"CARRYING OUT CIPL (CLOSE INTERVAL POTENTIAL LOG) AND DCVG (DIRECT CURRENT VOLTAGE GRADIENT) SURVEYS"

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Dehradun
May, 2008

"CARRYING OUT CIPL (CLOSE INTERVAL POTENTIAL LOG) AND DCVG (DIRECT CURRENT VOLTAGE GRADIENT) SURVEYS"

A thesis submitted in partial fulfilment of the requirement for the Degree of
Master of Technology
(Pipeline Engineering)

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UNIVERSITY OF PETROLEUM & ENERGY STUDIES

(ISO 9001:2000 Certified)

CERTIFICATE

This is to certify that the work contained in this thesis titled **"Carrying out CIPL (Close Interval Potential Log) and DCVG (Direct Current Voltage Gradient) Surveys"** has been carried out by **Akhil Pachaury** under my/our supervision during March/May 2008 and has not been submitted elsewhere for a degree.

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ABSTRACT

The pipeline being the national asset, corrosion collectively form a consensus on the issue of damage of the pipeline, which must be addressed judiciously keeping in mind the national interest and economic situation of India in the international area.

The pipeline industry is a very high investment industry. Fully implemented corrosion control can affect high dollar savings by reducing property loss, by reducing the cost of repairs, by avoiding catastrophic failures with loss of property and life, and by conservation of natural resources as the energy shortage crisis becomes ever more serious.

To ensure your pipeline will operate safely and reliable it's important to inspect it regularly. Pipeline coating is broad answer with respect to corrosion crisis, so coating inspection is big issue for industry like GAIL & IOCL which has big pipeline network.

To ensure the effectiveness of coating system or in other words in order to prevent the defects from developing further, it is required to inject energy into the system by means of continuous monitoring, review and making improvements in the system. Close interval potential logging (CIPL) and Direct current voltage gradient (DCVG) measurements over the pipeline are the tools that not only help to check the Pipeline integrity but also provide valuable information and data regarding health of pipeline coating for taking timely corrective actions.

In this project I am standing to inspect GREP (GAIL Rehabilitation Expansion Project) Pipeline with the help of CIPL survey followed DCVG survey. At that time I have located some coating defect and repair them according to there consequences.

In 10 km section first CIPL measures Pipe to Soil Potential (PSP) with the help of $Cu/CuSO_4$ Electrode, readings are implemented on Graph. These graphs will decide the suspected location

or locations for DCVG survey. CIPL measures the level of protection and DCVG locate exact location and size of defect.

Patch with mastic application and Cold applied tape are used to repair these defects, densolene tape is popularly used for coating repair. Patch with mastic application can be used in all types of defects whether minor, moderate and severe, but cold applied tape used at the time of large defect like coating disbondment etc.

All Actions are being planned and taken up for implementation of suitable corrective measures at GAIL (India) Limited based on the above recommendations. I am standing with GAIL (India) Strategy for completed my project.

ACKNOWLEDGEMENT

I am greatly indebted to my guides **Mr. R. P. Shriwas,** Course Co-ordinator, **UPES**, and **Mr. Ayush Gupta,** senior manager (Pipeline), *GAIL India* Ltd., Agra, for providing me an opportunity to work under their guidance. Their unflinching support, suggestions and directions have helped in smooth progress of the project work. They have been a constant source of inspiration in all possible ways for successful completion of my project work.

I acknowledge my sincere gratitude to **Mr. R. P. Shriwas,** Senior Adjunct Professor, **UPES**, and **Mr. Ayush Gupta,** Senior manager, *GAIL India* Ltd., for having me provided all the facilities to complete this dissertation work successfully.

I also acknowledge my sincere gratitude to employees of the pipeline department in GAIL India, Agra especially **Mr. Shushant Gautam** Dy. Manger (Pipeline) and **Mr. Gaurav Jain** Dy. Manager (Mechanical) for their support and cooperation throughout my project work.

I also acknowledge the help rendered by **HR Dept** of GAIL India especially **Mr. R.K Bhilwariya** and all other non-teaching staff of the **Department of Pipeline Engineering, UPES and Mr. B.P Pandey, Dean (College of Engineering).**

Finally, I would like to thank my family for their constant support. It would have been impossible for me to accomplish this study without their support.

AKHIL PACHAURY

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NOMENCLATURE

MMSCM	- Million square cubic meter
HBJ	- Hazira- Bijaipur- Jagdishpur pipeline
GREP	- Gas Rehabilitation & Expansion Project
CIPL	- Close Interval Potential Logging
DCVG	- Direct Current Voltage Gradient
GNP	- Gross National Product
CP	- Cathodic Protection
ICCP	- Impressed Current Cathodic Protection
O&M	- Operations & Maintenance
AC	- Alternating Current
DC	- Direct Current
CSE	- Copper Sulphate Electrode
mV	- millivolt
NACE	- National Association of Corrosion Engineers
RP	- Recommended Practice
TM	- Test Method
N/mm^2	- Newton per square millimeter
CCVT	- Closed Cycle Vapor Turbo-Generator
GPS	- Global Positioning System
PSP	- Pipe to Soil Potential
SV	- Sectioning Valve
IP	- Intermediate Pigging
RR	- Radio Repeater Station
TEG	- Thermo-electric Generator

Technical Terms

Anion: A negatively charged ion that migrates through the electrolyte toward the anode under the influence of a potential gradient.

Anode: The electrode of an electrochemical cell at which oxidation occurs. Electrons flow away from the anode in the external circuit. Corrosion usually occurs and metal ions enter the solution at the anode.

Attenuation: Electrical losses in a conductor caused by current flow in the conductor.

Backfill: Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system.

Barrier Coating: (1) A coating that has a high resistance to permeation of liquids and/or gases. (2) A coating that is applied over a previously coated surface to prevent damage to the underlying coating during subsequent handling.

Cathode: The electrode of an electrochemical cell at which reduction is the principal reaction. Electrons flow toward the cathode in the external circuit.

Cathodic Disbondment: The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

Cathodic Protection: A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electrochemical cell.

Cation: A positively charged ion that migrates through the electrolyte toward the cathode under the influence of a potential gradient.

Coating: A liquid, liquefiable, or mastic composition that, after application to a surface, is converted into a solid protective, decorative, or functional adherent film.

Coating System: The complete number and types of coats applied to a substrate in a predetermined order. (When used in a broader sense, surface preparation, pretreatments, dry film thickness, and manner of application are included.)

Corrosion: The deterioration of a material, usually a metal, that results from a reaction with its environment.

Corrosion Resistance: Ability of a material, usually a metal, to withstand corrosion in a given system.

Cracking (of Coating): Breaks in a coating that extends through to the substrate.

Current Density: The current to or from a unit area of an electrode surface.

Depolarization: The removal of factors resisting the current in an electrochemical cell.

Electrochemical Cell: A system consisting of an anode and a cathode immersed in an electrolyte so as to create an electrical circuit. The anode and cathode may be different metals or dissimilar areas on the same metal surface.

Electrode: A conductor used to establish contact with an electrolyte and through which current is transferred to or from an electrolyte.

Electrolyte: A chemical substance containing ions that migrate in an electric field.

Fouling: An accumulation of deposits. This includes accumulation and growth of marine organisms on a submerged metal surface and the accumulation of deposits (usually inorganic) on heat exchanger tubing.

Galvanic Anode: A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

Galvanic Corrosion: Accelerated corrosion of a metal because of an electrical contact with a more noble metal or nonmetallic conductor in a corrosive electrolyte.

Groundbed: One or more anodes installed below the earth's surface for the purpose of supplying cathodic protection.

Deep Ground bed: One or more anodes installed vertically at a nominal depth of 15m(50 ft) or more below the earth's surface in a drilled hole for the purpose of supplying cathodic protection.

Half-Cell: A pure metal in contact with a solution of known concentration of its own ion, at a specific temperature, develops a potential that is characteristic and reproducible; when coupled with another half-cell, an overall potential that is the sum of both half-cells develops.

Holiday: A discontinuity in a protective coating that exposes unprotected surface to the environment.

Impressed Current: An electric current supplied by a device employing a power source that is external to the electrode system. (An example is direct current for cathodic protection.).

Polarization: The change from the open circuit potential as a result of current across the electrode/electrolyte interface.

Primer: A coating material intended to be applied as the first coat on an uncoated surface. The coating is specifically formulated to adhere to and protect the surface as well as to produce a suitable surface for subsequent coats.

Remote Earth: A location on the earth far enough from the affected structure that the soil potential gradients associated with currents entering the earth from the affected structure are insignificant.

Stray-Current Corrosion: Corrosion resulting from current through paths other than the intended circuit, e.g., by any extraneous current in the earth.

Stress Corrosion Cracking: Cracking of a material produced by the combined action of corrosion and tensile stress (residual or applied).

Sacrificial Protection: Reduction of corrosion of a metal in an electrolyte by galvanically coupling it to a more anodic metal (a form of cathodic protection).

CHAPTER 1

INTRODUCTION

1.1 GAIL Overview

GAIL (India) Ltd. (earlier Gas Authority of India Ltd), India's principal gas transmission and marketing company, was set up by the Government of India in August 1984 to create gas sector infrastructure for sustained development of the natural gas sector in the country.

GAIL (India) Ltd. operates over 5500 Km of pipelines in all the four regions of the country, supplying about 62 million cubic meter (MMSCM) of gas per day as fuel to power plants, as feedstock for gas based fertilizer plants and other industrial units to meet their energy and process equipments. The backbone of the natural gas pipeline network is the 1900 km long HBJ pipeline. Further, GAIL is now operating the world's longest exclusive LPG pipeline from Jamnagar to Loni with a total length of 1240 kms.

GAIL today has reached new milestones with its strategic diversification into Petrochemicals, Telecom and Liquid Hydrocarbons besides gas infrastructure. The company has also extended its presence in Power, Liquefied Natural Gas re-gasification, City Gas Distribution and Exploration & Production through equity and joint ventures participations.Incorporating the new-found energy into its corporate identity, Gas Authority of India was renamed GAIL (India) Limited on November 22, 2002.

The Company operates six natural gas processing plants with an installed capacity to produce a total of 9,61,000 tonnes of Liquefied Petroleum Gas per year. Four of the Company's natural gas processing plants are located along the HBJ Pipeline - two at Bijaipur in Madhya Pradesh and one each at Vaghodia in Gujarat and Pata (Auraiya) in Uttar Pradesh. The other two natural gas processing plants are located at USAR near Mumbai in Maharashtra and Lakwa in Assam.

The Company also operates a petrochemical complex at Pata in Uttar Pradesh with an installed capacity to produce 2,60,000 tonnes of polyethylene and 10,000 tonnes of butane per year.

The 2800-km Hazira-Vijaipur-Jagdishpur (HVJ) pipeline became operational in 1991. During 1991-93, three LPG plants were constructed and some regional pipelines acquired, enabling GAIL to begin its regional gas distribution in various parts of India.

GAIL began its city gas distribution in Delhi in 1997 by setting up nine CNG stations, catering to the city's vast public transport fleet.

Gail's plans include an investment of over Rs.10,000 crore over the next 10 years mainly in the areas of natural gas & LPG transmission and distribution infrastructure, import of LNG. Its marketing and distribution, gas processing, petrochemicals, exploration & production of gas and non-conventional gas. GAIL is also considering tying up with major companies having access to right of way for providing a nationwide integrated communication grid for Telecom Sector.

Every year new pipelines are being added to the existing infrastructure and from an era of cross country pipelines, we are entering into an era of cross border or inter continental pipelines. With the pipelines getting older, the maintenance and rehabilitation costs are increasing along with the business stakes of the various oil and natural gas companies. When the pipelines get older, maintenance and rehabilitation is the solution to enhance the availability and the reliable life of the system. However, to ensure profit maximization no company can afford high operation and maintenance costs too. What is required to keep a control over the mounting costs on maintenance and rehabilitation is not just the use of good quality material and workmanship at the time of pipeline construction but more importantly a regular and routine health check up of the system.

1.2 Purpose

The primary purpose of this project is to provide information and guidance for repairing and locating coating defects in pipeline coating systems installed at GREP Pipeline of GAIL (India) Ltd. Proper maintenance resulted reduction in potential corrosion in pipeline.

GREP (GAIL Rehabilitation Expansion Project) Pipeline has 505 km length, potential corrosion reduction is beneficial step towards maintain pipeline integrity.

I am associating in this project study of AGRA region GREP pipeline with 'Carrying out CIPL (Close Interval Potential Log) and DCVG (Direct Current Voltage Gradient) Surveys' which focused on different coating survey scheduled once in five years. In my project i am using CIPS and DCVG in combination to detect coating faults.

The project shows how the calculation is carrying for coating sevirty wheather it's minor, Moderate and severe.
A comprehensive systematic Locating coating defect system provide means to improve safey of pipleine system.such a manage the integrity of pipeline upto large extent.

CHAPTER 2
LITERATURE REVIEW

2.1 Corrosion

A general definition of corrosion is the deterioration of the substance, or its properties, because of a reaction with its environment. Most metal corrodes when they are exposed with certain environment.

In simpler words, "The process by which metals convert to the lower-energy oxides is called corrosion".

Corrosion means the breaking down of essential properties in a material due to chemical reactions with its surroundings. In the most common use of the word, this means a loss of electrons of metals reacting with water and oxygen. Weakening of iron due to oxidation of the iron atoms is a well-known example of electrochemical corrosion.

Corrosion Fundamentals is described in Appendix A.

Regardless of what form it takes, corrosion is inevitable. However, it can be slowed or temporarily stopped. There are basic five forms of corrosion control:-

1. Change of material
2. Change of environment
3. Barrier film
4. Improved design
5. Electrochemical techniques

2.2 Cost of Corrosion – Study Goals

- Determine the cost of corrosion control methods and services
- Determine the cost of corrosion for specific industry sectors
- Extrapolate individual sector costs to a national total corrosion cost
- Assess barriers to progress and effective implementation
- Develop strategies for realizing cost savings

Previous Studies

- 1950 H.H. Uhlig – US Study: 2.1% of GNP
- 1970 T.P. Hoar – UK Study: 3.5% of GNP
- 1974 Japan Study: 1.2% of GNP
- 1975 Battelle/NBS – U.S. Study: 4.5% of GNP

Typical Corrosion Related Costs: Gas & Liquid Transmission Pipelines

- Annual ICCP System Investment - $40 Million
- Annual Sacrificial CP Investment - $9 Million
- Annual O&M Costs - $2.4 Billion - $4.8 Billion

Total Cost of Corrosion

Estimated Cost	B$	138
Extrapolated Cost	B$	236
Actual Cost	>B$	550

2.3 Pipeline Corrosion Mechanism

There are certain conditions that must occur before a corrosion cell can function:

- There must be an anode and a cathode
- There must be an electrode potential between the anode and cathode; this potential can result from a variety of conditions on pipelines.
- There must be a metallic path electrically connecting the anode and cathode, normally this will be the pipeline itself.
- The anode and cathode must be immersed in an electrically conductive electrolyte that is ionized and some of the water molecules (H_2O) are broken down into positively charged hydrogen ion (H^+) and a negatively charged hydroxyl ion (OH^-). The usual soil moisture or water surrounding pipelines normally fulfills this condition.

Once all the above condition is met: an electrical current flows and metals are consumed at the anode. Corrosion protection can thus be achieved by negative one of the above conditions.

The amount of metal that is removed is directly proportional to the amount of current flow. One ampere of direct current discharged into the usual soil electrolyte can remove approximately 8 kgs of steel in one year. This is based on the electrochemical equivalent of the metal involved: metals other than steel are removed at different rates.

Pipelines are generally well protected when cared for, through proper maintenance planning. When proper design and maintenance are in place, corrosion currents are not often found in pipeline system that even approach 1 ampere at one location. In most cases the currents found and measured are recorded as thousandths of an ampere (mill ampere). But even this small amount can cause metal degradation. For example, the duration of one year time interval, a single milliamp. If restriction to a few small points of discharge can cause seven, 6 mm (1/4 inch) diameter holes in a 2-inch steel pipe of standard wall thickness. In a well protected pipeline network however current discharge is usually distributed over wide areas so the rate of penetration is not necessarily as rapid as the given example.

2.4 Corrosion Mitigation Technique:

The two principle methods of external corrosion control are:

- Coating
- Cathodic Protection

2.4.1 Coating

Coating is the process to use an external agent on the parent material to protect it from the external environment and increase the life of the material.
First attempts to control pipeline corrosion relied on the use of coating materials, with the reasoning that if the pipeline metal could be isolated from contact with the surrounding earth, no corrosion could occur. Furthermore, a coating would be completely effect as a means to stopping corrosion if:

- The Coating material is an effective electrical insulator.
- It can be applied with no breaks and remain so during the backfilling process.
- It is an initially perfect film that remains so with time.

Why Coat the Pipe?
Essentially this is because of the high cost of pipeline repair in the field due to corrosion if adequate protection is not initially taken prior to the construction of the pipeline. Even more sensitive these days is the environmental impact of having leaking pipes and the safety regulations demand sound coating process to ensure long life of the pipeline. Field repairs are undesirable and costly and can be eliminated with a high quality coating practice after pipe manufacture.

2.4.2 Cathodic Protection

Cathodic protection is a method to reduce corrosion by minimizing the difference in potential between anode and cathode. This is achieved by applying a current to the structure to be protected (such as a pipeline) from some outside source. When enough current is applied, the whole structure will be at one potential; thus, anode and cathode sites will not exist. Cathodic protection is commonly used on many types of structures, such as pipelines, underground storage tanks, locks, and ship hulls.

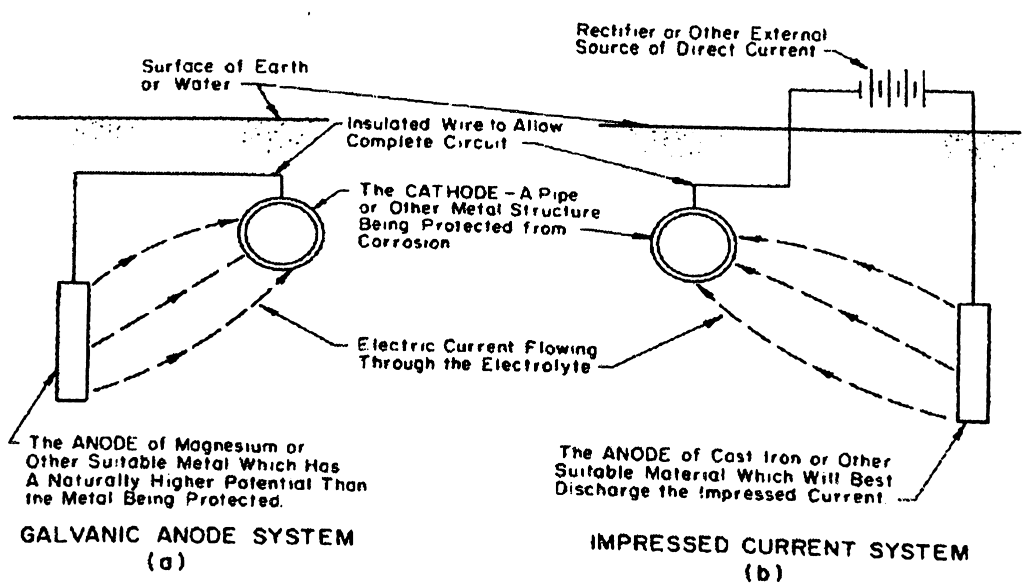


Fig 2.1 Cathodic Protection System (Galvanic and Impressed Current)

The principal methods for mitigating corrosion on underground pipelines are coatings and Cathodic Protection. A primary function of a coating on a cathodically protected structure is to reduce the surface area of exposed metal on the pipeline, thereby reducing the current necessary to cathodically protect the metal.
"Cathodic Protection" is defined as **"a reduction of the corrosion rate by shifting the potential of the structure toward a less oxidizing potential by applying an external current."**

Two types of cathodic protection system is used

1. Sacrificial or Galvanic Anode System
2. Impressed Current system

Both systems are shown in fig 2.1

2.5 How we will Locate Coating Defects

Pipeline is subjected to corrosion. To minimize the corrosion we used coating and cathodic protection. Coating is effective way to miimize the corrosion.but it's not 100% answer of corrosion problem, so we generally prfer coating and cathodic protection sytem in combined form.
At the defect location cp current will be discharged so we can predict coating defect with the help of survey instrument. So generally four types of survey carried out for that purpose:

1. Close Interval Potential

2. DC Voltage Gradient

3. Pearson survey

4. Signal Attenuation survey

All survey we will discussed in detail in chapter 4.

2.6 Desirable coating Material characteristics

Over the pass 50 years, pipeline have been coated with a variety of protective coatings with the wide performance.
Coatings, is a comprehensive guide to pipe coatings, and is required reading for a better understanding of their importance. NACE Standard lists the following desirable characteristics of coatings

1. Effective electrical insulator: Because soil corrosion is an electrochemical process, a pipe coating has to stop the current flow by isolating the pipe from its installed environment/electrolyte. To assure a high electrical resistance, the coating should have a high dielectric strength.

2. Effective moisture barrier: Contrary to the theory that water absorption is good because it increases the effectiveness of CP, water transfer through the coating may cause blistering and will contribute to corrosion by prohibiting isolation.

3. Applicability: Application of the coating to the pipe must be possible by a method that will not adversely affect the properties of the pipe and with a minimum of defects.

4. Ability to resist development of holidays with time: After the coating is buried, two areas that may destroy or degrade coatings are soil stress and soil contaminants. Soil stress, brought about in certain soils that are alternately wet and dry, creates forces that may split or cause thin areas. To minimize this problem, one must evaluate the coating's abrasion resistance, tensile strength, adhesion, and cohesion. The coating's resistance to chemicals, hydrocarbons, and acidic or alkaline conditions should be known for evaluating their performance in contaminated soils.

5. Good adhesion to pipe surface: The pipe coating requires sufficient adhesion to prevent water ingress or migration between the coating and the pipe, along with cohesion to resist handling and soil stress. Soil stress is the main cause of pipe coating failure. "Soil stress effects can be seen on flexible PE coatings with elastomeric adhesives as a characteristic wrinkling. However, other types of coatings can fail by blistering fusion-bonded epoxy (FBE) or fatigue cracking coal tar enamel (CTE) Effectiveness of Coatings as a Means of Corrosion Control that are exacerbated by soil movement: resistance to shear must be combined with a measurement of the resistance of the backing material (or outer jacket) to deformation and tensile force. The two properties combine to determine the ability of a pipeline coating to resist damage to soil movement." Soil stress resistance is measured by shear resistance, not by peel strength.

6. Ability to withstand normal handling, storage (UV degradation), and installation: The ability of a coating to withstand damage is a function of its impact, abrasion, and flexibility properties. Pipe coatings are subject to numerous handlings between application and backfill. Their ability to resist these forces vary considerably, so those factors need to be evaluated to know if any special precautionary measure should be used. Ultraviolet rays can be very destructive to pipe coatings. Storage life may vary from6 months to 5 years so resistance to ultraviolet is a very important consideration.

7. Ability to maintain substantially constant electrical resistivity with time: The effective electrical resistance of a coating per average square foot depends on the following.

- Resistivity of the coating material
- Coating thickness
- Resistance to moisture absorption
- Resistance to water vapor transfer
- Frequency and size of holidays
- Resistivity of the electrolyte
- Bond or adhesion of coating

If the effective resistance is unstable, the CP required may double every few years. It is easy to obtain misleading higher resistance measurements if the soil has not settled around the pipeline and if the moisture has permeated to any holidays in the coating. Experience is necessary to evaluate the validity of these resistance measurements and to use them for designing the CP system.

8. Resistance to disbonding: Because most pipelines are cathodically protected, the coating must be compatible with CP. The amount of CP required is directly proportional to the quality and integrity of the coating. The negative aspects of CP are that it may drive water through the coating and that the interface bond surrounding a holiday may have a tendency to disbond. No coating is completely resistant to damage by CP. When large amounts of current are required, stray current and interference problems may arise. This emphasizes the importance of proper coating selection, application, and installation.

9. Ease of repair: Because the perfect pipe coating does not exist, we can expect to make some field repairs as well as field-coating of the weld area. Check for compatibility and follow the manufacturer's recommendations. A field repair is never as good as the original coating. Tight inspection should be maintained.

10. Nontoxic interaction with the environment: Some coating materials have been modified, restricted, or banned because of environmental and health standards. Asbestos felts and primers with certain solvents have required substitution of glass reinforcements and modification of solvents; changes in fusion-bonded epoxy powders to eliminate carcinogenic agents have also been necessitated by health and environmental concerns. This has been a major influence of change on today's pipe coatings.

