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Intelligent Pigging of 48” diameter, 20 KM Offshore Crude Oil Pipeline at BPCL, Kochi, India

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Abstract:

KEI-RSOS Maritime Limited (KRML) was entrusted by Bharat Petroleum Corporation Limited (BPCL), India to carry out the Intelligent Pigging of 48” diameter, 20 KM Crude oil offshore pipeline from STF to SPM at Kochi SPM facility. KRML in association with M/s. 3P Services, Germany, executed the pigging project successfully. The methodology used for this project was Bi-directional pigging, which is the latest & was carried out first time in India. The paper discusses the details of the project including utilisation of cleaning pig, GEO pig, Intelligent (MFL) pig and our experiences. The paper also discusses the advantages & the benefits of the technology related to reduction in project execution time & project cost, simplicity of operation and environmental friendliness. The limitation of the method & problem encountered are also discussed and shared, so that the offshore industry can take benefit from our experience, in future.

1. Introduction

KEI-RSOS Maritime Limited (KRML) is an ISO 9001, 14001, 18001 & ISM certified professional outfit comprising of young and result oriented marine professionals who have come together to ensure single point accountability of offshore oil field, port, construction and infrastructural related services for the marine and infrastructure industry on the east and west coasts of India.

The Company was established in 1999. Currently our team consist of most seasoned marine professional with rich experience and the company is handling various contracts related to Port Management, SPM Operations & Maintenance and Offshore Logistics.

Bharat Petroleum Corporation Limited has started operation of its SPM facility at Kochi in 2007 and KRML was the first to take up the challenge of Operation & Maintenance fo SPM and has continued till date. As per the operational requirement BPCL has decided to do the Intelligent Pigging of offshore crude pipeline i.e. from STF to SPM and the contract was awarded to KRML.

As it is a specialized job, KRML scouted for the best specialist in the field. After thorough study on the pros & cons KRML entrusted the job to 3P services, Germnay.

3P Services GmbH & Co. KG Services, Germany is one of the specialist firm which is involved in the Pipeline inspection services since more than 20 years across the globe.

KRML tied –up with 3P Services, and took up the challenge to complete the Intelligent Pigging of the BPCL offshore pipeline and completed the job in the scheduled time. The job was completed in the most effective, safe, economical and satisfactory way.

2. Definitions

Pigging - in the context of pipelines refers to the practice of using devices known as "pigs" to perform various maintenance operations on a pipeline include but are not limited to cleaning and inspecting the pipeline.

Pig - (Pipeline Inspection Gauge) are devices / tools that are placed inside the pipe and traverse the pipeline for pigging.

Cleaning Pig – is the tool used for cleaning of the pipeline

GEO Pig- is the tool used for determining any geometric discontinuities of the inside of pipelines

Intelligent / MFL Pig- is the tool works on Magnetic Flux Leakage (MFL) principle to detect the defects of the pipeline both internal and external area of the pipeline.

STF – Shore Tank farm

SPM – Single Point Mooring

PLEM – Pipe Line End Manifold
ILI – In Line Inspection

3. Project Concept: Bi-Directional Pigging

In general, bi-directional tools are proposed for cleaning and inspection that are handled exclusively from shore. All pigs are pumped from shore to the offshore end and then – at reversed flow – pumped back to shore. The inspection tools are free-swimming high-resolution MFL and GEO tools that achieve comparable quality data as uni-directional inspection tools. These tools record data in both directions and operate without tether just like standard uni-directional tools.

Close cooperation and planning with the client is important for bi-directional inspections. Flow conditions during the inspection, in both ways, and the pipeline end approach need to be planned carefully during the project engineering.

The bi-directional concept of running cleaning and inspection tools requires no modifications to the pipeline. For the bi-directional application it is necessary that the propellant can be pumped back and forth so the tools can be run both directions. To be able to do this, at both ends, on land and at the single point mooring (SPM) there must be tank and pump capacity available. Tank volume should be at least 1.5 times the line fill and the pumping capacity should enable a pig speed in the range of 0.5 to 1.5 m/sec.

