

Recommended Practice for Application of Electric Submersible Cable Systems

API RECOMMENDED PRACTICE 11S5 (RP 11S5)
FIRST EDITION, FEBRUARY 1, 1993

American Petroleum Institute
1220 L Street, Northwest
Washington, DC 20005



Issued by
AMERICAN PETROLEUM INSTITUTE
Production Department

FOR INFORMATION CONCERNING TECHNICAL CONTENTS OF
THIS PUBLICATION CONTACT THE API PRODUCTION DEPARTMENT,
1201 MAIN STREET, SUITE 2535, DALLAS, TX 75202-3994 — (214) 748-3841.
SEE BACK COVER FOR INFORMATION CONCERNING HOW TO OBTAIN
ADDITIONAL COPIES OF THIS PUBLICATION.

Users of this publication should become familiar with its scope
and content. This publication is intended to supplement rather
than replace individual engineering judgment.

OFFICIAL PUBLICATION



REG. U.S. PATENT OFFICE

Copyright © 1993 American Petroleum Institute

TABLE OF CONTENTS

Policy	3
Foreword	4
Section 1: General	5
Section 2: Definitions of ESP Cable Terms	6
Section 3: Cable Conductors	17
Section 4: Cable Insulation Systems	18
Section 5: Jackets	20
Section 6: Braids & Coverings	21
Section 7: Armor	23
Section 8: Splicing and Terminating	24
Appendix A: Power Cost Considerations	29
Appendix B: Cable Types Guide	30

Note:

This is the first edition of this standard. It was adopted at the June 1991 Standardization Conference as reported in Circ PS-1952 and subsequently approved by letter ballot.

Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, American Petroleum Institute, Production Department, 1201 Main Street, Suite 2535, Dallas TX 75202-3994.

POLICY

API PUBLICATIONS NECESSARILY ADDRESS PROBLEMS OF A GENERAL NATURE. WITH RESPECT TO PARTICULAR CIRCUMSTANCES, LOCAL, STATE AND FEDERAL LAWS AND REGULATIONS SHOULD BE REVIEWED.

API IS NOT UNDERTAKING TO MEET DUTIES OF EMPLOYERS, MANUFACTURERS OR SUPPLIERS TO WARN AND PROPERLY TRAIN AND EQUIP THEIR EMPLOYEES, AND OTHERS EXPOSED, CONCERNING HEALTH AND SAFETY RISKS AND PRECAUTIONS, NOR UNDERTAKING THEIR OBLIGATIONS UNDER LOCAL, STATE, OR FEDERAL LAWS.

NOTHING CONTAINED IN ANY API PUBLICATION IS TO BE CONSTRUED AS GRANTING ANY RIGHT, BY IMPLICATION OR OTHERWISE, FOR THE MANUFACTURE, SALE, OR USE OF ANY METHOD, APPARATUS, OR PRODUCT COVERED BY LETTERS PATENT. NEITHER SHOULD ANYTHING CONTAINED IN THE PUBLICATION BE CONSTRUED AS INSURING ANYONE AGAINST LIABILITY FOR INFRINGEMENT OF LETTERS PATENT.

GENERALLY, API STANDARDS ARE REVIEWED AND REVISED, REAFFIRMED, OR WITHDRAWN AT LEAST EVERY FIVE YEARS. SOMETIMES A ONE-TIME EXTENSION OF UP TO TWO YEARS WILL BE ADDED TO THIS REVIEW CYCLE. THIS PUBLICATION WILL NO LONGER BE IN EFFECT FIVE YEARS AFTER ITS PUBLICATION DATE

AS AN OPERATIVE API STANDARD OR, WHERE AN EXTENSION HAS BEEN GRANTED, UPON REPUBLICATION. STATUS OF THE PUBLICATION CAN BE ASCERTAINED FROM THE API AUTHORIZING DEPARTMENT (TEL. 214-748-3841). A CATALOG OF API PUBLICATIONS AND MATERIALS IS PUBLISHED ANNUALLY AND UPDATED QUARTERLY BY API, 1220 L ST., N.W., WASHINGTON, D.C. 20005.

American Petroleum Institute (API) Recommended Practices are published to facilitate the broad availability of proven, sound engineering and operating practices. These Recommended Practices are not intended to obviate the need for applying sound judgment as to when and where these Recommended Practices should be utilized.

The formulation and publication of API Recommended Practices is not intended to, in any way, inhibit anyone from using any other practices.

Any Recommended Practice may be used by anyone desiring to do so, and a diligent effort has been made by API to assure the accuracy and reliability of the data contained herein. However, the Institute makes no representation, warranty, or guarantee in connection with the publication of any Recommended Practice and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use, for any violation of any federal, state, or municipal regulation with which an API Recommendation may conflict, or for the infringement of any patent resulting from the use of this publication.

FOREWORD

(a) This publication is under the jurisdiction of the API Committee on Standardization of Production Equipment.

(b) This document presents recommended practices for materials and application of Electric Submersible Cable Systems.

This Standard shall become effective on the date printed on the cover but voluntary conformance to the revisions may be used in whole or in part and either in lieu of or in conjunction with the current specification from the date of distribution to constitute conformance with the edition applicable at the date of manufacture.

SECTION 1 GENERAL

1.1 INTRODUCTION: This recommended practice covers materials and application of Electric Submersible Cable Systems. This recommended practice is generally appropriate for the majority of Electric Submersible Pump applications.

1.2 SCOPE: This RP covers the application of Electric Submersible Cable Systems by manufacturer, vendor, or

user. It does not include other Electric Submersible Pump System components.

1.3 JURISDICTION: This document covers generally accepted practices for submersible cable systems. All applicable local, state, and national codes and regulations should be followed for each installation.

SECTION 2

DEFINITIONS OF ESP CABLE TERMS

2.1 GENERAL

2.1.1 Antioxidants — Antioxidants are materials added to the rubber compound. They are used to prevent degradation (oxidation) in rubber or plastics by retarding hardening and embrittlement.

2.1.2 Compound — A compound is a mechanical blend of base polymer with other ingredients added to obtain the desired properties. The compounds are usually proprietary formulations of each manufacturer and are different. These variations may affect the cable performance.

2.1.3 Corrosion — Corrosion is the destruction of the surface of a metal by oxidation. This can be initiated by the action of chemicals alone or in combination with well fluids. Galvanic corrosion results from an electro-chemical reaction in which an electric current flows between two dissimilar metals in a conductive medium, such as salt water.

2.1.4 Cure — During the manufacturing of a cable, curing is the process of changing the physical characteristics of raw rubber to produce a suitable insulation or jacketing material. The change requires a curing agent, heat, and pressure. Vulcanizing and cross-linking are forms of curing.

2.1.5 ECTFE (Ethylene Chlorotetrafluoroethylene) — ECTFE is a chlorofluorinated thermoplastic copolymer composed of ethylene and chlorotetrafluoroethylene. The material is chemically inert and a good low voltage electrical insulator. ECTFE belongs to the group of plastic materials known as fluoropolymers.

2.1.6 Elastomer — An elastomer is a rubber-like material which can stretch under low stress and return to its original shape when the stress is removed.

2.1.7 Electrical Insulation Resistance — Insulation resistance is the resistance of the insulation to the radial flow of direct current through the insulation. Insulation resistance is generally referred to in megohms at 60°F.

The formula to measure Insulation Resistance ("IR") is:

"IR" = E / I (megohms), where:

E = the voltage applied between the conductor and ground (volts)

I = dc leakage current in microamps.

This electrical resistance will vary between compounds and cable geometries. A measure of performance is balanced values of insulation resistance or leakage current for each phase.

2.1.8 EPDM (Ethylene Propylene Diene Monomer) — EPDM is a polymer composed of ethylene, propylene, and diene units. This polymer, or rubbery material, can be cured with a sulfur or peroxide.

2.1.9 EPM (Ethylene Propylene Monomer) — EPM is a polymer composed of ethylene and propylene units. These materials have to be cured with a peroxide curing agent. Useful properties are similar to EPDM.

2.1.10 EPR (Ethylene Propylene Rubber) — EPR is a term used to describe either EPDM or EPM.

2.1.11 ETFE (Ethylene Tetrafluoroethylene) — ETFE is a fluorinated thermoplastic copolymer composed of ethylene and tetrafluoroethylene. The material is chemically inert and a good low voltage electrical insulator. ETFE belongs to the group of plastic materials known as fluoropolymers.

2.1.12 FEP (Fluorinated Ethylene Propylene) is a thermoplastic fluorinated ethylene propylene copolymer. The material is chemically inert and a good low voltage electrical insulator. FEP belongs to the group of plastic materials known as fluoropolymers.

2.1.13 Fillers, Compound — Fillers are materials added to compounds to enhance various properties such as mechanical strength, moisture resistance, and electrical characteristics.

2.1.14 Fillers, Physical — Physical fillers are materials to fill interstices in cable construction. Common materials are rubber and polypropylene.

2.1.15 Hoop Strength — Hoop Strength is a measure of the tangential resistance to elongation. Since internal gas pressure pushes in a radial direction, it creates a tendency for the surface of the insulation and jacket to elongate and rupture tangentially. The hoop strength resists this tendency, and can be aided by additional wraps applied over the round components.

2.1.16 Leakage Current — Leakage current is the current that flows across the surface or through the insulation when a dc voltage is applied. This value defines the insulation resistance at the specified dc potential. Regardless of the quality of the dielectric material, all materials will exhibit some leakage current.

2.1.17 Monomer — A monomer is a basic chemical unit which forms a polymer by chemical linking.

2.1.18 Nitrile — Nitrile is a copolymer of butadiene and acrylonitrile monomers. It is known by several names: Buna N, Nitrile Rubber, and NBR (Nitrile Butadiene Rubber). The ratio of acrylonitrile to butadiene may be varied to provide trade-offs between oil resistance or low temperature properties. This allows the compounder freedom in providing suitable properties for specific applications.

2.1.19 Plasticizers — Plasticizers are chemicals added to compounds to impart flexibility, workability, and stretchability.

2.1.20 Polyamide — A polyamide is a high molecular weight polymer thermoplastic material composed of polymers which contain an amide (-COHN-) group. The material exhibits a modest degree of chemical inertness and has a high tensile strength.

2.1.21 Polyethylene (PE) — Polyethylene is a thermoplastic material composed of chemically linked ethylene monomer units.

2.1.22 Polyimide — A polyimide is a fully reacted linear polymer incorporated with the imide group in the polymer main chain. Examples are Kapton® and Apical®.

2.1.23 Polymer — A polymer is a material formed by linking together monomers through a chemical reaction.

A polymer consists of a chain of repeated structural units. Prefixes denoting one, two or three basic units are "homo", "co", and "ter" respectively.

