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THE INTEGRITY MANAGEMENT CYCLE AS A BUSINESS PROCESS

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Abstract

It is a best-practice Oil & Gas pipeline integrity & reliability technique to apply integrity management cycles. This conforms to the business principles of continuous improvement. This paper examines the integrity management cycle - both goals & objectives and subsequent component steps - from a business perspective. Traits that businesses require, to glean maximum benefit from such a cycle, are highlighted. A case study focuses upon an integrity & reliability process developed to apply to pipeline operators' installations. This is compared & contrasted to the pipeline integrity management cycle to underline both cycles' consistency with the principles of continuous improvement.

1. Developing a shared vision in order to drive business in a unified manner

1.1 Why develop a shared vision?

Goals define the performance by which successful businesses are measured. Prior to the implementation of plans & strategies, the communication of goals identifies the end-game. In this way, a business' leadership team can manage the expectations of their stakeholders and influencers. Consistent performance measurement is required through change; effective & relevant performance metrics make this possible - goals must be S.M.A.R.T. in that they should be Specific, Measurable, Actionable, Relevant & Timely. Such goals empower the whole business team to pull in the same direction - each individual knowing and understanding both the goal itself and their role in enabling its achievement.

1.2 Shaping the shared vision – Business-wide Goals

The goals set by a business must satisfy the desires and wishes of it's stakeholders; in the private sector these are the business's equity holders; in the public sector, these are the electorate and their nominated representatives. An example of public-sector stakeholder led goals is seen in Mexico. Upon becoming President, in December 2006, Felipe Calderon issued a budget for 2007 that was forecast to balance; he also committed to maintain this balance for his full term. With an anticipated national growth slowdown & planned government expenditure growth, balancing the budget depended on revenues from the state-owned oil company Petroleos Mexicanos (PEMEX). Revenues were linked to an oil price of $42.5/barrel, so PEMEX's production goals were set[0]. Actually, 2007 average prices of $64.20[1] (and hedge cover on sub-$70 exports thereafter[2]) offset shortfalls on production goals, but economic slowdown maintained pressure.

Whereas stakeholders determine goals; influencers (for example: customers, business resources and regulators) set the boundaries within which such goals can be met. Determining how to meet the goals set by the stakeholders within the parameters set by other influencers, requires business strategy. In considering the goals placed upon them, in the example above, PEMEX examined those factors that influence and govern the way could meet production goals – product reserves, product demand and the means to extract and transport product from one location to the other.

1.3 Shaping the shared vision – Strategic Objectives

The needs & wants of a customer base (and their market influencers) shape ways that goals can be met. In addition, business managers must balance & prioritise the resources with which they can satisfy such needs & wants. Within the oil industry, this is illustrated in the Venezuelan heavy oil reserves & Albertan oil sands reserves. Extraction

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is only viable with oil prices above a certain threshold. Goals require exploitation according to market conditions means to control the threshold. At the highest level, oil-exporting nations can be said to exert some influence over the price of oil by controlling supply. At a more direct level, these producers can effectively reduce the threshold at which extraction is viable by seeking and applying new technology that has an incremental impact upon extraction efficiency.

1.4 Shaping the shared vision – Integrity Management Goals

Strategic objectives shape a pipeline's functional specification. Pipeline managers must align specific integrity management goals with these strategies. Commonality can be found across some integrity management-goals –for example both an offshore oil pipeline operator in SE Asia[3] and an onshore gas pipeline operator in N Africa[4] wish to:

- ✓ *Maintain a productivity that maximises contribution to our stakeholders.*
- ✓ *Ensure supply uptimes that satisfy the demands of our customer base.*
- ✓ *Minimise the environmental, health & safety impact of our operation.*
- ✓ *Demonstrate compliance with all appropriate regulations.*
- ✓ *Adopt procedural best practice that exceeds the statutory requirement.*
- ✓ *Prove "good value", in a tangible and consistent manner, to all influencers.*
- ✓ *Promote the reputation of our business on the world stage, should international expansion be sought*

Quantitative considerations also shape pipeline integrity goals, - these include commercial contracts, operating programs and transmission programs to which the pipeline operator's business is committed. Integrity management goals often also include consideration of hot topics that face pipeline managers. A Latin American operator[5], for example, wants to identify pipeline segments that are particularly vulnerable to intentional third-party damage; a North African[6] operator, on the other hand, wishes to characterise the cause and effect of black powder in pipelines. These considerations may have been highlighted by the rhythm of a previous iteration of the integrity management cycle.

