PROJECT TO OPERATION – CHALLENGES TO INSTITUTING A SUCCESSFUL INTEGRITY MANAGEMENT PLAN

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ABSTRACT

A successful Integrity Management Plan (IMP) has its roots formed during the project phase. Quality assurance through diligent and professional inspection during engineering project construction is required in order to provide accuracy of the necessary records and drawings that will be used by the IMP. Support for the IMP by senior project management and owner company management must be evident throughout design and construction in order to gain commitments from the different disciplines within the project team. As the project progresses to the operations phase, a clear understanding of the roles of Operations, Maintenance, and Engineering must be outlined and agreed upon. Failure to achieve the cooperation of these teams inevitably leads to costly mistakes. This paper outlines the necessary ingredients for a successful IMP while using examples from various oil and gas projects, both onshore and offshore to illustrate the above points.

Keywords: quality management, inspection, quality assurance, quality control, corrosion circuit, corrosion monitoring

INTRODUCTION

As a project moves through the various phases of design, construction, start-up, and finally to full-time operation, there are several factors that define the ultimate success of the project. The economic benefits of the project are the first to be examined, followed by impact to the environment, safety of workers and the community, and finally the integrity of the equipment and operation. While it is necessary for a project to be profitable in order for it to proceed, it should also be necessary for the project's profitability to include a thorough assessment of safety, environmental, and integrity factors.

Although safety and environmental impact studies are normally conducted, and reliability targets are established during the conceptual phase of a project, often these are performed with little consideration to the pressure equipment integrity management system that will ultimately support those requirements. Equipment failures can significantly impact the safety, environment, and the reliability of the project during its operating phase if materials are selected without due consideration as to the potential damage mechanisms or an effective integrity management system has not been designed and implemented. The cost of downtime associated with maintenance activities is becoming increasingly expensive. Should a significant safety or environmental event occur in conjunction or as a result of a preventable equipment failure, the monetary and reputational consequences can have long lasting effects.

INTEGRITY MANAGEMENT PROGRAM

A typical IMP for an oil and gas facility is shown in Figure 1. An effective IMP must take all potential threats (failure modes) into account. (Reference 1) This information is gained through industry experience and through evaluation of materials in laboratory settings. Specific project information such as quality assurance/quality control records, operating guidelines, and process flow drawings are also used to provide input into a corrosion manual for the facility. The process is then divided into corrosion circuits, which are determined, based on an evaluation of the expected damage mechanisms for the material properties, and with consideration to the design operating pressure, temperature and mechanical design. Within these corrosion circuits, the consequence of failure is assessed and used in conjunction with the probability of failure to arrive at a criticality rating. The criticality rating is used to determine the frequency of inspection (onstream and offstream). Corrosion monitoring and inspection programs are also defined within each corrosion circuit, with the expectation that the expected damage mechanisms are represented by appropriate inspection activities. Inspection information gathered from the onstream inspection program and turnarounds is used in conjunction with corrosion monitoring information to continually improve the corrosion manual and hence the overall IMP.

This paper examines many of the problems and challenges encountered during the design, construction, start-up, and operation phases that need to be addressed in order not to jeopardize the IMP and ultimately the economic success of the project.

DESIGN PHASE

As the design team is assembled for a project, it is important to identify the resources required for properly identifying the materials, corrosion, and inspection issues that arise. The project's management team should then be prepared to budget for these resources early in the project design. A seasoned corrosion engineer, preferably with operations background can properly assess the impact of alternate materials on the integrity of the equipment throughout its operational life.

It is also important early on in the design phase to gain the project management's and in turn the owner company management's commitment to the method to which alternate project designs will be evaluated. It is commonplace during the design phase to debate the economics of the project design on a lowest capital cost basis vs. lowest life-cycle cost basis. While most project management will say that they are using a life-cycle cost approach rather than capital cost approach, the real issue is whether the project costs are low enough to gain approval or sanction from the owner company. With the large budgets associated with some projects, it is often easier to explain cost overruns after the project has been sanctioned.