2.1.24 Polypropylene (PP) — Polypropylene is a thermoplastic material composed of chemically linked propylene monomer units. Electrical grades incorporate a small percent of ethylene or butene monomer to impart better low temperature properties.

2.1.25 Polyvinyl Fluoride (PVF) — Polyvinyl fluoride is a fluorinated thermoplastic material composed of chemically linked fluorine monomer units. PVF belongs to the group of plastic materials known as fluoropolymers.

2.1.26 Polyvinylidene Fluoride (PVF₂) — Polyvinylidene fluoride is a fluorinated thermoplastic material composed of chemically linked vinyl fluoride monomer units. PVF₂ belongs to the group of plastic materials known as fluoropolymers.

2.1.27 Thermoplastics — Thermoplastics are polymeric materials that will soften or flow at elevated temperatures but will harden when cooled. This is a reversible process. Examples of thermoplastic materials are polypropylene (PP), polyethylene (PE), polyvinyl fluoride (PVF), polyvinylidene fluoride (PVF₂), and polyamides (nylon).

2.1.28 Thermoset — Thermosets are polymeric materials that once cured are irreversibly cross-linked and cannot be remolded. Two common examples of thermoset materials are EPDM and nitrile rubber.

2.2 TEMPERATURE

2.2.1 Conductor Temperature — Conductor temperature is the temperature on the surface of the current carrying conductors. This temperature is a function of heat generated by current flow in the conductor, heat dissipation through the materials, and ambient temperature. Flat cables generate additional heat from other power losses due to the non-symmetrical construction.

2.2.2 Rated Temperature — The rated temperature is the maximum conductor temperature at which a cable can continuously operate without causing significant material degradation.

2.2.3 Operating Temperature — Operating temperature is the conductor temperature during steady state operation. The maximum operating temperature is defined as the rated temperature.

2.2.4 Bottom Hole Temperature — The bottom hole temperature is the static temperature at the mid point of the perforations.

2.2.5 Ambient Temperature — The ambient temperature is the temperature surrounding the cable at any point. In a downhole environment, the ambient temperature depends on many variables which include: the reservoir temperature, the heat rise from the submersible equipment, the well temperature profile, and the thermal conductivity of well liquids, foams, and gases.

2.3 TRADE NAMES

2.3.1 Apical® — Apical is a polyimide. This is a trade name of Allied Chemical. It is applied directly over the conductor as a primary insulation. Because Apical has no melting point, FEP is laminated with the polyimide to give a heat-sealable structure for fabrication purposes.

2.3.2 Halar® — Halar is an ethylene chlorotetrafluoroethylene. This is a trade name of Ausimont USA.

2.3.3 Halon ET® — Halon ET is an ethylene tetrafluoroethylene. This is a trade name of Ausimont USA.

2.3.4 Kapton® — Kapton is a polyimide. This is a trade name of DuPont. It is applied directly over the conductor as a primary insulation. Because Kapton has no melting point, Teflon FEP is laminated with the polyimide to give a heat-sealable structure for fabrication purposes.

2.3.5 Kynar® — Kynar is a polyvinylidene fluoride (PVF₂). This is a trade name of Pennwalt. It is used as a braid and as an extrudable barrier.

2.3.6 Nylon® — Nylon is a polyamide. There are many suppliers of nylon. Nylon is most commonly used in braids.

2.3.7 Tedlar® — Tedlar is a polyvinyl fluoride (PVF). This is a trade name of DuPont. It is used as barrier tape.

2.3.8 Teflon FEP® — Teflon FEP is a fluorinated ethylene propylene. This FEP is a trade name of DuPont. It is laminated with a polyimide to form a heat-sealable tape or extrudable layer.

2.3.9 Tefzel® — Tefzel is an ethylene tetrafluoroethylene. This is a trade name of DuPont. It is used as a barrier tape or as an extrudable barrier.

2.4 LEGEND AND LIST OF FIGURES

2.4.1 Scope

This Section includes figures pertaining to cable construction. Refer to Section 8 for figures pertaining to splices and terminations.

2.4.2 Cable Components Legend

Item	Description	Section Reference
1	Conductor	Section 3
2	Strand Gas Block	Section 3.1.2
3	Conductor/Insulation Gas Block	Section 4.2.3
4	Auxiliary Insulation, Type	Section 4.4, 4.5
5	Basic Insulation, Type	Section 4.2, 4.3
6	Physical Filler	Section 2.1.14
7	Jacket, Type	Section 5
8	Barrier Layer	Section 6.3, 6.4
9	Braid	Section 6.2
10	Lead Sheath	Section 6.5
11	Bedding Layer	Section 6.6
12	Struts	Section 6.5
13	Armor	Section 7

2.4.3 List of Figures

Figure	Title
2.5.1	Conductor Configuration
	(a) Solid
	(b) Concentric/Compressed Stranded
	(c) Compacted Stranded
2.5.2	Round Cable: Polypropylene Insulation, Nitrile Jacket

2.4.3 List of Figures (Cont)

Figure	Title
2.5.3	Flat Cable: Polypropylene Insulation, Nitrile Jacket (a) Typical (b) Tape & Braid (c) Encapsulated
2.5.4	Round Cable: EPDM Insulation, Nitrile Jacket
2.5.5	Flat Cable: EPDM Insulation, Nitrile Jacket (a) Typical (b) Motor Lead
2.5.6	Round Cable: EPDM Insulation, EPDM Jacket or Filler

- (a) Typical
(b) Tape and Braid
(c) Barrier and Filler

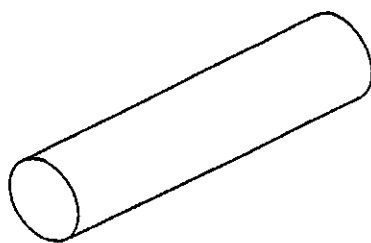
2.5.7 Flat Cable: EPDM Insulation, Double Wrapped Armor

2.5.8 Flat Cable: EPDM Insulation, Lead Encapsulated

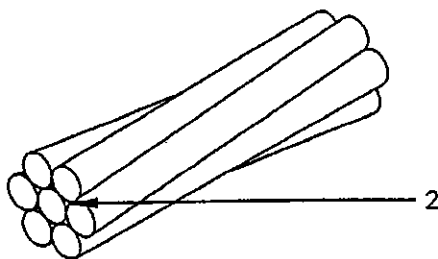
- (a) Typical
(b) Motor Lead

2.5.9 Flat Cable: EPDM Insulation, Lead Encapsulated, Strutted

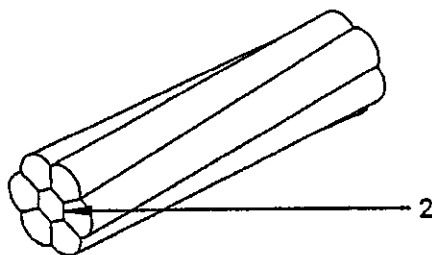
- (a) Edge Strutted
(b) Fully Strutted
(c) Motor Lead



a) SOLID



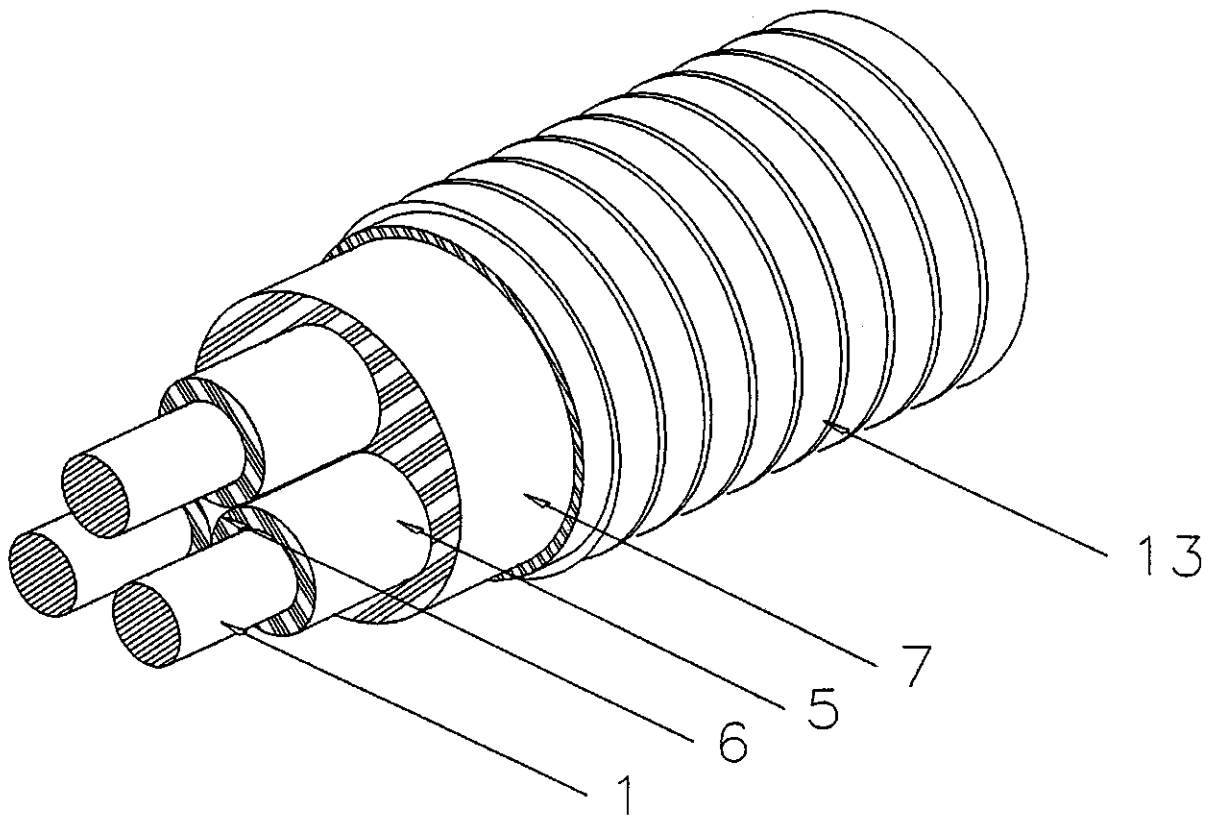
b) CONCENTRIC/
COMPRESSED



c) COMPACTED

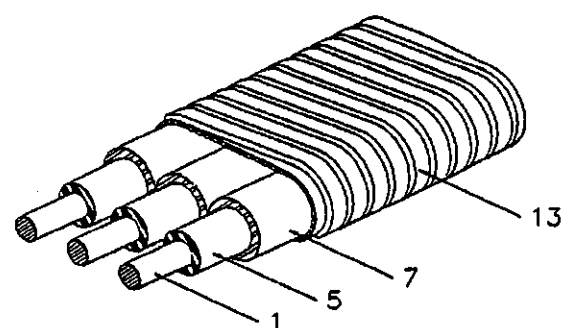
LEGEND		
ITEM	DESCRIPTION	SECTION
2	STRAND GAS BLOCK	3.1.2

