PIPELINE COATING SPECIFIATION AND REHABILITATION

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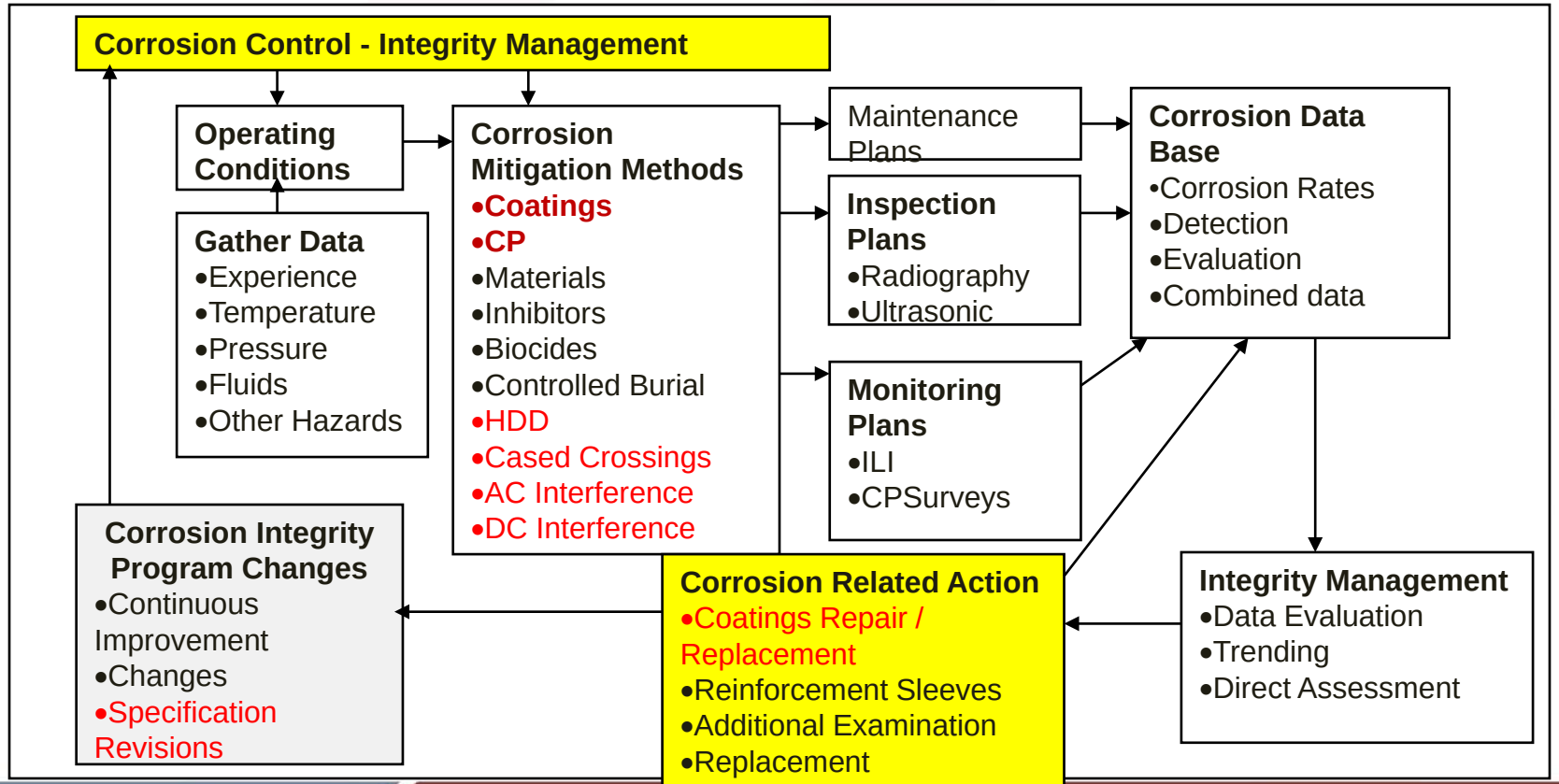
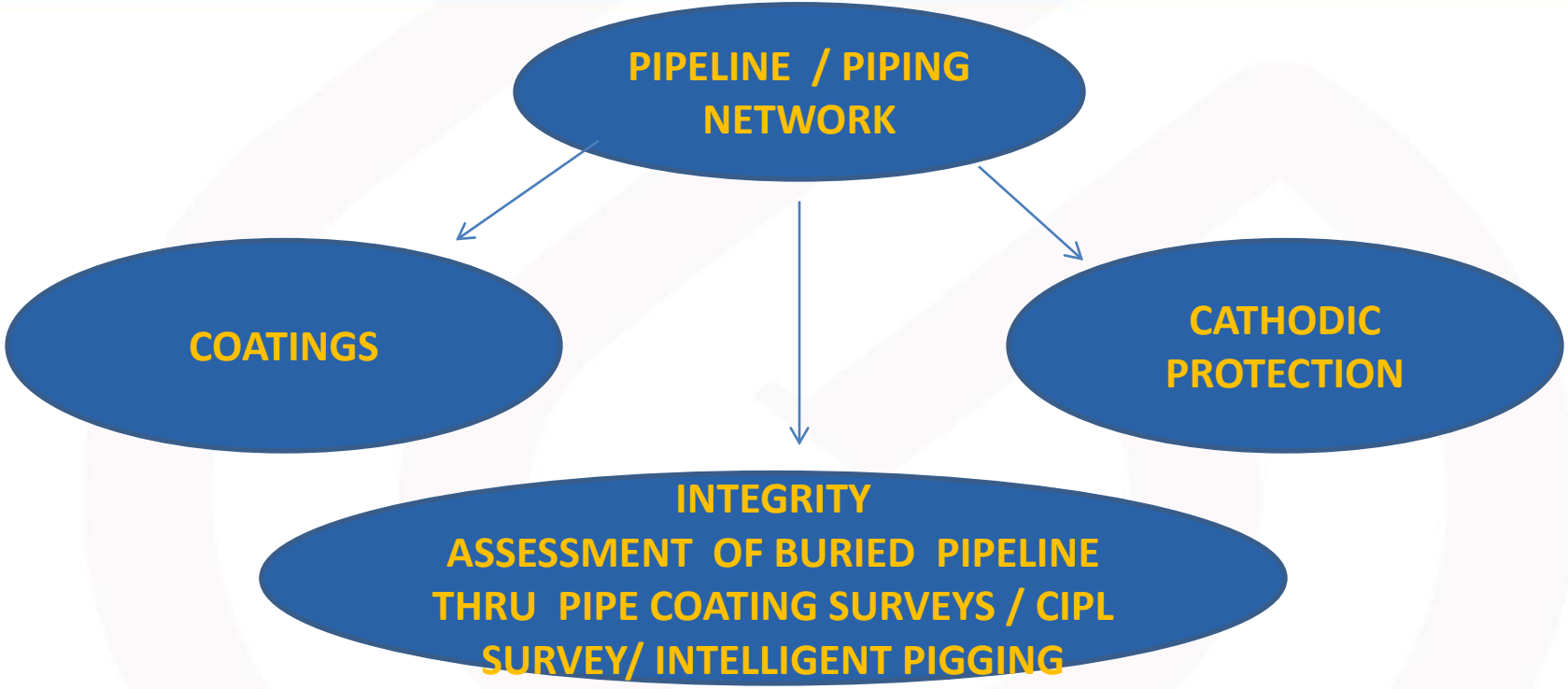
TRAINING | CONSULTING

CORROSION CONTROL - INTEGRITY MANAGEMENT



CONTROL OF EXTERNAL DEGRADATION ON UNDERGROUND OR SUBMERGED PIPELINES



EXTERNAL PIPELINE COATINGS

All pipeline coatings have a design and useful operational life.

