The Use of Friction Welding for Corrosion Control in the Offshore Oil and Gas Industry

To: Icorr, Aberdeen Branch 27.01.2015

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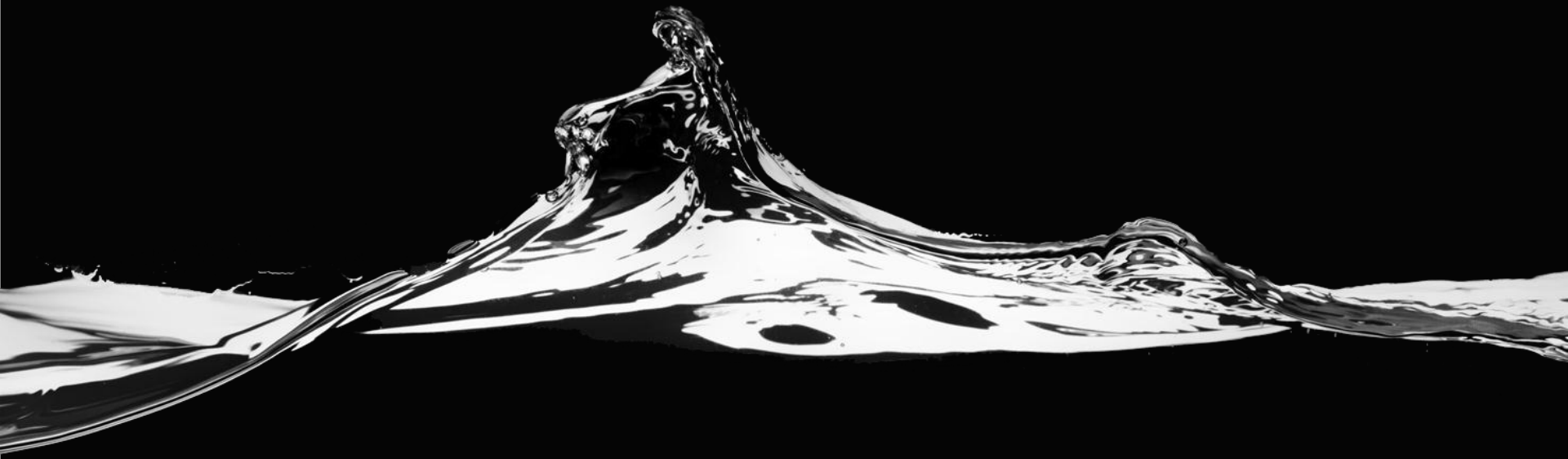

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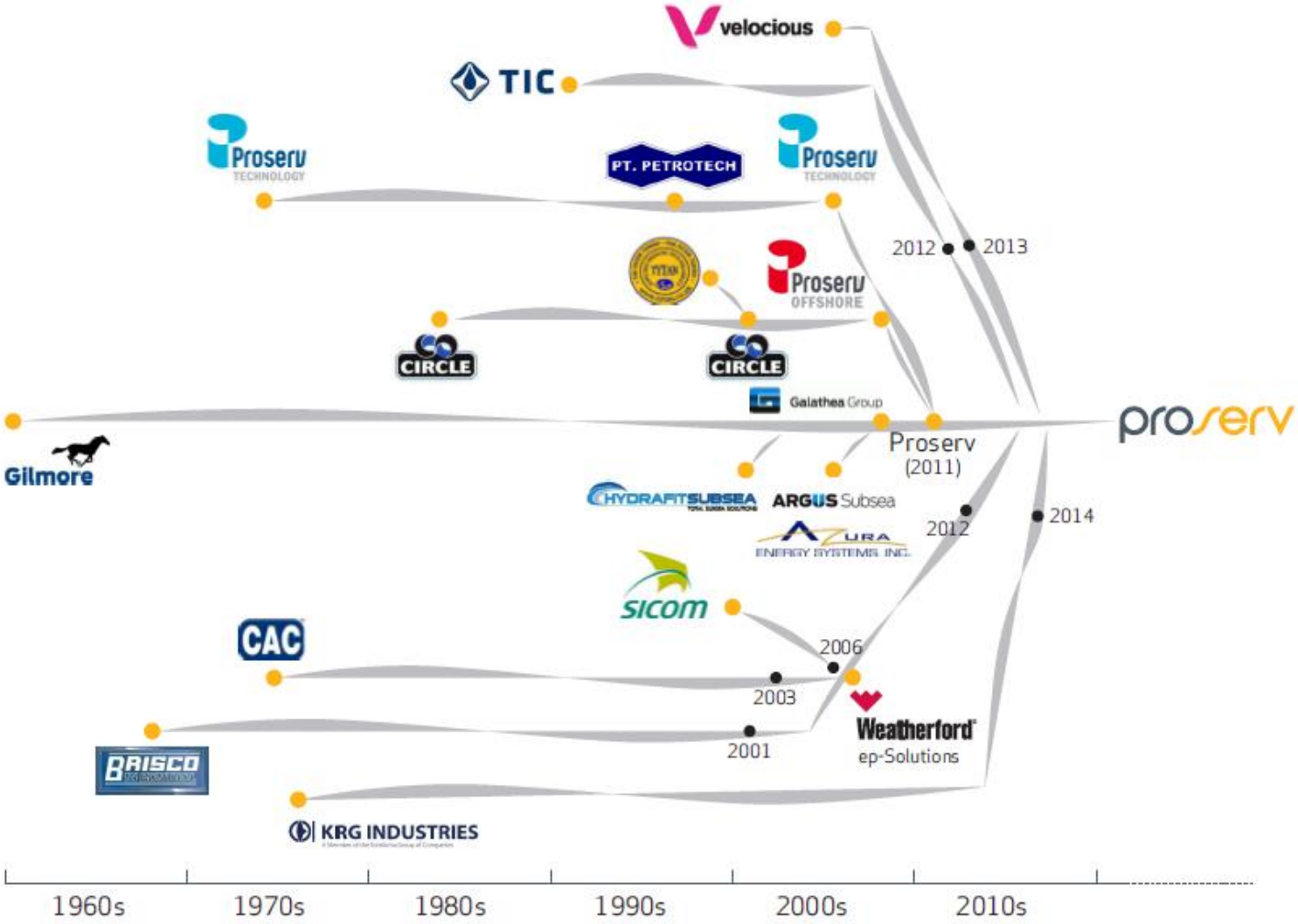
Our Evolution



What We Do: Life of Field Services

Business Division		What We Offer	Solutions & Services
Drilling Control Systems **(DCS)**		Products and services focussed **on operational assurance**	• **BOP Services** • **Drilling Control Systems Assurance & Performance** • **After-market & Lifecycle Management**
Production Equipment Systems **(PES)**		Products and services focussed on **production optimisation**	• **Flow Assurance & Sampling Solutions** • **Production Control & Safety Solutions** • **Asset Performance & Operational Integrity**
Subsea Production Systems **(SPS)**		Products, services and system design focused on **production enhancement**	• **Subsea Marginal Field Development** • **Subsea Brownfield Extension, Upgrade & Optimisation** • **Obsolescence Management** • **Subsea Life of Field Services & Support**
Marine Technology Services **(MTS)**		Products and services focused on intervention and remediation to assure **asset integrity**	• **Subsea Infrastructure, Repair & Maintenance** • **Emergency Pipeline Repair** • **Diverless Intervention** • **Wellhead Abandonment & Decommissioning** • **Friction Welding**

Summary

1. Why use Friction Welding Chosen for Corrosion Control ?
2. The Portable Friction Welding Process
3. Fatigue Strength of Friction Welds
4. Subsea Friction Welding Tooling
5. Subsea applications of Friction Welding for Cathodic Protection
6. Topside friction welding tooling
7. Topside applications of Friction welding for corrosion control
8. Corrosion Sensor Attachment

Why is Friction Welding Chosen for Corrosion Control?

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Subsea

- Welded, low electrical resistance, low maintenance connection
- Suitable for large flat surfaces where clamps can't be used (e.g. FPSO hulls, large diameter jacket legs and wind farm piles)
- Better fatigue strength than arc welds in the "as welded" condition
- When used with an ROV lower vessel costs and rapid installation.

