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DMaC: Flowline and Umbilical Connections for Commercial Application

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ABSTRACT

Significant advances have been made in Diverless Maintained Cluster (DMaC) technology since the conclusion of the Esso Exploration and Production (UK) development program in 1991. A Joint Industry Program sponsored by BHP (Americas), BP, EXXON and STATOIL has detailed the designs of the flowline and umbilical jumper connection systems, and has enhanced the capabilities of the tooling that operates them. Several potential applications for DMaC have been identified, and a fast track program has been initiated by BP with some funding from other JIP partners, to demonstrate the JIP designs offshore, in deep water, under severe working conditions.

INTRODUCTION

This paper describes the progress that has been made in commercialising the Diverless Maintained Cluster (DMaC) system, in particular the Retlock connector and the flowline and umbilical jumper connection systems, since the conclusion of the Esso Exploration and Production UK (EEPUK) funded development program in 1991.

References, Tables and Figures at end of paper

Further development of the DMaC system, from January 1992 until mid 1993, was undertaken by Costain Oil, Gas and Process Limited, FUEL Subsea Engineering (COGAP).

Full descriptions of the DMaC subsea production system and the prototype testing of the flowline and umbilical jumper connection systems have been presented in previous OTC papers, References 1 and 2, so only brief overviews are given here.

The paper gives details of work undertaken during a Joint Industry Program that was concluded early 1994; it outlines some of the potential applications for DMaC identified by the JIP participants; and describes the first steps that are being taken by them towards commercialisation of the flowline jumper connection systems.

The paper describes the capabilities of the Retlock connector and the DMaC connection systems, and their current technical status.

OVERVIEW OF THE DMaC SYSTEM

The DMaC system concept is illustrated in Figure 1. As configured for the EEPUK development program, the system provides up to 50,000 bbls/day production, round trip pigging and well test by subtraction with no loss of production. It comprises an eight well gathering manifold with an 8 inch production header and pigging loop. Manifolding is accomplished in two circular, block manifolds. Foundations are provided by a single pile, or by skirts, depending upon soil conditions.

Production can be through conventional satellite trees, although for deepwater applications the trees can be fitted with ROV retrievable chokes and control pods.

Connection between the tree and the manifold is achieved by twin four inch bore flexible flowline jumpers for production/testing and by umbilical jumpers for control; the end terminations being by two-bolt clamps and stab plates, respectively. The clamps and stab plates utilise the Retlock which was developed, built, and tested under the DMaC program. The design of the Retlock has been developed further by COGAP and applied on two significant deepwater field developments in USA and Norway. Control is accomplished with a conventional multiplexed electro-hydraulic control system. Each tree is controlled by its own control pod.

The cost advantages of the DMaC system are maximised by the use of the drilling rig and drill support ROV for installation of all of the system elements, with flowline and umbilical jumpers being installed concurrently with drilling and production.

The base case eight well production system can be augmented with gas lift and/or water injection, as required, within the 5m x 5m envelope. Conceptual designs have been developed for a TFL serviced system, and for a string of manifolds with through export headers, culminating in a standard manifold with a pigging loop. Thus the DMaC system may be adapted to suit a wide variety of client and site requirements.

STATUS AT THE END OF ESSO'S DEVELOPMENT TESTING PROGRAM

At the end of the development testing program funded by Esso Exploration and Production UK Limited in 1991, DMaC was at a stage where a field development could proceed without the need for further fundamental research. The manifold was at a detailed conceptual level, with the target size for an eight well production system confirmed at 5m x 5m. The overall concept for the subsea trees was developed, as far as possible on the basis that trees from any manufacturer could be used, with DMaC components incorporated into them: ROV replaceable control pod, choke/valve, and DMaC flowline and umbilical jumper systems. Flowline and umbilical jumper systems had been developed and tested sufficiently to confirm that the operational concepts were valid and hardware and tooling were workable. The program had been devised to identify those elements of the system that were existing technology; those that were low risk development items, i.e. could be developed fully in the time frame of a typical field development; and those that required detailed development and testing within the program to validate the system concept. The key items in the latter group were the flowline and umbilical jumper connection systems which were subject to prototype build and test described in Reference 2. In these tests the operational concepts of flowline jumper installation - deployment, acquisition by the connection tooling and bringing the mating faces together were proven valid, and a set of prototype hardware and tooling was built, but the hubs, seal plate and clamps were omitted since they were considered to be low risk development items. The umbilical jumper connection system was developed more fully; live hydraulic couplers and dummy electrical connectors (conductive) were made up in the test program.

