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| Asset Integrity Management System |
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| PIPING MODULE |

**RB-AIMS (Risk Based Asset integrity management system)**

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Asset Integrity Management System

PIPING MODULE

Overview of working process

**Overview**

The first step of integrity management is the risk ranking of assets. The risk ranking of Piping can be divided into POF (Probability of Failure) and COF (Consequence of Failure). The resultant will be risk ranking of each equipment and related inspection strategies based on priority for each damage mechanism.

Based on the priority of each damage mechanism, inspection strategies and frequencies are assigned and accordingly inspections are carried out.

Based on inspection findings ever-greening process completed and POFs are updated.

Integrity management system of Piping unique because of large number of piping in a typical plant compared to pressure vessels which can be handled individually. Due to this large number of piping number, it will be impossible to handle them individually so the concept of piping clusters are taken up in the system.

This will help the user to group pipe lines into clusters and study at cluster level. Based on the study results, apply the same to individual lines within the cluster for calculation of COF and some DMs which can be handled at cluster level. However provision also made for some damage mechanisms which are unique to particular pipe line to handle separately for each line.

**Piping Master**

**PIPING MASTER**

This is the master data table for the pipe lines that are present in the facility. All this data is supplied by the user either in excel sheet or directly from ERP system is entered in PIPE\_MASTER table.

It has all the data related to pipe line including

* Unique identity number
* Piping cluster number
* Year in service
* Plant code , area code
* Design data like temp, pressure etc
* Operating data
* Manufacturing data like design code, material , corrosion allowance etc
* Any special conditions like under ground, vibration etc
* As on status like external condition, any actions pending etc

**Piping Clusters and**

**Corrosion Study**

**Piping Clusters**

The process of grouping the lines into piping clusters is as follows. The cluster approach is used to reduce the number of assets for effective corrosion study.

**Identifying Corrosion Loops**

* Corrosion study generally done by the user with a group of specialists including corrosion engineer, inspection engineer , production and maintenance engineers.
* The first step in corrosion study is dividing the complex plant into manageable corrosion loops. The plant is divided into loops based on the similar operating conditions and studied further for possible damage mechanisms.
* Corrosion loop numbers are updated by the user in PIPE\_MASTER tables after corrosion study based on fluid and operating conditions.

**Creating Piping Clusters in PIPE\_MASTER table and updating unique Clusters into PIPE\_CLUSTER table**

* Once corrosion loops are updated in the piping master, based on selected parameters depending on users preference (example: plant code-corrosion loop no-material code/pipe spec-fluid code-PWHT) **piping clusters** are created automatically in PIPE\_MASTER table.
* A separate record is created in the PIPE\_CLUSTER table for all unique piping clusters from pipe master table(for updating corrosion study results- as corrosion study is done at cluster level to reduce the work).

**for example**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Line No | Plant Code | Corrosion Loop No | Material Code | Fluid Code | PWHT | Pipe Spec | Design Temp | Design Pr | Cluster Number |
| 601.AL1001 | A1 | 11 | CS | AL | N | AB1 |  |  | A1-11-CS-N-AL |
| 601.AL1004 | A1 | 11 | CS | AL | N | AB1 |  |  | A1-11-CS-N-AL |
| 601.GC10001 | A1 | 13 | LAS | GC | Y | AC1 |  |  | A1-13-LAS-Y-GC |
| 611.AL1001 | A2 | 11 | CS | AL | Y | AB1 |  |  | A2-11-CS-Y-AL |
| 611.GC1001 | A2 | 20 | LAS | GC | Y | AC1 |  |  | A2-20-LAS-Y-GC |
| 611.GC1002 | A2 | 20 | LAS | GC | Y | AA1 |  |  | A2-20-LAS-Y-GC |

From above pipe master table 4 unique cluster numbers are available and accordingly4 new records are created in pipe cluster table.

**Corrosion Study**

* Once the piping clusters are identified, each cluster is taken up in the corrosion study and relevant damage mechanisms are identified and updated in the PIPE\_CLUSTER table including the data like
  + COF required process fluid data
  + POF identifying relevant DMs
  + Assigning internal corrosion rates
  + SCC-severity values
  + Also relevant IOW parameters and its tag nos
* Also in this study user calculated DMs like creep and HTHA calculations are completed at each pipe line level and POFs are assigned.

**COF Calculation Process**

**Consequence of failure calculation process**

The process of COF calculation is summarized in the following process chart and described further below.

The COF calculation is done at two stages. The user interface with this calculation is at piping cluster level and this data is brought into COF\_MASTER table to complete the calculation at Pipe Line level.

The user interface data like selection of Reference fluid, initial fluid state , release state etc is done in Pipe Custer level and will be completed during corrosion study in the same form of PIPE\_CLUSTER which is also used for POF of certain DMs (which is discussed in the next section).