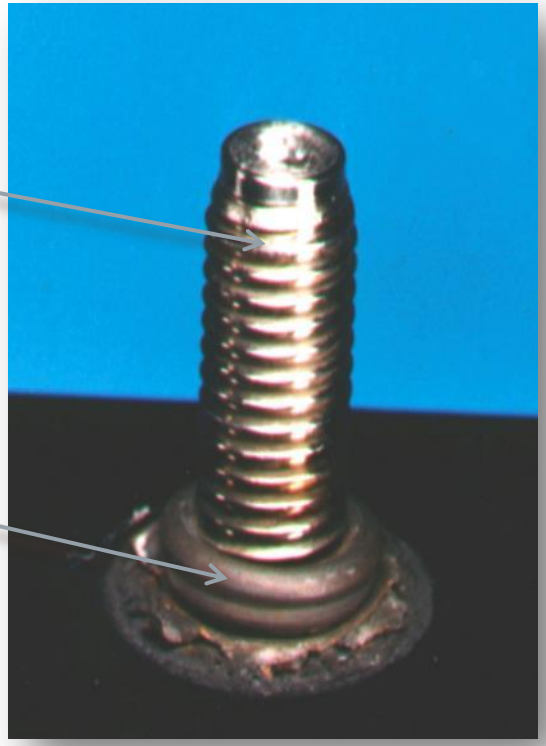
Topside

- Welding on live pipes and in Zone 1 outside of shutdown
- Minimizes coating damage
- Welds through most coatings
- Better fatigue strength than arc welds in the "as welded" condition

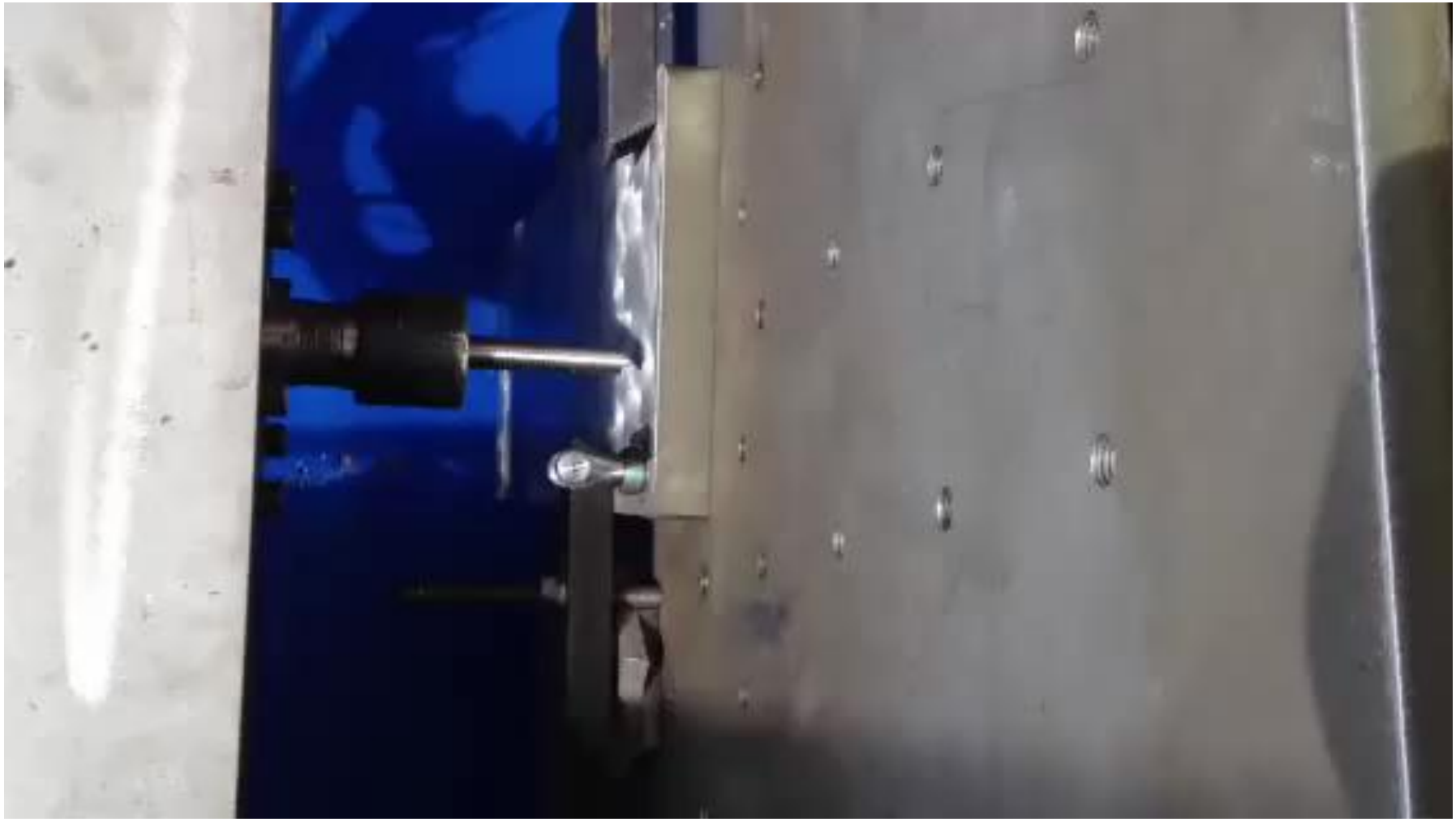
The Portable Friction Welding Process

The Friction Stud Welding process

1. Rotate the stud at high speed
2. Apply pressure forcing the stud onto the substrate.
3. Friction between the stud tip and the substrate causes the metal surfaces to heat and a thin layer of metal to flow plastically under pressure (without melting) to the periphery of the weld, removing impurities from the interface.
4. The rotation is stopped and the pressure maintained for a few seconds to produce a solid phase forged weld with a fine grain structure

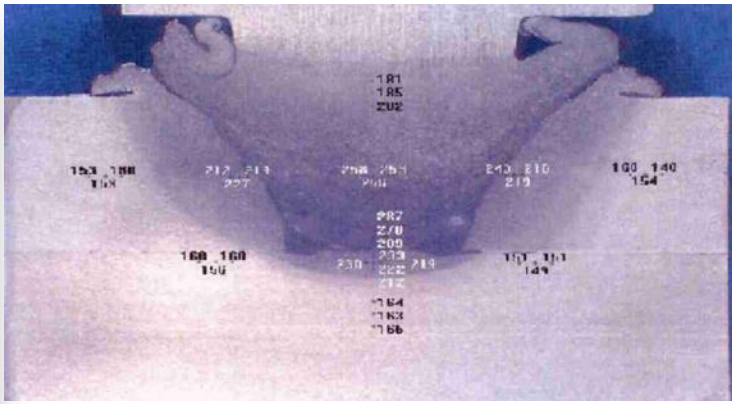


The friction welding process

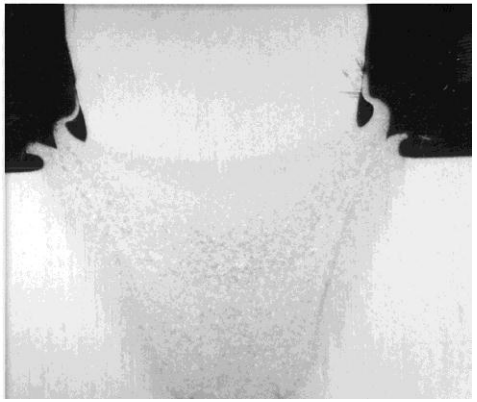


Friction Welding Configurations

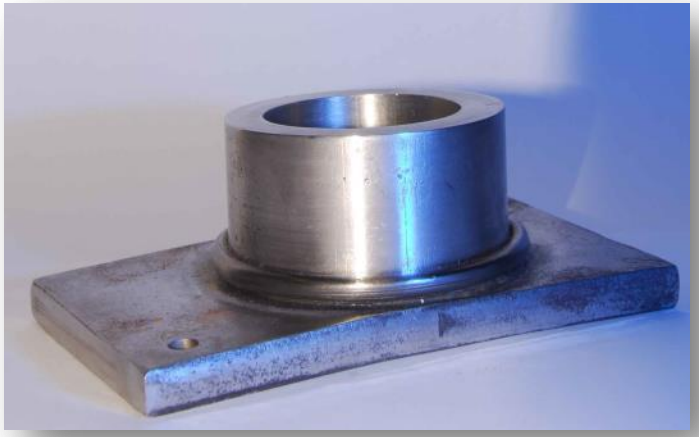
Stud Weld



Tripartite Weld



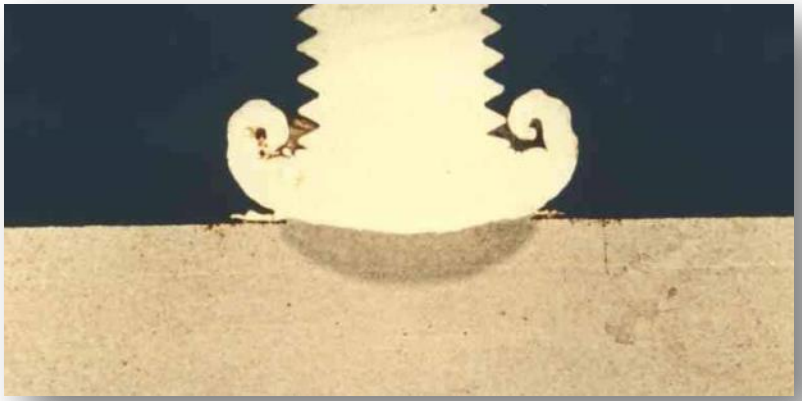
Taper Plug Weld



Nipple Weld

Friction Welding process characteristics

- Solid phase process with no liquid weld pool or electric arc
- Hydrogen is not evolved or absorbed in significant concentrations during welding
- No slag inclusions or porosity
- Welding can often be done without removing coatings
- No mixing of stud and base material so dissimilar metals can be joined readily
- Residual stresses at the weld are compressive giving good fatigue strength
- Used for welding underwater or in potentially explosive atmospheres with a shroud and water sprays
- Applied where avoiding damage to the coating on the back of the base material is critical

