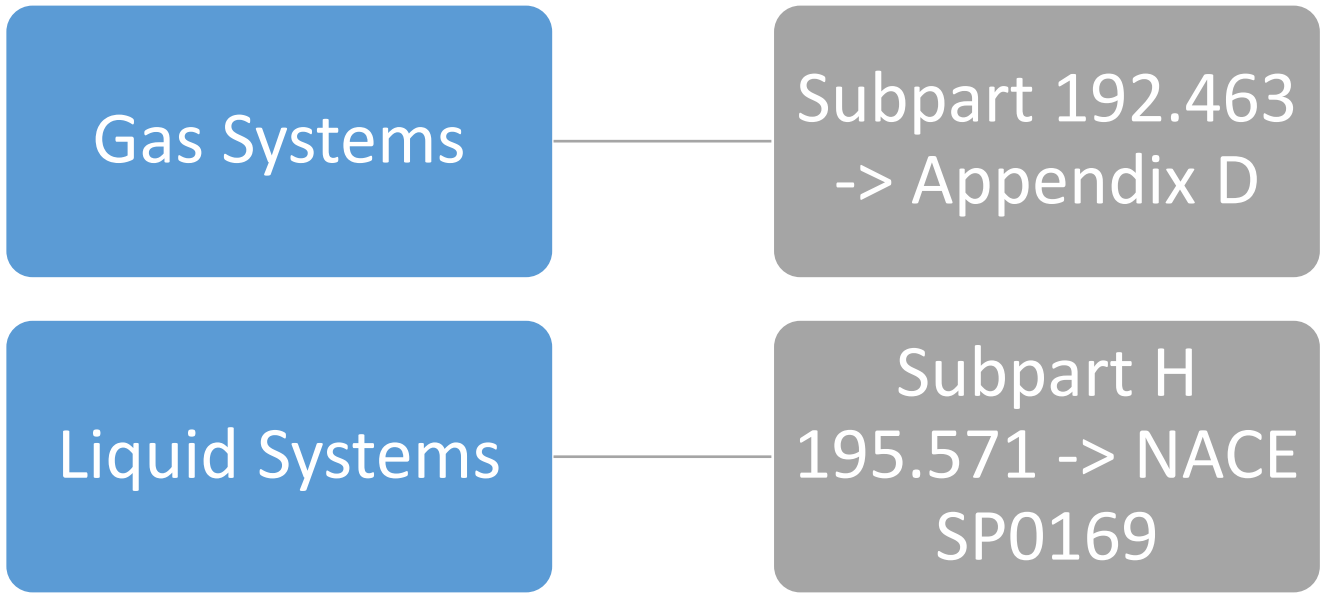
CP Criteria

Monitoring Standards



Part 192 - Appendix D

Appendix D Contains Criteria for Cathodic Protection and Determination of Measurements

Measurement Requirements

- Detailed, Written Procedures
- Qualified Technician
- Adequate Supervision
- Calibrated and Traceable Equipment
- Adequate Replication
- Detailed Documentation

Best Criterion

The use of CP criteria is an indirect inspection method for external corrosion. This is the primary alternative to direct inspection.

The best way to determine if CP has been effective in mitigating corrosion is by a direct visual inspection. CP is designed to reduce corrosion on the external surfaces of the pipe.

Direct visual examination can take place on these external surfaces.

Direct inspection can be an expensive process because of the requirement to expose the buried pipe.

Stress Corrosion Cracking

Caution is advised against using polarized potentials less negative than -850 mV for cathodic protection of pipelines when operating pressures and conditions are conducive to stress corrosion cracking.

An example would be a pipeline experiencing elevated temperatures (>100 degrees F).

Coating Disbonding

The use of excessive polarized potentials (>-1200 mV) on coated pipelines should be avoided to minimize disbondment of the coating.

The amount of CP current required is directly proportional to the quality and integrity of the coating.

Embrittle Steel

Excessive impressed CP may result in the generation of hydrogen which may cause (hydrogen) embrittlement of steel structures.

Particularly higher strength steel such as API-5L X70 pipe.

IR Drop

Uniform methods for determining voltage drops and polarization shall be selected.

Once voltage drop(s) (IR Drops), polarized potentials, and/or polarization have been determined, they may be used for correcting future potential measurements at the same location, **provided that conditions** such as pipe and cathodic protection system operating conditions, soil characteristics, and external coating quality **remain similar.**

Can’t Remove All Current

When it is impractical or considered unnecessary to disconnect all current sources to correct for voltage drop(s) in the structure-to-electrolyte potential measurements, sound engineering practices should be used to ensure that adequate cathodic protection has been achieved.

This may be the case for galvanic systems.

