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Managing ILI Projects to Get the Results you Need

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1 INTRODUCTION

There are 3.5 million km of transmission pipelines around the world. This system has been providing safe reliable transport for hydrocarbons for 100 years. A large proportion of that pipeline system has reached, or will soon reach, the end of its design life. Many of the pipelines operate in harsh environments, transport corrosive products, and as a result have suffered extensive corrosion damage. Oil and gas reserves are predicted to last for another 40 to 60 years. Consequently, much of the worlds existing pipeline infrastructure will be required to continue operating for many years to come. Inspection and rehabilitation are therefore critical for ensuring continued, safe reliable operation.

A great deal of work has been done on extending pipeline life by developing inspection technologies such as intelligent pigs, methods for recoating pipelines, techniques for internal painting, and hydrotesting regimes that will detect critical cracks. This wide range of options, the potential for problems such as a stuck pig, the costs associated, and the potential consequences of a failure, mean that a pipeline operator has to proceed very carefully when planning any inspection programme.

This paper will consider pipeline inspection based on the authors experiences from recent projects[1, 2, 3, 4], and recommend a simple strategy to ensure that a sensible, justifiable, plan is developed. This strategy is shown in Figure 1.

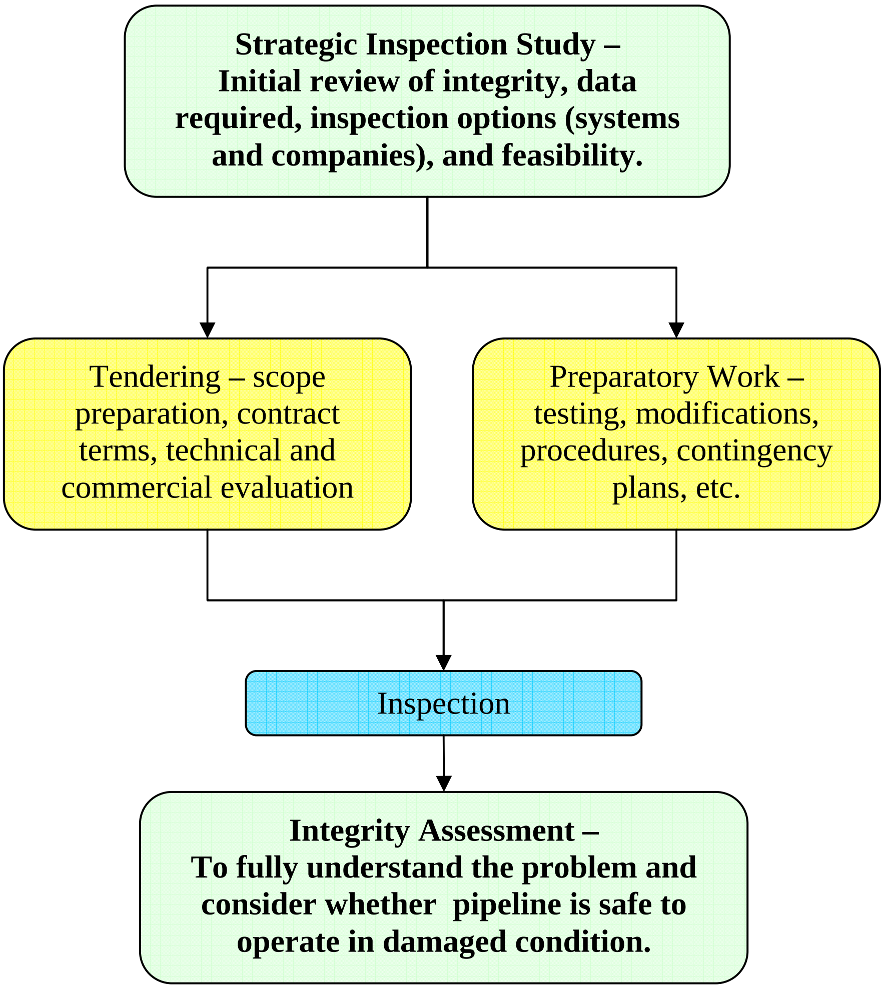

Figure 1: **Inspection Planning**

2 STRATEGIC INSPECTION STUDY

Uprating, change of use, life extension, change of ownership, scheduled inspection, suspected problems, known problems, regulatory requirements and leaks are just some of the reasons that pipeline operators may wish to collect some more information on the condition of a pipeline. To ensure that the right information is collected, and that projects run smoothly, it is prudent to undertake a strategic inspection study. Getting independent expert input at this stage will ensure that all issues are considered, and that the best decisions are made.

