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THE PROBLEMATIC OF DISBONDING OF COATINGS AND CORROSION WITH BURIED PIPELINES CATHODICALLY PROTECTED

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Problematic

- Overall good performance of the « modern » coatings based on plastics (when correctly qualified and applied)
- However several cases of massive disbonding with 3LLDPE reported, without significant corrosion
- Very recently, important external corrosion discovered on a major pipeline in Gabon after 15 years in operation, mainly under disbonded HSS but also 3LLDPE
- Question: this corrosion was discovered by ILI (In-Line Inspection). What could be the efficiency of the « external electrical measurements » to detect this corrosion?

Corrosion under disbonded coatings: the shielding effect

- As long as coatings remain bonded to steel and cathodic protection is correctly applied, monitored and maintained, no corrosion risk exists
- All the (few) external corrosion cases encountered by Total concerned onshore buried pipelines and were all due to disbonding of coatings
- Disbonding may prevent access of cathodic protection current to steel exposed to a corrosive electrolyte enough renewed: the "shielding effect"
- No corrosion experienced on offshore pipelines exposed to seawater due to its high conductivity

Corrosion underneath a disbonded asphalt enamel coating on buried onshore pipeline

Until recently, only onshore buried pipelines coated over the ditch with enamels or tapes were found corroded

Corrosion underneath a disbonded FBE coating on buried onshore pipeline

- Corrosion under disbonded FBE occurred on an onshore buried pipeline transporting hot heavy fuels from La Mède refinery to Fos-sur-mer storage facilities
- 18", 7.9mm, 8.9km, laid in 1988, 0.42mm FBE, Tg 100°C
- Operating temperature fluctuating between 40 and 80 °C
- Corrosion locations detected since 1998 through intelligent pigging and DCVG

Corrosion underneath a disbonded FBE coating

Experience with 3LPE disbonding by the end of 2003 (outside Total)

- **Increasing number of reported massive disbondments of 3LLDPE coatings on buried pipelines**
- **Main common characteristics of these failures:**
  - **disbonding between epoxy layer and the steel surface, with insignificant or superficial corrosion**
  - **PE remains compressed on pipe, without gap (no renewal of corrosive species)**
  - **identified only on buried pipelines (after cuts for modifications or repair)**
  - **comparison with spare pipes from the same production does not reveal loss of adherence of the pipes non exposed to soil**
  - **due to in-service conditions: physico-chemical (soil, potential) and/or mechanical (stresses) parameters**

Experience with 3LPE disbonding by the end of 2003 (inside Total)

2 cases identified in the Group:

- **16'' oil pipeline laid in 1994 in Syria**
  - discovered during repair works carried out due to mechanical damage
  - measured ON potential: -1.6 V/Cu- $CuSO_4$
  - disbonding between epoxy primer and steel, without any trace of corrosion
- **Pipeline in Argentina**
  - No precise information

