ADVANCED SYSTEMS OF OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

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ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

EXTERNAL CORROSION CONTROL

- *Combination of barrier coatings and Cathodic Protection*
- *Cathodic Protection current flows to coating defects that expose steel AND through the undamaged coating dependent upon the specific electrical resistance*
- *Overline electrical surveys are used to audit the performance of BOTH coatings and Cathodic Protection detecting where corrosion risk exists*
- *Internal intelligent pigging is used to audit the extent of existing corrosion*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

PAPER SUMMARY

- *Pipeline coating construction damage and in-service deterioration*
- *Increasing Cathodic Protection demand due to coating deterioration*
- *Impact of third party*
  - *- pipeline / Cathodic Protection deterioration*
  - *- rail*
  - *- ac power distribution*

on external corrosion control

- *Advanced CIPS + integrated recorded DCVG surveys to characterise Cathodic Protection and coatings*
- *Use of data from CIPS + recorded DCVG to prioritise remedial work to external corrosion control systems*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CASE STUDY

Year 2001 survey of SUMED's 42 in x 640 km pipeline network across Egypt

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

COATING DAMAGE & DETERIORATION

- *Damage during handling and laying*
- *Failures during commissioning and operation*
- *rock penetration during installation and service*
- *soil loading and shear failure during operation*
- *lack of coating integrity at elevated temperature*
- *disbonding through pipe movement and lack of adhesion*
- *disbonding due to inadequate surface cleaning*
- *enhanced failure at low temperatures*

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COATING DAMAGE & DETERIORATION (2)

- *poor coating electrical properties*
  - poorly formulated asphaltic enamel
  - "coked" asphaltic & coal tar enamel
  - thin FBE
- *deteriorating electrical properties*
  - *moisture absorption*
  - *film breakdown*
- *characteristic failures*
  - *spiral corrosion / disbondment : tapes*
  - *disbondment of coal tar and asphaltic enamels*

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COATING DAMAGE & DETERIORATION (3)

- *inadequate field joint coatings*
- *third party damage (plough / excavation)*
- *Construction damage has often been assessed at end of contract maintenance period*
  - coating attenuation survey
  - Pearson or DCVG surveys
  - CIPS + recorded DCVG
- Even the most robust pipeline coatings suffer construction damage
  - Ref 3 : 0 - 14 defects /km with 3 layer PE

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COATING DAMAGE & DETERIORATION (4)

- *Even without significant defects some (older) coatings will become more conductive with time, increasing Cathodic Protection demand*
- *Most in service conditions will result in through coating defects to expose steel thus risks of disbondment*

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IMPACT OF COATING DAMAGE / DETERIORATION ON CATHODIC PROTECTION

Notional Example:

- *New 14 in dia pipeline, 35μA/m² for Cathodic Protection increasing to 500μA/m² over 15 years. ["medium quality"]*
- *Cathodic Protection @ commissioning*

  2.5 Amp stations every 46km
- *Cathodic Protection @ 15 years*

  10.7 Amp stations every 15km
- *Localised defects may be inadequately protected*

i.e. C.P. stations must be MORE FREQUENT as well as greater capacity and the line requires survey to determine efficacy of corrosion protection

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THIRD PARTY DAMAGE & INTERACTION

- *Impact damage to coatings and pipe*
  - *- coating damage detect by overline survey*
  - *- pipe damage detect by intelligent pig*
- *Metallic connections*
  - *- unprotected pipelines crossing*
  - *- construction debris*
  - *[similar effects from:*
    - *- steel casings … frequent problem*
    - *- reinforcement contact at valve chambers*
    - *- electrical earthing at valves / terminals]*

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THIRD PARTY DAMAGE & INTERACTION (2)

- Third party pipelines with cathodic protection
  - new Cathodic Protection ≡ *new interaction*
  - *ageing pipeline ≡ increasing interaction*
- *dc rail systems*
  - *severe fluctuating dc stray current, widespread*
  - *1 Amp-year ≡ 10Kg steel consumed*
- *ac power distribution systems*
  - *induced current / voltage in pipelines*
  - *safety hazards*
  - *corrosion if ac discharge ≥ 30A/m²*

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PIPELINE SURVEY TECHNIQUES

- *Current attenuation surveys*
  - *average data over distance*
  - *coating resistance only, not corrosion*
- *Pearson surveys and DCVG surveys*
  - *local data, coating defects*
  - *coating quality only, not corrosion*
  - *normally not recorded; operator sensitive*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

PIPELINE SURVEY TECHNIQUES

- *CIPS surveys*
  - *- local data, cathodic protection / corrosion risk*
  - *- indication of coating defects but not as discriminating as DCVG*
  - *- recorded BUT no adequate International Standards*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

V_M = Measured potential

V_{IR} = Ohmic component (IR error)