2.1 Data Requirements

An initial review of the pipeline integrity based on the design, construction, operating history, and the results of any past surveys or inspections will identify the likely problems and consequently the additional data that may needed to make a decision about the future of the line.

2.2 Hazard identification and risk assessment

Selecting an inspection method requires a good understanding of the defects or damage that are credible, and will be of concern, for a particular pipeline. The potential consequences of a failure should also be considered. There is no point in carrying out an inspection for features that are either not credible, or would be of no concern even if present. To illustrate the process some examples are presented in Table 1 below.

	Line 1	**Line 2**	**Line 3**
Location	Offshore	Onshore	Onshore
Local activity	Some fishing	Industrial development	None (very remote)
Type	Infield	Power station supply	Trunk line
Length	50km	30km	300km
Diameter	26”	16”	42”
Wall thickness	19mm	7.68 mm	12mm
Line pipe	SAW	ERW (high frequency)	Spiral
Operating Stress	50% of SMYS	40% SMYS (cyclic as power station is not run constantly).	60% SMYS
Product	Multiphase produced fluids (inhibited).	Dry gas	Processed waxy crude
Operating temp.	100C	5C	50C
Burial	On seabed	1m	1m
Coating	Coal Tar + concrete	FBE	Tape wrap
CP	Sacrificial	Impressed current	Impressed current
Age	15 yrs	5 yrs	10 yrs
Inspection History	MFL inspection 10 years ago, light internal corrosion. ROV survey indicates no damage but some lateral buckling.	No internal inspection. CP survey indicates no problems. Surveillance has been unreliable	No internal, some CP problems (high current).
Other information	Flow changed 5 years ago due to new wells. New fluids composition corrosive.	Substantial recent development work near/over pipeline.	Clay soils with wet dry cycle. No evidence of internal corrosion in pipe work, storage tanks etc.
Potential problems	Internal corrosion due to new fluids, and high temp. Compressive stresses due to high temp. may affect failure pressure.	Mechanical damage – thin wall pipe is vulnerable to denting, cyclic load may lead to fatigue cracking at dents.	External corrosion – tape coating has poor resistance to soil stress. High temperature will accelerate corrosion.
Recommended inspection	Ultrasonic pig	Geometry pig.	MFL (HR) pig

Table 1 Hazard identification and inspection selection

These are simplified examples and any hazard identification process requires a detailed review of all available pipeline data and input from engineers with experience of pipeline problems.

2.3 Technology Options

There are many different inspection methods available to the pipeline operator. These range from simple bore inspections using a metal gauging disc to ultrasonic crack detection systems. In recent years there has been an explosion in the number of companies offering inspections and in the range and combinations of technologies available. You can choose from DMR, EMAT, TFI, UT, CD, MFL, GUL, geometry, profile, tethered, bi-di, laser, etc. etc.. Identifying the appropriate technology, and the companies best able to offer that technology is not simple. Some examples of different inspection pigs are show in Figure 2, Figure 3, and Figure 4.

Figure 2 Tethered UT

Figure 3 Bi-directional MFL

Figure 4 MFL Inspection Pig

The technology that should be chosen depends on the defects that are of concern and the feasibility of using a particular system in the pipeline being considered. API 1160[12] provides a summary of the defects that different intelligent pigs can detect, see Table 2. It should be noted that as technology improves this guidance may become out of date.

