

## A Diverless Retrofit-Tee Hot-Tap GMA-Welding Method

The basic principle of hot-tapping is to establish a new branch pipeline connection to an existing pipeline while the primary pipeline is under full pressure. This involves connecting the branch pipe, including a valve, to the primary pipeline. Usually, this is accomplished by means of welding or a mechanical clamp connection—cutting a hole in the pipe wall with a machine connected to the valve, retracting the cutting head, closing the valve, and disconnecting and recovering the cutting machine. The pipe branch then may be extended by means of spools and a tie-in to a new pipeline in the normal way. This strategy has been shown to be very cost-effective, compared with alternative methods, including shutdown and tie-in at ambient pressure conditions.

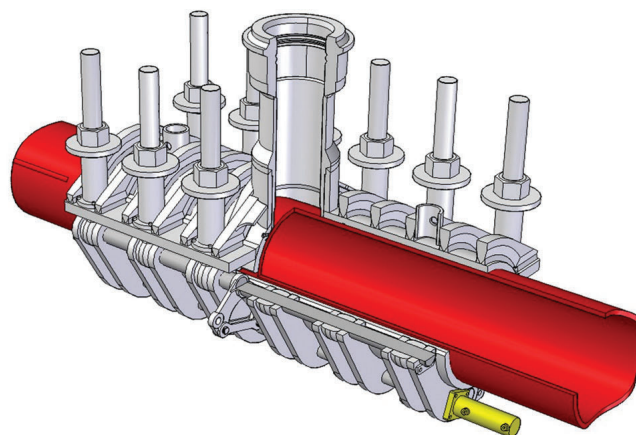
To date, for underwater applications, divers have been used to weld the branch pipe to the primary pipeline, and all installation and cutting operations also have been performed by divers. The cutting machines are essentially maritized versions of standard onshore hot-tap cutting machines and not optimized for the subsea application. This makes it diver-intensive, requiring the training and qualification of diver/welders in advance for the substantial welding job and operation of the cutting machine.

The primary focus of the remote hot-tap project has been the development of a novel design for a diverless installation, combining the use of a remotely installed mechanical clamp, providing the structural integrity and interface with the isolation-valve module and hot-tap cutting tool, and a “seal weld” made by remotely operated hyperbaric gas metal arc (GMA) welding inside the branch pipe (**Fig. 1**). The intention of the seal weld is not to provide structural capacity as such, but to make a highly reliable, “metal-to-metal” seal meeting at least the same quality standard as that which traditional manually welded hot-taps are meeting today.

The seal-welding qualification program has included work to demonstrate feasibility for up to 2000-m operation and a full, specific program for a potential 145-m application. The programs have included work on mechanical-property characterization and hydrogen pickup, and demonstration of repeatable hyperbaric-GMA-weld quality, even though it is not a structural weld as such. The new remote system will represent a substantial cost reduction because the vessel alone that is used for the remote equipment costs approximately half as much daily as a diver-supported vessel, even before diver-qualification costs are considered. More importantly, the system will extend the capability of the hot-tapping method beyond water depths limited by divers. The remote hot-tap welding tool is shown in **Fig. 2**.

### Subsea Applications—Sleeve Repair and Hot Tap

StatoilHydro is also currently developing a new equipment system employing hyperbaric GMA welding for a fillet-welded sleeve contingency, to be deployed and operated



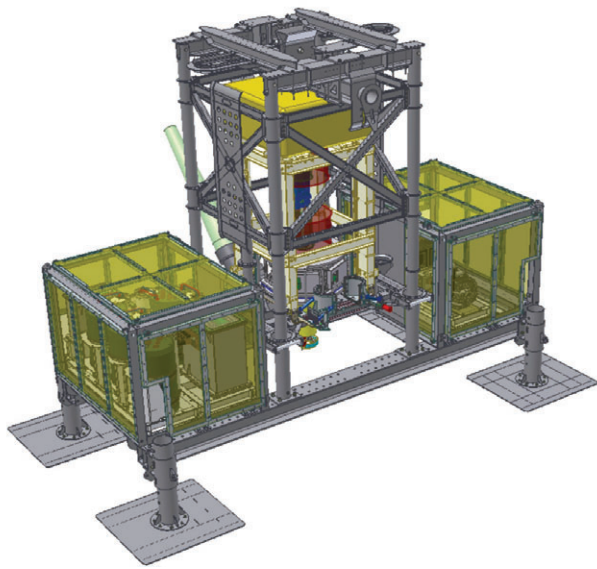
**Fig. 1—Retrofit tee design with internal hyperbaric GMA seal weld.**

remotely, without the use of divers. It is called the remote pipeline repair system. The use of a sleeve repair offers much greater operational flexibility over V-butt welding, in terms of both required tolerances to pipe ovality and radial offset and angular alignment of the pipe ends, because the sleeve is designed to include a root gap. It is anticipated that the sleeve design will incorporate environmental seals to prevent water ingress while welding the sealing passes, and that the sleeve inner diameter will allow for the required ovality, alignment, and installation tolerances. As already described, the use of hyperbaric GMA welding is ideally suited to the required material deposition and fillet-weld joint.