2.7 Different types of coating in pipeline

Pipe Coating	Desirable characteristics	Limitations
Coal tar enamels	• 80 + Years of use • Minimum holiday susceptibility • Low current requirements • Good resistance to cathodic disbondment • Good adhesion to steel	• Limited manufacturers • Limited applicators • Health and air quality concerns • Change in allowable reinforcements
Mill-applied tape system	• 30 + years of use • Minimum holiday susceptibility • Ease of application • Good adhesion to steel • Low energy required for application	• Handling restrictions—shipping and installation • UV and thermal blistering—storage potential • Shielding CP from soil • Stress disbondment

Crosshead-extruded polyolefin with asphalt/butyl adhesive	• 40 + years of use • Minimum holiday susceptibility • Low current requirements • Ease of application • Non polluting • Low energy required for application	• Minimum adhesion to steel • Limited storage (except with carbon black) • Tendency for tear to propagate along pipe length
Dual-side-extruded polyolefin with butyl adhesive	• 25 years of use • Minimum holiday susceptibility • Low current requirements • Excellent resistance to cathodic disbondment • Good adhesion to steel • Ease of application • Nonpolluting • Low energy required for application	• Difficult to remove coating • Limited applicators
Fusion-bonded	• 35 + years of use • Low current requirements • Excellent resistance to cathodic disbondment • Excellent adhesion to steel • Excellent resistance to hydrocarbons	• Exacting application parameters • High application temperature • Subject to steel pipe • surface imperfections • Lower impact and abrasion resistance • High moisture absorption
Multi-layer epoxy/ extruded polyolefin systems	• Lowest current requirements • Highest resistance to cathodic disbondment • Excellent resistance to hydrocarbons • High impact and abrasion resistance	• Limited applicators • Exacting application parameters • Higher initial cost • Possible shielding of CP current

Table: 2.1 Different types of coating

2.8 Selection of Coating Material

The effectiveness of a coating is dependent not only on its characteristics but also on using proper application procedures and protecting the coating during and after installation. Besides having a range of properties, selection of coating material depends on the following points:

- Type of environment
- Accessibility of pipeline
- Operating temperature of pipeline
- Ambient temperatures during application, installation
- Geographical and physical location
- Type of coating on existing pipeline
- Handling and storage
- Installation methods
- Pipe surface preparation requirements
- Safety characteristics
- Shop/field application and repair attributes.
- Surface preparation requirements.
- Physical performance requirements.
- Cost

In selecting a coating system for a given pipeline project, one of the most important characteristics to design for is stability. By this we mean a coating combination that will have a high electrical resistance after the pipeline has been installed and the backfill stabilized and will lose the least electrical resistance over time.
Those characteristics are important in any event but particularly so where CP is used to supplement the coating. When used with an unstable coating, a CP system that is fully adequate during the early life of a pipeline may no longer provide full protection as the coating deteriorates (as indicated by a reduction in the effective electrical resistance of the coating), which will require additional current. This means that continued expenditures will be necessary for additional CP installations. The overall economics of the coating plus CP concept are adversely affected by poor coating performance.

Coating Economics

Here we already emphasized that the most favorable coating system for any given pipeline is the most stable of those available—that is, the coating system with electrical and mechanical characteristics that will deteriorate at the slowest rate with time under the specific installation conditions. Such a coating used with a CP system will be the most economical combination.

Even the most stable pipeline coating system selected will suffer some deterioration with time. Designing and constructing the initial CP system with sufficient reserve capacity to allow for the expected increased current requirements from anticipated coating degradation will result in overall cost savings.

This saving tends to be greater in the case of rectifier installations where the cost of providing additional current output capacity can be substantially less than in the case of galvanic anode installations.

The direct cost of the installations will be a function of the electrical resistivity of the coating used. An excellent stable coating properly applied should have a high electrical resistance. Current requirements should be so low that the cost of providing additional capacity will be minimal. On the other hand, a coating initially having a substantially lower electrical resistivity will require correspondingly greater investments for CP and the additional cost for reserve capacity becomes much more significant.

A – Asphalt/ Coal tar : 1940 to 1970	
Advantage: • Easy to apply • Soil stress has been an issue • Limitation at low application temperatures • Environment and exposure concerns	Disadvantage: • Subject to oxidation and cracking • Soil stress has been an issue • Limitation at low application temperatures • Environment and exposure concerns • Association with corrosion and stress crack corrosion failure
B – Tape wrap (Two layer): 1960 to Present	
Advantage: • Simple Application	Disadvantage: • Poor shear strength resistance. • Many documented failures related to corrosion and stress crack corrosion • Shielded of cathodic protection • Adhesives subject to biodegradation
C – Two layer extruded polyethylene: 1960 to Present	
Advantage: • Excellent track record • Good handling	Disadvantage: • Limited temperature range • Poor shear stress resistance • Limited pipe size (< 24in.[610mm] outside diameter)
D – Fusion-bonded epoxy: 1975 to Present	

Advantage: • Excellent adhesion and corrosion resistance • Does not shield cathodic protection	Disadvantage: • Low impact resistance • High moisture absorption and permeation
E – Three-layer polytefin: 1975 to Present	
Advantage: • Excellent combination of properties	Disadvantage: • Best suited for electrical resistance welded pipes • High thickness to eliminate weld tenting
F – Composite Coating: 1990 to Present	
Advantage: • Excellent combination properties	Disadvantage: • Suitable only for large diameter pipes and is not designed for small diameter pipes (<406mm OD) • Conforms well to external raised weld profiles

Table: 2.2 Advantage and Disadvantage of main coating types used for pipeline protection

CHAPTER 3

THEORTICAL DEVELOPMENT

3.1 General

The management of pipelines presents challenges that are quite unique. Their long length, high value, high risk and often difficult access conditions, require continuous monitoring and an optimization of the maintenance interventions. The main concern for pipe-line owners comes from possible leakages that can have a severe impact on the environment and put the pipeline out of service for repair. Leakages can have different causes, including excessive deformations caused by earthquakes, landslides or collisions with ship anchors, corrosion, wear, material flaws or even intentional damaging.

3.2 Pipeline System Monitoring

The other tool used to validate the integrity of a pipeline is an intelligent pig survey. The intelligent pig survey measures any metal loss. The first intelligent pig survey may be done as part of the commissioning of the new pipeline. Metal loss on the pipeline is unlikely at this early stage of its life. The second intelligent pig survey is much more relevant: unfortunately, this normally occurs ~15 years later. In the meantime, corrosion may be active at the trenchless crossings and remains undetected. Corrosion rates vary but in some cases can be up to 1 mm wall thickness metal loss per year.

Maintenance Activity	**Maintenance Schedule/Frequency**	**Requirement/Remarks**
ROW Inspection	Annual	CSA Z 662: (2003) Sour gas(>10 moles H_2S/k-mole NG) required monthly/bimonthly.
		Sour condensate: bimonthly/weekly depending on class location.
Pipeline patrol/leak detection/corrosion (gas)	Monthly	Industry norm, B31 requires periodic/as required – leak and corrosion survey report kept while line in service.
	Bi weekly (liquids): LPG/NH_3 lines<1 week in common areas	ASME B 31.4 (1998)
Pipeline patrol (gas lines)	Class 1,2: Annual	ASME B 31.8 (1999)
	Class 3: 6 Months	
	Class 4: 3 Months	
CP Monitoring	Annual, not to exceed 15 months	ASME B 31.1 (1999)

CP: Pipe to Soil Potential and rectifier readings	Monthly, Soil survey once per year	Industry Norm
Internal corrosion Monitoring	< 6 Months	ASME B 31.4 (1998): if line internally coated, pigged, dehydrated/corrosion coupon used
Exposed pipe: External Monitoring	< 3 Years	ASME B 31.4 (1998)
Encroachment assessment	Periodic or annual	
Class location assessment (Gas line)	Annual	ASME B 31.8 (1999)
Valve inspection/operation	Annual	ASME B 21.4 and B 31.8, Partial operation required
Valve testing	Annual	
Remote control shutdown devices	Annual	B 31: For functionality test
Relief valve (liquid)	< 5 years	ASME B 31.4 (1999): LPG/CO2/NH3 line/Storage

Table 3.1 Maintenance Schedule of pipeline

3.3 Coating Monitoring

Coating monitoring is an important task as a part of Coating system maintenance and its operation. Coating performance monitoring at fixed regular intervals is undertaken to ensure that all the structures are receiving desired protection against corrosion and the total system is performing as intended for in design stage. Coating must be properly maintained in order to operate effectively. To accomplish this goal effectively, diligent monitoring is required.
Pipeline coating monitoring includes it's operation and maintenance work, it's should be work properly and effectively.

Within the pipeline industry, operators are constantly looking for metrics that can help them accurately measure coating properties, monitor coating performance in the field, and predict long-term coating performance in specific circumstances. These areas continue to be an active area of research and development.

Although it is not practical to develop specific tests and acceptance criteria for all coating systems, the available information (from laboratory tests, field experience, and operational practices) can be used to develop strategies to maintain the integrity of the pipeline coating.
Most important factor is the type of environment which pipeline faces due to location. If the pipeline is laid in a high salt air environment, for example, pipeline require more consistent monitoring than if the pipeline is laid in a fresh air environment where corrosion occurs less rapidly. But soil condition and environment vary at every location.

Maintenance will be referred to as the Monthly, Bi-annual, Annual, or Five Years inspection, monitoring, and repair of the given coating system. The various activities that are performed for regular monitoring are broadly classified as under:

- Potential Measurements-Fixed Point Measurements, close order potential survey.
- Measurement of protective current density.
- Interference measurement wherever suspected.
- Coating Performance Tests.
- Transformer-Rectifier unit operation checks (D.C. Power Source) and its inspection.
- Individual Anode Performance Checks.
- Insulation joint checks.
- Test for casing/ carrier short.
- Junction boxes.

Coating faults directly can be measured by current leak from the system, so generally from different surveys we get pipe to soil potential and based on that we decide the fault severity. In general we used for this purpose different type of surveys they will measure pipe to soil potential with the help of reference electrode.

These survey methods available to determine the condition of coating systems and cathodic protection systems in order that the condition of the pipeline can be evaluated either along a section or along its entire length.

3.4 Coating Inspection

Premature failure of coatings can be avoided if proper techniques are used during the initial application. Coating must be inspected when it is applied and whenever the pipe is exposed during service to ensure that it is performing as it should. Coating is inspected visually and by machine. Visual coating inspections may be performed on aboveground pipe or on exposed buried pipe. Inspections must be documented on the proper company forms.

3.4.1 ASTM Test Standards for Pipeline Coating:

ASTM Standard	Test Description
G6-88(1998)	Standard Test Method for Abrasion Resistance of Pipeline Coatings
G7-05	Standard Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials
G8-96(2003)	Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
G9-87(1998)	Standard Test Method for Water Penetration into Pipeline Coatings
G10-83(2002)	Standard Test Method for Specific Bendability of Pipeline Coatings
G11-04	Standard Test Method for Effects of Outdoor Weathering on Pipeline Coatings
G12-83(1998)	Standard Test Method for Nondestructive Measurement of Film thickness of Pipeline Coatings on Steel
G14-04	Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)
G17-88(1998)	Standard Test Method for Penetration Resistance of Pipeline Coatings (Blunt Rod)
G18-88(1998)	Standard Test Method for Joints, Fittings, and Patches in Coated Pipelines
G19-04	Standard Test Method for Disbonding Characteristics of Pipeline Coatings by Direct Soil Burial
G20-88(2002)	Standard Test Method for Chemical Resistance of Pipeline Coatings
G42-96(2003)	Standard Test Method for Cathodic Disbonding of Pipeline Coatings Subjected to Elevated Temperatures
G55-88(1998)	Standard Test Method for Evaluating Pipeline Coating Patch Materials
G62-87(1998) e1	Standard Test Methods for Holiday Detection in Pipeline Coatings
G70-81(1998)	Standard Test Method for Ring Bendability of Pipeline Coatings (Squeeze Test)
G80-88(1998)	Standard Test Method for Specific Cathodic Disbonding of Pipeline Coatings
G81-97a(2002) e1	Standard Test Method for Jaw Crusher Gouging Abrasion Test
G85-02e1	Standard Practice for Modified Salt Spray (Fog) Testing
G90-98	Standard Practice for Performing Accelerated Outdoor Weathering of Nonmetallic Materials Using Concentrated Natural Sunlight
G95-87(1998)e1	Standard Test Method for Cathodic Disbondment Test of Pipeline Coatings (Attached Cell Method) Coating Qualification Test Panel Series

Table 3.2 ASTM Test Standard for Coating Inspection

Evidence shall show an understanding of the inspecting of pipeline coatings on a Gas Industry pipeline, indicated by the following:

- Standard operating procedures for testing pipeline coatings
- Coating defect assessment survey methods
- Basic electrical principles and measurements
- Irregularities, deviations or problems in pipeline coatings
- Writing of simple reports on status of pipeline.

3.4.2 Test performed for coating Examination

Abrasion	
Abrasion Test: Taber abrasimeter method	ASTM D-4060and ASTM D-1044
Abrasion resistance of pipeline coating	ASTM G-6
Rubber property: Durometer Hardness	ASTM D-2240
Rockwell Hardness of Plastics and Electrical Insulating materials.	ASTM D-785
Penetration Resistance of Pipeline Coatings (Blunt Rod).	ASTM G-17
Corrosion	
Salt spray test	ASTM B-117
Cathodic Disbonding (water)	ASTM G-8
Cathodic Disbonding (soil)	ASTM G-19
Electrical	
Breakdown voltage, dielectric strength.	ASTM D-149
D C Resistance, Volume resistivity.	ASTM D-257
Flexibility	
Deflection temperature under flexural load.	ASTM D-648
Tensile strength	ASTM D-638
Tensile properties of thin plastic sheeting.	ASTM D-882
Flexural properties of Plastics.	ASTM D-790 and electrical insulating material.
Flexibility cylindrical mandrel bend test	ASTM D-1737
Flexibility conical mandrel bend test.	ASTM D-553
Mandrel bend test attached organic coating.	ASTM D-522
Hardness	
Rockwell Hardness	ASTM D-785
Durometer Hardness	ASTM D-2240
Persoz pendulum hardness	
Buchloz indentation hardness	
Compressive properties of rigid Plastics.	ASTM D-695
Penetration resistance of pipeline coating	ASTM G-17

Hardness test	ASTM D-3363
Impact	
Impact resistance	ASTM G-13
Impact resistance of pipeline coating.	ASTM G-14
Impact resistance (rapid deformation).	ASTM D-2794
Pendulum type hammer impact test.	ASTM D-256
Tensile impact energy to break plastics.	ASTM D-1822
Miscellaneous	
Evaluation of level of blisters	ASTM D-714
Flame resistance.	ASTM D-635
Chemical resistance test	ASTM D-1308
Physical	
Melting temperature	ASTM D-789
Density and Specific gravity.	ASTM D-792
Particle size (Sieve analysis)	ASTM D-1921
Water absorption of plastics	ASTM D-570
High humidity.	ASTM D-2247
Immersion in water	ASTM D-870
Film thickness	ASTM D-1186
Adhesion test.	ASTM D-4541
Cross cut tape adhesion test.	ASTM D-3359
Apparent shear strength.	ASTM D-1002
Shear strength of plastics by punch tool.	ASTM D-732
Slant shear test	ASTM C-882
Weathering	
Accelerated weather meter	ASTM D-2565
KTA Envirotest	ASTM D-2246
Atmospheric weathering	ASTM G-7
Spectroscopic analysis of coatings	ASTM E-932
Gloss	ASTM D-523
Color visual	
Colorimetry	

Table 3.3 Test for Coating Examinatation

3.5 Need for Specialized Surveys

Pipeline coating is the primary protection to any underground cross country pipeline In order to maintain the metal integrity of the pipeline; the foremost task is to keep the coating always in good condition.
This aspect becomes furthermore important when one deals with the old three layer polyethylene coating. To ensure the working of a healthy pipeline, it is of prime importance that the condition of coating on the line is watched closely. For this purpose technology has given us certain tools in the form of Specialized Survey techniques that ensure a sound and efficient working of the pipeline. Need for these surveys are:

- ★ Coating deteriorates with passage of time and the load on CP increases day by day.

- ★ It slowly reaches a limiting condition where any amount of additional CP protection does not improve the situation.

- ★ Therefore, identification of coating defects with highest accuracy becomes very important, so that coating repairs and subsequent line protection is achieved in shortest possible time.

- ★ These specialized surveys give accurate results with respect to a pipeline under inspection and have greater efficiency in locating the holidays in coating on the pipeline.
  Taking PSP reading does not serve the purpose of locating the defects on the line as the test lead points are located at every kilometer and so they give only one or two location of suspected points, which means that the success rate of finding out the holiday is very less. Further, the PSP gives only the ON reading for every suspected location.
  On the other hand, Specialized Surveys (like the CPL and DCVG), give the ON and OFF readings of the potential for every meter. This means that for 1 kilometer line there will be 1000 potential readings, which surely improves the success rate of these surveys, and so more defects are known. These surveys increase the operating life of a pipeline and help in keeping away defects.

Once the need for these surveys is known, we can highlight the basic requirements for the coating surveys. These are stated as under:

- ★ Accurately identify all the coating defects.
- ★ Provide accurate information regarding size and position of defects.
- ★ Whether corrosion is taking place at the defect location.
- ★ Interpretation independent of the skill of the operator.
- ★ Simple to operate and reproducible.
- ★ Results not influenced by interference from external factors.

3.6 Types of Survey

Periodical inspections are essential to perpetuate your protection system because the environment of the installation changes during use: aggressiveness of soil, coatings damage and equipment wear, etc.

Coating survey is need of every pipeline industry to regulate pipeline for proper and safety aspect. If coating damaged then pipeline could lead to be corrosion that cause leak or rupture. So the scheduled survey for pipeline coating is carried out once in every five year.
Generally four type of survey is used to monitor or locate the coating defect, most favorably used CIPS and DCVG combination. This combination is quick, efficient and economic
The following surveys are available:

1. Close Interval Potential
2. DC Voltage Gradient
3. Pearson survey
4. Signal Attenuation survey

3.6.1 Close Interval Potential Survey

Close Interval Potential Survey **(CIPS)** refers to potential measurements along the length of buried pipelines to assess the performance of Coating systems and the condition of the cathodically protected pipeline. The potential of a buried pipeline can be obviously be measured at the permanent test posts, but considering that these may be miles apart, only a very small fraction of the overall pipeline surface can be assessed in this manner.
The principle of a CIPS is to record the potential profile of a pipeline over its entire length by taking potential readings at intervals of around 1 meter.
Cathodic Protection systems are an electrical means of mitigating corrosion on buried and submerged metallic structures (primarily steel).
One of the most common methods of testing these systems is the annual test station survey. This requires the measurement and recording of pipe to soil potentials at designated test stations each year. While this is very useful information, particularly for well-coated pipelines, the test station data only represents the potentials on less than 1% of the pipeline surface. The test station data does not provide any information on the pipe to soil potentials at a distance from the test station. On bare or poorly coated pipelines, the test station data may not represent potentials more than a few meters from the test station.
Consequently, it has become a standard practice to undertake “close interval potential surveys” (C.I.S.) on pipelines, every few years, in order to provide the data for assessing the effectiveness of the Cathodic Protection system over the full length of the pipeline. The C.I.S. measures and records the pipe to soil potential on a regular spacing of between 1 and 3 meters (spacing depending on client requirements, field conditions and pipeline physical properties).

Methodology
A reference electrode is connected to the pipeline at a test post, and this reference electrode is positioned in the ground over the pipeline at regular intervals (around 1 meter) for the measurement of the potential difference between the reference electrode and the pipeline.

In practice, a three-person crew is required to perform these measurements. One person walking ahead locates the pipeline with a pipe locator to ensure that the potential measurements are performed directly overhead the pipeline. This person also carries a tape measure and inserts a distance marker (a small flag) at regular intervals over the pipeline. The markers serve as distance calibration points in the survey.

The second person carries a pair of electrodes that are connected to the test post by means of a trailing thin copper wire and the potential measuring instrumentation. This person is also responsible for entering specific features as a function of the measuring distance. Such details (road, creek, permanent distance marker, fence, rectifier, block valve, etc) serve as a useful geographical reference points when corrective actions based on survey results have to be taken.

The third person collects the trailing wire after individual survey sections have been completed. (Strictly speaking the first person may not be required if the distance can be monitored via a counter measuring the length of the unwinding copper wire). The interrupter switch is ON and OFF for a constant time interval or it is handled by GPS satellite systems. The ohmic drop at points indicates the corroded or poor CP region.

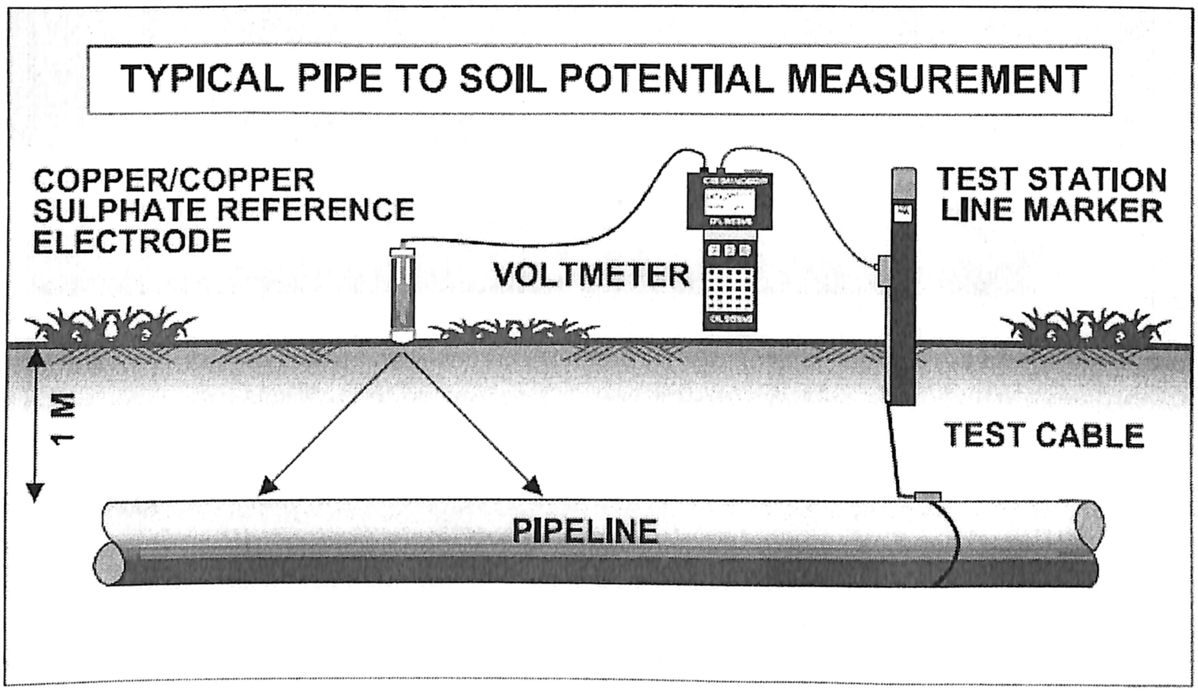


Fig 3.1 Pipe to Soil Potential Measurement In CIPL Survey

Close Interval Survey Data

During the C.I.S., most of the data collected will be pipe to soil potentials. There will also be comments relating to pipeline features and terrain features as well as special tests such as data logs or continuous logs. It is very important that the technician recording the data input as much information as possible. This can both be in the field and as extra notes in the data files.

Personnel who were not involved in the field survey will normally produce the C.I.S. report, and consequently, any field comments will greatly assist in the data handling and report generation. If the ground is dry, this information needs to be input into the datalogger. If there is a wire break and the survey has to restart at a different location and proceed in the opposite direction, this must be clearly noted. In summary, the C.I.S. data collection involves far more than just data collection. The field crew has the responsibility of providing all of the relevant field information so that the final report can be accurate.