FIGURE 2.5.1
CONDUCTOR CONFIGURATION

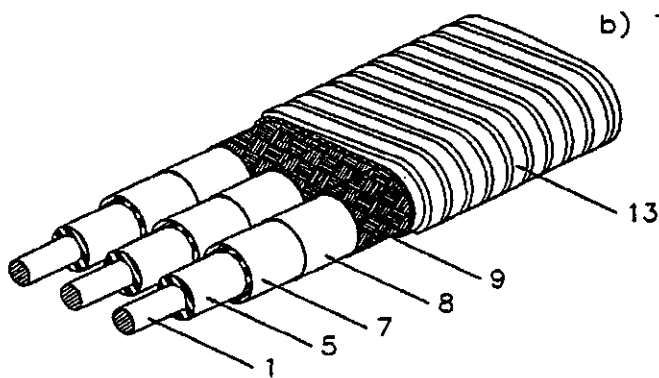


LEGEND		
ITEM	DESCRIPTION	SECTION
1	CONDUCTOR	3
5	BASIC INSULATION, POLYPROPYLENE	4.2
6	PHYSICAL FILLER	2.1.14
7	JACKET, NITRILE	5
13	ARMOR	7

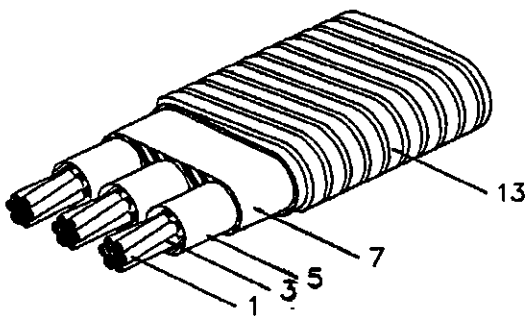
FIGURE 2.5.2
ROUND CABLE: POLYPROPYLENE INSULATION, NITRILE JACKET



a) TYPICAL



b) TAPE AND BRAID

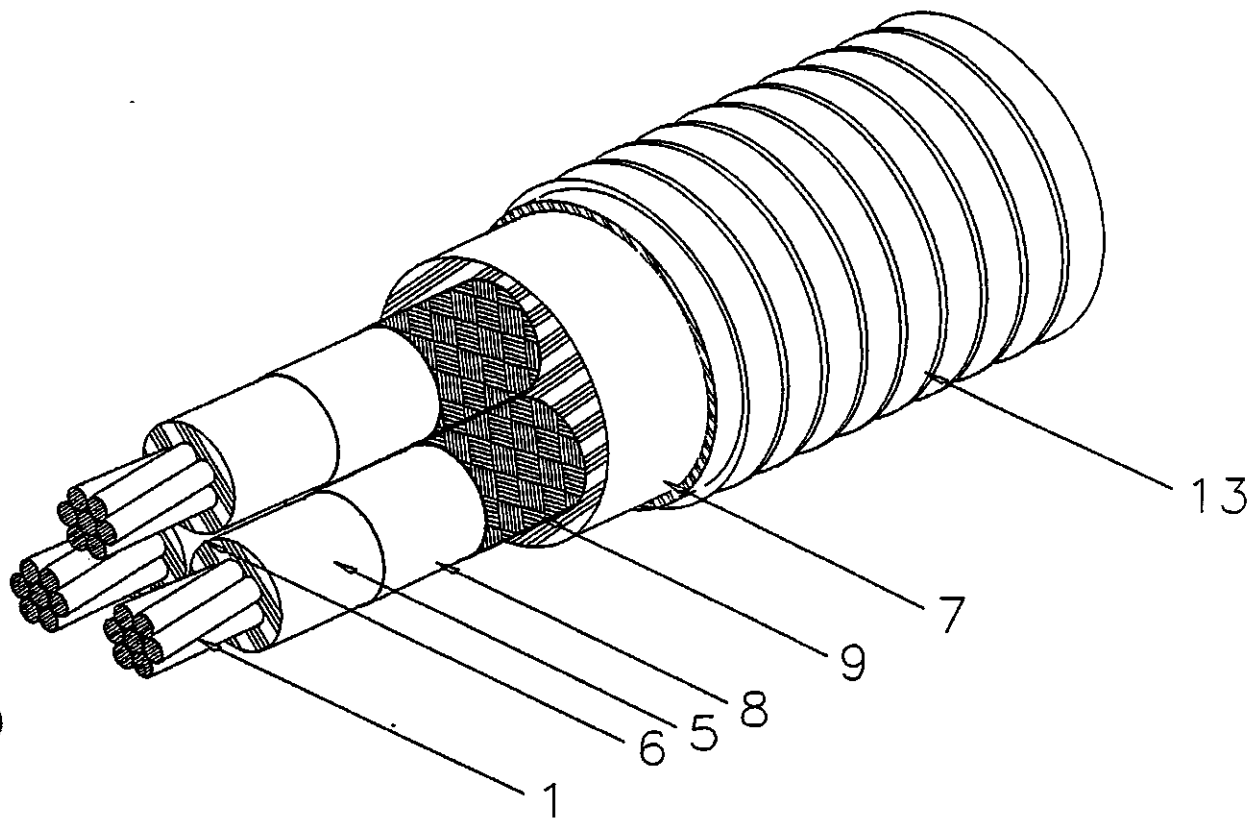


c) ENCAPSULATED

LEGEND

ITEM	DESCRIPTION	SECTION
1	CONDUCTOR	3
3	CONDUCTOR/INSULATION GAS BLOCK	4.2.3
5	BASIC INSULATION, POLYPROPYLENE	4.2
7	JACKET, NITRILE	5
8	BARRIER LAYER	6.3, 6.4
9	BRAID	6.2
13	ARMOR	7

FIGURE 2.5.3
FLAT CABLE: POLYPROPYLENE INSULATION NITRILE JACKET



LEGEND		
ITEM	DESCRIPTION	SECTION
1	CONDUCTOR	3
5	BASIC INSULATION, EPDM	4.3
6	PHYSICAL FILLER	2.1.14
7	JACKET, NITRILE	5
8	BARRIER LAYER	6.3, 6.4
9	BRAID	6.2
13	ARMOR	7