TECHNICAL ADVANCES MADE IN THE JIP

Background

The Joint Industry Program was sponsored by four oil companies, BHP (Americas), BP, EXXON and STATOIL, and the work was carried out by Costain Oil, Gas & Process Limited, FUEL Subsea Engineering. The objectives were to finalise detail manufacturing designs of the flowline jumper hubs and clamp and ancillary tools required to operate them (omitted from the earlier development program), and to upgrade the prototype tooling designs to enhance performance and incorporate lessons learned.

Flowline Jumper Connection Hardware

The DMaC flowline jumper connection system is intended for use on subsea tree-to-manifold jumpers, typically with twin 4"-6" production /test bores and a smaller gas lift line, and also on export line jumpers, typically with a single 8"-12" bore, all at system pressures up to 10,000psi. Likely jumper configurations were selected, at 5,000psi and 10,000psi, associated standard pipe sizes were identified, and working and test separation forces were calculated. This allowed four styles of DMaC hub and clamp to be classified, see Table 1, that could accommodate all foreseen requirements. Only three basic hub/clamp diameters are required, and two Retlock shaft sizes, simplifying design and manufacture.

For the JIP, it was agreed that a Style 3 hub and clamp should be designed, i.e. $16^1/_4$" OD x 10,000psi, with a 72mm Retlock, for a flowline jumper with twin 6", and a single 2", bores. This represents the largest likely 10,000psi rated subsea tree-to-manifold production jumper. Bore diameters through the hub are 4.875" and 1.77", and equivalent API5L X65 pipe sizes which interface with the hubs in the manifold and trees are 6.625" OD x 0.875" wall and 2.875" OD x 1.125" wall respectively.

The resulting DMaC flowline jumper connection porch design is illustrated in Figure 2. It consists of a structure with docking cones at 1m centres, an inboard hub, a blind hub with gaskets and needle valves, and a hot stab receptacle. This can be used to test for pressure integrity behind the blind hub before it is removed, and also for testing between the gaskets and an elastomeric seal after the jumper is installed. Interfaces are simple -the structural mountings and the pipework connections.

The mating flowline jumper pullhead is illustrated in Figure 3. This comprises an outboard hub, with seal plate and debris cap, connected via pipe bends to the flexible flowline end fittings. The pullhead is completed with a plated structure which has a smooth bearing area at the bottom to ride along the seabed and interfaces with the pull-in tool at side and top. The pipe bends and bores through the hub are 5D to allow pigging. Provision is made for a navigation transponder.

Flowline Jumper Pull-In Tool

The prototype flowline jumper pull-in tool incorporated two, 5 tonne rated coaxial twin capstan winches and storage drums with 50m line capacity. Calculation of the forces required to perform straight and bendaround pull-ins of the larger flowline jumpers highlighted the need for two 10 tonne rated winches, and studies of typical DMaC field layouts indicated that 150m line capacity would increase operational flexibility, and more closely match the ROV's excursion range. In view of the weight of steel ropes for the revised specification and the changes in trim when they are paid out, it was decided to adopt synthetic ropes for the JIP design. A test program was carried out to investigate the friction between the ropes and the winch sheaves, and it was concluded that the sheave should be coated to ensure adequate grip. The connector between the tool and the interface skid was uprated, to provide a through-frame lift capability. Overrides, limited to pullhead latch release, rope cutters, and a hot stab to set the winches to pay out under back tension, were designed. Other tool mechanisms, such as the pullhead yoke, which raises or lowers the pullhead within the tool to align hubs, were modified to improve efficiency, and the probes and the tool structure were redesigned to cope with the significantly increased loading. The buoyancy of the tool was specified for 1500m water depth, to meet the requirements of potential locations where DMaC technology could be used.

