FEW CASE STUDIES ON INTERNAL CORROSION

By : RAJESH UPRETY, Additional Director (Pipelines), OISD, NOIDA
OVERVIEW ABOUT INTERNAL CORROSION

- INTERNAL CORROSION IS NOT GIVEN THE DUE IMPORTANCE IN THE PRESENT OIL & GAS INDUSTRY IN INDIA
- IT IS A MAJOR AREA OF CONCERN FOR JETTY PIPELINES, OFFSHORE LINE & NON-PIGGABLE PIPELINES
- FIRE WATER LINES – AS THE QUALITY OF WATER IS NOT CONTROLLABLE
COMMON ISSUES ACROSS OIL & GAS INDUSTRY

- CORROSION COUPONS/PROBES NOT USED FOR MEASURING THE INTERNAL CORROSION RATE.
- CLEANING PIGGING IS NOT CARRIED OUT BY CLEANING PIGS, IN SOME CASES IT HAS BEEN OBSERVED THAT FOAM PIGS ARE USED.
- CORROSION INHIBITOR INJECTION IS NOT CARRIED OUT.
- PIG RESIDUE ANALYSIS IS NOT CARRIED OUT REGULARLY.
- IN MOST OF THE CASES IT HAS BEEN OBSERVED THAT NO STATISTICAL ANALYSIS HAS BEEN CARRIED OUT FOR PIG RESIDUE ANALYSIS FOR ESTABLISHING TRENDS OF INTERNAL CORROSION.
- THERE IS NO FOCUS ON CRITICALLY EXAMINING THE LOW ELEVATION AREAS W.R.T. INTERNAL CORROSION.
SOME COMPANIES SUCH AS HPCL ARE USING CORROSION INHIBITORS AS A NORMAL PRACTICE NOTWITHSTANDING THE INTERNAL CORROSION RATE (GREATER THAN 1 MPY). SO, GIVEN AT ANY POINT OF TIME IT IS VERY DIFFICULT TO PREDICT THE INTERNAL CORROSION RATE.

CHANGE OF SERVICE LIQUID WITHOUT CARRYING OUT A PROPER MANAGEMENT OF CHANGE PROCEDURE IN LINE WITH OISD-GDN178. (EXAMPLE: (i) MUNDRA-PANIPAT CRUDE PIPELINE - CHANGE OF SERVICE FROM PRODUCT TRANSPORTATION TO CRUDE OIL TRANSPORTATION - HIGH SULPHUR E.G. MAYA, QTR LS CON ETC., MAY HAVE AGGRAVATED THE MATERIAL DEGRADATION RESULTING INTO FAILURE, (ii) USE OF WET NATURAL GAS INSTEAD OF CRY NATURAL GAS ETC.,)
• **FIRE WATER LINES**: AT MANY LOCATIONS IT HAS BEEN FOUND THAT FIRE HYDRANTS/MONITORS ARE NOT PROVIDED ON THE TOP OF THE FIRE WATER PIPELINE, INSTEAD THESE ARE PROVIDED AS LONG BRANCH CONNECTIONS, WHICH DO NOT FORM A CLOSED LOOP SYSTEM FOR THE FIRE WATER LINE. THEREFORE, WATER IS STAGNATED IN THIS PORTION LEADING TO INCREASE IN INTERNAL CORROSION DUE TO MIC (MICROBIOLOGICALLY INDUCED CORROSION).
CASE STUDY – FIRE AT MUMBAI PORT TRUST

• A MAJOR FIRE TOOK PLACE IN THE MUMBAI PORT TRUST JETTY PIPELINE ON 13TH JUNE, 2015 AT AROUND 1845 HOURS.

• THE LEAK DEVELOPED IN THE 7.500 KM LONG 14” OD CARBON STEEL PIPELINE THAT CONNECTS HPCL & BPCL REFINERY TO HPCL MARKETING TERMINAL, WADALA-1; BPCL KHAU CREEK MARKETING TERMINAL AND IOCL MARKETING TERMINAL, WADALA-2 FOR TRANSFER OF POL PRODUCTS AT AROUND 2.5 KM AWAY FROM HPCL REFINERY.

• THE LINE WAS COMMISSIONED IN 1984.

