra-Lok<sup>®</sup> connection was carried out during the development programme. This included establishing basic compression, tension and bending strengths plus a separate Joint Industry Study programme of testing to investigate the fatigue performance of the connection. Other studies and tests included metallurgy testing on parent and weld metal subjected to the swaging process and the corrosion behaviour of the completed connection. All the work was supervised and witnessed by Lloyds Register of Shipping to gain 'Type Approval' of the technique and was followed by "Acceptance in Principle" from DNV. It has since been approved for use on projects certified by Bureau Veritas, American Bureau of Shipping (ABS) and the Russian Maritime Register of Shipping (RMRS).

Pile Size (Inches)	Wall Thickness (Inches)	Axial Load Capacity (Tons)			
		1 Groove	2 Grooves	3 Grooves	4 Grooves
24	0.75 to 1.25	232 to 379	330 to 538	465 to 758	697 to 1137
30	0.75 to 1.5	292 to 570	415 to 810	585 to 1139	877 to 1709
36	1.00 to 1.75	466 to 799	663 to 1135	933 to 1597	1399 to 2396
42	1.00 to 2.0	546 to 1066	776 to 1515	1093 to 2132	1639 to 3198
48	1.25 to 2.0	779 to 1226	1107 to 1742	1557 to 2452	2336 to 3678
54	1.35 to 2.5	947 to 1716	1346 to 2438	1894 to 3431	2841 to 5147
60	1.5 to 3.0	1169 to 2279	1662 to 3238	2339 to 4557	3508 to 6836
72	1.75 to 3.5	1638 to 3195	2328 to 4540	3276 to 6390	4915 to 9584
84	2.00 to 4.0	2185 to 4264	3106 to 6060	4371 to 8528	6556 to 12792

Above are a few examples of connections on various pile sizes and their Certifying Authority approved axial capacities for 1,2,3 & 4 grooved connections.

## Operational Advantages

- Real-time verification of connection formation
- Rapid full-strength connection
- Fast, reliable operations-reduced marine spread time
- Environmentally friendly, pollution-free
- Diverless - any current, any depth
- Short connection length saving pile weight & cost

## Full Service

Oil States MCS Ltd offer the full connection service of pile head and sleeve design including material specification. The swaging sleeves and pile heads can be supplied either by Oil States MCS or by the structure fabricator. The offshore swaging operation is performed by Oil States MCS personnel.

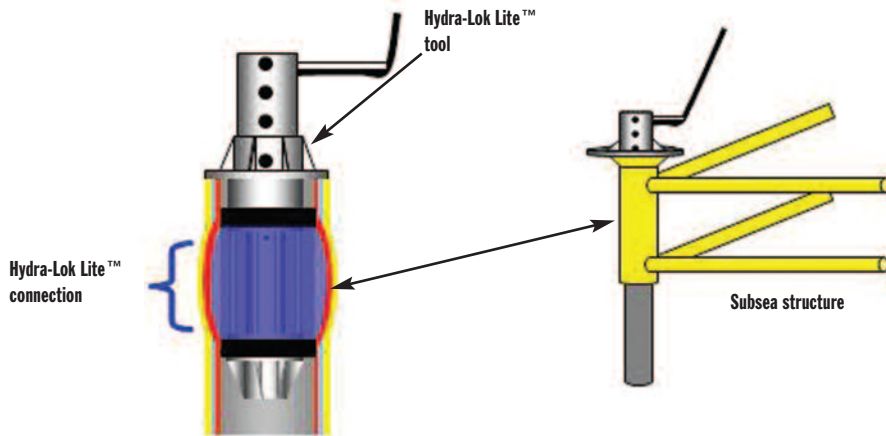
## Test Facility

Oil States MCS Ltd are certified to ISO 9001:2008 and we carry out all equipment assembly and testing at our premises in Barrow-in-Furness, Cumbria, UK. The facility has a 110 ton crane capacity and a 5 metre deep pit for testing equipment, both in-air and underwater, up to 84" pile diameter. The Hydra-Lok<sup>®</sup> swaging system has been used to make hundreds of pile-to-structure connections since 1984 at all the usual pile sizes between 24" and 84" inclusive.