FIGURE 2.5.4
ROUND CABLE: EPDM INSULATION, NITRILE JACKET

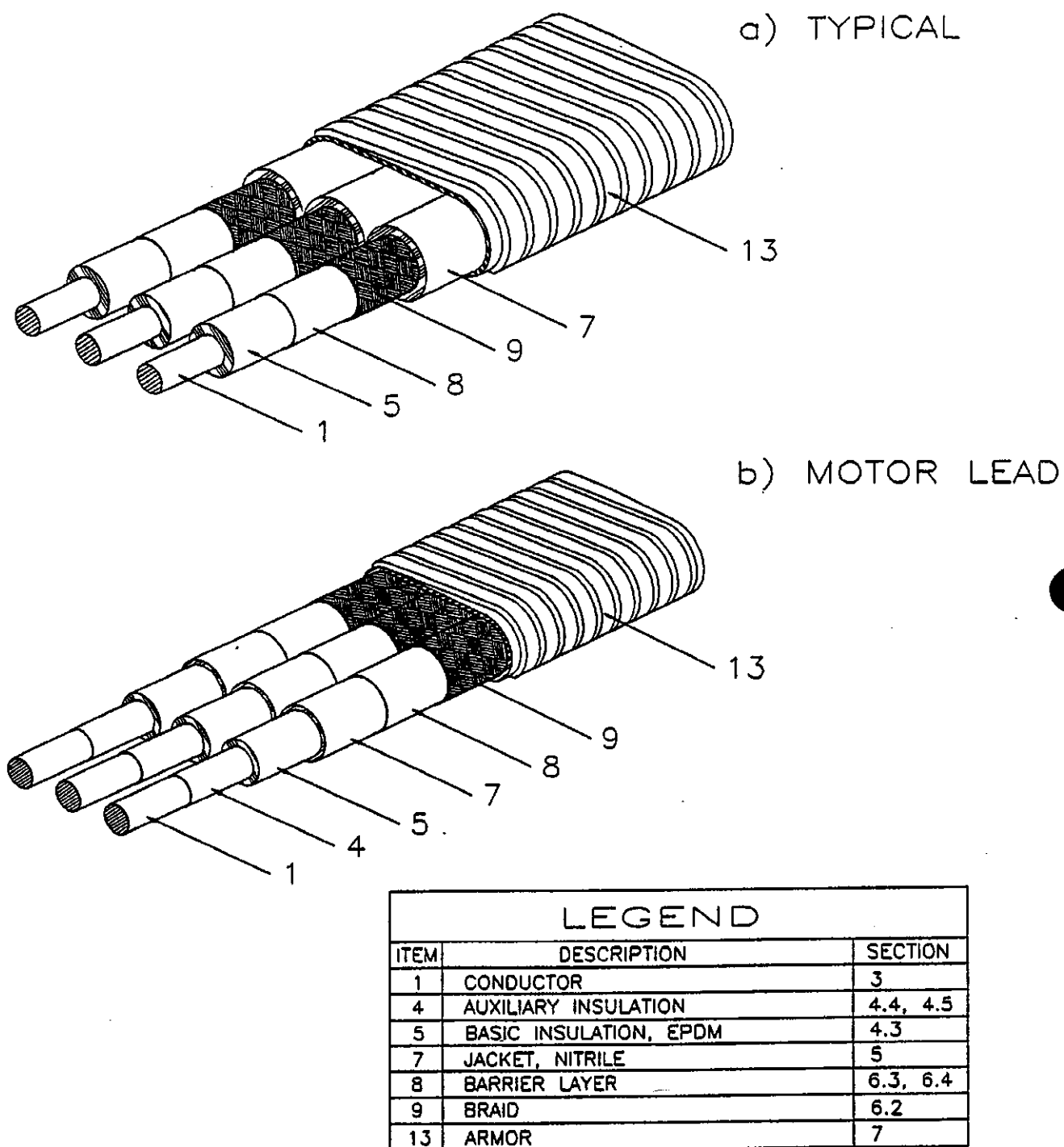


FIGURE 2.5.5
FLAT CABLE: EPDM INSULATION, NITRILE JACKET

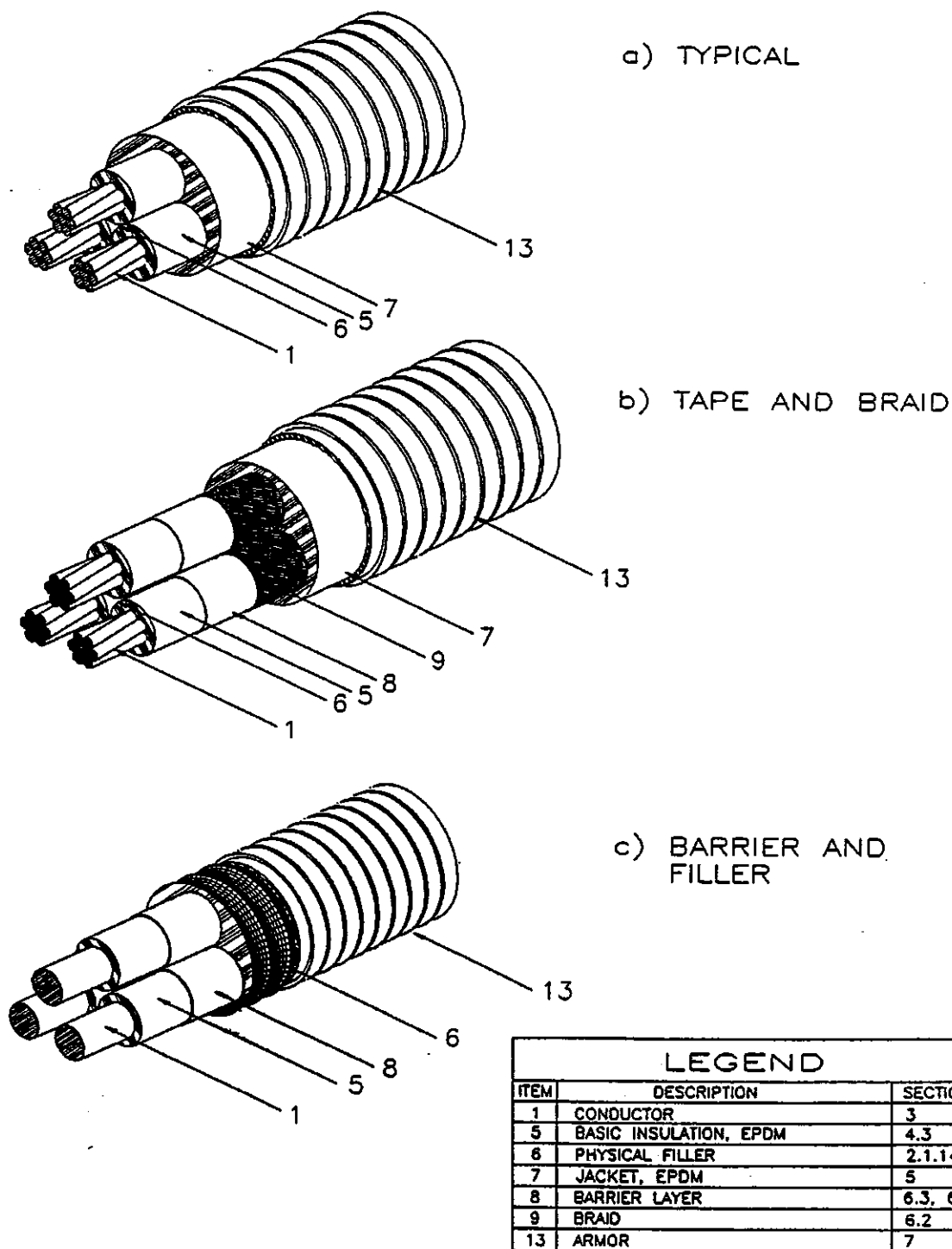
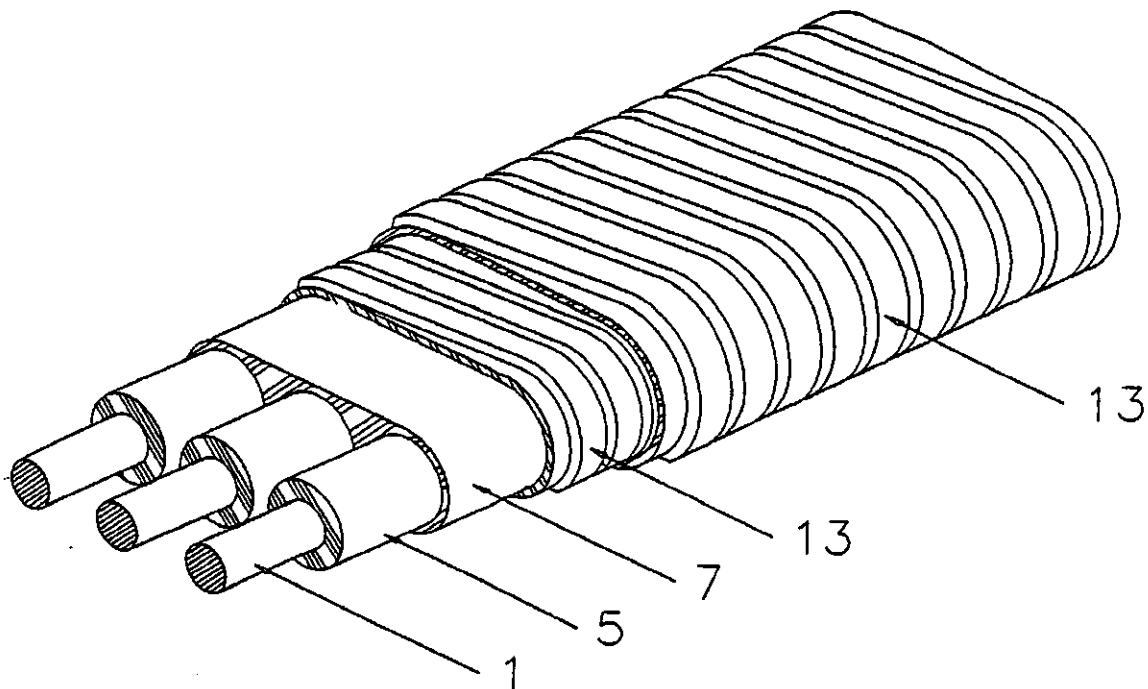
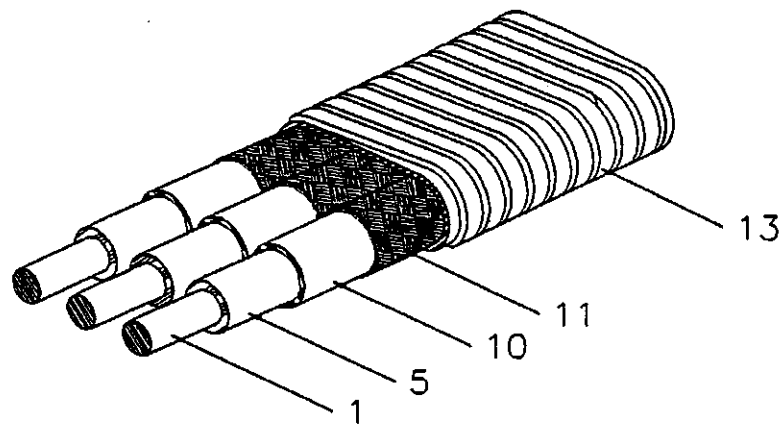


FIGURE 2.5.6
ROUND CABLE: EPDM INSULATION, EPDM JACKET OR FILLER

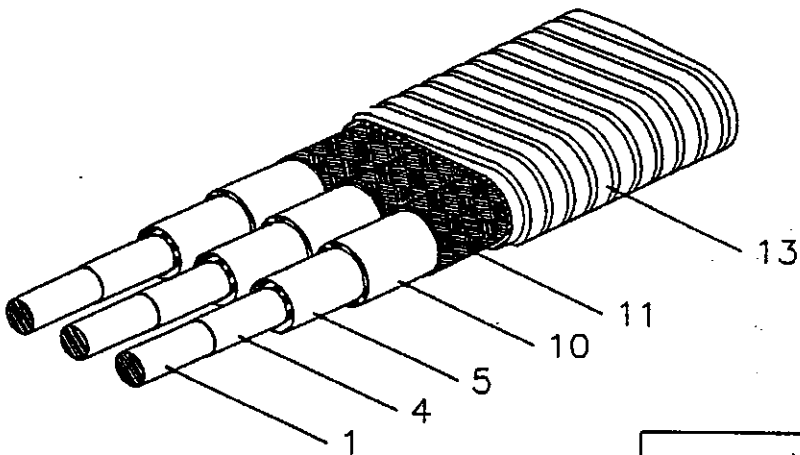


LEGEND		
ITEM	DESCRIPTION	SECTION
1	CONDUCTOR	3
5	BASIC INSULATION, EPDM	4.3
7	JACKET	5
13	ARMOR	7

FIGURE 2.5.7
FLAT CABLE: EPDM INSULATION, DOUBLE WRAPPED ARMOR



a) TYPICAL



b) MOTOR LEAD

LEGEND		
ITEM	DESCRIPTION	SECTION
1	CONDUCTOR	3
4	AUXILIARY INSULATION	4.4, 4.5
5	BASIC INSULATION, EPDM	4.3
10	LEAD SHEATH	6.5
11	BEDDING LAYER	6.6
13	ARMOR	7