Criteria at Locations

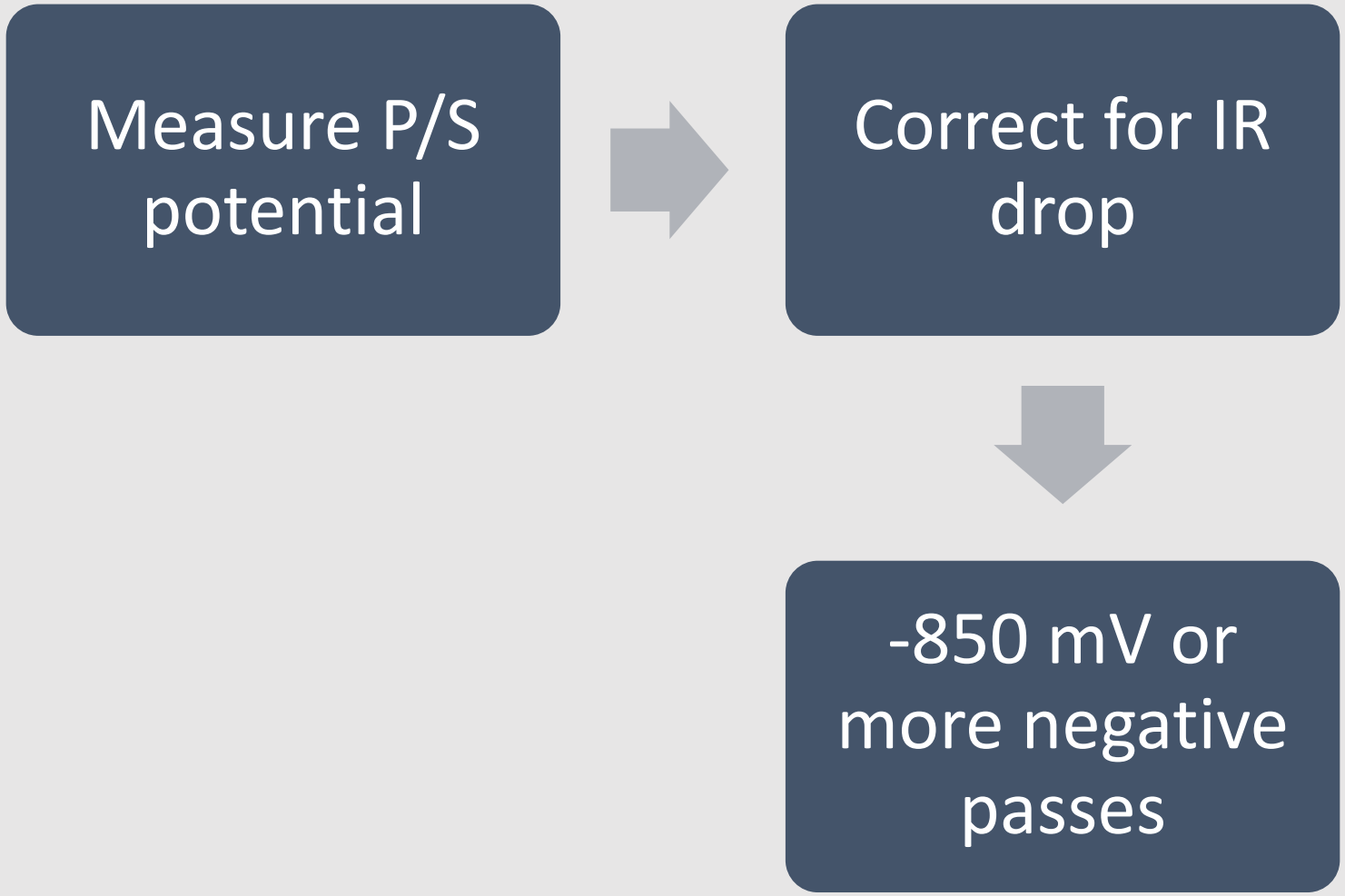
Situations may exist where a single criterion for evaluating the effectiveness of cathodic protection may not be satisfactory for all conditions.

Document Criterion Used

The criterion for determining adequate cathodic protection for each pipeline or pipeline segment shall be identified.

-850 mV Cathodic Potential Criterion

A **negative** (cathodic) voltage of at least 0.85 volt, with reference to a saturated copper-copper sulfate half cell.



-850 mV Cathodic Potential Criterion - Steps

Can be used for gas pipelines

Can be used for liquids pipelines

-850 mV Cathodic Potential Criterion

-850 mV Cathodic Potential Criterion - Couples

A negative (cathodic) voltage, measured in accordance with section IV of Appendix D, equal to that required for the most anodic metal in the system must be maintained.

Galvanic couples occur when two dissimilar metals are connected. The CP potential criteria must be met for the more active metal.

If one of the metals in the couple is amphoteric and can be damaged by high alkalinity, it must be electrically isolated using an insulating flange or equivalent.

-850 mV Criterion - Advantage

The main advantage of the -850 mV potential criterion is that it is easy to apply.

Only a single measurement is required.

-850 mV - Disadvantage

The main disadvantage of the -850 mV potential criterion is that it is very conservative.

Much more cathodic protection current is usually required to meet the –850 mV criterion than to stop corrosion.

In another words, when applying cathodic protection, corrosion normally is mitigated at less negative potentials than the –850 mV criterion.

Can be used for gas pipelines

Can be used for liquids pipelines

100 mV Polarization

Polarization Definition

Shift in potential caused by current

Polarization

The potential difference across the terminals of a battery is 12.6 volts before current flows.

The battery voltage drops to 10.1 V after the current starts flowing.

The polarization in this example is then 2.5 V.

- Battery Before Current Flows 12.6 V
- Battery While Current Flowing 10.1 V
- Polarization is equal to 2.5 V

100 mV Polarization

The half cell potential of an area of a pipe is –550 mV before any current flows.

The potential shifts to –670 mV after the current flow.