The pipeline coatings are generally selected based on

- Operating temperature,
- Type of soil,
- Underground water table,
- Soil resistivity,
- Backfilling material,
- Micro-organisms in soil,
- Soil stress resistance,
- Indentation / impact resistance and
- Cathodic disbondment resistance.

FUNDAMENTALS OF COATING

- The pipe coating is **designed to prevent the corrosive elements** of the backfill from coming into direct contact with the pipe steel.
- A coating may be deemed to have failed if any **soil or water** makes contact with the pipe steel.
- Some degree of coating failure is unavoidable and **CP provides a particularly cost effective solution** to this problem.
- A **low level of coating defects** and a fully effective CP system is, for most operators, a normal and acceptable condition for an operating pipeline.

FUNDAMENTALS OF COATING

- **Coating degradation** can take many forms and the objective is primarily to identify the cause and mechanism of the degradation processes and how they can be avoided.

- The importance of a coating degradation mechanism to a pipeline operator may be judged by the impact it has on the **corrosion risks** to a pipeline and **the cost, and complexity,** of implementing a corrosion management strategy to cope with the risks caused by the degraded coating.

Normalized specific coating conductance range(Gn) for 1000 ohm cm soil ($\mu S/m^2$)	Coating Quality
<100	Excellent
101 to 500	Good
501 to 2000	Fair
>2000	Poor

- Moisture absorption
- Blistering
- Cracking
- Disbondment
- Delamination

FUNDAMENTALS OF COATING

Active corrosion on buried pipelines can occur where the coating is defective and the corrosion process may be driven by one the following conditions:

- **Ineffective CP**
- **CP Shielding**
- **External Drivers**
- **Stress Corrosion Cracking**

FUNDAMENTALS OF COATING

1. INEFFECTIVE CP :

The commonest causes of ineffective CP are poor quality monitoring that fails to identify under-protection and **extensive coating breakdown** that creates a total current demand far in excess of the original CP design criteria.

2. CP SHIELDING :

CP current is prevented from flowing onto the pipe steel by a high resistance barrier, such as pipe coating that **has lost adhesion to the pipe.** This creates the conditions in which **pitting and general corrosion** occur and in anaerobic soil conditions the **rate of corrosion attack may be accelerated by bacterial or microbial activity.**

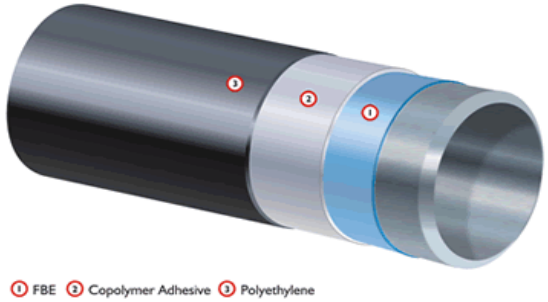
3. EXTERNAL DRIVERS:

Electrical interference, **stray current and galvanic effects can nullify the effect of the applied CP and create a corrosion problem where the pipe coating is defective.** AC induced corrosion is most commonly associated with small coating defects.

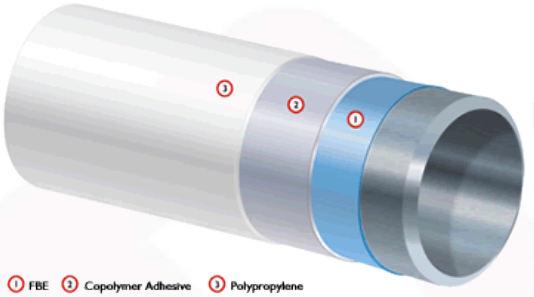
4. STRESS CORROSION CRACKING:

Stress corrosion cracking on buried pipelines is most commonly found beneath a coating that has become porous or has lost adhesion. Moisture must be present at the pipe surface but the critical potential for SCC initiation and growth is less negative than the commonly accepted protection potential of – 850 mV so CP shielding is a factor in SCC. Some degree of pressure cycling is required for axial crack growth.

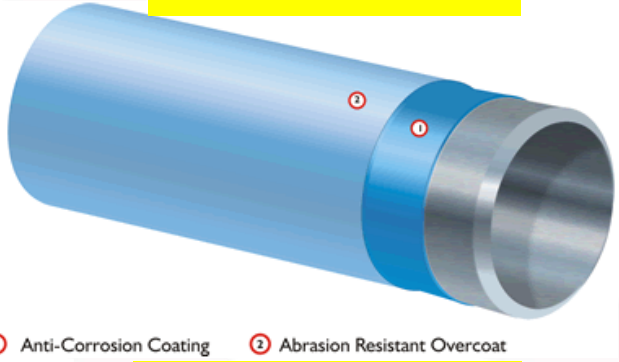
MAIN PIPELINE FACTORY APPLIED COATINGS



THREE LAYER PE



THREE LAYER PP



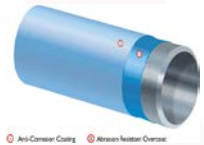
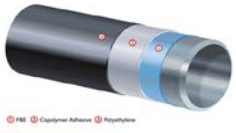
DUAL LAYER FBE

COAL TAR ENAMEL

USEFULL LIFE OF PIPELINE COATINGS

COAL TAR ENAMEL	Coal tar coatings generally have a useful life of 25~30 years. Beyond this period, the coating resistivity falls to a level where it is no longer economical to protect pipelines with supplementary CP systems. Generally at this point, in case the steel of the pipelines is good, end users look at a complete rehabilitation of the pipeline to extend the useful life of the pipeline.
FUSION BOND EPOXY (FBE/DFBE)	FBE coatings generally have a useful life of 25 to 30 years. Beyond this period, the coating starts to blister and disbond especially in high water tables.
THREE LAYER POLYPROPYLENE (3LPP)	3LPP coatings have a useful life of 30 years. High temperature coating – tends to crack.
THREE LAYER POLYETHYLENE (3LPE)	3LPE coatings have a useful life of 50 years. Very stable coating. Tends to disbond from steel surface causing surface corrosion. Problem comes if there continuous access to moisture. Can lead to pitting corrosion. CP does not help. New technologies – EMAT are being developed to dectect coating disbondment.

