Inspection of Pipeline CP Systems with ILI Tools

Pipeline Management Group

Nov. 8th, 2007

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Agenda

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- ***Review of Corrosion and CP of Pipelines***
- Description of the CPCM concept
- Field trials and CPCM data
- Benefits of CPCM
- Acknowledgments
- Questions & Discussion

Cathodic Protection

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- Reduction or elimination of corrosion of a metal by the application of direct current from an anode through the electrolyte to the metal surface.
- Same 4 components that are needed for corrosion are required for CP. We just control where the anode and cathode are located.
- Note: The DC current is normally supplied by a galvanic anode or by an impressed current source such as a rectifier.

Testing for CP – Common Practice

Standard practice is to measure the pipe-to-soil potential from the surface of the right of way at predetermined intervals. If the potential is more negative than some number (this number varies depending on many factors) then it can be assumed that at the pipe surface cathodic protection current is being applied.

Concerns with Potential readings

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- Limitations of using potential based criteria can be due to many factors.
- Both cp and non-cp related influences can cause problems in the collection of accurate potential measurements[3]
  - Right of way access issues (urban, rural, industrial)
  - Non conductive surfaces (pavement)
  - Congested rights of way
  - Waterways
  - High earth currents both AC and DC
    - Foreign or third party CP currents
    - Transit systems
    - Power Line Corridors
  - Distance to coating holiday (well coated lines) or pipe/soil interface

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Pipeline CP System

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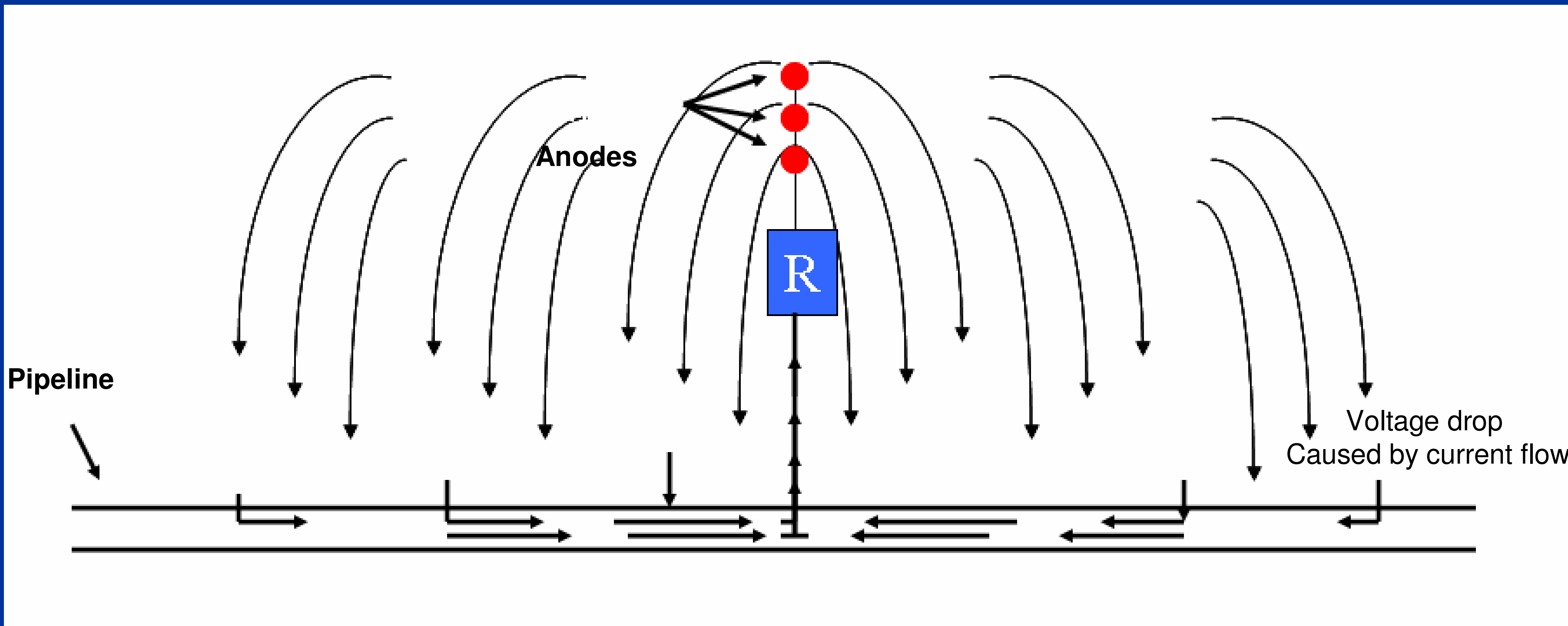

CP current is being "pushed" by the rectifier to the anodes where it enters the soil (electrolyte) then travels to the pipe surface where it enters the metal (cathode) and returns via a cable or other connection (negative).

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CPCM –

- Measures a voltage drop across a length of pipe (~ 2m) caused by the current flow from the CP system.
- Using Ohm's law we can calculate the actual current.
- Changes in current at any point along the pipe gives a signature which allows us to know something about the system.

The CP circuit (pipeline)--Current Graph

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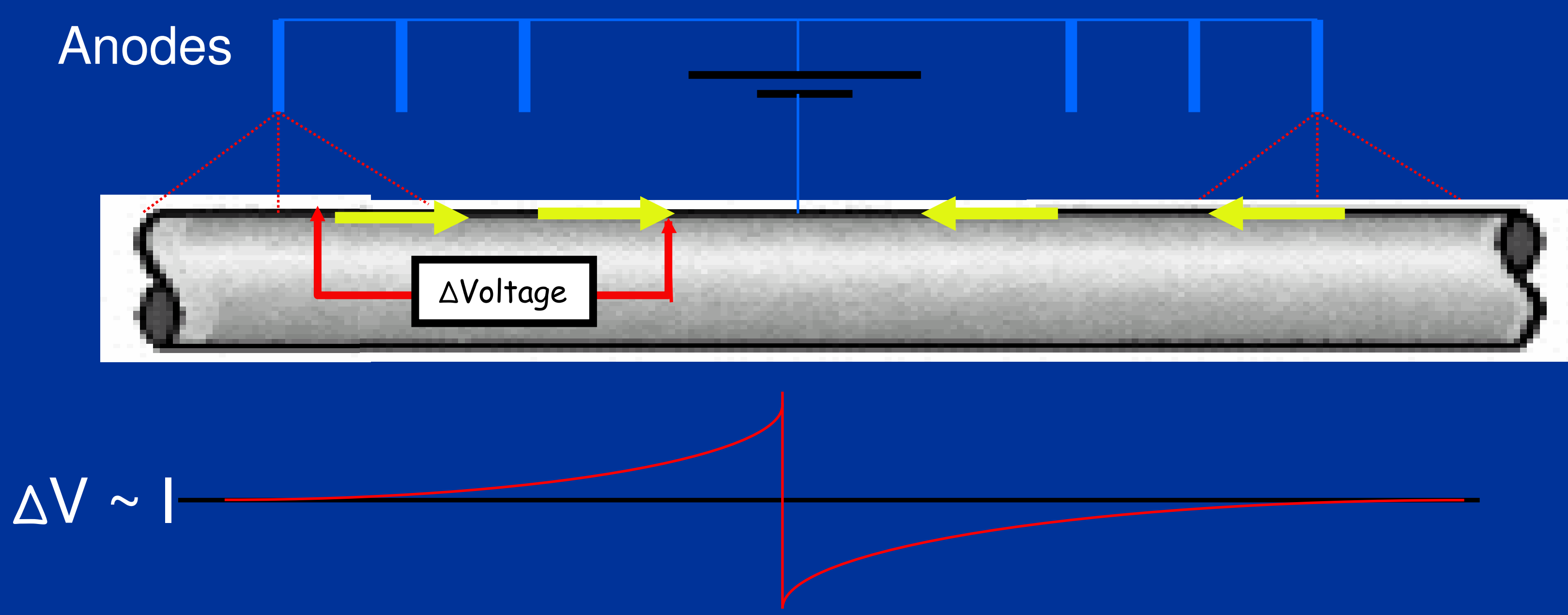
- In this illustration CP current is shown in it complete circuit. Notice that the current flowing in the pipeline causes a voltage drop because the pipe is a resistor.