The polarization in this example is 120 mV.

- P/S Potential Before Current -550 mV
- P/S Potential With Current -670 mV
- Polarization is equal to -120 mV

Polarization - Coating Effect

Poor Coating ~ Little Polarization

Good Coating ~ Much Polarization

Polarization - Diffusion Effect

Polarization is related to the ease of movement of molecules in the environment around the pipe.

- Water - Little Polarization
- Porous Soils - More Polarization
- Compact Soil - Much Polarization

100 mV - Measurement

Allow pipe to polarize to a stable reading

Shut off CP that caused polarization

Measure polarization that disappears

100 mV - Procedure

Three steps are required to apply the 100 mV criterion:

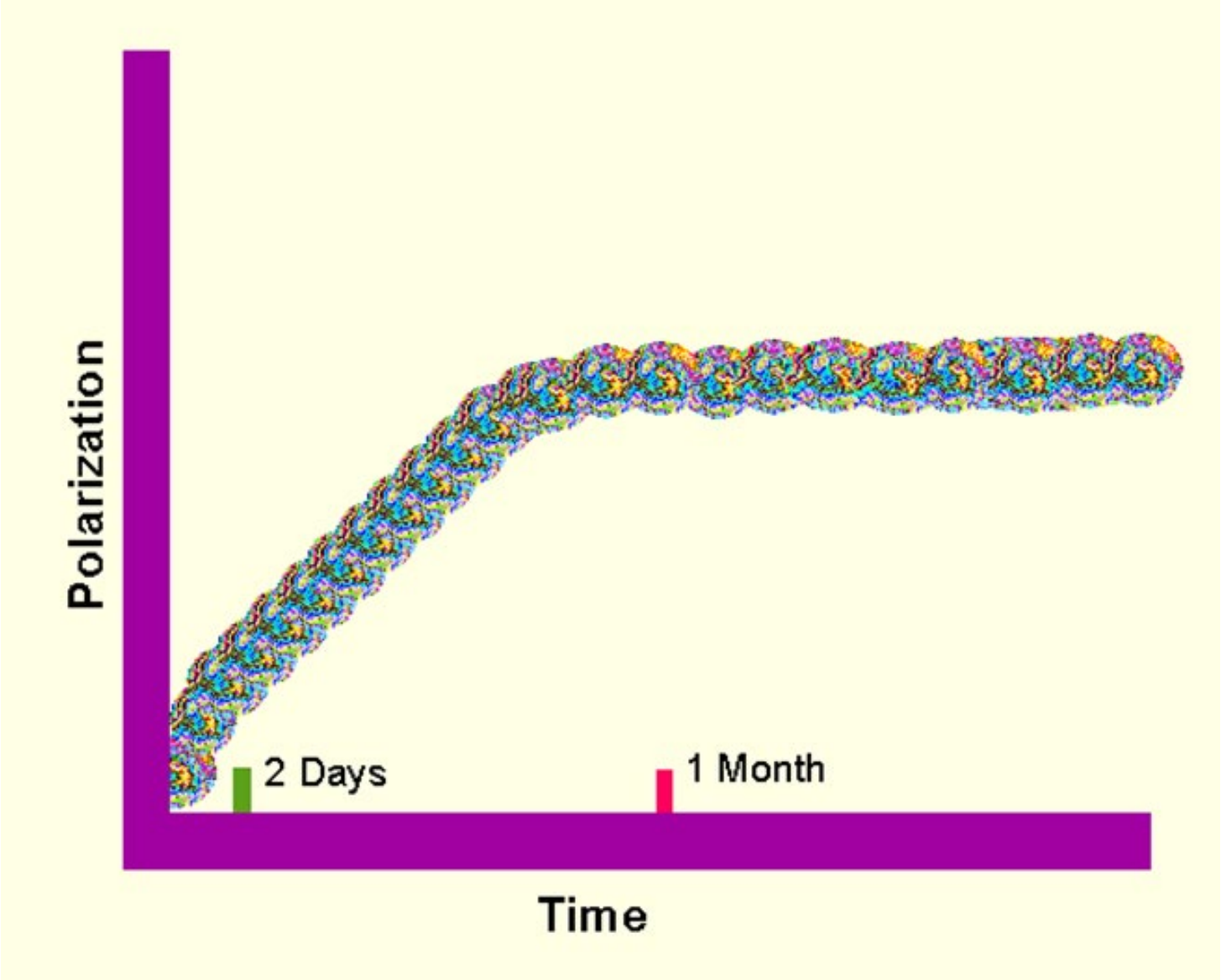
- Select site
- Measure polarized P/S (IR free)
- Shut off CP
- (Optional P/S readings during depolarization)
- Measure P/S after polarization dissipates