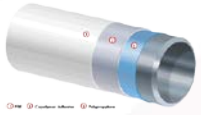
DEGRADATION MECHANISIM

FACTORY APPLIED COATING	PICTORIAL VIEW	MAXIMUM TEMPERATURE RATING	DEGRADATION MECHANISIM	USEFUL LIFE
Coal Tar Enamel		60°C	Brittleness, Cracking & Disbondment	25 years (<5000 0hm m^2) CD >800μA^2
3 Layer Polypropylene		140°C	Cracking of PP layer	25 years
Dual Layer Fusion Bonded Epoxy		120°C	Blistering and disbondment	25 to 30 years (<5000 0hm m^2) CD >500μA^2
3 Layer Polyethylene		80°C	Delamination and disbondment	50 years

DEGRADATION MECHANISIM COAL TAR ENAMEL

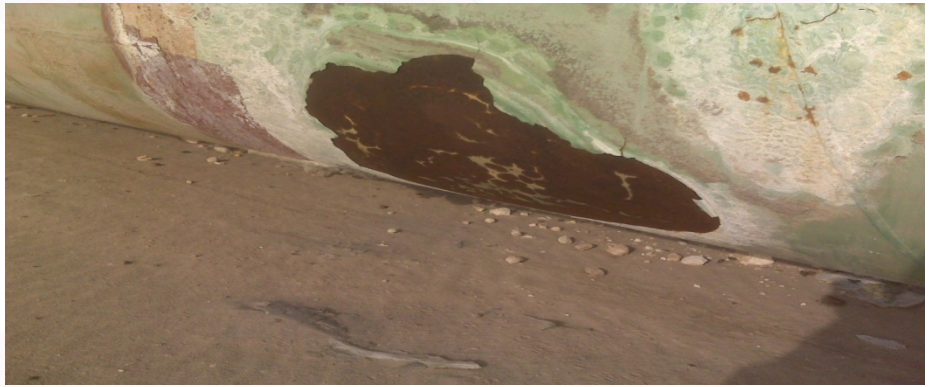
FACTORY APPLIED COATING	PICTORIAL VIEW	MAXIMUM TEMPERATURE RATING	DEGRADATION MECHANISIM	USEFUL LIFE
Coal Tar Enamel		60°C	Cracking & Disbondment	25 years (<5000 0hm m^2) CD >500µA^2

DEGRADATION MECHANISIM THREE LAYER POLYPROPYLENE

FACTORY APPLIED COATING	PICTORIAL VIEW	MAXIMUM TEMPERATURE RATING	DEGRADATION MECHANISIM	USEFUL LIFE
3 Layer Polypropylene		140°C	Cracking of PP layer	25 years

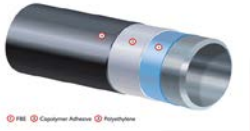
DEGRADATION MECHANISIM DUAL LAYER FBE

FACTORY APPLIED COATING	PICTORIAL VIEW	MAXIMUM TEMPERATURE RATING	DEGRADATION MECHANISIM	USEFUL LIFE
Dual Layer Fusion Bonded Epoxy		120°C	Blistering and disbondment	25 to 30 years (<5000 0hm m^2) CD >500μA^2



DEGRADATION MECHANISIM DUAL LAYER FBE

DEGRADATION MECHANISIM THREE LAYER POLYETHYLENE

FACTORY APPLIED COATING	PICTORIAL VIEW	MAXIMUM TEMPERATURE RATING	DEGRADATION MECHANISIM	USEFUL LIFE
3 Layer Polyethylene		80°C	Delamination and disbondment	50 years

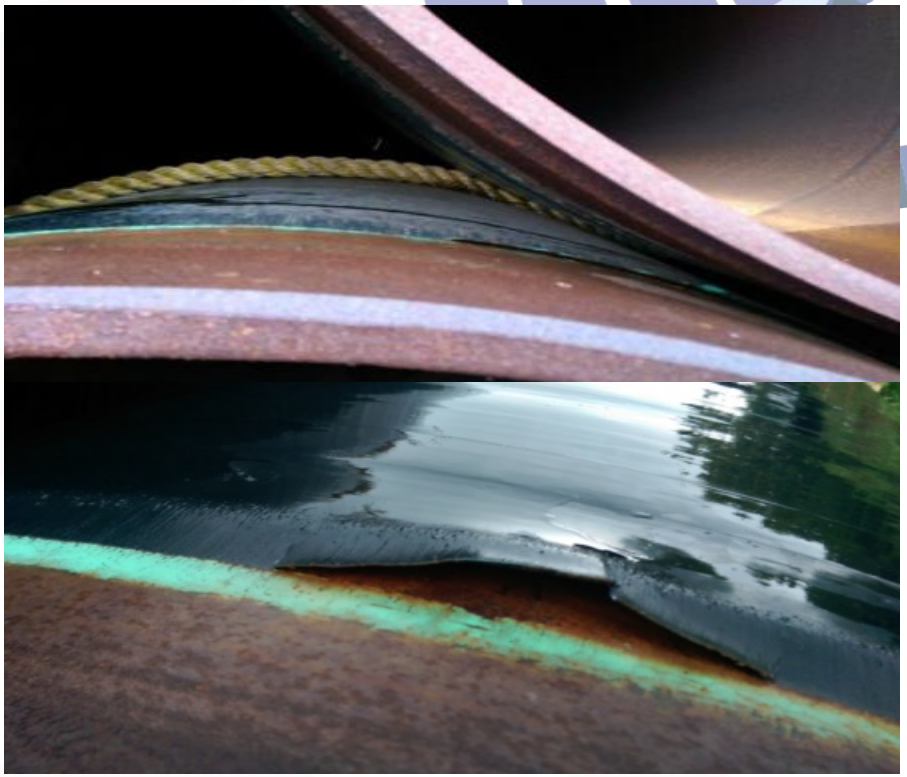
DEGRADATION MECHANISIM THREE LAYER POLYETHYLENE

DEGRADATION MECHANISIM COMPARISION

3LPE AFTER 25 YEARS – **NO CRACKING** OF OUTER SURFACE

CTE AFTER 25 YEARS **– CRACKING** OF OUTER SURFACE

DAMAGE MECHANISIM DURING CONSTRUCTIONS STORAGE



DAMAGE MECHANISIM DURING CONSTRUCTIONS STORAGE

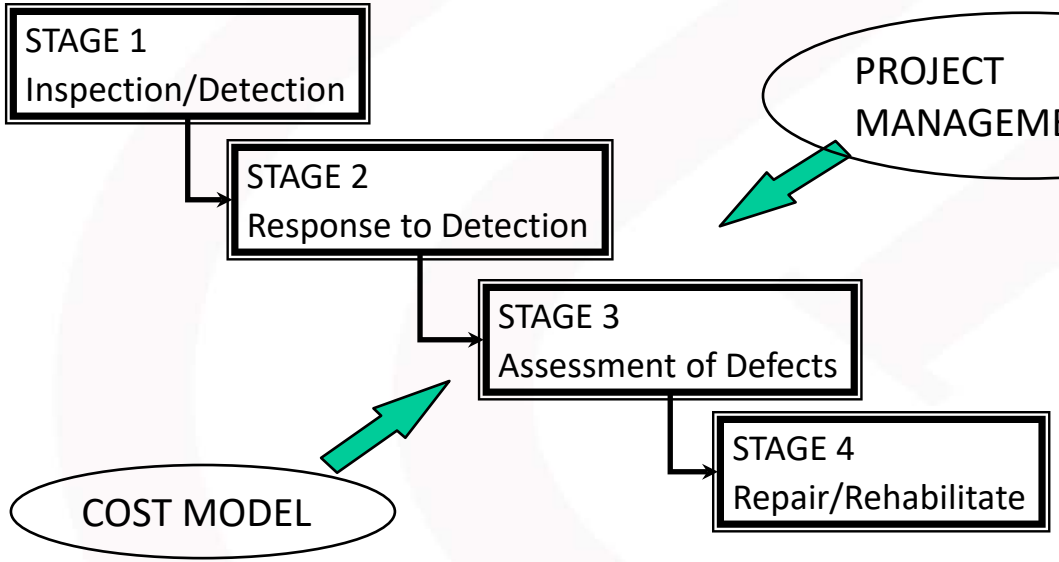
DAMAGE MECHANISIM DURING CONSTRUCTIONS STORAGE