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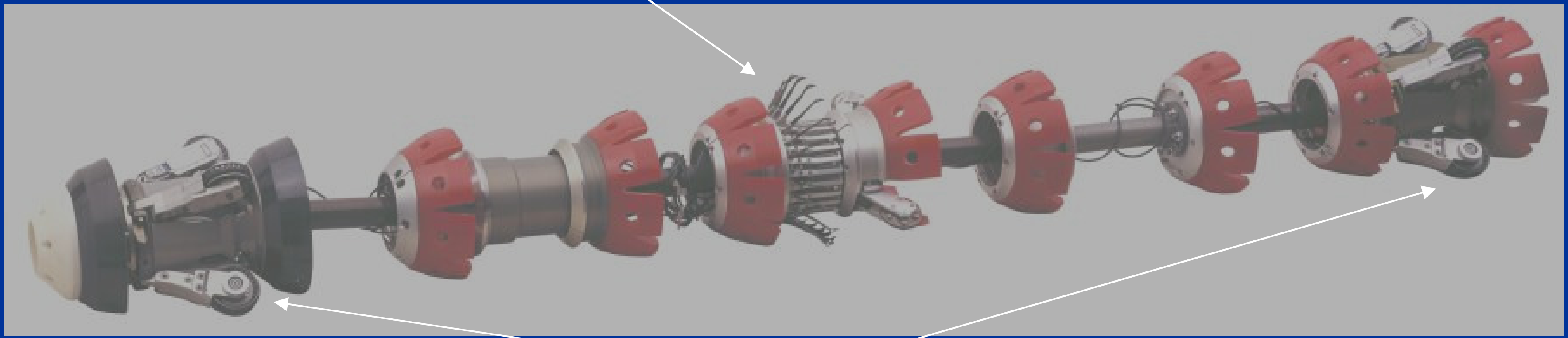
CPCM ILI Tool

On board caliper section used for alignment and deformation



Tool reads and records voltage difference (both AC &DC)
Between these two points.

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CPCM –Fast Facts

- Measure change in CP current due to poor/missing coating
- Identify galvanic anode and rectifier locations and measure current output
- Find unknown bonds and confirm bond current and locations
- 100% inspection of CP systems ensuring minimal gaps in integrity inspection data

  **(Especially viable in locations where access is difficult such as offshore, swamps, mountainous terrain and congested urban areas (HCA's))*

Note: The pipeline <u>cannot</u> be internally coated. Build-up of scale, paraffin, bitumen may be problematic.

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Field trials and data

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Signals

Large gains or losses over a single point = Rectifiers, Bonds, Shorts, Anodes

Large gains over several feet or meters = areas of poor coating or bare pipe – high current density

Small gains over longer areas are ideal and evidence of good coating and well distributed CP

Shallow positive (up left to right) slope across the zero line = mid point between sources and good CP coverage

Rectifier

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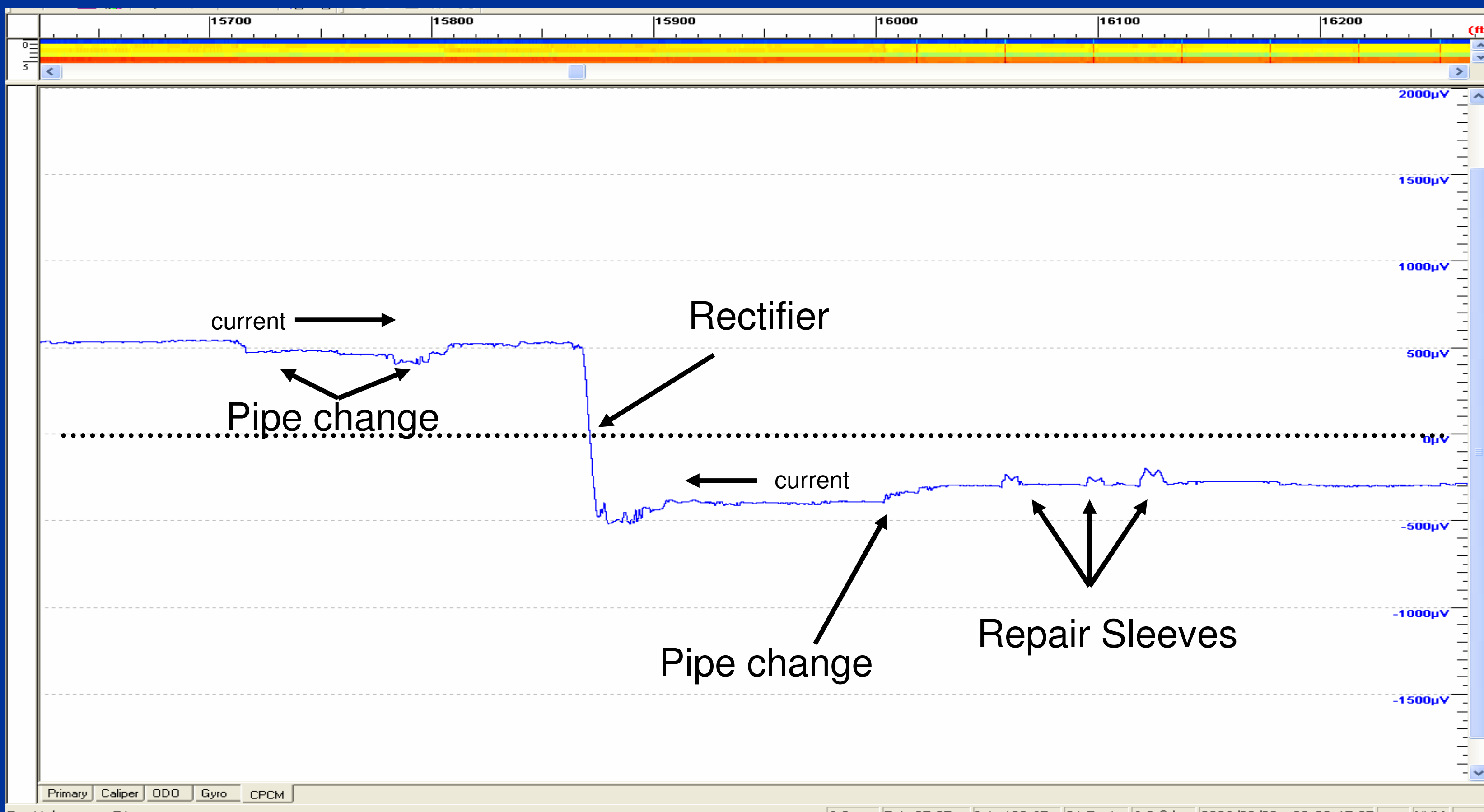