V_P = Polarised Potential

$V_M = V_{IR} + V_P$

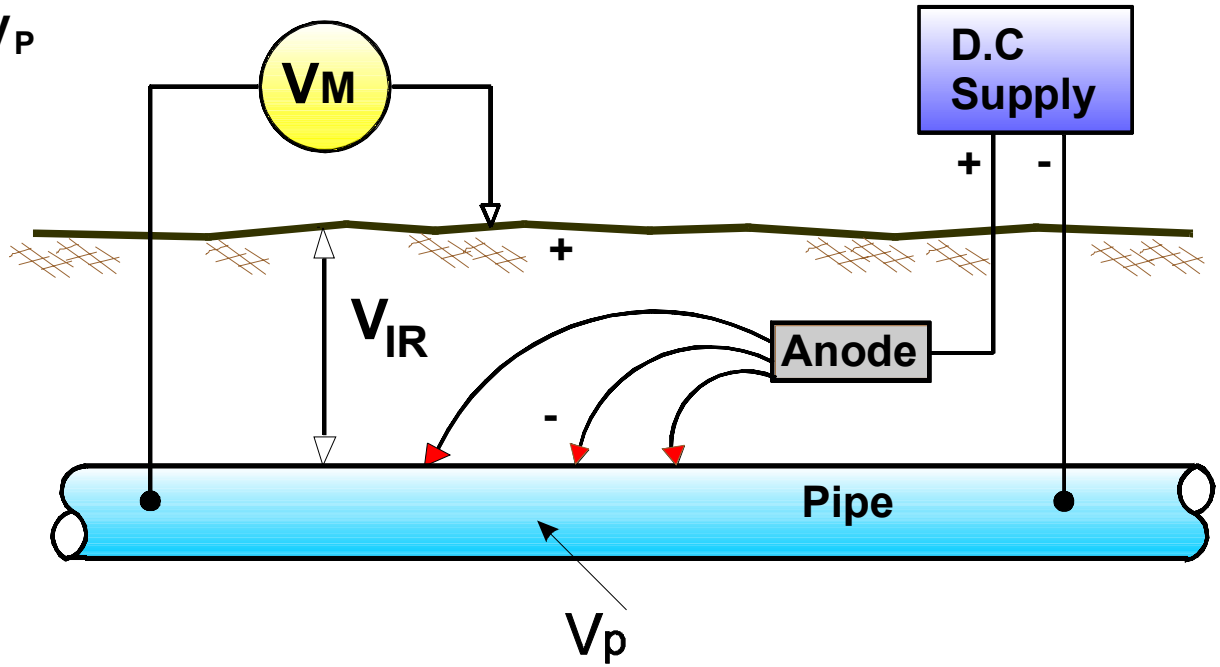

Fig 1
I.R. Drop Error Component of Potential Measurement

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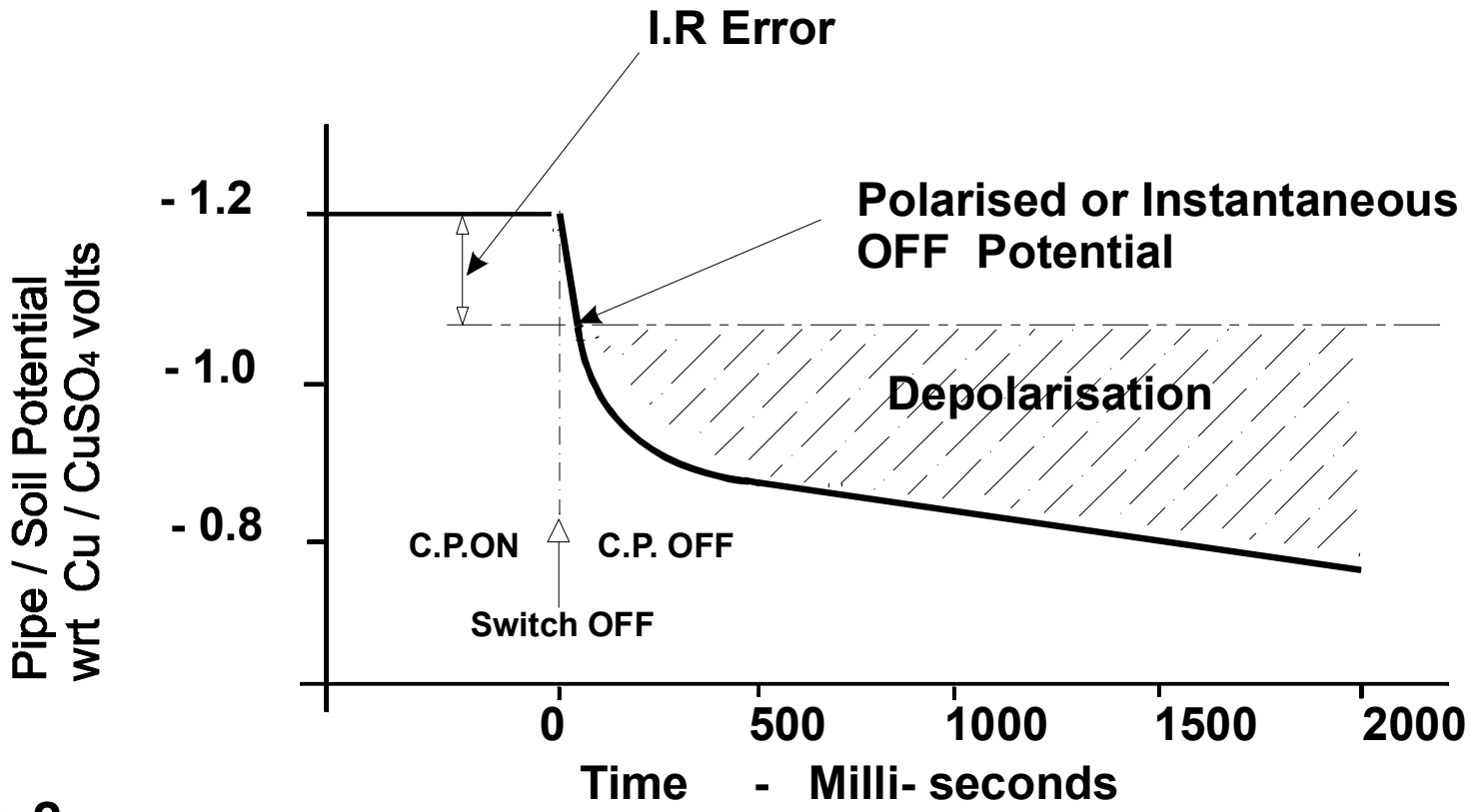

Fig 2
Idealised Polarised Potential Measurement

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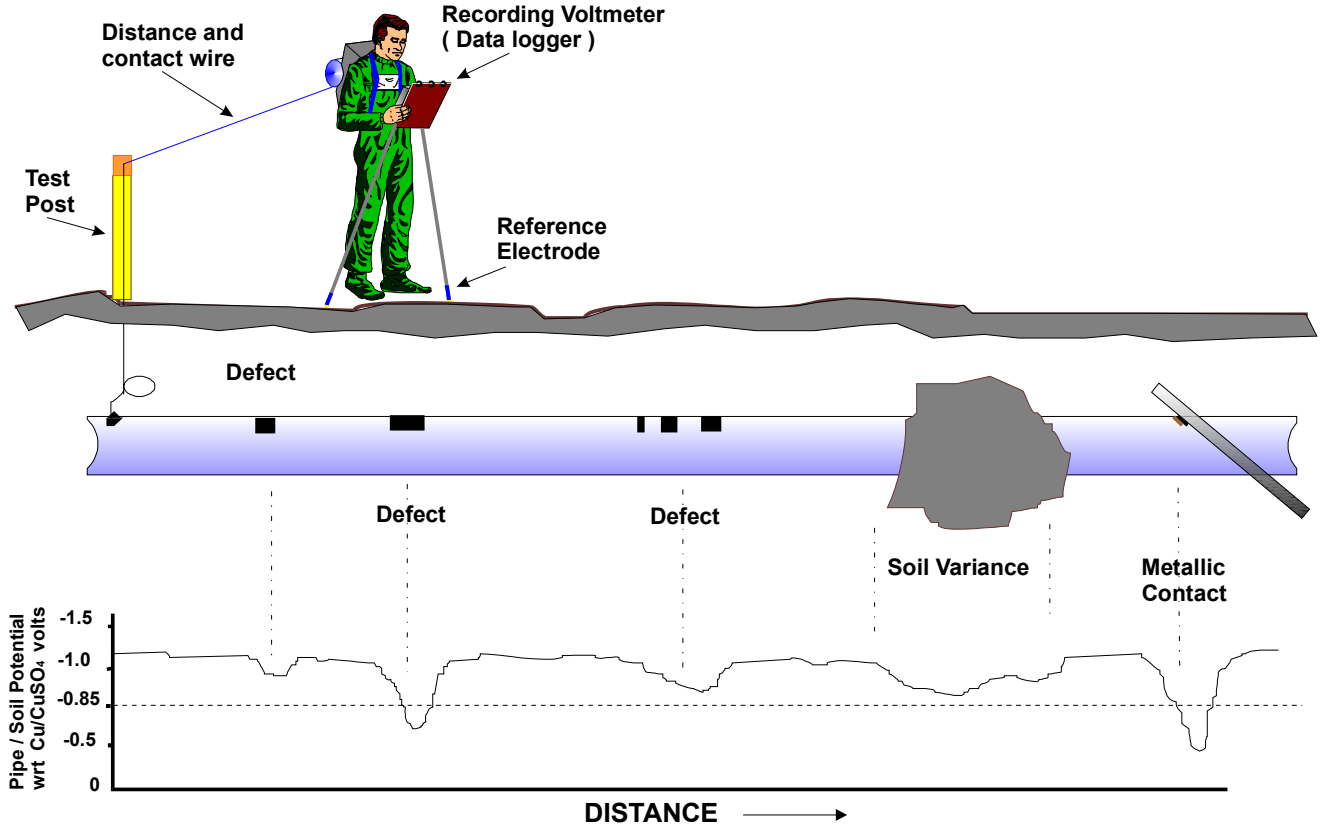

