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شرکت ملی گازایران

مدیریت پژوهش و فنآوری

امورتدوین استانداردها

IGS

راهنمای انتخاب پوشش

راهنمای انتخاب پوشش خارجی برای خطوط لوله گاز(مدفون)

Recommended Practice for Selection of Suitable External Coatings for Underground (Burried) Gas Pipelines

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ابلاغ مصوبه هیأت مدیره

مدیر محترم پژوهش و فناوری

باسلام،

به استحضار می رساند در جلسه ۱۳٤۷ مورخ ۱/ ۱۰/ ۱۳۸۷ هیأت مدیره، نامه شماره گ۹/۱۱۰٤۸۱/۰۰۰ مورخ ۸۷/۹/۱۳ آن مدیریت در مورد دستورالعمل راهنمای انتخاب انواع پوشش های خطوط لوله گاز ازجمله قیر اصلاح شده (با نام تجاری بیتوسیل) و پلی اتیلن سه لایه با حضور رئیس امور تدوین استانداردها ورئیس امور بازرسی فنی شرکت انتقال گاز مطرح و مورد تصویب قرار گرفت.

همچنین مقرر گردید انتخاب نهایی پوشش خطوط لوله اجرائی با رعایت استانداردهای مندرج در دستورالعمل فوق الذکر به عهده هیأت مدیره شرکت ذیربط باشد ودر پیمانهای اجرائی خطوط لوله نیز با پیشنهاد طراح وتائید نهایی هیأت مدیره شرکت ذیربط انجام پذیرد.

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FOREWORD

This standard is intended to be mainly used by NIGC and contractors and has been prepared on interpretation recognized standards , technical documents , knowledge , backgrounds and experiences in gas industries at national and international levels .
Iranian gas standards (IGS) are prepared , reviewed and amended by technical standard committees within NIGC Standardization division and submitted to the NIGC's "STANDARDS COUNCIL" for approval .
IGS Standards are subject to revision , amendment or withdrawal , if required , thus the latest edition of IGS shall be checked/inquired by NIGC users .
This standard must not be modified or altered by the end users within NIGC and her contractors . Any deviation from normative references and/or well known manufacturers specifications must be reported to Standardization division .
Any comments from concerned parties on NIGC distributed IGS are welcome to technical standards committees and will receive serious attention and consideration should a revision to standards is recommended .

GENERAL DEFINITIONS :

Throughout this standard the following definitions , where applicable , should be followed :
1- "STANDARDIZATION DIV." has been organized to deal with all aspects of industrial standards in NIGC . Therefore , all queries for clarification or amendments are requested to be directed to mentioned div.
2- "COMPANY" : refers to national Iranian gas company .
3- "SUPPLIER" : refers to a firm who will supply the service , equipment or material to IGS specification whether as the prime producer or manufacturer or a trading firm .
4- "SHALL " : is used where a provision is mandatory .
5- "SHOULD" : is used where a provision is advised only .
6- "MAY" : is used where a provision is completely discretionary .

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CONTENT PAGE

0. INTRODUCTION

The majority of gas transmission and distribution pipework and associated fittings is buried and therefore needs to be protected against corrosion.
All metallic pipelines should be provided with an external coating and, for buried or submerged sections, cathodic protection.
The possibility of external corrosion occurring shall be determined on the basis of pipeline operating temperatures and the external conditions along the pipeline.
Typical environments which shall be considered when evaluating the possibility of external corrosion include:

- Atmosphere (marine/industrial/rural);
- Sea water (tidal zone/shore approach);
- Fresh or brackish water;
- Marshes and swamps;
- River crossings;
- Dry or wet soil;
- Inside tunnels, sleeves or caissons.
- Human Interference

Environmental parameters which should be considered include:

- ambient air temperatures;
- resistivity, salinity and oxygen content of the environment;
- bacterial activity;
- water current (ground water depth);
- degree of burial;
- potential in-growth of tree roots;
- potential soil pollution by hydrocarbons and other pollutants.