In this case, we have suggested that the existing tank and pumping installations at the Shore Tank Farm to be used to propel the tools from the beach to the PLEM. For the return, the best solution is to use pumping capability that exists on the tanker(s) that are delivering crude at the SPM.

4. Project Planning

The Planning of the project started six months before the actual execution at site. BPCL has declared the project execution slot considering their operational requirements, tanker availability, buffer stock for the refinery & availability of suitable crude oil for propelling etc.

In order to complete the project in most professional way in the time slot allocated a lot of planning was carried out between BPCL, KRML & 3P Services. As during the project an external crude tanker has to be stand-by and job should be carried out without shut-down of the refinery. It was updated by BPCL operations team that they can provide a slot of maximum 6 days at a time. As the project execution time was minimum 12 days, the whole project divided into two phases of 6 days each.

KRML scope of work was to provide the services including mobilize the equipment, pigging tools, tackles, consumables, spares, accessories and personnel at work site including but not limited to mobilization and demobilization, handling, transportation of cleaning pigs, gauging, caliper pigs, MFL intelligent pig, carrying out internal cleaning and gauging including magnetic cleaning, caliper survey, conducting corrosion inspection through high resolution MFL type intelligent pigging, modification of pipeline as required, collection & disposal of sludge, submitting reports, etc as required for satisfactory and timely completion of “Intelligent pigging of 48” offshore pipeline from Single Point Mooring (SPM) to Shore Tank Farm (STF)” approx 20 KM.

KRML involved 3P Services as specialist firm for pigging. KRML kept the overall project responsibility, logistics, monitoring & control with themselves.

5. Project Execution

After lot of planning, the scope of work was revised as follows.

3P Services Scope of Work: 3P Services to mobilise all ILI tools & associated equipment and project engineers to site and execute the project.

KRML Scope of work: All other assistance as required to complete the project and overall supervision has been done by KRML.

Equipment Details:

Pipeline Details: The details of the pipeline are as below.

- Diameter of pipeline: 48”,
- Thickness of pipeline: 20.6 mm,
- Length of pipeline: Approx. 20 Kms.
- Maximum pumping rate: 8250 KL/Hr.
- Design Pressure: 12 Kg/cm² (Operating pressure: 5 – 8 Kg/cm²),
- Design Temperature: 45 Degree Celsius
- Temporary pig launcher under sea at Pipeline End Manifold (PLEM)
- Water Depth : 30 m,
- Length of the launcher : 4 meter,
- Pig receiver provision is at Shore Tank Farm.
- Coating: Coal Tar Enamel & concrete weight coating of adequate thickness.
- Service : Crude oil

Tool Details:

- Cleaning Pig
- Geo Pig
- Intelligent (MFL) Pig
- Tool navigation and locators Man power:
- Project Engineers – 4 Nos.
- Operation team – 5 Nos.
- Diving Team – 10 Nos. Marine Spread:
- Maintenance Vessel – 1 No.
- Support Vessel – 1 No.
- Mooring Boat – 1 No.
- Crude tanker – 1 No.

Project Execution - Field Operations- Phase-1

Inspection preparation & performance

5.4.1. Safety Checks for shore personnel, divers, ship staff was followed as per KRML / BPCL/ 3P internal procedures.

5.4.2. Inspection task

No cleaning or inspection device has been run through the pipeline since its commissioning. Target of the present inspection is to determine deformations and metal loss to enable an assessment of the integrity of the pipeline.

Preparation of the pipeline for the inspection campaign

The tanker unloading system was originally laid out to have a pig launcher on the shore within the boundaries of the Shore Tank Farm (STF). However, the actual trap facilities/ pig launcher were not in place. 3P Services has assisted with the trap layout during the project preparation. It was then manufactured in India by KRML and installed at STF. Sludge collection pit was also constructed by KRML at pig launcher/ receiver.

At the beginning of the first mobilization of 3P Services and prior to running the first tool, 3P Services' sub-sea antennae were placed by divers on the sea bed at 180m, 80m and 10m, measured from the PLEM/pipeline flange. These antennae are required for safe navigation of the tools near the PLEM. These help to track the tool's approach to the offshore end of the line and to accurately stop the tool at the pre-set turn-around position.