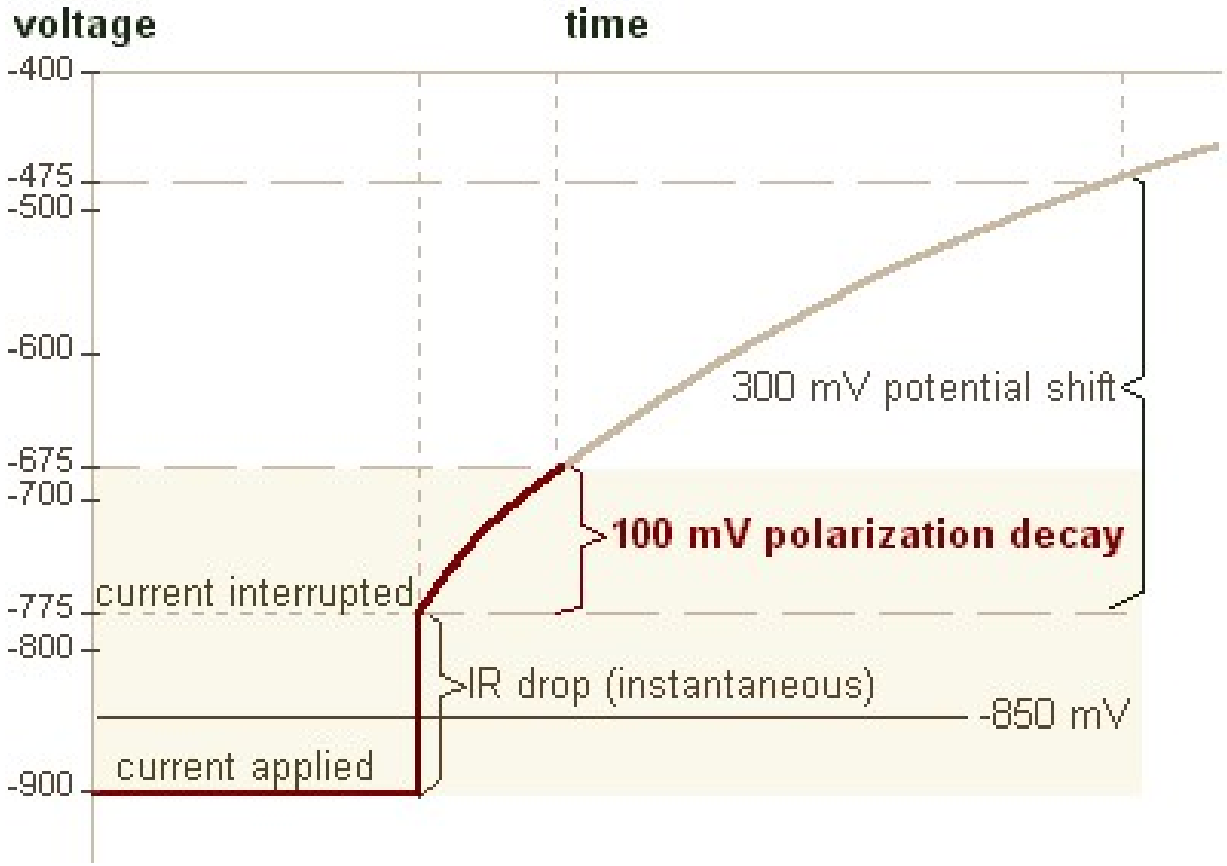
100 mV – Determine Shift

The polarization voltage shift must be determined by interrupting the protective current and measuring the polarization decay.

Formation of Polarization

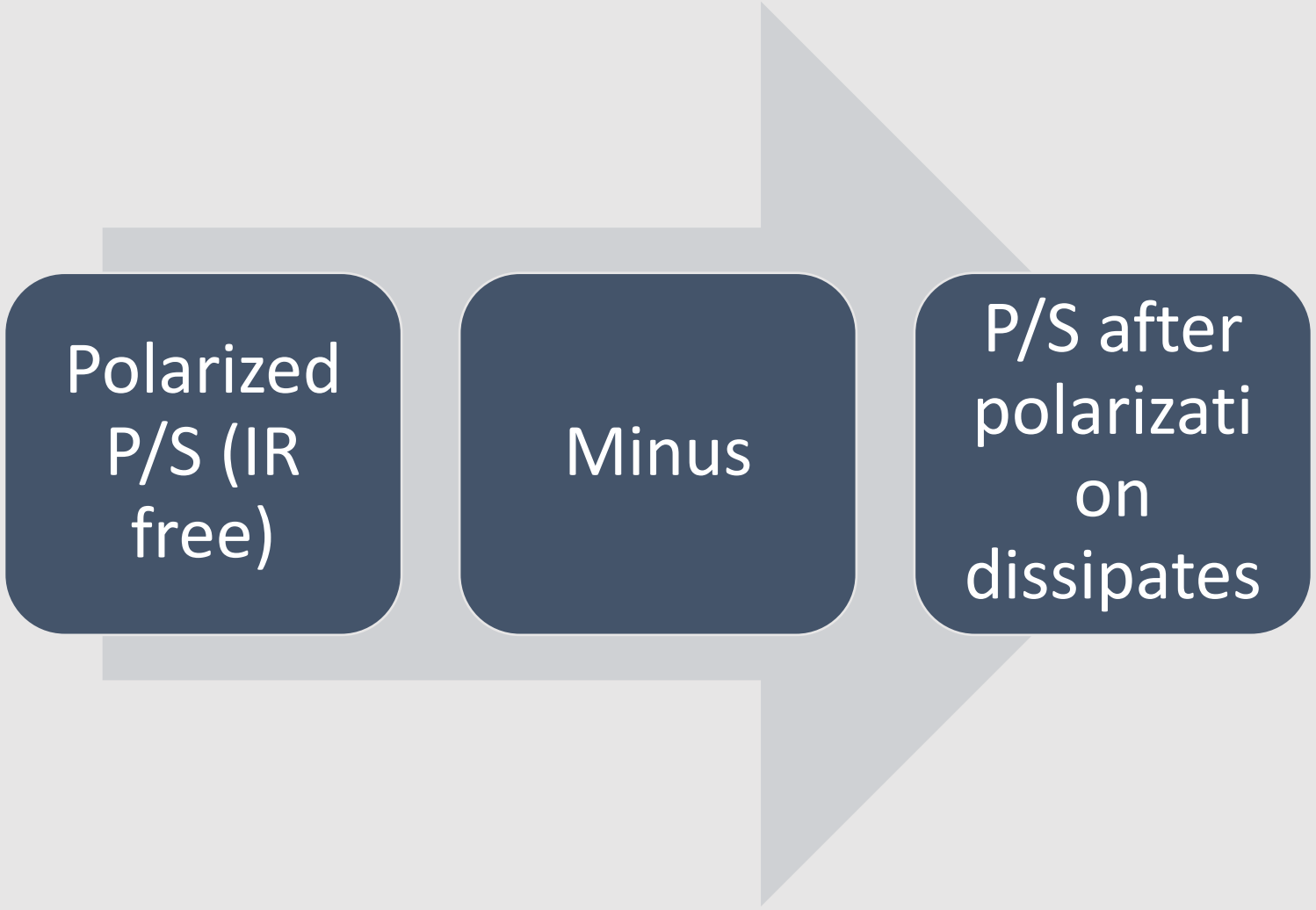
- The CP must be applied for long enough for the pipeline to reach its stable level of cathodic protection.
- The graph shows how polarization generally forms on a pipeline when cathodic protection is applied.