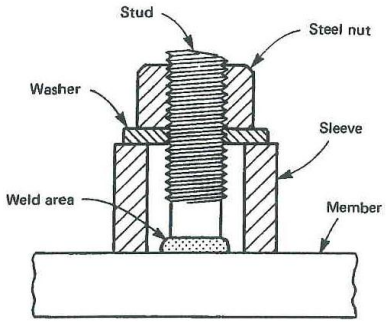


A Macro Section through a 316L Stud Friction Welded to Carbon Steel

The mechanical properties of friction stud welds

Tensile strength exceeds the specified minimum UTS for the stud

QW-466.5 TORQUE TESTING ARRANGEMENT FOR STUD WELDS

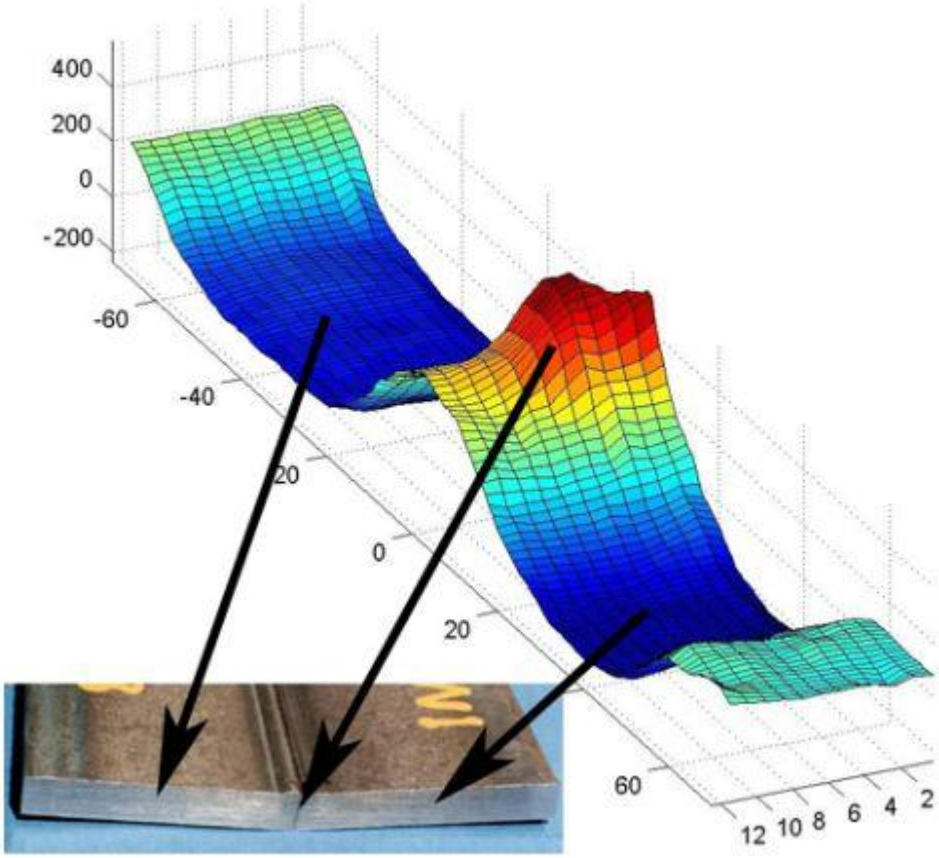


GENERAL NOTES:
(a) Dimensions are appropriate to the size of the stud.
(b) Threads of the stud shall be clean and free of lubricant other than residual cutting oil.

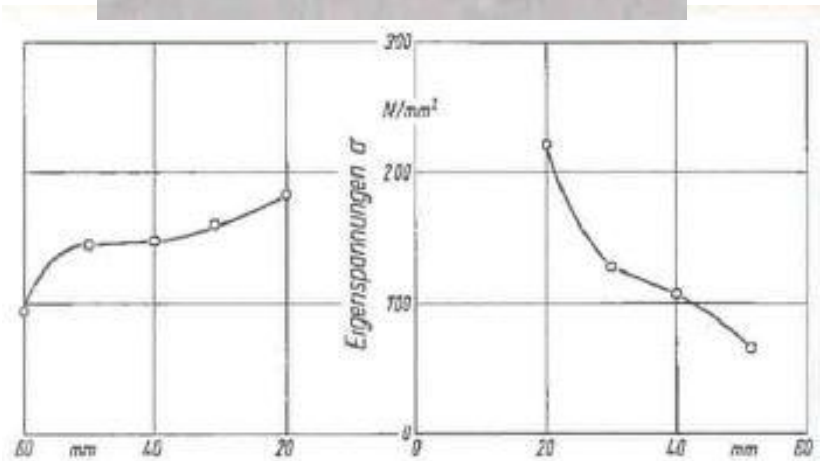
Bend test to ASME IX or AWS D 1.1

Fatigue Strength of Friction Welds

Residual Stress in Fusion Welds (Electric Arc Welds)