The evaluation of corrosion measures should take into account the probable long-term corrosiveness of the environment rather than be solely confined to the as-installed corrosiveness. For a pipeline on land , due consideration should be given to any known planned changes in the use of the land traversed by the pipeline route which may alter the environmental conditions and thus soil corrosiveness, e.g. irrigation of land previously arid or of low corrosiveness.
The possible effect of the PH of the environment and possible sources of stray and alternating currents shall be evaluated for pipelines on land.
The types of external corrosion damage to be considered shall include:

- general metal loss and degradation;
- localized corrosion, e.g. pitting under deposit or crevice attack;
- microbiologically induced corrosion;
- stress-corrosion cracking , e.g. carbonate / bicarbonate attack.

In a review of 50 years of literature on pipeline coatings, the following concepts emerged:

- Selection of a suitable coating and proper application of the coating both in the factory and in the field are very important for the pipelines intended service life.
- CP must supplement the coating in underground applications to ensure 100% protection.
- Field test results are more indicative of the long term suitability than laboratory tests.
- Results of adhesion tests do not correlate with those of cathodic disbondment tests.
- Cathodic disbondment tests are the best tests to measure coating performance.
- The current required for CP is the best measure of coatings performance when buried.
- Optimizing coating thickness is important.
- Soil stress on the coating is one of the main problems associated with buried pipelines.
- Resistance to cathodic disbondment and soil stresses are very important requirements of a pipe coating . For a pipe coating to be effective, it should meet these criteria: adhesion, adequate thickness, low moisture absorption / transfer, chemical resistance (especially alkalis from CP), and flexibility.
- The initial selection of a suitable coating system is very important, and also, perhaps the most important factor is that the coating system shall be applied as per the required specification.

1. SCOPE

This recommended practice defines the minimum requirements for selection of external coating systems for buried steel pipeline and piping (including associated fittings and appurtenances) and also gives guidance on the performance characteristics of these coatings.

NOTE:
1 - This standard will refer only to coating systems which are known to be successful when used by NIGC and major internationally well-known oil & gas companies.
2 - Additions will be made from time to time to the information available in order to cover products which are less widely used and new products which are considered to be of sufficient interest.

2. REFERENCES

Throughout this standard specification, the following standards and codes that are in effect at the time of issues of this specification (2008) shall, to the extent specified herein, form part of this specification.
The applicability of changes in standards and codes that occur after the date of standards that referred shall be mutually agreed upon by the purchaser and supplier and / or manufacturer.

ISO 21809-2	Petroleum and natural gas industries – External Coatings for buried or submerged pipelines Used in pipeline transportation systems Part 2: Fusion Bonded Epoxy Coatings
ISO 13623	Petroleum and natural gas industries – pipeline transportation systems
ASTM D 1000	Test method for pressure-sensitive adhesive-coated tapes used for electrical and electronic applications
AWWA C 203	Coal tar protective coatings and linings for steel water pipeline – Enamel and tape – Hot applied
NACE RP 01 05-2005	Liquid–epoxy coatings for external repair, Rehabilitation, and weld joints on buried steel pipelines
NACE RP 04 02-2002	Field –Applied Fusion Bonded Epoxy (FBE) pipe coating system for Girth Weld Joints: Application, Performance, and Quality Control
NACE SP 01 69-2007	Control of External corrosion on Underground or Submerged Metallic piping Systems

BS 4164	Specification for coal-tar-based hot-applied coating materials for protecting iron and steel, including a suitable primer
BS 7873	Code of Practice for application and testing of hot enamel external and/or internal coating of iron and steel pipes
BS EN 10300	Bitumen hot applied material coating for external coating
BS ISO 11359	Plastics – thermomechanical analysis (TMA)
IPS-M-TP-317	Hand applied petrolatum tape and primer
IPS-M-TP-311	Cold – applied laminated plastic tape as outer – layer tape
IGS-M-TP-010-1&2	3 layer PE coating system
IGS-M-TP-014-2-A	Polymer modified bitumen membrane
IGS-M-TP-014-2-C	3ply Cold applied plastic tape
IGS-M-TP-014-4	Hand applied laminated plastic tape
IGS-M-TP-014-5	Hand applied laminated bituminous tape
IGS-M-TP-014-3(1)	High temperature heat shrinkable sleeves
IGS-M-TP-014-6	Heat shrinkable sleeves (hot melt adhesive)
IGS-M-TP-014-7	Heat shrinkable sleeves (mastic adhesive)
IGS-M-TP-016	Modified bitumen enamel coating system
IGS-M-TP-020-1	Polyurethane coating for pipeline rehabilitation