The corrosion engineer is therefore constantly challenged with building a piece of equipment from lower cost materials in order to save capital cost (e.g. carbon steel vs. corrosion-resistant alloy); yet ensuring that the lower cost material can survive the operational lifetime of the project or that the risks associated with the lower cost material are understood and accepted by the operating company. It is easy for a design engineer to appear to save money for the project by choosing a cheaper material, however, the corrosion engineer can identify the associated inspection, maintenance, replacement costs with the alternate material design i.e. life-cycle cost. By looking at the life-cycle cost picture, project management and the owner companies can make a more informed decision as to whether or not the project has economic benefit. NACE International provides a number of these economic guidelines and approaches in "Economics of Corrosion". (Reference 2)

A good example here is the use of carbon steel in rich amine systems. In a clean rich amine system, carbon steel may develop a protective iron sulphide scale and not be subject to significant corrosion. However, amine systems seldom remain clean and frequently become contaminated by heat stable salts and other degradation products that may result in an aggressive corrosion rate and significant resource expenditure in order to monitor and maintain the system. The use of a corrosion resistant alloy in this case would offer significant life-cycle cost advantages.

It is sometimes necessary during project design to test different materials, coatings, or chemical treatment programs for their application to the design. The corrosion engineer can help to identify testing requirements, oversee the actual test program, and verify the results. Again, there should be adequate money in the budget to conduct these test programs.

It is important to consider the corrosion monitoring program as well as the onstream/offstream inspection program during the design phase. Allowances such as access fittings, instrumentation and computer requirements, and clerical support for these programs need to be included. There is often reluctance on the project's side to allow a lot of money to be spent on these items, however, they end up being a critical part of the IMP during operation and must be functional at the start of operation.

There may be instances where the material installed is a compromise or installed in prototype equipment where the final process conditions may not be fully understood. It is important to include some design flexibility to allow for testing coupons of alternative materials where lab testing is not able to accurately reflect expected operating conditions. As the operation stabilizes, the coupons can be analyzed and compared to the installed materials. Should the installed material fail to perform to its expected levels, data will be available to support the change management process.

Once the materials of construction have been identified, the task of specification writing begins. The corrosion engineer plays an important role in ensuring that not only the right materials are identified on various drawings, but also that suitable quality control procedures are written for the various components of the design. This aspect is particularly important in the area of coatings, where surface preparation and correct application are critical to the successful performance of the coating system.

However, the creation of good specifications does not guarantee success. Purchasing standards must be adhered to; material substitutions must be reviewed and approved by a qualified materials and corrosion engineer; construction quality must be monitored and formally audited; deficiencies must be acceptably rectified. The integrity of the specifications must be upheld in order for equipment to meet its design requirements.

During the latter stages of the design phase, there is usually a project challenge exercise often called “value engineering”. This is a critical step in the project as the design gets scrutinized for potential cost savings. Key specialist personnel, such as the corrosion/materials engineer who came up with the original design concept and rationale must be retained during this exercise to ensure that the integrity of the facility is not compromised.

CONSTRUCTION PHASE

Having good design specifications and quality control procedures are important for facilitating the construction phase of the project. In addition, there are a number of areas that can affect the IMP during the construction phase.

The most prominent area that affects the integrity of the facilities is the reluctance of project management to adequately budget quality assurance inspectors and clerical support staff. In this day, one can take some comfort in the progress that programs such as API Q1 and ISO 9001 have made in qualifying fabrication shops; however, there are still a number of issues surrounding these programs.

The best way to ensure that equipment meets project specifications is to use project or third-party inspection. Inspectors should have appropriate industry recognized credentials such as NACE, ISO, API, etc. At the beginning of fabrication, a kick-off meeting is held with representatives present from the fabrication shop, project, and project or third-party inspection. The schedule is reviewed and any specification clarifications are discussed. Once fabrication begins, the inspector needs to gain assurance that the fabrication shop is following proper procedures. The inspector stays at the shop as long as there are issues to be resolved. Ideally, the inspector should make one visit for the kick-off meeting and one for the factory acceptance test.