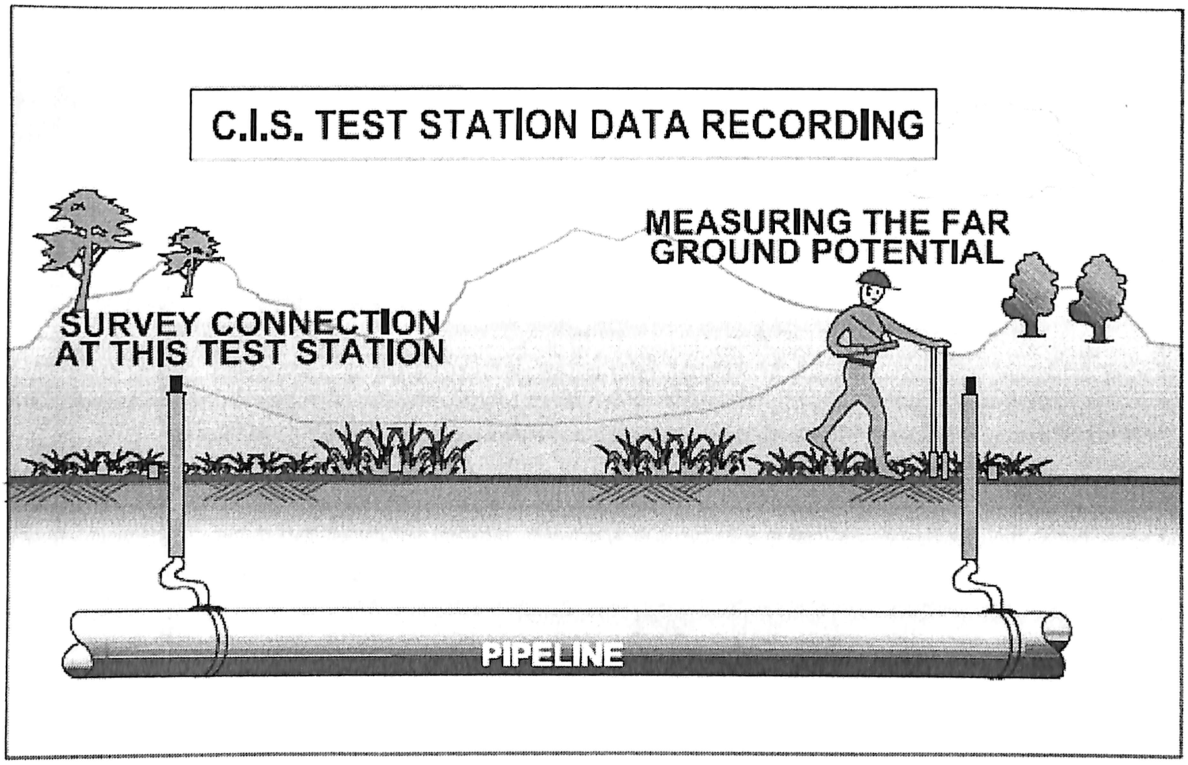


Fig.3.2 CIPL Data Recording

Test Station Data

Test Stations are normally located along the pipeline at locations such as roads, railroads, foreign line crossings, and at 1 to 5 Km separations in more remote areas.

The test stations provide a means of electrically contacting the pipeline for testing purposes. While a pipe to soil potential taken at a test station is not representative of more than a few meters of pipeline, it can be considered as a location for data sampling and comparison of year-to-year potentials.

For the C.I.S., the test station serves several functions:

- It provides a means of electrically connecting to the pipeline and a means of verifying the pipe to soil potentials being recorded from the last test station.

- The test station is a measurement point at which the voltage drop in the pipeline can be measured. The voltage drop in the pipeline will directly show if the interrupters are operating properly and if all of the rectifiers affecting that section of pipeline have been interrupted.

- If the test station is located at a road or railroad crossing, it provides a means of testing to verify that the pipeline is isolated from the casing. (If present) If the test station is located at a foreign pipeline crossing, it provides a means of testing the foreign pipeline to check for possible interference.

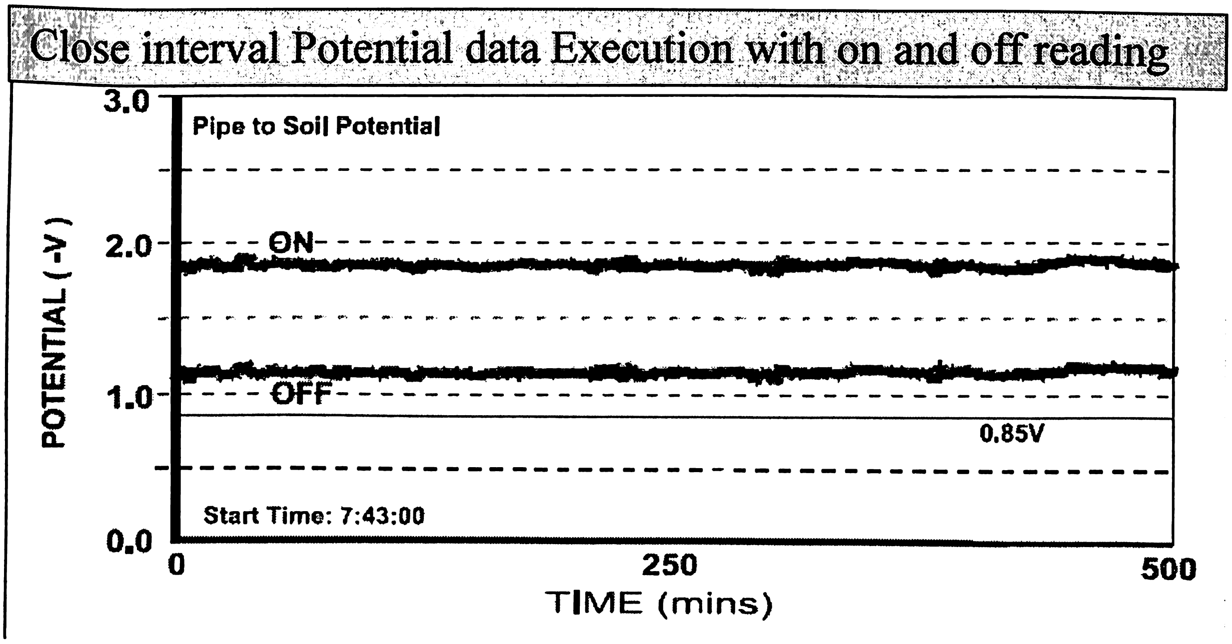


Fig.3.3 CIPL Data Execution

The following responsibilities of a pipeline operator in preparing for a CIPS are:

- Preparation of a detailed technical specification for the survey.
- Establishing and clearing the right of way (the path of the pipeline).
- Notification of land owners and foreign operators.
- Establishing the sphere of influence of existing rectifiers and foreign structures.
- Checking the condition and establishing functionality of rectifiers, bonds, and isolation.
- Characterizing the effectiveness of the CP systems in difficult terrain.
- Identification of suitable seasonal and weather windows.
- Specification of the reporting format.
- Ensuring availability of support personnel

Advantages

- The CIPS technique provides a complete pipe-to-soil potential profile, indicating the status of cathodic protection levels.
- The interpretation of results, indicating the identification of defects, is relatively straightforward.
- The rate of progress of the survey team is independent of the coating quality on the pipeline. When the entire pipeline is walked, the condition of the right-of-way and the cathodic protection equipment can be assessed together with the potential measurements.
- Provides a complete pipe to soil potential profile on the pipeline for both 'ON' and 'polarized OFF' potentials.
- The entire pipeline section is walked enabling an inspection of CP equipment and the right of way at the same time as the survey.
- A hard copy of the survey data is produced allowing easy identification of defect areas by non-technical personnel.
- A base line survey of the pipeline potentials can be obtained providing guidance for future operation and maintenance of the CP system.
- Provides information on CP levels at coating defects and likely active corrosion location.
- Identifies areas of stray current interaction.
- Survey less reliant on survey team for interpretation of result.
- Progress is independent of coating quality.

Disadvantages

- This survey does not indicate the actual severity of corrosion damage, because the corrosion potential is not a kinetic parameter.
- The entire length of the pipeline has to be walked by a survey team and significant logistical support is required.
- The technique is not applicable to certain terrain such as paved areas, roads, rivers, and so forth.

3.6.2 DCVG (Direct Current Voltage Gradient) Survey

DCVG stands for **Direct Current Voltage Gradient** and is a survey technique used for assessing the effectiveness of corrosion protection on buried steel structures. In particular, oil and natural gas pipelines are routinely monitored using this technique to help locate coating faults and highlight deficiencies in their cathodic protection (CP) strategies.

Direct Current Voltage Gradient Surveys (DCVG) is the application of a pulsed DC current either from the interruption of the cathodic protection rectifiers or the application of pulsed DC current from a temporary source. Voltage gradients are measured along the pipeline. Generally the larger the voltage gradient the larger the coating defect, but soil resistivity and current attenuation must be considered in the interpretation of the magnitude in the voltage gradient.

DCVG survey does not indicate the level of cathodic protection on the pipeline system. It's more recent methodology to locate defects on coated buried pipelines and to make an assessment of their severity. The techniques again relies on the fundamental effect of a potential gradient being established in the soil at coating defect under the application of CP current; in general, the greater the size of the defect the greater the potential gradient. The DCVG data is intricately tied to the overall performance of a CP system, because if gives an indication of current flow and its direction of soil.

Methodology

The potential gradient is measured by an operator between two reference electrodes (usually of the saturated $Cu/CuSO_4$ type), separated by a distance of say half a meter. The appearance of these electrodes resembles a pair of cross-country ski pole. A pulsed dc signal is imposed on the pipeline for DCVG measurements. The pulsed input signal minimizes interference from other current sources (other CP systems, electrified rail transit lines). This signal can be obtained with an interrupter on an existing rectifier or through a secondary current pulse superimposed on the existing "steady" CP current.

The operator walking the pipeline observes the needle of a milli voltmeter needle to identify defect locations. It is preferable for the operator to walk directly over the pipeline, but it is not strictly necessary. The presence of a defect is indicated by a increase needle deflection as the defect is approached, no needle deflection when the operator walks away from the defect. It is claimed that defects can be located with an accuracy of 0.1 to 0.2 m. which represent a major advantage in minimizing the work of subsequent digs when corrective action has to be taken.

An additional feature of the DCVG technique is that defects can be assigned an approximately size factor. Sizing is most important for identifying the most critical defects and prioritizing repairs. An empirically based rating based on the so called %IR value has been adopted in general terms as follows:

- 0 to 15%IR ("small"): No repair required usually
- 16 to 35% ("medium"): Repair may be recommended.
- 36 to 60% ("large"): Early repair is recommended
- 61 to 100% ("extra large"): Immediate repair is recommended

Principle of the DCVG technique

- In cathodic protection when current flows through the resistive soil to the bare steel exposed at defects. In the protective coating, voltage gradient is generated in soil. Larger the defect greater the current flow & hence the voltage gradient. This is utilized in the technique to give priority to the defects for repair.

- When the two electrodes are placed 1.5 meters apart on the soil in the voltage gradient form a coating defect, one electrode adopts a more positive potential than the other, which allows the direction of current flow to be established and defect to be located.

➢ The voltage gradient is monitored by measuring the out of balance between two reference electrodes using specially designed millivoltmeter, called as DCVG (Direct Current Voltage Gradient) survey meter.

Fig. 3.4 DCVG Survey technique

Operating Instructions

Finding a defect

Adjust the meter range switch to 100 mV range, and ensure that only one handle bias switch is ON adjusted to position 3. This is all that is necessary for normal surveying.
Place the probes, one in front of the other. Contact the soil with the probes approximately at 1.5 to 2 meter spacing. Turn the bias control potentiometer to bring the needle of the meter on to the scale. Keep the needle on the meter scale the whole time the probes are in contact with the soil. Look for the meter needle to be flicking in response to the pulsed DC. Lift the probes; step out from the test point at which the signal strength was previously measured. Move forward 2 paces and contact the ground with the probes. Use the bias if necessary to bring the meter needle on to the scale.
Look for a needle deflection. If there is no deflection then step out another two paces and then bring the needle on to the scale with the bias control. If there is a deflection, observe the needle to which direction the coating fault lies. If you are unsure either change to a lower meter scale or move the probe forward along the pipeline. The meter needle points to the probe, which is nearest to the defect. The Interrupter is OFF for longer than for what it is ON and when it is ON the current normally flows from the ground to towards the defect. **It is the size and direction of the needle flick, or swing that we are interested in. It may be possible that the coating fault is small and lies behind us, so correct identification of the direction of the needle swing is important. Recognizing the direction of the current flow, as indicated by the needle flick will take a little time. If we have observed a deflection lift the probe which is closest to the coating fault and move it 0.5 meter towards the defect. Bring the second probe forward and place it where the first probe used to be. Keep moving forward in this manner.**

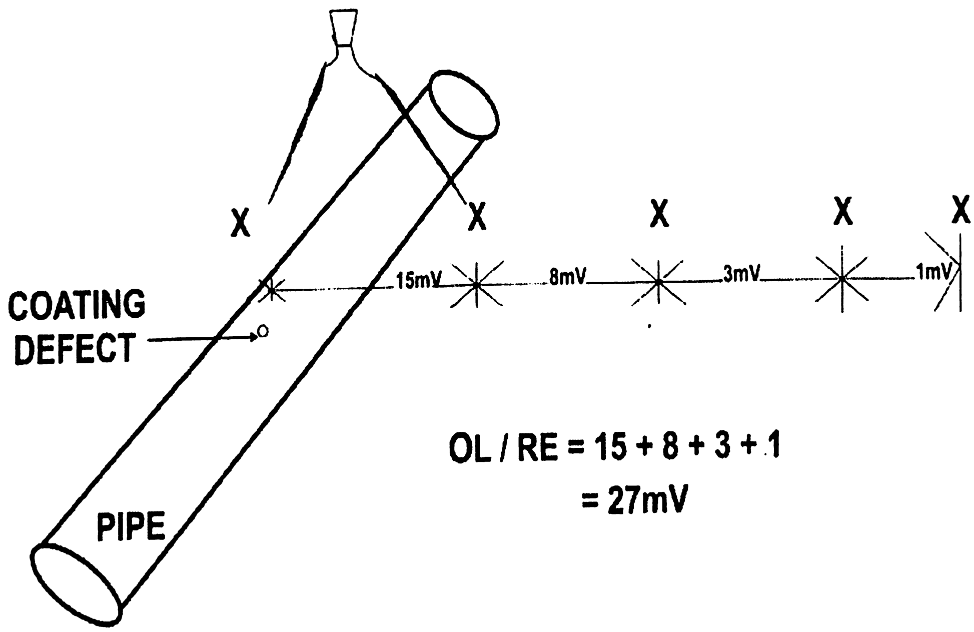


Figure 3.5 Over-line to Remote earth Potential

As we move towards the defect, the amplitude of the deflection will increase so there may be a need to change to a higher meter range as required. When the coating fault is passed, the needle deflection is completely reverses and slowly decreases as we move away from the defect. We retrace our steps to the suspected coating fault position where the change in meter needle direction occurs. At the approximate null position, with the probes at about 1.5 meters apart observe any meter deflection. If the deflection is from left to right, move the left probe 15 cm to the right and retest. Keep doing this until there is no deflection. It may be necessary to reposition the right hand probe. At the point of no deflection, the coating fault location lies midway between the two probes locations. Scratch a mark on the ground at the midway position.
The above process of nulling the meter is to place the probe tips on the same line of equipotential around the defect. Because it is an equipotential line there is no voltage difference between the probe tips and no meter needle deflection. Now we turn through 90 degrees to work across the pipeline direction. Stand facing the mark in the ground and repeat the coating fault location process.

At the new Null position mark the midway position between the probes on the ground to cross the first mark. Recheck the first location by turning back to the original position and checking for the null. Where the two lines cross is above the center of the coating fault voltage gradient and is called the coating fault epicenter. As a final check, that the location is correct, place on probe at the epicenter and the other about 1.5 meters away placed in turn at the four points of the compass. At each of the four locations the meter needle should indicate a direction of the coating fault epicenter. If this is not the case then the epicenter has been incorrectly located or the coating fault location is at on e end of the long crack in the pipe coating.
Place a numbered peg, or some means of indication at the coating fault location.

Surveying

Setting up the DCVG Signal

The most important parameter in ensuring an accurate survey and in determining the survey speed is the amplitude of the DCVG pulsed signal.

The interrupter should be connected into the electrical circuit shown in fig.

- ✓ The black terminal of the interrupter should be connected to the negative terminal of T/R unit. Keep T/R unit in Manual mode.
- ✓ The red terminal of the interrupter should be connected to the cable going to the pipeline.
- ✓ Polarity of the connection is important. If connection is wrong the interrupter will not switch the DC output. If this happen remedy is just reverse the terminal connections on the interrupter. The amplitude of signal strength is the difference between ON and OFF potential measured on the pipe using DCVG meter, whilst the interrupter is switching ON and OFF the applied source.
- ✓ The output signal from T/R unit along with interrupter should be less than 25 amperes.
- ✓ Adjustments beyond 25 amperes up to 50 amperes are possible but careful adjustment is necessary preferably using a scope meter. A pipeline requiring more than 25 amperes to get a good signal level over a 1 KM length is indicative of a very bad coating on pipeline.
- ✓ The amplitude of DCVG signal should at least 250 mV & no large than 1500 mV.
- ✓ Rapid decay of signal measured at two locations one kilometer apart would be on attenuation of signal amplitude with distance.

Adjustment to ensure a good signal level requires trial and error and patience but extra time spent in setting up the signal will give greater confidence in the quality of the survey, which usually can be achieved at greater speed than on pipelines with a poor signal.

Measurement of signal level at test posts are carried out in exactly the same way as measurements made to measure pipe-to-soil potential, except there are two measurements in this case:-

- From the copper wire or test post terminal to the soil alongside the test post.
- From the soil position alongside the test post to remote earth.

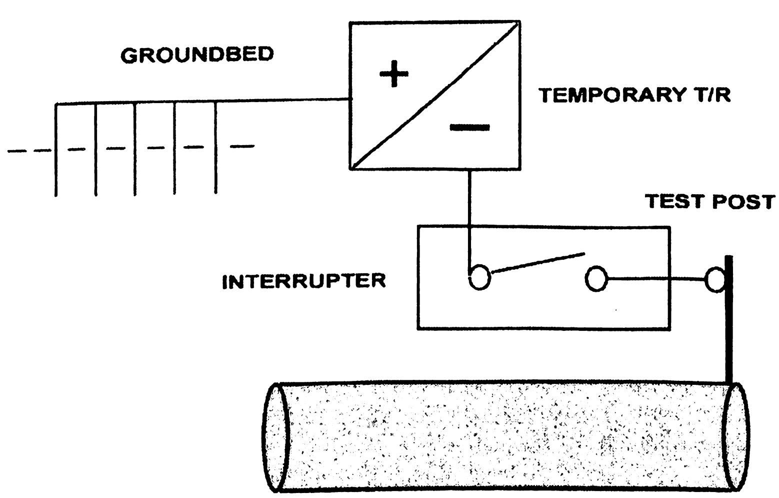


Fig 3.6 Temporary T/R and Ground-bed

Assembling the DCVG Equipment

- ✓ Probes are filled with copper sulphate solution.
- ✓ The DCVG meter is placed around the neck and waist so that the meter fits snugly on operator.
- ✓ Connecting leads are fitted into the meter and into the process to interconnect two probes with meter.
- ✓ The meter switch is then turned ON and the Range switch is adjusted.
- ✓ With the probe tips placed in the soil the bias to the right hand probe is switched ON.
- ✓ The bias to the left hand probe is not switched ON, it is a spare available if needed.

Application of DCVG Technique

- Evaluate pipeline coatings to define rehabilitation requirements
- Define weaknesses in the cathodic protection system
- Validate that the pipeline has been constructed with minimum coating faults
- Investigate Interference effects
- Establish effectiveness of insulating flanges and other methods of pipeline isolation
- Provides data for Operating License Validation
- Surveying complex pipeline networks not possible by other methods
- Capable of surveying under overhead power lines.
- Evaluation of test post integrity.

Advantages

- This technique is particularly suited to complex CP systems in areas with a relatively high density of buried structures.
- The DCVG equipment is relatively simple and involves no trailing wires.

Disadvantages

- The rating system is empirical and does not provide quantitative kinetic corrosion information.
- The survey team's rate of progress is dependent on the number of coating defects present

3.6.3 Pearson Survey

The Pearson Survey, named after its inventor, is an electrical method used to locate holidays in buried pipeline coating by the application of an AC signal on the pipeline and the reception of the signal by two surveyors wearing metal cleats and connected to the Pearson receiver.. Once these defects have been identified, the protection levels afforded by the CP system can be investigated at these critical locations in more detail.

Methodology
An A C signal of around 1000 Hz is imposed onto the pipeline by means of a transmitter, which is connected to the pipeline and the earth spike. Two survey operators make earth contact either through metal studded boots or aluminum poles. A distance of several meters typically separates the operators. Essentially, the signal measured by the receiver is the potential gradient over the distance between the two operators. Defects are located by a change in the potential gradient, which translates into a change in signal intensity.

As in CIPS technique, the measurements are usually recorded by walking directly over the pipeline. As the front person moves away from the defects, the signal intensity drops and later picks up again as the rear operator approaches the defect. The interpretation of signals can obviously become confusing when several defects are located between the two operators. In this case, only one person walks directly over the pipeline, with the connecting leads at a right angle to the pipeline.
In principle, a Pearson survey can be performed with an impressed cathodic protection system remaining energized. Sacrificial anodes should be disconnected because the signal from these may otherwise mask actual coating defects. A three-person team is usually required to locate the pipeline, perform the survey measurements, place defect markers into the ground, and move the transmitters periodically. The operator carrying the receiver should be highly experienced, especially if the survey is based on audible signals and instrument sensitivity settings. Under these conditions, the results are completely dependent on this operator's judgment.

Advantages

- By walking the entire length of the pipeline, an overall inspection of the right-of-way can be made together with the measurements.
- All significant defects and metallic conductors causing a potential gradient will be detected.
- There are no trailing wires and the impressed CP current does not have to be pulsed.
- Survey technique can provide an assessment of coating condition over areas of difficult access i.e. road, rail and water crossing etc.
- Estimates defect sizes in order to prioritize excavation and repair
  Minor defect: from 0% IR => 15% IR
  Medium defect: from 16% IR => 35% IR
  Large defect: from 36% IR => 100% IR
- Has already proven in use and accuracy
- One person can conduct survey, although 2 persons are recommended (progress, & safety).
- Provide data for cathodic protection adjustment/upgrading.
- Survey can be conducted in areas affected by stray currents and telluric effects in most soil conditions.
- Involves no trailing wires.
- High accuracy in locating and pin-pointing defects.
- Can be used in combination with other techniques.

Disadvantages

The disadvantages are similar to those of CIPS because the entire pipeline has to be walked and contact established with ground. The technique is therefore unsuitable to roads, paved areas, rivers, and so forth. Fundamentally, no severity of corrosion damage is indicated and no direct measure of the performance of the CP system is obtained. The survey result can be very operator dependent, if no automated signal recording is performed.

3.6.4 Current Attenuation Survey (CAT)

Current Attenuation is the measurement of the current attenuation on a pipeline with distance from the power source. The current attenuation is indicative of the coating quality and integrity. Current attenuation does not indicate the level of cathodic protection or the effectiveness of the CP system. CAT Survey is based upon measurement of magnetic field from AC current in the pipeline. Gradient profile of AC current in the pipeline is obtained by discrete measurement along the line. Line current is monitored by a set of coils in the receiver. Ripple current from transformer-rectifier unit or signal from AC current may be used fro signal.
A coated pipeline will have a loss of AC signal along the line due to capacitance and resistance of coating, capacitance and resistance of polarization layer in coating faults, form and shape of coating holidays, thickness of coating and soil resistivity. Loss of signal due to coating capacitance and resistance is proportional to signal strength and capacitance per unit length of the pipeline. Provided a uniform coated pipeline with no coating holidays, loss of signal will decrease logarithmically with distance.
Current Attenuation can be performed with various electromagnetic tools including the Pipeline Current Mapper and Precision Pipe Locator for AC attenuation and the Stray Current Mapper for DC attenuation. The pipe is located and depth of cover is determined while simultaneously obtaining current measurement and current direction. All the data is captured and stored into a portable submeter GPS instrument for later download into a computer for data compilation and interpretation.

Advantages of current attenuation include

- Measurements can be taken at 50 foot, 100 foot or larger intervals. Does not need to be take every 5 feet to be effective
- Measurements can be taken over many types of cover including concrete, rocks, pavement and water with no detrimental effect.
- Allows the operator a quick way to determine the overall pipeline coating condition
- Allows the operator to obtain information very quickly on the electrical CP circuit and whether there are shorts, bonds or other unknown areas of concern.
- Gives the operator a fast and reliable way to narrow down the areas of concern where more detailed and time consuming surveys can be performed.

3.7 Selection of the Type of Survey

The information required as the output of the survey defines the technique to be employed.

Close Interval Potential	To provide initial cathodic protection data for new pipelines To assess cathodic protection levels and areas of poor protection To identify major coating defects
DC Voltage Gradient	To identify specific areas of coating effect together with estimation of defect size
Pearson survey	To identify specific areas coating defect.
Signal Attenuation survey	To rapidly asses the coating condition and identify the worst areas

A Signal Attenuation coating survey followed by more detailed DCVG or Pearson Survey; in this way the entire pipeline can be raised in the most effective manner. A Signal Attenuation Survey can take 10% of the time of a Pearson Survey and 30% of the time of a DC Voltage Gradient Survey.