The resulting tool is illustrated in Figure 4.

Ancillary Tooling

The ancillary tooling is used in conjunction with the flowline jumper pull-in tool during jumper installation. It is carried at the front of the interface skid, from where it is controlled, and is placed by the manipulator.

The ancillary tooling comprises:

High Torque Tool

Opens and closes the Retlock Clamp. Based on a proprietary reciprocating piston and ratchet torque tool designed for underwater use.

Low Torque Tool

Opens and closes needle valves on the blind hub for pressure integrity tests of inboard valves, prior to blind hub removal.

May also be used on needle valves in the control system, if fitted.

May also be used with socket driver to drive Retlock clamp nuts at low torque.

Based on a proprietary rotary actuator, giving 5.5 turns per actuation via a gearbox.

Hot Stab Tool

The tool has two primary purposes in the DMaC system:

* Pressure integrity testing between the blind flange and inboard isolation valves prior to blind hub removal.

* Low pressure external testing of seals between porch and jumper hubs.

Other uses to which the hot stab may be put include:

* Fluid sampling.

* Fluid injection.

Design is based on an API 17D profile and rated to 10,000psi.

Seal Plate Tool

Used in conjunction with the flowline jumper pull-in tool to remove and replace seal plates from the inboard hub. Two seal plate tools are carried on the interface skid, one carrying a replacement seal plate, so that the entire replacement operation may be performed in one dive.

Designed to suit each hub and bore configuration.

ROV Operated Ancillary Tools

Other ancillary tools, such as a wire cutter, low pressure and high pressure water jets, may be used in DMaC operations, but since they are a normal part of a drill support ROV spread, they are not described here.

The JIP program included the building of a mockup of the front of the interface skid and ancillary tooling, a typical porch, hub and clamp, and experimentation with storage location and pick and place operations using a representative 'rate' manipulator. It was found that no single style of handle was satisfactory for all tools, due to the different storage and deployed positions, and the path by which they were placed, and that small changes could have a significant effect on operability. It is therefore essential to the smooth running of ancillary tool operations to experiment with the tools, interface skid, manipulator and mockup of the porches prior to subsea use.

The storage and deployed positions of the ancillary tool derived in the JIP are shown in Figure 5.

Interface Skid and Tool Control System

The prototype interface skid design has been uprated to operate the full suite of DMaC tooling; control pod maintenance tool, choke/valve maintenance tool, flowline jumper pull-in tool plus ancillary tooling, and the umbilical jumper connection tool. A computer based control system has been designed and control software, based on mimic diagrams of each tool, has been specified in outline.

The skid/tool connector has been uprated, as previously described, and the layout of the skid adapted so that a manipulator and the ancillary tooling may be carried at the front.

The resulting skid is shown in Figure 6.

Tool Deployment Basket

A tool deployment basket has been developed to allow the flowline jumper pull-in tool, the control pod maintenance tool or the choke replacement tool to be deployed to the seabed safely. The ROV and interface skid dock on and test all functions before disconnecting from the basket to perform the underwater task. Use of the basket allows the existing ROV deployment system to be used with little or no modification, from drill rig or DSV.

This is an alternative to the construction of specialist deployment systems capable of handling the stackup of the tool, interface skid, ROV and possibly tether management system.

The tool deployment basket is shown in Figure 7.

Umbilical Jumper Connection Hardware

The umbilical jumper connection hardware has been simplified as a result of experience with the prototypes, and has been configured to meet the specific requirements of the JIP.

The permanently installed inboard termination now has a single docking funnel, rather than the two part funnel and lock-back device of the prototypes, since it has been demonstrated that the terminations can be removed and flown to simple parking places very easily. Thus, if the controls distribution trunking on a manifold needs to be repaired, the termination would be flown to the trees, and parked there.