Again, one of the areas that often gets overlooked is coating. Whether the piece of equipment is large or small, the coating specification needs to be enforced. Problems with poor coating application often take some time to show up, usually after the warranty period has run out. The results however can be very expensive. Using a qualified coating inspector will help to ensure that surface preparation is carried out properly, environmental conditions for curing are proper, that the material is stored and handled properly, and that the application specification is met.

The various fabrication shops and facilities should take baseline inspection readings and observations as this is the easiest time to take these readings. The readings should be supplied to the project in electronic format to allow for easy downloading into the inspection database. Ideally project inspection personnel should witness these readings. Once the project enters the start-up phase, manpower restrictions, particularly for offshore projects where there are accommodation restrictions, will severely hamper gathering of this information.

The other approach is to perform baseline inspection readings after the equipment arrives at site, either before or after it is placed in its permanent location. Some advantages to this approach are: use of consistent work crews; improved quality of inspections through standard application of inspection criteria; work is easily audited; work crews can be held reasonably accountable for their quality; the corrosion assessment can likely be performed prior to inspection allowing selective monitoring locations. Disadvantages to this approach include difficulties in completing the work prior to startup, obtaining appropriate access to the equipment (scaffolding, installing insulation windows), and ensuring adequate resources have been secured to complete the work.

Regardless of the approach, should there be insufficient commitment by management to providing the resources and supporting the effort to obtaining baseline measurements, obtaining useful baseline inspection readings will be very difficult.

Most projects are now built using 3-D drafting software. For a large project, an electronic model will cost in the millions of dollars due to the amount of engineering time devoted to its creation. This software can be a valuable asset to plant management with respect to integrity management. Properly maintained, the model can become the primary registry for as built information as well as a repository for TML locations which can then be easily reproduced in the form of a scale isometric drawing. Corrosion circuit limits can also be identified, allowing an entire circuit to be displayed or printed to scale in an isometric format. Effective document and software management must be in place in order to support a successful IMP.

START-UP PHASE

The start-up phase of the project should be a relatively “quiet” phase from an integrity management standpoint, provided that the integrity issues have been addressed during the design and construction phases. Experience in a lot of cases unfortunately reveals the start-up phase as a catchup time for the items that were missed during construction. There's not a lot that can be done about poor construction practices such as inappropriate material selection or poor coating application, however attention to commissioning of corrosion monitoring equipment, chemical treatment pumps, and cathodic protection programs is important. Once again, the onus is on the owner company's management and the project's management to consider the implications of deferring these programs.

The corrosion engineer and support personnel from the various chemical treatment companies, corrosion monitoring companies, and cathodic protection companies play an important role during start-up to troubleshoot any problems with their respective programs. These disciplines must form an intimate and open relationship to ensure that problems are appropriately communicated and addressed prior to minor issues developing into major integrity threats.

OPERATIONS PHASE

Once the project is up and running, it is time to ensure that the various project documents have been organized and are readily accessible for reference. In an ideal world, the inspection database would already be populated with the appropriate equipment static data and baseline readings, corrosion monitoring equipment would be functioning properly, and the various chemical treatment and cathodic protection programs would also be functioning properly. For most projects, it takes one or two years to have these programs working properly. For this reason it is important to have service contracts and adequate warranty periods worked out when equipment is bought during the construction phase.

An additional challenge during this time is the changeover in personnel. Project personnel leave and operations personnel take over. The experience gained during the project phase is often lost in this step. Some projects have recognized this problem by building up the levels of operations personnel during the design, construction, and start-up phases. It is also important that the owner company's contract with the project team or company stipulates that the facilities are operating to the owner company's satisfaction before project personnel are allowed to leave.

One method to reduce the impact of personnel changes is to ensure the training system is effective and evergreen. For integrity management, this must include a requirement that all personnel have a specific training plan developed based on their position in the facility. A key question to ask of all site personnel is "who is responsible for asset integrity"? A typical response is that the integrity team is responsible. If one were to ask the same personnel "who is responsible for safety", the typical response is that all personnel are responsible. In fact, this is the proper response to the integrity question. Integrity management is a shared responsibility that is managed by the integrity team, just as safety is a shared responsibility but managed by the safety team. An effective training plan will help site personnel understand their responsibilities associated with integrity management which will subsequently reduce integrity risks in the facility.