Fig 3
Close Interval Overline Potential Survey

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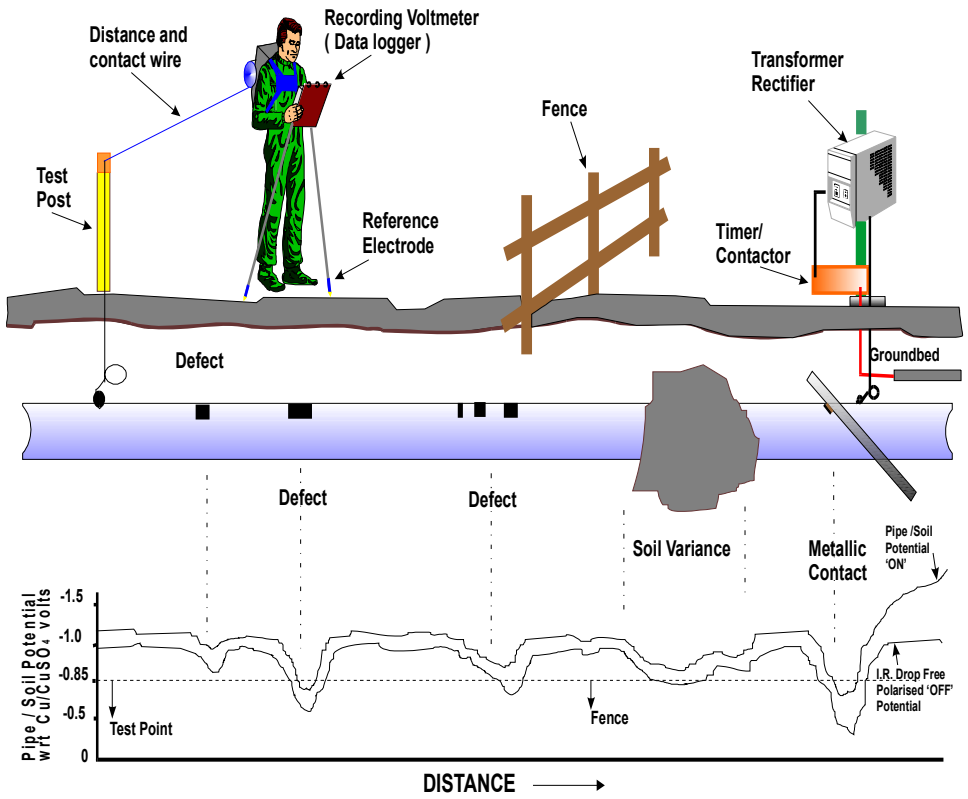

Fig 4
Close Interval Overline Polarised Potential Survey

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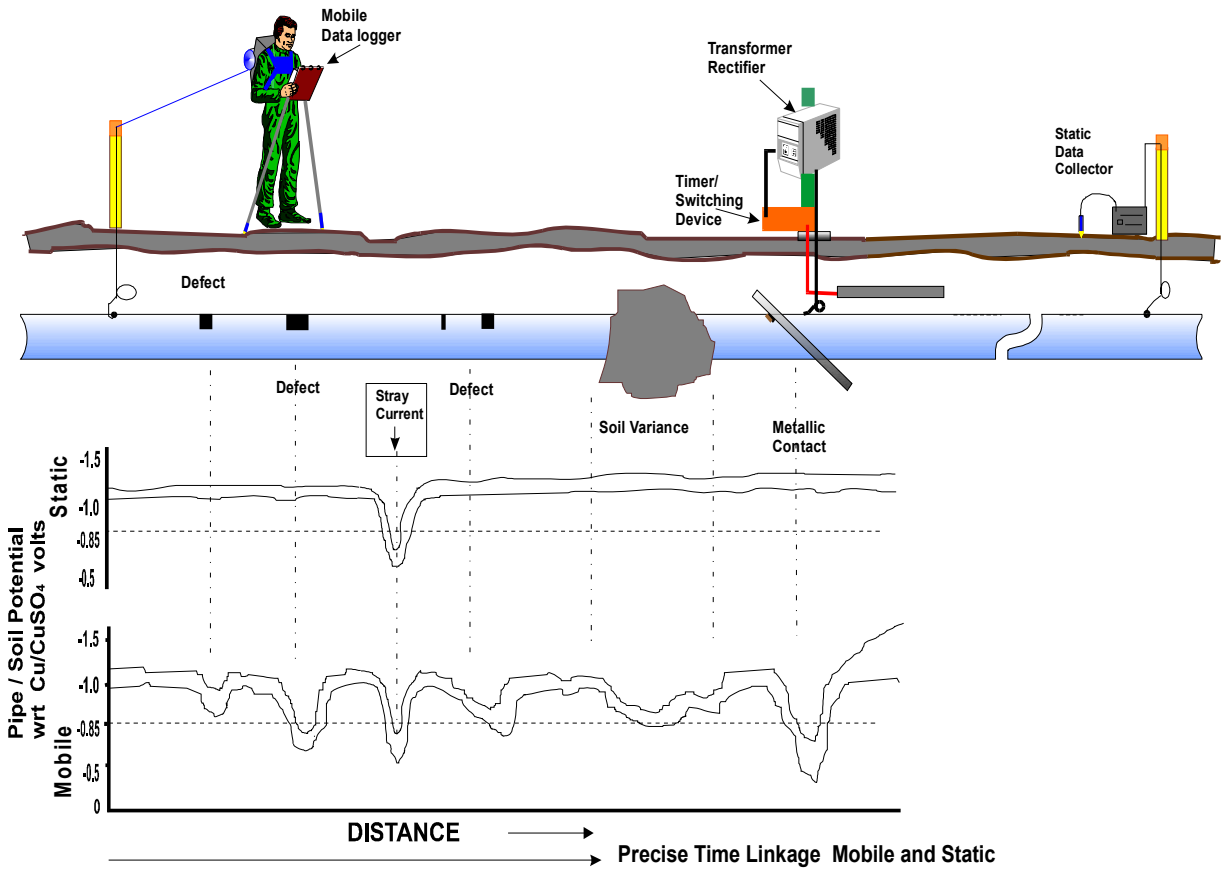


Fig 8
Close Interval Overline Polarised Potential Survey
Mobile + Static + Switching Device

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

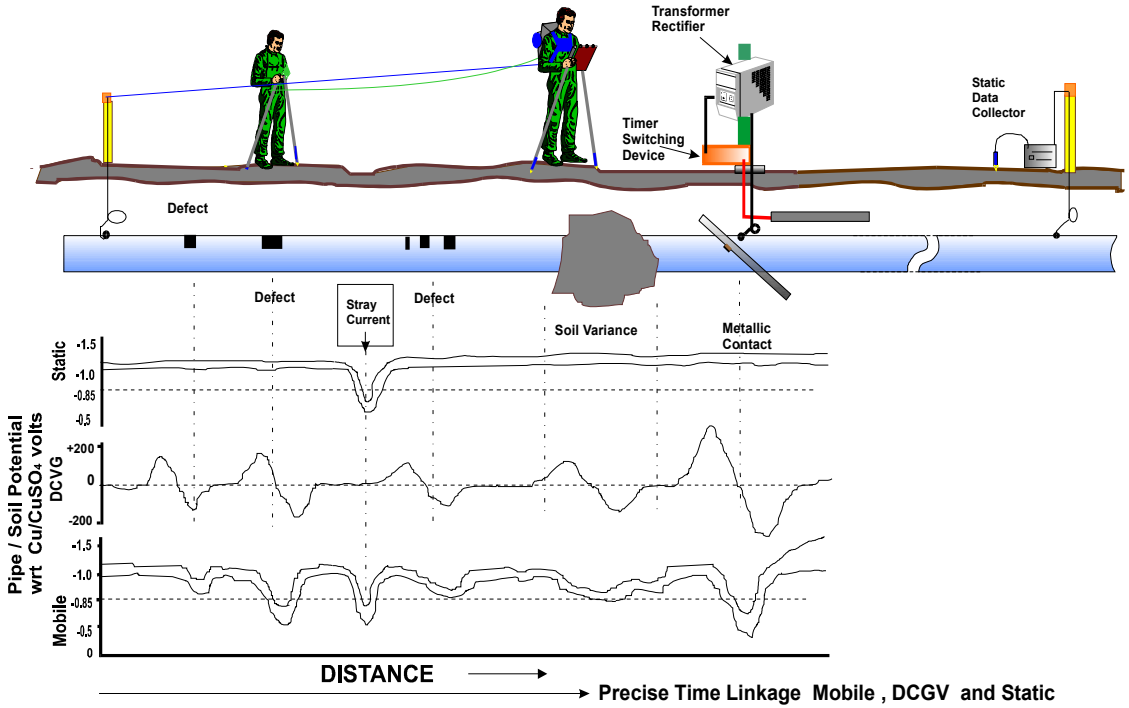


Fig 9
Close Interval Overline Polarised Potential Survey and DCVG
Mobile Data logger + Static + Switching Device