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Sample raw data – Rectifier and Rect/Interupter

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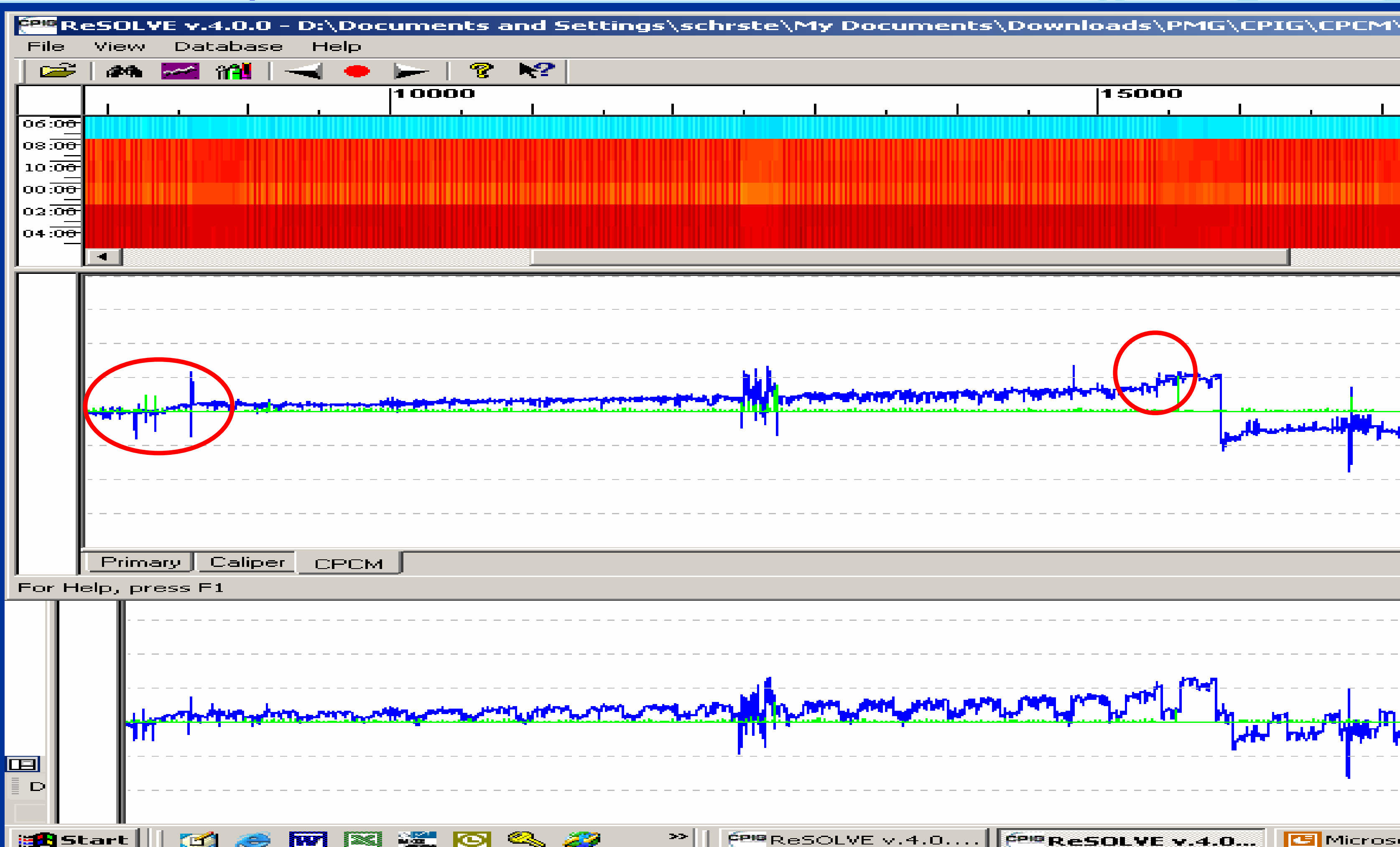

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Galvanic Anode & Short

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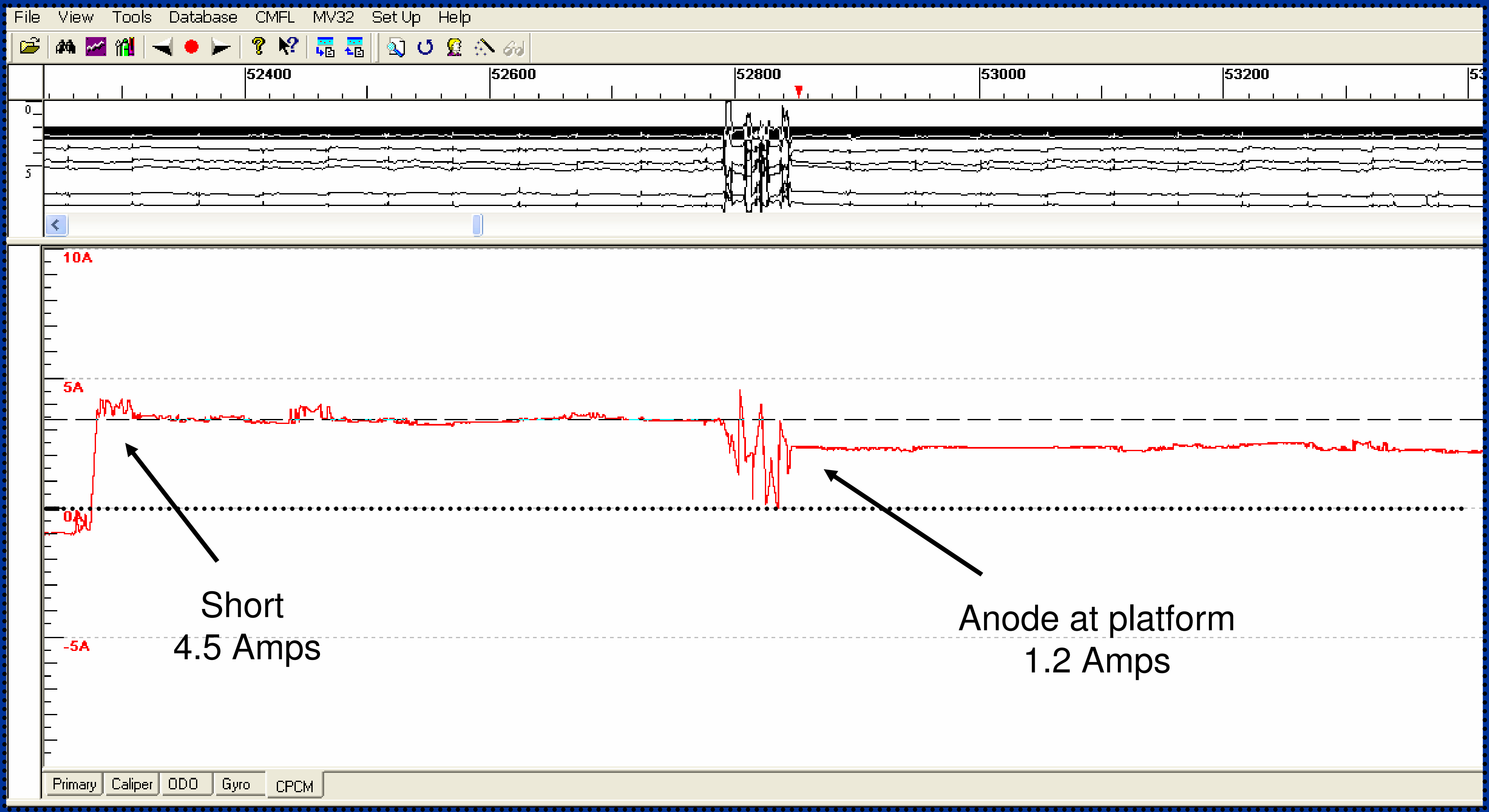

