How do they do that?

Deep water pipelines

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What's going on down there? Some people always have to stop at an excavation in the road, just to see what's going on. I have to admit to being one of them. The view can often be less than perfect if one is squinting through a join in the perimeter fence panels or from the top deck of a swaying bus – but even a brief peek at how some construction jobs progress can be fascinating.

Pipe laying at sea could possibly have the same draw but potential spectators don't have the convenience of a passing bus and even if the water were crystal clear, you can't see down a mile and a half. So for kindred spirits who would like to gaze down and see how it's done, here is a sketch of contemporary oil field layouts and how you get a pipeline down to those cold, still depths.

In a reverse of evolution, the oil industry started on land and has been heading back to the oceans for the last 50 years. Pipelines are one way to get the oil and gas products ashore and barges are used for their construction in shallow water. These barges are winched along on wire cables to anchors that are constantly being repositioned by a team of tugs. As the pipe sections are welded together and continually pushed into the water, supply vessels keep the pipe stock replenished.

As long as there is a demand for oil and gas, the producers will go to ever deeper and more hostile locations to maintain their stock reserves. Fields on the edge of the continental shelves, down to about 2,800 metres, are now on the front line. The development of DP (dynamic positioning) construction ships removed the constraints imposed by conventional anchor-positioning and contributed to solving the problem of how to work deep water locations. Positioning information can be provided from several sources including GPS (global positioning system), hydro-acoustic beacons, laser range and bearing (from reflectors mounted on fixed production platforms).

Divers can be routinely used for construction and maintenance work up to 300 m but greater depths require the exclusive use of ROV (remotely operated vehicle) submersibles. These are controlled by operators on surface craft while the vehicles descend but remain connected to the support vessel with power/communications umbilicals. The demands of deep water construction have required ROVs to evolve from small, observation only, 'flying eyes' to the equivalent of a construction site JCB with several tonnes of effective power (see Figure 1). ROV depth ratings of 4,000 m are not unusual: by comparison the depth ratings for military submarines are thought not to exceed 500m). In addition to sonar, floodlights, cameras and its robotic arms, a wide range of tools are available to the ROV among which are drills, saws, wire cutters, pumps and hydraulic power take-off.

Pipe design parameters

For most of us, one section of pipe looks very much like another but to the design engineer they are individual and have nearly infinite permutations. 40 ft is the standard length of a joint of pipe produced by the rolling mill. A double joint of 80 ft is a standard item supplied by pipe producers. Offshore pipe handling is usually in the form of quad joints which are effectively 50 m long.

The chosen pipe diameter relates to volume and pressure of product flow. The selected steel type has to have properties

▲ Figure 1

▲ Figure 2

▲ Figure 3

▲ Figure 4

▲ Figure 5

▲ Figure 6

▲ Figure 7

▲ Figure 8

▲ Figure 9

that can survive bending during the lay process and also resist chemical attack and erosion from the product. Clients will expect a 20 year working life from a pipe line.

The pipe wall thickness has to be sufficient to contain the fluids under pressure and resist seawater water pressure of up to 300 bar. A pipeline which has depth variations will have the wall thickness adjusted to suit. Wall thickness has a significant effect on the weight of the pipe catenary from tensioner to seabed, the total weight has obviously to be within the safe working load (SWL) of the handling machinery and the tensile strength of the pipe material.

Even in tropical regions the water temperature on the bottom will be just a few degrees above freezing. Cooling can coagulate wax in the oil or cause the formation of methane hydrate ice, which can block a line. Insulation material is introduced to reduce heat loss and can be moulded on to the pipe during its construction ashore. A common method of protecting the insulation from being crushed is to have a pipe within a pipe. The insulation material fills the space between the two tubes and a resin in-fill prevents unwanted longitudinal movement.