– Control of pipeline corrosion: A.W. Peabody

– Uhligs Corrosion Handbook

– FBE : Allen Kehr

3. DEFINITIONS

3.1 For definitions, please refer to the relevant section of the standards referred in section 2 above.

3.2 Abbreviated items:

ACS Approved coating system
3LPE Three Layer Polyethylene
FBE Fusion Bonded Epoxy
CP Cathodic Protection
SCC Stress Corrosion Cracking

4. GENERAL REQUIREMENTS

4.1 The effectiveness in providing the required protection and the possible hazards during application and service shall be considered when selecting external coatings.

4.2 Parameters to be considered when evaluating the effectiveness of external coatings include:

- electrical resistivity of coating;
- moisture permeation and its relation to temperature;
- ability to resist development of holidays with time(gouge resistance);
- ability to maintain substantially constant electrical resistivity with time ;
- ease of repair
- non-toxic interaction with the environment :
- required adhesion between the coating and the pipeline base material;
- required resistance to shear forces between the coating and additional coating, insulation or environment;
- resistance to cathodic disbondment and soil stress ;
- resistance to ageing , brittleness and cracking ;
- possible detrimental effects on the pipe material ;
- possible thermal cycling ;
- UV resistance(for above ground pipelines or long term storage)
- low/high temperature bending
- impact resistance
- soil stress resistance
- CP shielding

4.3 In addition to the above characteristics, the following typical factors should be considered when selecting a pipe coating.

- type of environment
- maximum (upset) operating temperature
- pipeline OD
- ambient temperatures during application, storage, shipping, construction, and installation
- geographical and physical location
- type of coating on existing pipeline(if any)
- equipment and location(i.e. shop or field) required for coating
- installation methods
- costs
- pipe surface preparation requirements
- Logistics

4.4 The following typical factors should be considered when selecting a girth-weld coating system.

- Application requirements:
    - Surface preparation
    - Speed of installation(application cycle time)
    - Applicator --skill requirements
    - Crew size
    - Equipment requirements

- Compatibility with main pipeline coating
- Pipeline construction and installation methods
- Material and application cost
- Pipeline environmental and operation conditions
- Required life span for the pipeline(longevity requirements)
- Routine maintenance budget for the pipeline
- Compatibility with cathodic protection requirements
- Local health, safety, and environmental (HSE) requirements and regulations
- Pipeline operating temperature/duty cycle
- Salinity and soil resistivity
- Pipeline movement and likelihood of soil stress/settlement
- Ground conditions/soil type
- Pipeline OD

5. MANDATORY REQUIREMENTS

5.1 External coatings of line pipe shall be factory-applied, except for field weld joints, rehabilitation of existing pipelines and other special points which shall be coated on site.

5.2 Field joints should be protected with a coating system which is compatible with the line-pipe coating. The field joint should meet or exceed the line-pipe coating specification and allow satisfactory application under the predicted field conditions.

5.3 Plant piping and other above grade pipelines in industrial or marine atmospheres shall be externally coated.

5.4 Paint systems shall not be used as the primary external coating on buried pipelines (including field girth welds).

5.5 Hand-applied tapes of the "primer activated" type shall not be used.
Hand-applied tape wraps shall be of the "pressure sensitive" type, meaning they can be applied over dry primer or no primer without adverse effect on adhesion**.**

6. SELECTION REQUIREMENTS

6.1 The NIGC's approved pipeline / field weld joint coating systems are given in table 1.

6.2 Selection of the appropriate coating system for a particular coating situation should be made by reference to tables 2 and 3.

6.3 The products identified in table 4 specify the preferred field-weld joint coating considered the most compatible with the various types and combinations of factory / field applied coatings.
Where site or operating conditions preclude the use of the preferred product, options are given where appropriate. In addition, the nominated contractor is permitted to submit a detailed technical proposal for alternative solution for the written approval of NIGC prior to use.

6.4 The main factory coating systems identified in tables 2&3 will require repair when damaged. The preferred repair materials are given in table 5.