Typical residual stress pattern for a fusion butt weld made with arc welding



Stress pattern for a 22mm fusion stud weld (drawn arc). Ref 5

Residual Stress in Friction Welds (TWI Report 485/1995) Ref. 1

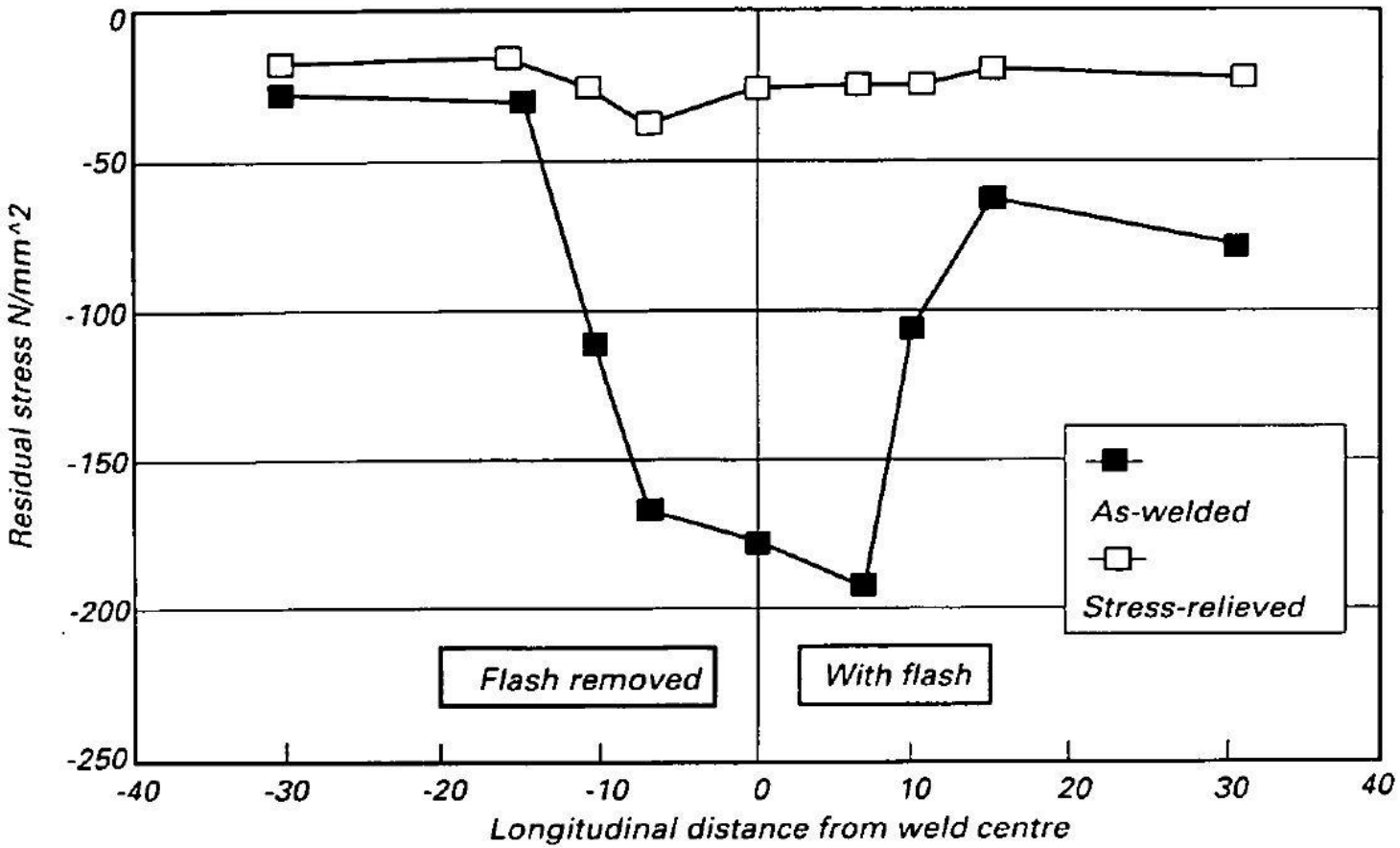


Fig.5 Residual stress measurements in the axial direction (i.e. perpendicular to the weld) obtained from specimens 77210-23 and 77210-24 representing the stress relieved and as-welded conditions, respectively.

Fatigue Strength of Friction Welds (TWI Report 485/1995) Ref. 1

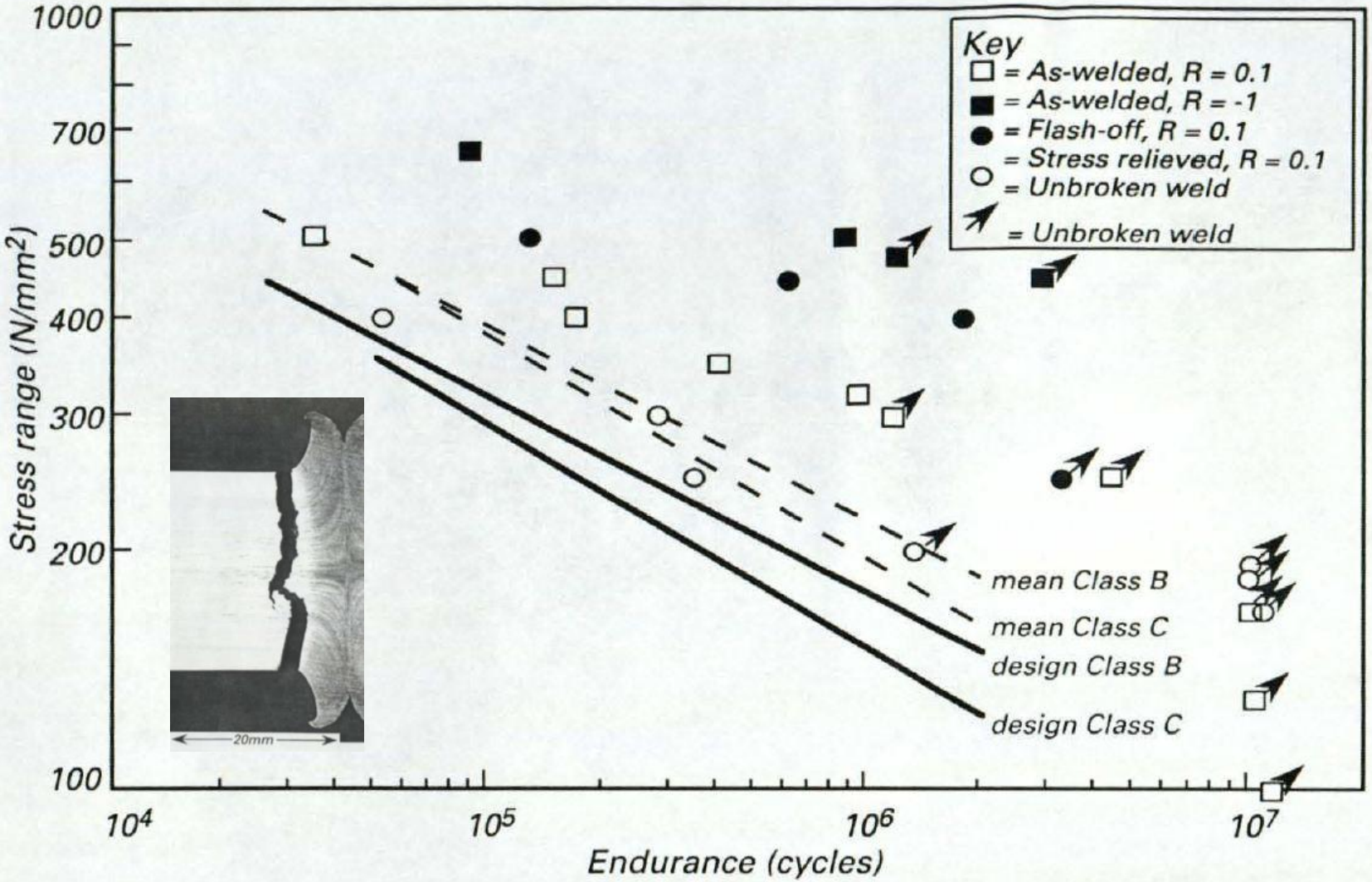


Fig.7 Fatigue test results obtained from friction welded rod-to-rod connections.

Conclusions from TWI Report 485/195 (Ref. 1)

- Fatigue strength of the friction welds tested at R=0.1 was superior to Class B, BS5400: Part 10
- The high fatigue strength of friction welds appears to be due to beneficial residual stress distribution at the surface adjacent to the failure site.
- Thermal stress relief reduced fatigue strength as a result of removing the beneficial compressive residual stress. Nevertheless the fatigue strength of the stress relieved specimens was still high roughly equivalent to Class C in BS 5400 Part 10.

Subsea friction stud welds – Fatigue Tests

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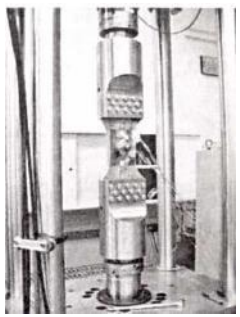
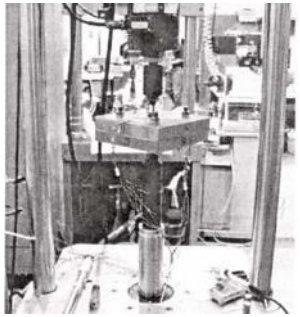
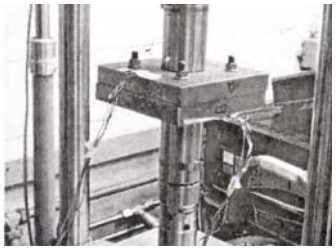
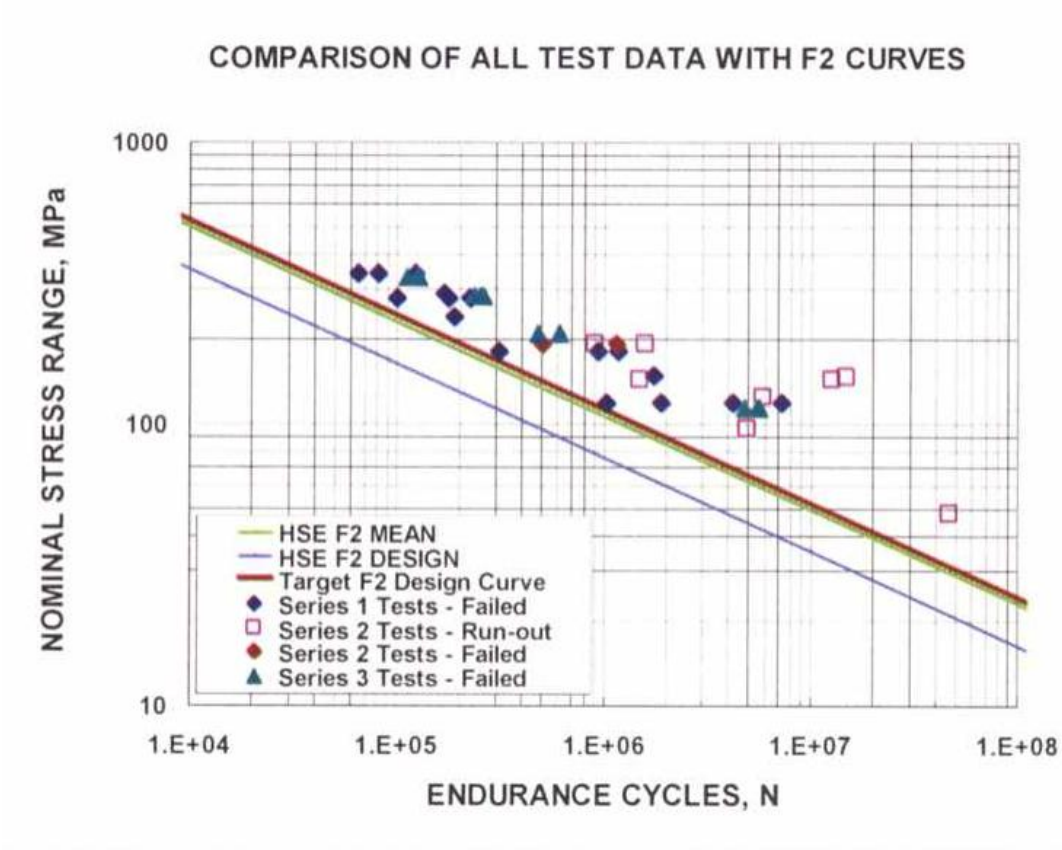