➤ Run #1: Cleaning and gauging

Since no tool has been run through the pipeline since commissioning the condition inside was unknown. Since various different types of crude were unloaded through this pipeline the paraffin sedimentation was a major concern in the first place.

The cleaning/gauging tool was designed in a way to scrape only softly when pumped towards the sea and to clean harder on the way back to shore. It is called a "soft in/hard out" design. Moreover, in order to limit the risk of accumulating excessive volumes of paraffin during the initial run the trip distance was limited to approx. 12 km.

Run No.	#1
Tool Function	Bidi Cleaning / profile
Type	Single Module, disc supported with gauge plate, magnet ring and transmitters
Manufacturer	3P Services
Gauge Plate Diameter	1050 mm
Run by	3P Services
Run Date	Nov 24, 2014
Total run time	Approx. 8 h
Average tool speed	Approx. 1m/s (calculated from pump rate)
Propelled by	Crude oil, type: Bombay High
Tool Performance (war/debris)	Tool in good condition, massive paraffin build-up on th tool body
Gauge plate performance	Ok, no scratches or marks
Result	Not OK for GEO

Table 1

The paraffin load had an estimated weight of 600kg. It was primarily sitting between the discs with only minor volumes in front and behind the tool.

On the trip back to shore a major volume of paraffin in front of the tool may have escaped with the general flow into the tank farm prior to the arrival of the tool on shore. Further paraffin is expected to have entered the trap together with the tool. It is assumed that the vacuum truck that emptied the trap prior to opening may have taken out most of this paraffin.



Figure 1

➤ Run #2: Cleaning and gauging

The original schedule for run #2 was to pump it close to the PLEM. Because of the paraffin load brought out by run #1 the schedule was changed. It was decided with BPCL to run it again the same distance in order to have a reference whether or not a trend towards a cleaner pipeline can be determined.

Run No.	#2
Tool Function	Bidi Cleaning / profile
Type	Single Module, disc supported with gauge plate, magnet ring and transmitters
Manufacturer	3P Services
Gauge Plate Diameter	1050 mm
Run by	3P Services
Run Date	Nov 25, 2014
Total run time	Approx. 9 h
Average tool speed	Approx. 1m/s (calculated from pump rate)
Propelled by	Crude oil, type: Bombay High
Tool Performance (war/debris)	Tool in good condition, massive paraffin volume around the bottom of the tool
Gauge plate performance	Ok, no scratches or marks
Result	Not OK for GEO

Table 2

After the tool had been received in the trap there was a delay of approx. 14h. Since it was a hot day with permanent direct sunlight onto the trap the entire installation heated up significantly. Therefore, the collected paraffin had a chance to melt down from its original position on the tool and it was found all around the bottom of the tool in the tray when finally pulled out of the trap. The estimate of paraffin collected was approx. 400 kg. The overall condition of the pipeline in view towards pipeline inspection was interpreted to have not improved from run #1 to run #2 and, consequently, it was declared “not ok” for continuation. The first phase of the pigging campaign was concluded and 3P Services’ personnel demobilized.



Figure 2

Project Execution - Field Operations- Phase-2.

➤ Run #3: Cleaning and gauging

With 3P Services' second mobilization BPCL had made another crude quality available for the following pig runs. This was "Arabian Light", having a gravity of 33° API and a very low pour point (below 0°C). With this change no further paraffin issues were encountered during the coming runs.

Run No.	#3
Tool Function	Bidi Cleaning / profile
Type	Single Module, disc supported with gauge plate, magnet ring and transmitters
Manufacturer	3P Services
Gauge Plate Diameter	1050 mm
Run by	3P Services
Run Date	Dec 13-14, 2014
Total run time	Approx. 24 h
Average tool speed	Approx. 1m/s (calculated from pump rate)
Propelled by	Crude oil, type: Arabian Light
Tool Performance (wear/debris)	Tool generally in good condition, massive paraffin volume around the bottom of the tool
Observations	Vibrations
Gauge plate performance	Ok, no scratches or marks
Result	OK for GEO

Table 3



Figure 3

Cleaning/profile tool with gauge plates and transmitter after run No solid paraffin was found on or around the tool.