REPAIR VS REHABILITATION

‘**Repair’** – small scale remediation (e.g. repair defect)

‘Rehabilitation’ – large scale remediation (e.g. recoat)

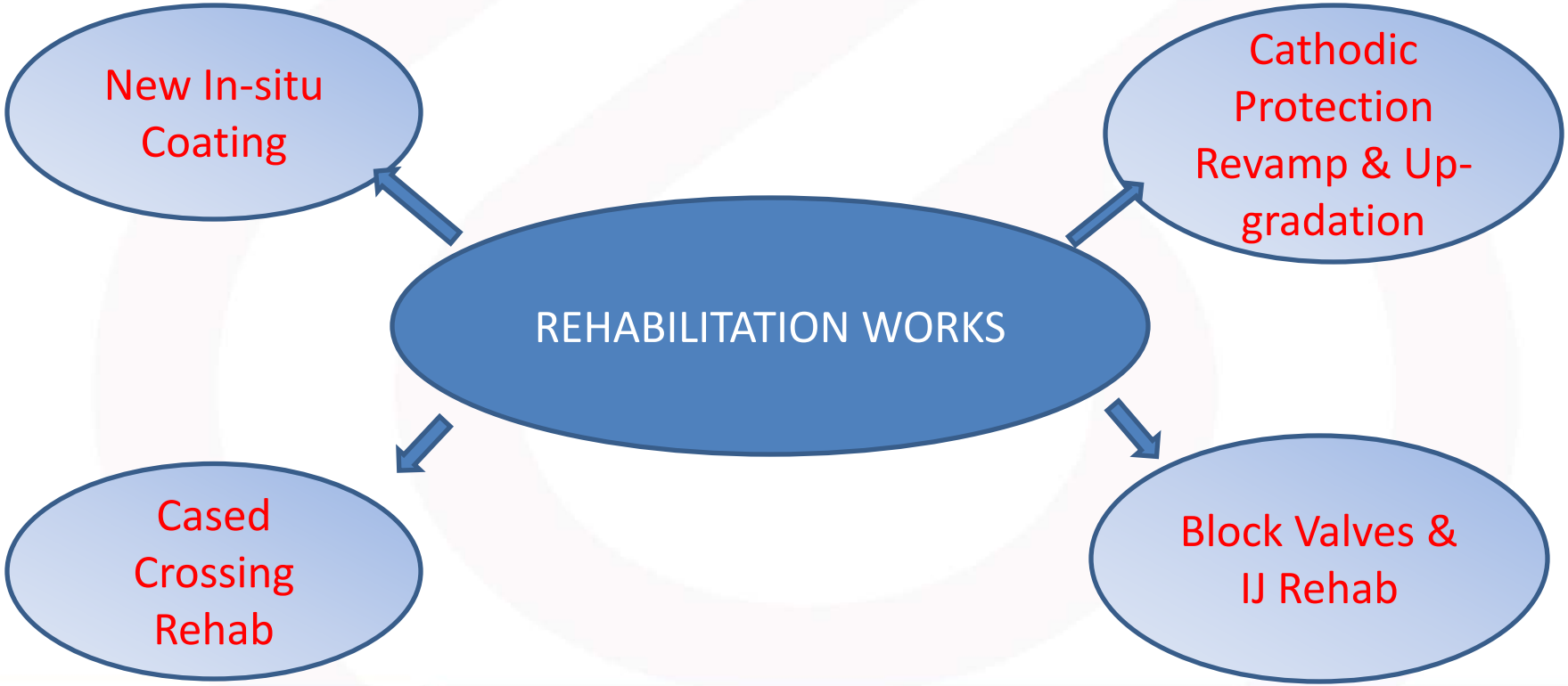
THE FOUR STAGES OF REPAIR AND REHABILITATION



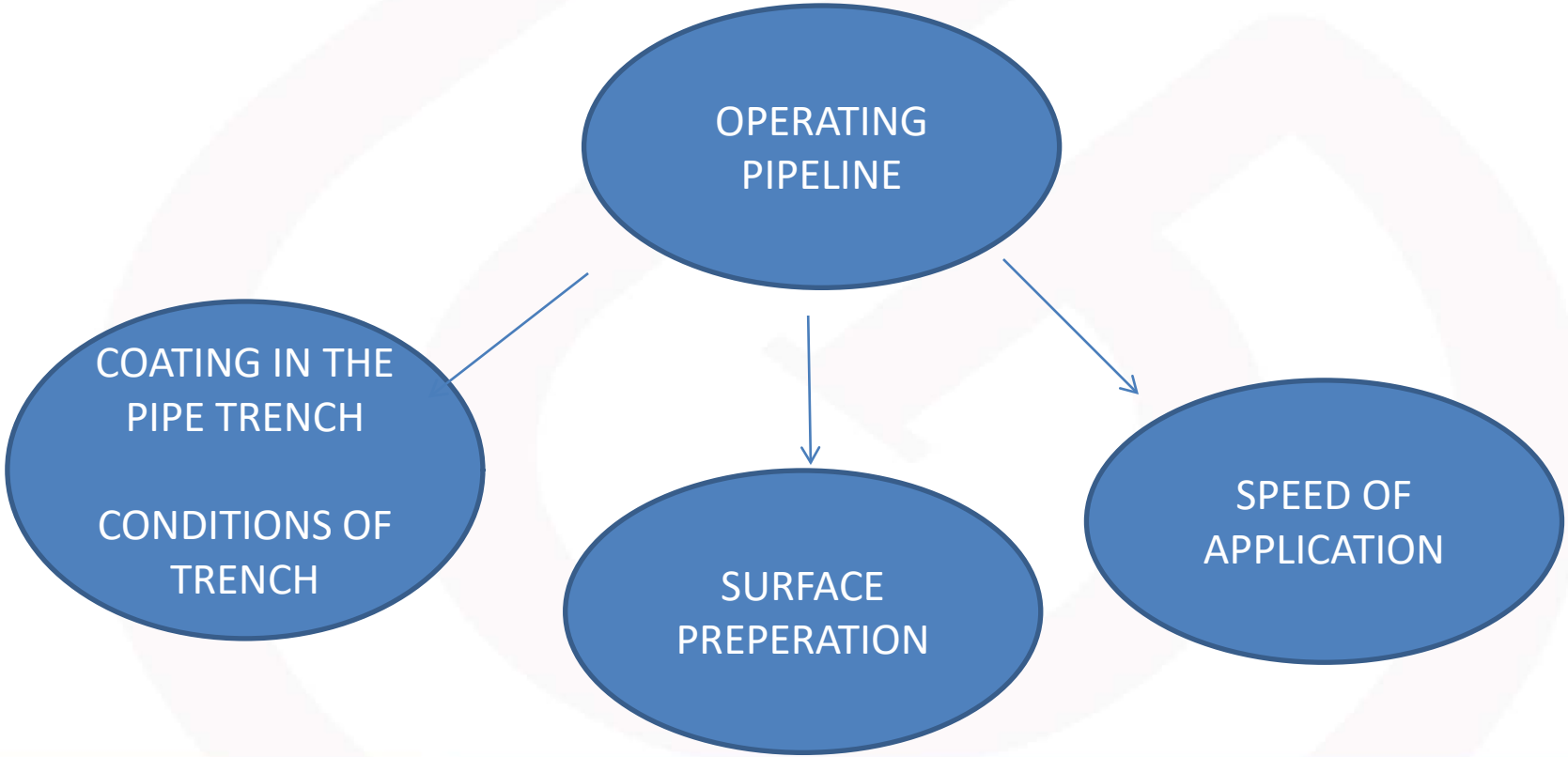
Repair and Rehabilitation is NOT about inspection, and is NOT about 'defect assessment'…