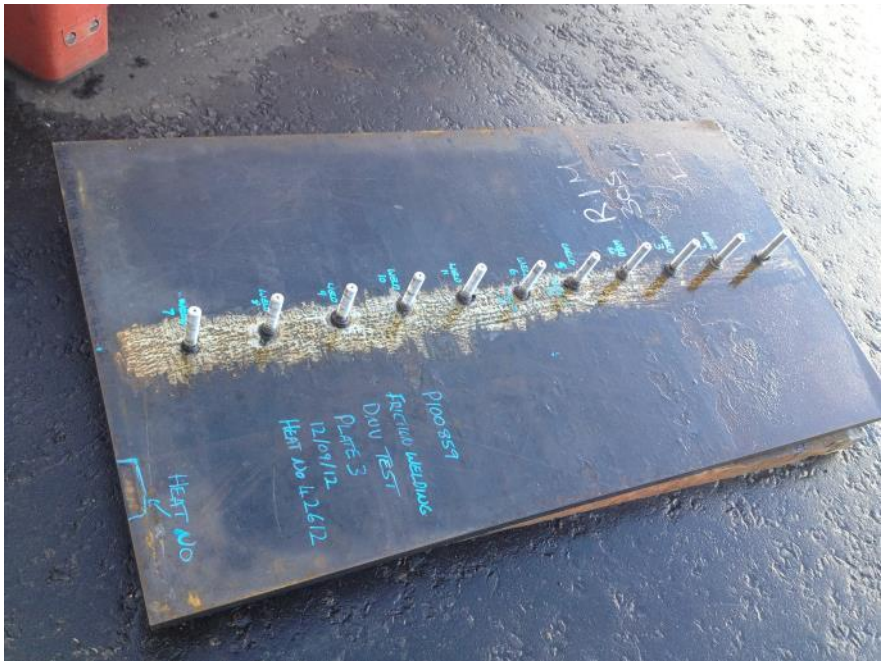




Fatigue testing of underwater 20mm friction stud welds for the Chevron Genesis project (Ref 3) .

Fatigue Tests for Wind Farm Piles by DNV

Bend tests on M16 underwater stud welds



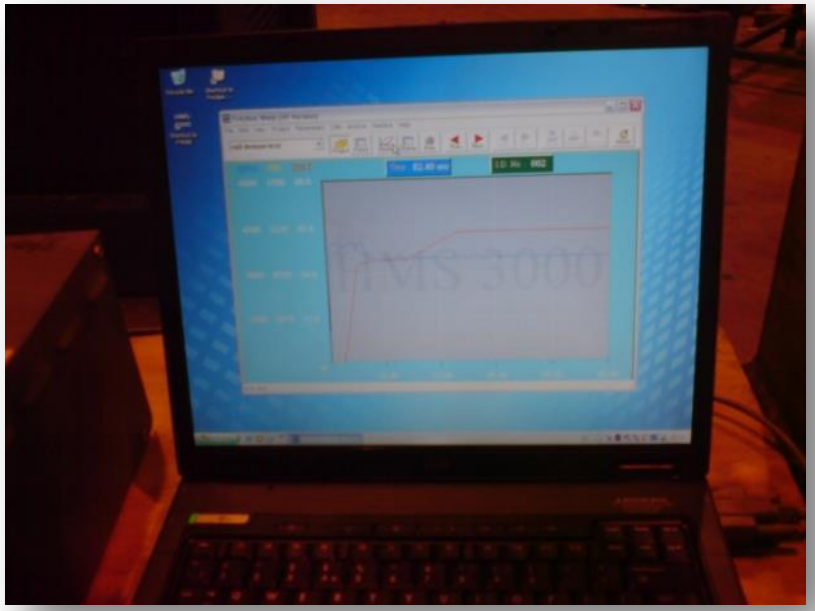
One of three test plates stud welded for fatigue testing by DNV

- The data from these tests gave a C1 curve

Subsea Friction Welding Tooling

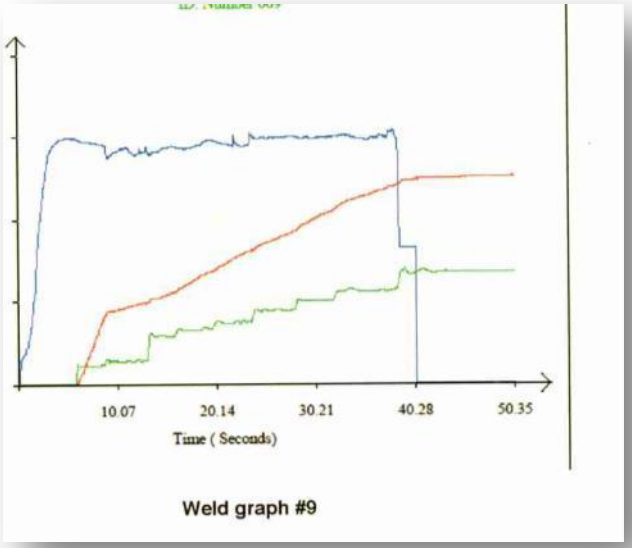
Hydraulic Friction Welding Systems

The HMS 3000 Hydraulically powered & computer controlled system

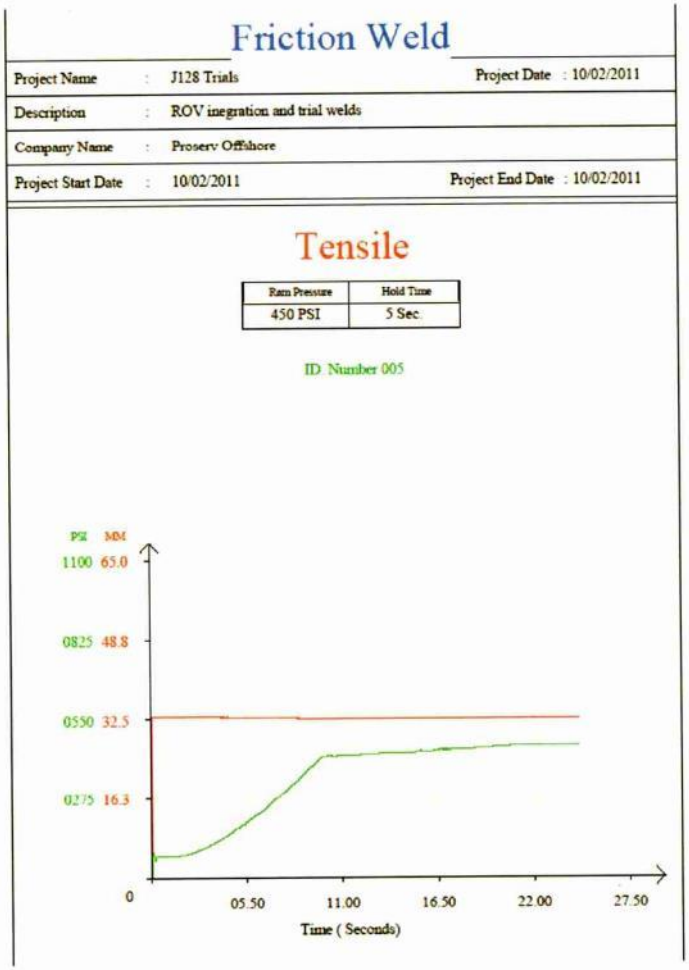


Capable of welding studs up to 25 mm diameter to a water depth of 1000m or more

Hydraulic Friction Welding System – Weld Data.