➤ Run #4: GEO+ inspection

The GEO tool is a tool developed by 3P Services for high resolution inspection of geometric discontinuities such as dents, ovalities and other restrictions of the pipe bore. Further, it can distinguish whether a restriction is due to a pipe deformation or whether it is caused by accumulations or internal layers of e.g. paraffin, sand or scaling.

Run No.	#4
Date of Inspection	Dec 15, 2014
Launch time	6.35
Receiving time	23.20
Total run time	16.45 H
Measured Total distance	6592 m
Max tool distance	1.2 m/s
Propelled by	Crude oil, type-Arabian light
Tool performance	Minor wear on tool components. No debris. Data recorder: failed after 6592 M
Observations	Significant noise from tool during launch and receive (vibration)
Result	OK for MFL

Table 4

Type of tool	GEO
Tool version	48z-GEO-01
Type of sensors	Bidi GEO
No. of sensors	24 x 2
Sensor spacing on the	154mm

Table 5

circumference	
Sampling frequency [per sensor]	400Hz
Envisaged sampling distance [per sensor]	2.5mm at 1m/s
No. of odometers	8
diameter of the odometer wheel	124mm
IP address	172.20.9.152

Table 6



Figure 5

The GEO tool has operated well in all components. The tool vibration is clearly recorded by the 48 GEO arms. The measurement capability is generally not influenced by the vibration.

➤ Run #5: Cleaning and gauging

With the lack of proper navigation near the PLEM and the incomplete GEO data BPCL and their contractors were looking for a solution for the continuation of the project. The final MFL tool could not be run to the previously planned point inside the PLEM. The MFL tool was, therefore, planned to be run to a position with safety distance from the PLEM. At this location the pumping was planned to be stopped and reversed and the tool brought back to the beach. In order to take special care of the pumping accuracy run #5 was a test run pumping it steady to 18km and back again. Purpose was to demonstrate this tool would not run into the end of the pipeline

Run No.	#5
Tool function	BiDi cleaning/profile
Type	single module tool, disc supported with gauge plate, magnet ring
Manufacturer	3P Services
Gauge plate diameter	1050mm
Run by	3P Services
Run date	December 16, 2014
Total run time	Approx. 11h
Average tool speed	~1m/s
Propelled by	Crude oil, type: Arabian Light
Tool performance (wear/debris)	normal wear / no debris / tool did not run into the end of line
Gauge plate performance	OK
Result	OK for MFL to 17000m

Table 7



Figure 6

Cleaning/profile tool with gauge plates after run

- Run #6: MFL-Inspection MFL tool applied

The tool is a high resolution MFL (magnetic flux leakage) system developed by 3P Services.

3.9.2 MFL tool settings Type of tool		MFL/DMR
Tool version		48z-MFL-01
Types of sensors	MFL	DMR
Type & No. of sensors	336	120
Sensor distance on the circumference	11mm	34mm
Sampling frequency [per sensor]	400Hz	
Envisaged sampling distance [per sensor]	2.5mm at 1m/s	
No. of odometers	6	
Diameter of odometers	73mm	
IP addresses	172.20.8.4	

Table 8

MFL tool performance

Run No.	#6
Date of inspection	December 17-18, 2014
Launch time [local time]	14:02 (17.12.2015)
Receiving time [local time]	04:02 (18.12.2015)
Total run time [hh:mm]	14:00
Measured total distance	17 km (total 33986m)
Calculated averagetool speed	0.8m/s
Maximum tool speed	1m/s at 2780m
Propelled by	Crude oil, type: Arabian Light
Tool performance	good
Observations	Sound from vibrations were noticed occasionally over 30min after launch
Result	successful