Oil States MCS facility, Barrow-in-Furness

# Hydra-Lok Lite™ for Subsea Structures



## The Hydra-Lok Lite™ Connection

Lightweight Subsea structures are installed for various applications including manifold protection, valve housings, PLEMs etc and usually need to be secured in place. A common method of securing them is by the use of tubular piles which are driven through legs/sleeves in the corners of the structures to which the pile may be connected by swaging.

The standard Hydra-Lok® connection described earlier in this brochure is primarily used to secure jackets and larger subsea structures. As such it may be unnecessarily heavy and complicated for smaller, lighter structures and a lower capacity version, Hydra-Lok Lite™ was developed.

The Hydra-Lok Lite™ connection system is a low cost version of the Hydra-Lok® swaged pile connection. As it does not need a thick walled sleeve the structure is less expensive and lighter in weight. The sleeve and piles have a minimum preparation requirement and the connection itself is short. As the pile does not need to be driven to a specific depth connection problems associated with underdrive are eliminated. The connection is specifically designed for smaller structures where individual pile loadings are up to 100 tons and is formed in the same way as the standard version by expanding the pile after it has been driven through the sleeve on the structure. In this connection the surrounding sleeve does not have a groove. Instead, as the pile expands, it contacts and in turn expands the sleeve by 1 to 2% of its diameter. On release of the swaging pressure the sleeve elastically contracts onto the pile to give an interference fit connection between the two. The connection strength can be varied significantly by using dissimilar strength steels for pile and sleeve.

## Offshore Operation

The Hydra-Lok Lite™ spread carries less equipment than the standard Hydra-Lok® spread and requires only two personnel for a normal operation. The offshore operation to make the connections is very quick, a single connection can be made in 20 to 30 minutes and a full 4 pile structure can be connected in 3 to 4 hours deck to deck. The operation is totally diverless, requiring an ROV only for observing the stab-in and can be used in any water depth and all but the most severe current/tidal states. As with all Hydra-Lok® connections the operation can be observed at the surface as it takes place by reference to the Pressure Volume (P/V) plot.

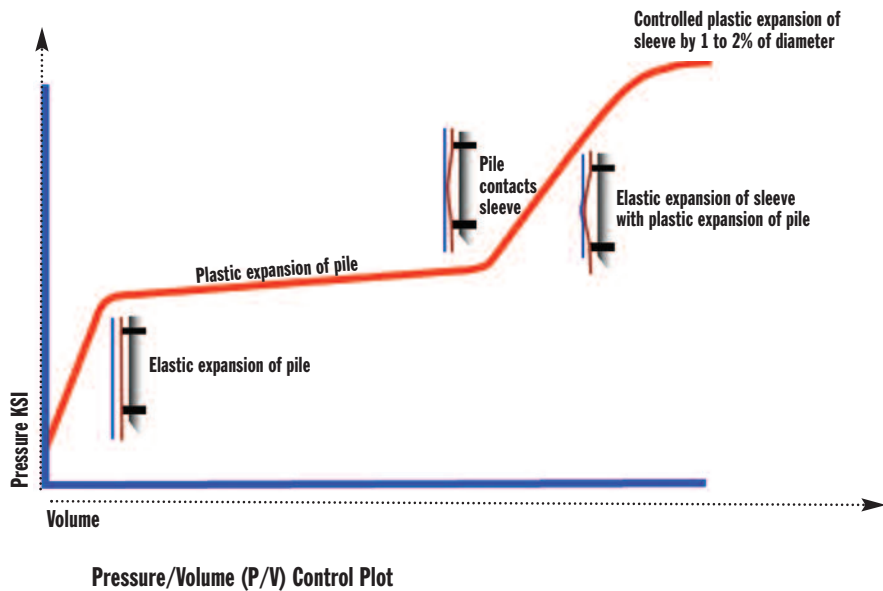
## Features

- Rapid connection, saving marine spread time
  - 30 minutes each pile
  - 3 to 4 hours per structure
- Immediate full strength
- 24" - 36" capability
- Integrated levelling system available
- Reduced spread footprint



