Pipeline Coatings
The Petrobrás Experience

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PETROBRÁS, BRAZIL
PIPELINE COATINGS
THE PETROBRAS EXPERIENCE

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PURPOSE

A REVIEW INCLUDING:

– Historical

– The performance of pipeline coatings used by PETROBRAS over the last forty years.

– Development from the early eighties to the present day.

– Several programs carried out last years including inspections at random bell holes, laboratory tests, material properties and research projects.
PIPELINE COATINGS IN BRASIL

• COAL TAR ENAMEL
  – The oldest coating, very important in the past (mainly in USA)
  – High thickness (3 - 5 mm)
  – Easy application
  – Very large experience (old coating)
  – Good results
1970 - CAMPOS BASIN

• PROBLEM WITH RAW MATERIALS SUPPLIERS
• Difficult to have Coal Tar Enamel
• Importation restricted
• First alternative: Asphalt Enamel
• Development of new alternatives for the Brazilian market
STUDY OF NEW MATERIALS

• Cold Applied PE and PVC Tapes
• Heat Shrinkable PE Sleeves and Tapes
• Fusion Bonded Epoxy (FBE)
• Liquid Epoxy and Polyurethane Coatings
• Two and Three Layers Extruded PE.
METHODOLOGY

• Specifications and procedures based on materials used in outside countries.
• Laboratory tests in the new materials to verify the specified properties.
• Small applications following the specific procedures.
• Laboratory test on applied coatings, including accelerated aging.
• Performance evaluation on installed pipelines coated with these materials and procedures (field evaluation).
QUALIFIED PROCEDURES IN EIGHTIES

• FUSION BONDED EPOXY (FBE)
• TWO LAYERS EXTRUDED PE
• THREE LAYERS EXTRUDED PE
• COLD APPLIED PE TAPES
• HEAT SHRINKABLE SLEEVES
• LIQUID COATINGS
FIELD INSPECTION
FIELD INSPECTION RESULTS

• ADHESION FAILURES ON FBE, TWO AND THREE LAYERS PE.
• COATING DISBONDING IN ALL TYPES OF APPLIED COATINGS.
• NO CORROSION PROCESS WAS OBSERVED
FIELD INSPECTION
ADHESION LOSS OF FBE COATINGS
ADHESION TEST OF PE COATINGS
FIELD INSPECTION

CONCLUSION

TO START A RESEARCH PROGRAM
RESEARCH PROGRAM
UFRJ

• Evaluation of physical and chemical properties (standard tests) of new materials applied under old and new application conditions (old and new samples).
• Cathodic Disbonding Tests.
• Polarisation Tests at different levels.
• Evaluation based on Electrochemical Impedance Measurements - new and aged samples.
• Polymers and Microbiological Analysis

INTERNATIONAL EXPERIENCE
– Technical meetings with independent survey consultants technical staff of pipeline operators companies and coating appliers and manufacturers.
RESULTS
• Each COATING showed different behaviour and forms of damage under different tests conditions.
• The modern coatings require more control in all process steps and coating requirements.
• Important coating properties:
  – Adhesion
  – Impact and Abrasion Resistance
  – Flexibility
  – Electrical Properties
  – Chemical and Physical Stability
  – Compatibility with Cathodic Protection
Bituminous coating are being replaced all over the world by modern coatings for two reasons: requirements of environmental laws and decreasing of efficiency (permeation, cracking, sagging and chemical deterioration).

European Companies prefer PE and PP coatings. The philosophy of “passive protection”. Extremely watertight coating, high dielectric strength and thickness and drain a very low CP current.

USA, UK prefer FBE, despite attributing to the coating, gives CP a much more important function. In this case the coatings, even with reasonable impermeability, are thinner and more compatible to CP systems.
CONCLUSIONS (I)

• The anti-corrosive properties of coatings, applied to cathodic protected pipelines, deteriorates with time. CP may always protect the steel and, at the same time, accelerate coating deterioration. The system require excellent coating quality.

• Peeling of coatings can occur due to intrinsic or external causes. Elevated temperature, soil stress, SRB attach, severe current situations and third part damages are the main external agents. But, after all, a good quality coating is formulated to resist all the foreseen external agents.
CONCLUSIONS (II)

• No significant difference was observed in the initial impedance measurements, between new and old samples. This fact suggests that the best performance of new samples is related to changes on coating application procedures.