Weld graph #9



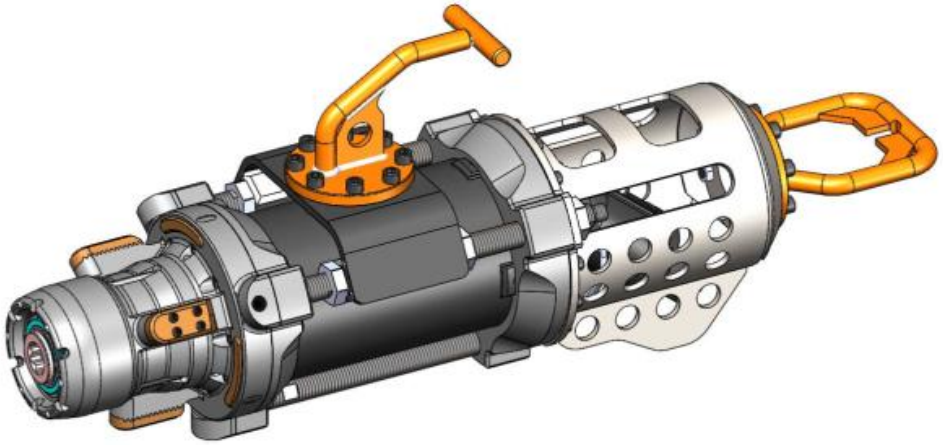
Tensile graph #5 (Aft)

- Typical data from the friction welding control system: Rotational speed, ram pressure and “Burn-off”. The tool can also perform a tensile test if required.

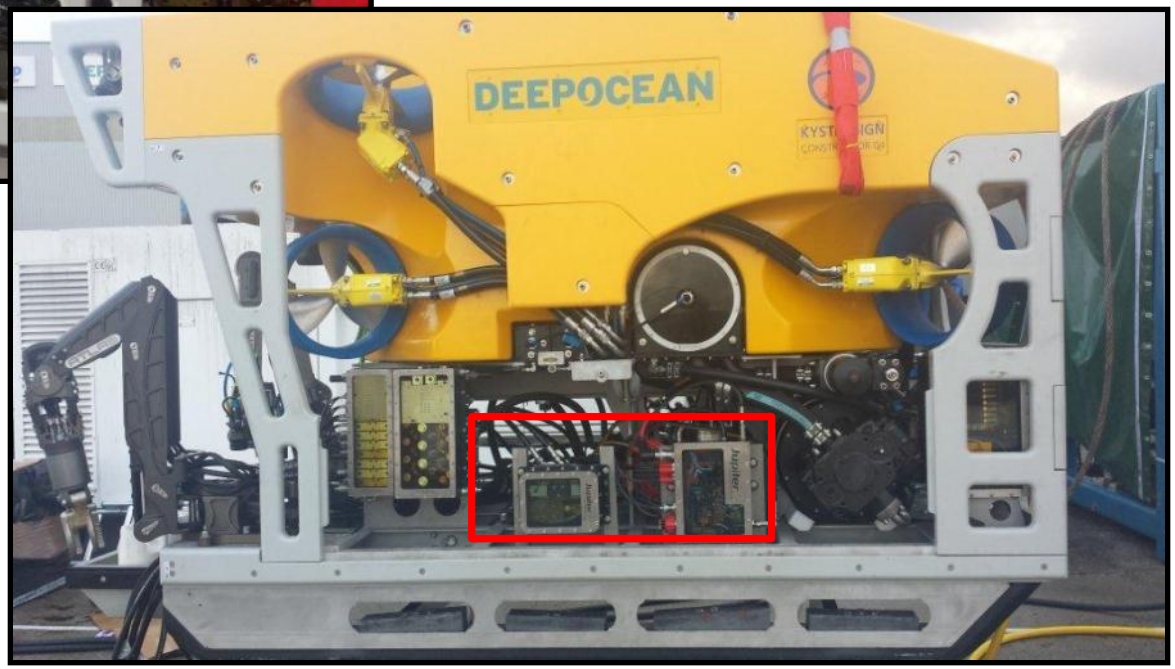
Technology Developments – Subsea Stud Changer