• THIS LINE IS USED BY DIFFERENT COMPANIES FOR TRANSPORTING THEIR RESPECTIVE PRODUCTS.

• THE LINE WAS MAINTAINED BY MUMBAI PORT TRUST.

• AT THE TIME OF LEAK, MS WAS IN THE PIPELINE WHICH WAS BEING TRANSFERRED FROM HPCL REFINERY TO ITS MARKETING TERMINAL.
A VIEW OF SEVERELY CORRODED PIPE
ANALYSIS ON THE CASE STUDY – FIRE AT MUMBAI PORT TRUST

- No health check-up such as thickness survey of the subject pipeline or hydro test of the pipeline was done since commissioning of the line.

- Proper maintenance of the pipeline has not been undertaken; no reportable preventive maintenance of the pipeline was carried out.

- Cathodic protection which is usual practice has not been provided in the subject pipeline for the underground sections.

- The uniform thinning of the pipeline, as may be seen from the attached photo indicates uniform external & internal corrosion in the longitudinal section of the pipeline was taking place for prolonged period of time.

- Further, there was no external coating in the underground pipeline.
THE PRACTICE OF FLUSHING THE LINES WITH SEA WATER IS DETRIMENTAL TO THE HEALTH OF THE PIPELINE.

DURING TWO DIFFERENT LINE OPERATIONS THE LINE FILLED WITH SEA WATER, USED TO BE IN STAGNANT CONDITION, WHICH LEADS TO MIC (MICROBIOLOGICALLY INDUCED CORROSION).

EARLIER LEAKAGES WERE CONTROLLED THROUGH CLAMPS AND S-WRAPS, WHICH ARE PURELY A TEMPORARY MEASURE & NOT A GOOD ENGINEERING PRACTICE. NO DETAILED ANALYSIS OF FAILURE WAS CARRIED OUT.

NORMALLY ROAD CROSSINGS ARE PROVIDED WITH CASINGPIPES/ SLEEVES TO TAKE THE ADDITIONAL LOAD; IN THE INSTANT CASE IT WAS NOT PROVIDED.
ANALYSIS ON THE CASE STUDY – FIRE AT MUMBAI PORT TRUST

- THE PHILOSOPHY OF REPLACEMENT OF PIPE SEGMENT AS & WHEN REQUIRED WITHOUT PROPER MAINTENANCE PRACTICES CANNOT ENSURE INTEGRITY OF THE PIPELINE.
THE UNIFORM PAPER LIKE THINNING OF THE PIPE INDICATES CORROSION FOR A PROLONGED PERIOD OF TIME.

THE CORROSION IN THE PIPELINE IS BOTH INTERNAL & EXTERNAL IN NATURE;

NO CATHODIC PROTECTION AND NO EXTERNAL COATING OF THE LINE MADE IT VULNERABLE AGAINST EXTERNAL ENVIRONMENT.

IT MAY BE PERTINENT TO NOTE THAT NEARER TO THE SEA LOCATION INDICATE THAT THE SOIL RESISTIVITY IS LOW WHICH IN TURN ENHANCES THE RATE OF CORROSION.

THE INTERNAL CORROSION IN THE LINE IS ATTRIBUTED TO USE OF SALINE (SEA) WATER AS FLUSHING MEDIA.
ROOT CAUSE ANALYSIS ON THE CASE STUDY – FIRE AT MUMBAI PORT TRUST

- FURTHER IN ABSENCE OF PERIODIC PLANNED MAINTENANCE ACTIVITY SUCH AS DIRECT CORROSION ASSESSMENT TESTS (HYDRO TEST, THICKNESS MEASUREMENT ETC.,) THE DAMAGE IN THE LINE COULD NOT BE ASSESSED TILL THE SAME FAILED.

- THE UNIFORM PAPER LIKE THINNING OF THE PIPE INDICATES CORROSION FOR A PROLONGED PERIOD OF TIME.