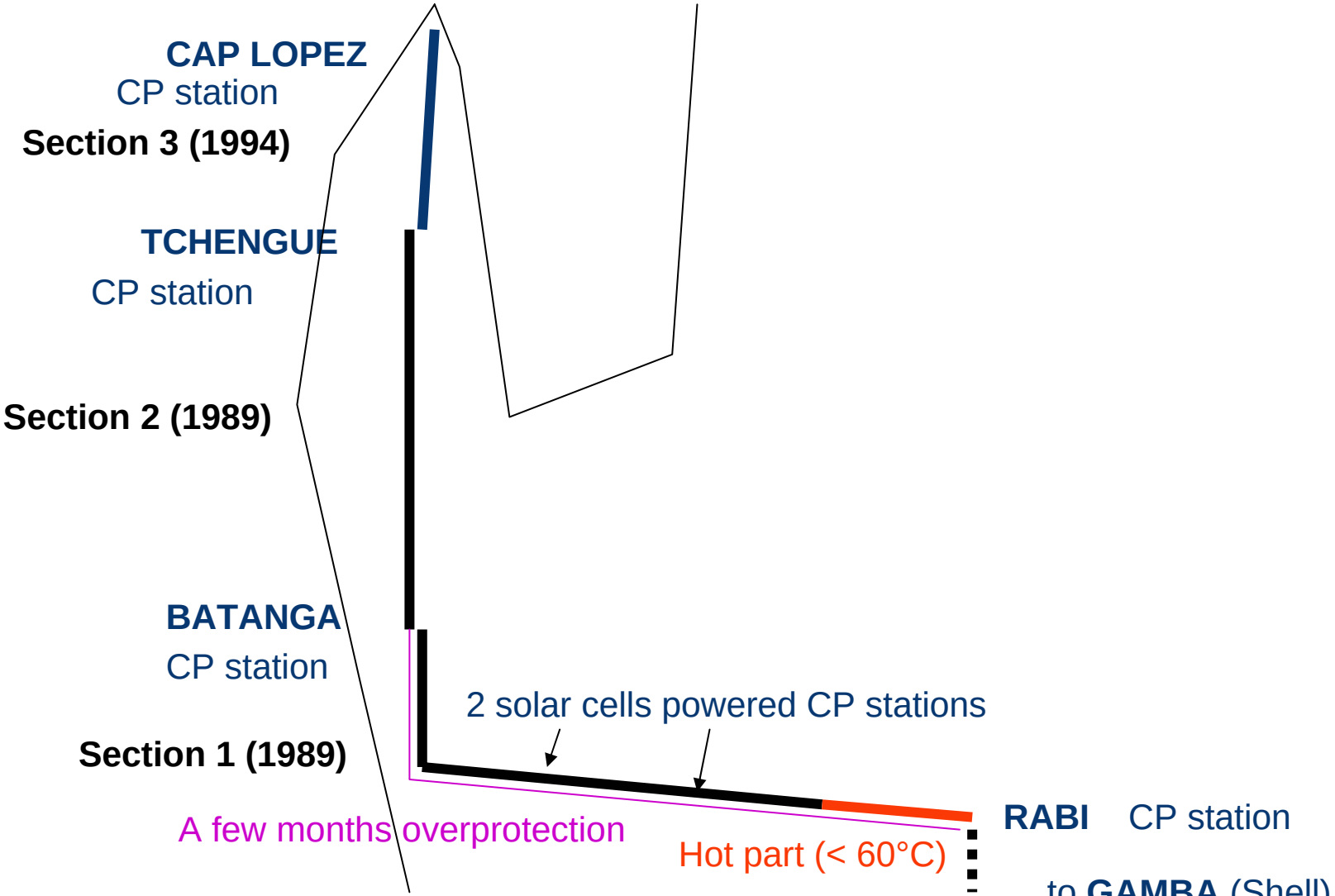
Recent experience with 18'' oil Rabi-Cap Lopez pipeline (Gabon)

- 234 km long 18'' X60 pipeline transporting oil
- 3 sections electrically disconnected at pig traps:
  - Section 1: Rabi – Batanga, 105 km, laid in 1988-1989, put in operation in 1989
  - Section 2: Batanga – Tchengué, 100 km, laid in 1988-1989, put in operation in 1989
  - Section 3: Tchengué – Cap Lopez, 29 km, laid in 1993-1994, put in operation in 1994
- 100 bar MAOP, 40 bars actual inlet pressure (section 1)
- Zero corrosion allowance (thickness 7.67 mm) decided due to no risk of internal corrosion and to the use of what was considered as the best external coatings

Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)

- **Pipe inlet temperature 60°C, constant because heating above inversion point for prevention of wax deposition**
- **Soil is wet compacted sand (pH of sample 5.4)**
- **CP stations using T/Rs at each extremity of sections + 2 automatic solar cells powered intermediate CP stations on section 1**
- **Section 1 has been overprotected (-6.4 V/SCE ON) in 1991 during 2 months due to dysfunctioning of one of the automatic solar cells powered CP station caused by lightning damage**

Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)



Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)

- **3LLDPE coatings applied by 2 applicators (France and Germany) in compliance with Elf General specification (> 70 microns FBE) and followed-up by inspectors**
- **Field joint coating with heat-shrinkable sleeves with hot-melt adhesive applied on fast-curing liquid epoxy on brush-cleaned surface. Application fully inspected by a Company inspector**

Recent experience with 18'' oil Rabi-Cap Lopez pipeline (Gabon)