With all considerations duly made, pipeline managers can compile a set of integrity management goals with which to direct the subsequent integrity management cycle. Provided that they are S.M.A.R.T., these goals align the pipeline operating team, manage stakeholder & influencer expectations and provide a performance measurement scale.

2. Examining the subsequent components of the Integrity Management Cycle.

2.1 Integrity Management as a Continuous Improvement Process

As a continuous improvement process, the integrity management cycle consists of four steps:
Plan ahead for change, analyse and predict results.
Do it, execute the plan by taking measured steps in a controlled environment.
Check the results against the prediction
Act to standardise or improve the process.

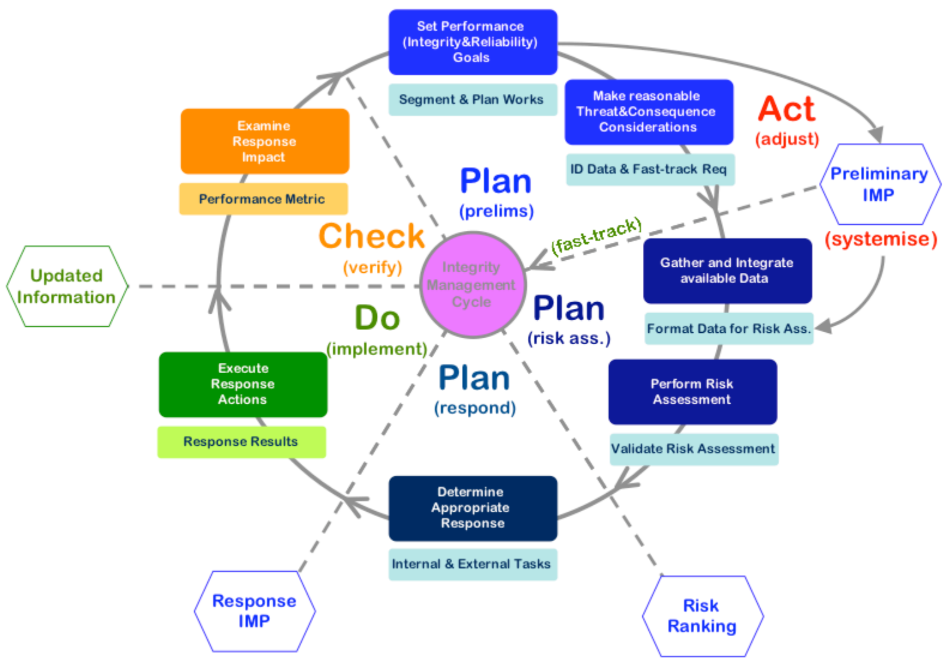

Figure 1. Pipeline Integrity Management Cycle

2.2 The Pipeline Integrity Management Cycle

All configurations of the integrity management cycle are broadly consistent with the Plan, Do, Check, Act cycle. When first aligning business rhythm to the integrity management cycle, the Plan Step is of three components:

Planning Preliminaries:	set performance goals;
	make threat and consequence considerations.
Risk Assessment:	gather and integrate data;
	complete and validate risk ranking.
Response Planning:	produce the response plan.

The three planning preliminaries culminate in a response plan which is executed in the Do Step. The Check Step verifies the impact of these response actions upon the defined goals. Information uncovered during response plan execution is used to refine subsequent iterations of the integrity management cycle. The Act Step replaces Planning Preliminaries within the Plan Step for subsequent iterations of the integrity management cycle - goals are reviewed & integrity management cycle maintenance is considered (for example: what internal & external resources are required).