6.5 The general characteristics of approved pipeline coatings are given in table 6.

TABLE 1: DESCRIPTION OF APPROVED COATING SYSTEMS (ACS)

Index	Title	Reference Standard
ACS-1	Three layer polyethylene coating for line pipe	IGS-M-TP-010 (Parts1&2)
ACS-2	Fusion Bonded Epoxy for line pipe	ISO 21809-2
ACS-3	Modified bitumen enamel coating for line pipe	IGS-M-TP-016
ACS-4A	Coal tar enamel coating for line pipe	BS 4164 & BS 7873
ACS-4B	Bitumen enamel coating for line pipe	BS EN 10300
ACS-5	Hand applied 3PLY tape	IGS-M-TP-014-2-C
ACS-6	Hand applied laminated bituminous tape	IGS-M-TP-014-5
ACS-7	Hand applied laminated tape	IGS-M-TP-014-4
ACS-8	Shop or field applied two-component EP	NACE RP 01 05
ACS-9	Shop or field applied two-component PUR	IGS-M-TP-020
ACS-10	High temperature 3-Layer heat shrinkable sleeve system for service temperature up to 80°C.	IGS-M-TP-014-3(1)
ACS-11	3-Layer heat shrinkable sleeve system (hot melt adhesive) for service temperature up to 60°C.	IGS-M-TP-014-6
ACS-12	2-Layer heat shrinkable sleeve (mastic adhesive) for service temperature up to 50ºC.	IGS-M-TP-014-7
ACS-13	Polymer modified bitumen membrane	IGS-M-TP-014-2-A
ACS-14	Hand applied petrolatum tape	IPS-M-TP-317
ACS-15	Pressure sensitive , hand applied laminated tape for elevated temperatures	See ANNEX A
ACS-16	Field Applied FBE for field girth welds	NACE RP 04 02

TABLE 2: EXTERNAL PIPE COATINGS, HIGH PRESSURE LARGE DIAMETER GAS TRANSMISSION PIPELINES (OD ≥ 24")

Categories	Approved coating systems	Remarks
Pipe body	ACS-1 ACS-2 ACS-3	ACS-2 is recommended to be used in the following conditions: - non-rocky terrains - Where handling of line pipes from pipe coating plant to construction site is done in controlled-manner with limited damage to pipe surface. * ACS-3 is not recommended to be used in the following conditions : - In tropical environments. - On line pipes larger than 30" OD. **
Field girth welds	ACS-8 ACS-10 ACS-13 ACS-16	ACS-13 should be used only with ACS-3 ACS-8 & ACS-16 should be used only with ACS-2.
Buried pipes , Fittings, appurtenances and spool pieces (in stations)	ACS-5 ACS-8 ACS-9 ACS-10 ACS-13 ACS-15 ACS-16	
Buried Valves	ACS-8 ACS-9 ACS-14	The valves body should preferably factory coated.

* In rocky areas the FBE coating system shall be used with rockguard materials (Rockshield) and dual layer FBE have been developed for harsher pipeline environments (procedures shall be required for the transportation, storage and construction of FBE coated line pipes).

**The ACS- 3 coating system overcoated with Polypropylene extruded sheet having 1 mm thickness(min.) have been used on some 48" projects with satisfactory results, although additional investigation is under process for final decision.

TABLE 3: EXTERNAL PIPE COATINGS, BRANCH AND SERVICE LINES (OD< 24")

Categories	Approved coating systems	Remarks
Pipe body	ACS-1 ACS-2 ACS-3 ACS-4A** ACS-4B**	ACS-2 is recommended to be used in the following conditions: - non-rocky terrains - Where handling of line pipes from pipe coating plant to construction site is done in controlled-manner with limited damage to pipe surface. * ACS-3, ACS-4A and ACS-4B coating systems are not recommended to be used in tropical environments. ACS-4B coating systems is not recommended to be used on line pipes larger than 12"OD.
Field girth welds	ACS-5 ACS-6 ACS- 8 ACS-11 ACS-12 ACS-13 ACS-16	ACS-6 should be used only with ACS-4A & ACS-4B. ACS-13 should be used with ACS-3 & ACS- 4B. ACS-8 & ACS-16 should be used with ACS-2.
Buried pipes , Fittings, appurtenances and spool pieces (in stations)	ACS-5 ACS-6 ACS-8 ACS-9 ACS-13 ACS-16	Use ACS-5 , ACS-6 & ACS-16 when these coating systems are used on the pipe body.
Buried Valves	ACS-8 ACS-9 ACS-14	The valves body should preferably factory coated.