- Corrosion discovered through ILI in January 2004
- The intermediate report of ILI (MFL) reported 13600 features, the majority of which being in the first 13 km (hottest side)
- External corrosion, the majority (12494) at less than 20% wt, 1168 between 20 and 40%, 11 greater than 40%
- Maximum 57% at pK 2,237 km (55°C)
- No defect mechanically dangerous as per ASME B31G (ERF max = 0.441)
- 3 excavations carried out in April near pipeline inlet (pK 0.523, 2.189, 2.237 km) confirmed the ILI information
- Potential measured with an electrode close to pipe during excavation: -1012 mV/Cu-CuSO4

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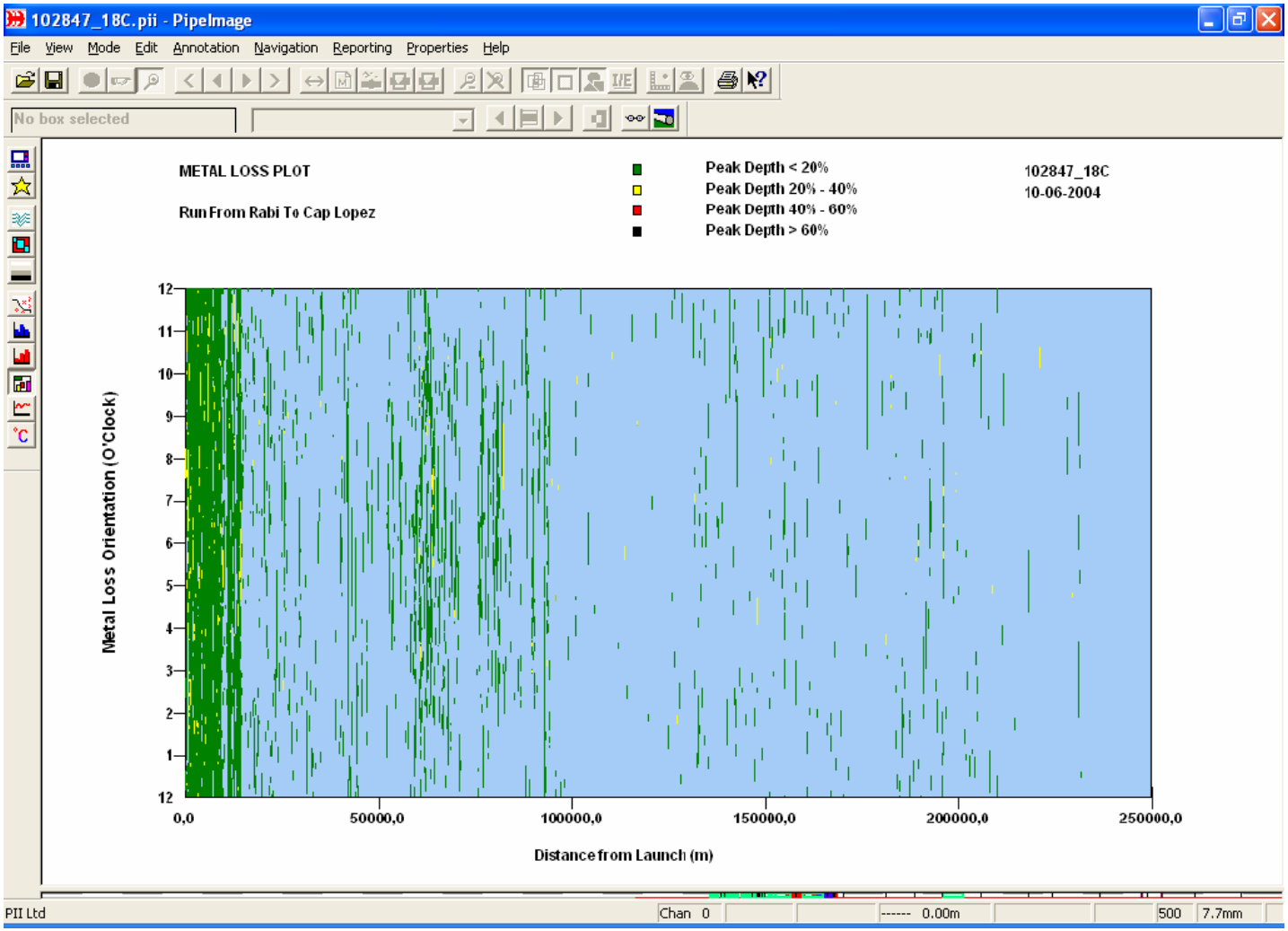