An extension of this logic is the formation of the integrity operating window (IOW). The IOW forms the basis of the process requirements within which the plant should be able to operate effectively without significant impact to the equipment integrity. For example: an ammonia injection rate is adjusted based on a resultant pH value; a temperature is lowered because it has risen above the level where the corrosion rates due to high temperature sulphidation are beyond an acceptable limit, or; a wash water injection rate is adjusted based on water sample testing results. These are all examples of operations controlled parameters that directly affect the integrity of the facility. The integrity team may audit and report on abnormal conditions associated with identifying these excursions, but it is Operations that is typically responsible for maintaining these parameters within the prescribed limits.

Accountabilities for maintaining the integrity operating envelope must be documented. The concern is that the plant may be able to meet its functional intent under certain operating conditions that are detrimental to equipment life. Critical operating targets must be established for pressures, temperatures, flows, and stream compositions which will affect equipment life. These targets must also include the appropriate corrective action and the functional group (operations, maintenance, engineering, inspection, etc) that is responsible for taking the corrective action. Notification and or auditing requirements for the deviation must also be developed so that the effects of the occurrence are effectively documented and the impact of the deviation identified.

Finally, it is important that the right lines of communication are set up between operations, maintenance, and engineering personnel. (Reference 3) It is incumbent on the owner company's management that this happens in a cooperative manner. As equipment problems occur, it must be clear who has direct responsibility for fixing the problems, and who is in a support role. With the loss of experienced personnel from the project team, it is important that the owner company maintains or even builds their staff levels, particularly during the first one to two years of operation.

EXAMPLES OF CHALLENGES

In the following examples, challenges during the early phases of a project are seen to result in costly rework during the operations phase of the project.

Pipeline Construction

One of the last construction activities that occur before a pipeline is installed in the trench is to apply a protective coating to the girth weld area. There is usually a dedicated crew that has been trained to apply the coating, whether it is a heat-shrinkable sleeve, or a brush or spray-applied liquid coating. Once the coating has been applied and cured the pipeline is lowered into the ditch and backfilled. In most cases, this activity is schedule driven and there is a lot of pressure on the coating crew to complete as many joints as possible during the shift. Rather than focus on the quality of the job, the focus is predominantly on quantity.

During a recent pipeline inspection in northern Alberta, it was discovered at a number of joint areas that a large percentage of the girth weld coating area was not bonded to the steel substrate. Although initially thought to be coating delamination, it was evident that the pipe had not been adequately preheated. Lack of preheat did not allow the underlying mastic to fuse properly with the sleeve material. The joint areas were obviously not checked properly for this potential problem; with the result that groundwater seeped underneath the coating causing corrosion.

Whether this problem was a result of cold weather and inadequate heating equipment or simply a schedule-driven problem, a simple quality control check would have detected the problem. Instead the problem was buried.

Offshore Coating

Coating of offshore structures and the various package facilities to be installed on these structures is often subject to schedule driven problems as well. In a lot of cases fabrication of the facilities falls behind schedule leading to extreme pressure on the coating applicator(s) to complete their activities under schedule. This can manifest itself in the form of poor surface preparation leaving a contaminated surface or inadequate surface profile or sharp edges on structural members, lack of environmental control during the coating application, lack of cure time between coats, or simply not enough paint to meet the specification thickness requirements.

In most cases, the coated surface initially looks good from a visual perspective, however within a few months of exposure to the offshore environment; a poorly coated surface will become evident. The cost of recoating the facilities in an offshore environment is enormous, which stresses the importance of doing it right the first time.

Offshore Corrosion Monitoring

Corrosion monitoring is a necessary component of a proactive IMP. Properly designed and located, corrosion probes, erosion probes, links to relevant process information on the process computer, and lab analyses help the corrosion engineer to assess metal deterioration rates in the facility. It is important to have this monitoring equipment commissioned and running at start-up in order to provide baseline information about the corrosion processes. While land-based facilities are readily accessible for maintenance and troubleshooting the equipment, offshore facilities are not. As previously mentioned, there is a constant challenge to get maintenance people offshore due to accommodation restrictions.