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

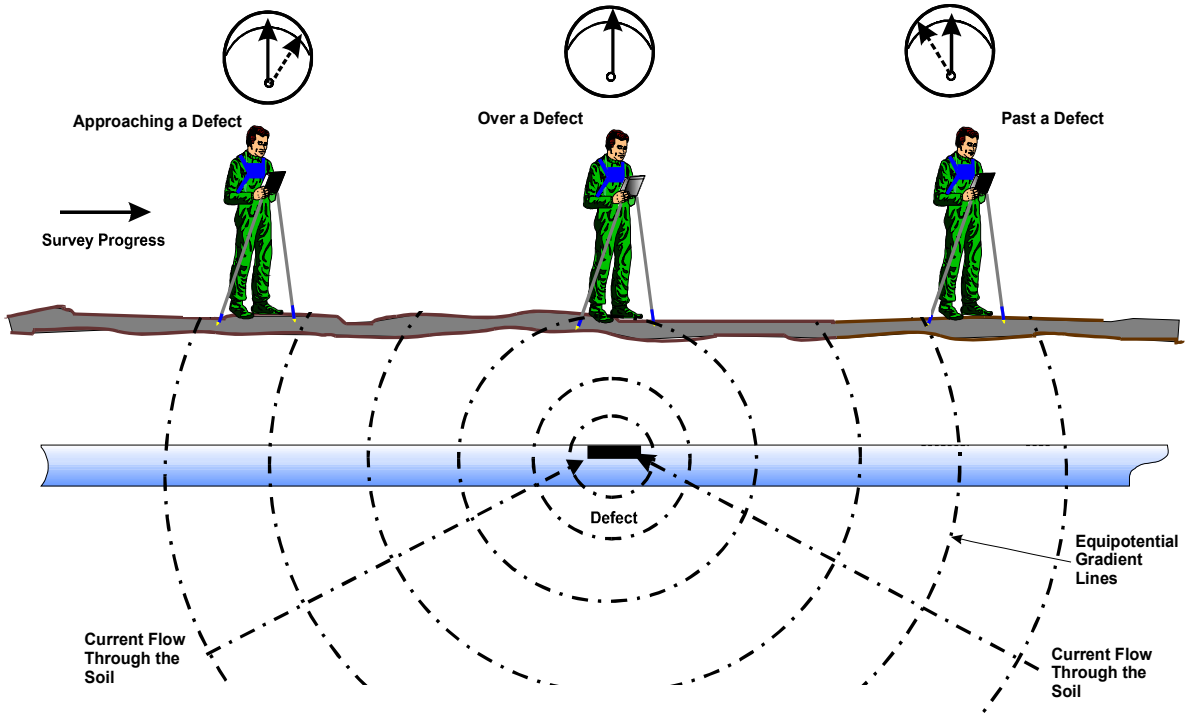
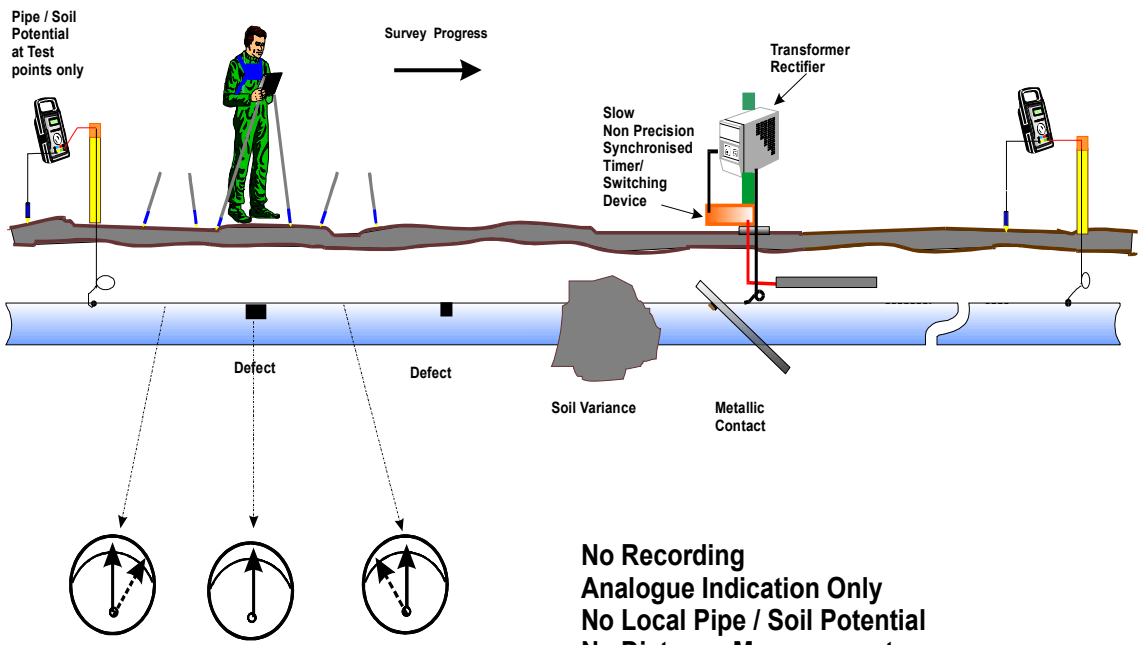


Fig 10
Basis of Analogue DCVG Defect Location.

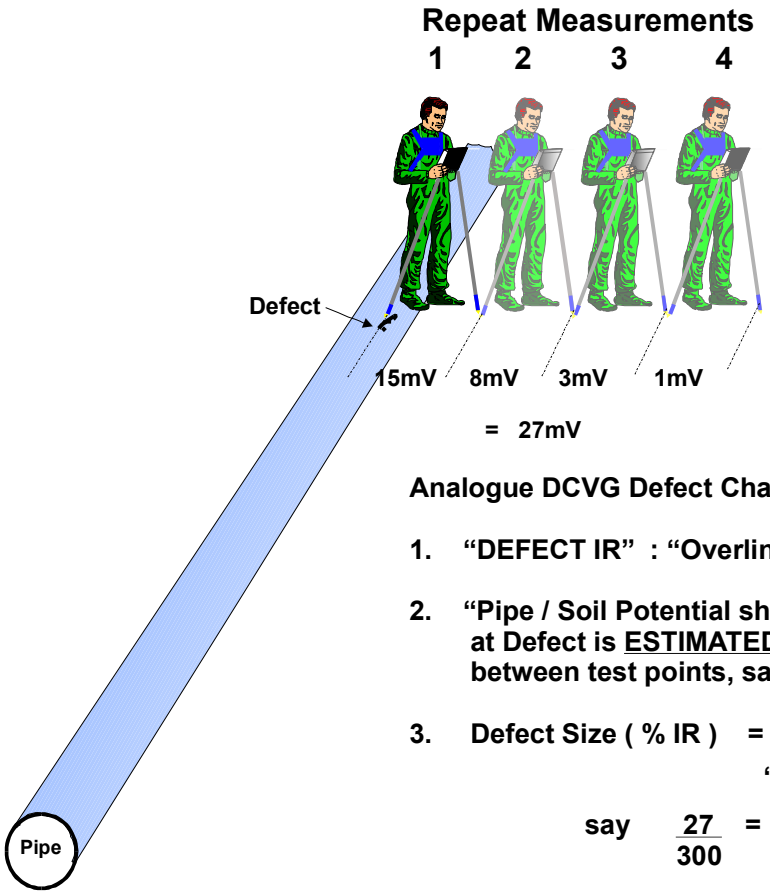
ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION



No Recording
Analogue Indication Only
No Local Pipe / Soil Potential
No Distance Measurement
Peg / Mark and Manually Record