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Bond or Short

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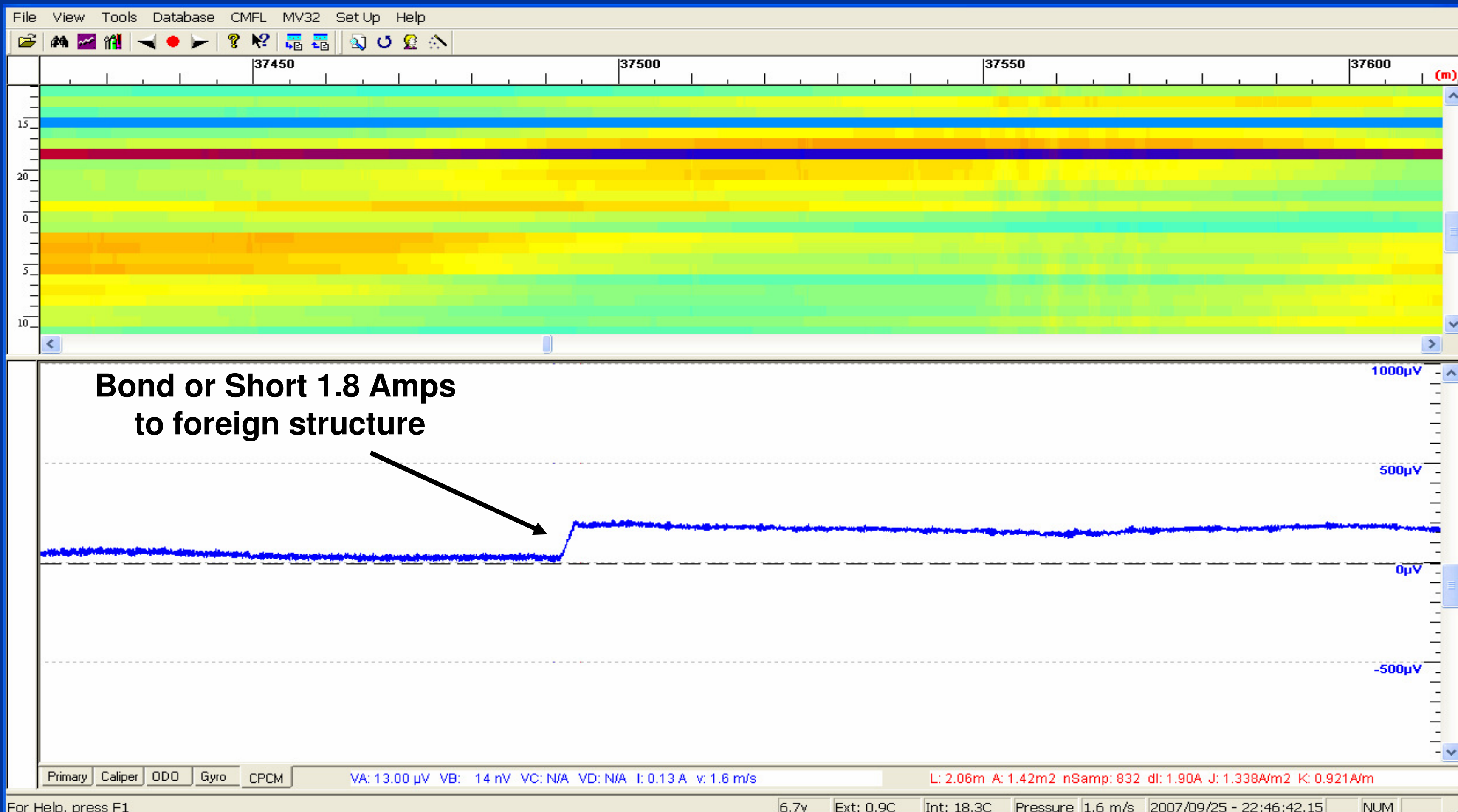

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8 Miles of pipeline before and after rectifier added

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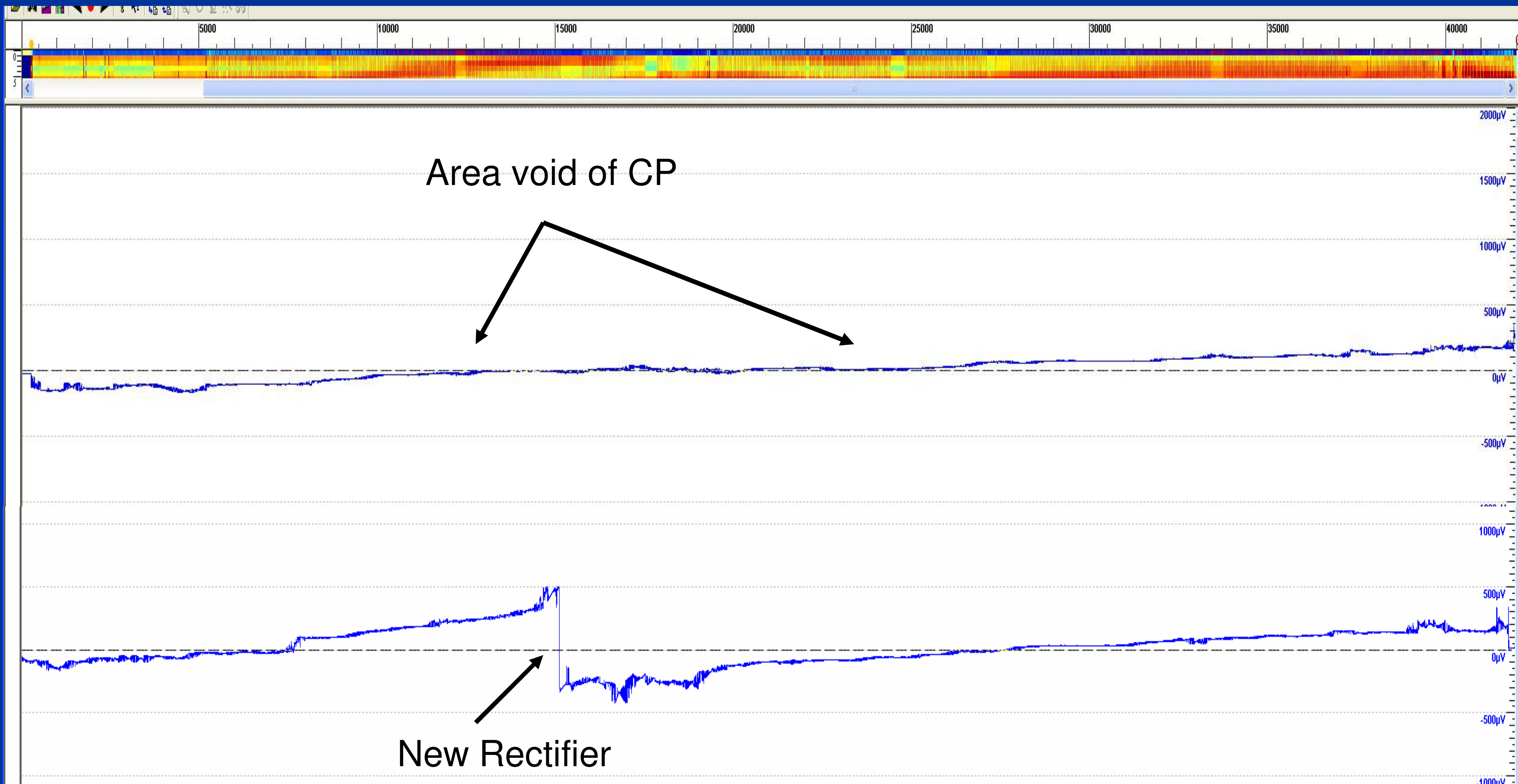