2.2.1. Plan Step

Component a) Planning Preliminaries: The pipeline "unit" is set to define the resolution by which the asset will be processed through the cycle. This is known as segmentation. Segmentation can be made according to location (including locations with common failure consequences), characteristic, data-availability or some combination of this – as a rule of thumb, segmentation must allow common issues to be identified and addressed in an efficient manner. This might require dynamic segmentation – overlaying perspectives to isolate sections that can be dealt with consistently.

Resource limitation dictates that segments cannot all be processed through the cycle at once - prioritisation is required. Provided all segments are processed in a timely manner, there may be justification to prioritise according to data availability; though normally the over-riding consideration will be that of inherited/perceived risk or criticality.

In the context of integrity, the definition of failure extends beyond engineering failure to and incorporates events that prevent or obstruct identified goals & objectives. For each segment, pipeline managers must identify relevant threats – the potential causes of failure – as a shortlist of the overall list of all possible threats. They must then consider what information is available to indicate the presence of such a threat and its likelihood to cause failure.

Probability of failure is one of two risk factors; consequence of failure is the other. Consequence describes the extent to which goals & objectives are missed. For all potential consequences, pipeline managers consider the information to be gathered that quantifies a degree of consequence associated with failure at each pipeline location.

Planning preliminaries conclude with Preliminary Integrity Management Plan. This identifies pipeline segments and plans their sequence through the integrity management cycle. It also contains a data requirement plan, identifying the information that must be gathered, integrated and analysed to create a robust risk assessment. Finally it sets-out immediate "fast-track" response for those threats & consequences that are conspicuous & unacceptable,

Component b) Risk Assessment: The data requirement plan is executed. Protocols must provide a contingency when items, identified as required in the data requirement plan, do not exist in a reliable form. These should consider the delays & additional cost associated with actively gathering this missing data (usually involving on-site surveys), engineering assumptions to be made as a temporary supplement for this missing data and "worst-case" scenarios to be input into the risk assessments. In all cases, the course of action must be documented; it is a best practice that necessary information, still absent upon risk assessment completion, should be prioritised for collection as a response action. These protocols are required to ensure that the integrity management cycle is not stalled as a result of missing or incomplete data. The cycle is a continuous improvement process; the accuracy of results improves with each iteration so initial risk assessments should be viewed as a best endeavours structured approach to meeting business goals.

The structured approach has evolved with regards to integrity evaluations such as in-line inspection (ILI). These stimulated pipeline integrity within transmission pipelines; risk assessments have often been founded upon the results of ILI. This sequence is consistent with the Six Sigma DMAIC (Define, Measure, Analyse, Improve & Control) approach to system-improvement, but two factors suggest a sequence that sees integrity evaluations as response actions:

First, operators with baseline ILI data can schedule risk-based re-inspection intervals. Second, as adoption of the structured approach encompasses more "unpiggable" pipelines, operators require sound business justification before making these lines 'piggable'. This justification only comes in response to risk, rather than as a means to characterise it.

Gathered, integrated and formatted data is processed into a ranked risk assessment. A risk assessment is simply a means to characterise risk by factoring consistently defined probabilities of failure with consistently defined consequences of failure. When pipeline managers have limited data at their disposal, it is therefore acceptable to gather subject matter experts to arrive at "engineering logic" conclusions regarding ranked risk. As with all qualitative inputs, the driving assumptions must be transparent and well documented to enable verification during subsequent iterations.

If historical pipeline failure data is available, the engineering logic approach can be reinforced with an extrapolated relative risk model. When the criticality of the lines justifies a more detailed risk assessment, scenario-based models can be built by examining detailed consequences & factoring-in failure probabilities using event, decision & failure tree processes. For full probabilistic models, specialist risk assessment software & expertise must be utilised.

These four approaches to risk assessment are recognised as appropriate according to individual circumstance. Some countries regulate the approach – for example, within Mexico a new regulation[7] is to be introduced that includes a requirement for a risk assessment to be conducted on pipelines by any such approved approach on an annual basis.

As risk assessments are central to shaping integrity management decisions, results must always be validated. Selected multidisciplinary validation teams should perform data & result reviews on representative sample sets. These teams should also cross check sample segments to ensure consistency with established engineering practice.