Fig 11
Non Recorded Analogue DCVG

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION



Analogue DCVG Defect Characterisation

1. "DEFECT IR" : "Overline to Remote Earth" = 27mV.
2. "Pipe / Soil Potential shift (ON - OFF) : Applied Signal" at Defect is <u>ESTIMATED</u> as straight line attenuation between test points, say 300mV
3. Defect Size (% IR) = $\frac{\text{" Defect IR" mV}}{\text{"Applied Signal" mV}}$

   say $\frac{27}{300}$ = 9%

Fig 12
Non Recorded Analogue DCVG Defect Characterisation

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

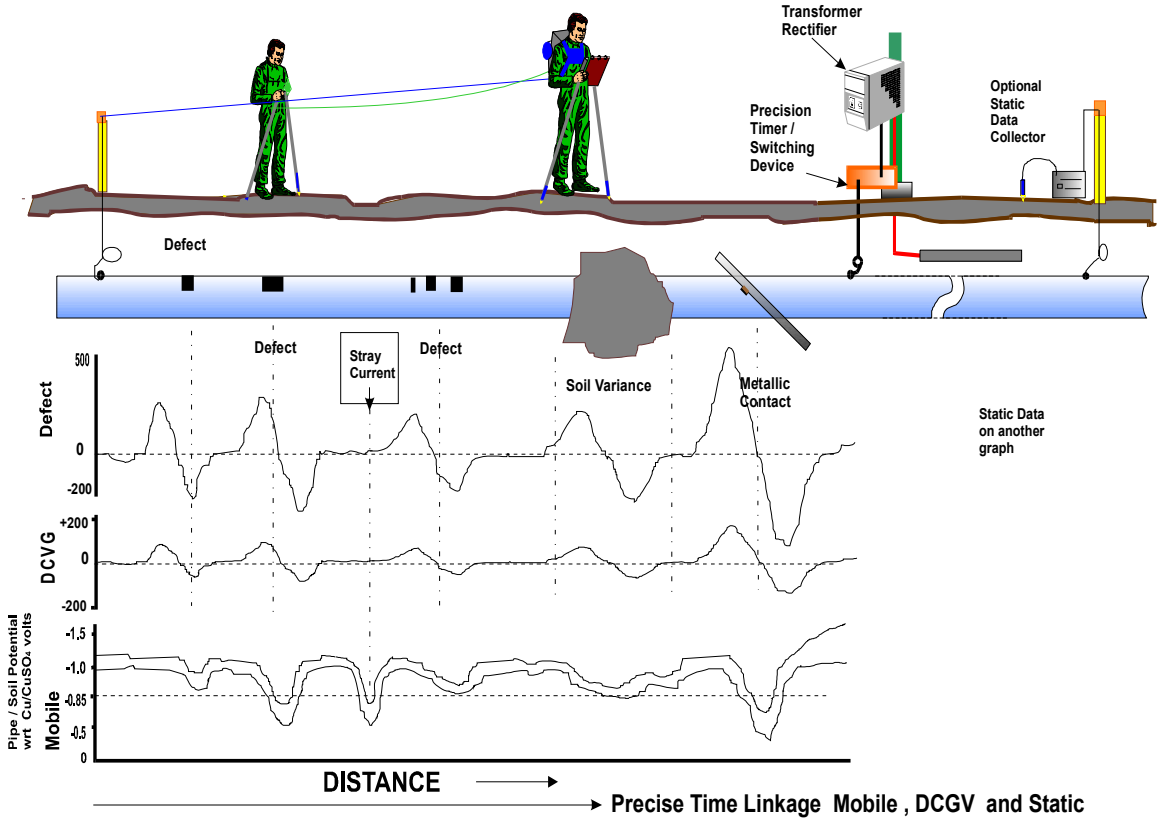
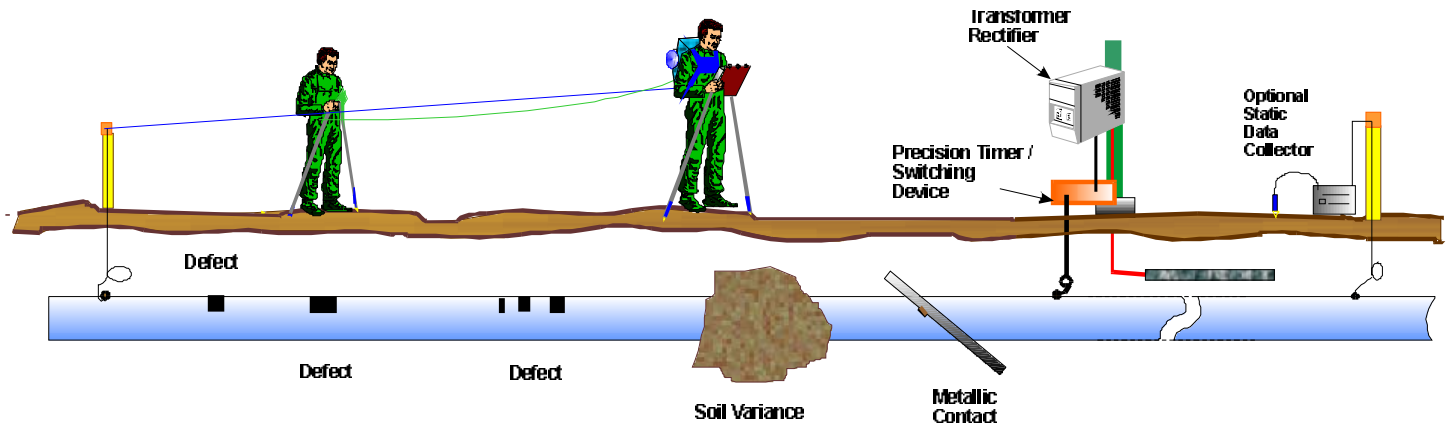


Fig. 13 Combined Enhanced CIPS & Recorded DCVG to Indicate Defect Size.

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION



$$\text{Defect Size} \propto \frac{\Delta U \quad \text{FIELD GRADIENT}}{\Delta V \text{ (ON - OFF) PIPE / SOIL POTENTIAL.}}$$

i.e. Similar to DCVG " %IR " But ALL data ACCURATELY measured (not interpolated), Cathodic Protection Status is accurately measured at each defect and location is accurately recorded.

Fig. 14 Combined Enhanced CIPS & Recorded DCVG Defect Characterisation.

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CASE STUDY

Year 2001 survey of SUMED's 42 in x 640 km pipeline network across Egypt

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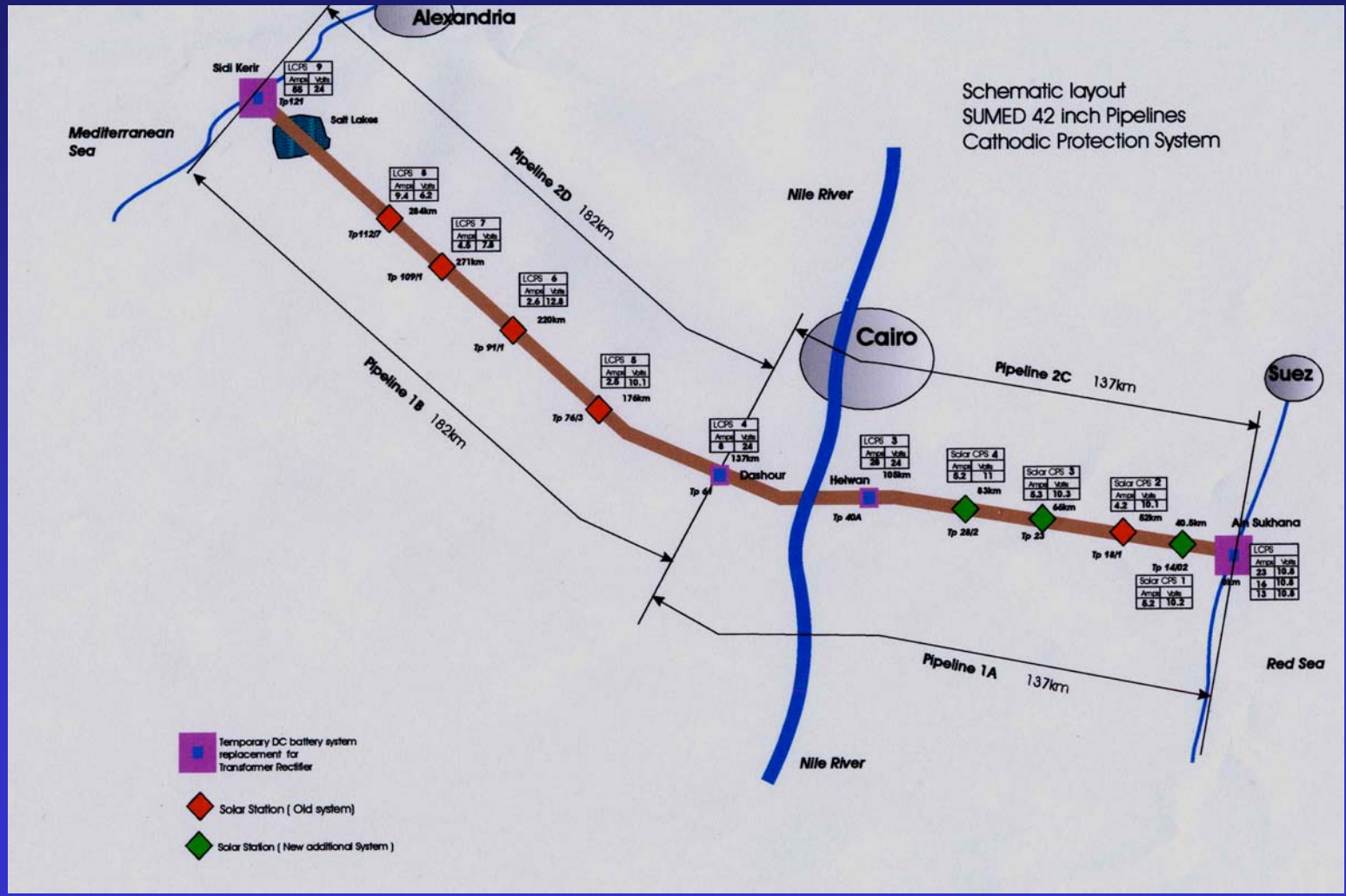


ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED PIPELINE NETWORK

- *Twin 42in dia (1068mm) pipelines from Red Sea to Mediterranean, circa 320km length*
- *Circumvents Suez Canal to permit VLCC's to partially unload and pass through canal*
- *Route incorporates desert, mountain, sabkha, industrial region, irrigated farmland, fresh water crossings including the Nile River near Helwan and salt water lakes*
- *Constructed in 1974 - 1975, butyl rubber / polyethylene tape coating with 10 % overlap plus outerwrap*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED CATHODIC PROTECTION SYSTEMS

- *At commissioning in 1975*

  - transformer - rectifier powered CP stations @ km 0, km 105, km 137 & km 320

  - solar / battery powered CP stations @ km 52, km 176, km 220, km 271 &km 284

  i.e. every circa 50km

- *In 1988 a new dc rail system at around km 105 dictated installation of potential controlled powered rail bond to overcome severe interaction*

- *in 1993 an analogue non recorded DCVG coating defect survey located some 3500 defects along the two pipelines*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED CATHODIC PROTECTION SYSTEMS

- *Coating repairs / re-coating programme instigated in 1993, plus additional solar powered CP stations @ km 40.5, km 66 & km 82*

i.e. CP stations now every 25 km for first half of line

- *Initial current circa 5μA/m^2 now circa 70 μA/m^2*
- *Leak at km 300 in 2001 due to impact damage and corrosion*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED ADVANCED CIPS & RECORDED DCVG SURVEY : 2001

- ***Syncronisation of switchers AND data loggers to +/- 10 mS / 24 hour***
- ***Switching 4 or 5 No CP stations throughout survey***
- ***Switching any inter-pipeline bonds > 20 mA***
- ***Daily calibration checks of all equipment and oscilloscope checks of syncronisation***

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED ADVANCED CIPS & RECORDED DCVG SURVEY : 2001

- *2 No Mobile Data Loggers, 1 per pipeline*
- *For each pipeline*

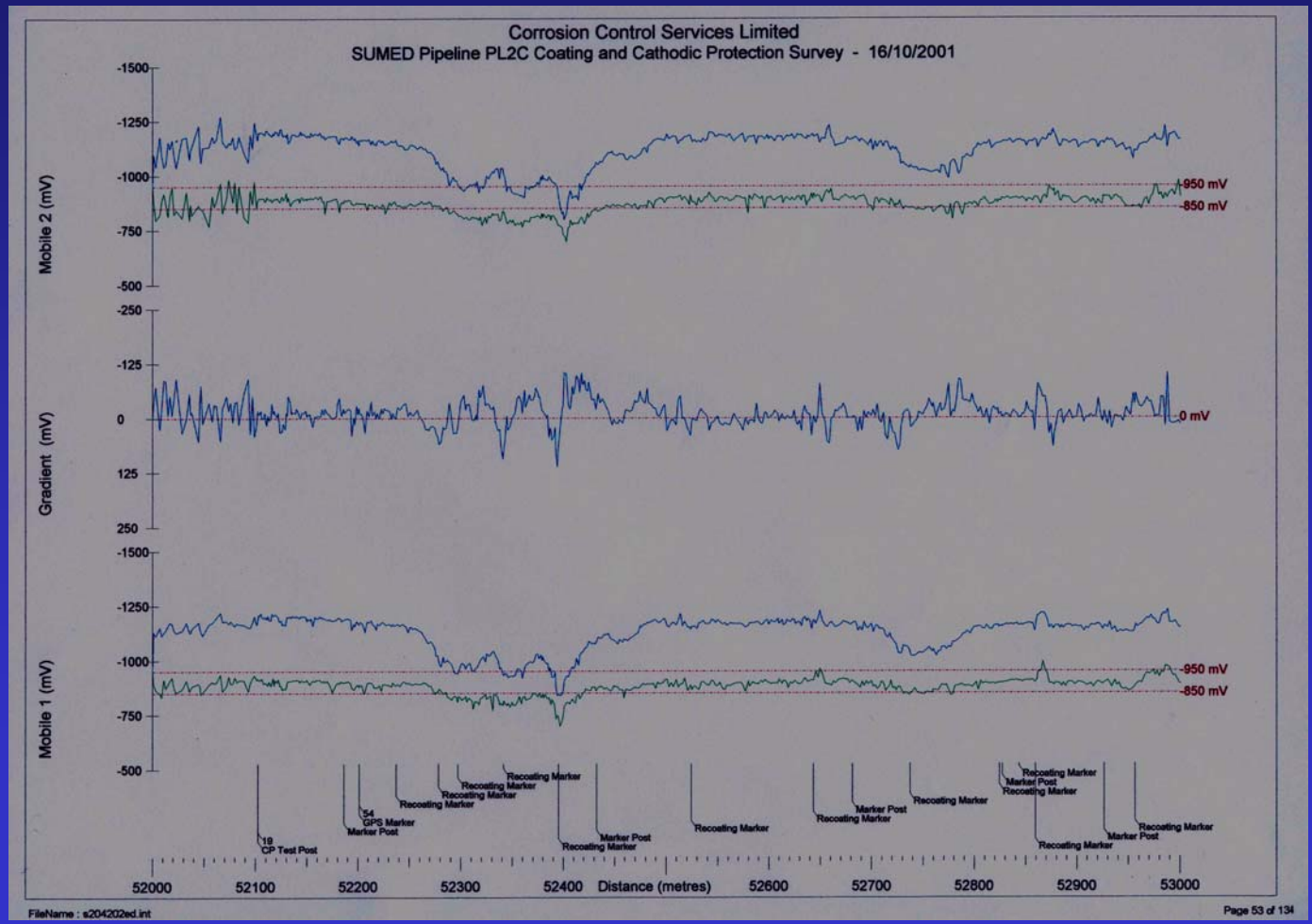
  - channel 1: "Mobile 1" ON and INSTANT OFF pipe / soil potential : CIPS data

  - channel 2 : Repeat ON / OFF pipe / soil potential 10 meters trailing "Mobile 2" : CIPS data: Quality check for both CIPS and DCVG