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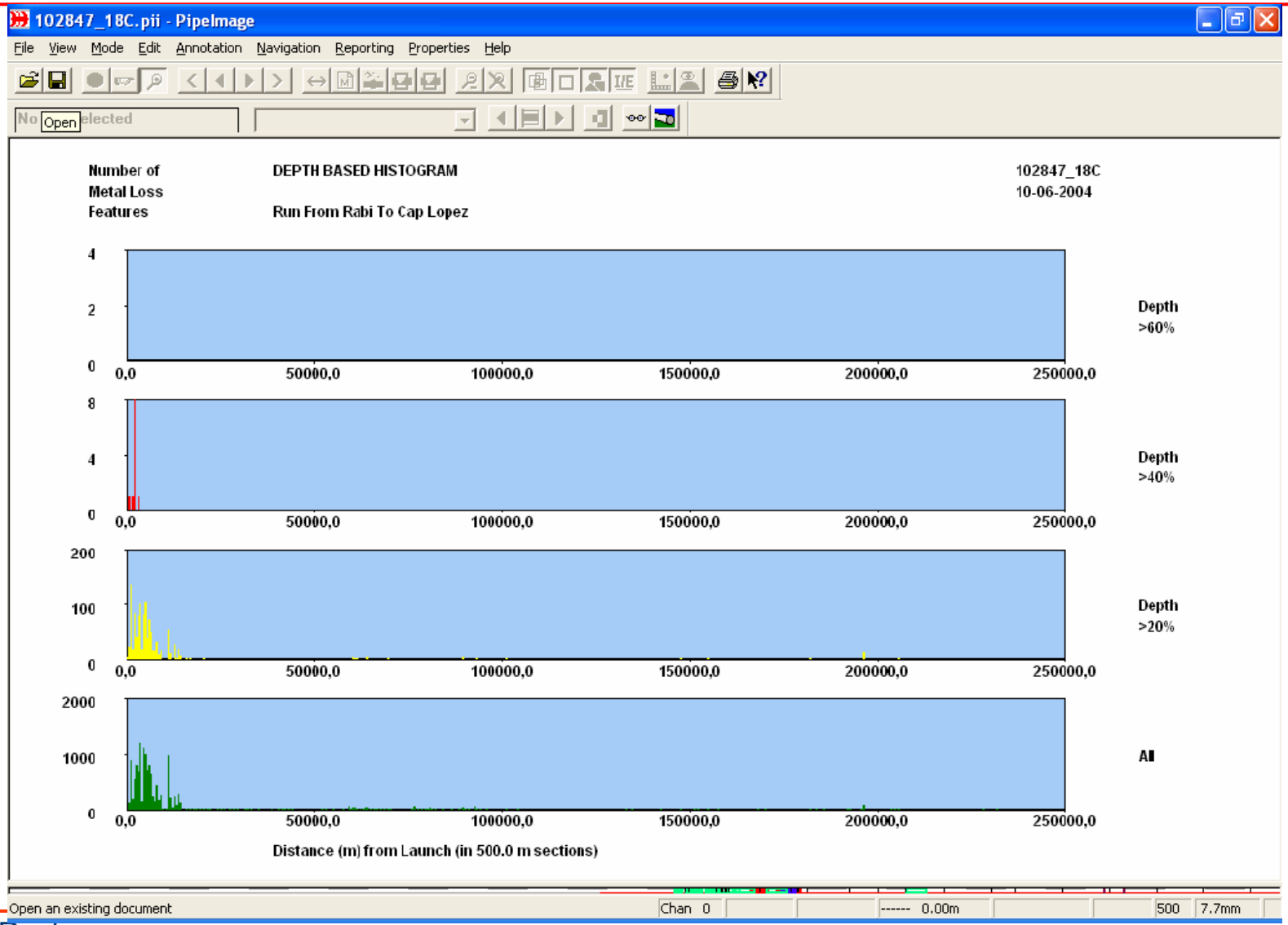