* In rocky areas the FBE coating system shall be used with rockguard materials (Rockshield). Dual-layer FBE have been developed for harsher pipeline environments. Procedures shall be required for the transportation, storage and construction of FBE coated line pipes.

** It is recommended that the ACS- 4A and ACS-4B coating systems to be selected in conditions where the using of other coating systems is not applicable.

TABLE 4: RECOMMENDED MATERIALS FOR PROTECTION OF FIELD GIRTH WELDS

Possible components of differing types of coating on each side of a weld		Choice of field girth welds coating	
		Preferred	Option
ACS-1	ACS-1	ACS-10* ACS-11* ACS-12**	ACS-5**
ACS-1	ACS-2		
ACS-1	ACS-8		
ACS-1	ACS-9		
ACS-1	ACS-4A	ACS-6	
ACS-1	ACS-4B		
ACS-2	ACS-2	ACS-8 ACS-16 ACS-10* ACS-11*	
ACS-2	ACS-8		
ACS-2	ACS-9		
ACS-8	ACS-8	ACS-8	ACS-10 ACS-11
ACS-8	ACS-9	ACS-8 or ACS-9	
ACS-9	ACS-9	ACS-9	
ACS-4A or ACS-4B	FBE	ACS-6	ACS-8***
ACS-4A or ACS-4B	ACS-8 or ACS-9		
ACS-4A or ACS-4B	ACS-4A or ACS-4B		
ACS-3	ACS-2	ACS-13	ACS-6
ACS-3	ACS-8 or ACS-9		
ACS-3	ACS-3		
ACS-3	ACS-1		
ACS-5 or ACS-7	ACS-1	ACS-5	ACS-7
ACS-5 or ACS-7	ACS-2		
ACS-5 or ACS-7	ACS-8 or ACS-9		
ACS-5 or ACS-7	ACS-5 or ACS-7		
ACS-5 or ACS-7	ACS-4A or ACS-4B	ACS-6	

* NIGC strongly recommends use of the induction heater post-heating method for applying H.S.Sleeves on pipeline with OD greater than 24 inches.

**This option is recommended for Branch & Service lines(see table 3).

*** The junction of ACS-4A or ACS-4B and two – component liquids (ACS-8 or ACS-9) shall be over wrapped with ACS-6.

TABLE 5: RECOMMENDED REPAIR SYSTEM

Existing factory/ field applied coatings	Repair systems	
	Preferred	Option
ACS-1	Melt stick , repair patch (with filler mastic) , heat shrinkable Sleeve(see ACS-10 , ACS-11 & ACS-12)	–
ACS-2	ACS-16 ACS-8(Spray or brush/ trowel applied)	Heat shrinkable sleeve/ repair patch(see ACS-10 & ACS-11)
ACS-3	ACS-13	-
ACS-4A	ACS-6	Hot enamel dope
ACS-4B	ACS-6	Hot enamel dope
ACS-8	ACS-8 (Spray or brush/ trowel applied)	-
ACS-9	ACS-9 (Spray or brush/ trowel applied)	-
ACS-5	ACS-5	-
ACS-7	ACS-7	-
ACS-15	ACS-15	-

TABLE 6: TYPES OF APPROVED PIPELINE COATING AND THEIR CHARACTERISTICS

Coating System	Advantages	Limitations
ACS-1	- Lowest current requirements - Excellent resistance to cathodic disbondment - Excellent adhesion to steel - Excellent resistance to hydrocarbons - High impact and abrasion resistance - High electrical insulation resistance - High resistance to water permeation - Is not affected by soil stress - Easy handling during transportation and construction activities - Resistant to many chemicals, environmental and bacterial attack - Excellent bendability - Service temperature: -20 to +80ºC	- Factory coating application parameters are very critical requiring strict quality control - Higher initial cost - Shielding of CP current is possible (possibility of coating disbondment) - If the FBE layer fails the entire coating system affected. - Repairs are difficult and susceptible to soil stress - Due to the main corrosion protection layer being hidden under other layers difficult to determine if application is good(the polyethylene can hide many faults)
ACS-2	- Low current requirements - Excellent resistance to cathodic disbondment - Excellent adhesion to steel - Excellent resistance to hydrocarbons - Excellent soil stress resistance - No known instances of SCC - Coating is visible and easy to inspect, application issues are solved immediately - Pipeline can be coated for full length with same coating material - Non shielding of CP - Excellent chemical resistance - Excellent oxygen barrier - Service temperature: -20 to +120ºC	- High moisture absorption - UV rays can cause the FBE to chalk when stored in direct sunlight for long periods of time (top coatings available for UV protection) - Lower impact and abrasion resistance(compared to 3LPE) - Susceptible to damage during transportation and backfilling - Not suitable for use in rocky environments as stand-alone coating - Exacting application parameters - FBE Field joint application parameters are critical and require trained operators and QC