Cathodic Protection Shut Off

- The plot shows the typical changes that occur when the CP is removed from a polarized pipeline.
- Notice that the first rapid change is potential is IR drop. It is not included in the polarization measurement. Then the P/S potential drops over a period of time (1 or 2 days). This change is the polarization.



100 mV - Calculation

100 mV - Depolarization Time

Some pipelines depolarize quickly and others depolarize slowly.

The depolarization rate depends primarily on soil porosity and soil characteristics.

100 mV - Depolarization Time

95% of Polarization Lost

Most of the time within 15 minutes

- Some times within an hour
- Unusual to be more than 24 hours
- Very, very unusual to be more than 48 hours

100 mV - Depolarization Time

The potential shift time period stops when depolarization ends.

This is before corrosion of the clean steel surface commences.

100 mV - Advantages

The main advantage of the 100 mV polarization criterion is that less current is required to meet the criterion than the potential criterion.

100 mV - Disadvantages

The main disadvantage of the 100 mV polarization criterion is that more measurements are required.

300 mV Shift

A negative (cathodic) voltage shift of at least 300 millivolts.

Determination of this voltage shift must be made with the protective current applied, and in accordance with sections II and IV of this appendix.

300 mV Shift

Can be used for gas pipelines

Cannot be used for liquids pipelines

300 mV Shift - Procedure

- The steps in performing the 300 mV shift measurements include the following:
  - Select site
  - Measure static P/S
  - Apply CP
  - (Optional P/S readings during polarization)
  - Measure P/S after polarization complete

300 mV Shift - Time

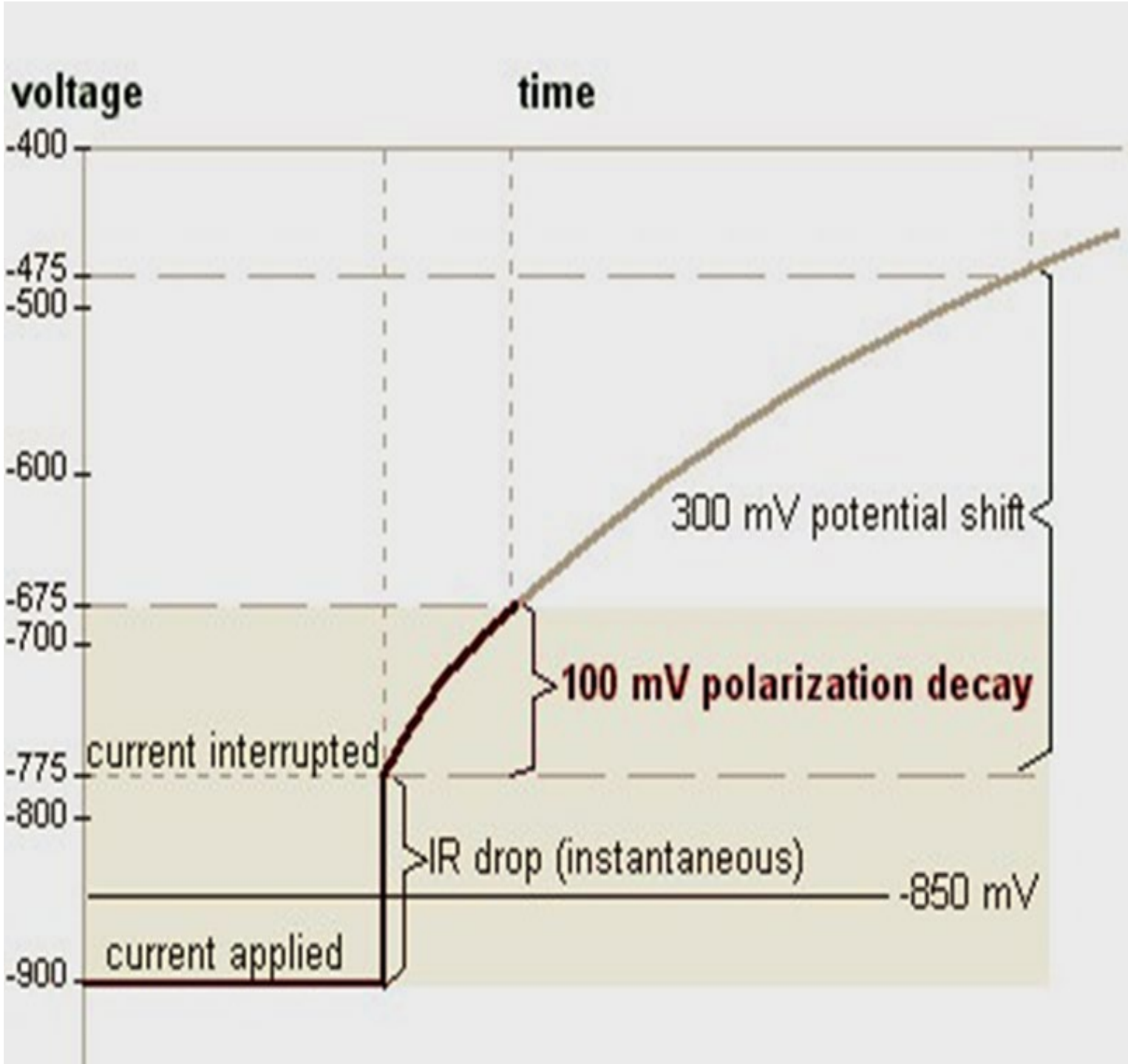
There must be a 300 mV difference between the native potential of the pipeline (before CP has been applied) and the measured potential after CP has been applied.