- Diver operation of the weld head with a magnetic clamp

- ROV deployed weld head assembly with a remotely operated subsea stud changer

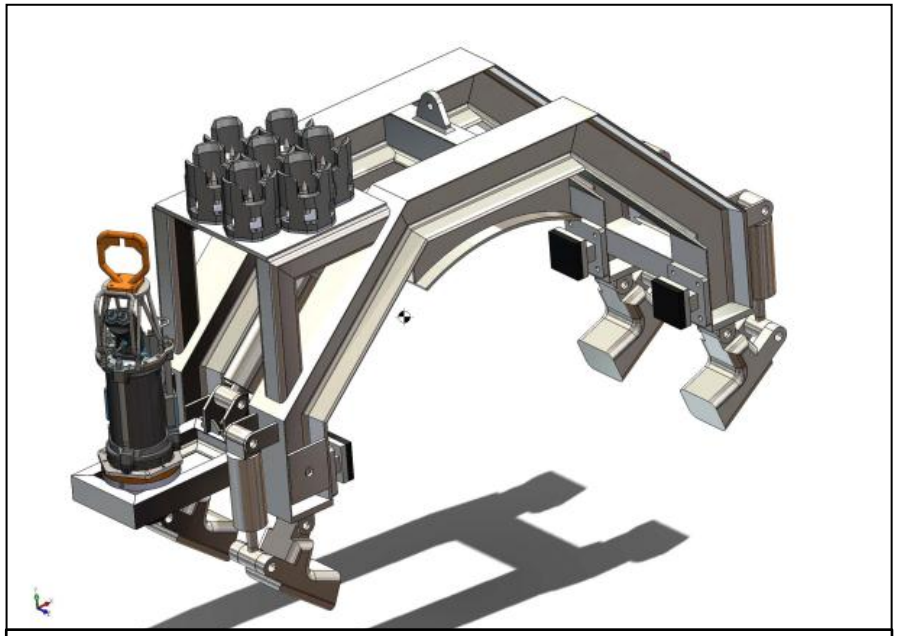


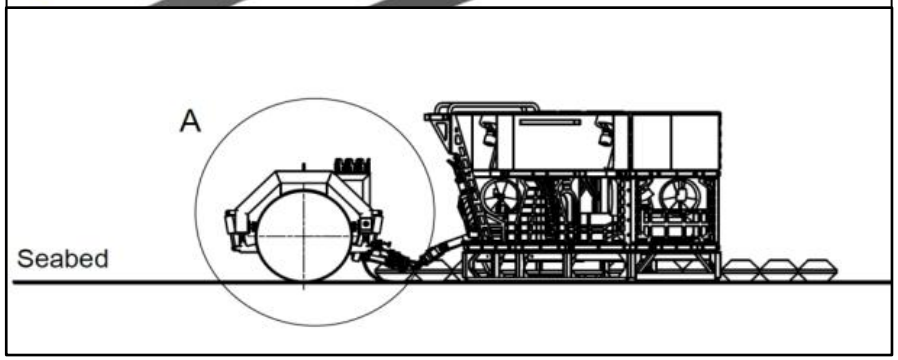
Hydraulic System Integrated onto an ROV



Stud Changer and clamps for subsea friction welding

Pipeline Friction Welding Clamp for anode mattress connection





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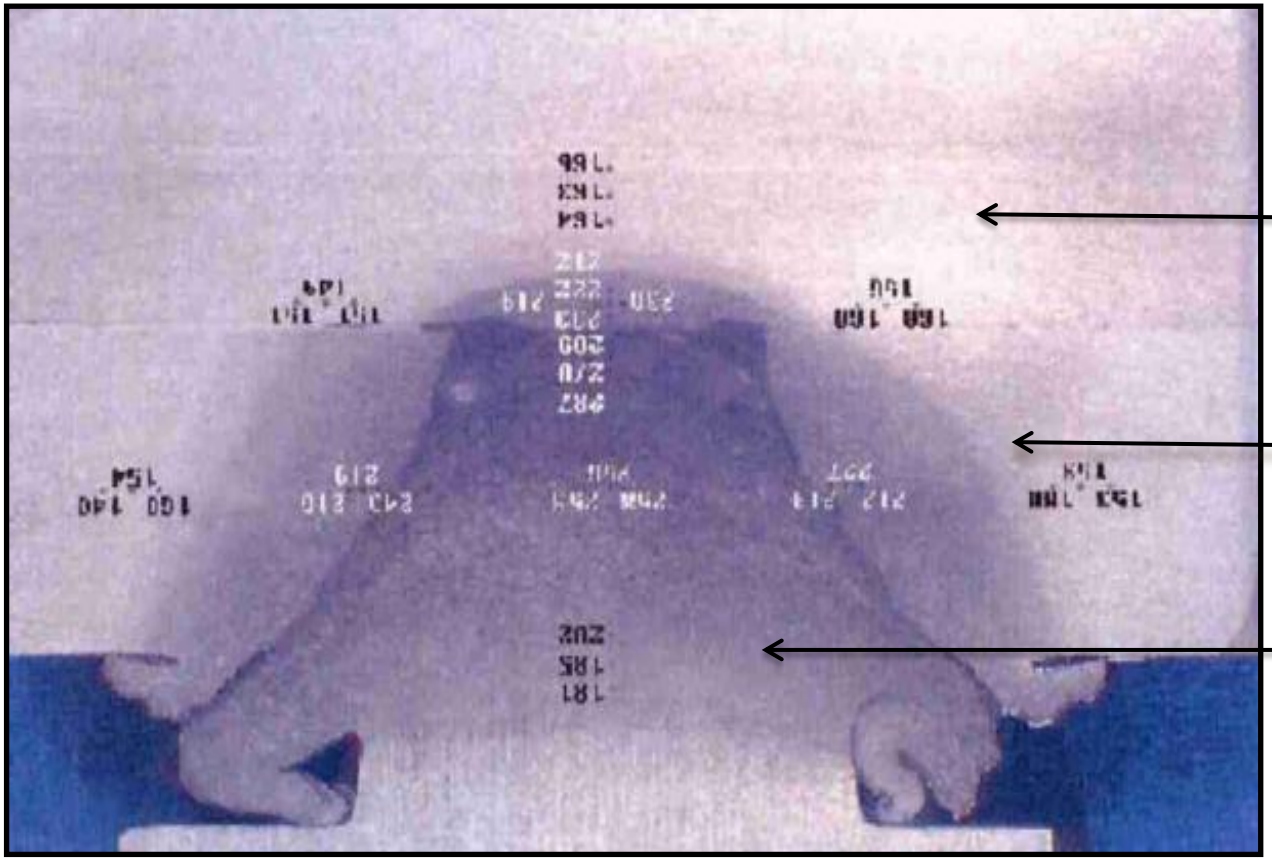
Subsea Applications of Friction Welding for Cathodic Protection

Anode attachment to an FPS Hull with an ROV

Proserv friction welded two hundred and twenty 450 pound anodes underwater to the hull of the BP Thunderhorse FPSO in the GOM from an ROV

Tripartite friction weld configuration used for welding anodes to the FPS



Tripartite friction welds done with an ROV for anode replacement on a FPS

Pad from previous anode

Anode Strap

Foam Shroud

Fatigue test welds for anode attachment to an FPS Hull

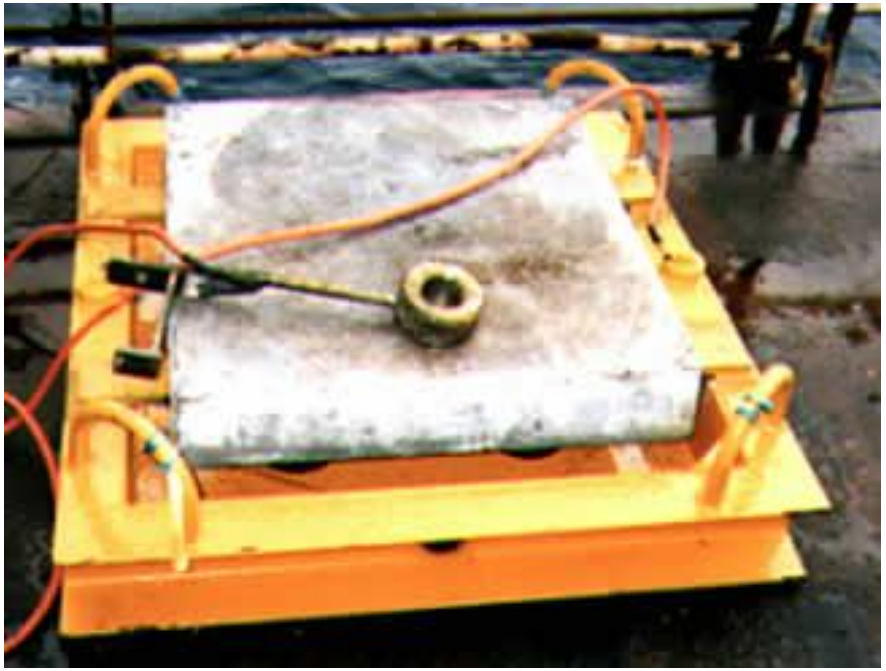
ROV tooling for anode replacement on an FPS

Final inspection of anodes on FPS hull

Anode Sled Connection to Subsea Assets

West of Shetland – using an ROV at 395 m (BP Schiehallion) . The studs and anode continuity tails were welded directly to 36inch subsea riser base piles using “Tri-partite” welds. This gives a welded connection between the anode continuity tail and the pipe minimising the electrical resistance of the connection.

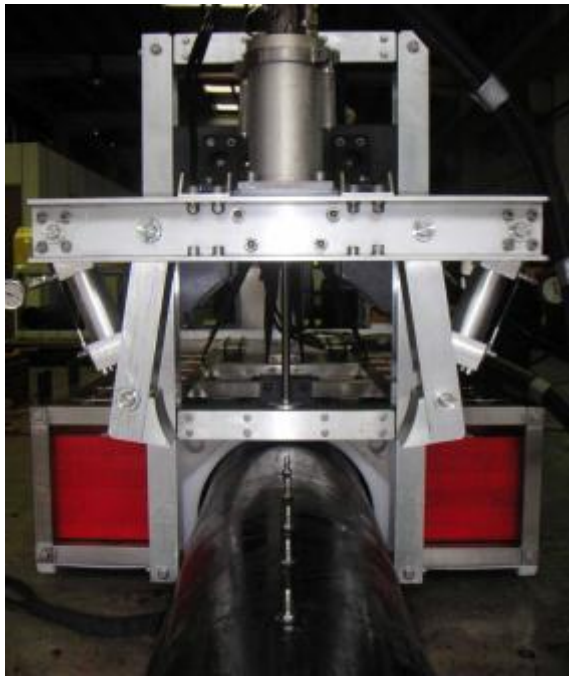
Schematic of ROV with Stud Welding tool



Anode skid with the continuity tail ready for Tri-partite friction stud welding

Anode Attachment on Live Subsea Pipelines

China 2005 – Water depth 113 to 120 m.s.w. M12 316L Stainless steel studs welded at 64 locations on the pipeline. The studs were welded to the top of the pipeline using an ROV and the anodes were then installed on the studs. Client CNOOC.



Testing the HMS3000 stud welding system in the ROV tool skid

The ROV with the stud welding tool skid

Friction stud on live subsea pipelines from an ROV

- A 316L stainless steel stud friction welded though an epoxy coating to a subsea pipeline

- Anode installation on the pipe following friction stud welding

Topside Friction Welding Tooling

Pneumatic Friction Welding Systems

Pneumatic Friction Welding System for use Topside
(shown here with a magnet clamp)

Friction Welding Underwater and in Areas where Hot Work is Not Permitted

The stud weld is encased within a foam and metal shroud.
In addition, for welding in zoned areas a water spray can also be applied during the welding and spark arrestors are fitted to the air exhaust .

Stud welding in zoned areas

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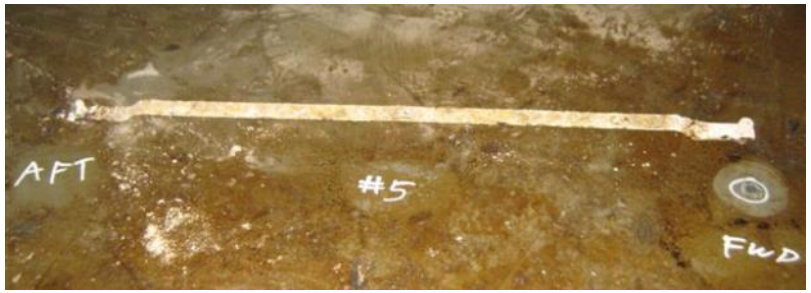
Topside Applications of Friction Welding on Corrosion Control

Anode Attachment in Oil or Ballast Tanks on FPSOs (Zone 1)

Proserv's R1400 pneumatic tool was used for retrofitting 160 anodes in a oil storage tank on the Terra Nova FPSO in Zone 1.



Anodes after 12 years service in an FPSO oil storage tank.

Friction Welding Explosive Atmosphere Test

After the weld has been completed the gas mixture of 14% Acetylene and air is detonated to verify that the gas was explosive.