it is a engineering exercise that needs a wide ranging engineering skills.

REHAHBILTATION WORKS



SELECTION OF REHAB COATING



WHY DO COATINGS FAIL ?

WHY DO COATINGS FAIL

IMPROPER COATING SELECTION

IMPROPER COATING APPLICATION

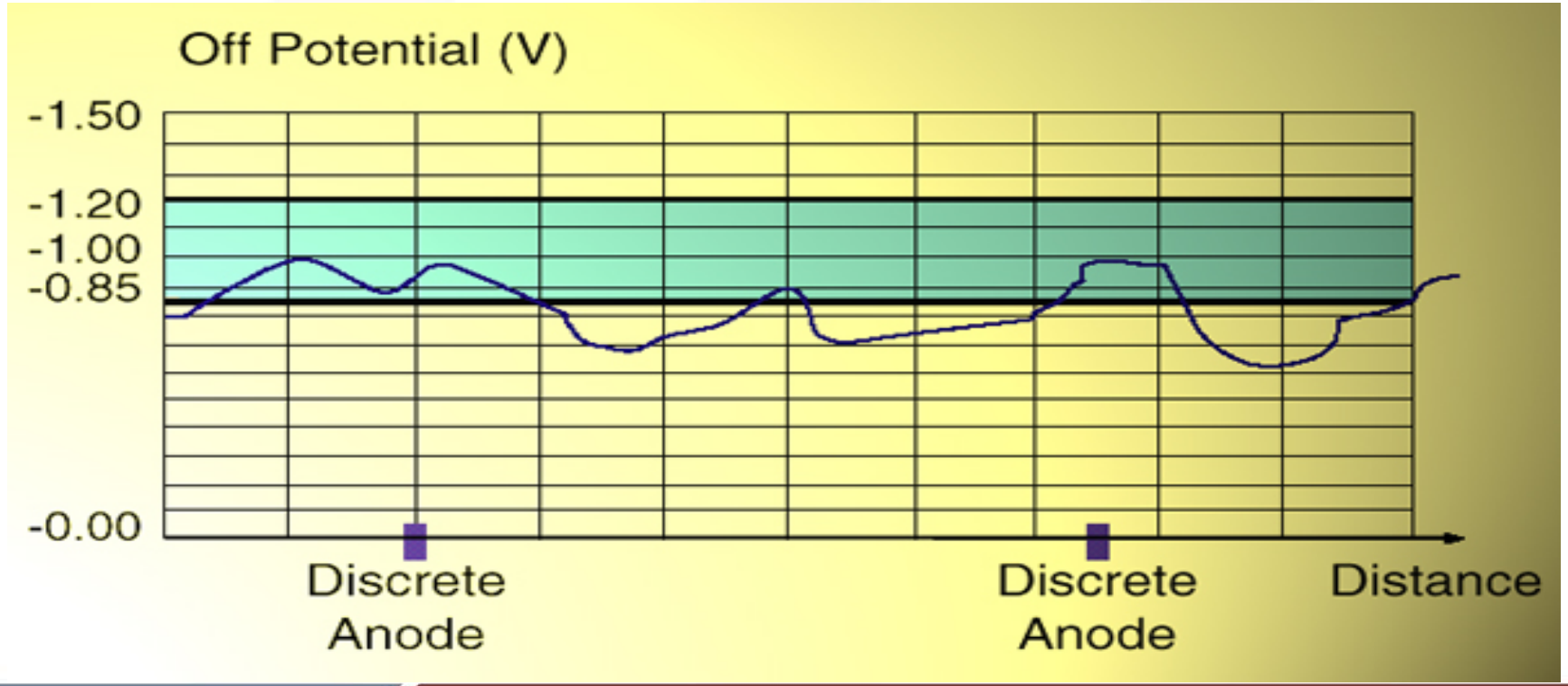
LAYING DAMAGES

PREMATURE FAILURE OF COATING MATERIAL

IMPROPER CATHODIC PROTECTION

COATING AGEING

CP SYSTEMS DO NOT PROTECT HIGH CURRENT ATTENUATION



WHEN COATINGS START TO FAIL WHAT STEPS ARE TO BE TAKEN

WHEN COATINGS START TO FAIL …

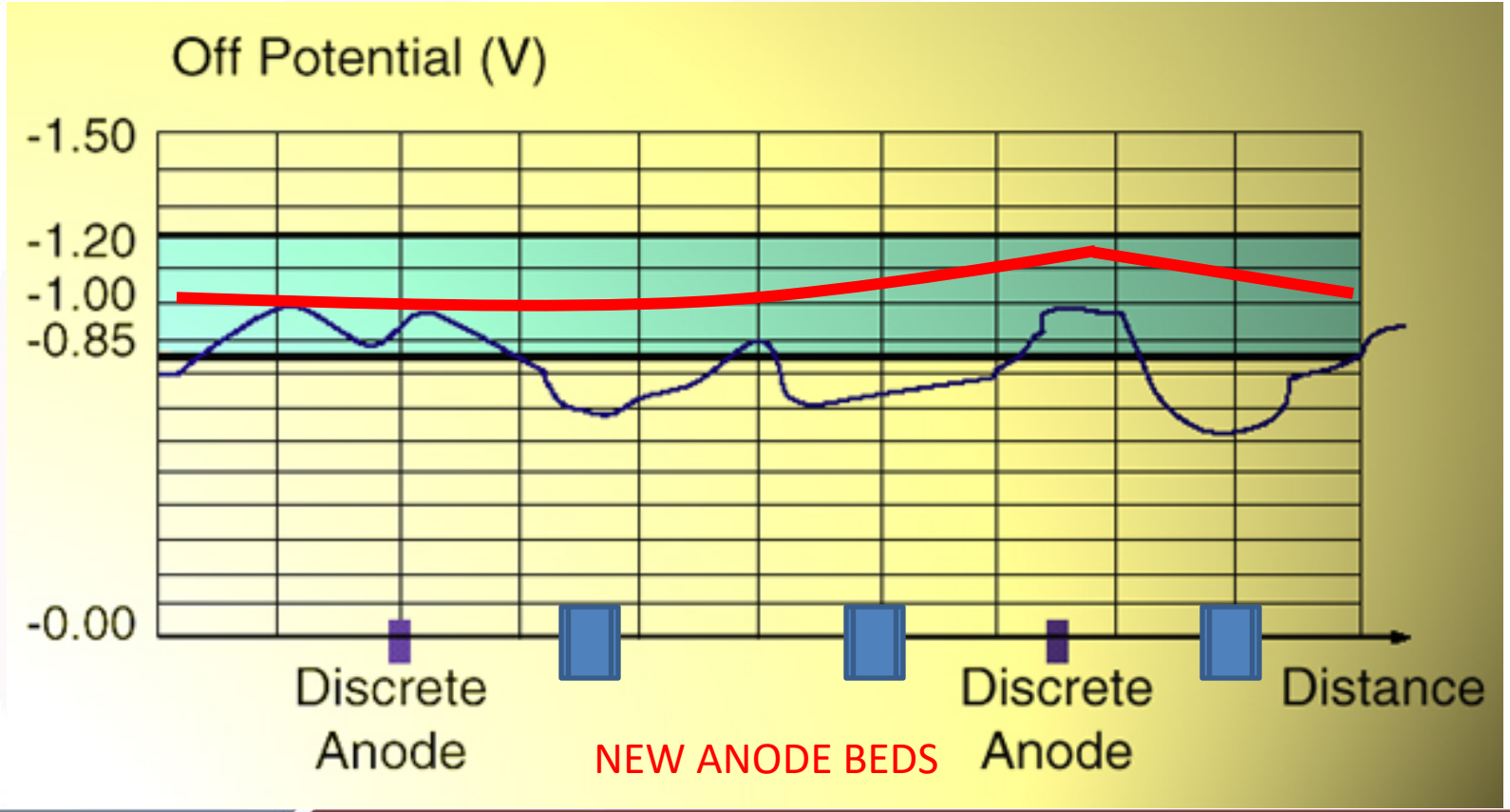
ENHANCE CATHODIC PROTECTION

REPAIR LOCALIZED COATING DAMAGES

RECOAT ENTIRE PIPELINE

REPLACE THE PIPE LINE

ENHANCE CATHODIC PROTECTION



REPAIR LOCALIZED COATING DAMAGES

RECONDITION / REPAIR

SMALL SECTIONS

IN BELL HOLE

RECOATING

The economic life of a coating ends when the CP systems are not capable of protecting the pipeline by ensuring PSP of ≥(-) 0.85V OFF with respect to $Cu/CuSo_4$ reference electrodes all long the ROW.

COATING RESISTANCE TO SOIL < 5000 ohm-sq.meter

CURRENT DENSITIES OF DIFFERENT COATINGS IN ACTUAL OPERATION

	DIA (inch)	LENGTH (km)	TYPE OF COATING	YEARS IN SERVICE (year)	AVG. CURRENT DENSITY ($\mu A/m^2$)
LINE 1	12	800	Over the Ditch CTE	42	400-500
LINE 2	24	800	Over the Ditch CTE	30	400-800
LINE 3	18	950	CTE (Plant Coated)	10	8-10
LINE 4	22	950	3LPE	13	13-15
LINE 5	10	110	3LPE	13	5-7
LINE 6	10	70	FBE	9	40-50
LINE 7	10	170	FBE+CTE	6	10-15

CP STATIONS OF DIFFERENT COATINGS IN ACTUAL OPERATION

	DIA (inch)	LENGTH (km)	TYPE OF COATING	YEARS IN SERVICE (year)	NO OF CP STATIONS
LINE 1	12	800	Over the Ditch CTE	42	40
LINE 2	24	800	Over the Ditch CTE	30	50
LINE 3	18	950	CTE (Plant Coated)	10	60
LINE 4	22	950	3LPE	13	24
LINE 5	10	110	3LPE	13	3
LINE 6	10	70	FBE	9	4
LINE 7	10	170	FBE+CTE	6	9

TYPE OF REHABILITATION COATINGS

INSITU TAPE COATINGS

- **COAL TAR TAPES**
- **POLYOLEFIN TAPE COATINGS – BUTYL RUBBER**
- **POLYOLEFIN TAPE COATINGS- VISCO ELASTIC**
- **PETROLATUM TAPE**