The measured potential must be made using a valid reference cell and IR drop must be considered.

- Rarely polarizes within days
- Often weeks or months
- Even longer if pipe is significantly rusted

100 mV Polarization vs. 300 mV Shift

- Note the 100 mV polarization is the difference between the polarized potential (IR free) and the depolarized potential.
- The 300 mV shift is the difference between the polarized potential (IR free) and the corrosion potential.



300 mV Shift - Interpretation

Measured potential shift from corrosion potential to polarized potential is equal to or more than 300 mV

300 mV Shift - Example

Static P/S before CP
-370 mV

P/S After CP (IR Free)
-490 mV

Polarization is equal to
120 mV

300 mV Shift Criterion
HAS NOT been met

300 mV Shift - Example

Static P/S before CP
-370 mV

P/S After CP (IR Free)
-700 mV

Polarization is equal to
330 mV

300 mV Shift Criterion
HAS been met

A voltage at least as negative (cathodic) as that originally established at the beginning of the Tafel segment of the E-log-I curve.

This voltage must be measured in accordance with section IV of this appendix.

E Log I

E Log I Criterion

Can be used for gas pipelines

Cannot be used for liquids pipelines

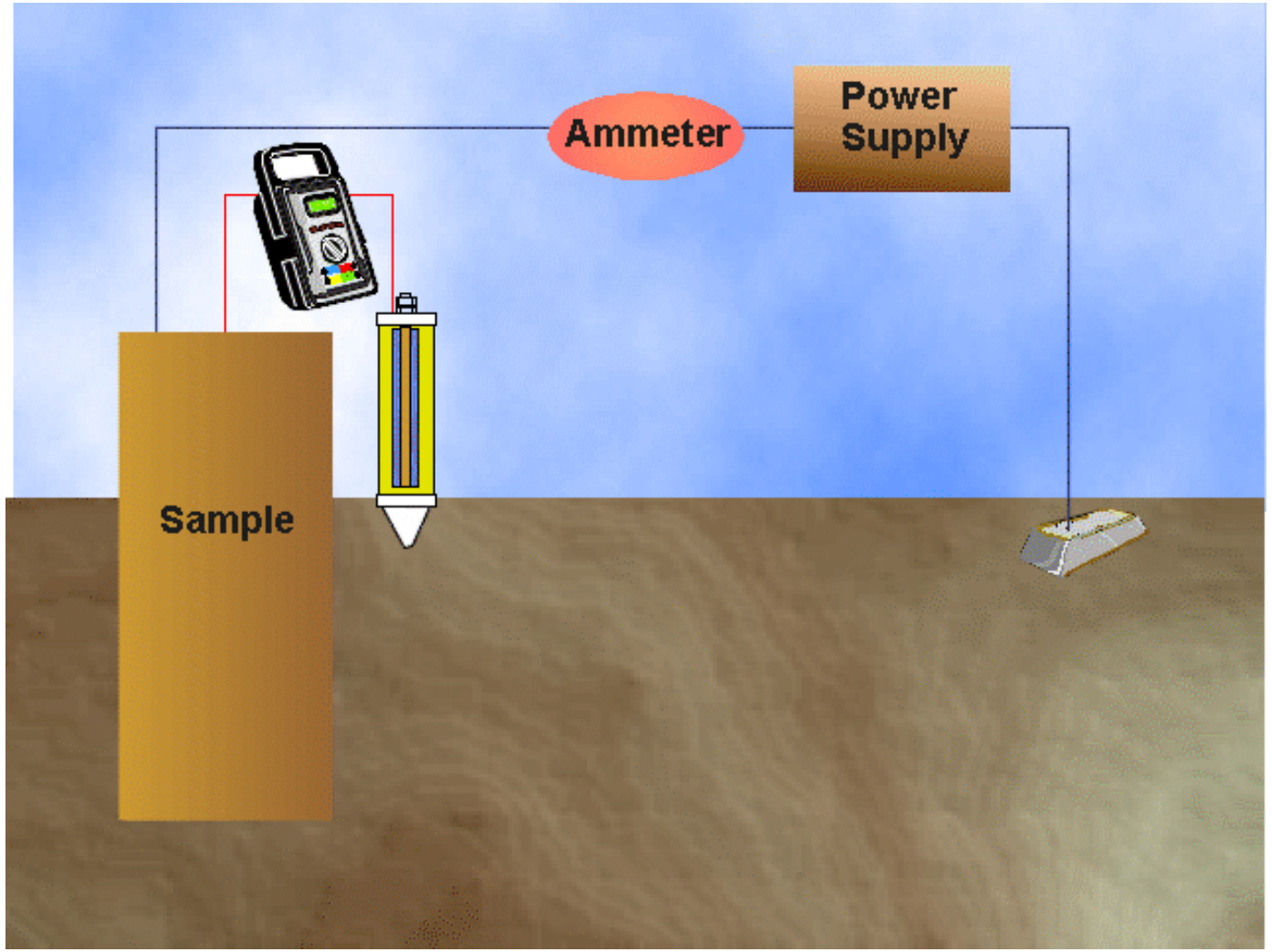
(No longer contained in NACE SP0169)