Friction Welding on Live Pipelines for corrosion sensor attachment

Anode retrofit in Seawater Discharge Pipes in an LNG Plant (Ref. 4)

- Welding inside a water cooling pipe for the attachment of anodes
- Friction welding was used to avoid damaging the outer coating of the buried pipes and to minimise coating damage on the pipe interior
- Curved vacuum pad used for mounting the weld head

Minimising coating damage on structural retrofits

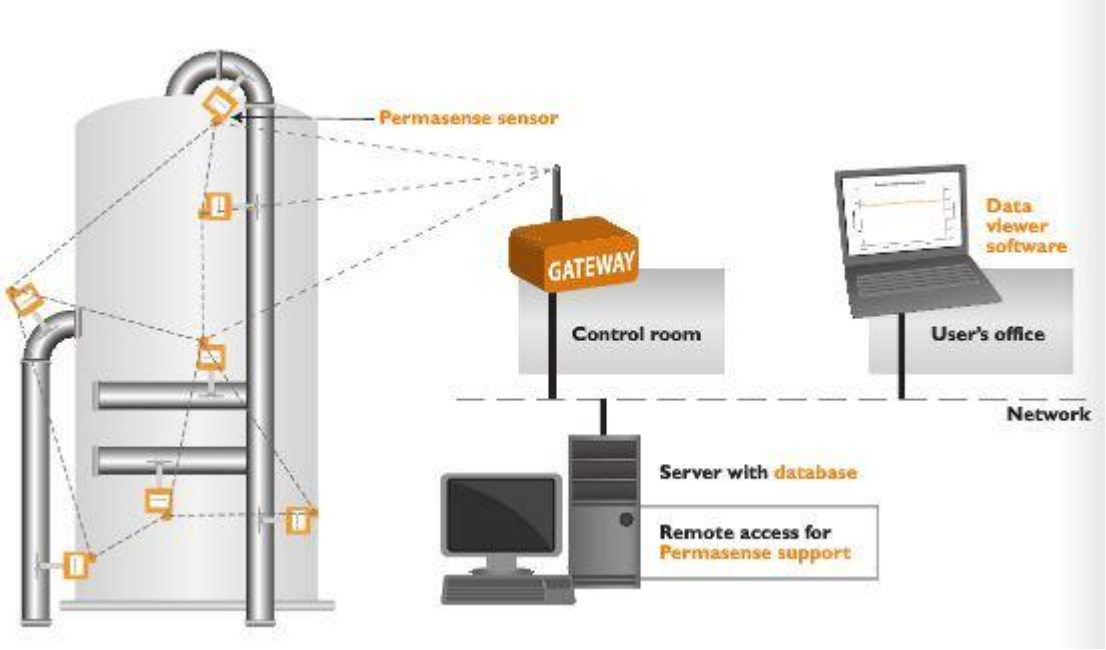
The R1004 Friction Welding tool in a magnet clamp.

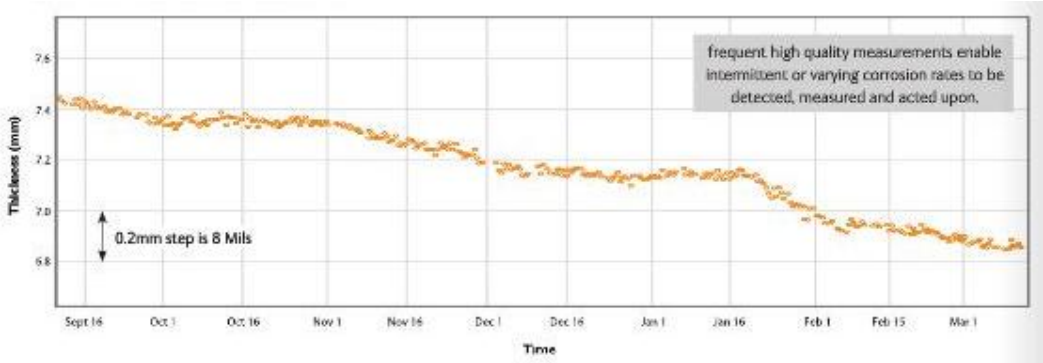
A stud for attaching a fire wall friction welded to the accommodation module on the platform

The accommodation remained fully occupied during the project with no fire risk on the inside due to welding

Corrosion Sensor Attachment

Continuous corrosion monitoring system installation





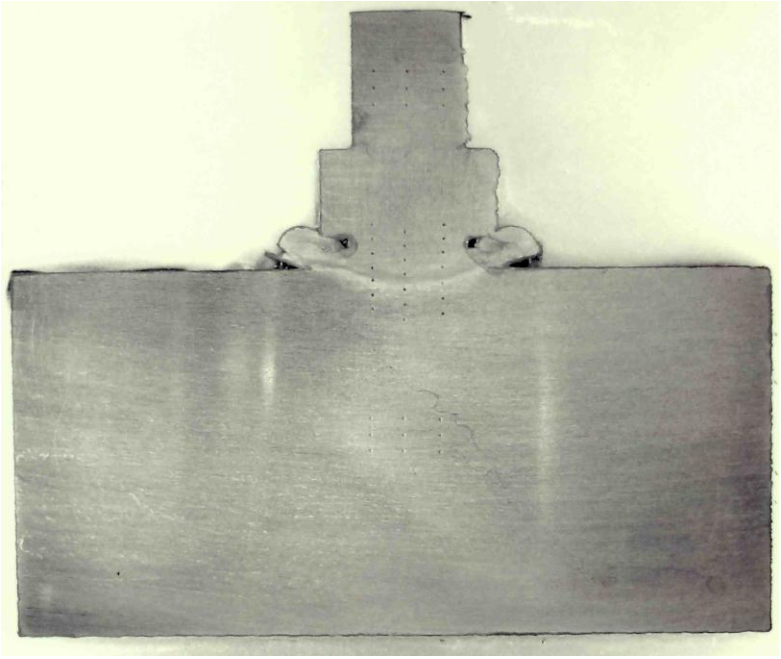
Continuous corrosion monitoring using wireless waveguide based ultrasonic thickness measuring sensors.

Friction stud welding on live pipes in zone 1 areas for sensor corrosion sensor attachment

Friction welding procedures were qualified using the explosive atmosphere test with the explosive gas mixture inside the pipe as well as surrounding the weld for pipes carrying hydrocarbons.

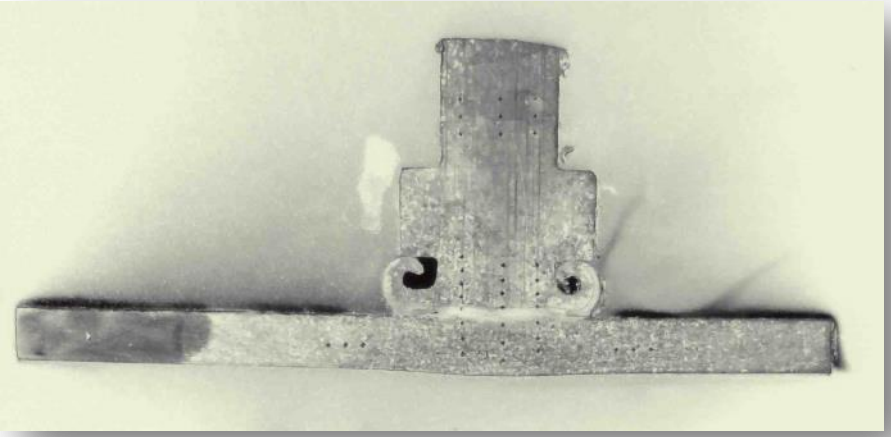
Friction Stud Welding on the wall 25.4 mm wall 2205 pipe.

A Welding Procedure Qualification test will be done in accordance with ASME IX for this project on the 2205 Duplex Stainless Steel pipe and witnessed by DNV. Preliminary tests gave acceptable bend and macro results. Maximum hardness was 279 HV10, Ferrite volume 56% and microstructures acceptable to DNV OS-F101:2010



2205 M8 Studs Friction Welding to 2205 Schedule 180 pipe

M8 Friction stud welds on SMO254 pipe



Explosive atmosphere test and macro for M8 friction stud welds on SMO 254 Super Austenitic Stainless Steel. The pipe is 3mm wall thickness and contains a water glycol mixture.

Max. Hardness 246 Hv10. Microstructure: Bond Zone – Ultrafine grained austenite. HAZs –Fine grained and equiaxed austenite with ultrafine grained austenite at the grain boundaries (see report)

Statoil Melkoya Island

Friction welding M8 studs friction welded to a live 3 inch dia. 3mm thick stainless steel pipe in a Zone 1 area for the attachment of corrosion sensors.

Statoil Melkoya Island

Insulation reinstalled on 3 inch pipe with corrosion sensors.

References

1. Manteghi S, “Some fatigue tests on friction welded steel bars”, TWI Report 485/1994, July 1994

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5. Welz W & Dennin G, “Fatigue strength of structures employing welded studs, Schweissen und Schneiden 33, Helf 2, (1981) p63-66.

The author would like to thank TWI for their permission to use data from TWI Report 485/1994 in this presentation.

THANK YOU

ANY QUESTIONS?

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