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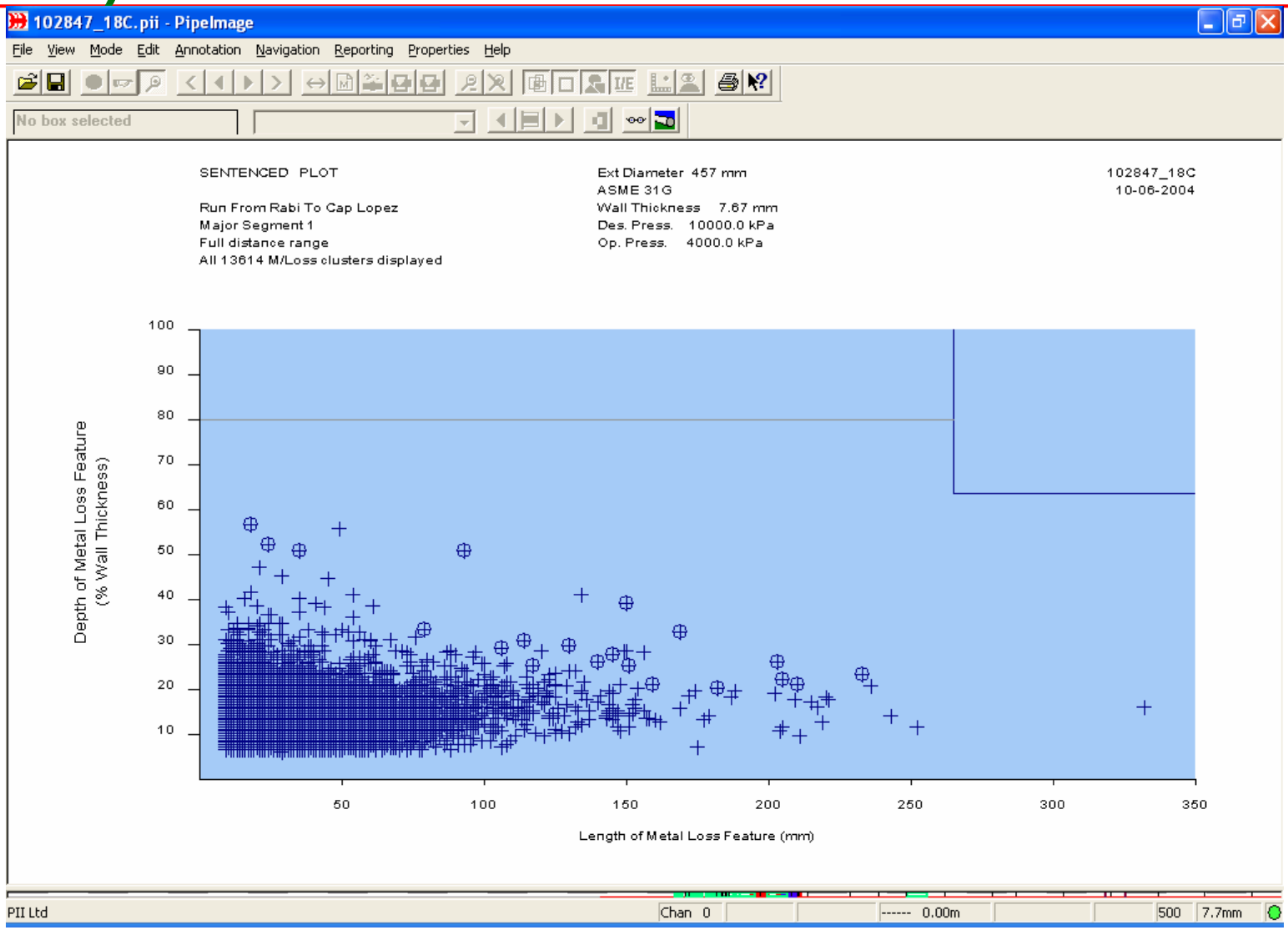

Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)

- The major part of corrosions are under field joint coatings at girth welds: massive disbonding of HSS with steel leading to corrosion caused by shielding effect
- Excavations reveal that in spite of a correct installation concerning applied heat shrinkable sleeves – no residual witness green points- and molten adhesive on the whole circumference, but lack of bonding on plant applied PE coating due to brushing limited to bevels of coating