DEFECT	**METAL LOSS TOOLS**			**CRACK TOOLS**		**GEOMETRY (calliper) TOOLS**	**MAPPING TOOLS**
	MFL - SR	MFL HR	UT	UT	MFL		
CORROSION	D&S[1]	D&S	D&S	D&S	D&S	NO	NO
CRACKS - axial	NO	NO	NO	D&S	D&S	NO	NO
CRACKS - circ	NO	d[3]&s[4]	NO	D&S[2]	NO	NO	NO
GOUGE	Detection[6] but no discrimination as gouges						NO
DENTS	d	d&s	d&s	d&s	d&s	D&S	D&s
LAMINATIONS	d	d	D&S	D&S	NO	NO	NO
MILL DEFECTS	d	d	D	D	d	NO	NO
OVALITY	NO	NO	NO	NO	NO	D&S	D&S[5]
1 – No ID/OD discrimination 2 – Modification needed (sensors need rotating 90 Deg) 3 – Lower Case D Means Limited Or Unreliable Detection 4 – Lower Case S Means Limited Or Unreliable Sizing 5 – If Tool Is Equipped With Ovality Measuring Gear 6 - Limited by the minimum detectable metal loss, and limited by the minimum detectable depth, length, and width of the defects.							

Table 2 Defects and intelligent pigs (from API 1160)

2.4 Schedule and Cost

Inspection tools may be fully booked for many months, some inspection methods may be much more expensive than others. Being aware of these issues will help the operator select the best option.

2.5 Pipeline Restrictions

Not all of the technologies can be applied to all pipelines, there may be limitations due to:

- Product – For example ultrasonic systems will only work in a liquid.
- Flow rates – high flow rates can prevent full magnetisation of the pipe wall and hence stop effective MFL inspection.
- Pressure and temperature.
- Construction – mitre bends may prevent the passage of some systems.
- Wall thickness.
- Access – restricted access may make getting large tools into the pipeline.
- Scale or debris in the pipeline.

An example of a mitre bend and forged bend combination in a 26" diameter pipeline that might prevent the passage of a pig is shown in Figure 5.

Figure 5 Mitre bend

3 TENDERING

To enable inspection companies to offer the most appropriate service at a competitive price a clear scope of work is required and relevant information should be provided. Following the Strategic Inspection Study it should be possible to prepare tender documents that provide the following information:

- A clear scope of work defining what type of inspection is required, why the inspection is required and what may be found. This will ensure the inspection company knows what is expected and understand the context. It will also allow them to suggest alternatives.

- Clear specification for the supply of results, including timescales, what should be reported, absolute and relative accuracies expected, the format, and the supply of any visualisation software.
- Pipeline details such as length, diameter, wall thickness, material, burial status and depth of burial, route maps, design code, product transported, operating pressures, operating flow rates, etc. etc.
- Facilities that are available including; pig traps (see Figure 6), workshop space, cranes, etc. With relevant specifications, drawings and photographs.
- Limitations that may affect the inspection such as access restrictions, hazardous areas, restricted spaces.
- Commercial terms with a fair distribution of risk.

Clear tender documents create a level playing field and allow a fair evaluation of technical and commercial proposals. However, the tender alone may not be sufficient and an understanding of the history, capabilities, and performance of different suppliers is required to ensure that the best option is selected.

Figure 6 Pig trap and working area

4 PREPARATION

For most inspections the pipeline operator will need to be prepared. The following are some of the things that may need to be considered:

- Modifications to pipe work to allow tools to travel through the system.
- Installation of pig traps.
- Pipeline cleaning to remove scale, wax, debris, black dust etc.
- Valve testing to ensure reliable operation.
- Availability of facilities (e.g. crane for lifting pig).
- Availability of staff (for operation of valves, monitoring pig launch and receive, control of flow rate etc.).
- Availability of product and ability to operate at a suitable flow rate during the inspection.
- Safe launch and receive procedures.
- Collection and safe disposal of debris such as pyrophoric black dust (see Figure 7).
- Site health and safety requirements.
- Site working risk assessments.
- Contingency plans for problems (e.g. stuck pig).
- Plans for shutdown, repair etc. should significant damage be identified.
- Verification of results after the inspection.

During the preparatory phase there will be a need to liase with health and safety representatives, control room staff, technicians, the inspection company, and management. The effort required should not be underestimated and the appointment of an experienced inspection project manager will help.