A Validated Risk Ranking completes the risk assessment component. This ranks segments according to risk and identifies the constituent threats and consequences that drive the ranking. These constituent drivers shape the approach to manage risk - in the case of the new Mexican regulation, mentioned above, a provision states that pipeline segments with a high risk ranking driven by consequence should be tagged for preventative response, for example.

Component c) Response Planning: The value of a risk assessment output is realised when it supports decisions to control risk by selecting & scheduling appropriate response actions. These actions selected fall into four categories:

First, predictive response actions may be identified & scheduled. Risk assessment activity will identify where certain conditions are conducive to certain threats. This justifies predictive responses to identify, locate & characterise threats before they cause failure. Responses include the full range of survey & in-line inspection techniques.

Second, corrective response actions may be scheduled. These address threats that are already present but have not yet caused failure. Corrective response actions, such as pipeline or coating repairs, are incorrectly referred to as "preventative" maintenance. Though taken prior to failure, they correct a threat that has already become apparent – they do not remove any chance for that threat to occur. Corrective responses can either be immediate (taken to remedy a defect that is considered critical) or scheduled (set-out to be completed prior to the next interim predictive response).

Truly preventative actions are a third option of response. These control conditions that nurture a threat, or they remove a potential consequence. A common example of preventative response is that of cathodic protection; a more comprehensive illustration is that of an LPG pipeline whose proximity to a school represented an unacceptable consequence should an engineering failure occur. The probability of pipeline failure could not be suitably contained, so response planning centred upon consequence removal by decreasing the proximity of the pipeline to the school. In this case[8], the most cost-effective way to decrease proximity was not by re routing the pipeline but by relocating the school.

Reactive actions form the fourth "last line of defence" regarding response. Due consideration is given to failure response and successful consequence limitation. World-class companies are often judged by the way they deal with adversity. Within Latin America and North Africa, two pipeline operators[9] stand out in the manner by which they have built response teams that can efficiently recommission pipelines following intentional third party pipeline strikes.

To select any of response actions, associated cost/benefits must be considered. An approach must be taken to determine what actions are the most economic way to address unacceptable and imminent risk concerns. This include, for example, the most appropriate repair choice to correct a critical pipeline defect. In addition, an approach must be configured to justify the early adoption of measures that economically address evolutionary risks that are not yet critical Ironically, from a business perspective, more conservative options may be extended beyond that which is required by imminent risk. For example, should a pipeline be planned to be operational for twenty-five year life, then corrective actions such as coating repairs completed in year six may be considered to be more economically viable than continued Integrity Evaluation and pipeline repair in year twelve. It is for these reasons that response planning beyond that prescribed in codes is often best considered on a cost/benefit basis.

A Response Integrity Management Plan marks the completion of the response-planning component. This identifies, justifies and schedules the mix of internal actions to be performed by the pipeline management team together with those tasks that must be performed by third parties and specialist contractors.

2.2.2 Do Step

Actions, scheduled in the Response Integrity Management Plan & fast tracked from the Preliminary Integrity Management Plan Here, are taken to respond to threats obstructing goals & objectives. These either predict threat location & pattern, correct a located threat before it can cause failure, prevent the threat from occurring or remove the consequence, or provide to react to a failure should it occur in order to limit consequence. Each individual response action, listed in the matrix below, is not exhaustive but it illustrates of an appropriate action for each scenario:

