

# Evaluation Standard for Internal Pressure Sheath Polymers for High Temperature Flexible Pipes

API TECHNICAL REPORT 17TR1  
FIRST EDITION, MARCH 2003



**Helping You  
Get The Job  
Done Right.<sup>SM</sup>**



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Upstream Segment

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## FOREWORD

This technical report is under the jurisdiction of the API Subcommittee on Subsea Production Systems. This document has been produced as part of a joint industry project “Evaluation of Polymers for High Temperature Flexible Pipes”.

This JIP involved a materials test programme, and finite element analyses of both global and local flexible pipe cross sections. Prototype testing of a high temperature flexible pipe was not performed under this JIP; consequently, the material properties discussed in this document are those which the steering committee considered are/will be important and relevant to the application. The JIP has been technically and financially supported by an international consortium of oil companies, flexible pipe manufacturers, polymer manufacturers, regulatory authorities and contractors.

A methodology is described for the development of a test plan for the evaluation of a polymer for high temperature service. Also defined are a set of evaluation criteria by which a material must be assessed for qualification. The standard does not seek to rigidly define acceptance and rejection criteria. These should be specified by the user, giving consideration to a particular flexible pipe application. This standard aims to give the user guidance on the selection of these criteria.

The evaluation methodology recommends performing a set of preliminary evaluation tests on polymers in situations where little or no information is available to indicate their likely performance. This is a low cost approach to which allows key materials properties to be screened. A *preliminary evaluation* is not required where there is sufficient confidence in, and information about, a materials suitability to proceed directly to a more comprehensive testing programme. In this instance, or where a material has passed the preliminary evaluation programme, a *full evaluation* programme is undertaken. This involves longer term more extensive testing to identify performance characteristics of the material. The full evaluation stage is compulsory for the qualification of materials for service according to this document.

Material properties which are relevant to the evaluation of polymers for high temperature flexible pipe service application are described. A test procedure is presented for each of these properties, making reference to existing standards where applicable. A protocol covering test procedural matters relating to the overall evaluation test programme is also provided.

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# 1 SCOPE

## 1.1 GENERAL

**1.1.1** This technical report defines the methodology and test procedures necessary for the evaluation of polymeric materials suitable for use as the internal pressure sheath of an unbonded flexible pipes in high temperature applications. It describes the processes by which the critical material properties, both static and dynamic, can be measured and evaluated against relevant performance criteria.

**1.1.2** This document relates primarily to the properties necessary for an internal pressure sheath required for oil and gas production. These are most relevant to high temperature applications. Only thermoplastic materials are considered for the internal pressure sheath. Elastomeric materials, which are used in bonded flexible pipes, are not considered in this document.

**1.1.3** This document has the following format:

Section 1 **Scope**

Section 2 **Referenced Documents**

Section 3 **Definitions and Acronyms**

Section 4 **Service Application**—Background to selection of material tests used in the evaluation programme

Section 5 **Evaluation Overview**—The overall methodology employed in the evaluation of a candidate material

Section 6 **Evaluation Test Programme**—Presents, in detail, each of the material tests which form the material evaluation test programme

Section 7 **Material Evaluation**—Presents the criteria against which material test results should be compared and gives guidance on the interpretation of results.

Section 8 **Bibliography**

**1.1.4** The following two applications of the Evaluation Standard are considered:

- the evaluation of a candidate polymer for HT flexible pipe service,
- the evaluation of a candidate polymer to determine its generic performance envelope/limits.

## 1.2 SIGNIFICANCE

**1.2.1** This Evaluation Standard provides a procedure for determining whether candidate polymeric materials have the property levels necessary for successful use as the internal pressure sheath of an unbonded flexible pipe in high temperature high pressure applications.

**1.2.2** For the purposes of this document, high temperatures are defined as those between 130 and 200°C. High pressure is considered to be at least 34.5 MPa (5000 psi).

**1.2.3** This Evaluation Standard also provides a means for comparing the performance attributes of several potential pressure sheath materials for high temperature applications.

## 1.3 CURRENT STANDARDS

**1.3.1** The current standards which relate to the evaluation of polymers for internal pressure sheath applications are:

- [API Specification 17J](#), “Specification for Unbonded Flexible Pipe,” First Edition [1],
- [API Recommended Practice 17B](#) “Recommended Practice for Flexible Pipe,” Second Edition [2].

**1.3.2** These documents address all aspects of unbonded flexible pipe technology relevant to current levels of high temperature service; that is, to 130°C.

## 1.4 UNITS

Système International (SI) units are used in this evaluation standard. Imperial units may be given in brackets after the SI units.