Once this selection is completed, the data is migrated into COF\_MASTER table in which there is a record created for each pipe line from PIPE\_MASTER table. In COF\_MASTER table calculation of COF done using data from PIPE\_MASTER and PIPE\_CLUSTER.

This calculation is a static system and there is no changes expected with time unless there is a change in the basic parameters (No ever-greening process).

COF calculation consists of 4 types (Toxic, Flammable, Steam and Other) based on the type of fluid handled.

**Refer the COF-MASTER form for calculation details**

**POF Calculation Process**

**Probability of failure calculation process**

**The process of POF calculation is summarized in the following process chart and described further below.**

* The design data for each pipe line is collected in excel sheet or directly from ERP system is entered in PIPE\_MASTER table.

**Calculation of POF**

Damage Mechanisms (DMs) are divided into 4 types and their POFs are calculated as below.

**1)Calculation of POF for Trendable DMs**

**1a**)**Calculation/Assigning Internal Corrosion Rates (IC rates)**

* In the PIPE\_CLUSTER table provision is available for either using qualitative approach (no calculation but assign directly corrosion rates) or quantitative approach using separate forms for calculation of Theoretical Internal corrosion rates.
* If quantitative approach is used, For each IC DMs there are tables/forms for calculating/selecting IC rates.
* Once the calculation is completed, the calculated IC rate is updated back into PIPE\_CLUSTER table.
* The same IC rates are updated back to PIPE\_MASTER table for each Pipe Line number related to this cluster number from PIPE\_CLUSTER table.

Example:

* Considering 601.AL1001 line, the cluster number is "A1-11-CS-N-AL".
* A row is created in PIPE\_CLUSTER table for this cluster number.
* During corrosion study, the CO2 corrosion is selected and a row is created in CO2 corrosion table. Based on selected criteria in this table Theoretical Internal corrosion rate (TICR) is assigned in this table for this cluster number.
* This TICR is updated back in the PIPE\_CLUSTER table and also in PIPE\_MAST Table for all the lines with same cluster number including 601.AL1001.
* If previous experienced internal corrosion rates (LICR or SICR) available for these lines in TML\_HISTORY table same are updated in PIPE\_MAST table automatically after each inspection report for this line.
* User can select either TICR or LICR or SICR as effective corrosion rate in PIPE\_MASTER table
* This EICR is used from PIPE\_MAST table for POF-IC calculation in POF\_IC table.
* Based on Inspection confidence updates from INSP\_CONFIDENCE table POF-IC will be updated when ever there is a change as a part of ever-greening process.

**1b)Calculation of POF for Stress corrosion cracking (POF-SCC)**

* During corrosion study relevant SCC damage mechanism is selected by user In the PIPE\_CLUSTER table.
* For each SCC there are tables/forms for calculating POF. After selecting the relevant SCC in PIPE\_CLUSTER by user, related form is opened and required data is filled by user.
* Calculation of POF performedin the related SCC table and the calculated POF rate is updated back intoPIPE\_CLUSTER table.
* Additionally, a separate record is created in **the same SCC table for each pipe line** which is having same cluster number with calculated POF. These records are used for future ever greening process since ever-greening process depends on history related to each line not the cluster (once inspections done based on inspection results these POF are updated for each line).

**Example:**

* Considering 601.AL1001 line , the cluster number is "A1-11-CS-N-AL".
* A row is created in PIPE\_CLUSTER table for this cluster number.
* During corrosion study, the AMINE SCC is selected as possible DM and a row is created in AMINE SCC table. Based on selected criteria in this table POF is assigned for this cluster number.This POF is updated back in the PIPE\_CLUSTER table.
* Once the PIPE\_CLUSTER updated, records are created in the AMINE SCC table for all lines in PIPE\_MASTER which are having same cluster number duplicating all calculations and POF of the cluster to individual lines.
* Future ever-greening process is done at each pipe line level based on individual inspection and reports.

**2) Calculation of POF for Auto calculated DMs**

* Auto calculated DMs like EC/CUI/EXSCC are calculated directly at PIPEMASTER level (without any requirement of pipe cluster approach).
* For each pipe line in PIPEMAST a row is created in these tables(POF\_EC, POF\_CUI and POF\_EXSCC) as per conditions below:

1. If material code is not "SS" and Insulated is not "Y" then in POF-EC table
2. If material code is not "SS" and Insulated is not "N" then in POF-CUI table
3. If material code is "SS" and Insulated is "Y" then in POF-EXSCC table

* Using the required date and parameters POF is automatically calculated for these DMs and updated in POF\_MASTER Table.
* After each inspection report, the data is updated into respective tables and POF rerun completed and updated in POF\_MASTER.