Response Integrity Management Plan Pipeline Risk&Response Matrix		Predictive Response *To confirm Threat likelihood, location and pattern*	Corrective Response *To address a detected Threat before it causes Failure*	Preventative Response *To remove a Threat or mitigate a Consequence*	Reactive Response *To contain Consequence once a Failure has occurred*
Evolutionary Threat	Internal Corrosion	Sampling, MFL ILI +Int.Eval	Lining, Replace	Chemical Cleaning	Strike/Leak Detection
	External Corrosion	ECDA, MFL ILI +Int.Eval	Repair, Replace	Cathodic Protection	
	EAC	HT, CD ILI, Screen +Int.Eval	Repair, Replace	Environment Change	Supervisory Control
Binary Threat	Fabrication Defect	UT ILI +Int.Eval QA	Replace	Specification, QA	
	Construction Defect	Geo & MFL/TFI ILI +Int.Eval	Replace, Stabilise		Emergency Response
	Faulty Accessory	UT/NDT Surveys +Int.Eval	Replace	Preventative Maint.	
Event-led Threat	Mech. Damage (intent)	Susceptibility Screen	Intruder Detection	RoW Management	Strategic Reserve
	Incorrect Operation	QA Auditing	Corrective actions	Procedural Compliance	
	Climatic Force	Susceptibility Study	Replace, Stabilise	Re-routing	Root-cause Analysis

Figure 2. Risk Response Matrix

2.2.3. Check Step

The Check Step closes the iteration of cycle by verifying the impact of implemented response actions upon the identified integrity & reliability goals. As with the goal-setting element, this is an essential step in fully reconciling the integrity management cycle with the objectives set out by both business and pipeline managers.

A simple code-based example can be used to test the effectiveness of the cycle. Within the American Petroleum Institute's Approved National Standard 1160 (Managing System Integrity for Hazardous Liquid Pipelines), the following two questions are used as a basis of Program Evaluation:

Did you do what you said you were going to do?

This prompts validation that the actions set-out within the Preliminary & Response Integrity Management Plans were completed. It exposes those actions that must be carried-forward into the subsequent iteration of the cycle.

Was what you said you were going to do effective in addressing the issues of Integrity in your Pipeline system?

This prompts a comparison of the status of the pipeline system at the end of the cycle compared to that at the beginning. It requires the use of the goals & objectives as a consistent metric; it should include a consideration of the incremental position against that metric compared to that if no actions had been taken over the period of the cycle.

As with all structured approaches, the value of the Check Step is in its use to either validate continuation along a consistent approach or determine how subsequent iterations of the integrity management cycle should be adjusted to improve incremental impact of each action. Any such adjustment is made during the subsequent Act Step of the cycle.

2.2.4 Act Step

The Act Step substitutes the Planning Preliminaries component of the Plan Step beyond the first iteration of the cycle. It streamlines this component, after the baseline task completion, and strengthens the foundation from which subsequent iterations are launched.

The goals & objectives are reviewed to establish whether they remain valid, are liable for an improved metric/target point or should be replaced with a goal more relevant to the next iteration of the cycle. The segmentation exercise is also checked for applicability and efficiency; perceived threats and consequences are adjusted as appropriate. There are three fundamental provisions that must be made during this step. First, a mechanism must be put in place to ensure that additional data gathered during response implementation in the previous iteration fed into the next risk assessment where appropriate. Second, outstanding tasks that carry over from the last iteration of the cycle must be programmed for completion during this iteration. Third, assuming the business wishes to retain an integrity function in-house, consideration should be given to the development of the pipeline management team to make them increasingly able to manage subsequent iterations of the integrity management cycle with diminishing external dependence.

The updated Integrity Management Plan marks the completion of the Act Step. This drives the next iteration of the cycle, identifying tasks to be completed therein. It is anticipated that fast-track response actions diminish during each iteration of the integrity management cycle – this is symptomatic of a greater degree of control over the asset.

3. Highlighting traits that ensure businesses benefit from integrity management cycles.

There are proven benefits to the alignment of a pipeline operator's rhythm with the flow of an integrity management cycle; additional key traits that govern the effectiveness of the approach.

Businesses must be structured to facilitate the flow of an integrity management cycle. The dynamic way in which departments are organised, how they communicate and how they flow work interactively between teams all impact the harmony and effectiveness of the integrity management cycle.

Within these structures, leaders make a difference – they require sufficient domain knowledge and objectivity to organise and allocate resources in an appropriate manner. Additionally, they must be able to track, review and adjust performance. Their leadership traits must be coupled with an ability to encourage imaginative and creative response. This coupling can be found within every organisation that is considered to be successful.