Table 9



Figure 7

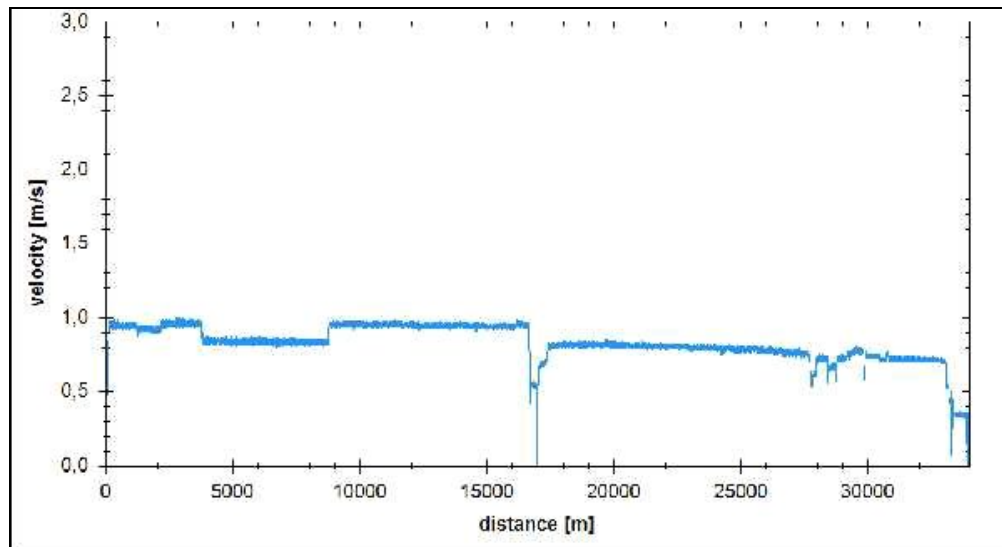


Figure 8

In order to reduce the risk of vibrations as occurred on the GEO tool, a significantly slower travelling speed was suggested for the MFL run. Due to limited flexibility of the crude pump spread at STF the speed was set at 0.9 m/s. Why the speed profile shows reduced speed between approx. 4000m and 8500m is not known. On the way back to shore the speed was generally between 0.7 and 0.8m/s. Data records from both way out and way back are good. On the way out towards the PLEM occasional vibrations were recorded, however, significantly less than the GEO.

6. Project Performance & Control

6.1. Sub-Sea Antennae

During the first mobilization of 3P Services' engineers, the cables of the sub-sea antennae were damaged. This happened after the placement of the three antennae on the sea floor underneath the single point mooring (SPM). All three cables were torn apart. Though the special type of cable is supposed to be not repaired for underwater service by the manufacturer an attempt was made by 3P engineers and the antenna systems indicated full working condition after the repair.

6.2. Propellant Crude Quality

Upon return of 3P Services' personnel to Germany the situation was analyzed and communicated with BPCL/ KRML. The primary cause of the excessive paraffin sedimentation was found to be the crude quality. Though the "Bombay High" is a light crude (40° API), its pour point of approx. 30°C is too high for the purpose. While a crude temperature of >30°C may be maintained during the tanker transport or storage in the tank farm on land, the crude is exposed to lower temperature environment as soon as it enters into the subsea pipeline. Apparently the process of paraffin solidification started onto and around the cleaning/gauging tool in runs #1 and #2 right after the launch.

6.3. Customs Clearance of 3P Equipment

During first phase of importation of 3P Equipment, due to wrong packing list, the clearance of equipment by customs was delayed. Due to the delay we lost one day execution time and lost the return of customs duty. Overall Project was successfully completed in the time span provided.

7. Reference Codes & Standards

[POF09] Pipeline Operator Forum [POF] - Specifications and requirements for intelligent pig inspection of pipelines, Version 2009
[API1163] API STD 1163 - In-Line Inspection Systems Qualification Standards

8. Conclusion

We are pleased to inform that the project was successful. The Bi-Di Pigging methodology, which was utilised for the first time in India for single pipeline proved to be successful. The method utilised leads to saving of time, project cost, simplified method of working as there is no intervention at underwater pipeline. The chances of pollution at sea are very less. We feel in future the method will gain more popularity due to the clear advantages.

9. Future works

The method utilised is gaining popularity due to the clear advantages and the future projects will demand the above technology.

10. Acknowledgments

We, KEI-RSOS Maritime Limited hereby thankfully acknowledge the cooperation extended by BPCL team & 3P Services to complete the project successfully.