**2.a) External corrosion (EC)**

* Coating quality and climate condition are selected from MANAGEMENT table.
* Theoretical external corrosion rates are selected from Table\_15.2 based on pipe master data (as explained in the calculation form).
* External condition history updated from EXT\_HISTORY table.
* If previous experienced external corrosion rates (LECR or SECR) available for these lines in TML\_HISTORY table same are updated in PIPE\_MAST table automatically after each inspection report for this line.
* User can select either TECR or LECR or SECR as effective corrosion rate in PIPE\_MASTER table
* This EICR is used from PIPE\_MAST table for POF calculation in POF\_EC table.

**2b)Corrosion Under Insulation (CUI)**

* Coating quality and climate condition are selected from MANAGEMENT table.
* Theoretical external corrosion rates are selected from Table16.2 based on pipe master data (as explained in the calculation form).
* External condition history updated from EXT\_HISTORY table.
* If previous experienced external corrosion rates (LCUICR or SCUICR) available for these lines in TML\_HISTORY table same are updated in PIPE\_MAST table automatically after each inspection report for this line.
* User can select either TCUICR or LCUICR or SCUICR as effective corrosion rate in PIPE\_MASTER table
* This ECUICR is used from PIPE\_MAST table for POF calculation in POF\_CUI table.

**2b)External SCC (EXSCC)**

**3)Calculation of POF for Non-Trendable DMs**

* These are the Special conditions related to that particular pipe line (like Dissimilar weld, Bellows, etc) that can't be calculated and user want to keep them in inspection strategies.
* For these DMs Susceptibility (High/Medium/Low) can be selected by user on qualitative basis in the PIPE\_MASTER table itself (max of 5 nos available in PIPE\_MASTER form). Once selected, a row is created in the table POF\_NT.
* Based on the susceptibility, severity index is assigned (1000 for High, 100 for Medium and 10 for Low) in POF\_NT table.
* Once the POF is selected a record is pushed into POF\_MASTER for each of the selected DM.
* Evergreening of POF done using Inspection confidence history, similar to SCC in POF\_NT table.

Example:

* 601.AL1001 has a dissimilar joint. So User selects DSM as one DM (drop down from DM Master table) and selects severity as HIGH/MEDIUM/LOW based on the probable anticipated damage. Like this, provision is available to create max of 5 DMs in PIPE\_MASTER table.
* For each DM a row is created in POF\_NT table with assigned severity.
* If any inspections done the history of Inspection confidences updated in the table.
* Auto calculation of POF taking age and inspection confidences will be done and updated into POF\_MASTER table.

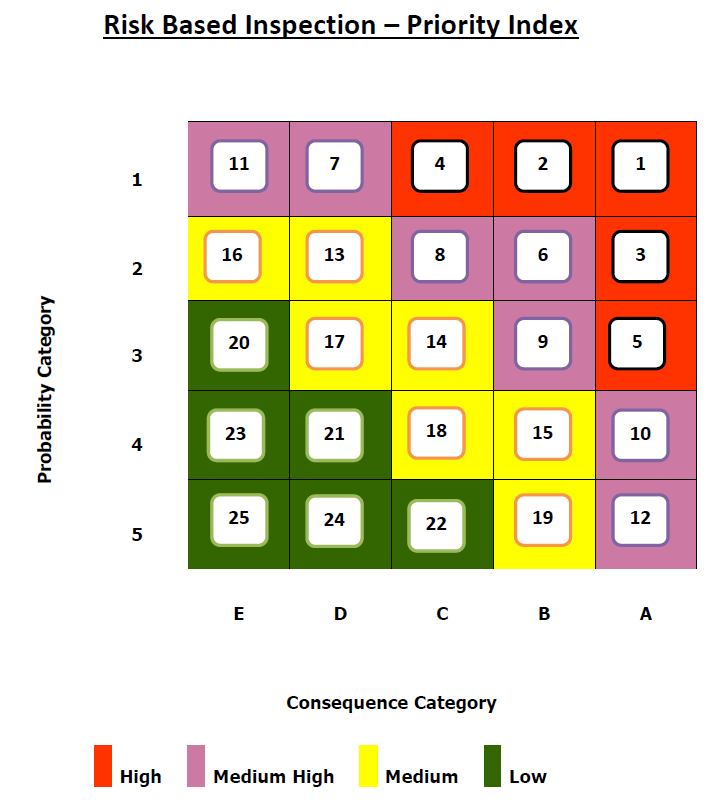
**4)Calculation of POF for User calculated DMs**

* These are the DMs like CREEP and HTHA which require user intervention for calculating POF at pipe line level.
* **CREEP:** Any pipe line operating temp is more than Creep threshold temp for that material from CREEP\_THRESHOLD table, a line is created in POF\_CREEP table with data from pipe master table. User need to calculate the POF for creep using this data and supplied curves from API 579 level-1 screening.
* **HTHA:** In corrosion study clusters that are to be evaluated for HTHA damage are identified. Accordingly a line is created for each line in that cluster in POF\_HTHA table. User need to calculate the POF for HTHA using this data and supplied Nelson curves from API 579.