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- **3LLDPE plant applied coating generally appears externally OK but found fully disbonded (when cut with a tool) between FBE and steel**
- **Corrosion under PE plant-applied coating on some pipe lengths (46 tubes, all in the first 13 km, except 1)**
- **Excavations show that in this case PE coating is longitudinally cracked and opened at 3 and 9 o'clock**
- **Presence of a black powder on steel surface (under HSS and plant-applied PE). Analysis shows it is mainly magnetite Fe_3O_4 and goethite Fe_2O_3,H_20 + pyrrhotite Fe_7S_8 and $Fe_2(OH)_2CO_3$)**
- **No correlation between cracking/opening and bending during laying (4 pipes bent over 46)**

Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)

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- **The first measurements made on samples taken from PE disbonded coatings reveal:**
  - **an important loss of elongation at break**
  - **an important increase of viscosity (melt index)**
- **Other measurements on the way: Water content, Shore hardness, IR spectrum, rheology**

Recent experience with 18’’ oil Rabi-Cap Lopez pipeline (Gabon)

- Recent excavation at Tchenghé on section 3 (started in 1997) reveals no disbonding and no corrosion
- Very wet area, PE coating covered with Bidim

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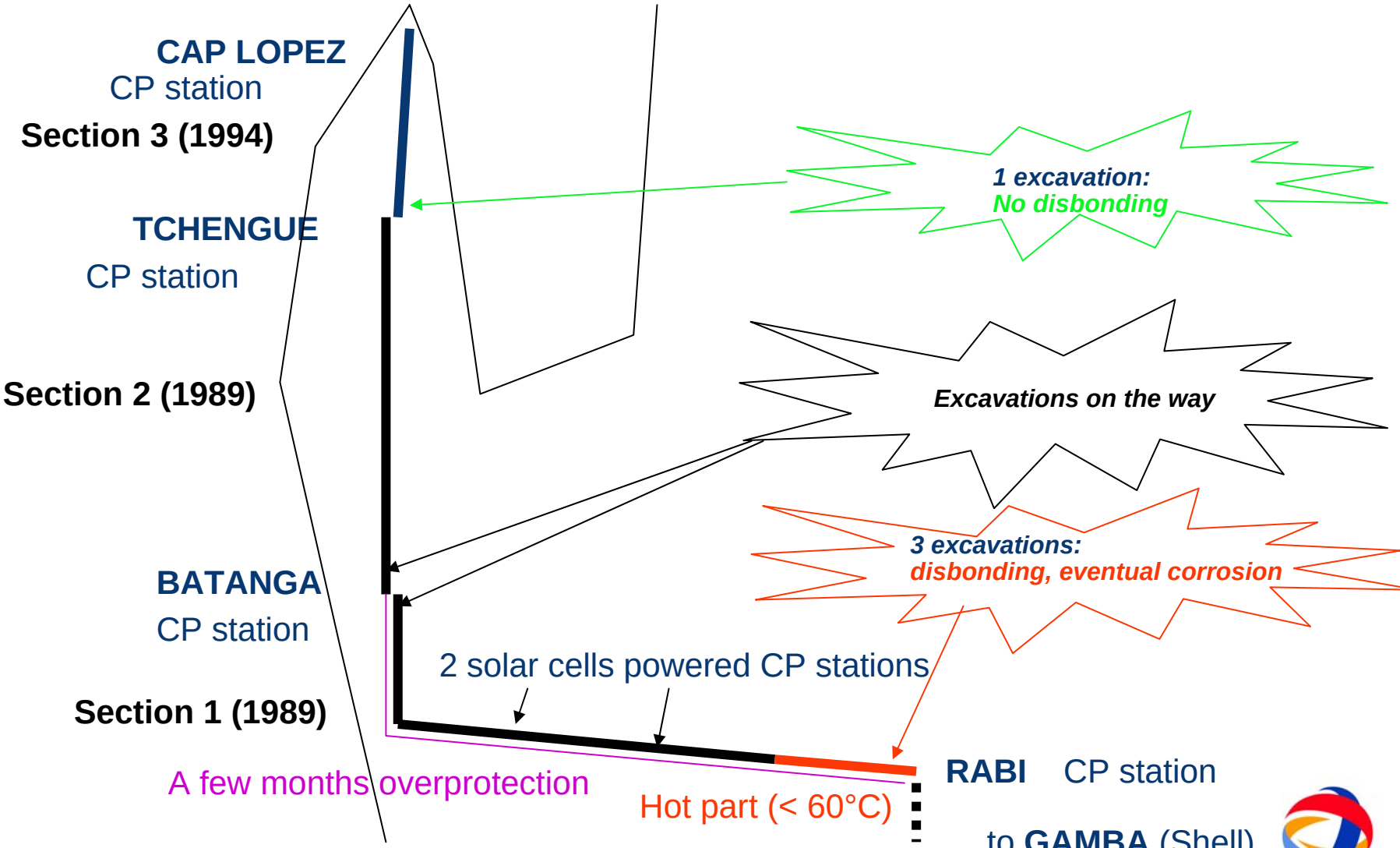