Skill-set optimisation is common to all successful businesses. Gap analysis of workforce skills and those required to sustain the integrity management cycle must be integral to all threat and consequence considerations. Businesses that find effective and sustainable methods to close these gaps have a greater propensity to thrive. Seeking ways to secure acceptance and familiarity with new techniques resulted in a "learning-by-doing" approach as a central cornerstone of operating reliability methods amongst pipeline operators.

Other traits centre upon motivation and utilisation of the workforce. In Egypt one of the leading pipeline companies has developed a centre of excellence to develop team skills that can be contracted to neighbouring pipeline operators; practical skills such as cleaning, inspection and repairs. Among other benefits, this initiative has allowed viable workforce retention a level desired by their stakeholder, the government.

In examining Integrity Management from a business perspective, businesses with an open communication flow - from high-level goals, through to business strategy and onto integrity goals and objectives - are differentiated. The integrity management cycle brings best value when it is considered as an extension of a goal driven functional specification. This portrays the cycle as a means of ensuring pipeline health required and set out by the business & pipeline managers – implying that such health results in regulatory compliance as a by product of an iteration.

With effective goals and strategies in place, pipeline managers require well-defined processes to break down seemingly formidable tasks into a series of manageable steps. The processes sit as macro-processes above the integrity management cycle and micro processes within it. Well-managed processes also serve to provide support for decisions that result in the implementation of tasks and the appropriate choice of tools and technology.

Processes ensure that individual actions and tactics collectively result in the execution of strategy that in turn serves to meet the goals of the business. Any business process needs to be reviewed frequently to ensure that it is still the appropriate vehicle for delivering goals in a changing business environment. They should be organic in that they are capable of being adapted to suit changing needs. The integrity management cycle is just one such process.

Finally, world-class businesses anticipate change and resistance to change. Continuous improvement cycles, by definition, involve change. The effectiveness of the cycle is governed by the degree to which such changes are facilitated throughout the cycle and beyond. A trait common to those companies who see most benefit from this structured approach to integrity management is that they accompany the approach with change management programmes. This advantage is underlined by change management considerations that are formally included within operating reliability systems aimed at improving pipeline & facility integrity & reliability on a company wide basis.

4. Underlining that the Integrity Management Cycle is a business process by illustrating how a comparable business process was extended beyond pipelines & shaped to apply to a pipeline operators facilities.

PEMEX implemented a structured approach toward pipeline integrity management, business-wide, in 2007. This is known as PAID – an acronym (in Spanish) for Pipeline Integrity Management Plan. A PAID Process & Code of Practice, broadly similar to the integrity management cycle described above, was developed and refined in application. Within the context of a wider approach to ensuring reliability throughout their operations (PEMEX is a wellhead to consumer Oil & Gas company) PAID sits as one element within a component to ensure the "reliability of installations and pipelines". PEMEX sought to complete the other element with a comparable approach for installations – this was named PAICI – an acronym (in Spanish) for the Installation Integrity & Reliability Management Plan.

In developing the PAICI Process, applicable codes, standards and regulations were considered alongside existing PEMEX Maintenance Processes. Due to the strategic PAICI & PAID symmetry, when approaching operating reliability, a review of the existing PAID Process & Code of Practice was conducted to determine alignment & consistency wherever possible.

4.1 Description of the PAICI Process

The PAICI Process was designed as an integrated, annual process incorporating two simultaneous cycles operating throughout each year shown in figure 3 below.