Early oil field designs had a production facility on a steel-legged platform over every well and major fields produced a forest of these structures. Nowadays production and well control is generally from a central hub, commonly a moored FPSO (floating production, storage and offloading vessel), TLP (tension leg platform) or Spar platform which will be the only sign at the surface of extensive seabed development. As extraction in a field continues the natural pressure of the product will decline. Seawater or gas can be pumped down through injection lines from the FPSO into lower levels of rock to increase oil pressure and the delivery rate. Oil field operations require a network of pipes between the wells in a field and the FPSO. To allow satellite well monitoring and control functions by the FPSO communication and power lines are bundled into control umbilicals which radiate from the control hub.

Lay methods

■ **1.** A rigid pipe can be laid from a large diameter reel (Figure 2). The pipe is prepared on rollers in a construction yard ashore, the lengths are welded together to form stalks about one mile long (Figure 3). When the pipelay vessel arrives, the stalks are wound up on to the ship's reel which imparts a bend to the pipe (Figure 4). The end of one stalk is welded to the next as it comes onboard so a continuous pipe is formed on the reel. When the pipe is laid the end is passed over an alignment wheel, then through a series of caterpillar-track type friction drives (tensioners) which also re-bend the pipe so that it is straight (Figures 5 and 6). It can then pass down through the moonpool and safely take the increasing weight of all the suspended pipe as the end approaches the seabed. A 400t load is typical for 14-inch diameter pipe in 2,000 m of water.

■ **2.** The alternative method (J-lay) is to supply 50 m (a quad joint) lengths of pipe to the vessel (Figure 7). They are stowed in bins on deck and lifted individually to a ready rack where the end faces are profiled to accept a weld. A prepared length is lifted into the pipelay tower with the loader arm (Figure 8). The top end is gripped by a clamp on a pulley system (Figure 9). The pipe is lowered through the moonpool by the pulley system. At full stroke the pipe end is gripped by an hydraulic clamp at the moonpool and the pulley system is released and hoisted back up the tower.

Another pipe is loaded into the tower and its end is welded (Figure 10) on to the end in the moonpool clamp. The head clamp is attached and takes the weight. The moonpool clamp is released and the two lengths of pipe lowered. The cycle is about 30 minutes for a medium sized single wall pipe and can be repeated continuously. This technique is slower than the reeled method but the ship does not have to break off and return to port for another load of pipe and a shore spooling facility is not required. Some pipe is too rigid to be bent round the reel. Only the quad joint method is suitable for larger diameters.

■ **3.** Sometimes flexible pipe is specified for special applications. This is formed from patent armoured and spiral built lines sealed with membranes and coatings. This product is normally trans-shipped from rotating storage 'carousel baskets' (Figure 11) on a barge to similar units on or within the ship. Well control umbilicals are handled in the same way.

Prevention of buckles

If you have ever bent a piece of copper plumbing pipe to break it you will have seen how the circular cross-section deforms to two parallel sides with virtually no cross-section, a flat piece of metal not a pipe. This is a buckle which, if allowed to form, can be propagated by water pressure and collapse an entire section of pipe.

Repairs are difficult, slow and expensive. Bending the pipe on too small a radius causes the buckle: they can form in the area where the pipe changes attitude from 'vertical' in the water column to horizontal on the seabed.

To prevent this from occurring the pipe is always kept under tension with the touch-down point on the seabed being up to 700 metres astern of the ship's moonpool. Even in still wind/water conditions the propulsion may have to push ahead with 50 tonnes of thrust to maintain the correct curve.

The stress and tension in the pipe during various stages of laying are calculated at the design stage. Care is taken to keep the touch-down-point, pipe tension, lay tower angle, ship motion and other variables within safe limits. Normally rigid pipe cannot be recovered on to a reel as the additional bending and straightening will start to decrease the fatigue life of the steel. In general terms the ship never moves astern during normal pipelay.

Initiation, lay and termination

Usually a pipeline starts and finishes with a sled (end termination) that incorporates a patent push-on hub connection. In shallow water divers would bolt up the short piece connecting the well to the pipeline but in deep water connection jumpers (Figure 12) are designed to be lowered into position by crane or wire where they are locked-on by the ROV.

