Pipeline Integrity Management: The key to safe operation

by Tim Callan, ILF Consulting Engineers

Introduction

Pipeline integrity management is an important aspect of the planning, design and operation of new pipelines. The main goal of pipeline integrity management is to ensure safe, long-term operation of the pipeline, in particular, protection against leakage. Additional benefits of a pipeline integrity management program include improved efficiency and economics of operation.

Pipeline integrity management (PIM) was a major consideration during design of the Middle European Crude Oil Pipeline (MERO) This 345 kilometre, 710 mm (28 in) diameter pipeline provides a link between a new crude oil tank farm in Vohburg (Germany) and the refineries of Kralupy and Litvinov (Czech Republic). MERO is the largest oil pipeline constructed in Germany within the last ten years, coinciding with the introduction of stricter environmental standards and new authority approval procedures. The adoption of clearly defined PIM principles during the initial planning and design stages was a major factor in facilitating the authority approval procedures and in enhancing public acceptance of the new pipeline.

Key Aspects of Pipeline Integrity Management

Pipeline integrity exists when the pipeline is mechanically sound and there is no foreseeable risk of failure during operation. Pipeline integrity management is mainly concerned with the management of risk: designing, installing and operating the pipeline such that the associated risks are at an acceptable level.

The PIM program defines the operation, inspection and maintenance procedures that must be implemented to ensure that the' risks are minimised. This program must include at least the following key aspects:

1. Defined operating and maintenance procedures.
2. A maintenance and inspection program.
3. A program for monitoring and regulating third party activities.
4. A corrosion control program.
5. An "on-line" leak detection system.
6. An emergency response plan.
7. A training program for personnel.
8. A system for assessing operating risks.
9. A quality management system to ensure compliance with the above procedures and programmes.

The quality management system must also include: a system to ensure compliance with applicable codes; a system for follow-up of technical recommendations and management of any changes; procedures for maintaining permanent file records of inspection, repair and maintenance activities.

The elements of the PIM program can be categorised as either primary or secondary safety measures. Primary measures are those which are taken to ensure that the pipeline remains leak-free. These include corrosion control, maintenance and inspection programs. Secondary measures are those taken in case of pipe leakage to ensure that the impact on the population and the environment is minimised (for example, an emergency response plan).

For the MERO project, several aspects of the planned PIM program were identified as being crucial to the success of the authority approval procedures and the public awareness campaign. These were:

- Operational Risk Assessment
- Leak Detection System
- Emergency Response Plan

These items were therefore addressed at an early stage of the planning of the new pipeline.

Operational Risk Assessment

During pipeline operation it is important to quantify the risk of an event occurring that may lead to loss of pipeline integrity. In the most extreme case, such an event may endanger public safety or compromise environmental protection standards. Also important, from the point of view of the pipeline operating company, are events that may lead to loss of asset value or revenue.

Operational risk assessment involves identification of these hazards and assessment of the magnitude of each individual risk. Appropriate steps must then be taken to reduce the more significant operational risks.

To assist in the risk assessment procedure, a 'Risk Matrix' is typically used. The matrix plots 'probability' against 'consequence' to give an assessment of overall risk. Risk will be reduced by reducing either the probability or the consequences of an event, or both.

For a particular pipeline operation, it is first necessary to develop a list of incidents or scenarios that may affect pipeline integrity. Event scenarios are typically grouped under headings such as: leak resulting from corrosion; third party and/or geological damage; leaks related to steel quality or mechanical factors; leaks associated with pipeline operating conditions. The risk to pipeline integrity is then determined by positioning the event on the risk matrix according to its relative level of probability and consequence.

While this exercise is somewhat objective (although formaliscd risk assessment methodologies are now commonly used), it does force the designer to focus on the parameters of consequence and probability associated with a particular event. Proposals to reduce risk can then be assessed in terms of repositioning the event on the risk matrix.

Operational risk assessment should be carried out during the initial planning stages of the new pipeline to allow an adequate period for local authority and public scrutiny. This strategy of open review demonstrates that the assessment and consequent mitigation of risk arc of paramount importance to the designer. This represents an important step in promoting public acceptance of the new pipeline.

Leak Detection System

The primary goal of the PIM program is to avoid pipeline leakage. If, however, a leak does occur during operation, it is important that the occurrence and location are determined quickly. permitting fast and appropriate response. To achieve this aim, the pipeline is equipped with a state-of-the-art Leak Detection System. This computer-based system continuously monitors and evaluates the pressures. flowrates and other operational parameters of the pipeline via the SCADA system. The LDS identifies any possible leakage without delay and alerts operations and meintenance personnel. The system also assists with analysis of any occurrence and provides the necessary information for decision making and implementation of counteractive measures.