The outboard termination now has a simple tube rather than the docking funnel of the prototype, to save weight, since it is always located in a docking funnel, either at the deployment tray, tree or manifold when the tool docks in. The spring which ejects the termination from the tool probe in case of a power failure has been relocated onto the tool from the outboard termination to save cost.

The subsea connection plates in the terminations have been configured to accommodate the services and couplers listed in Table 2, an increase from 5 ways for the prototype to 9 for JIP. Consequently the preload requirement has increased from 4 to 8.5 tonnes and the Retlock shaft diameter has been increased. Subsea connection plate thickness has also increased to control deflection.

Umbilical jumper terminations are shown in Figure 8.

Umbilical Jumper Connection Tool

The umbilical jumper connection tool follows the same format as the prototype, but the drive socket has been made compliant to ease mating with the Retlock, and the separation spring for emergency ejection of the termination has been incorporated in the tool. The tool is shown in Figure 9.

Umbilical Jumper Deployment Tray

The umbilical jumper deployment tray remains substantially the same as the prototype, with only minor detail changes to ease manufacture and to make it suitable for deployment to 1500 metre water depths.

TECHNICAL STATUS AT THE END OF THE JIP

The technical status at the end of the JIP is summarised in Table 3.

POTENTIAL APPLICATIONS FOR DMaC

The JIP partners have identified a number of potential deepwater applications for DMaC and its jumper connection systems.

BP, with its partner Shell UK, has identified its Atlantic Frontier Development, Block 204, West of Shetland in 300-900m water depth, as potentially benefitting from the use of DMaC.

An early production scheme is being considered using a floating production system connected by flexible risers to a multiple well subsea development. Both deep water template and cluster well schemes are under consideration. DMaC technology is being evaluated, with other technologies, for this application and longer term basin developments. An operability demonstration project is underway.

Several areas identified as being suitable for DMaC include the Voring Plateau in the Norwegian Sector in the North Sea, and Nigeria and Angola in West Africa.

Field development studies for North Sea fields in shallow water have demonstrated that DMaC can be used cost effectively in place of diver based jumper installation techniques.

FIRST STEPS TOWARDS COMMERCIALISATION OF THE DMaC JUMPER CONNECTION SYSTEMS

In view of their interest in the use of the DMaC jumper connection system for their Atlantic Frontier Development. BP have initiated a fast track project to demonstrate the operability of the DMaC subsea hardware and ROV tooling.

It is planned to build a complete set of flowline jumper and umbilical jumper connection tooling, a pair of flowline connection porches and a flowline jumper; two umbilical terminations and a jumper, and a deployment tray, all based on the JIP designs. The subsea hardware will be amended to match more closely the requirements of the proposed development; a 12", 3,500psi flexible jumper for export lines will be tested as well as a 5" x 5" x 2", 5000psi jumper for subsea tree to manifold connections.

The testing will be performed offshore, from a drilling vessel on location West of Shetland, so the entire jumper installation process can be demonstrated, from transportation of the jumper offshore through deployment, pull-in and connection and testing. It is also planned to test emergency and disconnection procedures in deep water.

The program was initiated in early January 1994, with "The FUEL SubSea Offshore Alliance", a joint venture between Costain Oil, Gas & Process Limited, FUEL Subsea Engineering and the major international underwater contractor, SubSea Offshore Limited, working on the provision of all DMaC related items and performance of the offshore trials. Offshore testing is planned for July 1994.

CONCLUSIONS

DMaC technology has been further detailed since completion of EEPUK's development program in 1991. The fundamental principles and designs remain unaltered, but the details of the system have been enhanced to widen capabilities and improve operability. COGAP has gained valuable field experience with the Retlock connector which is used widely throughout DMaC.

Oil companies participating in the JIP have acknowledged the potential that DMaC offers for lowering the costs of oil and gas recovery, both in deep and shallow water.

ACKNOWLEDGEMENT

We thank the four oil companies participating in the JIP; BHP, BP, EXXON and STATOIL, and COGAP for permission to publish this paper.

REFERENCES

1. D.R. Pejaver; J.W. Jones; and J. White: Diverless Maintained Cluster (DMaC) Subsea Production Systems, Offshore Technology Conference Paper No OTC6720

May 1991.