Corrosion monitoring is considered a low priority in most operations and therefore may be neglected for a considerable amount of time before being fixed or maintained. Without this valuable information, the integrity of the facility can be jeopardized. Furthermore, a lack of information reporting from the corrosion monitoring system, can dictate higher inspection costs. For example, the use of corrosion probes at the beginning and end of a pipeline when used in conjunction with fluid analyses allows the corrosion engineer to put together a fairly accurate story of whether or not the pipeline is suffering from corrosion. When none of these systems are working properly, it may dictate the use of a more costly inspection such as an intelligent pig survey, sooner than later.

Refinery Crude Unit Overhead Corrosion/Fouling

The overhead piping and equipment of a crude distillation tower is often subject to corrosion and fouling issues. Over the years this has been fought with various materials options, and chemical treatment programs. In one particular refinery that was 40 years old, the issue of corrosion and fouling had become bad enough to cause several unscheduled shutdowns. Senior management recognized the cost impact of these shutdowns and a task force was assigned to prevent future occurrences.

The task force made up with representatives from operations, maintenance, and engineering was given sufficient time and resources to solve the problem, which turned out to be the practice of reprocessing slop oil. Over the years the slop oil tanks had become severely contaminated with a thick emulsion, which reduced the residence time and subsequent separation of water from the oil to a minimum. When the slop oil (mostly water) was reintroduced into the crude distillation train, an upset would occur sending suspended solids up the tower where they fouled the trays. The decision was made to spend the money to remove the contaminated slop oil from the refinery. Furthermore, online corrosion monitoring was implemented in the overhead piping, daily checks of the online pH system and chloride levels in the water phase was instituted, and finally a training program was carried out by the task force for all the operations staff. There has not been a recurrence of fouling in this system and corrosion levels are under control.

In another example, a diluent recovery unit overhead system was designed without consideration for wash water in the stripper overheads. It was discovered late in the design phase that the overhead system would be prone to condensing ammonium chlorides. The heat and material balance for the design would not accommodate the use of continuous wash water, and the wash water injection efficiency was significantly compromised by equipment placement which would have cost millions to rectify. It was determined that the high corrosion rates associated with ammonium chloride corrosion would be partially combated with a rigorous chemical program and the intermittent use of wash water. Additionally, it was accepted that the reliability of the unit would not meet the original design goal as equipment failures could be reasonably expected. This problem would have been recognized by an experienced materials and corrosion engineer well before the design was at a point of no return and could have been easily rectified early in the design phase.

At another facility, a diluted heavy oil inlet was to be stripped of its diluent prior to additional processing. The effects of the high TAN and high sulphur feed were not understood by the designers and materials were originally selected that would not have provided the design life required by the project specifications. Equipment had already been fabricated to the original materials specifications. Some equipment had to be reassigned or abandoned in favor of improving the corrosion resistance and ultimately meeting the expected design life for the equipment.

RECOMMENDATIONS

Based on the challenges faced during the various phases of a project, the following recommendations are made in order to avoid high maintenance/replacement costs during the operations phase:

1. Commitment by senior management from the Owner Company and project to support the IMP. This takes the form of money in the project budget and time in the project schedule to allow for appropriate inspection, and staff levels, etc.

2. Specialist personnel such as a corrosion/inspection specialist who has had experience in the operations phase of a project need to be placed in the project team during the design phase of a

project and retained through any “value engineering” exercises to ensure that the integrity of the facility is maintained.

3. In addition to economic, safety, and environmental goals, quality goals/targets should be used to define project success.

4. Lessons learned from similar projects should be used to identify potential pitfalls in the design phase. In addition, the costs associated with various designs should be closely examined from a life-cycle perspective.

5. If maintaining the IMP during the operations phase is foreseen as being difficult, such as in an offshore facility, a more corrosion-resistant design should be used that will allow less frequent inspection intervals.