The basic data for implementation of the LDS are obtained through a comprehensive unsteady state hydraulic analysis of the pipeline system. This analysis determines the normal and masimum operating pressures (including transient conditions) at each location along the pipeline. On this basis the electronic devices and control algorithms required for the SCADA and LDS systems can be defined, as well as additional mechanical pressure relief systems.

The theoretical leakage volume at each location along the pipeline is also determined This calculation considers the proposed location of line and check valves in comparison to the hydraulic profile. According to the environmental consequences thus determined, the number and location of the valve stations are optimised. Line valves are fitted with motorised actuators and can be remotely controlled via the SCADA system from the new control centre.

In addition to "on-line" leak detection, a program of regular maintenance and inspection is necessary to maintain the leak integrity of the pipeline. External monitoring procedures include regular coating inspections and continuous monitoring of cathodic protection systems. The pipeline easement is inspected regularly for evidence of degradation and/or third party damage.

Routine internal pipeline monitoring opetations are performed in order to identify trends that might provide an early indication of deterioration. These include: product analysis; use of corrosion coupons and probes: and analysis of pig debris.

Non-routine inspection and testing are also carried out to demonstrate the mechanical integrity of the pipeline. During pipeline standstill, so-called pressure difference tests are performed on the flat sections, whereby leakages can be identified to an accuracy of 20 litres/hour.

Additionally, a leak detection pig will be sent through the pipeline at regular intervals. This diagnostic tool identifies very small leaks by recognition of the ultrasonic vibrations caused by the escaping oil. Other "intelligent" pigs will be sent through the pipeline according to a defined program. These identify deformations of the pipe, loss of wall thickness and material changes.

Emergency Response Plan

The Emergency Response Plan is a secondary safety measure taken in case of pipe leakage to ensure that the impact on the population and the environment is minimised. The ERP consists of two main parts: the Emergency Shutdown Plan and the Oil Alarm Plan.

The Emergency Shutdown Plan identifies shutdown and counteractive procedures to minimise the consequences of a possible leak at any location. The systems for control and monitoring of the pipeline incorporate the necessary software to automatically implement pre-programmed shutdown sequences as far as possible in response to identification of a possible leak.

The ESP also determines, if a leak is identified, whether it is necessary to shutdown pump stations or to immediately close line valves. In many cases, shutdown of pumps and line valves upstream and downstream of the leak can cause a larger oil volume to be released than if no action is taken. It must be considered whether it is more appropriate to prevent further oil flow to the leak location, or to accelerate the outflow of oil.

The Oil Alarm Plan defines technical and organisational measures to be taken in case of leakage at specific locations. The use of safety vehicles and oil clean-up equipment in an emergency case is also defined. Such equipment will generally bc located at depots along the pipeline. Protective measures are proposed for all areas, particularly special locations such as river crossings.

The functionality of the OAP, as well as the capability and readiness of the equipment and the effectiveness of training procedures are checked by regular practice exercises.

Relevance of Pipeline Integrity Management in Australia

While this article has described the experience gained during design of a crude oil pipeline in Europe, the PIM concept is becoming increasingly relevant to the pipeline industry in Australia.

The current moves to introduce competition to the gas supply industry, combined with ongoing development of new and existing fields has resulted in proposals for a number of new pipelines. These have coincided with an unprecedented level of public sensitivity to the environmental and safety issues associated with any new infrastructure development. Some professional engineering groups have also expressed concerns that the industry restructuring (including increased participation by the private sector) may lead to a relaxation of safety standards.

While there can be no doubt that the pipeline industry in Australia has enjoyed an enviable safety record in the past, the proposed routing of new pipelines through the more heavily populated coastal regions will inevitably reinforce concerns about safety issues.

Most of the aspects of pipeline integrity management are already considered by the operators and designers of new pipelines in Australia. Safety issues arc addressed during the EIA; operating and maintenance procedures are defined prior to commissioning; corrosion monitoring and leak detection systems are considered by the relevant engineering disciplines during the design phase.

These aspects can be conveniently grouped under the overall concept of "pipeline integrity management". This permits a common basis for resolution of all issues involved with pipeline safety and a clear focus for public discussion. Furthermore, the lesson of the European experience is that pipeline integrity management should be addressed early during the planning stages.

Clearly, the implementation of a PIM program requires a significant ongoing commitment of resources by the pipeline Owner/ Operator (an annual cost of 1-2% of asset value is a typical figure). Faced with the commercial pressures of operating in a newly competitive market, this could be seen as one area where investment and operating savings could be made. However, experience has shown that adoption of a PIM program also results in improved efficiency and economics of operation. These savings. combined with improved safety standards. justify the costs of a PIM program.