Venture Sycamore Pipeline End Manifold (PLEM)

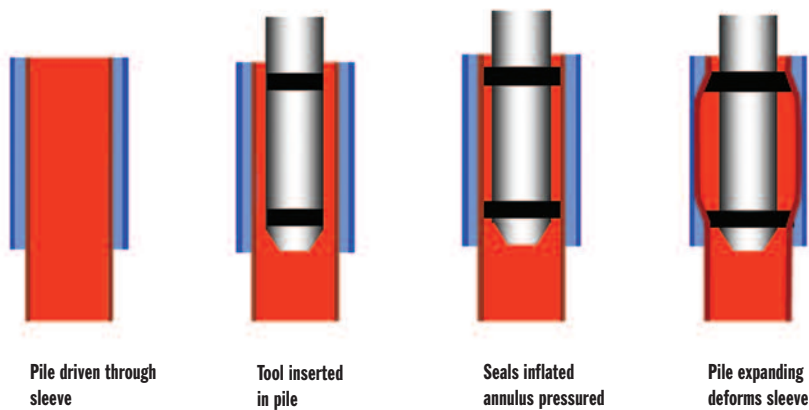
# Hydra-Lok Lite™ for Subsea Structures



## Benefits

- Real-time verification of connection formation
- Rapid full-strength connection
- Fast, reliable operations, reduced marine spread time
- Environmentally friendly, pollution-free
- Diverless - any current, any depth
- Short connection length saving pile weight and cost
- Reduced equipment spread and fewer personnel-reduced cost with respect to Hydra-Lok®

## Hydra-Lok Lite™ Connection Stages



Full connection strength is achieved immediately the swaging operation is complete. The connection is maintenance free and does not need ongoing inspection by divers or ROV.

As the equipment spread is minimal, personnel requirements are correspondingly reduced and a normal single structure installation requires only two personnel.



Hydra-Lok Lite™ tool

# Hydra-Lok® DH for Downhole Connections

## Expandable Downhole Tubular System for Casing Connectors



### Hydra-Lok® Downhole (DH) System

Hydra-Lok® sealing/tubular expansion technology has a 25 year track record covering pile swaging, localised pressure testing and caisson repair operations. Most of these activities involve working pressures below 10,000 psi (690 bar), but the basic Hydra-Lok® sealing arrangement can work at pressures in excess of three times this value. This capability is now being exploited for downhole and pipeline repair applications.

Hydra-Lok® DH utilises the higher pressure capability in the downhole environment, for “cold forging” pressure-tight, metal-to-metal connections (such as casing “cross-over” joints) or localised pressure testing.

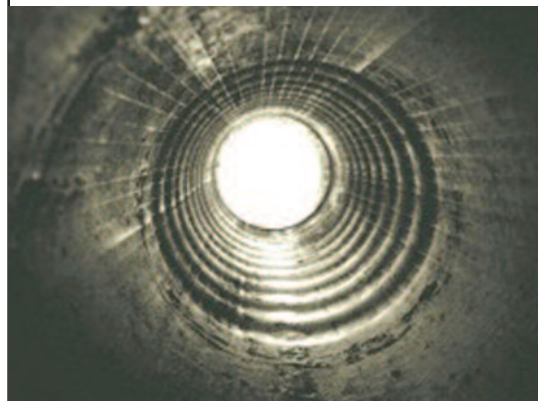
The downhole system was initially developed for a casing patch application, the aim being to use a Hydra-Lok® tool to expand the top end of a slumped casing into a multi-groove, over-shot sleeve fitted to the foot of a new casing string. The swaged connection produced by this process is clearly illustrated in the adjacent photographs. A feature of the system is that, after forming the connection and without the necessity of recovering it, the tool can be re-positioned to span the joint interface and then used to internally pressure test the connection to its full test pressure.