TABLE 6: Continued…

ACS-3	- Minimum holiday susceptibility_ (due to self healing properties) - Low current requirement for cp - Good resistance to cathodic disbondment - The coating system with the same quality field joint coating - Good adhesion to steel - Ease of application - Non polluting - Easy repair procedure using the same coating material that is on the pipe body - Plant applied(compared to ACS-4A and ACS-4B) - Very good electrical insulating properties - No known instances of CP shielding - No known instances of cold flow - No known instances of SCC - No known instances of Soil Stress	- Limited bendability at higher ambient temperatures - Low chemical resistance, - Limited manufacturers - Limited applicators - Limited ambient temperature resistance - Max. operating temp. : unknown - Limited track record of using for underground or submerged metal corrosion protection in the world - Handling and installation restrictions in tropical environments
ACS-4	- Minimum holiday susceptibility - Lower current requirements with respect to ACS-4B - Good resistance to cathodic disbondment - Good adhesion to steel - Very good electrical insulating properties - Low water permeation - Resists bacterial attack and root penetration	- Limited manufacturers - Health and air quality concerns - Soil stress may cause the coating to wrinkle, crack, disbonded and expose steel surfaces - CP requirements increases as the coating ages . - Operating temperatures are normally limited to 65°c. - "Cold flow" (leaving the top of the pipe without adequate coating especially on high temperature pipelines) - Low soil stress resistance - Susceptible to SCC - Limited bendability

TABLE 6: Continued...

ACS-4	- Good adhesion to steel - Good electrical insulating properties - Non polluting environment	- Soil stress may cause the coating to wrinkle, crack, disbond and expose steel surfaces - CP requirements increases as the coating ages - Operating temperatures are normally limited to 60°C - "cold flow" (leaving the top of the pipe without adequate coating especially on high temperature pipelines) - Low soil stress resistance - Susceptible to SCC - Root penetration - Low chemical resistance - Brittle at low ambient temperatures - Sags at high ambient temperatures - Limited bendability - Handling and installation restrictions in tropical environments

Annex A

ACS-15

I. TYPE OF COATING

Pressure-sensitive, hand-applied tape-wrap for elevated temperature service

II. GENERAL DATA

a) uses: for onshore buried services. Primarily used for in-plant piping and for pipeline coating renovation on lines operating in the temperature range 55 to 100°C.
b) coating system: primer
inner wrap tape
outer wrap tape
c) Not suitable for: continuous contact with hydrocarbons, including oil – contaminated ground water.
d) service limitations:
temperature: min. -30°C
max. +100°C
e) Purchase specification or other product/performance requirements: Minimum tape thickness = 0.64 mm.
Polyethylene backing.
Butyl rubber adhesive with minimum TMA softening point equal to 100°C (Test method: ISO 11359).
Minimum allowable 180 degrees peel strength per ASTM D1000 shall be 1 N/mm for tape–to–tape and 2 N/mm tape–to–steel when applied over dry primer.
Maximum allowable slippage in Alyeska tape shear test shall be 15 mm at 80°C (Test method: TP-206)* .

III. SURFACE PREPARATION AND COATING APPLICATION REQUIREMENTS

a) Commercial blast, Sa2. Double wrap required. Outer wrap required for all services.
b) Compatible repair coatings : ACS-15

* See Annex C.

Annex B
(Informative)

PIPELINE REHABILITATION COATING SYSTEMS

B.1 coating materials

There are a number of coating materials available for using in pipeline rehabilitation, each with its own particular set of advantages and disadvantages. The most common materials type and characteristics are listed in table B1.