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Short

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Signals – cont.

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Downstream of Rectifier w/ Filter On

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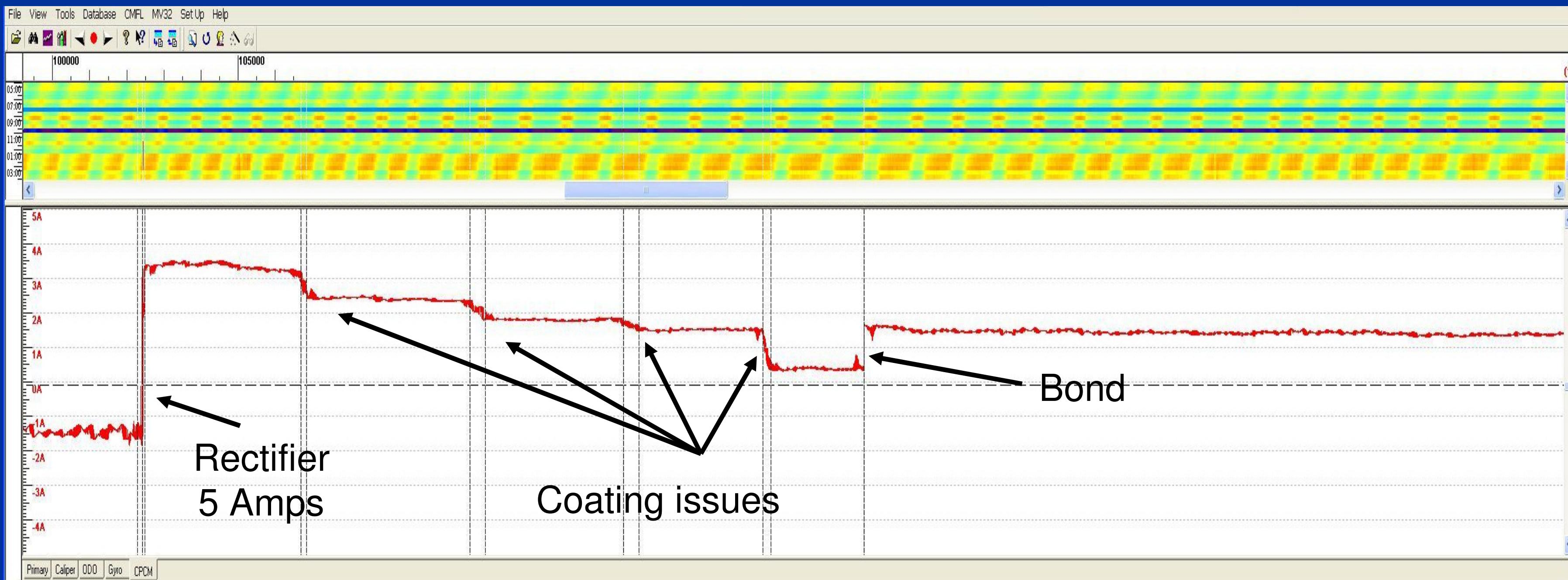

Odometer	Length	WT	Pipe Type	Pipe Gr...	Diameter	PipeResistivity(µOhm.ft)	Current(A)	CurrentDensity(mA/ft2)	Comments
102427.84'	60.01'	0.188"	ERW	X42	8"	0.59	-2.41	-17.83	Rectifier
102487.84'	0.01'	0.188...	ERW --	X42 --	8"	0.59	-2.41	-112.89	
102487.85'	4212.62'	0.188"	ERW	X42	8"	0.59	0.01	-0.02	
106700.47'	156.29'	0.188"	ERW	X42	8"	0.59	-0.70	-1.63	
106856.76'	4400.85'	0.188"	ERW	X42	8"	0.59	-0.03	-0.01	
111257.62'	417.44'	0.188"	ERW	X42	8"	0.59	0.19	-0.57	
111675.04'	3728.80'	0.188"	ERW	X42	8"	0.59	-0.02	-0.02	
115403.85'	416.15'	0.188"	ERW	X42	8"	0.59	-0.27	-0.19	
115820.01'	3345.85'	0.188"	ERW	X42	8"	0.59	0.03	-0.01	
119165.86'	204.18'	0.188"	ERW	X42	8"	0.59	-0.53	-2.00	