Development testing was carried out on 5” O.D. L80 and P110 casings, and subsequently on 9 5/8” O.D. P110 and XT155 casings. As a result of this work, an optimised sleeve geometry was derived and a Hydra-Lok® tool built that can make a 9 5/8” casing connection in around 35 minutes and operate at pressures up to 35,000 psi (2,414 bar). The final P110 test connection was pressurised to an internal pressure of 11,000 psi (759 bar) whilst simultaneously loaded to 620Te with entirely satisfactory results.



Section through swaged test specimen

- Downhole pressure testing
- Internal Casing Patch
- External tie back connection
- Zonal isolation barrier
- Expandable liner hanger



Internal view of completed casing patch

## Case Study (Agip) - Cross-over Connection Installation

This project consisted of two onshore wells, where the casing configuration needed to be changed some 200 m below ground level. The plan was to carry out an explosive back-off at the required elevation on an existing 9 7/8” T95 casing joint, recover the upper casing, run in with a new 10 3/4” casing string and make up to the 9 7/8” T95 casing using a standard cross-over sub. As a contingency, the 9 7/8” casing could be cut and then swaged into a new 10 3/4” casing string with the Hydra-Lok® multi-groove over-shot sleeve being the cross-over joint.

The existing 9 5/8” swage tool was modified for drill string deployment and remote operations, and a full 9 7/8” T95 test connection was made prior to mobilisation to the site. The test connection was successfully tested to 300 Te axial load with simultaneous 3,000 psi internal pressure.

# Hydra-Lok<sup>®</sup> DH for Downhole Connections



Combined axial internal pressure testing 9 7/8" T95 casing connection



Overshot end for 9 7/8" T95 casing connection sleeve

## Case Study (Total) - Pressure Testing

On another project, the client wanted to pressure test some suspect 10 3/4" casing joints in five offshore High Temperature/High Pressure wells. In each well, the Hydra-Lok<sup>®</sup> tool was deployed on the drill string to a depth of approximately 300 m and located such that it spanned the suspect casing joint. The seals were inflated and the tool pressurised to carry out the necessary localised pressure integrity tests. Each joint was subjected to a hydrostatic pressure test at 11,000 psi followed by a gas pressure test at 5,000 psi without the need for tool recovery.

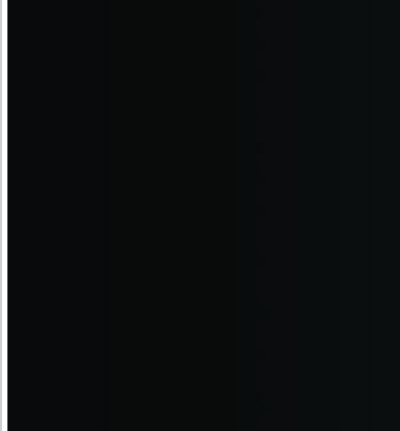
The tool for this project (see photograph to the right ) was purpose built for this project, but used the existing main seals from the 9 5/8" swage tool. Prior to mobilisation, the new tool was pressure tested to 15,000 psi using water and 6,500 psi using nitrogen.

## Features

- New casing run with overshot Hydra-Lok<sup>®</sup> DH sleeve
- Existing steel casing swaged into overshot sleeve
- Hydra-Lok<sup>®</sup> DH tool run on drillpipe
- Connection made and tested in a single deployment
- Casing material up to 155 ksi yield connected
- Metal to metal seal
- No reduction in I.D.



10 3/4" downhole pressure testing tool



OIL STATES MCS LTD  
BOUTHWOOD ROAD  
BARROW-IN-FURNESS  
CUMBRIA LA14 4HB  
ENGLAND, UK  
Tel: +44 (0) 1229 825080  
Fax: +44 (0) 1229 839791  
e-mail: [sales@osmcs-bar.co.uk](mailto:sales@osmcs-bar.co.uk)  
[www.osmcs-bar.co.uk](http://www.osmcs-bar.co.uk)  
[www.oilstates.com](http://www.oilstates.com)