## 1.5 SAFETY

The procedures described in this evaluation standard include materials tests requiring the use of high temperature and high pressure conditions, often with hostile chemicals. It is the responsibility of individuals or organisations using the standard to ensure that all appropriate safety procedures are implemented to prevent injuries to personnel and/or damage to equipment or facilities.

# 2. REFERENCED STANDARDS

[API Spec 17J](#) Specification for Unbonded Flexible Pipe

[API RP 17B](#) Recommended Practice for Flexible Pipe

[ASTM D256](#) Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials

[ASTM D638](#) Test Method for Tensile Properties of Plastics

[ASTM D2990](#) Test Methods for Tensile, Compressive, and Flexural Creep and Creep Rupture of Plastics

[ASTM E831](#) Test Method for Linear Thermal Expansion of Solid Materials by Thermo-mechanical Analysis

ESIS draft protocol “A Testing Protocol for Conducting J-Crack Growth Resistance Curve Tests on Plastics,” Hale, G., May 1994.

## 3 DEFINITIONS AND ABBREVIATIONS

### 3.1 DEFINITIONS

For the purposes of this standard, the following definitions apply:

**3.1.1 Flexible Pipe:** An assembly of a pipe body and end fittings. The pipe body comprises a composite of layered materials (polymeric and metallic) that form a pressure containing conduit. The pipe structure allows large deflections without a significant increase in bending stresses. The term “pipe” is used in this document as a generic term for unbonded flexible pipe.

**3.1.2 Conventional Flexible Pipe:** An unbonded flexible pipe which is suitable for internal fluid temperatures of up to 130°C.

**3.1.3 High Temperature Flexible Pipe:** An unbonded flexible pipe which is suitable for internal fluid temperatures of between 130 and 200°C.

**3.1.4 Internal Pressure Sheath:** The innermost contiguous polymeric layer of an unbonded flexible pipe, designed to contain transported fluids and ensure pipe integrity.

**3.1.5 Candidate Polymer:** A polymeric material which is proposed for use as the internal pressure sheath of an unbonded flexible pipe and is being submitted for evaluation testing.

**3.1.6 End Fitting:** A mechanical device which forms the transition between the flexible pipe body and the connector. The different pipe layers are terminated in the end fitting in such a way as to transfer the load between the flexible pipe and the connector.

**3.1.7 Test Temperature, Test Pressure:** The temperature (T) and pressure (P) at which a test is to be run for the purposes of evaluating a candidate polymer. The choice of test temperature/pressure will depend only on the performance requirements for the proposed application.

**3.1.8 Test Result:** The outcome of a materials test. This may be in the form of a physical quantity (e.g., Young’s modulus) or a subjective rating (e.g., blister damage).

**3.1.9 Maximum Property Temperature (MPT):** The maximum temperature for which a specified property meets the performance criterion; for example, if a candidate polymer swells 50% in oil at 165°C, but only 1% at 160°C, its MPT (for compatibility with the oil) is 160°C, assuming that 1% volume swell has been defined as acceptable for the application. See Figure 1.

**3.1.10 Maximum Service Temperature (MST):** The maximum temperature for which all measured

properties meet the specified performance criteria. In practice, there is little point in testing above the rapid gas decompression (RGD) MPT (other than when conducting accelerated ageing based on another property). If the MPT value of another property is lower then it will give the MST. For example, if a candidate polymer has the following MPTs – RGD (190°C), tensile (>190°C), crack growth fatigue (165°C), liquid compatibility in three different fluids (180°C, >190 °C, 170°C) – then the MST for the material is defined by the lowest MPT, that is, 165°C. See Figure 2. It is implicit that MST is significantly below candidate polymer melting point.

**3.1.11 Maximum Pipe Service Temperature (MPST):** The maximum temperature for which all measured properties meet performance criteria specific to a particular flexible pipe design. For example, the analysis of a particular design might indicate that the allowable strain in a material with a MST of 180°C is exceeded under certain bending conditions at 175°C but not at 170°C—hence MPST must be set to 170°C. Note that the determination of MPST is beyond the scope of this evaluation standard; it is included here for completeness. See Figure 1.

**3.1.12 Evaluation Criterion:** A predetermined criterion against which test results are compared in order to facilitate the evaluation of a candidate polymer.

**3.1.13 Performance Criterion:** A performance criterion specifies an acceptable range or limit for a measurable material property, within which a candidate polymer must lie if it is to have any chance of functioning successfully in the high temperature flexible pipe application.