TABLE B1: TYPES OF COATING FOR USEING IN PIPELINE REHABILITATION

Type	Advantages	Limitations
ACS-5	- Minimum surface preparation - Backfill time - Ease of application - High electrical resistance - Minimum holiday susceptibility - Very good adhesion to steel - Low energy required for application	- Tenting at weld seam is unknown - Shielding CP from soil is unknown - Soil stress resistance is unknown - Susceptibility to SCC is unknown - Susceptible to bacterial attack (due to butyl rubber adhesive) - Limited max. operating temperature (<50 ° C)
ACS-9	- Fast curing - Low temperature cure - Good soil stress resistance - No known instances of SCC - Lower backfill time than ACS-8	- Less resistant to cathodic disbondment than ACS-8 - Adversely affected by moisture or high humidity - Higher moisture absorption compared to ACS-8 - Acid / alkali attack - Limited max. operating temperature (<60 ° C)
ACS-8	- Good adhesion - Good mechanical properties - Good soil stress resistance - Immersion resistance - Good cathodic disbondment resistance - Good performance in wet conditions - No known instances of SCC - Suitable for pipelines with operating temperature of higher than 60°C	- Longer cure time compared to ACS-9 - slow cure below 5 ° C

B.2 Materials selection: liquid epoxy / liquid polyurethane

With all coating systems, there are trade-offs in application and performance characteristics. Through improvements in chemistry, rehabilitation materials for pipeline – coating replacement have properties approaching that of premium-grade, plant applied FBE materials (see table B2). Selection depends on balancing factors like requirements for backfill time, material cost, and performance. Typically, epoxy is the coating of choice, unless the temperature at the time of application is too low or the time to backfill is critical.

TABLE B2: REHABILITATION COATINGS NOW HAVE PERFORMANCE PROPERTIES APPROACHING THOSE OF PREMIUM – GRADE FBE MATERIALS

Test /Property	ACS-2	ACS-8	ACS-9
Cathodic disbondment resistance – 14 days, 65°C, 1.5 V, mm radius	4.3	6.5	9
Impact – ASTM G-14, 16mm tup, 23±2°C(Jules)	2.4	2.8	3.2
Material cost per unit volume	X	3.1 X	2.6 X
Moisture vapor transmission G/ (mil) (square inches) (24 h)	1.8	1.8	4.3
Time to backfill at 23±2°C (minutes)	-	160	30

Annex C
(TP 206)

ALEYSKA SHEAR STRESS TEST

4.1.1 The purpose of this test is to determine if the sleeve has adequate resistance to shear stresses that might result from friction between the coating and the ground during pipe movement . The normal and shear loads simulate the forces experienced actual operation due to back–fill and to pipe movement .

4.1.2 The test set–up is shown schematically in figure 1 .

4.1.3 A strip cut from a heat shrink sleeve is bonded to a degreased steel plate by applying a load of approximately 34 kPa (5 psi) and placing in an oven at the vendor–recommended application temperature (typically about 150^0C) for a minimum of 4 hours . After removal from the oven , the joint shall remain at room temperature for one day before testing . The 34 kPa load shall remain on the test joint during cool down . The bonded strip of heat shrink sleeve shall be trimmed to a final size of 15.2 cm (6.0 inch) long by 3.1 cm (1.2 inch) wide . The test fixture , the coated plate , and the weights are then conditioned in an oven at the test temperature for 5 hours prior to testing .

4.1.4 The coating plate is fixed in place on the text fixture . The 18.6 kg normal load and the 6.8 kg shear load are applied (Note: the 18.6 kg weight has coarse sandpaper (120 grit) bonded to it , rough side exposed , so that is will not slip on the coating during the test) .

4.1.5 A dial indicator , reading to the nearest 0.025 mm (0.001 inch) is set in contact with the upper , moveable weight and zeroed . Readings are taken after 18 hours , 25 hours , and 50 hours and reported to the nearest 0.025 mm .

4.1.6 The test report shall include the dimensions of the coating strip , weights used , test temperature (including tolerance) , surface preparation of the steel panels , amount of movement after the time intervals given in paragraph 4.1.5 , and the time to complete failure (if complete failure occurs within the 50 hour test period) .

Figure 1 – Test setup for TP-206 – Alyeska Shear Stress test