3.8 Possible Pipeline Coating Defects & Deterioration

The exposed steel comprising the less than 1% of total surface on a well-coated pipeline is due to small defects in the coating film. These defects (commonly called Holidays) may result from:

- Skips by the coating machine
- Manufacturing applications
- Pinholes in the coating film as applied
- Cracks from excessive mechanical or thermal stresses
- Scraps or gouges caused during subsequent handling of the coated pipe
- Penetration by rock, clods or debris in the backfill surrounding the pipe
- Distorting stressed exerted on the coating by certain soils having a very high shrinkage rate upon drying
- Penetration by growing roots
- Action of solvents in soil surrounding the pipeline (e.g. from leaks on a products pipeline).
- Action of bacteria in the soil surrounding the pipeline; some coating materials are relatively inert in this respect while others are sensitive to such damage (this subject has been extensively researched in recent years)

- Damage from subsequent construction on other facilities making it necessary to uncover the pipeline.
- Any other action that may damage the coating film.
- Damage during handling and laying
- Failures during commissioning and operation
- Rock penetration during installation and
- Soil loading and shear failure during operation
- Lack of coating integrity at elevated temperature
- Disbonding through pipe movement and
- Disbonding due to inadequate surface cleaning
- Enhanced failure at low temperatures

Whenever an existing pipeline within a system is exposed, the industry's practice is to examine the coating system and report on problems area and record the overall condition of the pipeline system.

Possible reason of these Failures:

- Poor coating electrical insulation properties due to improper formulation or application.
- Deteriorating coating electrical insulation due to moisture absorption and/or general breakdown of coating film.
- Characteristic failures of particular coatings (e.g. spiral corrosion and disbondment with tape coatings with inadequate properties/overlap, disbondment of fiber reinforced coal tar and asphaltic enamels at elevated temperatures particularly in moist conditions.
- Failures of inadequately designed or applied field joints and repairs
- Damage due to third party interventions (e.g. deep plough or excavation damage).
- Action of bacteria in the soil surrounding the pipeline. Some coating materials are relatively inert in this respect while others are sensitive to such damage.
- Damage on subsequent construction on other facilities making it necessary to uncover the pipeline.
- If PSP value becomes either too low or too high beyond the prescribed range (i.e. -0.85 to -1.5) it either leads to corrosion or coating disbondment.

3.9 Pipeline Coating Repair

General pipeline coating repair are:

1. Coating repair with PERP-Patch
2. Coating repair with Cold Applied Tapes

3.9.1 Coating Repair with Patch

- Remove loose coating from the damaged area with a knife, scrapper or power wire brush. Eliminate all sharp edges and clean the damaged area and adjacent coating to remove all foreign material such as dirt, rust, oil, grease and moisture.
- Abrade adjacent coating extending 100 mm beyond the damage.
- Cut a patch from the repair material so that it extends at least 50 mm beyond the damaged area. Round-off the corners.
- Preheat the exposed bare metal and adjacent pipe coating to 60 ± 10°C.

- Apply the filler material, if required to all areas of exposed steel.
- Heat the filler and smooth it down with a paint scrapper to cover all bare metal without air entrapments.
- Flames brush the adhesive side of the patch until the adhesive becomes glossy.
- Position the pre-cut patch over the damaged area.
- Check that adhesive is soft to the touch of the gloved fingered. Smooth the repair patch with a gloved hand or roller to eliminate air entrapments and ensure good bonding.

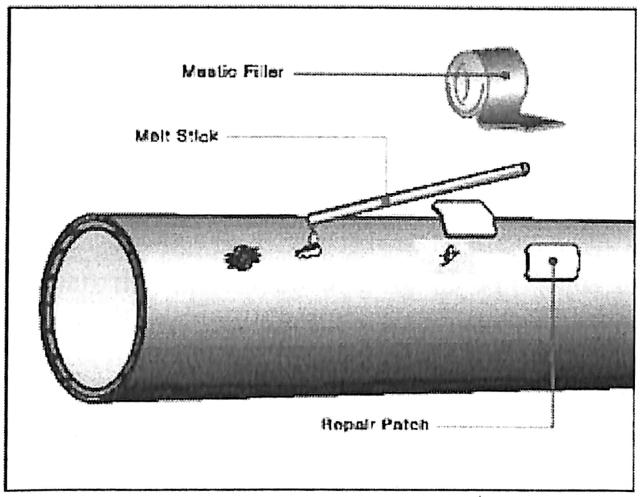


Fig 3.7 Coating Patch Repair

Pipeline coating repair patch products are widely used from the field which are various for the pipe coating repair which is damaged and a continuous stipendiary prevention effect. The Repair Patches and Mastic Fillers and Melt Sticks are the product it will be able to repair the damage which occurs from pipe transportation and load process effectively

3.9.2 Coating Repair with Cold Applied Tape

[A] Surface Preparation

1. The old/damaged coating shall be totally removed carefully with scrappers.

2. After the coating is removed, the pipe-surface shall be prepared by hand-brush/emery-paper/scrappers etc or a combination of all above with full removal of loose point, coating, rust, oil, grease, dirt, etc. to the entire satisfaction.

[B] Application of Primer

1. Priming shall be carried within immediately after cleaning/surface-preparation of the pipeline. Before applying the primer, the pipe-surface shall be cleaned with a clean cloth ensuring that the surface is free from dust particles.

3. Stir the primer in its original container and apply a uniform coat of primer to the cleaned surface of the pipeline (and where applicable to the adjacent mill – coating) with a good

quality point brush. Consumption of the primer is approximately 0.2 ltrs per sq. mtrs of surface.

3. The primer is to be allowed to dry for thirty minute, during drying time of the primer; enough precautions must be taken to ensure that no dust particles are falling on the fresh primed surface.

4. Thumb test is to be done and is found ok, wrapping may be started within 8 hours of application of primer.

[C] Wrapping

1. **Inner Wrap:** Wrap densolene tape S 25 HT hand – wrapping machine under proper tension and without wrinkles spirally around the pipe into the sticky primer with grey side of the tape facing the steel surface overlap on to the adjoining factory applied coating.

2. **Outer Wrap:** Wrap the densolene tape R 25 HT with under the proper tension and without wrinkles spirally around the pipe with butyl adhesive facing the inner wrap with a minimum of 50% overlap. Ensure that the outer wrap completely covers the inner wrap.

The cold applied tapes shall be kept in shade and the coated pipeline section shall also be protected from direct sunlight by using tarpolene/ polythene sheet/ gunny bags filled with soil, if not backfilled immediately.

CHAPTER 4

EXPERIMENT/ COMPUTATIONAL/ FIELD WORK ANALYSIS

4.1 General

The GAIL owns and operates a network of over 5500 kilometers of pipeline. This includes the prestigious Hazira-Bijaipur. Jagdishpur (HBJ) Pipeline, a 2,702 kilometer long pipeline which runs from Hazira on the western coast of India through Bijaipur to Jagdishpur in North India having links with Delhi and over 1,300 kms of regional pipelines in different states including Maharashtra (Mumbai area), Gujarat, Rajasthan, Andhra Pradesh, TamilNadu, Pondicherry, Assam and Tripura.

GREP pipeline and its branch pipeline of varying diameters ranging from 36" to 8" have been laid underground to supply natural gas to various customers such as power plants, fertilizer plants, chemical plants etc in the states of MP, Rajasthan, UP, Haryana and Delhi through a network of 505 kms of pipelines. The GREP pipeline and its branch lines have 3-layer poly ethylene coating and impressed current system has been provided for the cathodic protection of the pipelines.

The survey followed to detect coating defect, and after detection we used some repair technique for entire pipeline. So this project includes detection of coating defect and its repair work.

4.2 Scope of the Work

This project includes finding out coating fault location and repair work in GREP pipeline. CIPL followed DCVG using for locating coating faults and there severity.

4.3 Objective

The ultimate objective of the project is to study the coating conditions and locate and repair the defect of GREP Pipeline system under Agra region at GAIL (India) Ltd. and come out with conclusion and recommendations for effective maintenance of pipeline coatings the following objectives include:

- Monitoring and maintenance of the Coating system according to the set schedule to check the health status.
- Associated with ongoing CPL and DCVG survey to ascertain exact location of coating defect its severity as minor, moderate and severe according to criteria.
- Data is observed using CPL & DCVG survey, its interpretation & analysis by plotting graphs for the defect locations under scanner.
- After completion of survey, the exact location of defect is known than see how the repair work is carried out.
- Carry out with recommendations for future projects.

4.4 Pipeline Details

GAIL Pipeline details:

NAME OF PIPELINE	LENGTH in Km
HBJ/GREP	2760
KG/Kaveri Basin	770
Mumbai	125
North – east	64
Gujarat & Rajasthan	710
Agra – Firozabad city gas pipeline	100
Jamnagar – Loni LPG P/L	1232
TOTAL PIPELINES	5762

Table 4.1 GAIL Pipeline Description

GREP: Vijaypur to dadri pipeline alogwith spur line are being divided into six regions namely, Vijaipur, Gwalior, Agra, Mathura, Faridabad & Dadri.

S. No.	NAME OF PIPELINE	LENGTH (Km)	DIA. (inch)
(A)	**Vijaipur Region**		
1	Vijaipur - Khordhar	0.00 – 132.00	36"
(B)	**Gwalior Region**		
1	Khordhar – Chambal River	132.00 – 246.00	36"
(C)	**Agra Region**		
1	Chambal River – Bajhera	246.00 – 334.85	36"
2	Bajhera – Agra spur line	0.00 – 52.70	10"
3	Agra – Firozabad	0.00 – 34.95	8"
4	Agra – Firozabad loop line	34.30	10"
5	Agra City gas network	50.00	2" to 8"

6	Firozabad city gas network	50.00	2" to 8"
(D) 1 2	**Mathura Region** Bajhera – Jatauli Lalpura – Mathura Refinery	 334.85 – 425.35 0.00 – 12.53	 36" 14"
(E) 1	**Faridabad Region** Jatauli – Yamuna River	425.35 – 460.00	36"
(F) 1	**Dadri Region** Dadri – Yamuna River	460.00 – 500.00	36"

Table 4.2 GREP Pipeline Description

Agra maintenance base is looking after 100 kms of GREP pipeline. Besides these cross country pipelines, Agra region is looking after approximately 100 Km of spurlines and 100kms of city gas distribution pipeline network in Agra and Firozabad districts.

4.4.1 Coating

i. Main line: 3-layer Polyethylene Coating (3LPE)
ii. Branch line: 3LPE
- **a)** Bajhera – Agra spur line
- **b)** Agra – Firozabad:
- **c)** Agra – Firozabad Loop line:
- **d)** Lalpura– Mathura Refinery:

iii. City Gas Pipeline: in Agra and Firozabad: Combination of 3LPE and CTE

4.4.2 Cathodic Protection System for GREP pipeline: ICCP (Impressed Current Cathodic Protection)

No of CP Station: 11 Nos.

- Manual test stations for current and potential measurement are installed at:

a) Approximately, 1 km interval in GREP main lines and 1 km in spur lines.
b) All HT overhead power transmission lines of 66 kV and above.
c) All railway crossings
d) All road – crossing
e) All major river crossings (with insulation joints on either bank)
f) SV/ Terminal/Scrappers/Compressor Stations
g) Foreign Pipeline crossings.

- Galvanic anodes have been provided for casing and carrier pipes at railway crossings and for river section of pipeline. But normally the river section is also protected by the ICCP system by providing links across insulating joints.

- At all above ground insulating joints, spark gap arrester have been installed across insulating joints.
- External corrosion sensing probes have been installed to monitor the external corrosion rate at approximately each 10 kms.
- The grounding cells have been provided near insulation joints.
- Two types of anode ground bed configuration are in use:
  a. Horizontal anode ground bed
  b. Deep well type.

4.4.3 Sites visited and covered in detail during the project

4.4.3.1 Sone Ka Gurja (Sectioning Valve (SV) & Intermediate Pigging (IP) Station)

1. **CPPSM (Cathodic Protection Power Supply Module) Unit**

DC Input Voltage	=	49- 53.2 V
Reference Voltage (PSP)	=	- 1.26 V
DC Input Current	=	0.25–5 Amps (Varies between this range to maintain the Reference voltage of -1.26 V)
DC Output Current	=	0.5 – 0.7 Amps.
DC Output Voltage	=	1.5 V

Sone Ka Gurja is a remote location, approximately 70 kms from Agra on the banks of river Chambal. Being far from Agra city, there is a problem of availability of state electricity in this place which gives rise to many domestic problems at this place. Therefore, to overcome this problem TEG (or thermo-electric generator) is used. The power source to the CPPSM Unit is this TEG (or Thermo-Electric Generator) only which is imported from Canada. Thermo-electric generators convert heat directly into electricity, using the voltage generated at the junction of two different metals. It works on the principle of Seebeck Effect.

At Sone Ka Gurja, it is a system of five (5) sets of Dual TEG system connected together in series parallel combination to produce 5350 Watts at 48 Volt DC nominal. Each set contains two (2) 24 volt DC generators in series to provide the 48 Volt DC nominal requirement and five (5) of these systems are wired in parallel to provide 5350 Watts. Since the TEG system naturally provides 48 volt DC nominally, no DC to DC converter is required at the output of the system.

4.4.3.2 Farah (Sectioning Valve (SV) Station), Mathura

Actual PSP	=	-1.2
Off PSP	=	-1.2 (Natural Potential)
Min. P/L Potential	=	-1.1
Max. P/L Potential	=	-1.8
Max. Set Potential	=	-1.15

Solar Charge Controller; Voltmeter = 13 V

Unlike Sone Ka Gurja station where TEG is installed, here we have solar chargers installed on the top of the station rooms to generate energy for operating the units installed. The reason for using these solar chargers is almost the same as that for Sone Ka Gurja station i.e. there is either intermittent or no power supply at this location.

4.4.3.3 Bajhera (Sectioning Valve (SV) & Intermediate Pigging (IP) Station)

This station is very similar to Sone Ka Gurja station in term of installation and the operations looked after from this location.
The Cathodic Protection System of GAIL (India) Ltd. initially during the construction phase of the line used galvanic anode (or sacrificial anode) system. Once the line was commissioned, a permanent cathodic protection system was used. The permanent impressed current system provide protection to the external exposed surface of trunk pipeline ranging from 36" to 18" diameter and 12" diameter branch pipelines. In addition the permanent galvanic anode system offer cathodic protection to the carrier and casing pipes at railway crossings and to the carrier pipes at river crossings. Cathodic Protection system must be properly maintained in order to operate effectively. To accomplish this goal efficiently, diligent monitoring is required.

The monitoring and maintenance routine calls for visual inspection of components and observation of system's performance whenever the station is visited, for whatever reason for cleaning and for testing systems performance, and possible re-adjustments. This approach of observing and analyzing system's performance whenever possible will result in keeping the number of unscheduled service calls to a minimum.

4.4.3.4 Agra City Gas Station (ACGS) & City Network

The Agra City Gas Station is situated at Teri Bagiya on the outskirts of Agra. The total gas handled at this station is 1,30000 to 1,70000 scm per day as compared to the handled at Firozabad City Gas Station (FCGS) which 10,0000 to 11,00000 scm. This huge difference is because of the industrial base (glass industry) in Firozabad which requires great quantities of gas for the purpose. Whereas in Agra, nature of industries is such that they require lesser quantity of Natural gas.
There is an inlet of 10" spur line from Bajhera which supplying gas at a pressure of 60 -70 kg/cm^2. From this 10" spur line, an 8" and a 10" line are moving to Firozabad station. Now on the exit of the 8" line a filter separator is mounted followed by Shutdown Valve (2 Nos.), and Pressure Control Valve (2 Nos.). Out of these, 1 SDV and PCV each is in operating mode while the remaining two are in standby mode.

Thereafter, from the Pressure Control Valve the gas is sent to the metering unit (turbine meter) where the amount of gas outflow is being measured. And finally, the gas is distributed to the customer in the local market at the pre-decided price.

4.4.3.5 Firozabad City gas Station & City Network

Firozabad city gate station is situated at Raja ka Tal in Firozabad; it's 5 km away from Firozabad. Natural gas requirements or handling is higher than Agra city gas station.
A similar installation is found at the Firozabad City Gas Station (FCGS).

The only change is handled natural gas because of higher glass industry which has higher Natural gas required to melt glass. Firozabad has large city gas network. This network contain 8" line to 2"line and valve and all facility same as Agra city gas station.
Large network required larger maintenance per year, so Firozabad city gate station has higher maintenance than Agra city gas station.
During the project work, I am associating with the CIPL and DCVG survey, which being carried out for the pipeline under Agra region.

4.5 Specialized Techniques & Survey for Monitoring

The main objectives of the survey were to:-

- Find out the effectiveness of CP System over the entire length of pipeline.
- Find out the current drain points/ coating defects locations.
- Find out under and over protected zones.
- Find out possible coating disbondment locations due to over protection
- Find out pin pointed location and size of coating defects.
- Find out locations prone to foreign interference.

Survey Agency: The survey has been carried out by M/s Corrtech International Pvt. Ltd., Ahmedabad.

a. Carry out CIPL (ON-OFF) Survey at every 1.0 meter along the pipeline as per the specified procedure and guidelines.
b. Determine exact location, size and magnitude of coating defect throughout the periphery of the pipeline by carrying out the DCVG survey at the probable defect locations identified by the CPL Survey. Also quantify and categorize the coating defects in the terms of severity as 'minor', 'moderate', and 'severe' and anodic/ cathodic in accordance with NACE standards.
c. To establish the existence of interference situations, if any.
d. To excavate at least 5 locations on every 100 kms of surveyed length to verify the survey results. Based on 80% accuracy of the result, the survey is continued. If results are not found proper at these locations, excavation is to be done at additional locations.

4.6 CIPL Survey

CIPL survey carry out to measure pipe to soil potential along the pipeline. This survey determines:

- ♦ Probable locations of defects in pipeline coating, and
- ♦ Status of cathodic protection system by close interval potential logging (CIPL) Survey.

Procedure: A reference electrode is connected to the pipeline at a test post, and this reference electrode is positioned in the ground over the pipeline at regular intervals (around 1 meter) for the measurement of the potential difference between the reference electrode and the pipeline.
In order to achieve measurements of both "ON" (including IR drop error) and "INSTANT OFF" potentials (in principle excluding IR drop error), the sources of cathodic protection current require to be interrupted; typically they are switched ON : OFF in a ratio of 8:2 to avoid depolarization during the survey. As most pipelines have more than one source of current

(transformer-rectifiers, bonds to other networks, sacrificial anodes) it is often necessary to deploy multiple switching devices or current interrupters.

Standard ON:OFF ratio is 4 : 1 which we used for CIPL PSP monitoring, reason for ON potential time is more otherwise line depolarize, so interrupter is used for this purpose.

Now project will start from here. We have inspected 10 km part of pipeline where we have monitored coating and performed coating survey.
In every meter we placed electrode of $Cu/CuSO_4$ and take reading of ON potential and with the help of interrupter shut the supply and take reading of OFF potential.

CHAINAGE	OFF PSP(-V)	ON PSP (-V)
264.000	1.041	1.362
264.001	1.065	1.386
264.002	1.075	1.377
264.002	1.106	1.371
264.003	1.106	1.344
264.004	1.131	1.338
264.005	1.053	1.399
264.006	1.082	1.392
264.007	1.078	1.370
264.008	1.061	1.374
264.009	1.086	1.379
264.010	1.091	1.361
264.011	1.138	1.400
264.012	1.100	1.353
264.012	1.111	1.356
264.013	1.112	1.350
264.014	1.053	1.312
264.015	1.050	1.335
264.016	1.066	1.320
264.017	1.073	1.363
264.018	1.102	1.377
264.019	1.104	1.354
264.020	1.113	1.362

264.021	1.141	1.365
264.022	1.123	1.357
264.023	1.060	1.384
264.024	1.127	1.353
264.024	1.146	1.363
265.025	1.125	1.342
264.026	1.062	1.329
264.027	1.068	1.345
264.028	1.124	1.334
264.029	1.080	1.332
264.030	1.113	1.361
264.031	1.113	1.353
264.032	1.121	1.364
264.033	1.124	1.362
264.034	1.145	1.365
264.035	1.076	1.344
264.036	1.085	1.323
264.037	1.171	1.378
264.038	1.162	1.329
264.039	1.115	1.366
264.040	1.102	1.386
264.041	1.134	1.371
264.042	1.176	1.368
264.043	1.149	1.374
264.044	1.117	1.312
263.045	1.097	1.293
263.046	1.145	1.288
263.047	1.068	1.358

Table 4.3 CIPL PSP Field Readings

Now all readings regarding to 10 km pipeline are showing in Appendix, We will plot graphs with respect to these readings.

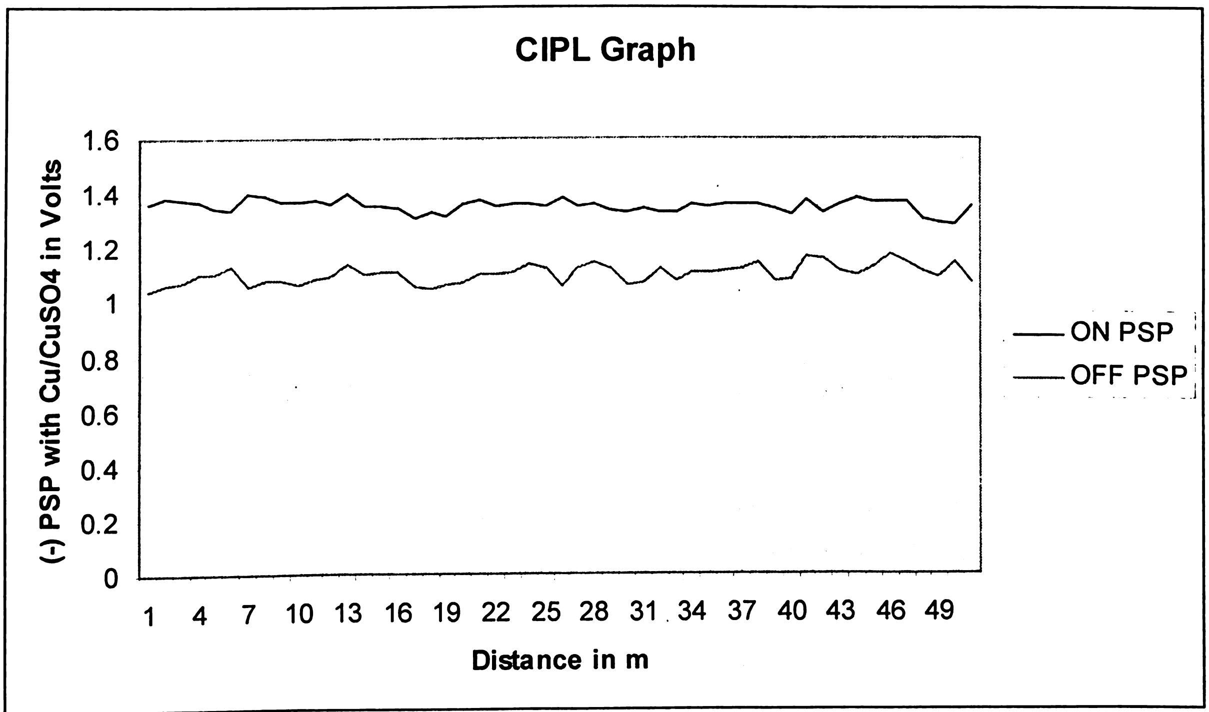


Fig 4.1 CIPL Graph

Based on the CIPL graphs, entire pipeline is cathodically protected within acceptable PSP range if any voltage drop in OFF reading, so that will be suspected location and monitored by DCVG survey.

CIPL survey drop is to be investigated by DCVG survey for investigation of nature of coating fault for observed suspected locations.
A computerized field data logger is used for measurement of potentials and synchronisable current interrupters are connected for continuously switching ON/OFF DC power source during the survey. The selection of ON/OFF measurement cycle of current interrupter in 4:1 ratio depends on technical, economic and practical considerations.
This survey requires more time and cost but provides better and more comprehensive information then other CP surveys.