**3.1.14 Extrusion:** For flexible pipe application, extrusion is the preferred term to describe the deformation (“flow”) of the pressure sheath into armour gaps as a result of applied pressure. Extrusion (of a semi-crystalline polymer) has three components: *elastic extrusion*, the instantaneous response to the applied stress, *plastic extrusion* (irrecoverable deformation of the polymer) and time-dependent *creep extrusion*. For completeness, the definition of creep is also provided. *NB Internal pressure sheaths are normally produced by a manufacturing process also termed extrusion, involving polymer melt flow. This is only referred to herein by the term “extruded pipe” or the like.*

**3.1.1.5 Creep:** The increase in strain of a viscoelastic material as the result of a constant applied stress. The response of an amorphous polymeric material to the stress commences with an instantaneous elongation, followed by creep (rapid at first, then slowing to a constant rate). The viscoelastic term creep has both elastic and viscous components. When the stress is removed, the creep deformation is not completely reversible; the non-recoverable portion being due to viscous flow.

## 3.2 ABBREVIATIONS

The following acronyms are used in this document:

**API:** American Petroleum Institute  
**ASTM:** American Society for Testing and Materials  
**ESIS:** European Structural Integrity Society  
**HP:** High Pressure [34.5 MPa (5000 psi) for development work]  
**HT:** High Temperature

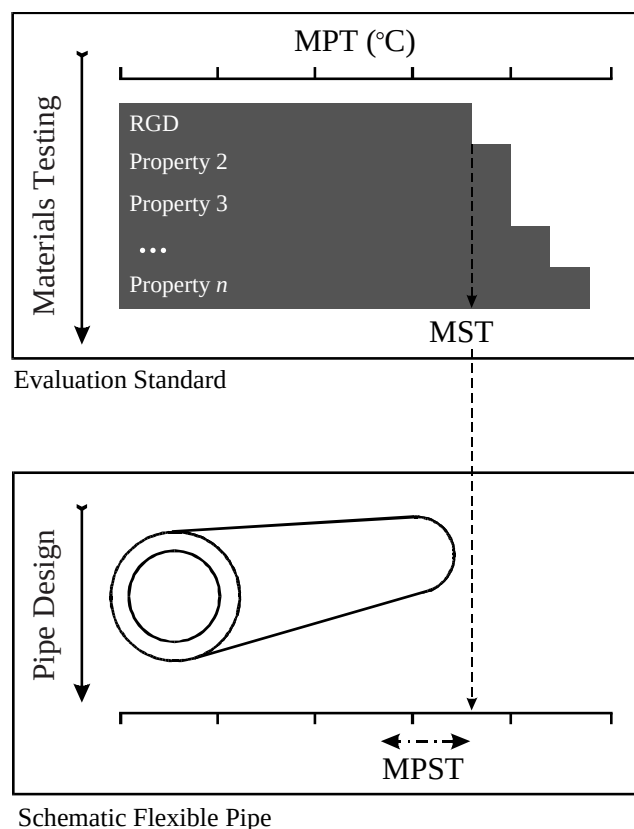


**Figure 1—Relationship between MPT, MST, and MPST**

## 4 SERVICE APPLICATION

### 4.1 OVERVIEW

This section relates potential failure modes of an internal pressure sheath for high temperature service to their underlying failure drivers and critical material properties. These properties form the basis of the material evaluation test programme as defined in Section 6.

## 4.2 POTENTIAL FAILURE MODES AND RELATED MATERIAL PROPERTIES

**4.2.1** Table 1 lists potential failure modes of an internal pressure sheath relevant to high temperature service. Each mode, and associated failure mechanism, has a number of failure drivers which relate to key material properties.

**4.2.2** Table 2 presents a list of the service conditions that are critical to the definition of the material tests carried out in the material evaluation test programme. These conditions provide the basis for test parameters such as temperature, pressure, etc. Annexe A presents a more detailed review of these service conditions, including analytical considerations and typical values.

**Table 2 Critical Service Conditions**

| Mechanical Load Limits | Physical/Chemical Conditions  |
|------------------------|-------------------------------|
| Static Bending         | Maximum Internal Temperature  |
| Dynamic Bending        | Minimum Internal Temperature  |
| End-fitting Crimping   | Temperature Cycling           |
| Internal Pressure      | Transported Fluid Composition |
| Decompression Cycling  |                               |

**4.2.3** The materials tests which comprise the evaluation programme are defined such that they will measure each of the material properties identified in Table 1; these are summarised in Table 3 and are applicable across the service temperature range.