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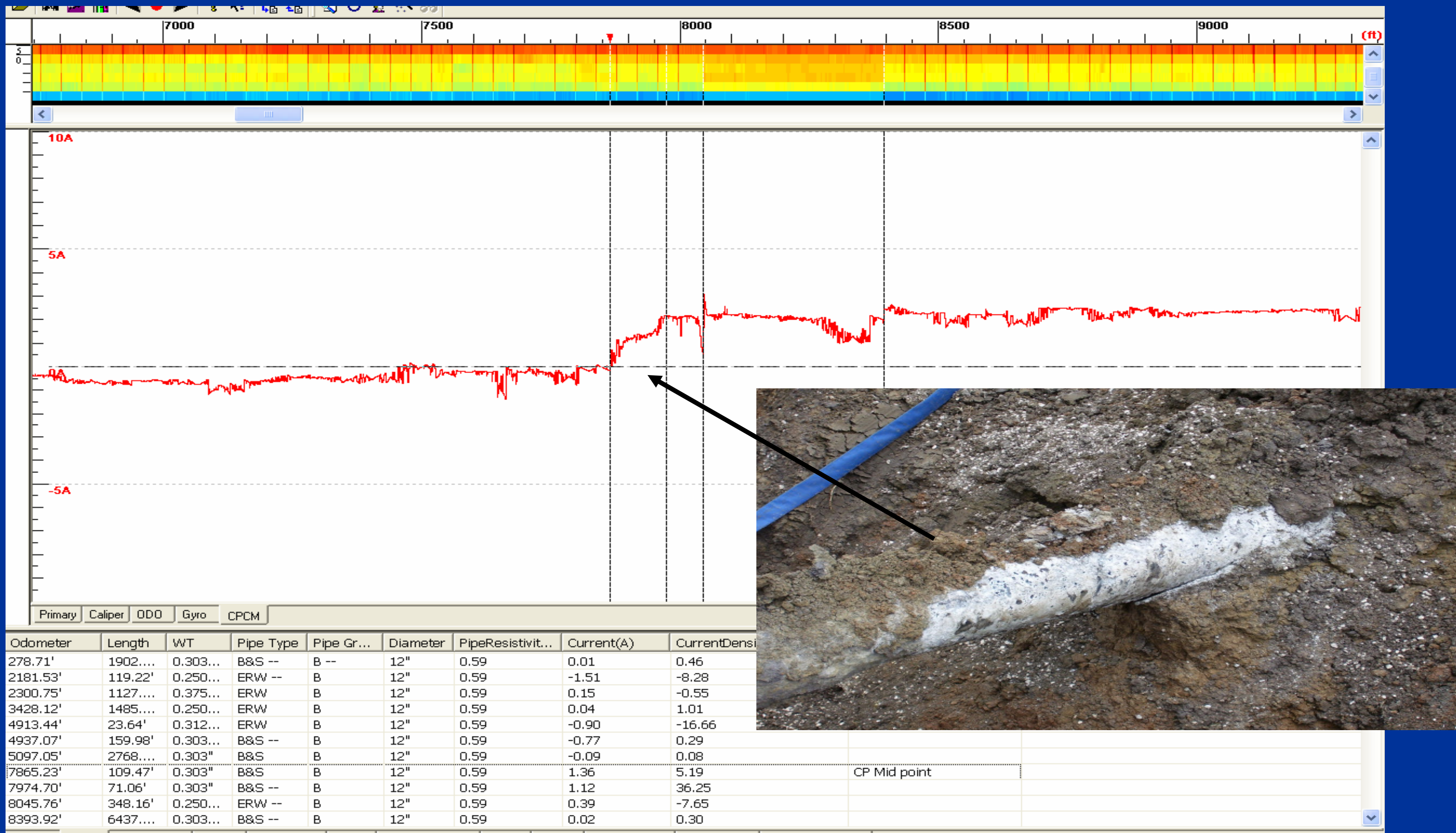
Area of damaged coating



Odometer	Length	WT	Pipe Type	Pipe Gr...	Diameter	PipeResistivit...	Current(A)	CurrentDensi
278.71'	1902....	0.303...	B&S --	B --	12"	0.59	0.01	0.46
2181.53'	119.22'	0.250...	ERW --	B	12"	0.59	-1.51	-8.28
2300.75'	1127....	0.375...	ERW	B	12"	0.59	0.15	-0.55
3428.12'	1485....	0.250...	ERW	B	12"	0.59	0.04	1.01
4913.44'	23.64'	0.312...	ERW	B	12"	0.59	-0.90	-16.66
4937.07'	159.98'	0.303...	B&S --	B	12"	0.59	-0.77	0.29
5097.05'	2768....	0.303"	B&S	B	12"	0.59	-0.09	0.08
7865.23'	109.47'	0.303"	B&S	B	12"	0.59	1.36	5.19
7974.70'	71.06'	0.303"	B&S --	B	12"	0.59	1.12	36.25
8045.76'	348.16'	0.250...	ERW --	B	12"	0.59	0.39	-7.65
8393.92'	6437....	0.303...	B&S --	B	12"	0.59	0.02	0.30

Signals cont.

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Well coated pipe

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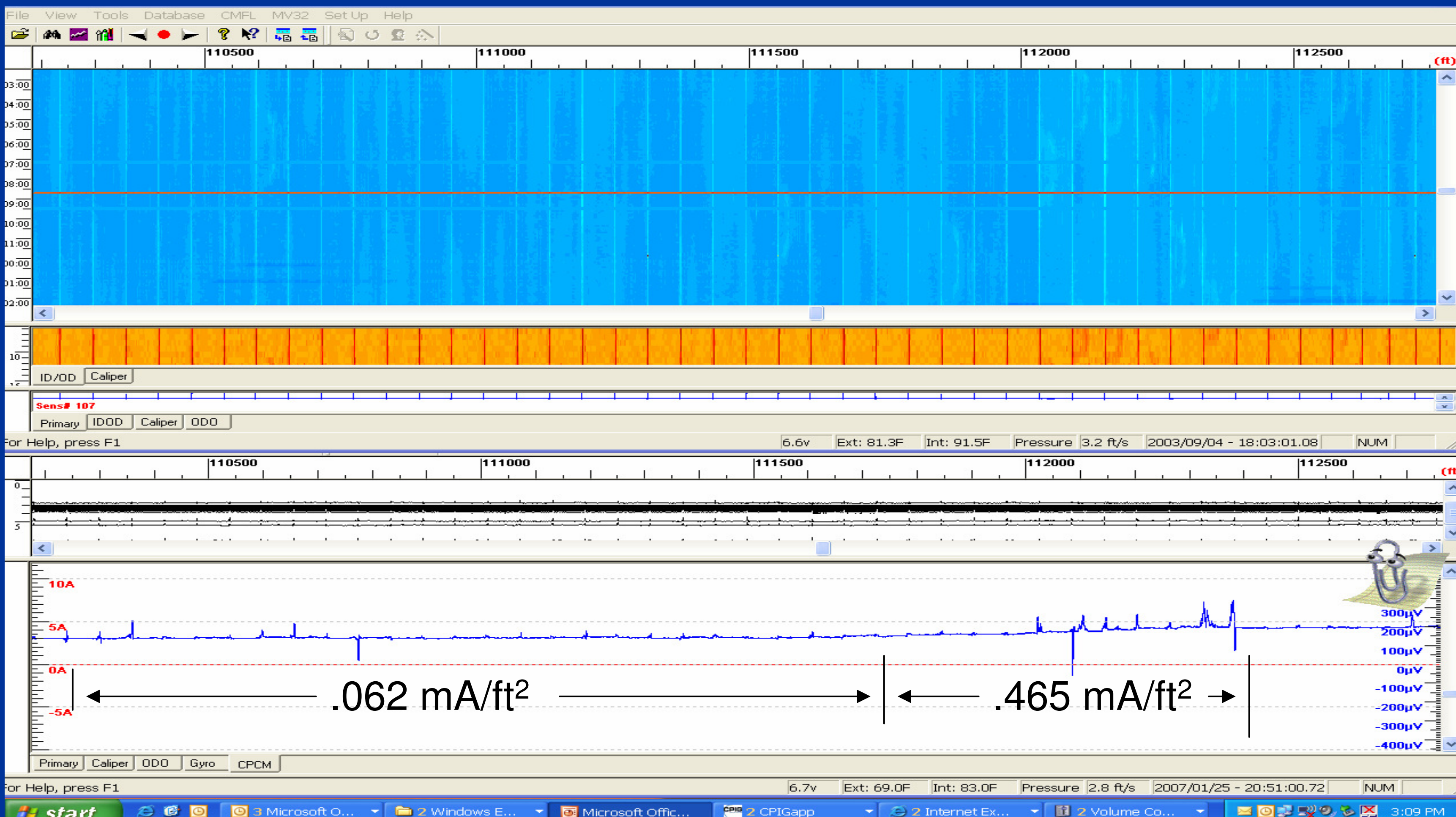