The result of the CIPL survey is shown as under:

S No.	Chainage from (in mtr.)	Distance to (in mtr.)	Spot Length (in mtr.)
1	266.790	266.850	60
2	267.320	267.350	30
3	268.650	268.700	50
4	269.270	269.295	25
5	270.270	270.280	10
6	270.460	270.500	40
7	270.680	270.700	20
8	271.035	271.055	20
9	271.270	271.300	30
10	272.335	272.345	10
11	272.820	272.835	15
12	273.410	273.440	30

Table 4.4 Suspected Location Resulted From CIPL Graph

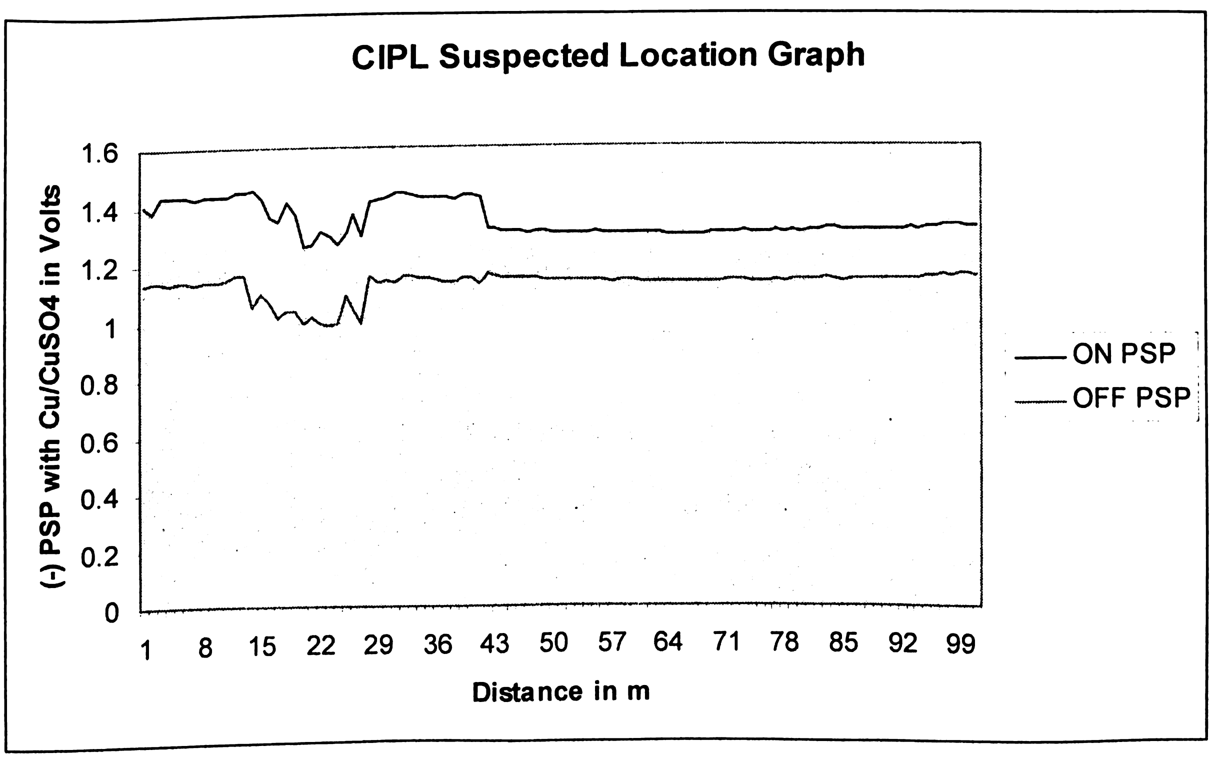


Fig 4.2 CIPL Suspected Location graph from 2800 to 2900m

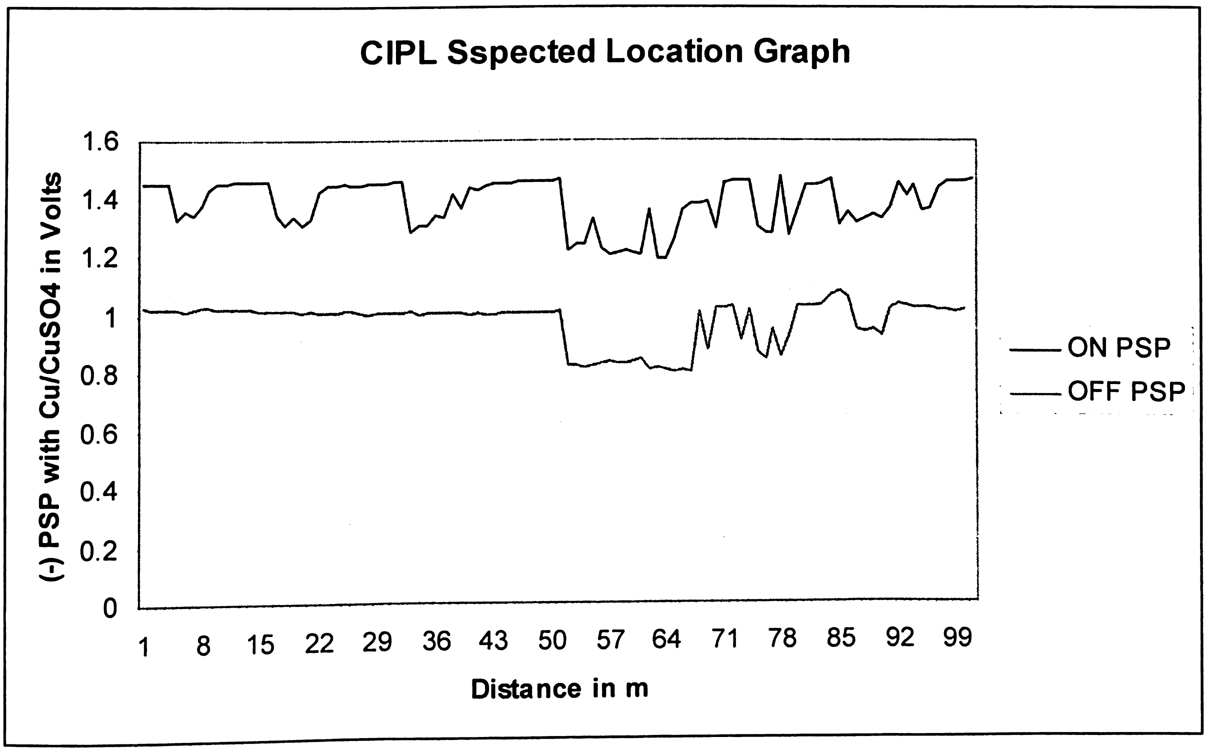


Fig 4.3 CIPL Suspected Location graph from 4600 to 4700m

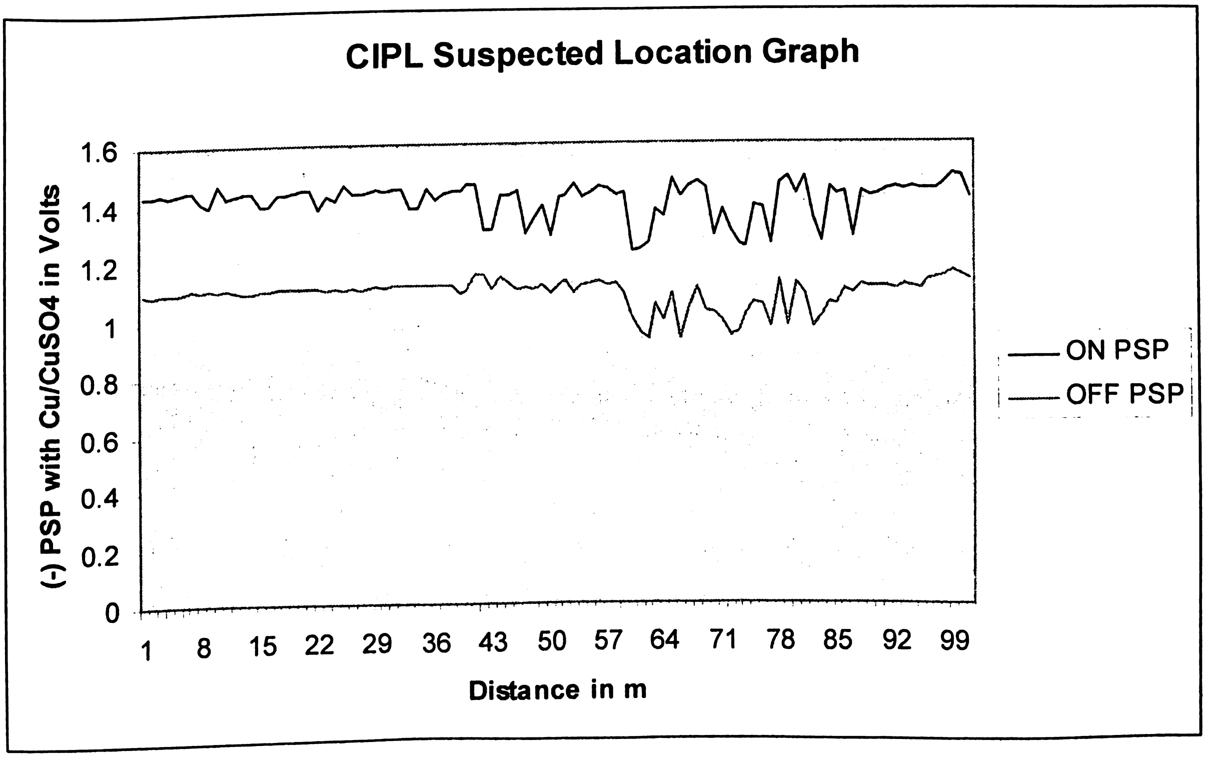


Fig 4.4 CIPL Suspected Location graph from 6400 to 6500m

4.7 DCVG Survey

Direct Current (dc) is applied to pipeline by existing / temporary cathodic protection system for determination of location and relative size of defects in coating by DCVG (Direct Current Voltage Gradient) Survey. With the help of this survey the following information about the pipeline can be inspected:

1. Coating fault epicenter location to within a 15 cm circle, which means that the excavation cost can be reduced.
2. The approximate severity of the coating fault can be established so that coating faults can be prioritized for repair.
3. The approximate corrosion behavior of the coating faults can be established to ease identification of those coating faults that do not have sufficient Cathodic Protection. The DCVG technique does not however, detect metal loss but identified sites where metal loss is possible.
4. Identification of where a coating fault gets its Cathodic Protection (CP) from, so that the vulnerability of a coating fault to being unprotected, if a CP source becomes inoperable can be established.
5. Identification of those coating fault which are discharging and picking up DC Traction Interference so that more effective mitigation techniques can be implemented.
6. Identification the interfering structures that rob CP from pipeline.
7. Establish the effectiveness of Insulating Flanges.
8. Identification of defective test posts at which Pipe to Soil potentials are routinely monitored.
9. Rapidly establish sections of pipeline that have a larger number of coating faults by studying the rate of decay of DCVG signal on the pipeline.

The data gathered by the DCVG technique is not absolute but relative and is not influenced by a series of parameters such as soil resistivity, depth of burial etc. whose effects must be taken into account to improve the accuracy of any data.

S. No.	Location (m)		Signal at upstream	Signal at downstream	Length (m)	OL-RE at Defect location	REMARKS
	From	To					
1	266.790	266.850	1500	1500	60	80	Defect found at 266.824
2	267.320	267.350	1500	1500	30	-	Defect not found
3	268.650	268.700	1500	1500	50	327	Defects found at 268.655

4	268.650	268.700	1500	1500	50	125	Defects found at 268.670
5	269.270	269.295	1500	1500	25	-	Defects not found
6	270.270	270.280	1500	1500	10	-	Defects not found
7	270.460	270.500	1500	1500	40	40	Defects found at 270.461
8	270.680	270.700	1500	1500	20	-	Defect not found
9	271.035	271.055	1500	1500	30	-	Defects not found
10	271.270	271.330	1500	1500	30	-	Defects not found
11	272.335	272.345	1500	1500	10	-	Defects not found
12	272.820	272.835	1500	1500	15	-	Defects not found
13	273.410	273.440	1500	1500	30	-	Defects not found

Table 4.5 DCVG Survey on Suspected Locations

Calculating the severity of the coating fault

The relative severity of the coating fault is expressed by the term of %IR drop, which is calculated using the formula:-

$$\text{Coating Fault Severity } \mathbf{(\%IR)} = \frac{\text{Fault Epicenter to Remote Earth } \mathbf{(OL/RE)} \times 100}{\text{Calculated Pipe to Remote Earth } \mathbf{(P/RE)}}$$

To be able to calculate the severity of the defect it is necessary to know the distance of defects and the DCVG signal strengths at test posts either side of the sector being surveyed.
The Pipe to Remote Earth Potential is calculated as follows:

$$P/RE = S_1 - \frac{dX\,(S_1 - S_2)}{D_2 - D_1}$$

Where:
S_1 = Signal at upstream test post
dX = Distance between upstream test post and defect
D_2 = Distance of downstream test post
D_1 = Distance of Upstream test post
S_2 = Signal at downstream test post
Now result of CIPS is taken account here:

The Coating Fault Severity Grading is:-
0 - 5% MINOR DEFECT
5 – 15% MODERATE DEFECT
15% AND ABOVE SEVERE DEFECT

Now calculating the defect severity we prepare one more table:

Chainage (m)	Signal Strength at Upstream TS (mV)	Signal Strength at Downstream TS (mV)	Distance of Upstream (d2) TS to Defect location (m)	Distance of Downstream (d1) TS to Defect location (m)	OL/RE (dx) at Defect location
268.824	1500	1500	818	154	80
268.655	1500	1500	648	354	327
268.670	1500	1500	672	330	125
270.461	1500	1500	459	563	10

Table 4.6 Coating Defect Severity Calculation

Chainage (m)	P/RE = S1-{dx [(S1 – S2)/ (d2 – d1)	%IR = (Defect epicenter to remote Earth *100)/ calculated pipe to remote earth	Defect severity
266.824	1500	5.3	Moderate
270.655	1500	21.8	Severe
270.670	1500	8.3	Moderate
272.461	1500	0.7	Minor

Table 4.6 Coating Defect Severity Calculation

S. No.	Defect Information	Description
1	Survey Location	266.824
2	Interrupter installed	Every one km
3	Interrupter switch setting	0.3 sec ON/ 0.6 sec OFF
4	Signal strength at Upstream TS	1500 V
5	Signal strength at Downstream TS	1500 V
6	Distance of upstream TS to defect location	818 m
7	Distance of downstream TS to defect Location	154 m
8	OL/RE at Defect Location	80
9	P/RE at Defect Location	1500
10	% IR = OL/RE x 100 / P/RE	5.3%
11	Analysis of defect	Minor/ **Moderate**/ Severe

Table 4.7 Defect Information at 2818

S. No.	Defect Information	Description
1	Survey Location	270.655
2	Interrupter installed	Every one km
3	Interrupter switch setting	0.3 sec ON/ 0.6 sec OFF
4	Signal strength at Upstream TS	1500 V
5	Signal strength at Downstream TS	1500 V
6	Distance of upstream TS to defect location	648 m
7	Distance of downstream TS to defect Location	354 m
8	OL/RE at Defect Location	327
9	P/RE at Defect Location	1500
10	% IR = OL/RE x 100 / P/RE	21.8%
11	Analysis of defect	Minor/ Moderate/ **Severe**

Table 4.8 Defect Information at 4655

S. No.	Defect Information	Description
1	Survey Location	270.670 m
2	Interrupter installed	Every one km
3	Interrupter switch setting	0.3 sec ON/ 0.6 sec OFF
4	Signal strength at Upstream TS	1500 V
5	Signal strength at Downstream TS	1500 V
6	Distance of upstream TS to defect location	672 m
7	Distance of downstream TS to defect Location	330 m
8	OL/RE at Defect Location	125
9	P/RE at Defect Location	1500
10	% IR = OL/RE x 100 / P/RE	8.3%
11	Analysis of defect	Minor/ **Moderate**/ Severe

Table 4.9 Defect Information at 4670

S. No.	Defect Information	Description
1	Survey Location	270.461 m
2	Interrupter installed	Every one km
3	Interrupter switch setting	0.3 sec ON/ 0.6 sec OFF
4	Signal strength at Upstream TS	1500 V
5	Signal strength at Downstream TS	1500 V
6	Distance of upstream TS to defect location	459 m
7	Distance of downstream TS to defect Location	563 m
8	OL/RE at Defect Location	10
9	P/RE at Defect Location	1500
10	% IR = OL/RE x 100 / P/RE	0.7%
11	Analysis of defect	**Minor**/ Moderate/ Severe

Table 4.10 Defect Information at 6461

4.8 Completion of the Survey

Upon completion of the survey all cover plates and accesses to test post wires shall be returned to their original condition. All rectifier settings shall be returned to their original settings before the survey. The ON pipe to soil potential at the nearest test post shall be measured to ensure that it has returned to that before the survey. At the end of the survey, any adjustments to rectifier settings that are not the same as those before the survey shall only be made by the Contractors Engineer under written instructions from the owner. Any damage to any pipeline right of way furniture such as test post, marker post, rectifiers, etc. either caused by contractor or by vandals or any intrusion or excavation on the right of way shall be reported to the owner in writing as soon as possible.

4.9 Repair of Defects

After completion of the survey and analysis of the report, the size and location of the defects are to be marked as Severe, Moderate & Minor for each region. All the defects are to be verified with probability of detection 80%, and rectify all defects (Severe, Moderate & Minor) by excavating the pipeline [exposing the pipe surfaces] as per the requirement to repair the defects, removal of defective coatings, cleaning & repairing using coating materials, holiday checking, backfilling & restoration, and resolving the dispute with the formers for any compensation.

4.10 Procedure for Coating Repair

The job is to be carried out as per the stage inspection format:

4.10.1 Excavation

- Without regard the soil condition or topography of the ground, the trench shall be excavated and finished to the dimensions, a view to expose the pipeline and to provide for sufficient working space for carrying out the work of manual removal of old coat and wrapping all round the circumference of pipeline. The free movement while coating with a coating machine by coating gang and enable the gang freely removes the old coat and wrap, to carry out cleaning, new priming, coating etc. Safety of working person as well as pipeline shall be taken into consideration. The pipeline excavated length shall be such as to carry out the intended length of coat with required side overlapping to be provided.

- The site engineer is warned that while excavation job is carried out, the pipeline, which is carrying highly explosive natural gas should not be damaged by chiseling, hammering, etc. shall not be allowed on the pipeline surface in any case. The person or contractor shall be responsible for all necessary fire hazards precautions and for taking actions to prevent any damage whatsoever to the pipeline. The contractor shall be responsible for taking all preventive measures keeping adequate number of fire extinguishers duly charged and in good working condition near the worksite.
  Contractor shall exercise care to see that the fresh soil recovered from trenching operation intended to be used for backfilling over the laid pipe in the trench is not mixed with loose debris or foreign matter. The excavated earth shall be deposited sufficiently away from the trench sides, in such a manner so as not to collapse on the trench sides and also not to obstruct other operation.

- Maximum unsupported length of pipeline shall not exceed 10 mtrs. If the some exceeds 10mtrs, the contractor has to provide supports of every 6-8 mtrs, with gunny bags, sand bags, wooden bags, etc.

- In most of the sectionalizing valve stations [SV] and Radio-Repeater stations/Intermediate Pigging stations/concreting has been done. In case of any coating defect in those areas the some has to be excavated by dismantling the concreting.

4.10.2 Witnessing of the Defects

The "EIC/SIC" of the respective region will witness the defect with respect to the reported one of that of survey and accordingly the report will be signed jointly by the contractor. The defected area of the coating to be photographed with proper numbering of the defects and the copy of the defects and the copy of the some should be a part of final report.

4.10.3 Types of Coating Repair

Generally two type of coating repair work is used in GAIL India.

1. Coating repair using cold applied tape
2. Coating repair using –PERP

Different type of tape and patch detail given in Appendix C.

4.10.3.1 Coating – Repair Using Cold Applied Tape

[A] Surface Preparation:

1. The old/damaged coating shall be totally removed carefully with scrappers.

2. After the coating is removed, the pipe-surface shall be prepared by hand-brush/emery-paper/scrappers etc or a combination of all above with full removal of loose point, coating, rust, oil, grease, dirt, etc. to the entire satisfaction.

[B] Application of Primer:

1. Priming shall be carried within immediately after cleaning/surface-preparation of the pipeline. Before applying the primer, the pipe-surface shall be cleaned with a clean cloth ensuring that the surface is free from dust particles.

2. Stir the primer in its original container and apply a uniform coat of primer to the cleaned surface of the pipeline (and where applicable to the adjacent mill – coating) with a good quality point brush. Consumption of the primer is approximately 0.2 ltrs per sq. mtrs of surface.

3. The primer is to be allowed to dry for thirty minute, during drying time of the primer; enough precautions must be taken to ensure that no dust particles are falling on the fresh primed surface.

4. Thumb test is to be done and is found ok, wrapping may be started within 8 hours of application of primer.

[C] Wrapping:

1. **Inner Wrap:** Wrap densolene tape S 25 HT hand – wrapping machine under proper tension and without wrinkles spirally around the pipe into the sticky primer with grey side of the tape facing the steel surface overlap on to the adjoining factory applied coating.

2. **Outer Wrap:** Wrap the densolene tape R 25 HT with under the proper tension and without wrinkles spirally around the pipe with butyl adhesive facing the inner wrap with a minimum of 50% overlap. Ensure that the outer wrap completely covers the inner wrap.

The cold applied tapes shall be kept in shade and the coated pipeline section shall also be protected from direct sunlight by using tarpolene/ polythene sheet/ gunny bags filled with soil, if not backfilled immediately.

4.10.3.2 Coating Repair Using Patch:

[A] Surface Preparation:

1. The loose/damaged coating shall be totally removed carefully with scrappers.

2. After the coating is removed, Clean the pipe surface and 50 mm of adjacent mill coating using – brush/emery – paper/scrappers.

[B] Patch Application:

1. Measure the holiday and cut the Patch from roll consideration 50 mm overlapping from all sides.
2. Round off the edges of the Patch.
3. Pre – heat the entire repair area to approximately 60 – 70 deg cent.
4. Apply the filler mastic to fill the holiday then heat the mastic and smooth it down with a paint-scrapper.
5. The adhesive side of patch shall be flame brushed until the adhesive becomes glossy.
6. Apply the pre-cut patch over the damaged area and heat until the adhesive melts roll out.
7. Complete the installation by smoothing with gloved hand or roller to avoid air entrapments.
8. Repeat the post heating and smoothing operation three times.

4.10.4 Installation procedure:

1. Clean damage areas. Cut away loose parts of the mill-applied coating. Round out nicks and slits. Remove adhering rust and dirt, and roughen the mill-applied coating in the repair zone using abrasive paper. The surface must be free from oil, grease and moisture.

2. Cut a length of filler to fit the damage. Pre-heat the damaged zone to +60°C, apply the filler, heat it and smooth it down with a hot putty knife.
   Important: do not spread the filler over the mill-applied PE coating.

3. Cut the repair patch for the damaged area so that there is an overlap of at least 50 mm all round. Then heat the patch on the adhesive side until the adhesive softens, shown by the surface turning glossy.
   The patch should be made of selected coating material; it depends on environment and cost consequences.
   In one end of patch should be some adhesive when this patch exposed with heating application then it would come in to picture.

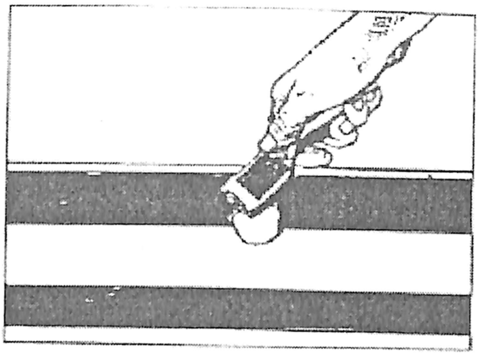


Fig 4.5 Surface Preparation with Application of Abrasive paper

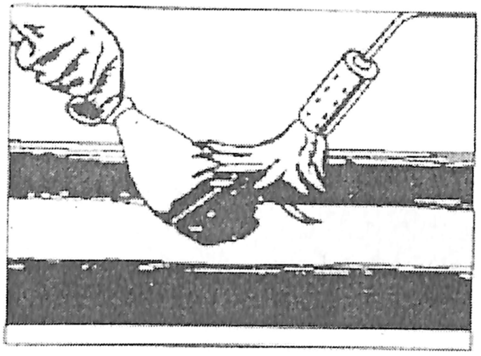


Fig 4.6 Preheat the pipe

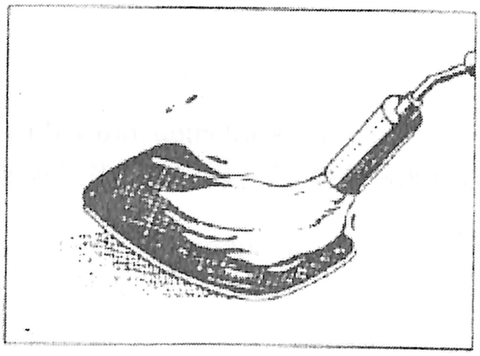


Fig 4.7 Heating of Patch

4. Using a soft yellow propane flame, warm the patch until the thermo-indicating paint changes color.

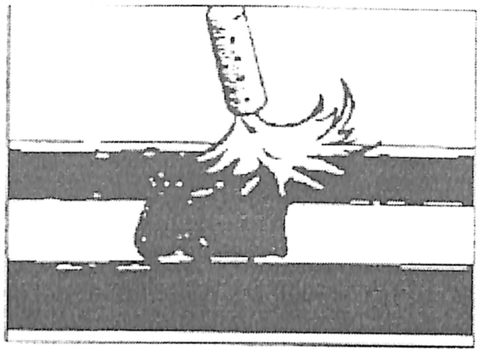


Fig 4.8 Heating of pipe surface

5. Smooth down with a glove hand or with a hand roller. Once in place, the patch repair system must be smooth and free from air enclosures. Adhesive flow is evident at all edges of the sleeve.