Recent experience with 18'' oil Rabi-Cap Lopez pipeline (Gabon)

- **Missing information:**
  - **New excavations in different locations are on the way for determining the extent of disbonding and the effects of temperature and cathodic over-protection (especially at Batanga, on sections 1 and 2)**
  - **Precise temperature profile**
  - **Correlation of disbonding with origin of plant coating**
  - **Measurement of peeling strength on spare pipes and pipeline itself when some bonding remains**
  - **DCVG and CIPS and any other "most advanced" methods to be tested as soon as possible on damaged section. Call for bids on the way.**

Ways of research and improvements

- It is necessary to continue to identify and document failures and non failures cases
  - launching of an EPRG (European Pipeline Research Group) data base for feedback of experience with the most detailed information for each case
- It is necessary to explain these failures (plant and field joint coatings) even if they do not seem to lead always to significant corrosion (case of PE if not cracked) for:
  - preparing inspection programmes of the existing pipelines (RBI approach)
  - preventing the risk for new pipelines

Ways of research and improvements

EPRG (European Pipeline Research Group)

PIPELINE COATINGS SURVEY

Experience feed-back sheet

Information on pipeline	
Owner/ Operating company	
Pipeline (inlet/outlet)	
Diameter (“) x thickness (mm)	
Length (km)	
Transported fluid (gas/oil/refined products/other)	
Temperature (min/mean/max)	
Pressure (min/mean/max)	
Date of laying	
Date of start-up	

Information on plant coating		
Epoxy primer (if any)	Type (FBE/Liquid)	
	Thickness (mm)	
	Supplier	
	Trade name	
Adhesive (if any)	Type (extruded/powder)	
	Thickness (mm)	
	Supplier	
	Trade name	
PE/PP (if any)	Type (LDPE/MDPE/HDPE/PP)	
	Thickness (mm)	
	Supplier	
	Trade name	
Coating company		
Coating plant		
Date of application		
Applicable standard or specification		
Surface preparation (Sa 2 1/2/Sa3)		
Phosphate treatment?		
Chromate treatment (if yes, product)?		

Information on field joint coating		
Type (tapes/heat-shrinkable sleeves/ PP/other		
Surface preparation (St3/Sa 2 1/2/…)		
Epoxy primer (if any)	Type	
	Thickness (mm)	
	Supplier/ Trade name	

Investigation on coating	
Date of investigation	
Location of investigation (pK/description)	
Circumstances of investigation/Means used	
Disbonding (If yes, description, especially level of disbonding between steel and coating)	
Any corrosion or staining on steel under disbonded coating?	
Photos taken?	
Sample taken?	
Coating defects evaluation (DCVG, Pearson…)	

Information on environment at location investigated	
Type of soil (sand/rocks/clay/other)	
Type of contact of soil on coating (possible stresses?)	
Humidity of soil/bacteria	
Soil resistivity (Ohm.m)	
ON and OFF Cathodic protection potential history with time at the location investigated (min/mean/max)	
Any other comment	

Ways of research and improvements

- **It is necessary to carry out R & D to investigate the parameters:**
  - **surface preparation, products, thickness of FBE, effect of temperature, cathodic overprotection, stress cracking of polyolefins, accelerated tests representative of long-term behaviour,...**
- **Some possible ways for explanations:**
  - **cathodic overprotection:**
  - **temperature:**
    - Effect on disbonding
    - Effect on corrosion
    - due to problems in coating specification or application conditions