The previous paragraph explained why the pipe always has to be kept taut, this is particularly important when landing a heavy (typically 40 t) end termination. The concentration of weight in the sled can raise bending forces at the pipe/sled weld to unacceptable levels. Additional tension is applied and buoyancy units may be attached to the sled before the landing operation.

Until the first end sled is firmly landed in its target box a fixed point to pull against is provided by a pre-installed anchor or a suction pile. The pipe touch-down point is continuously monitored by the ROV. The video is relayed to all control stations along with position graphics from the survey spread. The reel lay method can operate up to speeds of one knot but production is normally about one kilometer an hour as the pipe is stopped every three hundred m or so to bolt on anode collars.

The second end sled (Figure 13) is held in the tower while it is welded onto the end of the pipeline. An abandonment hook (Figure 14) is attached to the sled and it is lowered on a heavy wire as the ship moves ahead and the sled is lowered to its target box. The base wings of the sled are folded in to pass through the moonpool. The ROV releases the wings and facilitates the unhooking of the lay-down wire. There may be intermediate valves or structures in a line and they are deployed in the same way as the second end sled.

The use of support vessels with additional ROVs and wires is common. A pressure test and a detailed survey of the finished pipeline is another of the support vessel functions.

Pipes connected to a floating unit

Moored and tension-leg platforms all present design engineers with the problem of connecting fixed pipelines to hulls moved by current and waves.

Three methods in use are:

1. Flexible pipe. This is often laid over a mid-depth buoy so there is a bight to absorb movement.

2. SCR (steel catenary riser). This is a rigid pipe that is kept under the same sort of tension as when being laid so that the touch down point of the pipe is some way off the host. The pipe adopts a curve similar to that of a mooring chain, this provides the necessary 'give'.

3. A rigid riser: moored to the seabed and supported by a sub-surface flotation unit.

Bridge and DP operations

The bridge watch is always double handed with a chief officer and a second officer. Pipelay operations are continuous so two COs and two 2/0s, are standard manning. One of the watch will attend the DP control desk at all times while the other deals with marine activities such as marshalling supply vessels, transferring personnel by launch or helicopter, ballast control and VHF traffic.

The pipelay operation requires all the active parties to be closely coordinated. A round-robin open intercom connects following centres:

- Pipelay machinery control room;
- ROV control;
- Pipelay deck supervisor;
- Survey desk;
- Bridge.

Ship and pipe moves are controlled by the Construction Manager. Every activity in the construction phase is fully documented and risk assessed in advance. Deviations from the accepted plan are subject to formal written change management. Daily task plans are

▲ Figure 10

▲ Figure 11

▲ Figure 12

▲ Figure 13

generated from the master manuals and distributed to duty personnel.

The survey team will supply the bridge with a route which is programmed into the DP system. The ship is set up to follow the route automatically. If the pipe touch-down point is a long way astern the ship has to take corners wide. The DP will take account of this, automatically making lateral position changes, heading changes and maintaining forward movement.

Much of the time there will be several ships, rigs and other craft in the field. Movements need careful coordination and monitoring. Occasionally through traffic will steer to pass too close, however, the AIS has made it much easier to deal with these situations.

Like all computer systems, the DP will follow the instructions it is given. Therefore it is important for operators to make sure that all the settings on multiple menu pages are entered with the appropriate values. Once you press the 'execute command' button you may get a nasty surprise if something has been missed. All operators complete a status check-list when coming on duty. In critical circumstances both DP operators will check settings and command activation.

Working close to platforms and other vessels is normal (Figure 15): 10 m is the minimum clearance and an additional allowance has to be made for natural 'footprint' around the set position of the ship and structures. The captain works closely with the construction manager and will keep a close eye on bridge operations. Night orders are issued as normal.

Ready for trouble

DP operators must understand the characteristics and limitations of their systems and be able to take immediate action if a failure occurs. Redundancy is predicated on running with enough plant on line so that a single major failure will not leave the ship with insufficient electrical power or propulsion units.

Diesel electric plant with several generators on line at any one time is a common arrangement. Power distribution and control lines for individual elements in the power/thruster train are kept separate or protected so single component failures will not destabilise the whole system. Separate compartments for groups of generators provides redundancy in machinery spaces.