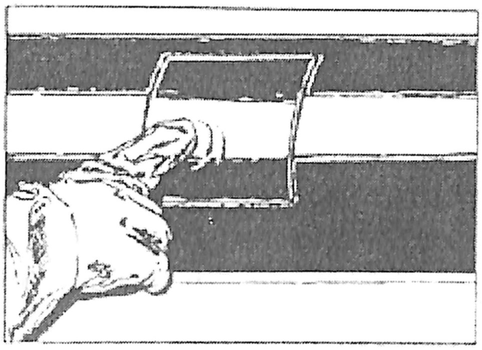


Fig 4.9 Patch Application

4.10.5 Holiday Testing

Test the coated surface with a holiday detector at 20 kV for any imperfections. The test probes of the holiday detector must touch the surface of the wrapping. The same has to be done in the presence of owner-personal.
The repaired coating areas are to be photographed.

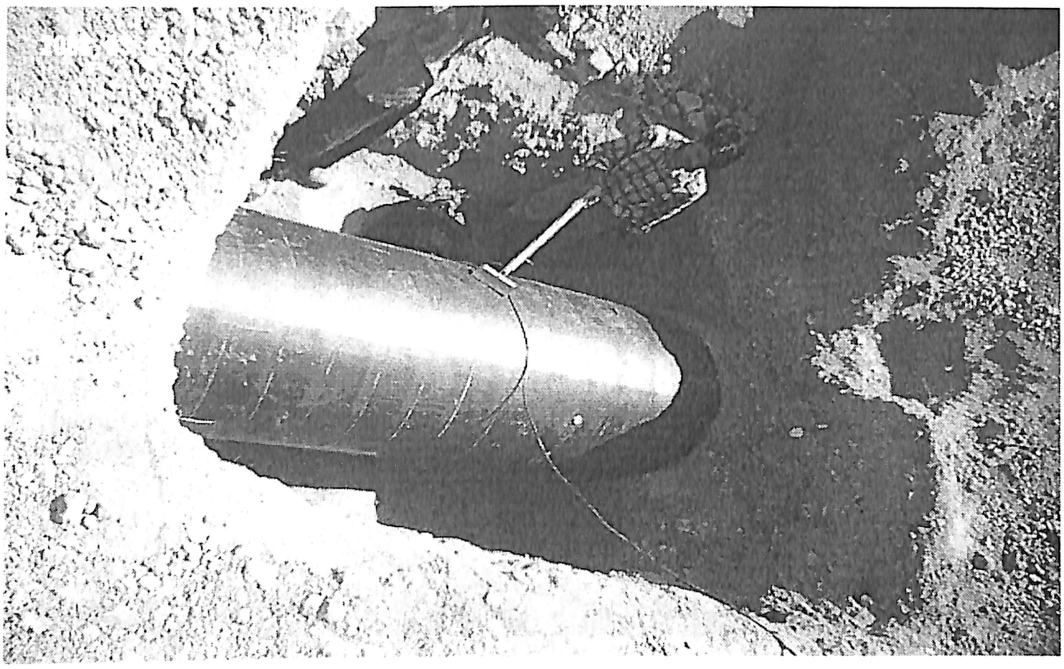


Fig 4.10 Holiday Testing By Holiday Detector

4.10.6 Backfilling and Final Restoration

The backfilling operation shall be performed in such a manner as to provide firm support and avoid any injury at damage to be new coating, wrapping and pointing. Suitable soft selected earth, free from lumps, etc. shall be used for providing the soft good earth padding up to 200 mm above the top of the pipe [if soft good earth is not sufficient within the excavated soil then the supply of good earth/sand up to 200mm from the top of the pipe]. Prior to backfilling of the trench, the contractor shall insure that the trench shall be cleaned of all spills of old and new coating material which may be lying inside the trench subsequent to coating operations. The coating spills removed from trench shall be disposed off suitably outside the row. The soft earth pad for the pipe shall be neatly covered over the ditch and there on to a minimum height of 0.200 mtrs above the adjacent ground.

The entire field/ground shall be brought to the original level and conditions which were existing prior to taking up to the job. All fencing, bunds, and other structure shall be restored to their original condition, i.e. entire ROW shall be smoothened to a manner satisfactory to he landowner/tenant.

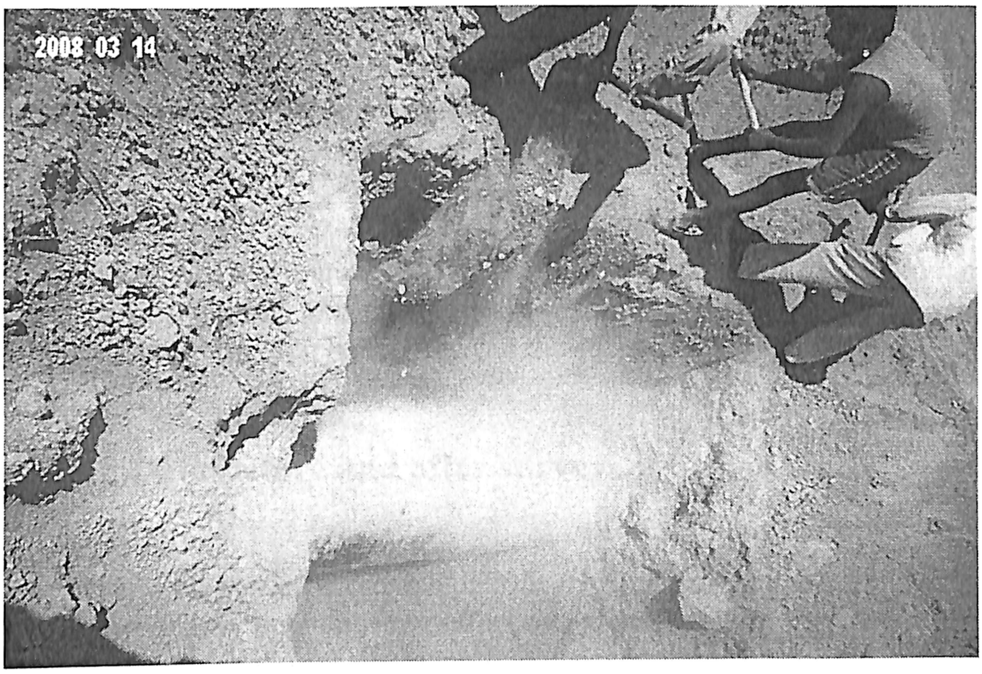


Fig 4.11 Backfilling of Pipeline

CHAPTER 5
RESULTS AND DISCUSSION

5.1 General

This project carrying out CIPL and DCVG survey to locate coating defects in natural gas pipeline coating, CIPL results nothing but they just show the PSP reading and its execution in form of graph. On the basis of these graphs we find out the suspected locations.

5.2 Recording Data before and after survey

5.2.1 Before Survey

Before these survey starts we record the data from given instrument, its PSP level is measured, line temperature, pressure these does not effect on external environment.
PSP recorded quarterly, this gives the overall view of pipeline.

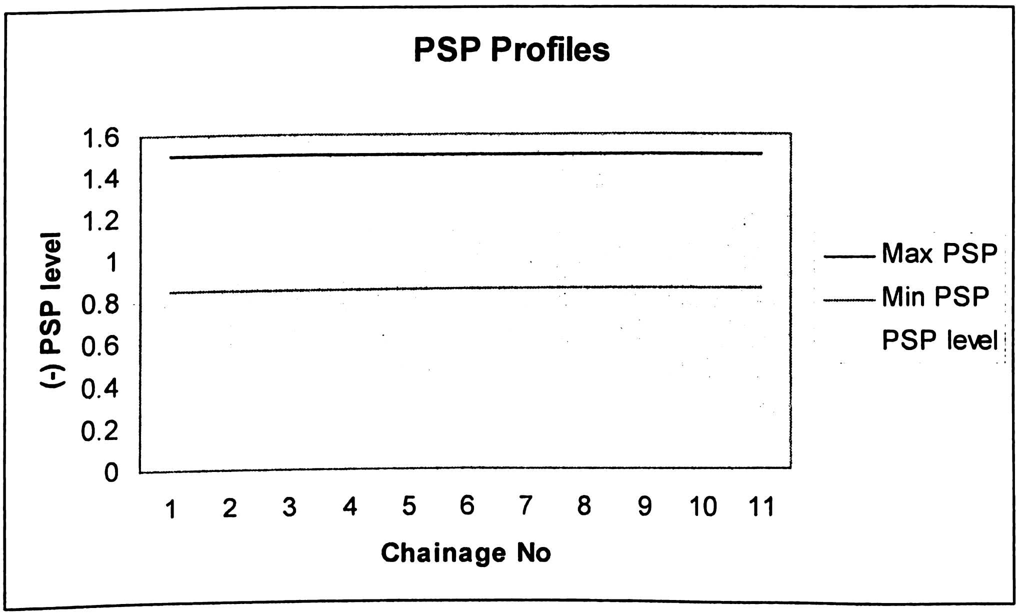


Fig 5.1 PSP profiles from 264 Chainage to 273 Chainage

These profiles give the overall information about system, but it's not able to give the defect information, so at the time of survey we check our various parameters which used to protect our pipeline, as current applied by T/R unit, level of max and minimum level.

Voltage measured at every meter distance: vary 0.85 to 1.5 (-)

Voltage gradient; check out from 2 readings of voltage

Line pressure: 18 kg/cm^2

5.2.2 After Survey

For Chainage 266.824 (after Surveying)

PSP Level 0.996 (-) V OFF reading 1.291 (-) V in ON reading

Voltage gradient 0.051(-) in OFF reading and 0.076 (-) in ON reading

5.2.3 After repairing

When survey has finished now we have already locate exact defect location, so now we will go for repair according to its severity, when once repair has complete now we record and check data is in desired limit or not,
Firstly we applied holiday testing in which sound waves of 20 KV identify the defect location, if any spark will be there it means some disbonding is there, after successful completion we record data of that location where this defect has found. We take result of Chainage 266.824 and show the collected data:

PSP level: 1.038 (-) V in OFF reading and 1.356 in ON reading

Voltage gradient 0.009 (-) V in OFF reading and 0.11(-) V in On readings

5.3 CIPL results and discussion

CIPL survey are used to check protection level of our pipeline system, in which Cu/CuSO4 electrode is placed and walking survey is there which give the survey ON/OFF PSP readings and based on these readings we locate our suspected location that will be input for DCVG survey and output of CIPL survey which shown below:

S No.	Chainage from (in mtr.)	Distance to (in mtr.)	Spot Length (in mtr.)
1	266.790	266.850	60
2	267.320	267.350	30
3	268.650	268.700	50
4	269.270	269.295	25
5	270.270	270.280	10
6	270.460	270.500	40
7	270.680	270.700	20
8	271.035	271.055	30
9	271.270	271.300	30

10	272.335	272.345	10
11	272.820	272.835	15
12	273.410	273.440	30

Table 5.1 CIPL Result

These readings will be decided by observing CIPL graph, now when I have started to locate these defects then my mentor is suggested to locate the suspected location because various time potential drops will be there due to various interferences.
Interference may be due to external crossing, T/R unit does not produce optimum quantity current, and various other reasons will be there.
So CIPL output will be input of DCVG system. Now DCVG will carried out exact location of defect.

5.4 DCVG Results

DCVG directly pinpoint the defect locations with the help of meter deflection, whenever the meter needle does not give any deflection then it meant that was defect location, produce field marker there and continue until complete the survey.
When survey pinpoint the location, then at that point also measures the over line to remote earth, locations that has to be helpful to locate defect severity.
During this project I find out four defects:

Chainage	%IR	Defect severity
266.824	5.3	Moderate
270.655	21.8	Severe
270.670	8.3	Moderate
272.461	0.7	Minor

Table 5.2 Coating Severity

Repairing work has been done according to defect severity, if defect is minor and moderate then we can use patch repair but if severe defect like coating disbondment then we have to go for inner outer wrap.

At last, we can say CIPL combining with DCVG survey is effective way to find out coating defects.

CHAPTER 6

CONCLUSION & RECOMMENDATIONS

6.1 Conclusion

Corrosion costs the industry billion of rupees in India. With liberalization of Indian economy, the industrial revolution sprang a surprise in the pipe industry with a great demand of pipelines. The pipe manufacturers, pipe coaters, and pipe laying companies have seen a tremendous growth in the last decade and in the near future it is going to multiply ten times. India is now a big industry in pipeline both for crude transportation and supply of natural gas.

The company like IOCL and GAIL has tremendous pipeline Network, they required more security from corrosion. The pipeline industry is confronted with a wide range of corrosion problems. External surfaces of the pipelines in contact with soils, waters, or an atmospheric environment, and the interior surfaces of pipelines which are in contact with a potentially corrosive material being carried by the pipeline, are subject to most of the basic corrosion processes and most of the forms of corrosion attack. All forms of installations need protection in order to enhance their life. Material selection is the first and foremost method of corrosion protection. A material to be selected must have lower corrosion rate in the said environment. However, cost consideration is an important factor. Thus the choice should be a relatively cheaper material with low reactivity.

CIPL and DCVG is unable to locate coating internal defects like adhesion, bonding between pipe and coating, so these types of defect can be measured with other techniques.

Regular inspection and condition monitoring of underground Oil & Gas Pipelines is essential to ascertain the health of pipeline coating. The various monitoring techniques that can be used for health checkup of the pipeline system are installation of corrosion sensing probes, thickness survey, PSP monitoring, current drainage survey, Pearson Survey, CAT, CIPL on-off survey, DCVG survey, Intelligent Pigging etc. All these techniques provide information or data which can be utilized to assess the health of the pipeline

CIPL On-Off survey and DCVG Survey are one of the most effective techniques in achieving the above results. GAIL (India). CIPL surveys are used to identify the levels of protection that exist along pipelines and DCVG is pinpointing method which detect the exact defect location. DCVG can not used for whole pipeline because it will be time consuming, required more man power and infeasible.

CIPL instrument measures the gradients in both the On/Off condition allowing later calculation of DCVG Survey. As the spacing of the surveys is 1 metre and defect epicenters are not located it may be that the resultant calculations are entirely representative of the defect size, the information obtained gives a very good indication of the coating and cathodic protection conditions in a single pass survey.

Coating inspection and testing has already scheduled quarterly or half in year, but the survey including CIPL and DCVG survey has scheduled once in five years.

Once coating Fault location is find out then we started repair work according to their defect severity.

Patch Repair and Cold Applied Tape repair are practically and economically suitable approach for coating repair. For minor and moderate defect we applied patch repair and for severe Cold applied tape.

At last in this project we find out in my calculations 1 minor, 2 moderate and one 1 severe and all defects are repair with patch applications. NACE RP 0185 standard is used for for 3 layer Polyethylene Coatings.

6.2 Recommendations

The recommendations are always set up for our work it's related to material environment, processing condition, design, operations, maintenance etc. These recommendations are giving to avoid any recurrence during in operation our system. The recommendations are:

- Coating inspection and survey is carried out as per schedule.
- Coating need to be repaired at defect locations.
- It is recommended that the entire section of pipeline between Vijaipur and Sone Ka Gurja may be electrically isolated in to three independent sections at the IP stations.
- Before going on routine survey firstly pipe to soil potential (PSP) survey carried out.
- For avoiding failures in a pipeline, a company has to have a well designed inspection and maintenance programme.
- The choice of a technique shall be made after taking into consideration the pipeline operating parameters, the type of CP, pipeline characteristics, the end result and objective that is desired from a particular technique to be applied.
- Operating pressure in the pipeline should be continuously monitored and pressure surging should be avoided.
- To ensure correct interpretation of data in areas of stray current interaction, a simultaneous "static" pipe to soil potential is always recorded.
- Current interrupters are set up in synchronization with the datalogger commonly at a switching ratio of 4 : 1 On : Off to prevent pipeline depolarization. A timing cycle of 0.8 seconds On and 0.2 Off is commonly adopted.
- To check the accurate deflection of mill voltmeter at suspected location in the DCVG survey.

- Proper set up of all equipments for carrying survey.
- Extra care and vigilance is required to be taken by the personnel inspecting the pipe surface during coating re-visioning work of operating pipelines and coating of pipes to ensure that no corrosion patch goes unnoticed anywhere on the pipe surface.
- The accuracy of the instrument and the skill of the operator allow detailed investigation of the location and the collected data can be interpreted to categorize many defects along the route and prioritise on coating repairs, so operator should be experienced.
- Before repair work at coating defects, surface preparation include cleaning of surface, primer application required.
- Patch repair with mastic application is recommended generally with minor and moderate defects, and some time can be applied on severe defects.
- Cold applied tape or inner and outer wrap is recommended with serious problem as coating disbondment, and its failure.
- Different types of tapes are using for coating repair work given in Appendix C.
- Once coating repaired then Holiday inspection should be recommended to check out your repair work properly or not.
- Effective backfilling exercise care to minimize damage in the ditch, so it is recommended at the time backfilling soft clay on pipe surface.
- Standards like NACE and OISD must be strictly followed and there should be no slackness to ensure good health of the pipeline system.
- Coating monitoring is difficult task should be handled by experienced person, who had undergone some training programme for this purpose.
- Coating defect directly affect the performance of Cathodic Protection so it is recommended to repair coating defects as soon as possible.
- Pipeline different accessories should be monitored properly they can affect directly or indirectly on coating performance.
- Safety engineer is always allowed or posted at the excavation period when coated pipe repaired.
- The ON/OFF potential measurements methods provide good information for determination of remoteness of anode ground beds and performance of insulating joints, cased crossings and overall Cathodic protection system.

- GAIL recommended CIPL followed by DCVG survey, because this combination is time saving, economic and efficient.

- Scheduled coating inspection required as peel test, hardness, abrasion test etc has recommended knowing the exact information about coating health.

- All instrument using in inspection and survey as half cell, voltmeters etc are properly calibrated.

- All coatings to be though roughly checked for defect, regular monitoring of Cathodic protection system to be adopted.

- At last for efficient monitoring proper care of pipeline, and scheduled work being carried out.

6.3 Recommendation for future projects:

- It will recommend CIPL followed DCVG survey once in five year but behalf of that quarterly or bi quarterly regular inspection being carried out.

- Efficient operator will always recommend for carrying CIPL and DCVG survey.

- The field reading should be easily fit in the graph and based on based on these graph future plan as where DCVG will be carrying.

- DCVG is not economic and time consuming so our suspected location selection wit directly effect on our economy so experience person will require making decision like that.

- Dig verification is important aspect when we will go for repair.

- Any project it will be important our instruments should be properly calibrated.

- In future wherever these surveys found the procedure locating defect will be same manner but we can applied these survey on effective way with use of effective technique or advance technique.

- Repair work is being advanced when we will go for future projects so it will recommend when coating disbondment is there, an effective repair work will be there.

REFERENCE

- Report of GREP Pipeline CIPL Survey and DCVG Survey.
- Peabody A.W., Control of Pipeline Corrosion, published by NACE, Houston 1967.
- John Morgan, Cathodic Protection, published by NACE, Houston, 1967.
- GTI Manual, GAIL (India) Limited.
- NACE Standards for Pipeline Corrosion.
- Mo Mohitpour, Jason Szaba, "Pipeline Operation & Maintenance-A Practical Approach", published by ASME PRESS, New York, 2005.
- Google.com

APPENDIX A

(Refer chapter 4)

CIPL Readings and Graph

CIPL ON/OFF readings

CHAINAGE	OFF PSP(-V)	ON PSP(-V)
264	1.041	1.362
264.001	1.065	1.386
264.002	1.075	1.377
264.003	1.106	1.371
264.004	1.106	1.344
264.005	1.131	1.338
264.006	1.053	1.399
264.007	1.082	1.392
264.008	1.078	1.370
264.009	1.061	1.374
264.01	1.086	1.379
264.011	1.091	1.361
264.012	1.138	1.400
264.013	1.100	1.353
264.014	1.111	1.356
264.015	1.112	1.350
264.016	1.053	1.312
264.017	1.050	1.335
264.018	1.066	1.320
264.019	1.073	1.363
264.02	1.102	1.377
264.021	1.104	1.354
264.022	1.113	1.362
264.023	1.141	1.365
264.024	1.123	1.357

264.025	1.060	1.384
264.026	1.127	1.353
264.027	1.146	1.363
264.028	1.125	1.342
264.029	1.062	1.329
264.03	1.068	1.345
264.031	1.124	1.334
264.032	1.080	1.332
264.033	1.113	1.361
264.034	1.113	1.353
264.035	1.121	1.364
264.036	1.124	1.362
264.037	1.145	1.365
264.038	1.076	1.344
264.039	1.085	1.323
264.04	1.171	1.378
264.041	1.162	1.329
264.042	1.115	1.366
264.043	1.102	1.386
264.044	1.134	1.371
264.045	1.176	1.368
264.046	1.149	1.374
264.047	1.117	1.312
264.048	1.097	1.293
264.049	1.145	1.288
264.05	1.068	1.358
264.051	1.151	1.315
264.052	1.078	1.374
264.053	1.099	1.388
264.054	1.122	1.372
264.055	1.143	1.368
264.056	1.137	1.364

264.057	1.045	1.315
264.058	1.084	1.356
264.059	1.105	1.351
264.06	1.060	1.364
264.061	1.040	1.280
264.062	1.054	1.294
264.063	1.090	1.267
264.064	1.040	1.292
264.065	1.096	1.359
264.066	1.073	1.330
264.067	1.056	1.335
264.068	1.049	1.338
264.069	1.039	1.348
264.07	1.053	1.340
264.071	1.045	1.335
264.072	1.069	1.343
264.073	1.066	1.333
264.074	1.058	1.348
264.075	1.033	1.280
264.076	1.069	1.299
264.077	1.108	1.267
264.078	1.039	1.331
264.079	1.078	1.360
264.08	1.096	1.372
264.081	1.098	1.368
264.082	1.110	1.370
264.083	1.105	1.377
264.084	1.106	1.381
264.085	1.112	1.385
264.086	1.119	1.382
264.087	1.113	1.327
264.088	1.116	1.392

264.089	1.106	1.377
266.79	1.121	1.431
266.791	1.121	1.414
266.792	1.123	1.418
266.793	1.123	1.415
266.794	1.140	1.434
266.795	1.131	1.424
266.796	1.145	1.377
266.797	1.138	1.410
266.798	1.134	1.403
266.799	1.140	1.379
266.8	1.141	1.430
266.801	1.138	1.434
266.802	1.140	1.431
266.803	1.142	1.431
266.804	1.138	1.425
266.805	1.145	1.433
266.806	1.142	1.430
266.807	1.142	1.433
266.808	1.151	1.435
266.809	1.165	1.445
266.81	1.166	1.448
266.811	1.054	1.451
266.812	1.101	1.422
266.813	1.066	1.358
266.814	1.021	1.346
266.815	1.039	1.413
266.816	1.038	1.369
266.817	0.995	1.260
266.818	1.016	1.265
266.819	1.000	1.312
266.82	0.992	1.291
266.821	0.995	1.268
266.822	1.092	1.305
266.823	1.047	1.367
266.824	0.996	1.291
266.825	1.153	1.412
266.826	1.138	1.417
266.827	1.140	1.422
266.828	1.135	1.441
266.829	1.159	1.437
266.83	1.153	1.432
266.831	1.148	1.426
266.832	1.150	1.427
266.833	1.140	1.422
266.834	1.133	1.426
266.835	1.137	1.420
266.836	1.150	1.431
266.837	1.152	1.431
266.838	1.126	1.423

266.839	1.162	1.315
266.84	1.158	1.319
266.841	1.152	1.307
266.842	1.150	1.310
266.843	1.150	1.310
266.844	1.146	1.304
266.845	1.147	1.308
266.846	1.142	1.307
266.847	1.144	1.305
266.848	1.145	1.305
266.849	1.143	1.304
266.85	1.143	1.302
267.32	1.124	1.398
267.321	1.118	1.399
267.322	1.115	1.397
267.323	1.123	1.397
267.324	1.119	1.403
267.325	1.118	1.402
267.326	1.117	1.401
267.327	1.114	1.403
267.328	1.119	1.401
267.329	1.120	1.400
267.33	1.119	1.399
267.331	1.115	1.406
267.332	1.122	1.401
267.333	1.120	1.402
267.334	1.080	1.358
267.335	1.066	1.358
267.336	1.069	1.386
267.337	1.072	1.360
267.338	1.125	1.393
267.339	1.127	1.399
267.34	1.125	1.398
267.341	1.119	1.387
267.342	1.123	1.394
267.343	1.121	1.400
267.344	1.125	1.394
267.345	1.119	1.392
267.346	1.115	1.398
267.347	1.114	1.387
267.348	1.116	1.389
267.349	1.116	1.385
267.35	1.115	1.392
268.65	1.003	1.459
268.651	1.012	1.211
268.652	0.823	1.240
268.653	0.823	1.234
268.654	0.818	1.324
268.655	0.824	1.225
268.656	0.832	1.197