LIQUID COATINGS

- **HIGH BUILD EPOXY**
- **POLYURETHANE**

PARAMETERS FOR SELECTION REHAB COATING

TYPE OF EXTERNAL CORROSION

- SURFACE RUSTING / ISOLATED PITTING /EXCESSIVE PITTING

TYPE OF PARENT COATING

- 3LPE / CTE / FBE / 3 LPP

CONSTRUCTION OF PIPE

- ERW / HSAW /LSAW

FIELD APPLICATION METHODOLGY

SURFACE PREPARATION REQUIREMENT

- SA 2 ½ /ST -2 /MANUAL CLEANING

APPLICATION PROCESS – REQUIREMENTS

- EASE OF APPLICATION / EQUIPMENT REQUIRED /ENVIRONMENTAL ISSUES & APPLICATION PARAMETERS

PAST TRACK RECORD

COST ANALYSIS

TYPE OF REHABILITATION COATINGS

Soil/Trench condition	Acceptable Cold Applied Tape Coatings	Surface Preparation Required	Backfill
Dry with normal soil	3ply/2ply tape	Abrasive blasting (Sa21/2 with 50~70 micron anchor profile)	Soft soil padding of at least 20 cm around the periphery. Soft soil may be screened from the excavated soil
High water table with normal soil. Abrasive blasting not possible	Visco-elastic tape	Power/ Hand wire brushing to remove rust (St2 / St3)	Soft soil padding of at least 20 cm around the periphery. Soft soil may be screened from the excavated soil
Very High water table with normal soil Pipe surface wet	Petrolatum tape	Power/ Hand wire brushing to remove rust (St2 / St3)	Soft soil padding of at least 20 cm around the periphery. Soft soil may be screened from the excavated soil

TYPE OF REHABILITATION COATINGS

Sl No	Characteristic	Unit	Type of Rehabilitation Coatings			
			3 ply/2 ply	Visco-elastic	Petrolatum tape	Bituminous tape
1	Surface Preparation		Sa 2½	St 2 / St 3	St 2 / St 3	Sa 2½
2	Thickness (Nominal ±10%)	mm	≥ 2.5 ±10%	≥ 2.5 ±10%	≥ 2.5 ±10%	≥ 2.5 ±10%
3	Holiday detection	—	15 kV	15 kV	15 kV	at 15 kV
4	Impact resistance	J/mm	≥ 10 J	≥ 10 J	≥ 2 J*	≥ 5 J
5	Indentation resistance, Test pressure – Residual thickness	N/mm2 mm	10.0 ≥ 0.6	10.0 ≥ 0.6	0.1 ≥ 0.6	10.0 ≥ 0.6
6	Specific electrical insulation resistance	Ω·m2	≥ 10^8	≥ 10^8	≥ 10^6	≥ 10^5
7	CD resistance at 28 days	mm	≤ 5 mm	0 mm	< 20	<20mm