The qualification program considered the sleeve-welding application for five different large offshore gas pipelines. The main study has focused on the Åsgard Transport pipeline, a 42-in. API X65-strength pipe with 29-mm wall thickness, considered a significant challenge for new technology because it is a comparatively large, sour-service pipeline—in a depth range of 180 to 370 m—that is relatively highly stressed during the system pressure test. Much of the equipment required for sleeve repair may also be used for the hot tap, including topside equipment employing sensing and control, subsea welding-control systems, and GMA-welding power sources.

### Procedure Development and Welding-Process Performance

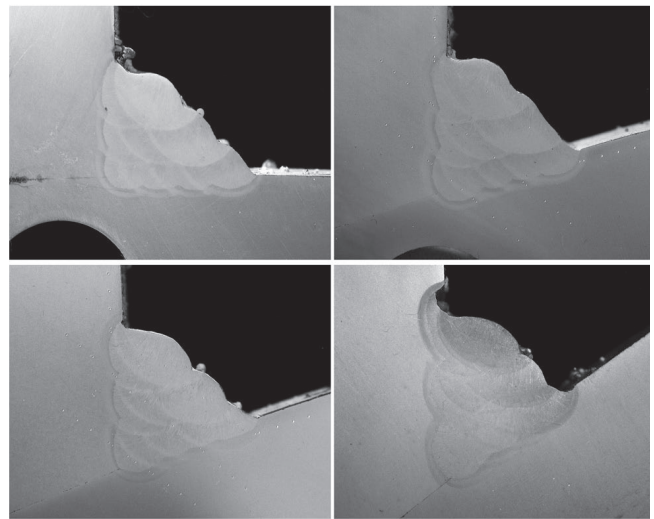
Procedure development has been carried out in a hyperbaric chamber at Cranfield University, UK. The experimental facility at Cranfield comprises a 250-bar pressure chamber with an internal volume of approximately 1.2 m<sup>3</sup>. It contains a manipulation system, either a three-axis Cartesian manipulator for linear welds in all positions or a four-axis



**Fig. 2—Retrofit tee-welding tool to make the internal hyperbaric GMA seal weld.**

orbital head for welding in the 5G position. Previous hyperbaric-GMA-welding research and development work has fully demonstrated the capabilities of the process for orbital V-butt welding, with highly satisfactory fusion profiles (and extremely few defects) and acceptable tensile performance for up to 2500-m operation. However, the Charpy V Notch impact-strength specimens extracted from the root area of 29-mm-wall-thickness joints, made using commercially available solid wires and X65 pipeline material, allowed room for improvement. New experimental wires were supplied by ESAB, a global welding-equipment and -consumable supply company, and were tested with other commercial wires during the previous programs, with particular focus on the toughness performance. Recent work has established that weld-metal toughness is now both better on average and more consistent than that obtained from solid wires. Furthermore, over the compositions tested during that period, the toughness response surface shows a plateau, with no single Charpy result below 76 J at  $-50^{\circ}\text{C}$  being recorded over the ranges 0.05–0.95% Ni, 0.01–0.04% Ti, and 216–485 ppm oxygen in the weld metal.

Using the metal-cored ESAB wire at 145 m, mechanical properties have demonstrated acceptability—with an all-weld tensile strength of  $\approx 600$  MPa 0.2% proof strength,  $\approx 670$  MPa ultimate tensile strength, and  $\approx 20\%$  elongation. Charpy V Notch weld-metal specimens exhibit typically 100 J at  $-30^{\circ}\text{C}$ , and fracture-toughness crack-tip-opening-displacement values are in the 0.4- to 0.9-mm range (satisfying the 0.20-mm minimum). Acceptable mechanical properties also have been achieved at 500 and 1000 m. Actual-size fillet-welded joints 9-pass procedures were made on the linear manipulator (Fig. 3) in key locations around the saddle— $90^{\circ}$  access at the saddle top,  $72^{\circ}$  access welding both down- and up-hill inclines at the saddle sides, and a worst-case  $56^{\circ}$  access at the saddle bottom.



**Fig. 3—Seal weld macros (clockwise from top left): saddle top, saddle-side up-hill, saddle-side down-hill, and saddle-bottom welding.**

### Conclusions

A general prequalification program for the retrofit-tee hot-tap application (145, 500, and 1000 m) and a specific qualification program (10-in. branch on 20-in. primary pipe at 145 m) have been carried out. The following conclusions are drawn:

- The use of a fully diverless retrofit remote-hot-tap tee is a significant advance in subsea technology, enabling hot taps to be made at up to 1000 m water depth.
- Hyperbaric GMA welding offers a viable joining option for seal welding for retrofit tees. Extensive work has been carried out in the 145- to 1000-m range, with previous work demonstrating process capability to 2500 m.
- Procedure-development and mechanical-property-testing work reported here confirms that the hyperbaric-GMA-welding process is capable of producing consistent, high-quality sealing welds suitable for the internal saddle-seal weld for the retrofit-tee hot-tap application.
- The bulk mechanical properties derived to date demonstrate the acceptability of the optimized welding wire with the welding parameters employed for the anticipated environmental conditions.

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**JPT**