268.657	0.835	1.210
268.658	0.829	1.217
268.659	0.828	1.205
268.66	0.834	1.199
268.661	0.842	1.355
268.662	0.804	1.188
268.663	0.811	1.186
268.664	0.804	1.251
268.665	0.801	1.352
268.666	0.806	1.374
268.667	0.801	1.372
268.668	1.006	1.385
268.669	0.873	1.290
268.67	1.018	1.445
268.671	1.021	1.453
268.672	1.025	1.452
268.673	0.910	1.455
268.674	1.013	1.293
268.675	0.867	1.276
268.676	0.845	1.270
268.677	0.947	1.466
268.678	0.852	1.265
268.679	0.922	1.351
268.68	1.023	1.439
268.681	1.026	1.442
268.682	1.024	1.450
268.683	1.031	1.461
268.684	1.062	1.301
268.685	1.077	1.346
268.686	1.053	1.307
268.687	0.949	1.321
268.688	0.935	1.341
268.689	0.946	1.323
268.69	0.926	1.362
268.691	1.016	1.447
268.692	1.034	1.403
268.693	1.025	1.442
268.694	1.020	1.356
268.695	1.019	1.363
268.696	1.018	1.434
268.697	1.014	1.453
268.698	1.010	1.457
268.699	1.006	1.457
268.7	1.012	1.461
269.271	1.078	1.425
269.272	1.077	1.426
269.273	1.075	1.424
269.274	1.079	1.400
269.275	1.079	1.414
269.276	1.073	1.422

269.277	1.074	1.408
269.278	1.080	1.440
269.279	1.077	1.407
269.28	1.070	1.402
269.281	1.083	1.421
269.282	1.067	1.464
269.283	1.073	1.442
269.284	0.987	1.457
269.285	0.986	1.468
269.286	0.990	1.473
269.287	1.005	1.470
269.288	1.025	1.464
269.289	1.048	1.406
269.29	1.033	1.408
269.291	1.030	1.416
269.292	1.035	1.413
269.293	1.027	1.410
269.294	1.032	1.410
269.295	1.058	1.409
270.27	1.067	1.429
270.271	1.067	1.353
270.272	0.994	1.368
270.273	0.982	1.359
270.274	1.008	1.428
270.275	1.023	1.437
270.276	1.028	1.377
270.277	1.056	1.418
270.278	1.063	1.421
270.279	1.044	1.428
270.28	1.045	1.352
270.46	0.950	1.243
270.461	0.931	1.268
270.462	1.054	1.371
270.463	0.995	1.354
270.464	1.090	1.473
270.465	0.928	1.417
270.466	1.040	1.456
270.467	1.116	1.472
270.468	1.036	1.446
270.469	1.028	1.286
270.47	0.995	1.375
270.471	0.948	1.300
270.472	0.962	1.255
270.473	1.017	1.249
270.474	1.063	1.386
270.475	1.053	1.382
270.476	0.972	1.255
270.477	1.131	1.459
270.478	0.983	1.483
270.479	1.128	1.428

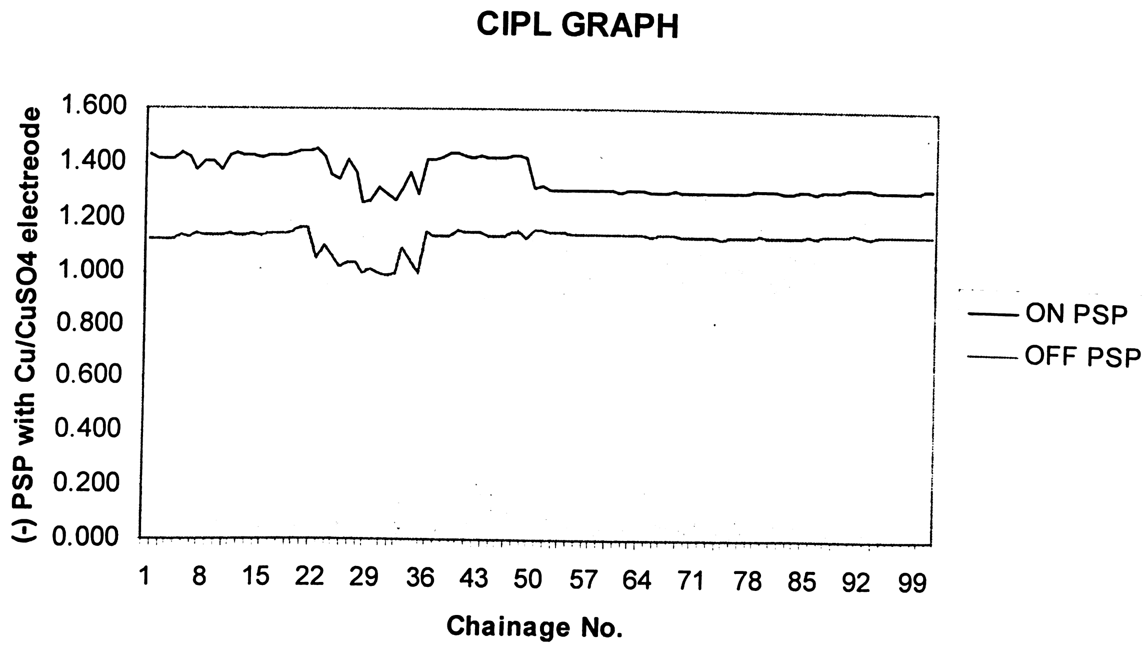
270.48	1.094	1.485
270.481	0.971	1.345
270.482	1.013	1.266
270.483	1.059	1.447
270.484	1.051	1.422
270.485	1.106	1.432
270.486	1.092	1.280
270.487	1.119	1.436
270.488	1.111	1.417
270.489	1.112	1.424
270.49	1.112	1.443
270.491	1.109	1.448
270.492	1.117	1.441
270.493	1.112	1.447
270.494	1.109	1.440
270.495	1.132	1.438
270.496	1.139	1.439
270.497	1.152	1.461
270.498	1.165	1.488
270.499	1.149	1.482
270.5	1.132	1.408
270.68	1.103	1.448
270.681	1.110	1.445
270.682	1.108	1.444
270.683	1.109	1.455
270.684	1.103	1.418
270.685	1.105	1.412
270.686	1.103	1.426
270.687	1.021	1.397
270.688	1.038	1.339
270.689	1.043	1.323
270.69	1.045	1.309
270.691	1.034	1.356
270.692	1.050	1.350
270.693	1.018	1.345
270.694	1.087	1.436
270.695	1.084	1.439
270.696	1.082	1.439
270.697	1.082	1.441
270.698	1.097	1.443
270.699	1.080	1.440
270.7	1.074	1.444
271.035	1.053	1.429
271.036	1.049	1.421
271.037	1.046	1.285
271.038	1.071	1.320
271.039	0.987	1.290
271.04	0.994	1.320
271.041	0.941	1.297
271.042	0.926	1.360

271.043	0.951	1.384
271.044	0.955	1.393
271.045	0.952	1.404
271.046	0.949	1.409
271.047	0.951	1.419
271.048	1.055	1.426
271.049	1.057	1.327
271.05	1.058	1.322
271.051	1.050	1.346
271.052	1.053	1.396
271.053	1.057	1.442
271.054	1.058	1.425
271.055	1.059	1.429
271.27	1.063	1.423
271.271	1.057	1.426
271.272	1.065	1.427
271.273	1.061	1.428
271.274	1.060	1.431
271.275	1.051	1.423
271.276	1.048	1.421
271.277	1.043	1.409
271.278	0.956	1.330
271.279	0.999	1.367
271.28	1.012	1.377
271.281	1.034	1.405
271.282	0.944	1.332
271.283	1.045	1.410
271.284	1.049	1.428
271.285	1.044	1.421
271.286	0.946	1.413
271.287	1.049	1.330
271.288	0.969	1.400
271.289	1.061	1.332
271.29	1.061	1.416
271.291	1.026	1.443
271.292	1.044	1.403
271.293	1.029	1.450
271.294	1.073	1.457
271.295	1.052	1.436
271.296	1.076	1.406
271.297	1.054	1.418
271.298	1.034	1.424
271.299	1.078	1.425
271.3	1.099	1.420
272.335	1.135	1.439
272.336	1.081	1.400
272.337	1.060	1.432
272.338	1.132	1.430
272.339	1.136	1.383
272.34	1.021	1.391

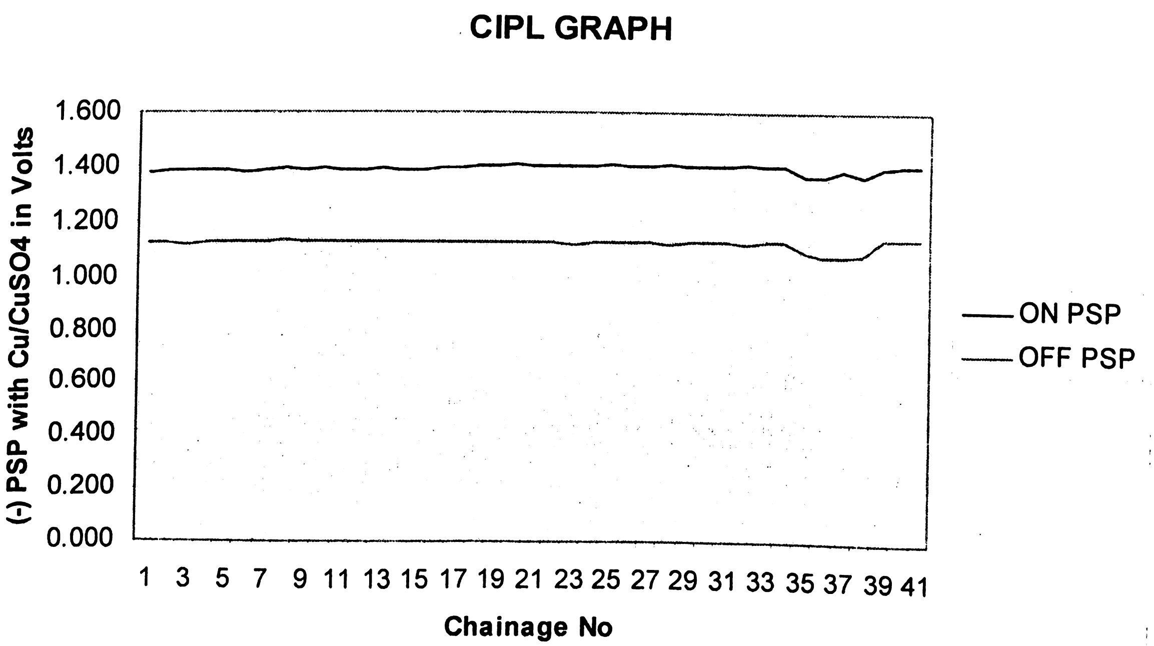
272.341	1.025	1.445
272.342	1.046	1.408
272.343	1.135	1.486
272.344	1.134	1.488
272.345	1.131	1.488
272.82	1.080	1.319
272.821	1.079	1.301
272.822	1.077	1.293
272.823	1.077	1.365
272.824	1.017	1.300
272.825	1.012	1.328
272.826	1.003	1.360
272.827	1.008	1.305
272.828	1.043	1.325
272.829	1.079	1.340
272.83	1.080	1.400
272.831	1.081	1.416
272.832	1.082	1.397
272.833	1.080	1.388
272.834	1.075	1.399
272.835	1.083	1.404
273.41	1.052	1.380
273.411	1.070	1.318
273.412	1.066	1.359
273.413	1.066	1.387
273.414	1.065	1.385
273.415	1.067	1.392
273.416	1.018	1.315
273.417	1.003	1.301
273.418	1.035	1.315
273.419	1.006	1.301
273.42	1.002	1.303
273.421	1.001	1.303
273.422	1.001	1.310
273.423	1.040	1.315
273.424	1.001	1.302
273.425	1.002	1.301
273.426	1.016	1.315
273.427	1.001	1.305
273.428	1.002	1.304
273.429	1.067	1.265
273.43	1.067	1.269
273.431	1.066	1.315
273.432	1.071	1.312
273.433	1.068	1.316
273.434	1.071	1.352
273.435	1.072	1.363
273.436	1.075	1.372
273.437	1.075	1.373
273.438	1.078	1.379

273.439	1.079	1.381
273.44	1.082	1.380
273.94	1.044	1.209
273.941	1.040	1.271
273.943	1.044	1.260
273.944	1.043	1.210
273.945	1.040	1.194
273.946	1.040	1.191
273.947	1.046	1.203
273.948	1.041	1.243
273.949	1.049	1.244
273.95	1.045	1.194
273.951	1.044	1.205
273.952	1.047	1.237
273.953	1.048	1.235
273.954	1.043	1.199
273.955	1.040	1.211
273.956	1.044	1.234
273.957	1.045	1.228
273.958	1.047	1.236
273.959	1.039	1.201
273.96	1.043	1.200
273.961	1.051	1.238
273.962	1.048	1.199
273.963	1.049	1.242
273.964	1.056	1.203
273.965	1.043	1.201
273.966	1.052	1.194
273.967	1.049	1.195
273.968	1.052	1.250
273.969	1.049	1.200
273.979	1.048	1.249
273.98	1.057	1.258
273.981	1.050	1.210
273.982	1.050	1.217
273.983	1.049	1.178
273.984	1.048	1.181
273.985	1.047	1.320
273.986	1.046	1.328
273.988	1.044	1.332
273.989	1.041	1.344
273.99	1.046	1.348
273.991	1.045	1.349
273.992	1.045	1.352
273.993	1.044	1.345
273.994	1.046	1.355
273.995	1.040	1.307
273.996	1.045	1.250
273.997	1.044	1.250
273.998	1.044	1.249