FIGURE 2.5.8
FLAT CABLE: EPDM INSULATION, LEAD ENCAPSULATED

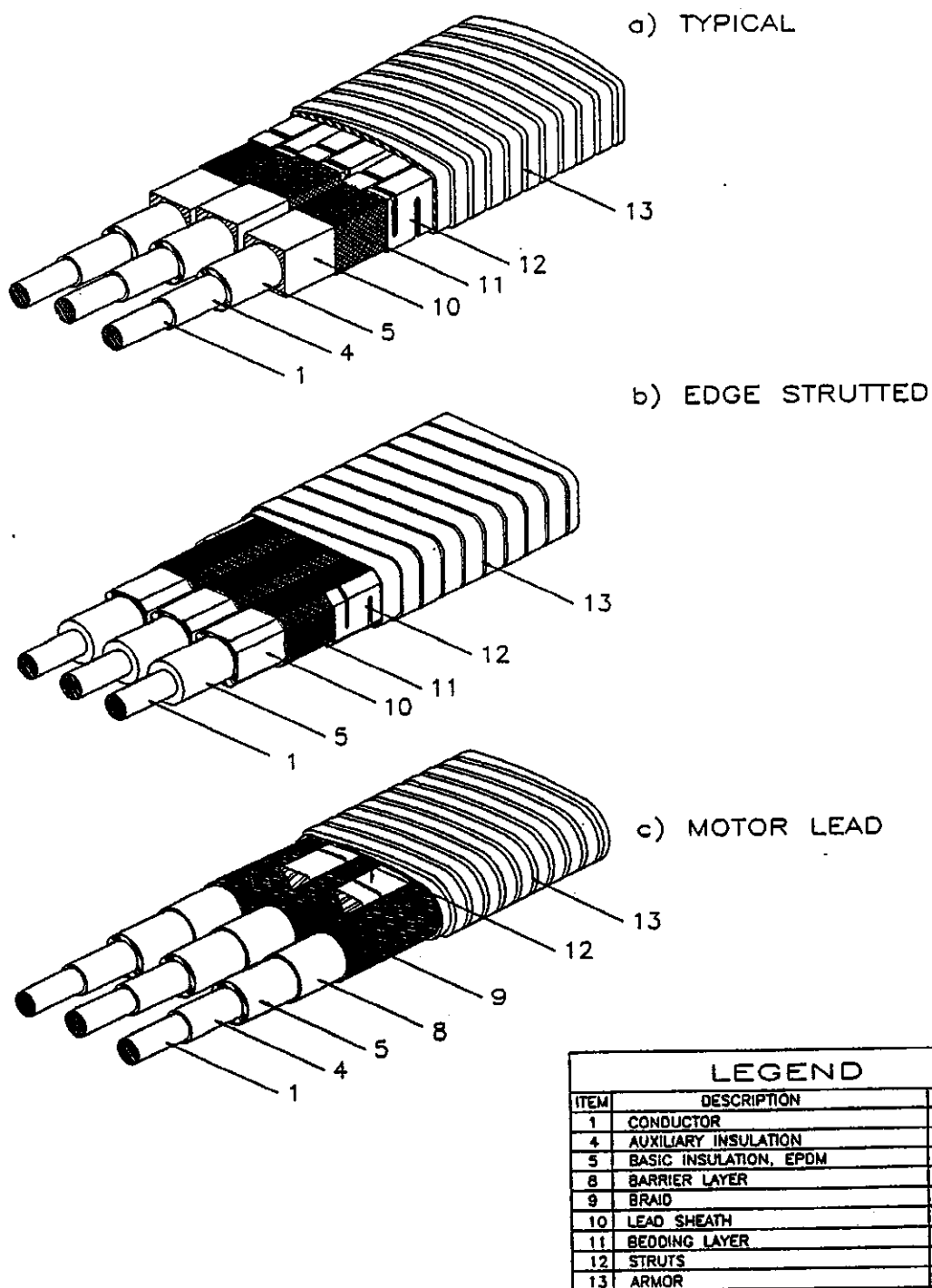


FIGURE 2.5.9
FLAT CABLE; EPDM INSULATION LEAD ENCAPSULATED, STRUTTED

SECTION 3 CABLE CONDUCTORS

3.1 GENERAL

3.1.1 Description: Either copper or aluminum conductors are used to carry the AC current from the surface to the motor.

For submersible pump applications, the industry has essentially standardized on conductor sizes #1, 2, 4, and 6 AWG. Other sizes are available on special order.

3.1.2 Applications: Cable AWG size is selected based on ampacity rating, economic considerations, and well clearance. First, the maximum allowable cable diameter is determined by wellbore clearance. Second, the minimum conductor size is determined by the required motor current and permissible voltage drop. Finally, economic comparisons are made between cable sizes.

For a given conductor size, increasing current will increase both the power losses and cable operating temperature. Increasing the conductor size for a given current will decrease the losses and operating temperature.

ESP cable can be purchased with either stranded or solid conductors. Solid conductors have the smallest diameter. For the same AWG size, stranding increases conductor diameter and flexibility. Stranding is more common in larger conductor sizes. Motor lead extensions are usually solid.

Solid conductors minimize gas migration and hydrogen sulfide deterioration. "Compressed" or "compacted" stranded conductors filled with a gas blocking compound are an alternative approach to addressing these problems.

The diameters of AWG wire sizes are defined as a concentric strand. Compressed stranded conductors have 98% of the diameter of concentric stranded conductors. Compacted stranded conductors have 92% of the diameter of concentric stranded conductors.

Traditionally, aluminum has been less expensive and it is lighter in weight than copper conductors. Therefore cable manufacturing costs for the same ampacity wire should be less.

3.1.3 Limitations: Aluminum is generally less desirable as a conductor for submersible pumps because it provides only 61% of the conductivity of an equivalently sized copper conductor. Therefore, a larger diameter wire must be used to carry the same current as copper. This can cause clearance problems in the wellbore.

Aluminum conductors are more difficult to terminate or splice than copper. Special crimp type connectors must be used when joining ends of aluminum conductors. The aluminum must not be cut or nicked when removing the insulation.

Copper's main disadvantage is its susceptibility to damage by hydrogen sulfide (H_2S). This problem is overcome, in high temperature applications, by using a continuous lead sheath completely covering the insulation.

SECTION 4

CABLE INSULATION SYSTEMS

4.1 GENERAL

4.1.1 Description: Insulation isolates the electrical potential between conductors and other conducting materials. Insulation also minimizes leakage current from the conductors. Different materials will affect the space required to maintain electrical isolation.

4.1.2 Applications: Typical materials used in oil well submersible cables are thermoplastics like polypropylene and thermoset compounds like EPDM.

Some cables use a composite insulation system comprised of a basic and auxiliary insulation. Films or thinly extruded materials are used as the auxiliary insulation. These materials have a high dielectric strength (volts per mil) for their thickness. As a system, the insulations provide a synergistic effect.

4.1.3 Limitations: An auxiliary insulation cannot operate as a single system. It must be used in combination with a basic thermoplastic or thermoset insulation to enhance electrical and mechanical properties.

Cables with polyethylene or polypropylene thermoplastic insulation have a lower rated temperature than cables with thermoset insulation.

Operation at elevated temperature will shorten the life of a cable. In general, cable life decreases exponentially as the temperature increases. A general definition of useful life is described by embrittlement (age hardening) of the insulation. Localized heating zones will exist near the pump and motor.

Other forms of insulation degradation are caused by pressure cycling and exposure to downhole chemicals. Insulation choice is also influenced by well environment, gas type and gas concentration.

The handling of pump cables at low temperatures is limited not only by the type of insulation within the cable, but also by the jacket material. If cables have been exposed to low temperatures they should be preconditioned to room temperature (>60°F) for at least 48 hours before handling.

As a guideline, pump cables with polypropylene insulation should not be handled below temperatures of +14°F.

As a guideline, pump cables with EPDM insulation and nitrile rubber jackets should not be handled below temperatures of -20°F.

As a guideline, pump cables with EPDM insulation and EPDM rubber jackets should not be handled below temperatures of -40°F.

4.2 THERMOPLASTIC

4.2.1 Description: A thermoplastic is a plastic material which may be shaped when heated to an elevated temperature, and retains a well defined shape or form when cooled. On re-heating above its deformation temperature, the material will reshape/reform when an outside force is applied. The deformation temperature decreases as the applied force increases.

Typical thermoplastic materials include polyethylene, polypropylene, and nylon.

4.2.2 Application: Polypropylene is a relatively inexpensive insulation material useable in low-temperature oil well environments. It is useful in the range +14°F (ambient) to +205°F (conductor) temperature.

4.2.3 Limitations: The useful temperature range is under ideal conditions where there is no chemical attack or applied mechanical forces. Cables with polypropylene insulation should not be handled in ambient temperatures below 14°F. Bending at lower temperatures may crack the insulation.

There are several detrimental well conditions which are known to affect polypropylene. Carbon dioxide initiates premature cracking. Light ends of crude oil lead to softening. External forces (cable clamps, tensile forces) applied on a cable operating near the upper temperature limit lead to premature deformation.

Polypropylene is susceptible to accelerated aging from contact with copper metal. Special anti-aging materials are added to reduce this impact. Once the agents have been consumed, residual free copper ions will attack the polypropylene. Most manufacturers apply a tin or lead alloy coating to isolate the copper from the polypropylene.

In cables utilizing polypropylene insulation direct contact with an aluminum conductor does not affect the aging of the insulation.

After the cable has been flexed, polypropylene will allow gas to migrate between the conductor and insulation. For applications where gas migration would be a problem, a conductor/insulation gas blocking material must be applied.

4.3 THERMOSET

4.3.1 Description: A thermoset material is a material modified through a chemical reaction which becomes permanently shaped when cured. Typical thermoset materials include nitrile rubber (NBR); EPR materials such as EPDM and EPM; styrene butadiene rubber (SBR); and cross linked polyethylene (XLPE).

4.3.2 Application: For ESP cable, EPDM is the most commonly used thermoset material.

EPDM retains good flexibility at extremely low ambient temperature (-40°F). EPDM has been found to be preferred in CO₂ environments and is resistant to many types of well treatments.

EPDM materials are generally preferred in higher temperature oil well applications. Some compound formulations of EPDM are useful to conductor temperatures of 400 F if properly constrained by the cable construction.

4.3.3 Limitations: EPDM materials swell in oil, but this characteristic can be reduced by proper formulation. EPDM is highly dependent on outer constraining coverings to retain its integrity.

4.4 FILMS

4.4.1 Description: Films are generally thin tapes of materials applied directly over the conductor. The films are helically wrapped with an overlap and are heat sealed.

Typical films are polyimides such as Kapton® or Apical®.

4.4.2 Applications: Films are typically used where high dielectric strength (volts per mil) is required with minimal thickness of insulation. The material is suitable for high temperature (450+/-°F) applications. The most common applications are motor lead (flat) extension and motor winding insulation.

4.4.3 Limitations: Polyimide films are chemically attacked by moisture which significantly degrades insulation characteristics and mechanical strength. The major limitation is extremely high cost.

4.5 EXTRUDED AUXILIARY INSULATION

4.5.1 Description: Several materials are currently being extruded as auxiliary insulation. Thermoplastic polyvinylidene fluoride (PVF₂) and ethylene chloro-

tetrafluoroethylene (ECTFE) are used for temperatures up to 300°F, and fluorinated ethylene propylene (FEP) is used for temperatures up to 400°F.

4.5.2 Application: The materials extruded directly over the conductor or over the insulation to provide added dielectric strength and chemical resistance. The material is less susceptible to damage from ingress of well fluids than the EPDM covering. Therefore, it provides greater protection and may extend the life of the cable. See Section 6.4 on extruded barrier coverings for additional information.

4.5.3 Limitations: The thermoplastic covering may be expensive.

Special splicing techniques must be used when repairing or terminating the cable.

SECTION 5 JACKETS

5.1 GENERAL

5.1.1 Description: Jackets are protective coverings used to mechanically shield the insulation from the downhole environment.

The jacket materials protect the insulation from mechanical abuse associated with handling. Some jacketing material may provide secondary insulation.

Currently nitrile and EPDM elastomers are most commonly used.

5.1.2 Applications: A jacket's useful properties depend on the ambient temperature and well conditions. The rated temperature of the cable may be limited by the temperature rating of the jacket material.

Compounding can raise the upper temperature limit by adjusting the type of cure and antioxidants. For lower temperature limits, a plasticizer is added. These additions slightly affect other physical properties such as elongation, hardness, or tensile strength.