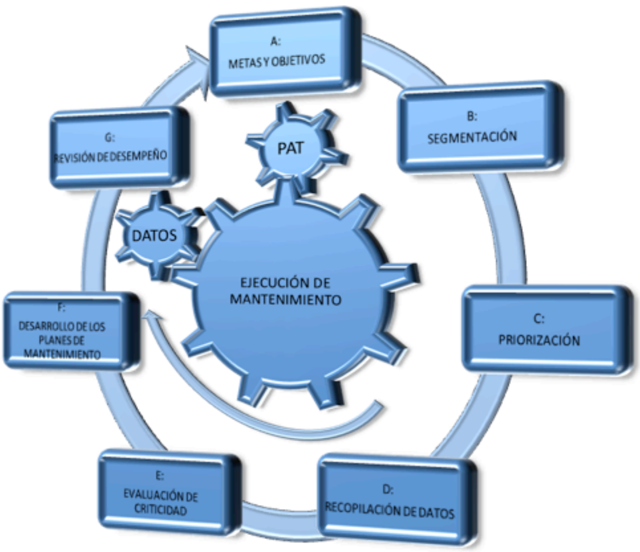

Figure 3. Annual PAICI Process Cycles

The "outer" PAICI cycle is performed annually; it is broadly comparable with the pipeline integrity management cycle. The cycle includes the identification of installation-specific activities, such as the application of the reliability methodologies, alongside schedule maintenance actions that are performed when the Maintenance Plan is executed – the "inner" Maintenance Execution cycle.

4.2 PAICI Cycle

The following is a general description of the activities included in each step of the PAICI cycle:

4.2.1 Plan Step

Cycle component A: Metas y Objectivos (Goals & Objectives): A determination is made as to how business goals should drive the integrity goals & objectives for the following year. During a review session, performance results from the previous cycle, plus identified improvement and optimisation areas, are assessed in paralleled with associated resourcing, budgeting or timing constraints. PAICI specific goals & objectives are then established. Key Performance Indicators (KPI's) are set to monitor progress towards achievement of the Goals and Objectives. This component is comparable to the Goal Setting & Planning elements that are performed within a pipeline integrity management cycle.

Cycle component B: Segmentacion (Segmentation): Segmentation sets the resolution for all subsequent works. A balance must be struck between the level of detail that provides sufficient focus for appropriate maintenance plans the level that eliminates unnecessary complexity when optimising such plans. With segments defined, existing installation data is reviewed & validated so that segment data requirements can be set. This component is comparable to the segmentation & data requirement planning elements performed in pipeline cycles.

Cycle component C: Priorización (Prioritisation): When planning appropriate reliability methodologies, prioritisation is required to focus efforts upon equipment with highest strategic important and/or perceived risk. A multi-disciplined team agrees relative perceptions of each installation's strategic value and risk ranking. Perceived risk is based upon qualitative team consensus using notional criteria including known operational problems, failure history and prioritisation according to incremental benefit associated with the application of a reliability methodology. The prioritisation shapes the allocation of resources to focus data gathering and engineering effort upon those areas where maintenance activities is most effective. This exercise compares to the sequencing task of the planning preliminaries component for the pipeline integrity management process – similar provisions apply for the validity of other commercial considerations and regards for expediency alongside those of perceived risk.

Cycle component D: Recopilacion de Datos (Data Gathering): The data and database format, used to store, integrate and maintain data gathered for each installation, is agreed. The required data is gathered, validated and integrated into the database as an ongoing process; any missing information is identified. Missing information may be substituted with data from published reference databases; a protocol is in place to ensure a review of the validity and source of any generic data is conducted. This step compares with the data-gathering component of a pipeline integrity management cycle; consistency can be seen with the provisions to ensure the cycle remains dynamic, rather than being stalled by a lack of immediate data upon early iterations of the cycle.

Cycle component E: Evaluacion de Criticidad (Criticality Analysis): The critical nature of an installation is defined in a distinct manner to the definition of risk within pipeline - the frequency with which a failure happens substitutes the probability of failure calculation. This is then multiplied by the magnitude of the consequence. The results for each item are plotted on a Criticality Matrix - the equipment is categorised as high, medium or low criticality. Though more qualitative than many risk-assessment techniques applied to pipelines, this approach is comparable to one that suits operators of networks that do not warrant quantitative level analysis – for example pipeline gathering systems.

Cycle component F: Desarrollo de los Planes de Mantenimiento (Developing Maintenance Plans): The Maintenance Plan for low criticality equipment remains based upon manufacturer specifications, recognised maintenance standards & experience of that specific installation. High or medium criticality equipment is evaluated using Reliability Centred-maintenance or Risk-based Inspection (Spanish acronyms: MCC & IBR, respectively).