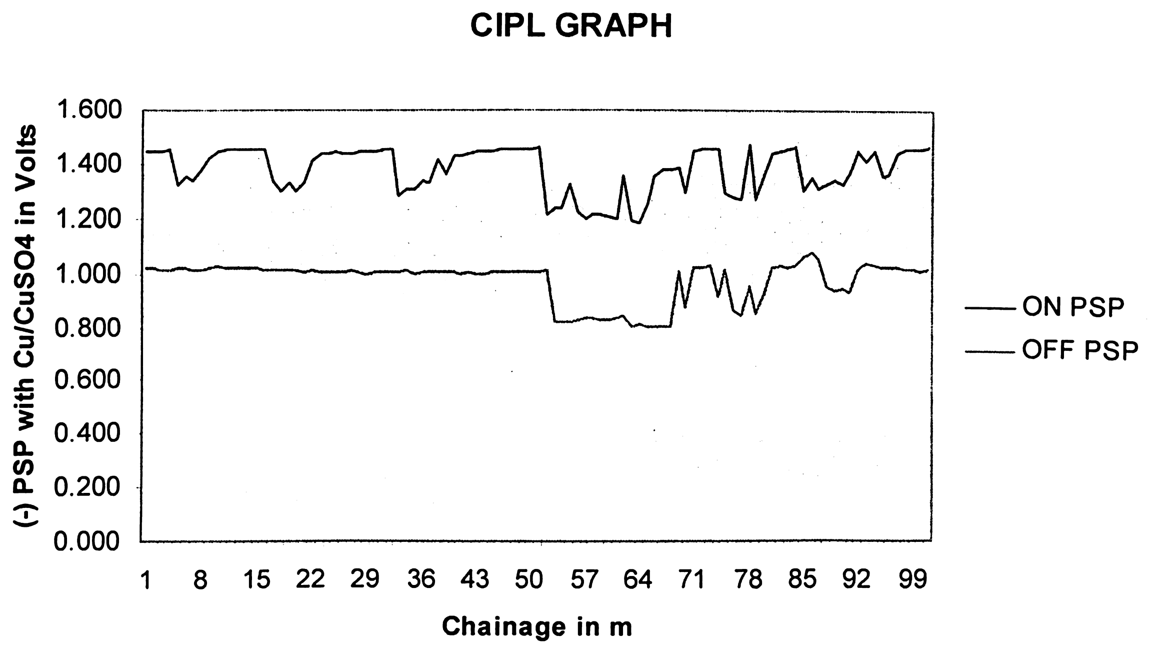
CIPL Graphs



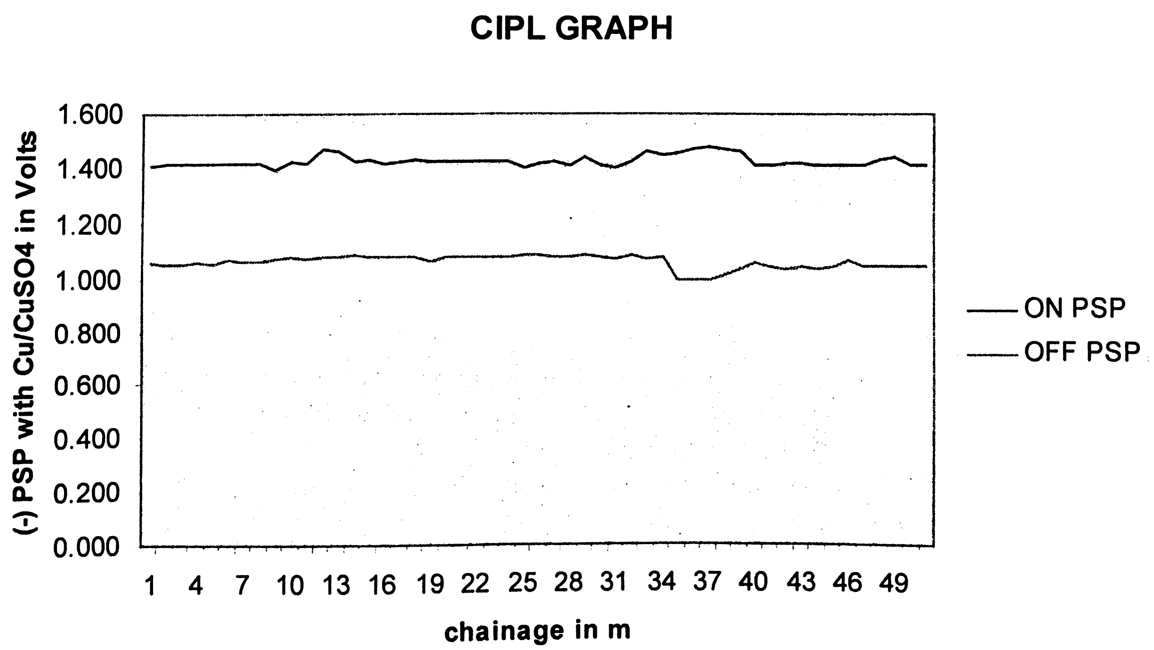
CIPL Graph from 266.790 to 266.890



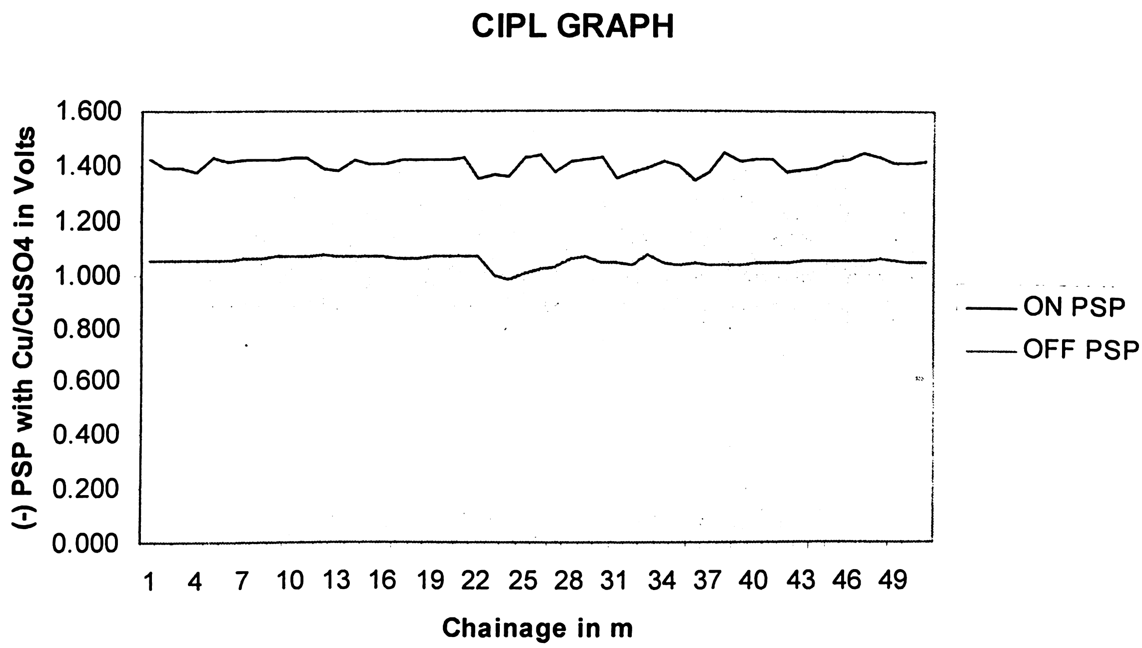
CIPL Graph from 267.300 to 267.400



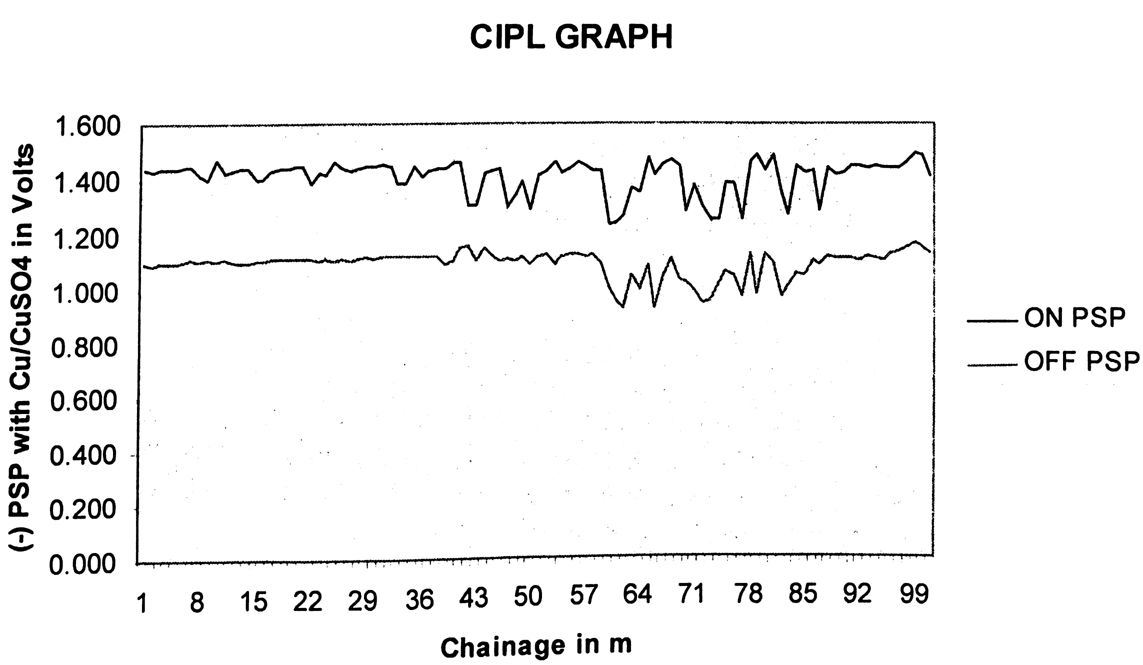
CIPL Graph from 268.600 to 268.700



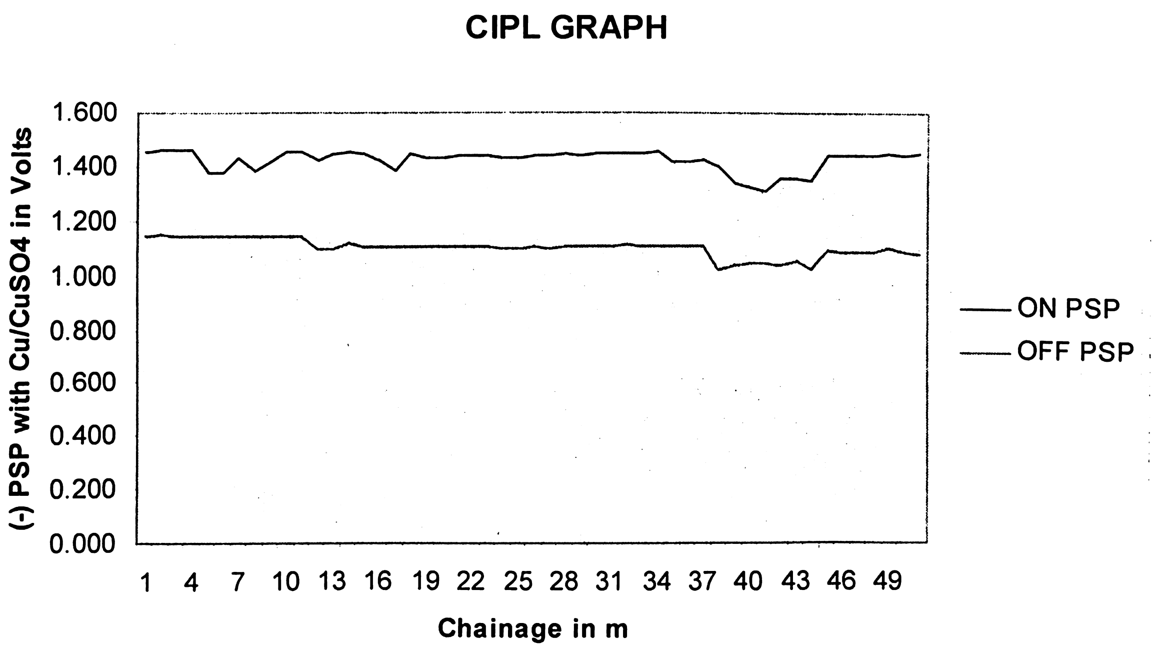
CIPL Graph from 269.250 to 269.300



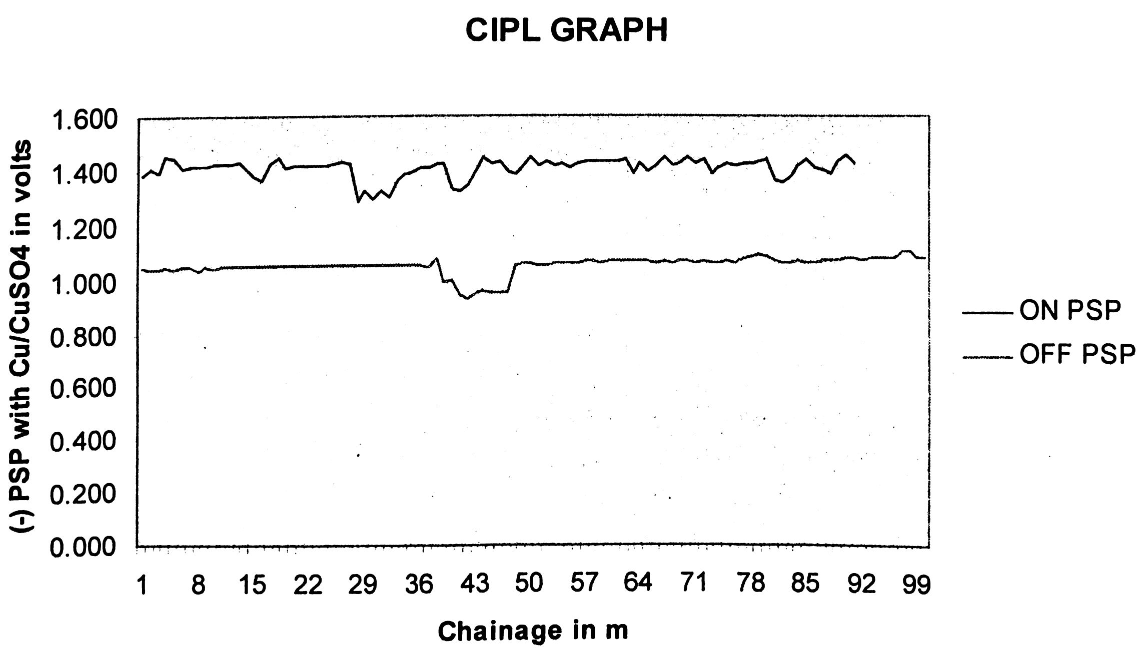
CIPL Graph from 270.250 to 270.300



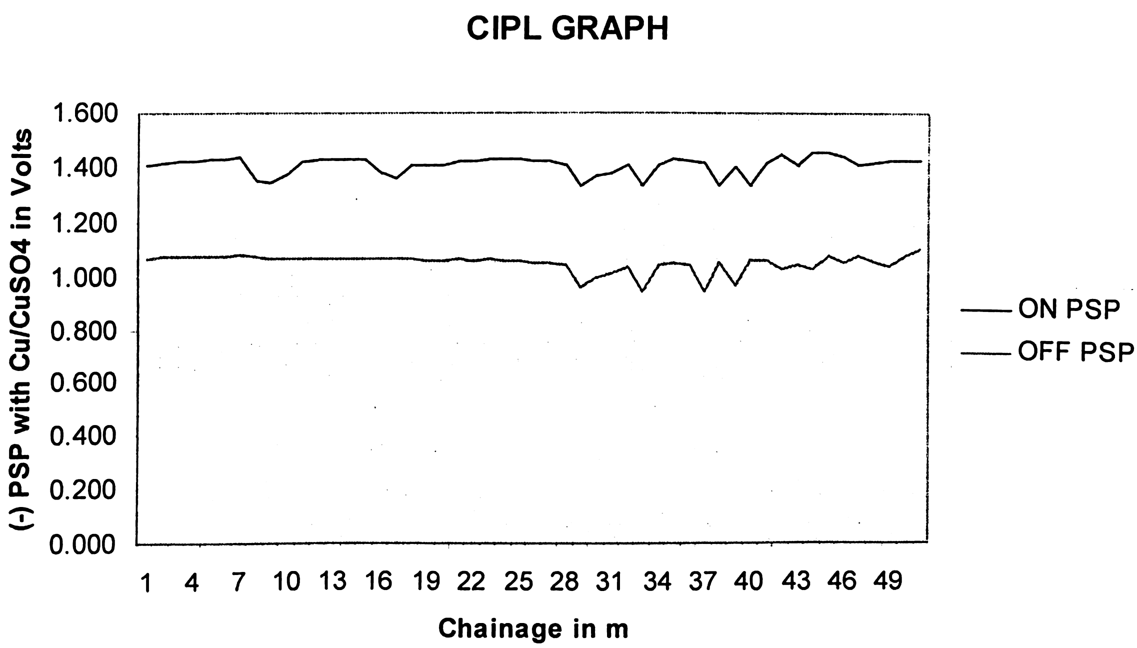
CIPL Graph from 270.400 to 270.500



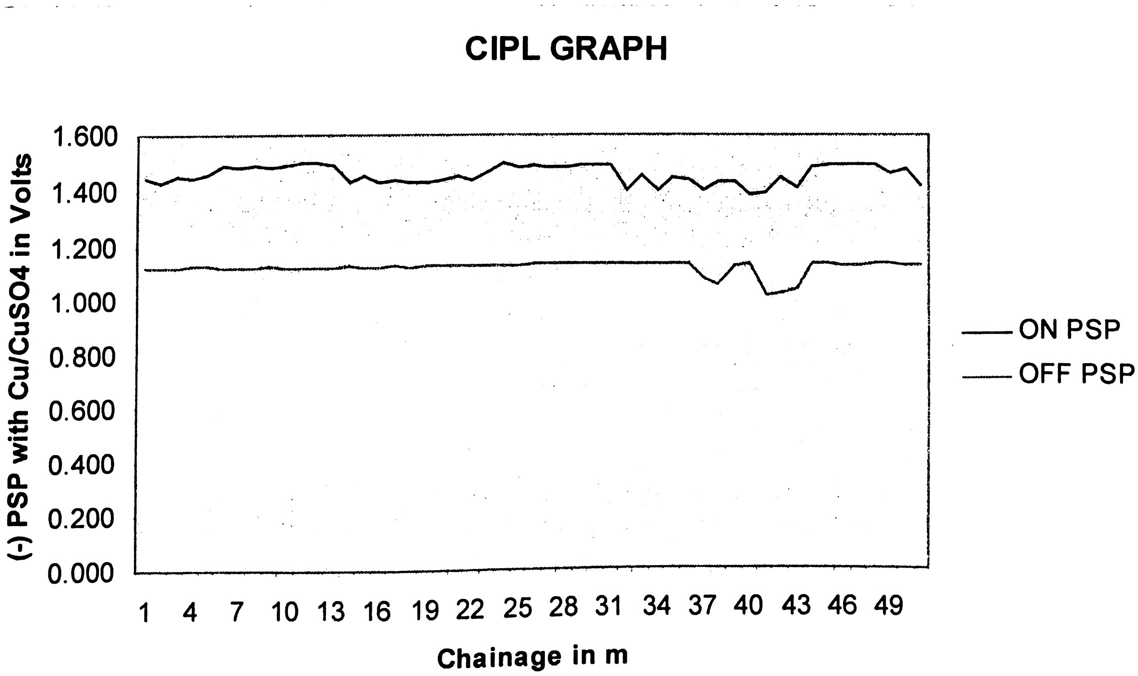
CIPL Graph from 270.650 to 270.700



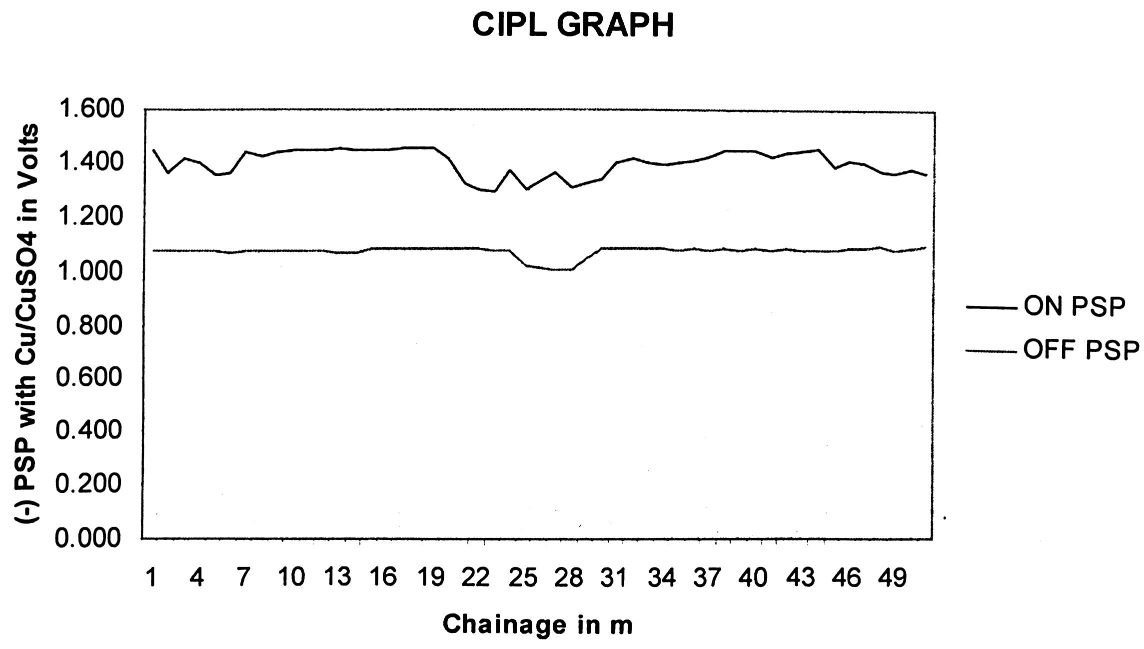
CIPL Graph from 271.001 to 271.100



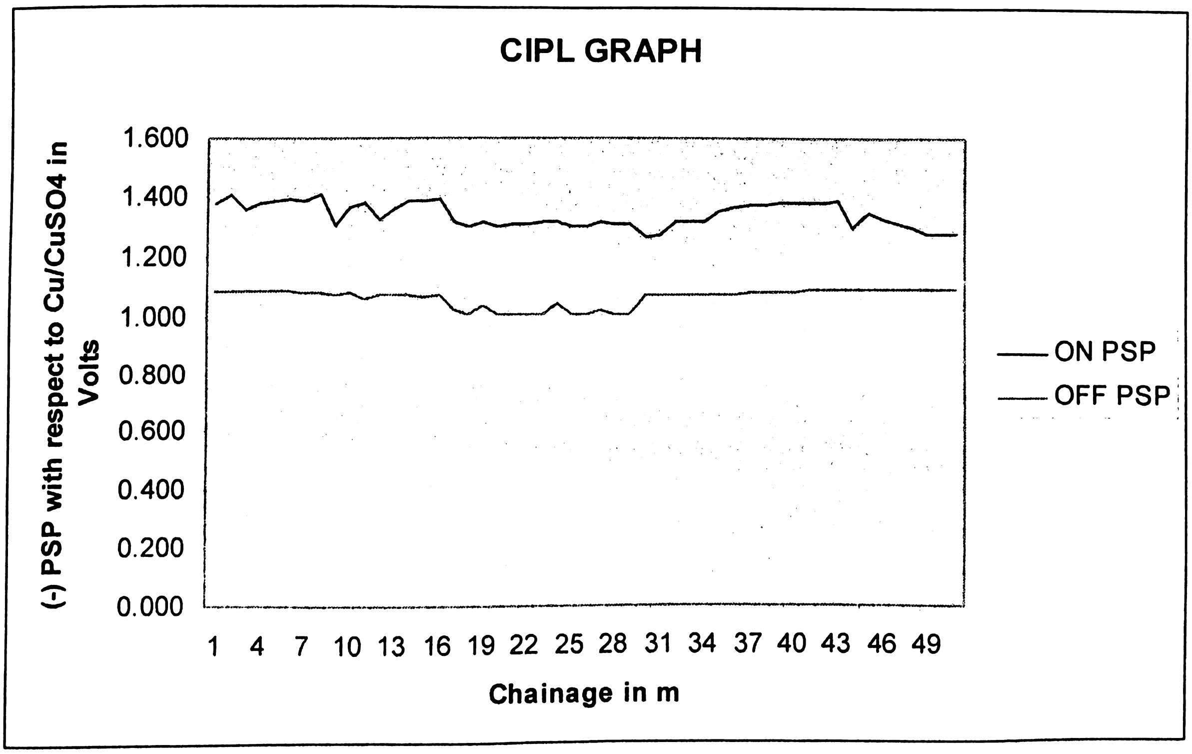
CIPL Graph from 271.250 to 271.300



CIPL Graph from 272.300 to 272.350



CIPL Graph from 272.800 to 272.850



CIPL Graph from 273.400 to 273.450

APPENDIX B

(Refer chapter 3)

DCVG Equipment Description

Survey Switch (Interrupter)

The survey switch utilizes a solid-state device to switch the applied DC at one of the two speeds determined by the position of STD/SLOW switch. The STD/SLOW switch has two positions which represent:-

STANDARD (STD) Setting	0.45 seconds ON followed by 0.9 seconds OFF
SLOW Setting	0.9 seconds ON followed by 1.8 seconds OFF

The STD **(STANDARD)** setting of the switch is used for normal surveying to find coating faults. This speed of switching matches the typical response time of a survey operative. Surveying on the **SLOW** switch position, whilst possible, does mean that the operator is often waiting on the response from the analogue meter and hence is wasting time.

The SLOW switch position is used in conjunction with the digital voltmeter for Pipe to Soil Potential measurements, or Current measurements via an inline calibrated shunt.

The solid state switch is protected against damage caused by spikes or surges by means of a parallel wired transorb. The status of the switch position is indicated by the color of a tri-colored LED and is as follows:

RED..............................Switch On (Passing Current)
GREEN..........................Switch Off (No Current Passing).
YELLOW..........................Low Battery or Battery on Charge

The interrupter will cease to operate when the battery charge will becomes too low. This prevents the damage to components that make up the interrupter timing circuit. Under normal operation the interrupter internal battery has sufficient capacity to work for one week without charging.

A typical current to be switched by the interrupter is up to 50 amperes. The interrupter will safely handle up to 80 amperes. Although the switch is rated at 100 amperes, when switching large currents the corresponding large cathodic spike of two times or more the normal when switching ON, will cause the switch Tran sorbs to fuse making the interrupter switch inoperative. It is the large spike that causes the problem and not the average level of current switched.

Survey Meter

The dominant visible feature of the survey meter is the analogue meter movement. The meter which is manufactured for the Military use, has a centre zero needle position. This means that

with zero voltage across the meter input, the needle rests at mid scale irrespective of the range switch position. The Survey meter has the following voltages ranges:-
10 mV, 25 mV, 50 mV, 100 mV, 250mV, 1 V, 2.5 V, 4 V.

The 10mV on the voltage range switch corresponds to the zero to ten milli-volts full scale deflection on the analogue meter.
The 25 mV on the voltage range switch corresponds to the zero to twenty five milli volt full scale deflection on the analogue meter.
The 50 mV on the voltage range switch corresponds to five times the zero to ten milli volt full scale deflection on the analogue meter. It would also correspond to two times the zero to twenty-five millivolt full scale deflection.
When not in use the range switch should be turned to the 4 volt range to minimize any chance of meter damage.

Probes and Handle

The standard probes used with the DCVG Equipment are especially adapted to approximately one meter long copper/copper sulphate reference electrode.
The probes are lightweight, high strength tubes fixed at one end to an insulated stainless steel stud that provides both electrical and mechanical connection to the probe handle. The other end of the probe electrode contains a wooden plug to make electrochemical contact between the soil and the copper sulphate solution/copper electrode. The probe handle has a built in bias that is controlled via an ON/OFF/Range Switch and a Bias Adjustment potentiometer.

Battery Charger

The Battery Charger comes as small black plastic box with a lead out of either end. At the rear of the battery charger is a cable for connection to mains electricity. At the other end, set in a silver colored panel is a mains voltage range switch so that either 120 or 240 volts AC can be utilized. There is also a one ampere fuse to protect the battery charger and a LED that glows RED when the charger is operational. The Low Voltage cable also comes out of the silver panel and has a two pin plug sized to fit into the handles, DCVG Meter or Interrupter.

APPENDIX C

(Refer chapter 6)

Coating Repair Patch:
This product consists of an irradiated, cross linked polyolefin sheet coated with a heat activated adhesive and is designed specifically for sealing and protection of damaged pipeline coatings up to 150 mm x 150 mm in size.

Advantages

- No special tools or equipment required
- Excellent abrasion resistance
- Inert to common acids, alkalis and solvents
- Barrier to moisture & corrosion

Component of Patch repair:

Melt Sticks (MS):
Melt Sticks are heat-activated adhesives supplied as rods for ease of application Ideal for small repairs (holidays and cracks up to 10 mm x 10 mm).
Advantages

- Flexible
- Excellent adhesion
- Solvent free
- No mixing or measuring
- Flows into hard-to-reach locations
- Quick setting
- Excellent moisture resistance

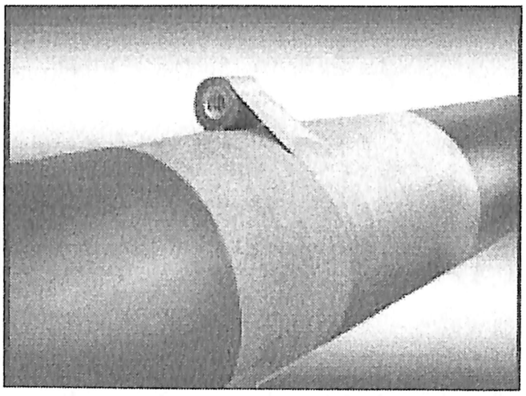
Mastic Filler (MF):
Prior to CRP application, deep crevices should be filled with Mastic Filler.

Advantages

- Excellent adhesion to PVC, PE, FBE, and steel.
- Non-shrinking
- Remains flexible. Fills surface irregularities.
- Excellent water resistance.

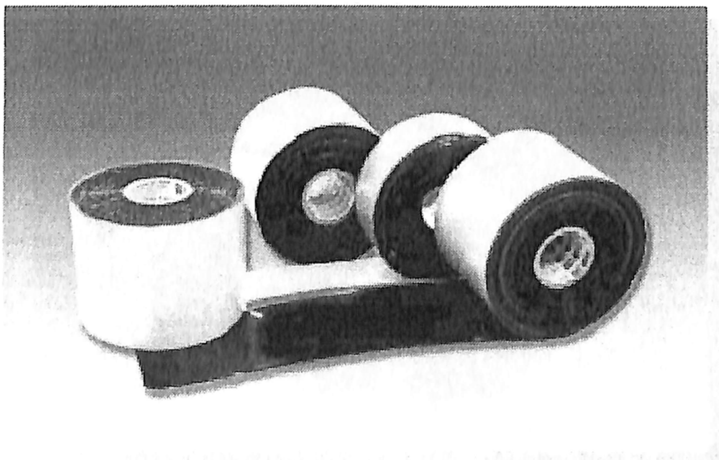
Different types of Coating repair tapes used:

Petrolatum Tape:
Petrolatum Tape is composed mainly of petrolatum, tannin, inert silica and special anti-corrosive agents, it will never evaporate, harden and its viscosity will never change. It will never crack or peel off. Since it can perfectly adhere to any material and any complicate shape, the viscosity film formed on the applied surface prevents the penetration of moisture or air onto the applied surface; it prevents all physical factors of corrosion. Because the composition of Petrolatum Tape is chemically stable, it will resist acids, alkali and salts. The anti-corrosive effect never changes with climate or temperature.



Petrolatum Tape

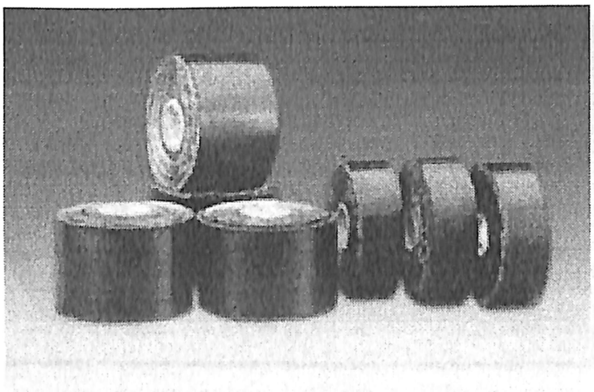
Heat Shrinkable Tape:
Heat shrinkable Tape is a hand wrapped heat shrinkable tape designed for corrosion protection of straight pipes, fittings, bends, elbows and other irregular configurations.



Heat Shrinkable Tape

It has a cross linked polyethylene backing coated with butyl rubber based thermoplastic adhesive. When heated the backing layer shrinks and the adhesive flows and forms a reliable corrosion protection seal onto adjacent coating surfaces.

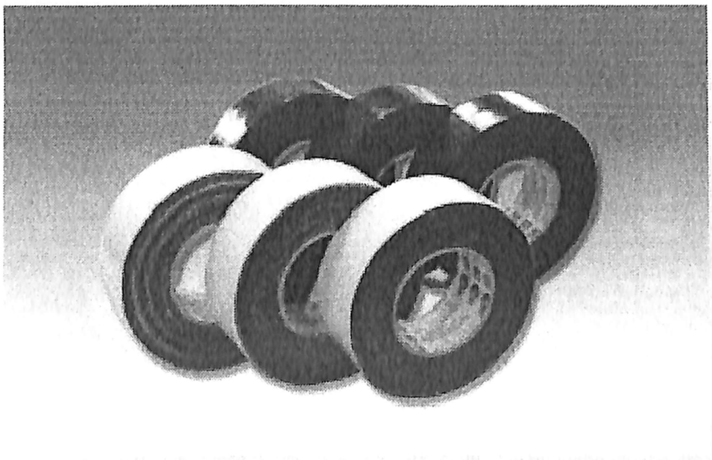
Three Layer Heat Shrinkable Tape:
Three layer heat shrinkable tapes is designed for corrosion protection of straight pipes, joint wrap, fittings, bends, elbows and other irregular configurations. It has a cross linked polyethylene backing coated with heat sensitive adhesive and two part of liquid epoxy primer



Three Layer Heat Shrinkable Tape

Polyethylene Anti-Corrosion Tape:
Polyethylene Anti-Corroding Tape is designed to provide corrosion protection and mechanical resistance to metal pipes, underground steel pipes, and bare pipe joints of PE, Epoxy & PP coated pipes by hand or machine application.

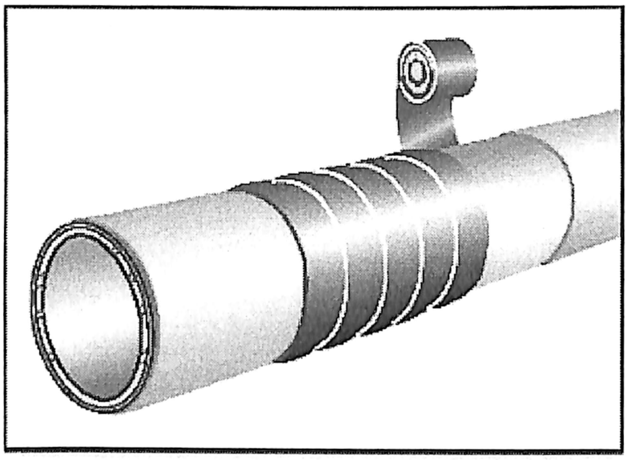
The main material used is a stabilized polyethylene backing and butyl rubber based synthetic elastomer adhesive.



Polyethylene Anti-Corrosion Tape

Joint Wrap Coating Tape:

Joint Wrap Coating Tape is a designed to provide reliable corrosion protection and mechanical resistance to metal pipes, underground steel pipes, and especially girth welded joints. Epoxy & PP coated pipes by hand or machine application. The main material used is a stabilized polyethylene backing and butyl rubber based synthetic elastomer adhesive.



Joint Wrap Coating Tape