Currently two types of jackets dominate the submersible pump cable market. These are made of nitrile or EPDM.

The EPDM will operate at higher temperatures than the nitrile but the nitrile is tougher and more oil resistant.

EPDM jackets may be compounded to improve oil swell resistance. Furthermore, EPDM is inherently better than nitrile for handling and installation at lower surface temperatures.

5.1.3 Limitations: Nitrile is limited to +284°F, while EPDM has an approximate limit of +400°F. These limits influence the cable's rated temperature.

Operation at elevated temperature will shorten the useful life of a cable. In general, cable life decreases exponentially as the temperature increases. A general definition of useful life is described by embrittlement (age hardening) of the jacket. Localized heating zones will exist near the pump and motor.

Other forms of jacket degradation are caused by pressure cycling and exposure to downhole chemicals. Jacket choice is also influenced by well environment, gas type and gas concentration.

Armor and/or constraining layers are critical to the protection of the jacket. Particularly, EPDMs tend to swell in the absence of armor. When a cable without armor protection is pulled or pressure cycled, the jacket may balloon and rupture due to absorbed oils and gases.

SECTION 6 BRAIDS AND COVERINGS

6.1 GENERAL

6.1.1 Description: Braids and coverings are supplementary layers of material used to provide specific mechanical performance characteristics to the cable system.

6.1.2 Application: The braids and coverings are applied over the insulation and may be on either side of the jacket.

These materials provide additional strength and protection to the underlying cable components.

6.1.3 Limitations: These materials increase the cable diameter and the cable cost. They are also susceptible to deterioration from well fluids and conditions.

6.2 BRAIDS

6.2.1 Description: Braids are a woven reinforcement layer of synthetic material applied over the insulated conductor. Braids vary in degree of coverage or openness.

The most common braid material is Nylon (polyamide). A more exotic material such as Kynar® may be used in cables operating in highly corrosive and/or high temperature applications.

6.2.2 Applications: The primary purpose of a braid is to provide additional hoop strength for the insulation during decompression of entrapped well gases. Decompression may occur when the well fluids are rapidly pumped off during start-up operations, or when the cable is pulled out of the well.

Braids also provide construction integrity to hold oil resistant tapes in place over the insulation.

In round cables, the presence of a braid assists in the separation of the jacket from the insulation during cable termination or repair.

6.2.3 Limitations: The braid provides a possible path for migration of well fluids under some conditions. Escaping liquids and gases can interfere with splicing soon after the cable is pulled.

Less than full coverage braids may have a tendency to cut the underlying material during decompression.

The braid increases the cable cost. It also increases the overall diameter of the cable.

Nylon is susceptible to degradation when exposed to moisture at temperatures above 212°F.

6.3 BARRIER TAPES

6.3.1 Description: Barrier tapes are commonly applied directly over the insulation to provide an oil and chemical barrier. The tape is used in conjunction with a overlying braid. Barrier tapes are helically wrapped. Each successive wrap of tape is applied to overlap the previous layer by approximately 50%.

The most common barrier tape materials are Polyvinyl Fluoride (PVF) tape and Ethylene Tetrafluoroethylene (ETFE). PVF is very chemically resistant, but it has a temperature limit of 300°F. ETFE is less chemically resistant, but has higher temperature capabilities up to

380°F. However, one may want to consider the cost of ETFE compared to PVF for a particular application.

Tape thicknesses may vary. For a specific material, thicker tape provides better barrier properties.

6.3.2 Applications: The primary purpose of barrier tape is to protect the underlying materials. With polypropylene insulation, low molecular weight oil fractions (light ends) and gases may enter the insulation and soften the material. With EPDM insulation, the material is very prone to oil absorption causing it to swell and rupture. The presence of the barrier tape extends the life of the cable by retarding the ingress of fluids into the underlying materials.

The tape also provides additional hoop strength for the insulation during decompression of entrapped well gases.

6.3.3 Limitations: Barrier tapes add appreciably to the cost of the cable. The tapes are generally used in conjunction with an overlying braid covering. Together, the tape and braid increase the overall dimensions of the cable.

6.4 EXTRUDED BARRIER COVERINGS

6.4.1 Description: Another type of barrier uses an extruded covering in place of the tape and braid construction.

Several materials are currently being extruded as barriers. Thermoplastic polyvinylidene fluoride (PVF₂) and ethylene chlorotetrafluoroethylene (ECTFE) are used for temperatures up to 300°F, and fluorinated ethylene propylene (FEP) is used for temperatures up to 400°F.

6.4.2 Application: The barrier is extruded over or under the insulation to provide chemical resistance, mechanical protection, decompression resistance, and electrical strength. When the barrier layer is extruded over the insulation, there are no gaps or seams as found with the conventional tape and braid design. See Section 4.5.2 for additional information.

6.4.3 Limitations: The thermoplastic covering may be expensive.

Special splicing techniques must be used when repairing or terminating the cable.

6.5 LEAD SHEATH

6.5.1 Description: A lead sheath or jacket is a continuous seamless covering over the insulated conductor.

The composition of the lead varies from one supplier to another. Pure lead is never used. Alloyed lead metals containing copper, or cadmium and tin are utilized to maximize the chemical resistance and mechanical properties of the metallic sheath.

The lead sheath covering is applied onto the cable via an extrusion process.

The geometric shape of the lead covering may be round, square, or eight-sided.

6.5.2 Application: The seamless and continuous lead sheath provides an excellent gas and liquid barrier for the

insulation. In wells with H_2S , lead provides an effective barrier to protect the copper.

6.5.3 Limitations: Lead is a soft metal and can be easily damaged. The lead sheath can crack due to work hardening from bending.

The cables are very heavy and can pose handling difficulties. Special splicing techniques are required when working with these types of cables. The cost of lead sheathed cables is higher than conventional EPDM cables.

After lead-sheathed cable has been pulled three to five times, the sheath has potentially been damaged from handling and bending. The size of sheave and method of handling impact the reuseability. Cable geometries, configurations with struts, and/or specific lead alloys are designed to increase cycle life.

Flat-grooved sheaves should be used when running parallel (flat) cables. Conformal-grooved sheaves should be used for round cables. Minimum sheave size should be 48 inches diameter.

Voltages on the phase conductors induce circulating currents in the lead sheath. On long cables, these currents have the potential to cause corrosion of the lead. An electrical bonding connection between the individual sheaths must be incorporated in the bedding layer to greatly reduce these currents. This bonding connection

must be applied properly to prevent damage to the lead. The bonding connector may be metal or a semiconductive tape or thread.

6.6 BEDDING MATERIALS

6.6.1 Description: Bedding materials are required during the manufacture of lead-sheath cable to protect the lead surface from mechanical damage during armoring.

A typical bedding material is nylon braid. Another material used is EPDM impregnated tape.

6.6.2 Application: The bedding provides some protection for the lead during pulling and running operations. Some bedding materials may fill small holes in the lead extrusion. The bedding material also provides additional hoop strength if gases penetrate the lead.

The electrical bonding connection is contained in the bedding material.

6.6.3 Limitations: EPDM swells when exposed to oil. Nylon decomposes and loses strength in high moisture environments at temperatures over 212°F. Neither of these limitations are critical to the application of the cable as long as the armor is intact.

The cycle life may be shortened if the bedding materials deteriorate. Loss of these materials allow the armor to come in contact with the lead.

SECTION 7 ARMOR

7.1 GENERAL

7.1.1 Description: Armor is the outer covering which provides mechanical protection during installation and removal of cable. The armor also provides mechanical constraint against swelling or expansion of underlying elastomeric materials on exposure to well fluids.

Armor may provide some of the longitudinal support for the weight of the cable between bands.

The armor configuration may be either flat or interlocked steel strips. Some designs use two layers of armor. A special design uses helically applied round wires.

Armor material usually consists of galvanized steel. For some environments, stainless steel or Monel is used.

7.1.2 Application: Armor is used in applications where jacket materials do not provide adequate mechanical protection for the cable.

Flat armor is used where the overall thickness of the cable is restricted.

Interlocked armor is used to minimize the tendency of the armor to unravel. Furthermore, it is less likely to snag during running and pulling.

Helically applied round wires are used where the armor is required to provide most of the longitudinal strength of the cable, such as where there are long distances between bands.

Normal industry practice is to put one band in the middle of a joint of tubing and a second band just above the coupling. These bands are to support the weight of the cable.

7.1.3 Limitations: The integrity of the armor is influenced by the environment in which it operates. Corrosion is one of the major factors that influences the choice of materials.

For very severe applications and where cost can be justified, Monel armor can be used to withstand the most corrosive conditions. Stainless steel armor, though not as effective, is a lower-cost alternative to Monel.

Helically applied flat armor has one edge exposed. Therefore the cable should be installed so that the exposed edge is toward the top of the well. This reduces the risk of snagging the armor during installation.

7.2 GALVANIZED STEEL

7.2.1 Description: Galvanized steel armor is constructed from a low carbon (mild) steel that has been zinc-coated on all sides.

7.2.2 Applications: Most well environments permit the use of galvanized steel armor.

7.2.3 Limitations: Galvanized steel is susceptible to corrosion in the presence of H_2S , CO_2 , strong acids, alkaline environments, as well as brines.

The corrosion problem becomes more intense as temperature rises.

For some cable suspended systems it may be necessary to use either a high strength steel or stainless steel round wire to provide the required longitudinal strength.

Due to the magnetic characteristics of ferrous metals, there will be increased electrical power losses in the cable. This is the result of hysteresis and eddy currents induced in the steel from current in the conductor. The effect is more significant in flat cables with unbalanced phase currents.

7.3 STAINLESS STEEL

7.3.1 Description: Stainless steel is a class of steels containing a significant quantity of chromium, in conjunction with other alloys.

The predominant grades of stainless steel used for cable armor are 316 and 409.

7.3.2 Applications: Stainless steel armors are used in corrosive environments. Although there are limitations, stainless steel may still be selected over more expensive alternatives.

7.3.3 Limitations: Where chloride ions are present, pitting may occur in stainless steels. Stress corrosion cracking of 300 series stainless may occur in these environments at temperatures greater than $160+/-^{\circ}F$.

Neither 316 nor 409 stainless steel is recommended for H_2S applications. CO_2 environments can also affect the 400 series stainless steels. The 400 series is generally useful to pressures of 3000 psi in 10% CO_2 .

7.4 MONEL

7.4.1 Description: Monel is a metal alloy with a content of greater than 60% nickel, less than 4% iron, 2% manganese, and the remainder copper.

7.4.2 Applications: Monel is used in the most severe environments. Some of these include CO_2 , H_2S , and high temperature ($>160+/-^{\circ}F$) brine solutions.