In the case of dynamic equipment, MCC involves further data gathering & validation. This requires process diagram development and failure mode cause & effect identification. Maintenance strategy and technical feasibility is evaluated for each mode, with cost and resource considerations influencing application frequency.

In the case of static equipment, IBR includes a review of previous inspection & maintenance data, failure history, repair history and failure detection, isolation or mitigation systems. IBR groupings are made according to threat mechanism. Inspection plans are developed for each unit or system in accordance with recognised codes.

MCC & IBR unit-based activities are then aggregated and optimised as components of the Maintenance Plan.

Equipment with chronic failure history or with high impact failures, irrespective of criticality is subjected to Root Cause Analysis (Spanish acronym: ACR) to identify all potential failure modes & effects. This prioritised, with root causes and corresponding solutions determined and agreed using a cost benefit analysis.

The resulting MCC, IBR & ACR unit-based activities are aggregated and optimised as components of the overall Maintenance Plan. This Plan is broadly comparable to a Response Integrity Management Plan developed for pipelines; it is risk-based with provision to configure-in subsequent risk discoveries, underlining its dynamic nature.

4.4.2 Do Step

The implementation of the works identified during the Plan Step of the PAICI cycle is integrated into the "inner" Maintenance Execution cycle. This distinguishes PAICI from the pipeline integrity management cycle – the configuration integrates all activities in one Maintenance Plan, not just those identified in the Plan Step.

4.4.3 Check Step

Cycle Step G: Revision de Desempeno (Performance Review): This step includes the review of the operational, integrity and reliability performance of each installation and includes the results of KPI's. Maintenance Execution is reviewed against the Maintenance Plan. Validation measures check that records have been updated to maintain accuracy and reflect any installation. Achieved performance is compared to the goals & objectives; improvement & optimisation areas are identified. Outputs are fed into the Comp. A Goals & Objectives review session.

The Check Step is consistent across applications to both Pipelines and Installations – it relies upon consistent and robust initial goals & objectives. When applied to installations, the Check Step incorporates greater focus on updating the records during this step, rather than doing so during the Adjust Step. The reason for this is clear below.

4.4.4 Act Step

A contrast between integrity management cycles applied to installations as opposed to pipelines is the apparent lack of an Act Step within the installation cycle. As the PAICI cycle was developed as an adjustment to the overall maintenance rhythm, the first iteration of the cycle was not a "fresh" activity. So, activities prescribed within the Plan Step are as valid for subsequent iterations of the cycle as they are for the first. It can be seen that the Plan Step incorporates the considerations of the Act Step – other than record updates that are required during the Check Step.

5. Conclusions

In applying a structured approach serving to ensure improved security, safety and risk-control within Oil & Gas pipeline operations, it is worth noting that a continuous improvement process lies at the heart of that approach.

By aligning an integrity management cycle with the principles of continuous improvement, pipeline managers benefit from sound business logic integrated into their operational rhythm. This helps to maintain harmony between pipeline operations and the overall business – whether in the public or private sector.

Regulatory efforts are a potential technique to stimulate best practice in pipeline integrity managers. This is based on the consideration that regulators are attempting to implant an overall dynamic process into the day-to-day rhythm of pipeline operators, but are often only able to do so by calling for deliverables and reports that can best be produced as a by-product of such an integrity management cycle.

Though a continuous improvement process lies at the heart of effective integrity management, the impact of following the process is governed by the way a pipeline operator's business is structured, the priority with which the business seeks to lead and develop its people and the contingency that all planned changes must be sensitively delivered and accompanied by effective change management programmes.

In comparing the integrity management cycle, developed for pipelines, with one configured to suit installations a consistent approach is seen; this underlines the concept that these cycles are based in a continuous improvement cycle.

In contrasting the integrity management cycle, developed for pipelines, with one that was configured to suit installations some interesting differences emerges – rather than pointing towards disparity between the two cycles, these differences may indicate potential for the pipeline integrity management cycle to evolve in a manner that incorporates a more unified approach to operations and maintenance and that is configured with provisions for seamless sustainability in mind.

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