**Assigning Inspection Strategies and Frequency**

**Development of Inspection Strategy and Frequency**

Once the POF for each DM and COF for each line is calculated as explained above, the inspection strategies are picked from DM\_MASTER table based on the priority in the risk matrix for each DM.



As shown above the risk matrix is a 5X5 matrix with consequence on X-axis from A-E in the order of severity and probability is on y-axis from 1-5 in the order of highest probability.

Each point in the matrix is given a number (from 1 to 25) which is called the priority. In DM\_MASTER table for each DM and for each priority a Inspection strategy and frequency is assigned by default. This is a user definable table which can be changed by the admin of the user.

Example: **Consider a Pipe line 601.AL1001**

The results of the risk ranking is COF: B and POF :2 (Lowest POF) and Risk Rank : B2 - Medium High (from above matrix).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 601.MS1001 | COF | B |  |  |  |
| Damage Mechanisms | DM Code | POF | Priority | Inspection program | frequency |
| Internal Corrosion | IC | 2 | 6 | TM at 2 location on each shell | 4 |
| External Corrosion | EC | 4 | 15 | Visual Inspection, | 6 |
| AMINE SCC | SCC-AMINE | 3 | 9 | PA UT and MPI | 4 |

**Inspection Reporting**

**and**

**Ever-greening Process**

**Piping report**

Once the inspection strategies are established along with frequencies, Inspections are performed and findings along with recommendations and inspection confidence levels are reported in PIPE\_REPORT.

Piping report table gets data from pipe master, POF master and COF master tables.

Once the inspection is completed the user will update the inspection results like

* TML measured values
* External condition status
* Inspection confidence level for each DM
* Observations and Recommendations with target dates

Based on above data, the ever greening process of POF is updated in all tables and new inspection strategy and frequency is updated for that pipe line. In this process

* TML data is populated to TML\_HIST table ,
* Inspection confidence data is updated into INSP\_CONFIDENCE table
* External condition data updated into EXT\_CONDITION table
* Recommended actions are updated into RECOM\_ACTIONS table

For all the recommended actions a interface to be developed with ERP system (say SAP) to generate notifications. Once the work-orders are closed in the ERP system, the same should be updated back to our system.

The report table should have facility for authority control and approval based on roles assigned and plant codes.

Company Name

Piping Inspection Report

Master Data

Report No (A-xxxx/yy), Work order Number (U- xxxxxxxx) Equipment Number (U- xxxxxxxxxxxx) Date (A- Today), Overall Status (U-POOR/ACCEPTABLE/GOOD)

Retrieve Master Data as per Equipment number

Description, Plant, Line from to , P&ID number, Cluster Number, Material, Fluid, Risk rank, Revised Status

POF

TML

Recom

Distribution

Actions

TML

POF

Pipe Mast

Distribution

Distribution from table including carried by, approved by

Followup

Next Insp date , Follow-up date

Temp repair Y/N, Temp repair followup comment, Sl no (report no/slno), Comment (if available), Present status

Recommendations

Sl no (report no/slno),Recommendation 250, Priority, Responsible, Target date, WO number

+ to add new lines

External condition;

Observations (text 250) + to add new lines

TML table

SCR IC: EC: CUI: LCR IC: EC: CUI:

TML – CUI or EC or IC- Nom Dia-Nom Thk, Min reqThk, MeasuredThk (as Table)

+ to add new lines

Inspection Program – From POF table for this equipment- as table

Damage Mechanism-Priority-Inspection Program-Inspection due date-Confidence-Next Insp Date

**Additional requirements**

* All the POF and risk ranking to be updated automatically every year (say 31st Dec Night) taking the new year.
* Provision should be available for projection of the risk ranking for future year. This requires running of all POFs for a selected set of equipment/plant and present the data to facilitate informed decision by the user.
* Development of reports may be using crystal reports.
* Development of approval process and action pending using dash-board approach

**Tables**

1. PIPE\_MASTER
2. PIPE\_CLUSTER
3. COF\_MASTER
4. DM\_MASTER
5. CREEP\_THERSHOLD
6. POF\_MASTER
7. POF\_IC (+ related tables)
8. POF\_SCC (+ related tables)
9. POF\_EC (+ related tables)
10. POF\_CUI (+ related tables)
11. POF\_EXSCC (+ related tables)
12. POF\_NT (+ related tables)
13. POF\_CREEP
14. POF\_HTHA
15. PIPE\_REPORT
16. TML\_HIST
17. INSP\_CONFIDENCE
18. EXTN\_CONDITION
19. RECOM\_ACTIONS