• The smaller extent of cathodic disbonding values, exhibited by new samples, submitted to cathodic protection until -1.5 V, demonstrated that, under these potentials levels, CP is not the main factor responsible for coating disbonding.
CONCLUSIONS (III)

• The main causes for coating disbonding observed in field inspection were related to surface preparation (contaminants on the surface), application quality control, materials quality, and inspections. Production, laboratory and field tests are mandatory.

• **PETROBRAS MUST CHANGE SPECIFICATIONS AND START A NEW QUALIFICATION PROGRAM WITH SUPPLIERS AND COATING APPLICATORS ACCORDING TO ACCURATE SPECIFICATIONS**
GASBOL

- GAS PIPELINE BRASIL/BOLÍVIA
- TOTAL LENGTH: 3.160 Km
- Coated external area: 6.6 million sq.m
- Coated internal area: 5.4 million sq.m
- Coating cost: US $ 630 million

QUALIFIED COATINGS

⇒ COAL TAR ENAMEL
⇒ FUSION BONDED EPOXI
⇒ THREE LAYERS EXTRUDED POLIETILENE
GASBOL
GASBOL - COATINGS

Participation per coated area

- Coal-tar: 48,2%
- FBE: 27,5%
- PE: 24,3%
PROCEDURES QUALIFICATION

• APPLICATION PLANT INSPECTION
• RAW MATERIALS LABORATORY TESTS
• COATING APPLICATION IN 5 PIPES FOLLOWING PETROBRAS APPROVED PRE-QUALIFIED APPLICATION PROCEDURE.
• PRODUCTION TESTS
• LABORATORY TESTS OF COATED SAMPLES
• FIELD TESTS.
RESULTS
GASBOL - COATINGS

THREE LAYERS EXTRUDED PE

- PE was the most reliable despite river transport.
- Very good mechanical properties.
- Low quantity of damage and repairs in all steps including crossing.
- Very good dielectrical properties, low initial protection current density - 0.6 μA/sq.m = 10% of installed capacity.
- Used in direction drilling crossing.
GASBOL - PE COATING
CROSSING - PE COATING
GASBOL - COATINGS

FBE

• Great quantity of transport damage (more than one per tube)
• Low quantity of bending or welding damage.
• Low cost and time for repairs.

COAL TAR ENAMEL

– Great quantity of damage during transport, handling, storage and welding.
– Excessive bending damage.
GASBOL - FBE COATING
GASBOL - CTE COATING
GASBOL - CTE COATING
GASBOL - CTE COATING
GASBOL - CTE COATING
FIELD JOINTS
REPAIRS
COLD APPLIED PE TAPES
THERMAL INSULATION COATINGS
THERMAL INSULATION COATINGS

• PETROBRAS SPECIFICATION
  – PRIMER
  – POLYURETHANE FOAM
  – POLYETHYLENE PROTECTIVE LAYER
  – OPERATION TEMPERATURE: UP TO 80ºC
THERMAL INSULATION COATINGS PROBLEM

• Severe corrosion process and pipe rupture.

CAUSES

– Break of external polyethylene layer
– Moisture and water penetration.
– Chemical reaction between water and foam that was formed with halogen gases (CFC)
– Very low pH (2-3) electrolyte solutions.
– Corrosion.
THERMAL INSULATION COATINGS NOWADAYS

• PETROBRAS is repairing many pipelines with this thermal insulation coating using new materials and special (non corrosive) polyurethane foams.

• PETROBRAS will start new research project in order to evaluate different foams (polyurethane, epoxy and polypropylene) synthetic materials.
FIELD JOINT OF THERMAL INSULATED OFFSHORE PIPELINE
FIELD JOINT OF THERMAL INSULATED OFFSHORE PIPELINE
FIELD JOINT OF THERMAL INSULATED OFFSHORE PIPELINE
OFFSHORE PIPELINE LAYING
INTERNAL COATINGS

ROUGHNESS REDUCTION

API - STANDARD
INTERNAL COATING
CONCLUSIONS

• PETROBRAS has now more experience in external coatings, using modern specifications, qualified procedures, laboratory tests, development of aging tests, and electrochemical evaluation tests.

• PETROBRAS follows API standards for internal coatings.

• PETROBRAS develops two new research programs:
  – Thermal Insulation Coatings
  – In-situ Internal Pipe Coatings