2. D.R. Pejaver; J.W. Jones; J. White; and J. Brydon: Prototype Testing of the Diverless Maintained Cluster (DMaC) Subsea Production System, Offshore Technology Conference Paper No OTC7006 May 1992.

STYLE	DMaC HUB SIZE	RETLOCK SHAFT SIZE	5,000 PSI JUMPER CONFIGURATIONS (FLEXIBLE BORE SIZES (mm))	10,000 PSI JUMPER CONFIGURATIONS (FLEXIBLE BORE SIZES (mm))
1	13 1/4" OD x 10,000 psi	56mm	2 x 4", 1 x 2" 3 x 3", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1"	2 x 4", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1"
2	16 1/4" od x 10,000 psi	56mm	2 x 4", 1 x 2" 3 x 3", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 2 x 6", 1 x 2"	2 x 4", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 2 x 3", 1 x 2"
3	16 1/4" OD x 10,000 psi	72mm	2 x 4", 1 x 2" 3 x 3", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 1 x 10", 1 x 2" 1 x 12"	2 x 4", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 2 x 6", 1 x 2" 1 x 10", 1 x 2"
4	20 5/8" OD x 10,000 psi	72mm	2 x 4", 1 x 2" 3 x 3", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 2 x 8", 1 x 2" 1 x 12", 1 x 2"	2 x 4", 1 x 2" 1 x 6", 1 x 2" 1 x 8", 1 x 1" 2 x 8", 1 x 2"

TABLE 1
DMaC HUB AND CLAMP STYLES, AND CORRESPONDING JUMPER CONFIGURATIONS

SERVICE	PRESSURE OR RATING	COUPLER SIZE	QUANTITY
HP Hydraulic Supply	10,000 psi (690 bar)	1/4" (National)	1
LP Hydraulic Supply	3,000 psi (207 bar)	1/4" (National)	1
Hydraulic Return	3,000 psi (207 bar)	1/2" (National)	1
Manifold Valve Supplies	3,000 psi (207 bar)	1/4" (National)	2
Methanol Supply	10,000 psi (690 bar)	1/2" (National)	1
Other Chemical Supply	10,000 psi (690 bar)	1/4" (National)	1
Conductive Power Connector	0-1Kv/20A, 4 Pin	Mini CE (Tronic)	1
Conductive Signal Connector	0-1Kv/20A, 4 Pin	Mini CE (Tronic)	1

TABLE 2
JIP UMBILICAL JUMPER TERMINATION CONFIGURATION

SUBSYSTEM/ COMPONENT	DESIGN STATUS	PROTOTYPES AND TESTS
MANIFOLD		
Base Structure	Concepts only	No
Manifold Structure	Concepts only	No
Circular Valve Blocks	Concepts only	No
Controls Trunking	Concepts only	No
Pigging Valve and Tooling	Concepts only	No
SUBSEA TREE		
Main Structure	Detail designs available for components; Concepts only for overall assembly	Components proven
Flowline Connection Base	Concepts only	No
ROV Replaceable Choke	Detail design available	Choke Insert/Receiver extensively land tested
ROV Deployed Choke Maintenance Tool	Considerable detail engineering done	Docking Latches and Compliance System land tested
ROV Replaceable Control Pod	Detail design available	Dummy Unit tested on land and underwater
ROV Deployed Control Pod Maintenance Tool	Detail design available	Complete operational tool exists; Land and Underwater Tests done
FLOWLINE JUMPERS		
Jumper Pullhead, Porch and Sealplate	Manufacturing designs available	Land and Underwater Testing carried out on prototypes
Clamp Connector and Hubs	Manufacturing designs available	No
Pull-In Tool	Manufacturing designs available for 2nd generation tool	Land and Underwater Testing carried out on prototype
Tool Deployment Basket	Manufacturing designs available	No
Ancillary Tooling	Manufacturing designs available	Seal Replacement partially tested on prototype
Interface Skid	Manufacturing designs available for 2nd generation skid	Land and Underwater Testing carried out on prototype
UMBILICAL JUMPERS		
Jumper Connector and Inboard Termination	Manufacturing designs available	Land and Underwater Testing carried out on prototypes
Main Umbilical Connection	Concepts available for some aspects	Pull-In aspects tested
Umbilical Jumper Connection Tool	Manufacturing designs available for 2nd generation tool	Land and Underwater Testing carried out on prototype
Umbilical Jumper Deployment Tray	Manufacturing designs available for 2nd generation tray	Land and Underwater Testing carried out on prototype