  - channel 3: DC Voltage gradient between Mobile 1 and

  Mobile 2 : DCVG data

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION



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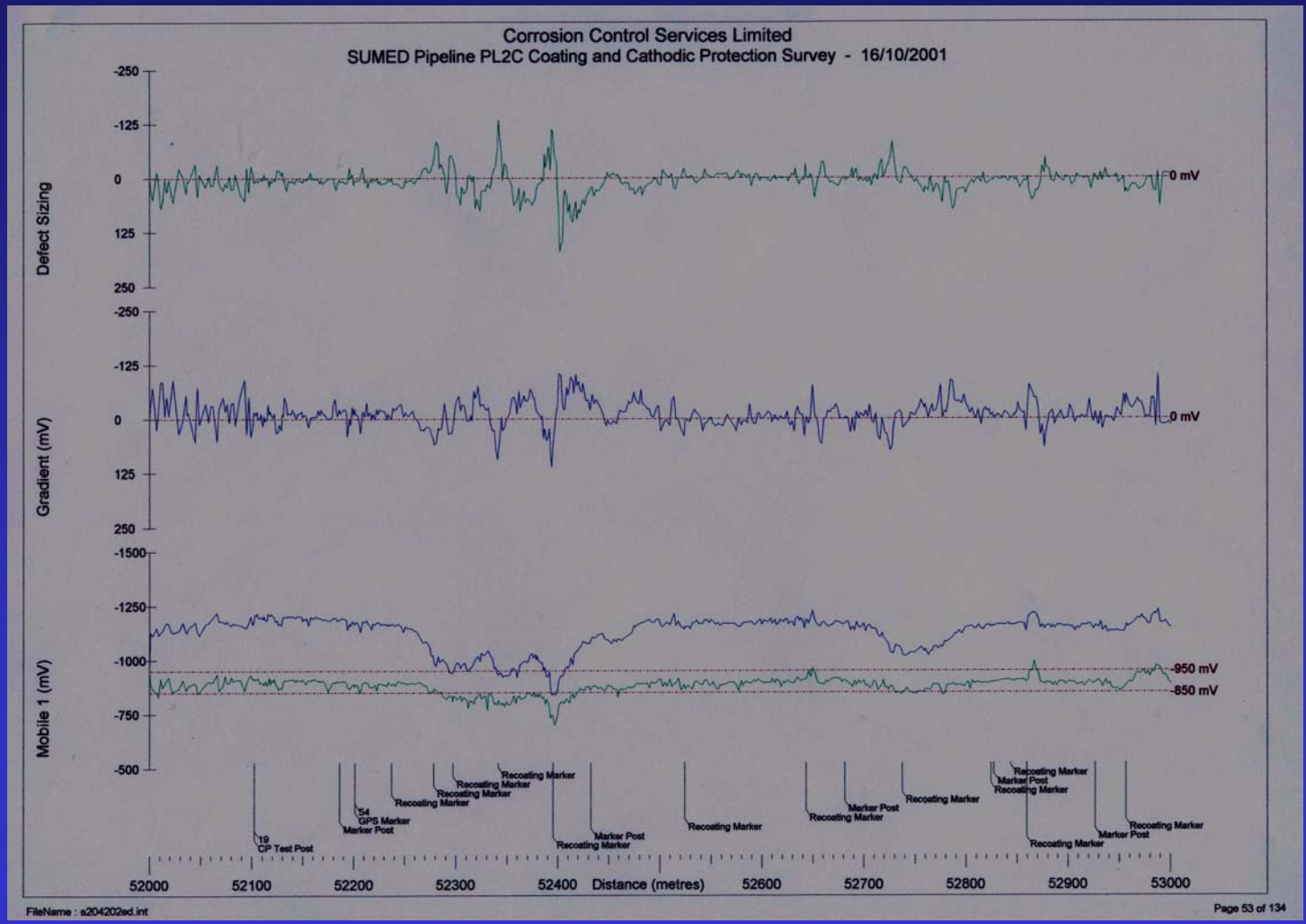

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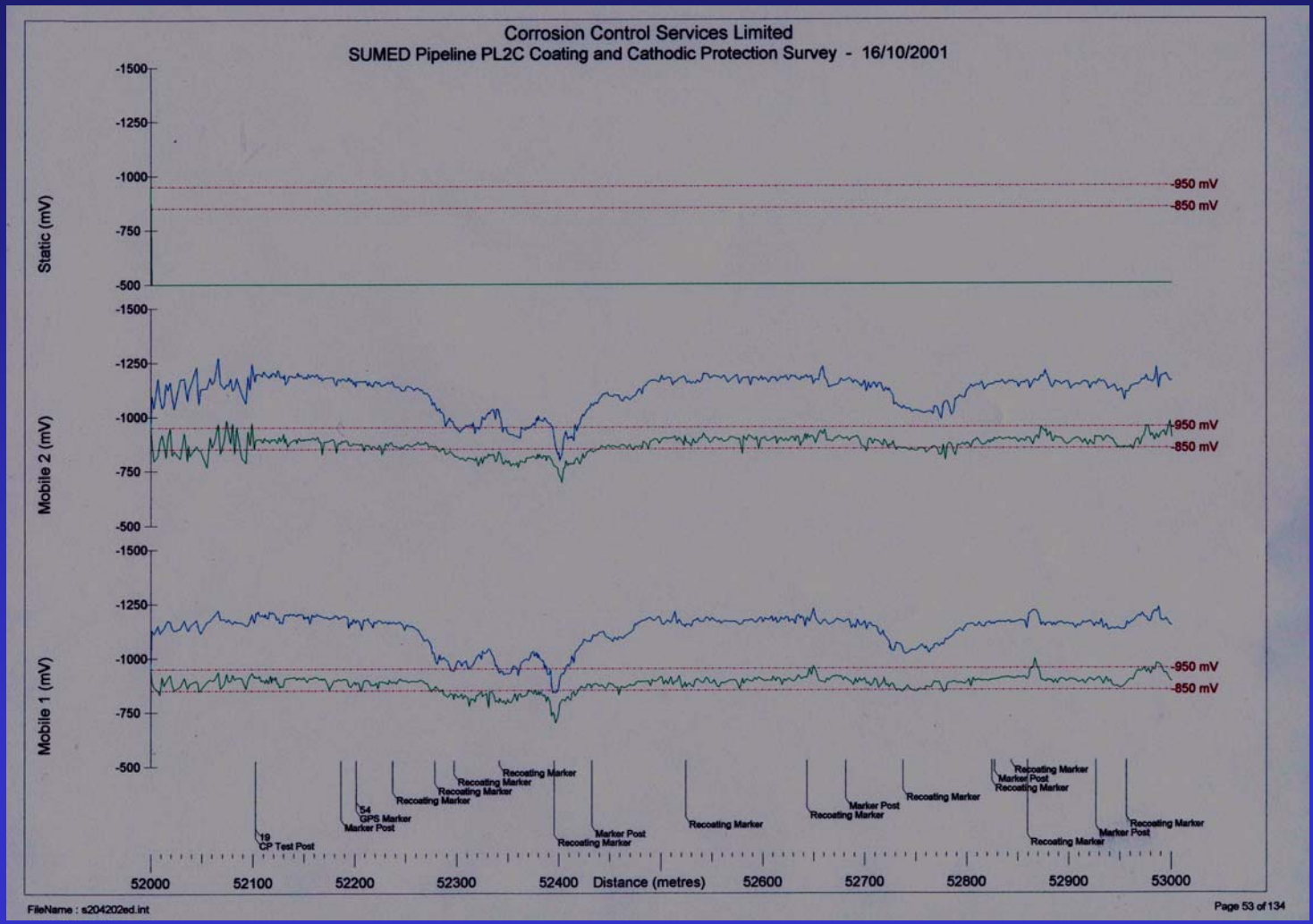