- PIPES WERE INTERNALLY COATED (WITH CEMENT LINING) BUT NO COATING WAS DONE ON THE GIRTH WELD JOINTS SO WELD JOINT BECAME A WEAK AREA.
RECOMMENDATIONS ON THE CASE STUDY – FIRE AT MUMBAI PORT TRUST

• REGULAR HEALTH & INTEGRITY ASSESSMENT OF THE PIPELINE SHALL BE CARRIED OUT BY CARRYING OUT THICKNESS MEASUREMENT OF THE PIPES, HYDRO TESTING ETC.,

• CORROSION PROBES/ CORROSION COUPONS SHALL BE PROVIDED FOR MONITORING THE RATE OF INTERNAL CORROSION. CORROSION INHIBITORS MAY BE USED IN THE PIPELINE, IF THE INTERNAL CORROSION RATE EXCEEDS 1 MPY.

• FLUSHING OF PIPELINE WITH SEA WATER MUST BE DISPENSED WITH. IN THE EVENT LINE FLUSHING IS ABSOLUTELY NECESSARY, MUST BE DONE WITH FRESH WATER OR IDEALLY KEPT WITH PRODUCT FILL; IN THE LATER CASE, NECESSARY ACCOUNTING MUST BE DONE.
PHOTOGRAPHS – FIRE AT MUMBAI PORT TRUST
INTERNAL COATING OF FIRE WATER PIPELINES
INTERNAL COATING OF FIRE WATER PIPELINES

FIRE PROTECTION IN PIPELINE PUMP STATIONS / HYDRO-CARBON STORAGE TANK FARMS ETC., IS OF UTMOST IMPORTANCE. ONE OF THE MOST IMPORTANT SYSTEMS UNDER FIRE PROTECTION FACILITIES IS THE FIRE WATER SYSTEM. PIPE DISTRIBUTION NETWORKS ARE ESSENTIAL PART OF THE FIRE WATER SYSTEM.

SELECTION AND DESIGN OF THE PIPING MATERIAL IS VITAL ELEMENT IN DELIVERING THE WATER REQUIRED AT CORRECT FLOW AND PRESSURE FOR FIRE FIGHTING. THE FIRE WATER HYDRANT SYSTEMS ARE DESIGNED FOR A MINIMUM RESIDUAL PRESSURE OF 7.0 KG/CM² AT THE HYDRAULICALLY REMOTEST POINT OF APPLICATION. HOWEVER, THERE CAN BE CASES OF SUDDEN UNPLANNED FAILURES OF THE SYSTEM LEADING TO HIGH RISKS IN MAINTAINING THE FIRE WATER SYSTEMS.
ONE OF THE CAUSES OF THE UNPLANNED FAILURES IS INTERNAL CORROSION OF THE FIRE WATER PIPELINES. THE CONSEQUENCES CAN BE SEVERE IF ANY FIRE ACCIDENT HAPPENS DURING SUCH FAILURES
INTERNAL COATING OF FIRE WATER PIPELINES
SELECTION OF MATERIAL

FIRE WATER PIPELINES ARE DESIGNED TO CARRY EITHER RIVER WATER, UN-TREATED WATER OR IN MANY CASES SEA WATER WHICH IS HIGHLY CORROSIVE.

VARIOUS MATERIALS ARE USED TO DESIGN AND MANUFACTURE.

FIRE WATER PIPELINES / FIRE PIPING HYDRANT SYSTEMS.
- CARBON STEEL
- CARBON STEEL WITH INTERNAL COATING
- GLASS REINFORCED POLYESTER (GRP)
- HDPE / PVC
- CORROSIVE RESISTANT STEEL – SS-304 / SS-316.
Carbon steel piping system:
Low initial cost compared with other materials,
Ready availability of pipes and components (bends, tees, fittings etc.,)
Established welding procedures.

However, steel corrodes in contact with normal fresh water /sea water
For fire water systems working on sea water, failures may occur within a year or two and complete and system may required substantial replacement in five years

GRP / HDPE piping system:
Material costs for plastics (HDPE) or reinforced plastics (GRP) may not be unduly high, but there drawbacks centered around:

- Availability of satisfactory jointing and fabrication procedures.
- Long term durability under a range of environmental conditions.
- Vulnerability of the materials in the event of fire.
- Occurrence of marine bio-fouling.
- Poor shock-resistance
Stainless steel piping system:
Traditional ferritic / austenitic stainless steels (including types 304 and 316) are unsuitable for use in seawater because they are prone to crevice corrosion and pitting attack, giving rise to a high probability of premature failure.