TABLE 3
DMaC TECHNICAL STATUS AT THE END OF THE JIP
FIGURE 1 DIVERLESS MAINTAINED CLUSTER (DMaC) WELL SYSTEM

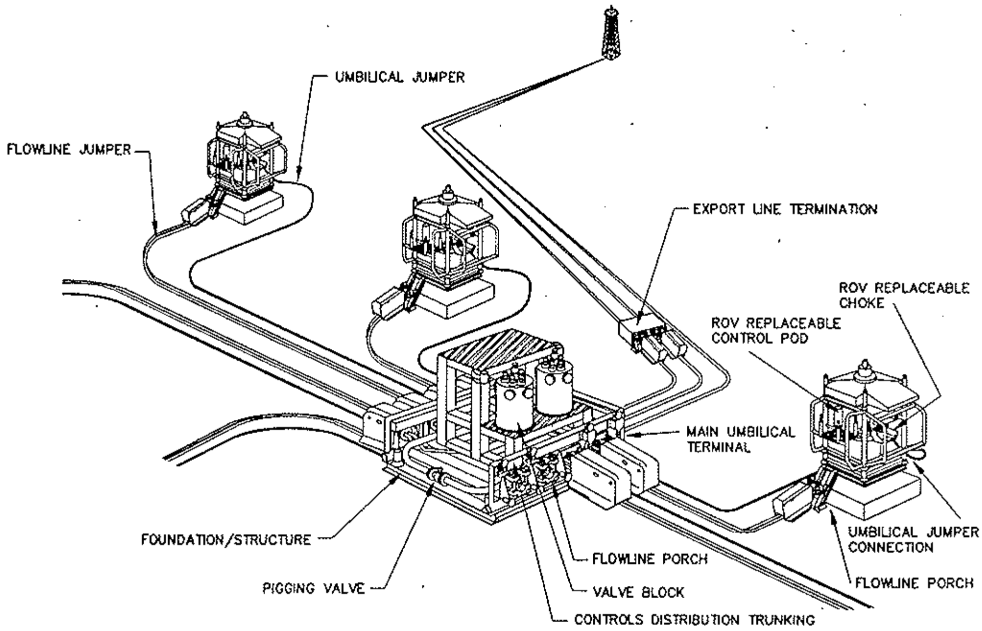


FIGURE 1. – DIVERLESS MAINTAINED CLUSTER (DMaC) WELL SYSTEM

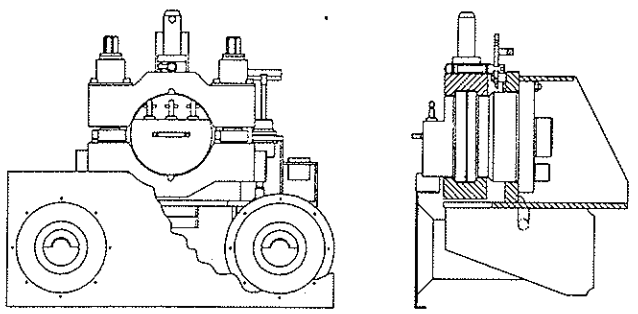


FIGURE 2 – DMaC FLOWLINE JUMPER CONNECTION PORCH