Determine Polarization Curve

Protection at Slope Change

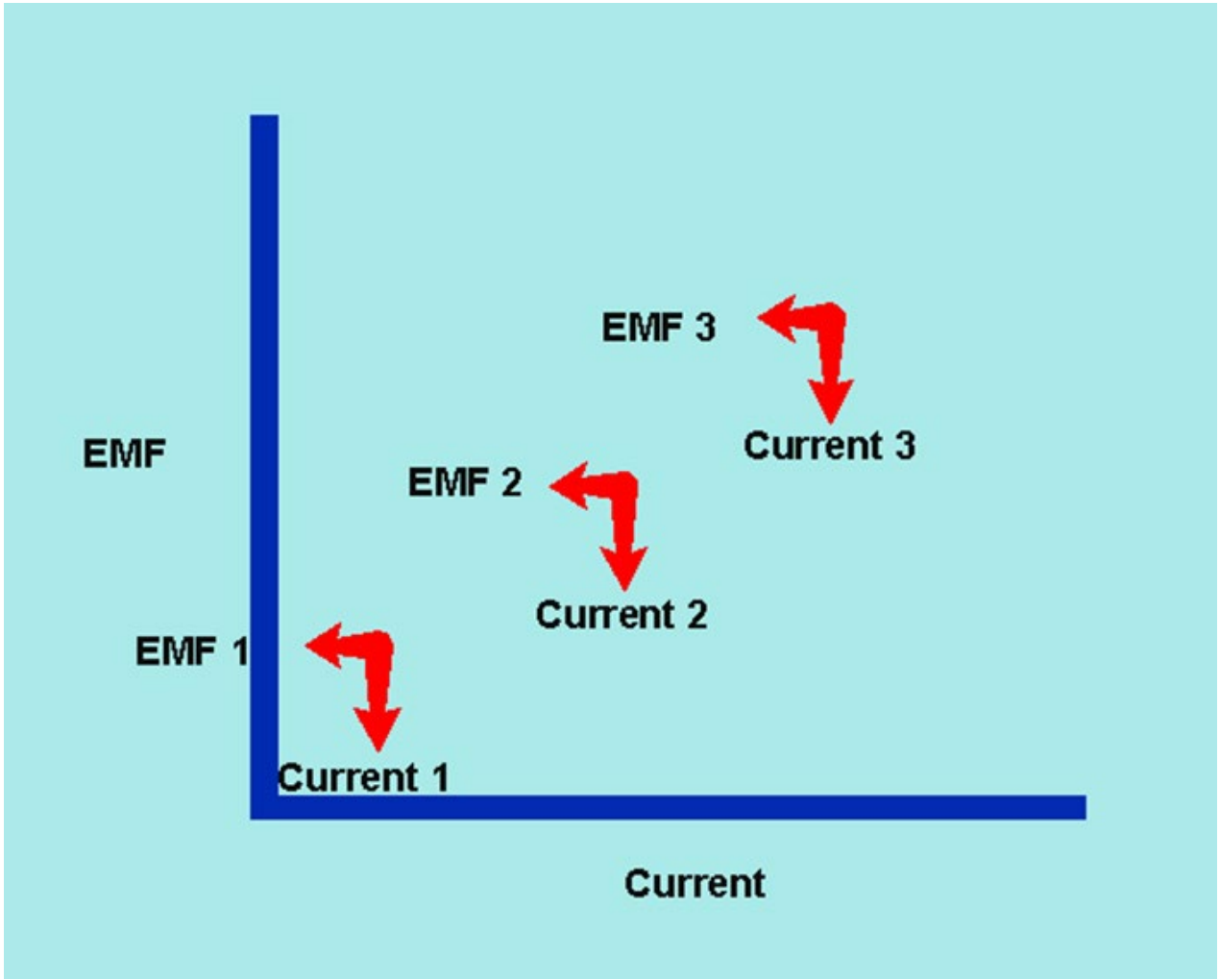
E Log I Criterion - Procedure

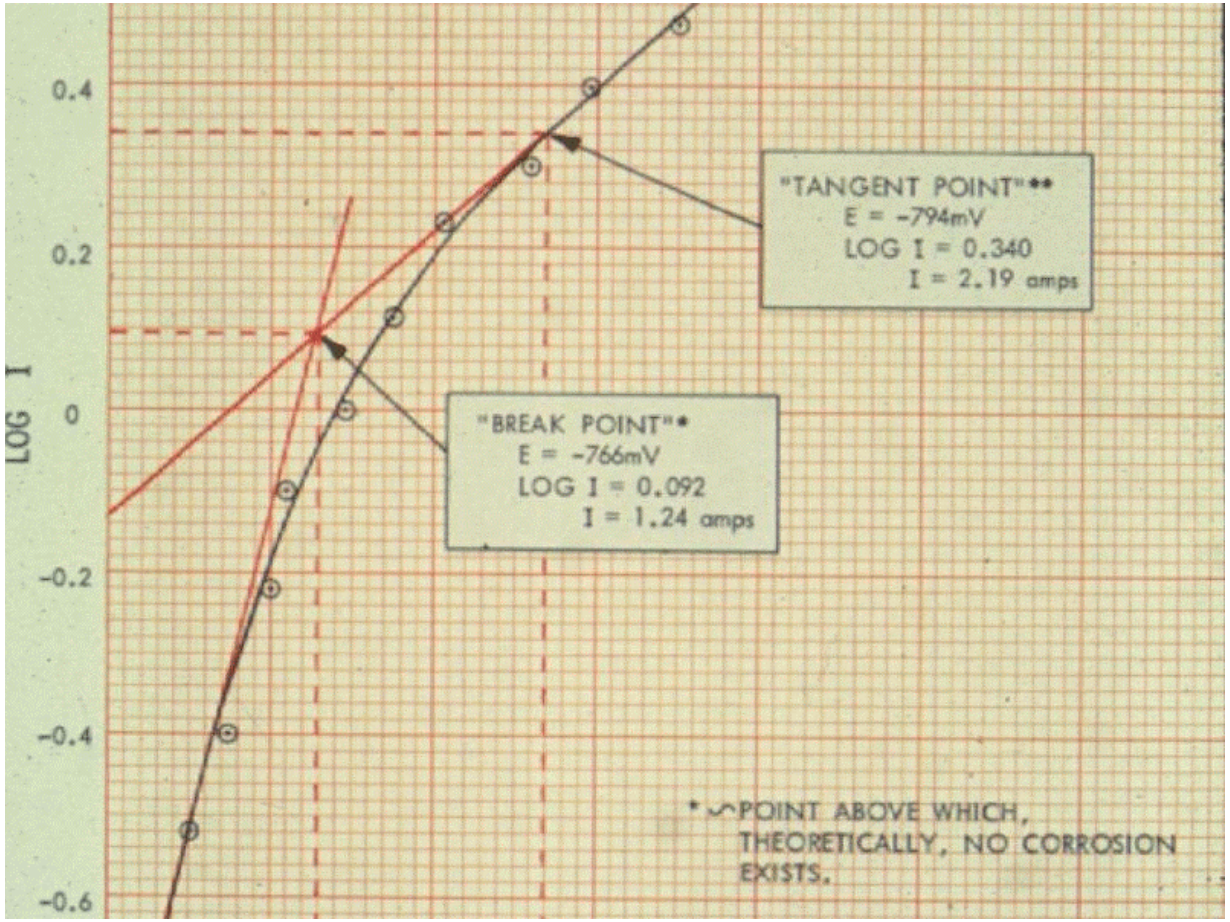
Polarization Curve



Determination of E Log I

- This criterion requires a series of measurements in order to determine the minimum current requirement.
- Current is applied using a temporary ground bed and a series of measurements are made, with a valid reference cell, while increasing the current.





Determination of E Log I

- A plot of voltage with respect to the log of current is created from the measurements.
- The Tafel Slope is the part of the curve in which the slope changes values. The point at which the slope changes is considered the current at which corrosion will be mitigated.

E Log I – Steady State

The operator of a pipeline using the E Log I criterion must wait at each step for polarization to reach steady state for accurate application of the criteria

Still Included in Appendix D of Part 192

No Longer Included in NACE SP0169

Net Current

Net Current Criterion

A net protective current from the electrolyte into the structure surface as measured by an earth current technique applied at predetermined current discharge (anodic) points of the structure.

Net Current Criterion

Current Flows Onto Pipe at All Points

or

Anode Installation Where Current Flows Off Pipe

Invalid Net Current

- General Corrosion
- Coated Pipe
- Under Concrete
- High Resistance Surface Layer

Coating Damage

§192.463(c) –

- The amount of cathodic protection must be controlled so as not to damage the protective coating or the pipe.

CP Criteria

The End!