Figure 7 'Black Dust' cleaned from a gas pipeline

5 INSPECTION

Provided adequate preparation has been carried out the inspection should go smoothly; however, it is important for the operator to be represented during the inspection to be aware of any problems that may arise that impact on the results of the inspection or have commercial implications. For pigging representatives should witness the preparation of the tool, the loading into the pipeline, the launch and the receive. This will ensure that any issues can be recorded and will help avoid disputes should problems occur.

6 INTEGRITY ASSESSMENT

Pipeline integrity is ensuring a pipeline is safe and secure. It involves all aspects of a pipeline's design, inspection, management and maintenance[5]. A detailed integrity assessment will provide much valuable information, for example on the condition of a pipeline, and the ability of the team maintaining the line to keep it in good condition, that can inform any rehabilitation plan.

A key part of the integrity assessment will be an assessment of the 'fitness-for-service' or 'fitness-for-purpose' of the pipeline. This is the element that we will review in this paper.

6.1 Fitness for Purpose[1] Assessment

A 'fitness for purpose' assessment (better described as an 'engineering critical assessment' [6,7]), calculates the failure condition of a structural defect and compares it with the operating condition of the structure.

The fitness for purpose of a pipeline containing a defect may be estimated by a variety of methods ranging from previous relevant experience, to model testing, to engineering critical assessments, where a defect is appraised analytically. These latter assessments can be by:

- Generic methods [8,9],
- Traditional pipeline industry methods [10-11],
- Recognised pipeline codes developed using the traditional methods [6,7],
- Publications from pipeline research groups [11-15],
- 'Best practice' publications emerging from Joint Industry Projects [16-19].

6.2 Key Considerations

Any operator conducting a fitness for purpose calculation should consider the following[20, 21, 22]:

- Understand the defect – what caused it, how it may behave.
- The engineer doing the assessment - experience, training, independence, overview, support.
- Assessment methods – use best practice.
- The consequences

Further details of these considerations are given in Reference 20.

6.3 Input Data

The type and level of detail of information that is required in any assessment depends on the depth and scope of the assessment. The issues that typically should be considered include[20]:

1. The pipeline – geometry, materials, operation, environment, history, etc..
2. Stresses – all loads acting, future changes, cyclic loads, etc..

[1] We use 'fitness for purpose' in the pipeline integrity business as 'a failure condition will not be reached during the operation life of the pipeline'. Note that fitness for purpose also has a (different) legal meaning, particularly in the construction business, with differing liability.

3. Inspection method – capability and accuracy.
4. Defect – cause, dimensions, type, location, growth, etc..
5. Consequences – leak, ignition, pollution, etc..

Further details are given in Reference 20.

6.4 Considerations when Using Intelligent Pig Data.

The following points should be considered when using intelligent pig data to aid a fitness-for-purpose assessment[20]:

1. Pigs cannot detect all defects, all of the time.
2. Pigs measurements have associated errors.
3. Pigs cannot discriminate between all defects.
4. Treat simple defect assessments by pigging companies (e.g. the ERF) with care – they may not be appropriate for all defects and all pipelines.
5. Use all available inspection data – e.g. past inspection reports.
6. Location – defect location accuracies of pigs vary and have errors.
7. Origin – always be able to explain the presence of a reported defect.

6.5 Benefits of the Integrity Assessment

An integrity assessment that takes into account the issues outlined above will:

1. Provide the operator with best possible understanding of the current condition of the pipeline, and whether it is safe to continue to operate it.
2. Identify degradation mechanisms and give conservative estimates of the rate of degradation.
3. Identify other issues that may affect the feasibility of repair or rehabilitation (e.g. location).

7 CONCLUSIONS

Our experiences on recent projects have led us to four key conclusions

1. A planned and structured inspection strategy, as proposed in Figure 1, is essential.

2. A strategic inspection review is critical to ensuring realistic expectations and a successful inspection that provides the required data, safely, and at a reasonable cost.

3. An integrity assessment both before and after the inspection is a vital part of the strategy, and helps to fully understand the problem.

4. Using a project manager, or involving a consultant, with experience of inspection projects and an understanding of pipeline integrity issues will minimise problems.

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