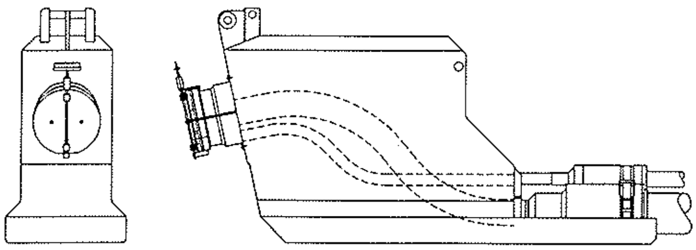


FIGURE 3 – DMaC FLOWLINE JUMPER PULLHEAD

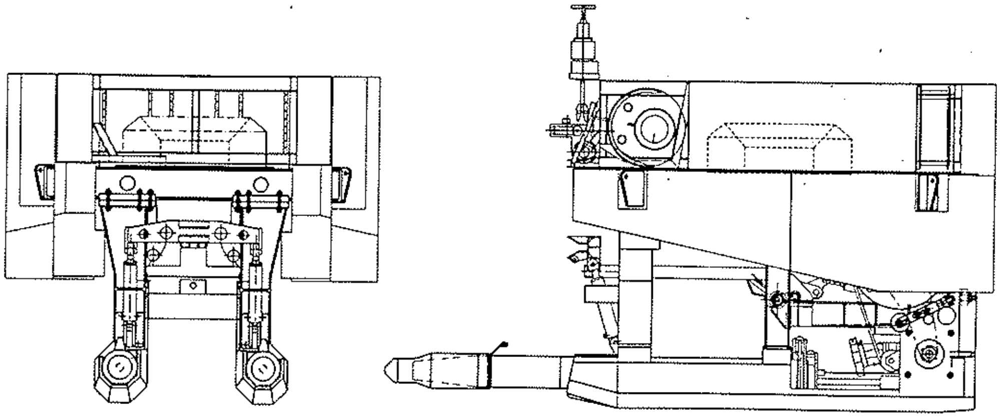
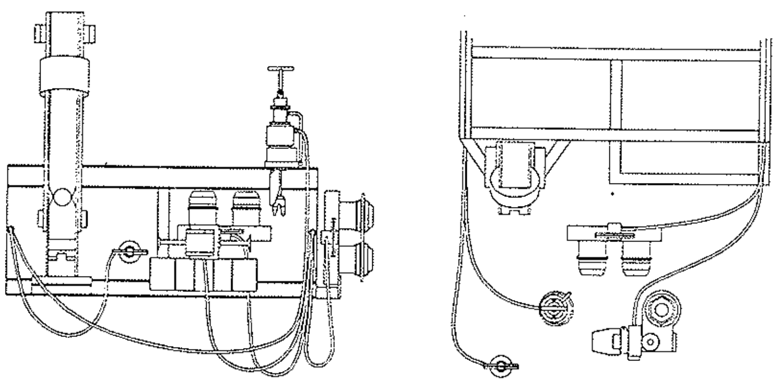


FIGURE 4. – FLOWLINE JUMPER PULL-IN TOOL, INTERFACE SKID AND ANCILLARY TOOLS



ANCILLARY TOOLS STOWED ON THE INTERFACE SKID (FRONT VIEW)

ANCILLARY TOOLS DEPLOYED (TOP VIEW)