Many back-up and safety functions activate automatically. At the start of each pipe laying operation there is a trial to see that all the plant and control equipment is operating satisfactorily. All systems are given a thorough work out at annual trials. These normally take about two days and will be observed and commented upon by a team of independent auditors.

Environmental conditions are critical to the ship's station keeping. Weather from ahead is easily coped with but as forces act on to the beam power consumption and thruster output start to increase. To apply the correct tension to the suspended pipeline the ship is always pushing ahead and cannot deviate from the pipeline heading. If the ship is approaching the limit of its station keeping ability the pipe can be cut and a pulling head welded on. It can then be hung-off below the hull on the abandonment wire and a ship heading adjustment made to ease the load in the thrusters.

Launching pipeline end termination sleds and holding the pipe in the moonpool hang-off clamp are particularly sensitive to current and vessel heave. Sometimes one just has to wait for conditions to improve.

Different, but the same

Much of the time crew changes are made with helicopters and a busy day can see four flights. Certain marine crew are trained as helicopter landing officers (HLO) and manage the aircraft movements, passengers and baggage. Seamen provide the closed-up fire party manning foam monitors. The Medic/Admin organises the safety briefing, checking of weights and passenger manifests.

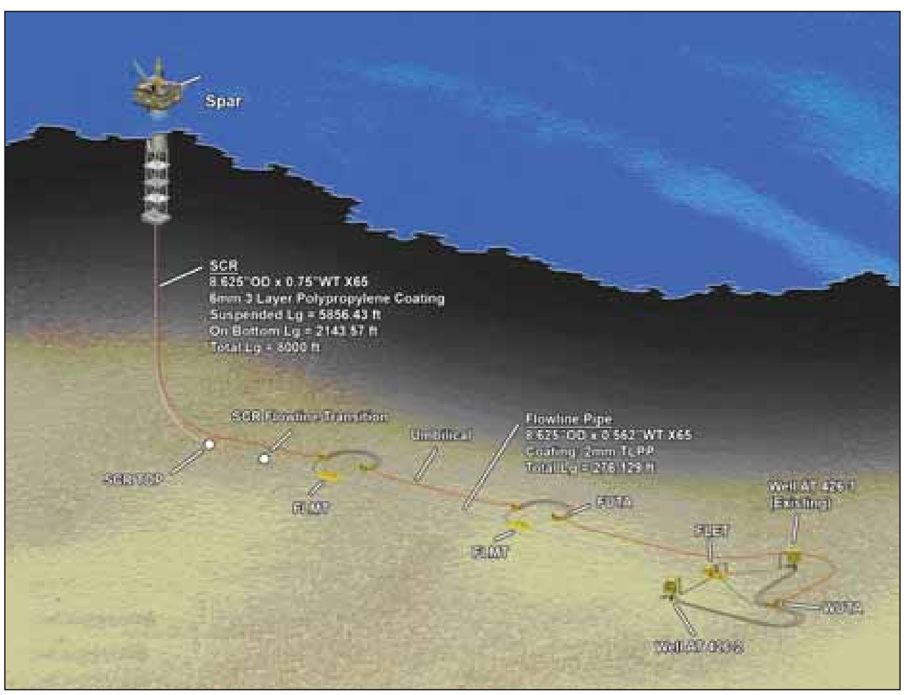
Apart from supporting the pipelaying operation, the bridge officers have the normal range of marine responsibilities to fulfil. On positioning voyages or during transit to the spool base the retractable thrusters are hoisted and mono-hull ships can navigate normally. The pipe production areas will still be a blaze of lights as round the clock maintenance and job preparation continue.

Marine crew life on a pipe lay vessel is very different from conventional trades but the practices of repeated cross-checking, prudence, preparedness, tidiness and seamanship are still common to us all.

So next time you see a pipelay vessel apparently idle in the middle of nowhere, don't be fooled: there is plenty going on.

▲ Figure 14

▲ Figure 15



▲ Field layout