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Well coated pipe

noise caused by welds

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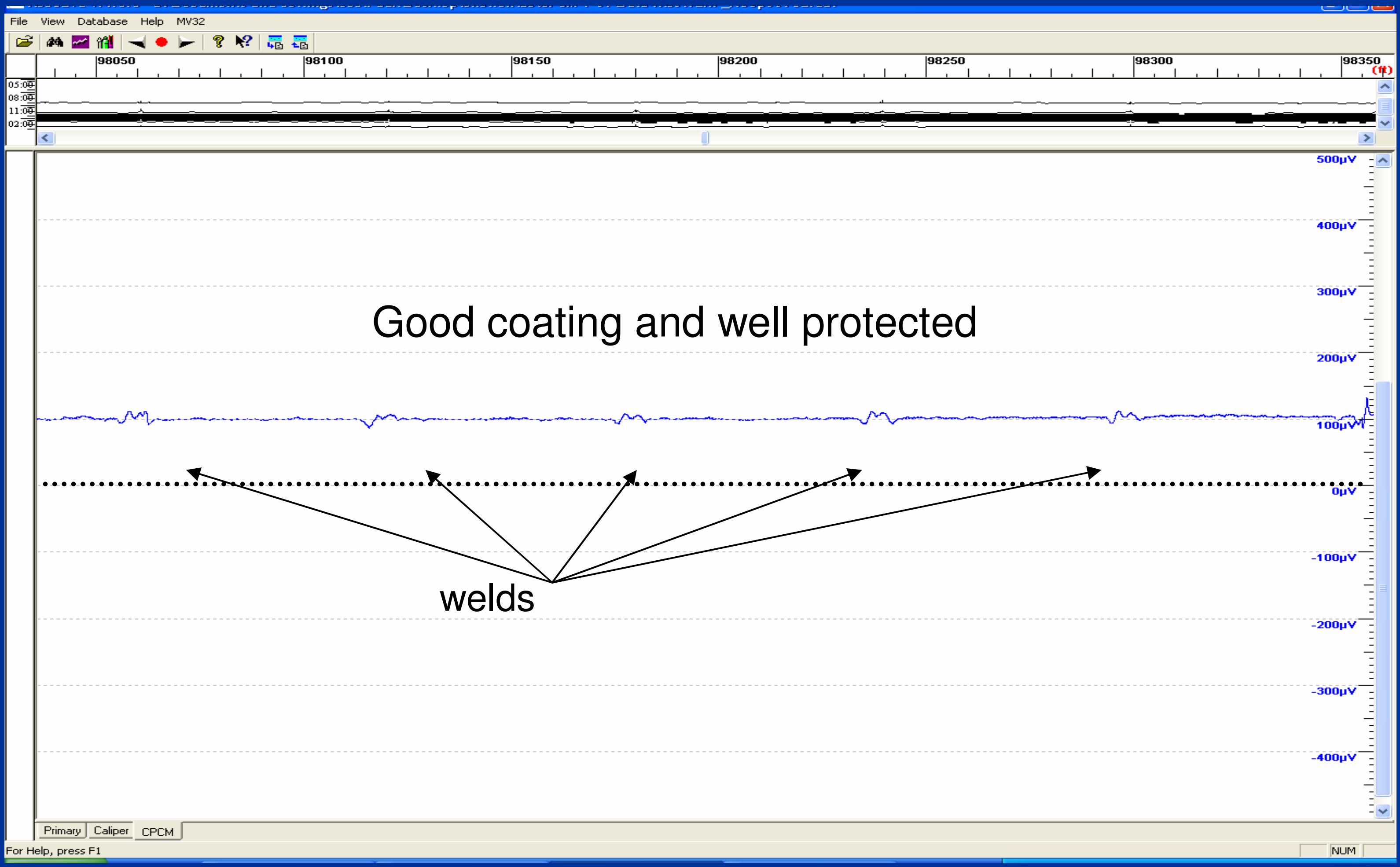

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Area void of CP

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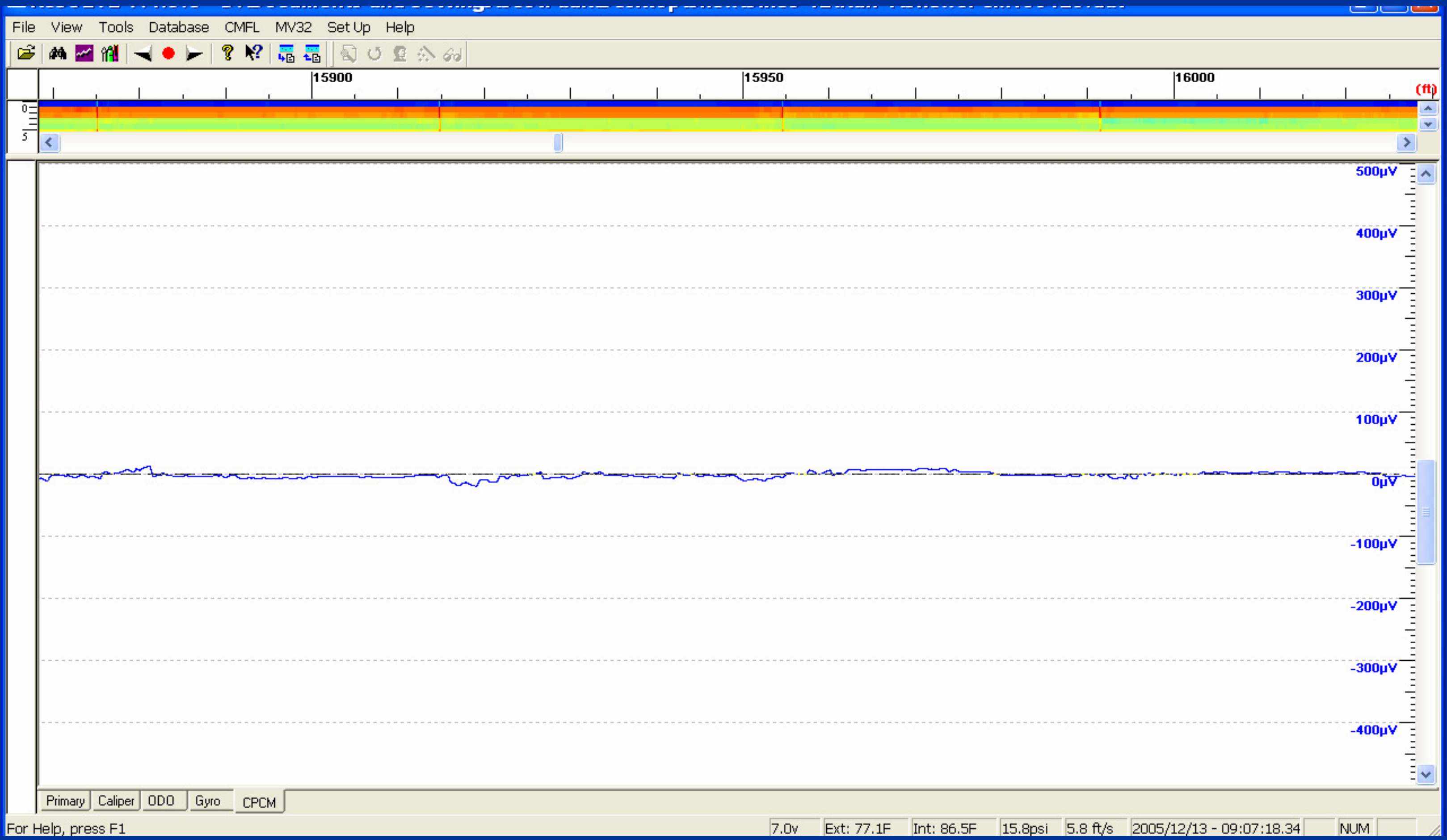

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Signals cont.