FIGURE 5. – ANCILLARY TOOLS ON THE INTERFACE SKID

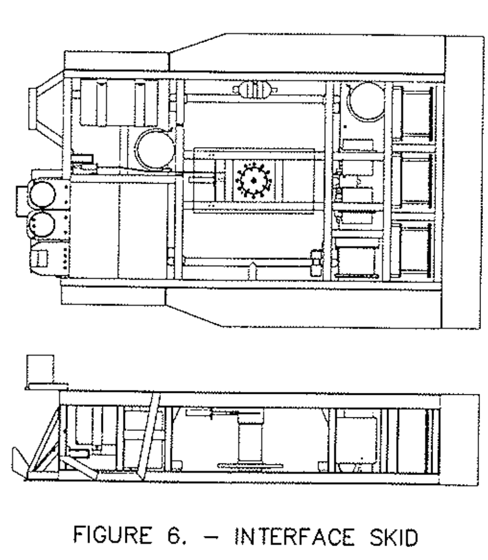


FIGURE 6. – INTERFACE SKID

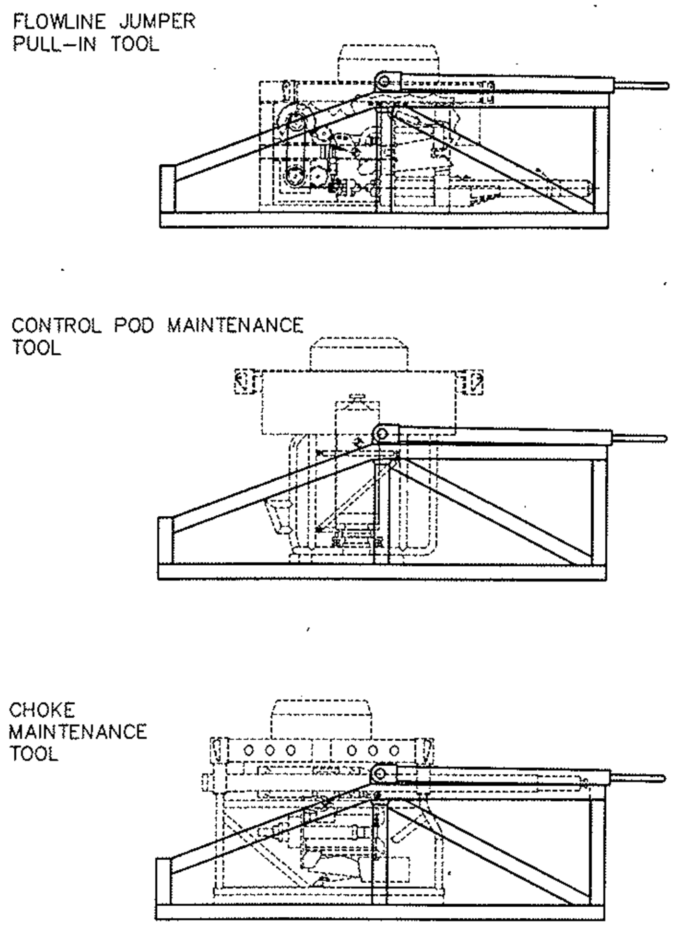


FIGURE 7. – TOOL DEPLOYMENT BASKET

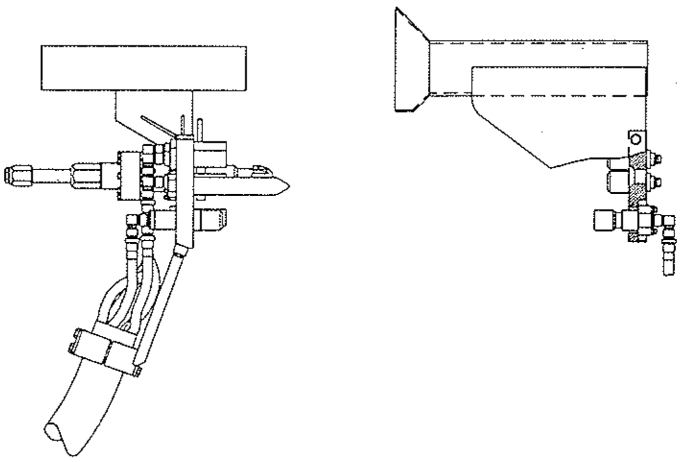


FIGURE 8 – UMBILICAL JUMPER TERMINATIONS

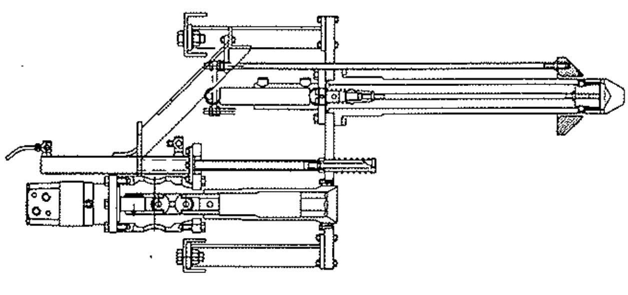


FIGURE 9 – UMBILICAL JUMPER CONNECTION TOOL