6. Clear, effective communication between the operations, maintenance, and engineering departments should be made during the operations phase of the project.

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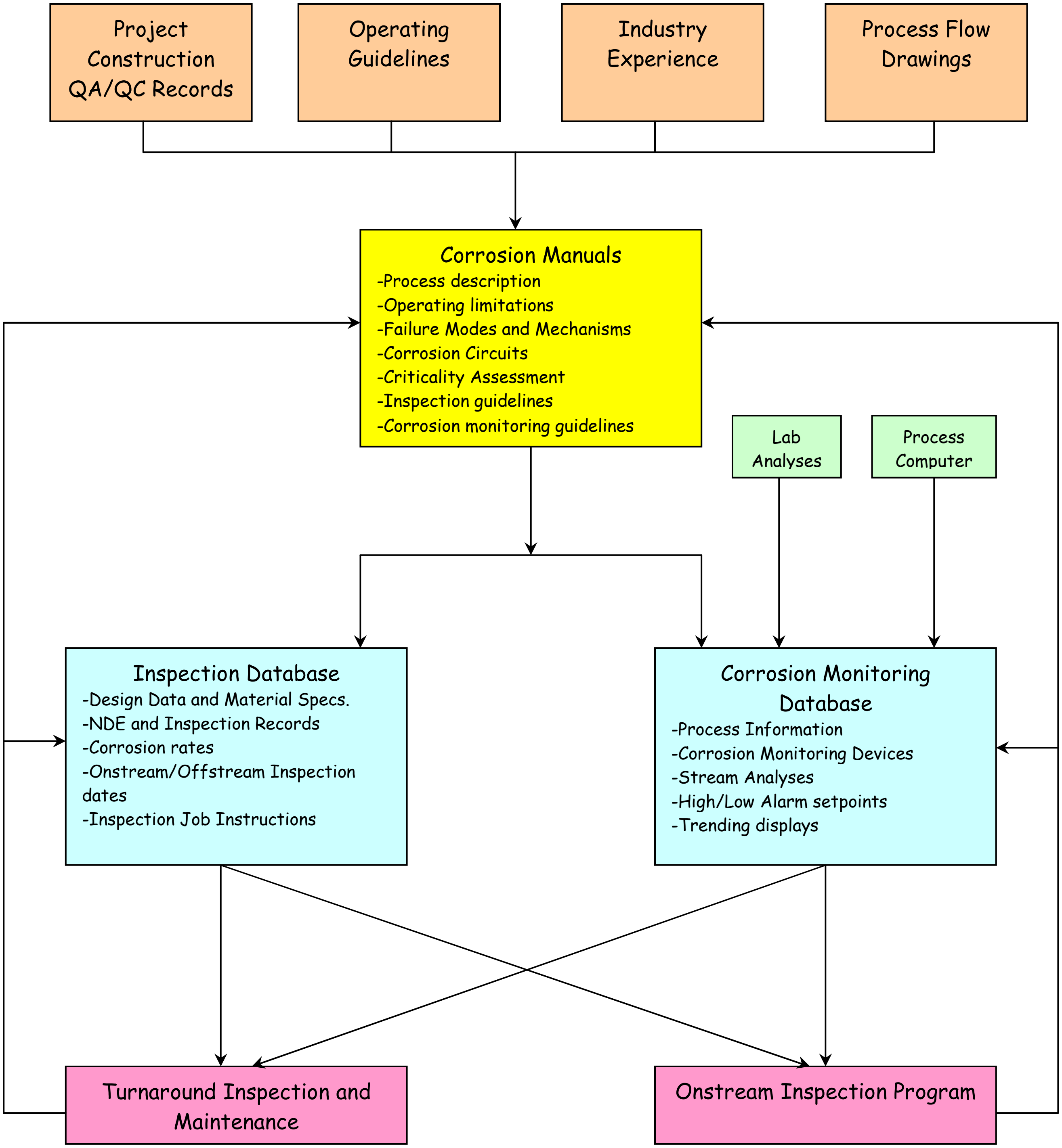

Figure 1 – Integrity Management Plan for Oil and Gas Facility