TYPE OF REHABILITATION COATINGS

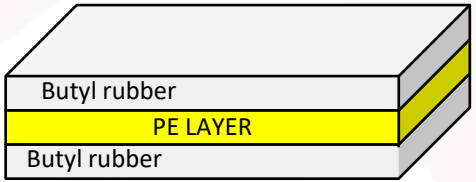
Sl No	Characteristic	Unit	Type of Rehabilitation Coatings			
			3 ply/2 ply	Visco-elastic	Petrolatum tape	Bituminous tape
8	Peel strength – to steel surface	N/mm	≥ 1.00	≥ 0.2	leave a film of compound on the substrate	≥ 1.00
9	Water Vapour permeability	g/m2 – 24 hr	<0.2	<0.2	<0.3	<0.2

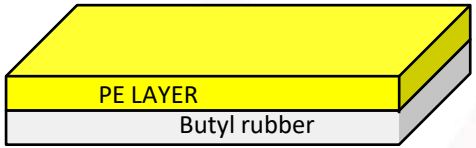
TYPE OF REHABILITATION COATINGS - 3ply / 2ply

Butyl rubber based primer
WFT 75 microns

3ply tape (Inner corrosion layer)
Overlap 50%
Thickness 0.75mm

2ply tape (outer mechanical layer)
Overlap 50%
Thickness 0.5mm





3ply / 2ply COATING

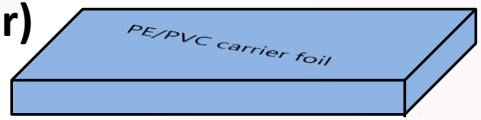
- **FIELD** APPLIED
- HAND WRAPPING MACHINE
- ANY LENGTH OF PIPE
- MAX OPERATING TEMP: 80^0C
- APPLIED **THICKNESS 2.5 mm or more**
- HIGH IMPACT STRENGTH
- HIGH INDENTATION STRENGTH
- CATHODIC DISBONDMENT RESISTANT
- EN 12068

APPLIED THICKNESS : 2.5mm

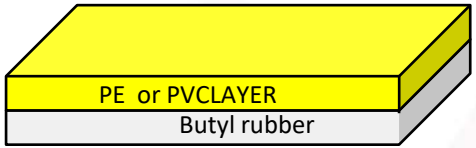
TYPE OF REHABILITATION COATINGS - VISCO ELASTIC

No Primer
WFT 75 microns

Visco Elastic Wrap (Inner corrosion layer)
Overlap 10mm
Thickness 1.5mm



2ply tape (outer mechanical layer)
Overlap 50%
Thickness 0.5mm



APPLIED THICKNESS : 2.5mm

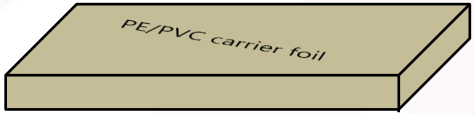
Visco Elastic

- **FIELD** APPLIED
- ANY LENGTH OF PIPE
- MAX OPERATING TEMP: 100^0C
- APPLIED **THICKNESS 2.5 mm or more**
- HIGH IMPACT STRENGTH
- HIGH INDENTATION STRENGTH
- CATHODIC DISBONDMENT RESISTANT
- ISO 21809 Part 3

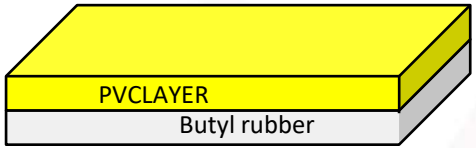
TYPE OF REHABILITATION COATINGS - PETROLATUM

No Primer
WFT 75 microns

Petrolatum Tape (Inner corrosion layer)
Overlap 25mm
Thickness 1.5mm



2ply tape (outer mechanical layer)
Overlap 50%
Thickness 0.5mm



Petrolatum Tape
- **FIELD** APPLIED
- ANY LENGTH OF PIPE
- MAX OPERATING TEMP: 50^0C
- APPLIED **THICKNESS 2.5 mm or more**
- HIGH IMPACT STRENGTH
- CATHODIC DISBONDMENT RESISTANT
- ISO 21809 Part 3

APPLIED THICKNESS : 2.5mm

TYPE OF REHABILITATION COATINGS - 3PLY / 2 PLY

TYPE OF REHABILITATION COATINGS - VISCO ELASTIC

TYPE OF REHABILITATION COATINGS - PETROLATUM

TAPE COATINGS

POLYOLEFIN TAPE COATINGS – 3ply / 2ply

-Surface preparation Sa 21/2

-Ease of Application – Hand wrapping machine required

-Primers have VOC – to be handled carefully

-Low CP current requirement

-**Tenting effects around weld seam** .

VISCO ELASTIC COATINGS:

-Extremely surface tolerant - St3 surface preparation

-No primer application

-Easy to apply – manual application.