7.4.3 Limitations: Monel may be an expensive armor material.

SECTION 8

SPlicing AND TERMINATING

8.1 GENERAL

8.1.1 Description: Splicing and terminating is the transition from a single cable to another cable or connection. Splicing and terminating must provide electrical, mechanical, and environmental integrity.

8.1.2 Application: Splices are used when individual cable lengths are too short for the application.

Terminations are used when the cable must be connected to other equipment.

8.1.3 Limitations: The diameter of field splices and terminations will be larger than the cable itself.

The voltage stresses tend to be concentrated at the transition areas around the conductor connectors.

8.2 FACTORY REPAIRS

8.2.1 Description: A factory repair is the minor correction to insulation, jacketing, armoring, or lead during manufacturing. It does not involve the conductor.

8.2.2 Application: Factory repairs enable the manufacturer to effectively correct flaws or other imperfections in the cable without compromising the end performance of the cable. The finished, repaired cable should be tested to new cable specifications.

8.2.3 Limitations: Manufactured cables that are repair-free may be preferred to repaired cable.

8.3 FACTORY SINGLE CONDUCTOR LENGTHENING

8.3.1 Description: Single conductor lengthening is the joining of two insulated lengths of single conductors during the manufacturing process.

8.3.2 Application: Occasionally it may be necessary to extend the length of one or more conductors to achieve the desired assembly length. This lengthening is done by butt welding the conductors and re-insulating the section. For stranded cable, each strand must be individually butt welded in a staggered pattern. The finished, lengthened conductor should be tested as would an unlengthened conductor.

8.3.3 Limitations: The customer should be made aware of any lengthening by the manufacturer. Manufactured cables that have not been lengthened may be preferred to those containing joined conductors.

8.4 SPLICES

8.4.1 Description: A splice is the joining of two individual cables. This involves complete cable assemblies, which includes conductors, insulation, sheathing, jacketing, and armor as applicable.

8.4.1.1 Conductor Joining: The most common way of joining conductors uses crimped connectors. An alternate method for solid conductors is butt welding.

8.4.1.2 Insulation and Jacket Replacement: The three fundamental replacement methods are molded, vulcanized, and tape-wrapped.

A molded splice uses thermoplastic material for the insulation. This is accomplished in a heated, injection-molding press.

A vulcanized splice uses curable, thermosetting tapes for the insulation and/or the jacket. The process is completed in a heated mold.

A tape-wrapped splice may use thermoplastic, cured, uncured, or low-temperature curable tapes for the insulation and/or the jacket. No additional processing is required.

8.4.1.3 Metallic Coverings: For lead-sheathed cable, a sheet of lead is wrapped around the insulation and overlaps the existing lead sheathing. The sheet is either soldered or taped in place. However, gas will migrate through taped joints.

Replacement armor is helically applied over the entire splice. The ends are then soldered to the existing armor.

8.4.2 Application: A cable splice may be used to lengthen the cable string, to repair failed or damaged cable, to join the motor flat cable to the main cable, to join the main cable to the pigtail, or to make a transition between cable types or sizes.

The connection of the conductors provides electrical continuity.

Insulating material is applied over the connection to provide voltage isolation. Additional materials are added to protect the electrical insulating material from well conditions. The integrity of the insulating material will impact the transfer of gases through the cable.

The metal coverings over the cable provide mechanical and environmental integrity.

8.4.3 Limitations: The properly trained cable splicer must deal with many variables which can effect the quality of work being performed. The quality of the splice is influenced by weather conditions, the conditions of the available work area, pressure to finish the job quickly, and skill level of the splicer.

Molded and vulcanized splices generally provide better integrity. However, they do require more time to make than taped slices.

Whenever possible, splices should be kept above the operating fluid level.

Splice-free cables are preferred to those containing splices. Reuse of cables with splices and the number of splices in the string increases the probability of cable failure.

8.5 TERMINATIONS

8.5.1 Description: Power cables are terminated at each end using either connectors or penetrators.

8.5.2 Application: Terminations are located at most wellheads, at the submersible motor, and at some downhole packers. Wellhead and packer terminations which use a short piece of cable are referred to as "pigtailed".

Motor terminations are referred to as "potheads". A pothead is usually supplied as part of a motor lead assembly which is spliced to the main power cable. Where the space between the motor and casing permits, the pothead may be installed directly on the power cable.

Wellhead and packer terminations can be of several types. One common type is a molded termination supplied with

a length of cable which is spliced onto the main power cable. Another type is an attachable termination which is installed directly on the power cable.

A common wellhead penetration is a straight feed-through of the power cable with appropriate sealing. This is not considered a termination. These penetrations are limited to wellhead pressures less than 300 psig. The armor is removed to make this penetration. In some wells where the lack of armor allows swelling of the jacket and insulation because of exposure to gases, or where higher wellhead pressures may be encountered, penetrator assemblies are used.

8.5.3 Limitations: Available space in the wellhead dictates the size and type of termination. The wellhead manufacturer's recommendations should be followed.

Termination materials must be compatible with the main cable for conductor size and metallurgy, temperature rating, and insulation types to ensure the longest possible life. The materials must also be compatible with the well fluids and conditions.

Wells containing H_2S or CO_2 require the same special considerations in the selection of termination materials as previously noted for cable components. The more terminations there are, the greater the chances of a failure.

8.6 LEGEND AND LIST OF FIGURES

8.6.1 Scope: The following diagrams provide a representation of typical cable splices and terminations. These are not intended to limit or restrict alternative configurations.

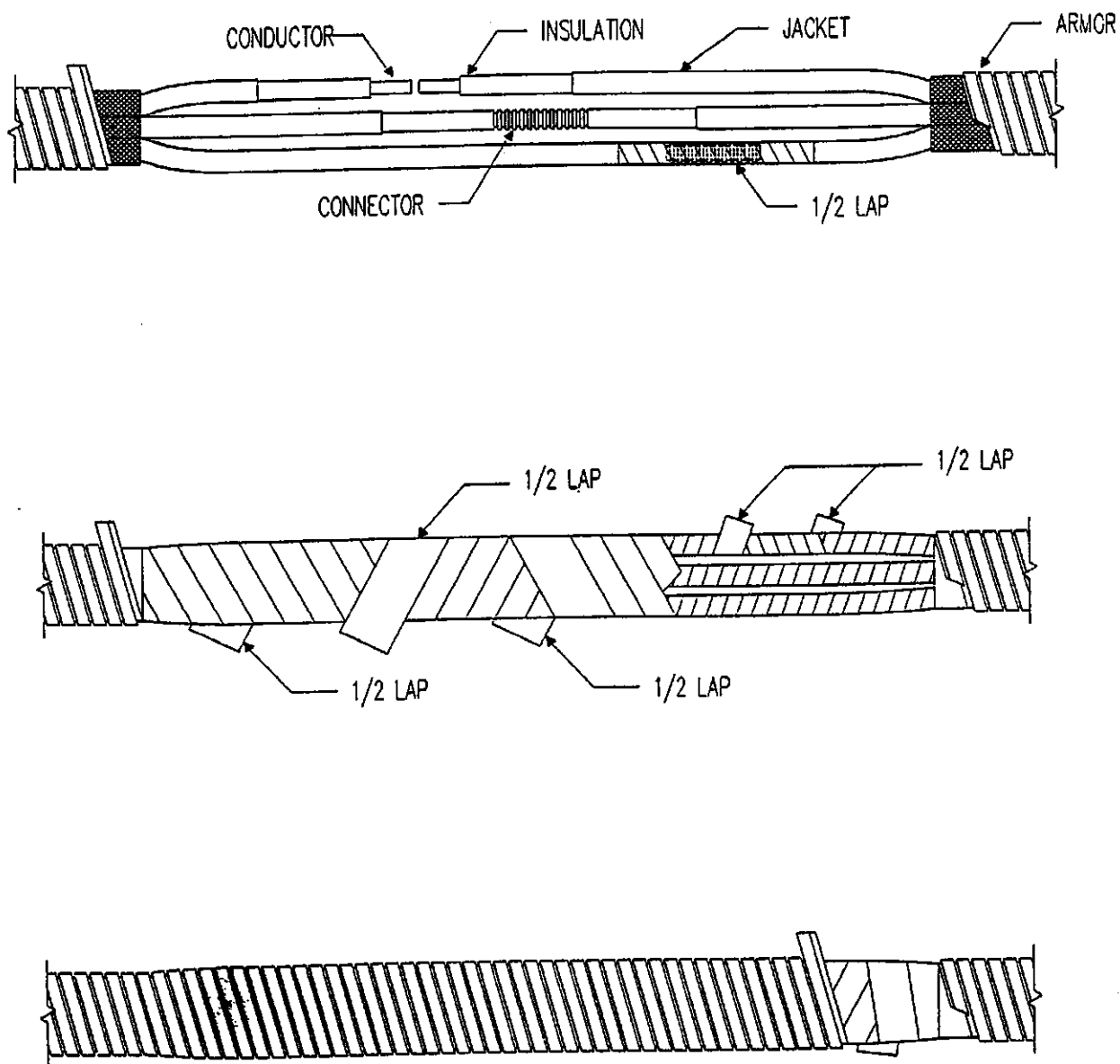
8.6.2 Splices and Terminations Components Legend

Item	Description
A	Conductor
B	Crimp Sleeve
C	Insulation
D	Jacket
E	Molded Elastomer
F	Insulating Tapes
G	Bedding Tapes
H	Spacer
I	Grommet Seals
J	Packing Gland
K	Compression Nut
L	Contact Pin
M	Contact Socket
N	Potting
O	Housing
P	Coupling Nut
Q	Armor

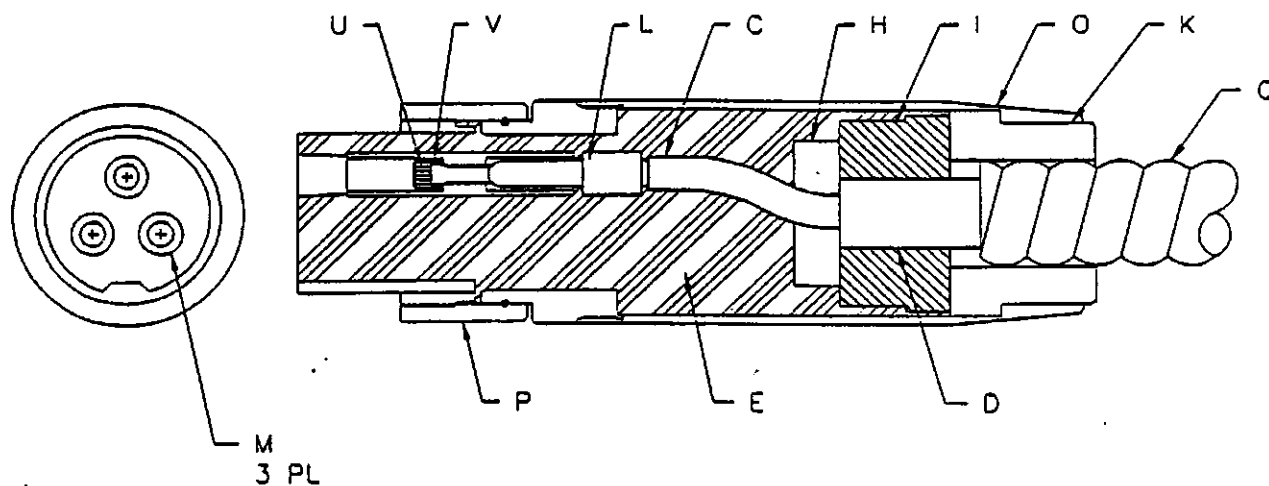
8.6.3 List of Figures

Figure	Title
8.7.1	Typical Taped Splice
8.7.2	Typical Field Attachable Connector
8.7.3	Typical Wellhead/Packer Connector
8.7.4	Typical Pothead