Carbon steel piping system with internal lining:
As Carbon steel is still the preferred material used for fire water pipelines systems, most of the industrial & hydro-carbon plants internationally use internal lining systems for internal corrosion protection of the pipelines.
The challenges are:

- Varying quality of the water used in these networks. Quality of water may have wide range of pH and chemicals detrimental to the lining systems.

- Varying levels of suspended matter and particulates in the water which can lead to erosion corrosion.

- Varying diameters of pipes in the fire water net work ranging from 4” to 36”

- Varying lengths of pipes, with associated fittings – miter bends and tees

- Connecting the pipes with welding / flanges
Various internal lining materials can be used for carbon steel pipelines for fire water systems. The linings are:

- Cement
- Glass reinforced Vinyl ester epoxy
- 100% solids high build epoxy
- Polyurethane
- Fusion Bond epoxy
SELECTION CRITERIA FOR INTERNAL COATING SYSTEM

- Ability of the lining material to provide an effective barrier between the steel pipe and the corrosive water for the design life of the fire water system.

- Avoid reduction in the diameter of the fire water pipeline due to the thickness of the internal lining.

- Increasing hydraulic efficiency so as to have minimum pressure drop at the far end of the fire water system.

- Lesser sediment build up and associated bio-hazards – MIC.

- Ease of application and reliability of quality: - adhesion to steel and uniform thickness.

- Ease of internal joint coating.
Abrasive blasting:
Due to various diameters ranging from 2.75” to 36” the Coating contractor used various methods for abrasive blasting methodology as under:

- For pipe dia from 30” to 36” – manual blasting process
- For Pipe dia from 8.625” to 24” - Rotating blasting unit.
- For pipe dia from 2.75” to 6.625”- Static blast pipe cleaning tool
Requirement:
- Thickness 1 mm
- Holiday detection 100%
- Cross cut test – Rating 1
- Pull off adhesion: >1500 psi.

Inspection at site:
- Measuring thickness at the edges for pipe Ø 18” and less.
- Measuring thickness at the edges and center for pipe Ø >18”
- Holiday detection using conductive rubber ring at 5 KV
- Cross cut test / Pull off adhesion

Challenges:
Inspection of small diameter pipes < 18” was a challenge and most of the section could not be inspected for surface preparation / applied coating thickness.

Holiday repair also was difficult and inspection of the same not reliable.

No equipment was available for visually inspecting the coated pipe.
For pipeline network with internal lining, the most important area to prevent corrosion is the girth weld area. Due to the following reasons:

Difficult to remove slag of the root run of the welding

Difficult access to abrasive blast, apply coating and the most important very difficult to control quality / inspection.

Depending on how the internal jointing is done limits the progress of site.

Placement / stringing of the pipes need to be done in a proper planned manner to limit the number of “Tie-In Joints
Internal field joint coating was carried out by inserting a rotating lance – pipe by pipe and experience was

- Very difficult to maintain quality
- Slow progress
- No inspection
- At Tie-In-Joints, flange joints provided.
INTERNAL FIELD JOINT COATING

- INTERNAL JOINT COATING USING ROBOTIC COATING SYSTEM.
- INTERNAL JOINT COATING USING PRE-MANUFACTURED INTERNALLY COATED STEEL SLEEVES
CONCLUSION & RECOMMENDATIONS:

- COATING OF FIRE WATER PIPELINES WITH LIQUID EPOXY LINING IS AN ACCEPTABLE TECHNOLOGY BUT TO ENSURE THE INTEGRITY OF THE PIPELINE NETWORK, THE INDIAN INDUSTRY HAS TO HAVE TRAINED APPLICATORS WHO CAN CARRY OUT THE COATING AS PER INDUSTRY STANDARDS WITH HIGH QUALITY.

- IT IS RECOMMENDED TO DO THE INTERNAL COATING OF THE PIPES / FITTINGS AT THE PIPE MILLS AND LIMIT THE APPLICATION OF THE INTERNAL COATING IN THE FIELD. FOR FIELD JOINTS, PRE-MANUFACTURED COATED SLEEVES ARE RECOMMENDED.
FINAL WORDS

CORROSION IS DETRIMENTAL, 
BE IT EXTERNAL, 
OR BE IT INTERNAL
Thank you