-Fill and flows easily and hence no tenting effect on the weld seams

-Low CP current requirement

-**No tenting effect around weld seam**

REHABILTATION OF COATING- 14” DIA PIPELINE

ORIGINAL COATING COAL TAR ENAMEL

PIPE STEEL CONDITION OK

REHABILTATION OF COATING- 14” DIA PIPELINE

REHABILTATION OF COATING- 14” DIA PIPELINE

Brittleness, Cracking & Disbondment

REHABILTATION OF COATING- 14” DIA PIPELINE

CTE COATING REMOVAL

BY CHIPPING & HAMMERING CTE

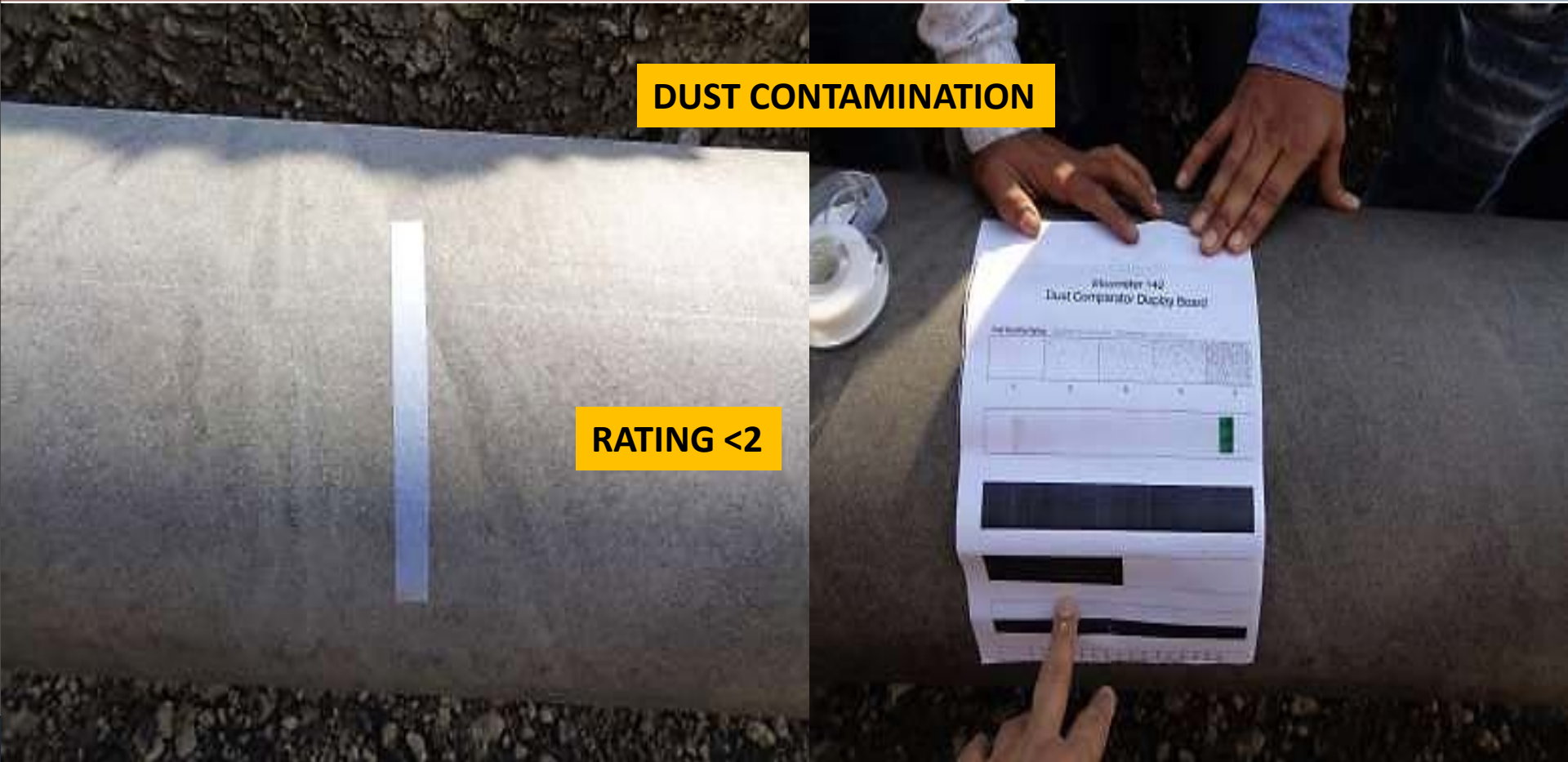
REHABILTATION OF COATING- 14” DIA PIPELINE

REHABILTATION OF COATING- 14” DIA PIPELINE

REHABILTATION OF COATING- 14” DIA PIPELINE

MEASURING ANCHOR PROFILE

REHABILTATION OF COATING- 14” DIA PIPELINE



REHABILTATION OF COATING- 14” DIA PIPELINE

SALT CONTAMINATION

<2micro grams/cm²

REHABILTATION OF COATING- 14” DIA PIPELINE

REHABILTATION OF COATING- 14” DIA PIPELINE

APPLICATION OF 3PLY / 2PLY TAPE COATING

REHABILTATION OF COATING- 14” DIA PIPELINE

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REHABILTATION OF COATING- 14” DIA PIPELINE

REHABILTATION OF COATING- 3LPE COATED PIPELINE

POWER TOOL CLEANING
FBE REMOVED
ANCHOR PROFILE > 50 50MICRONS

HIGH BUILD EPOXY APPLIED TO A THICKNESS > 500 MICRONS

REHABILTATION OF COATING- 3LPE COATED PIPELINE

AFTER APPLICATION OF HIGH BUILD EPOXY, THE EPOXY CURES IN 24 HOURS (SHORE D > 70. 3PLY / 2PLY TAPE COATING IS APPLIED

REHABILTATION OF COATING- PETROLATUM TAPE

ST3 CLEANING
PETROLATUM PASTE BEING APPLIED

PETROLATUM TAPE BEING WRAPPED

REHABILTATION OF COATING- CONDENSING GAS PIPELINE

REHABILTATION OF COATING- CONDENSING GAS PIPELINE

SPECIAL VISCO ELASTIC TAPE & PE OUTER WRAP

REHABILTATION OF COATING- VISCO ELASTIC TAPE

NO BLASTING

NO PRIMER APPLICATION

VISCOELASTIC TAPE

OUTER MECHANICAL LAYER

LIQUID COATINGS

HIGH BUILD LIQUID EPOXY

- FIELD APPLIED (**BRUSH** OR SPRAY)

Liquid Epoxy coatings are defined as **products made from reaction of Novalac epoxy resin (Part A) and Amine (Part B)**

POLYURETHANE

- **FIELD** APPLIED (ONLY SPRAY)

Polyurethane coatings are defined as **products made from reaction of Polyisocyanates (Part A) and Polyols (Part B)**

Part A
Resin

Part B
Hardener

Two-component films provide higher hardness with enhanced resistance to moisture permeation, soluble salts, and chemicals.

In chemistry, a hardener (Part B) is defined as a separate ingredient that reacts with the first component (Part A) of a two-component paint.

LIQUID COATINGS

SURFACE PREPERATION IS CRITICAL

MORE GROUND CLEARANCE REQUIRED

THICKNESS AT BOTTOM OF PIPE IS CRITICAL

TRENCH HAS TO BE COMPELTLY DRY

LARGE WIDTH O F TRENCH FOR MOVEMENT

LIQUID COATINGS

LIQUID COATINGS

URETHANE BASED

-100% urethane or tar urethanes
-With or without primer application
-Surface preparation critical
-Chloride levels on steel ≤20µgms/cm^2
-High adhesion to steel
-No tenting effect
-Higher water permeability
-Low material cost
-Sophisticated spray machine and trained applicators required.
-Applied thickness1~ 1.5mm
-Low CP requirement
-No cathodic shielding

EPOXY BASED

-100% solids high build or glass flake
-Without primer application
-Surface preparation critical
-Chloride levels on steel ≤20µgms/cm^2
-Adhesion to steel higher than urethanes
-No tenting effect
-Lower water permeability
-Higher material cost
-Sophisticated spray machine and trained applicators required.
-Applied thickness 0.7~1mm
-Low CP requirement
-No cathodic shielding

SUMMARY OF COATING REHAB

BELL HOLE

BLASTING

Sa 21/2 SURFACE

INNER WRAP

OUTER WRAP

FINISHED COATING

REHABILTATION OF COATING- ISO STANDARD

ISO STANDARD 21809 PART 11

PETROLEUM & NATURAL GAS INDUSTRIRES –
EXTERNAL COATINGS FOR BURIED AND SUBMERGED
PIPELINES USED IN PIPELINE TRANSPORTATION SYSTEM

PART 11
COATINGS FOR IN FIELD APPLICATION , COATING REPAIRS AND REHABILITATION

CONCLUSION

Pipeline Owners / Consultants need to select rehabilitation coatings considering various factors highlighted in the presentation. From wide spectrum of rehabilitation coatings available along with their associated application technologies. Price of the Rehabilitation coating ***should not be the only deciding factor***. For Indian Conditions – MOST IMPORTANT PARAMETER TO CONSIDER ARE:

- ***ACHIEVEMENT OF SURFACE PREPERATION***
- ***SKILL LEVEL OF CONTRACTORS***
- ***SKILL LEVEL OF APPLICATORS***

THANK YOU

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