8.7 Figures

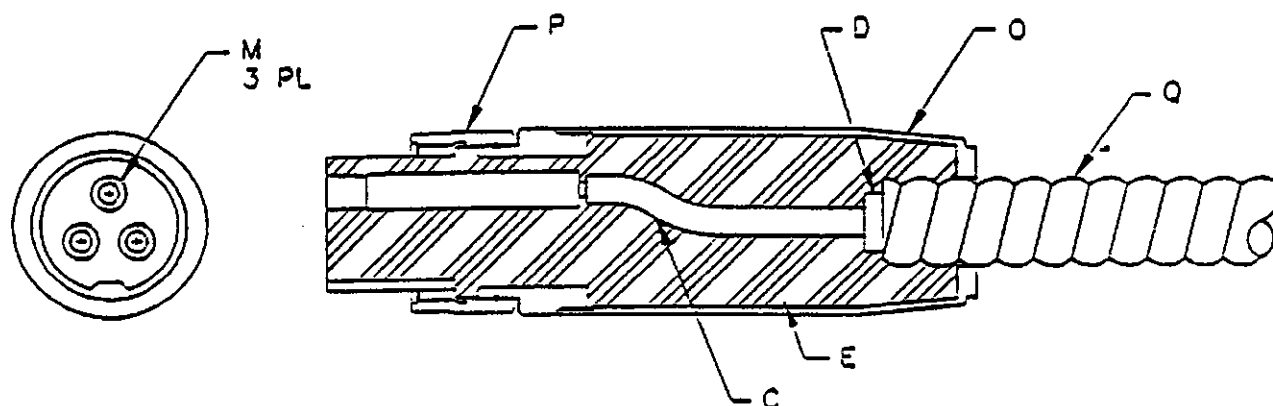


**FIGURE 8.7.1
TYPICAL TAPED SPLICE**



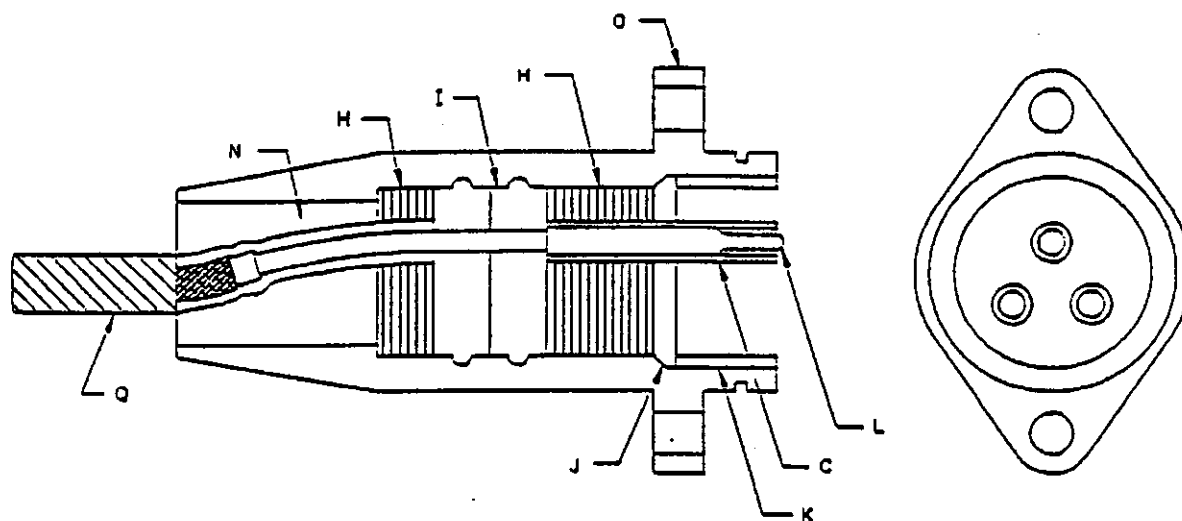
LEGEND	
ITEM	DESCRIPTION
C	INSULATION
D	JACKET
E	MOLDED ELASTOMER
H	SPACER
I	GROMMET SEAL
K	COMPRESSION NUT
L	CONTACT PIN
M	CONTACT SOCKET
O	HOUSING
P	COUPLING NUT
Q	ARMOR
U	SEALING SCREW
V	O-RING SEAL

FIGURE 8.7.2
TYPICAL FIELD ATTACHABLE CONNECTOR



LEGEND	
ITEM	DESCRIPTION
C	INSULATION
D	JACKET
E	WELDED FLUTTER
M	CONTACT SOCKET
O	HOUSING
P	COUPLING NUT
Q	ARMOR

FIGURE 8.7.3
TYPICAL WELLHEAD/PACKER CONNECTOR



LEGEND	
ITEM	DESCRIPTION
C	INSULATION
H	SPACER
I	CONTACT SEAL
J	PACKING SLIP
K	COUPLING NUT
L	CONTACT NUT
M	CONTACT
O	HOUSING
Q	ARMOR

FIGURE 8.7.4
TYPICAL POTHEAD

APPENDIX A POWER COST CONSIDERATIONS

A.1 Introduction: Once the horsepower requirements for an ESP have been determined, several items must be considered to achieve minimum overall costs from the cable system. These considerations are size of cable, voltage requirements and current requirements.

A.2 Voltage/Current: The power used by an electrical submersible motor is related to the motor current through the cable and to the motor voltage. Since the required power remains relatively constant, higher system voltages will result in lower motor current. Power losses in the cable are equal to the product of cable resistance, number of conductors, and current squared. Higher voltage, lower current motors reduce power losses for a fixed conductor size.

The National Electric Code suggests that a maximum cable voltage drop of 5% of motor nameplate voltage will provide reasonable efficiency.

A.3 Conductor Size: Although numerous conductor sizes have been used, the industry has essentially standardized on No. 4 AWG, No. 2 AWG, and No. 1 AWG for the main feeder to the electrical submersible motor. No. 6 AWG wire is available, but is not recommended because of electrical and mechanical limitations. Conductors larger than No. 1 AWG are also available.

Provided there is adequate clearance in the well bore, the selection of the electrical conductor size is based on the amount of current the conductor must carry.

An economic comparison should be made between the cable conductor size and cost of the cable power losses.

The economic analysis should evaluate whether lower power costs over the life of the cable will offset the higher initial purchase price of a cable with larger conductors.

A.4 Analysis Method: The basic equation for calculating current when sizing a cable is given below. Additional information will be required from other sources to provide a complete analysis.

$$I = \left(\frac{k * CD}{RD * PC * Ph * ECL} \right)^{1/2}$$

where,

I = The load current value above which the larger conductor size can be justified. [amperes]

k = constant = 0.114
= 1000 [Wh/kWh] / 24 [hr/day] / 365 [days/year]

CD = Cost difference between two cables using different conductor sizes. [\$/1000 ft]

RD = Difference in resistance between two conductor sizes at the well's bottom hole temperature. [ohms/1000 ft]

PC = Electrical power cost. [\$/kWh]

Ph = Number of Phases = 3.

ECL = Estimated cable life. [years]
(The number of years required for an investment payout could be used here in lieu of cable life.)

APPENDIX B CABLE TYPES GUIDE

B.1 Introduction: This Appendix correlates the various components of a cable with the operating conditions. The guide is grouped by sections corresponding to the cable construction. References are given to other documents for additional information that is not identified in this RP.

Temperature Rating (Section 2)

Temperature Designation
Material That Determines Rating
Conductor Temperature (deg F)

L	M	H	S
Polypropylene	Nitrile	EPDM	Lead*
205	284	350	400

* - Lead sheath over elastomer
or other special construction

Conductor (Section 3)

Temperature Designation
Material
Coating
Metal Properties
Specifications of Dimensions
Type
Sizes (AWG)

L	M	H	S
Copper	Copper	Copper	Copper
Tinned	Untinned / Tinned		
NEMA WC - Code			
NEMA WC - Code			
Solid, Stranded, Compacted			
6, 4, 2, 1			

Insulation (Section 4)

Temperature Designation
Material
Tests
Properties
Dimensions
Films
Over Conductor Films

L	M	H	S
Polypropylene	EPDM	EPDM	EPDM
IEEE 1019	IEEE 1018	-	-
IEEE 1019	IEEE 1018	-	-
IEEE 1019	IEEE 1018	-	-
-	Kynar	Teflon	-
-	Kapton	Kapton	Kapton

Jacket (Section 5)

Temperature Designation
Material
Tests
Properties
Dimensions

L	M	H	S
Nitrile	Nitrile	EPDM	EPDM
IEEE 1019	IEEE 1018	-	-
IEEE 1019	IEEE 1018	-	-
IEEE 1019	IEEE 1018	-	-

Braids & Coverings (Section 6)

Temperature Designation
Braids
Alternative Braid
Sheath
Tapes
Bedding

L	M	H	S
Nylon	Nylon	Tefzel	-
-	Kynar	-	-
-	-	-	Lead
Tedlar	Tedlar	Tedlar	Tedlar
-	-	-	Nylon / EPDM

Note - Braids and coverings are optional and subject to wide variations among manufacturers. These are the most widely used types.

Armor (Section 7)

Temperature Designation
Standard
Special Construction
Corrosion Resistant
High Corrosion Resistance
Dimensions

L	M	H	S
Galvanized	Galvanized	Galvanized	Galvanized
-	-	Double Galv.	Double Galv.
Stainless	Stainless	Stainless	Stainless
Monel	Monel	Monel	Monel
IEEE 1019	IEEE 1018	-	-

API RP*11S5 93 ■ 0732290 0506217 072 ■

Order No. 811-05944

Additional copies available from
AMERICAN PETROLEUM INSTITUTE
Publications and Distribution Section
1220 L Street, NW
Washington, DC 20005
(202) 682-8375