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Mid point between rectifiers

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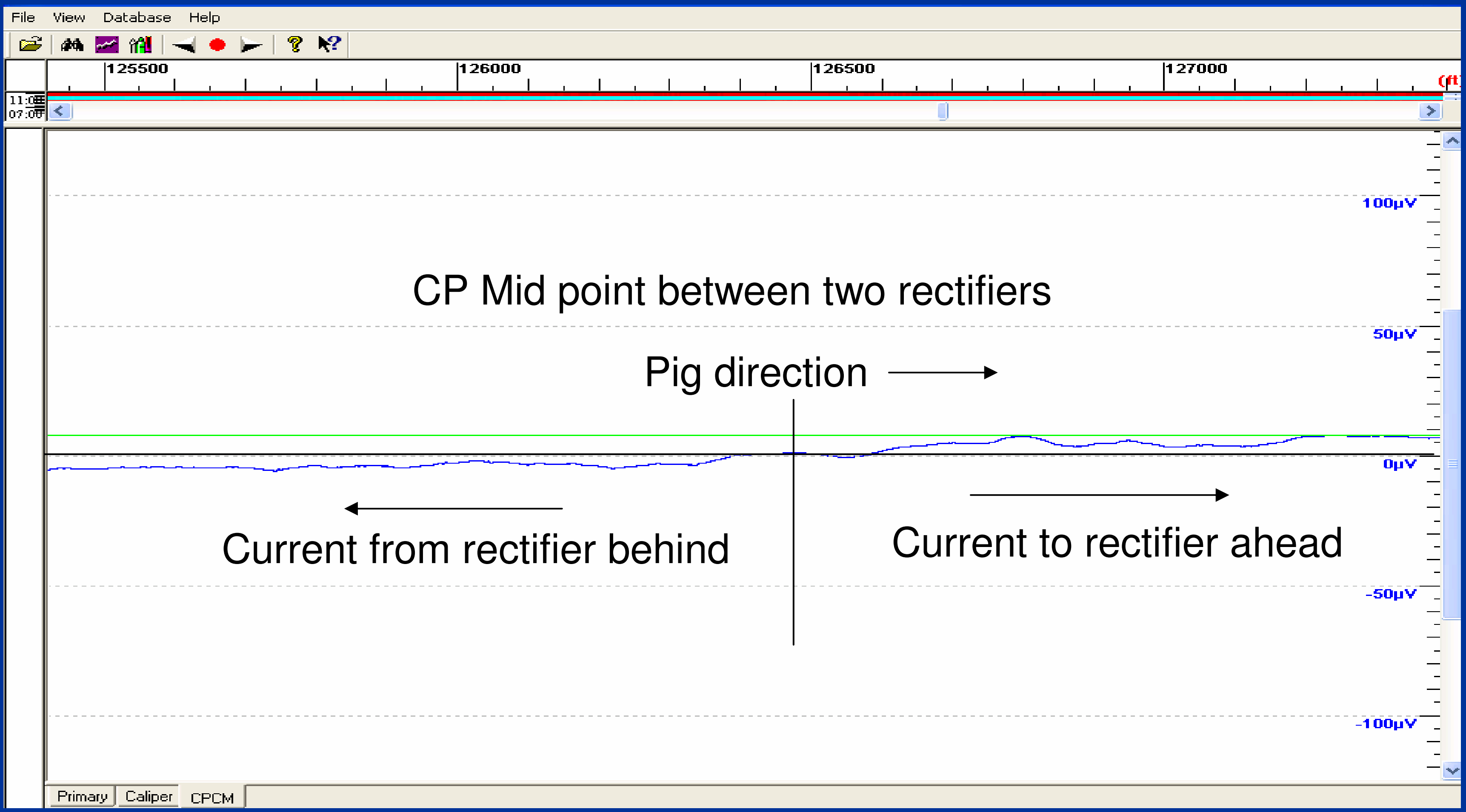

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- ***Benefits of CPCM***
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Benefits of CP Current Monitoring via ILI

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- Minimal personnel requirements
- Ease of evaluation
  - Only affecting currents are recorded
  - Good understanding of overall pipe condition
- 100% inspection
- Not dependent on ROW access
- Ease of which data is integrated with other ILI information

Data Integration

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- Direct correlation with metal loss data makes data integration easy and meaningful.
- Aids in action planning
  - Is metal loss likely active or passive?
  - Is more CP needed to arrest corrosion?
  - Is shielding the most probable cause and recoating needed?
  - What action is needed to prevent future repairs?

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Groups working on CPCM

Shell Oil Company

Kevin Scott – Shell Pipeline Co. L.P.
Mark Mateer – Shell Global Solutions
Paul Nichols – Shell Global Solutions
Bert Potts – Shell Global Solutions
Kola Fagbayi- Shell Global Solutions
Peyton Ross – Shell Pipeline Co. L.P.

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Steve Schroder
Paul Pirner - Proj. Mgt and Mech Eng
Vyacheslav Akulshyn - Mech Eng.
Mark Kalicki - Electrical Engineering
David Chung - Software

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Jim Merritt – R&D Program Manager

Peter Katchmar – Project technical manager

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Patent Issued

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(12) **United States Patent**
Pots et al.

(10) **Patent No.:** **US 7,104,147 B2**
(45) **Date of Patent:** **Sep. 12, 2006**

(54) **SYSTEM AND METHOD FOR MEASURING ELECTRIC CURRENT IN A PIPELINE**

(75) Inventors: **Bert Pots**, Houston, TX (US); **Kola Fagbayi**, Houston, TX (US); **P. Kevin Scott**, Harvey, LA (US); **Mark W. Mateer**, Katy, TX (US)

(73) Assignee: **Shell Oil Company**, Houston, TX (US)

3,539,915	A	*	11/1970	Wood et al.	324/220
3,568,053	A	*	3/1971	Kilpatrick et al.	324/722
4,427,943	A	*	1/1984	Cloutier et al.	324/326
4,639,677	A		1/1987	Goolsby	205/730
4,654,702	A	*	3/1987	Tolino et al.	348/84

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 235 478 B1 11/1993

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- References

1. Peabody, A.W., Control of Pipeline Corrosion. (Houston, TX: NACE, 1967) p.19
2. Fontana, Mars G., and Greene, Norbert D., Corrosion Engineering 2nd Ed. (USA, McGraw-Hill, 1978) p. 205
3. Hosokawa, Y., Kajiyama, F., and Nakamura, Y., New cathodic protection criteria based on direct and alternating current densities measured using coupons and their application to modern steel pipelines. Corrosion (March 2004) p.305

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Questions

&

Discussion

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