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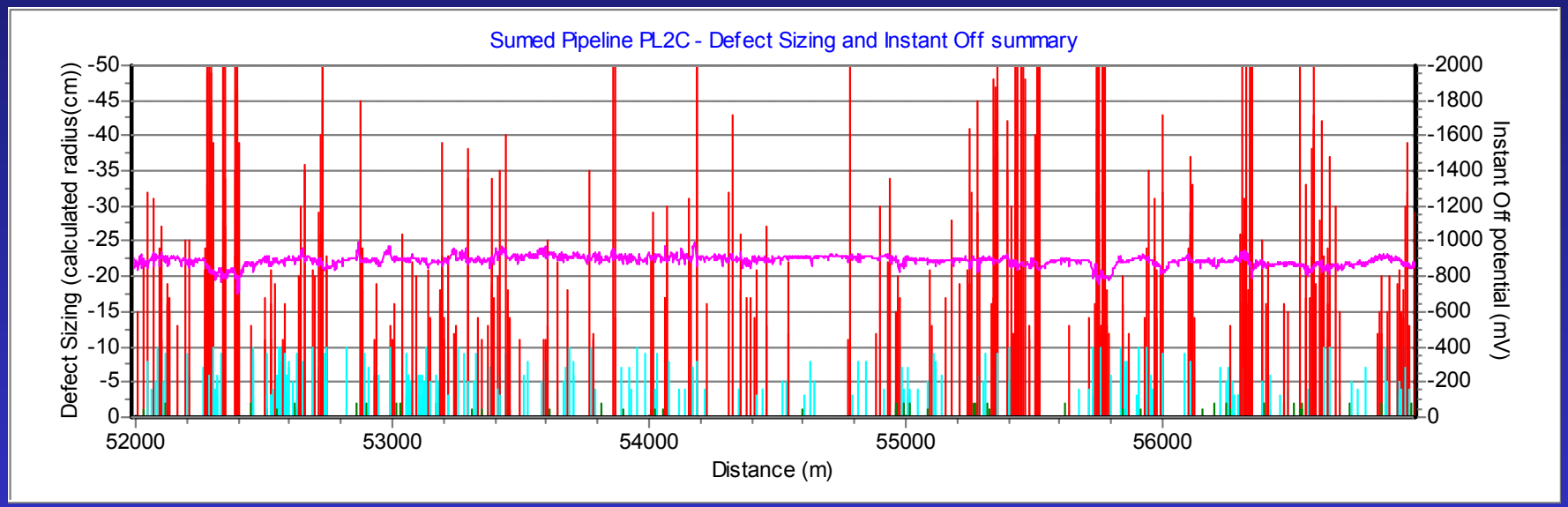

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

SUMED PIPELINE PL2C : DEFECT AND CP SUMMARY TABLE

Km	Largest Indicated Defect			No of Defects				Large	Medium	Small
	Distance	Sizing	instant off	>=10	<10 and >3	<3	Total	size off	size off	size off
52-53	52342	-134	-815	91	52	10	153	-15 -850	-08 -854	-01 -909

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CONCLUSIONS

- *Pipeline coatings are NEVER perfect. They ALWAYS suffer damage and deterioration during construction and service*
- *This deterioration dictates increased cathodic protection current AND decreased spacing between CP stations.*
- *Third party impact damage along with soil stress / soil movement / pipe movement damage results in coating defects exposing steel to soil*
- *Pipeline environments vary with time due to third party activity, in particular dc rail, ac power distribution and interfering Cathodic Protection systems*
- *Advanced CIPS + recorded DCVG with accurate syncronisation of switchers AND data loggers can fully characterise external corrosion control measures, BOTH CP and coatings*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- *CIPS + DCVG surveys will determine those areas at corrosion risk. Intelligent pig surveys will determine the extent of past corrosion damage including corrosion under intact disbonded coating.*
- *The SUMED case study demonstrates that:*

  - CIPS + DCVG surveys can be undertaken with a full quality audit trail and duplicate data measurement to ensure accuracy

  - Survey rates of 7.5 km per day are possible even in difficult terrain

  - The 2001 CIPS + recorded DCVG survey located and characterised some 130,000 coating defects compared with the 1993 analogue DCVG survey that located only 3500 defects

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- The 2001 CIPS + DCVG survey characterised the Cathodic Protection performance and identified corrosion risk areas

- The 2001 CIPS + DCVG survey presents SUMED with three levels of survey record :

1. A tabular summary , 1 line per km of significance of defects and their corrosion activity

2. A 10 km per page graphical presentation of coating defect significance and "Instant Off" pipe / soil potential

3. A detailed graphical presentation of 1 km per page presenting duplicate CIPS ON and INSTANT OFF pipe / soil potential data at 1-2 meters intervals,recorded DCVG data, recorded static pipe / soil potential data and calculated coating defect intensity

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- All data can be individually accessed via an electronic data management system

- From the results SUMED can determine which areas of the pipeline network require

1 Localised coating repair

2 Extensive coating refurbishment

3 Cathodic Protection system enhancement

- In conjunction with intelligent pig survey these data should enable the full asset management requirements of SUMED to be implemented

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- *A variety of overline survey techniques are available; their selection is critical and a combination may be appropriate*
- *Non recorded surveys are subject to operator error and can not be properly audited*
- *Combined CIPS + DCVG surveys require proper specification and Quality Management; present International Standards are inadequate*
- *Combined CIPS + DCVG surveys may require to be supplemented with ac corrosion data and testing and investigation at casings*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- *No overline survey can locate disbonded coatings without through coating defects/exposed steel*
- *Investigations at Integrated CIPS + Recorded DCVG coating defects may enable a risk assessment of disbonded coatings if disbondment is associated with through coating defects*
- *Corrosion under disbonded coatings can only be located and assessed with certainty by appropriate intelligent pig inspection surveys*

ADVANCED OVERLINE ASSESSMENT OF COATINGS AND CATHODIC PROTECTION

CONCLUSIONS

- *Overline Combined CIPS + Recorded DCVG surveys can provide a definitive external CP and Coating performance audit*
- *Combined CIPS + Recorded DCVG surveys should be undertaken towards the end of the pipeline construction defects maintenance period and thereafter at no longer than 10 year intervals*

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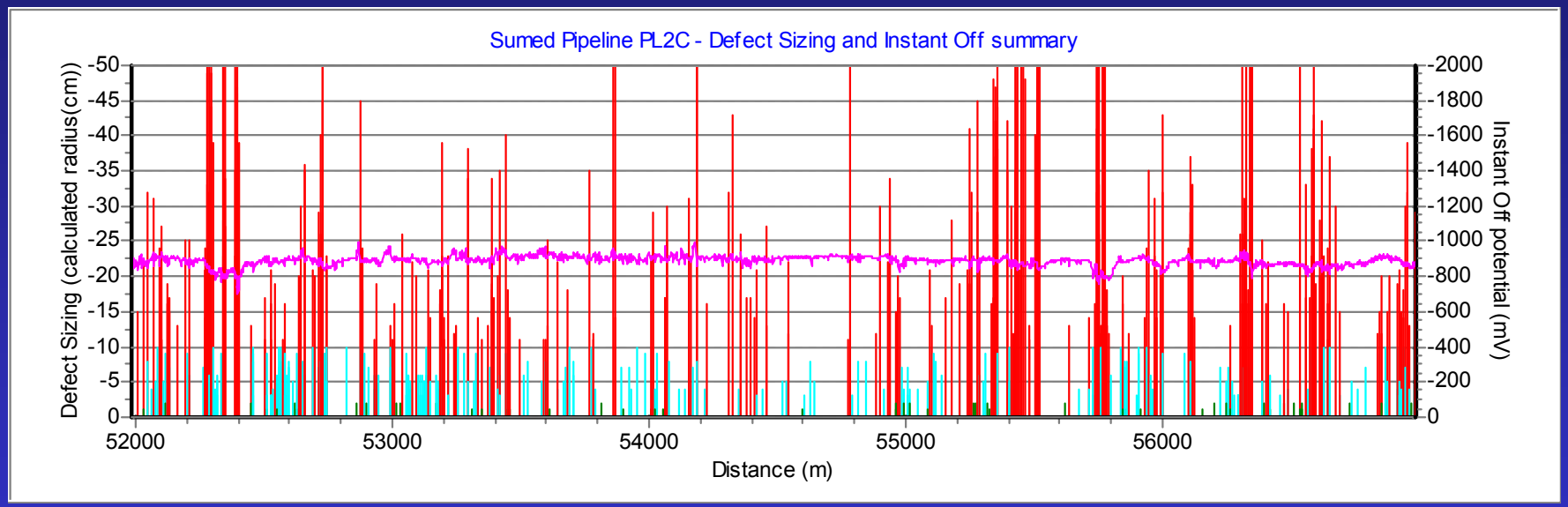

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