**Table 3 Critical Material Properties**

| Polymer Material Property                               |
|---------------------------------------------------------|
| RGD resistance                                          |
| Stress-strain curve                                     |
| Extrusion/creep characteristics                         |
| Stress relaxation rate                                  |
| Fracture toughness                                      |
| Crack growth resistance                                 |
| Coefficients of permeation, diffusion, solubility at HP |
| Liquid compatibility                                    |
| Coefficient of Thermal Expansion*                       |

Note: These properties relate to those properties measured during the material evaluation test programme, ref. Table 4, except \*.

**4.2.4** The failure modes listed are based on current technology and experience of conventional flexible pipes which has been expanded to encompass high temperature applications.

**Table 1—High Temperature Pressure Sheath—Potential Failure Modes<sup>1</sup>**

| Cause of Failure                  | Potential Failure Mechanisms                                                                                                                                                                            | Failure Drivers and Critical Levels                                                                                                                                                                                                     |                                                                                                           | Related Material Properties Relevant to this standard                                                                             | Comments                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                   |                                                                                                                                                                                                         | Drivers <sup>2</sup>                                                                                                                                                                                                                    | Critical level                                                                                            |                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                              |
| Extrusion                         | Local stiffening of pipe where armour grooves fill. Local thinning of sheath leading to possible crack/hole in sheath <sup>3</sup> .                                                                    | Temperature<br>Pressure<br>Sheath wall thickness<br>Sheath mechanical props<br>Local armour geometry<br>Liquid absorption<br>Pipe curvature<br>Chemical attack                                                                          | High<br>High<br>Low<br>Low<br>Large g/r <sup>4</sup><br>High<br>Large<br>High                             | Extrusion/creep resistance,<br>Stress-strain relation,<br>Fracture toughness,<br>Crack growth resistance,<br>Liquid compatibility | In dynamic situations, high local stresses may cause crack initiation. Depending on the stress direction, the crack may propagate radially, causing sheath failure, or across the base of an extruded rib, causing it to break off. Sheath materials which resist stiffening (via chemical means) will extrude more than those which do not. |
| Wear/abrasion                     | Local thinning of sheath leading to crack/hole in sheath <sup>3</sup> .<br>Local reduction in bending stiffness of pipe.                                                                                | Fatigue<br>Pipe layer motions<br>Temperature<br>Sheath wall thickness<br>Sheath mechanical props<br>Liquid absorption<br>Chemical attack                                                                                                | Low<br>High slip<br>High<br>Low<br>Low<br>High<br>High                                                    | Fracture toughness,<br>Crack growth resistance,<br>Liquid compatibility                                                           | Mainly the result of dynamic service; complete abrasion of sheath extremely unlikely, hence not a common concern with the internal pressure sheath layer.                                                                                                                                                                                    |
| Chemical ageing                   | Stiffening/cracking, especially of inner sheath wall, leading to sheath leakage <sup>3</sup> .<br>Embrittlement may increase pipe bend stiffness.<br>Possible eventual molecular weight loss (extreme). | Chemical attack<br>Liquid absorption<br>Temperature<br>Pressure (for gases)<br>Sheath wall thickness<br>Sheath morphology<br>Pipe curvature<br>Fatigue                                                                                  | High<br>High<br>High<br>High<br>Low<br>Low crystal.<br>Large<br>Low                                       | Fracture toughness,<br>Crack growth resistance,<br>Liquid compatibility,<br>HP permeation,                                        | Ageing tends to embrittle sheath polymers, making dynamic service likely to promote localised sheath surface fracturing. Pressure is relevant only if the gas chemically attacks the sheath polymer. High molecular weight/crystallinity helps resist attack.                                                                                |
| Rapid gas decompression (RGD)     | Blistering, splitting, cracking, micro-fracturing; Volume increase likely, unless sheath polymer is plasticized.                                                                                        | Temperature<br>Pressure<br>Decompression rate<br>Sheath wall thickness<br>Gas concentration<br>Gas concentration profile<br>Diffusion coefficient<br>Sheath constraint<br>Sheath mechanical props<br>Local armour geometry<br>Extrusion | High<br>High<br>High<br>High<br>High<br>Saturated<br>Low<br>None<br>Low<br>Large g/r <sup>4</sup><br>High | RGD resistance,<br>Modulus,<br>Fracture toughness,<br>Diffusion coefficient,<br>Gas concentration,<br>Extrusion/creep resistance  | The amount of dissolved gas in the sheath is important; for some candidate sheath materials extruded ribs are more susceptible to RGD damage than bulk polymer, hence the desirability of a low extrusion/creep rate; adequate mechanical properties essential. Some types of bulk damage may be acceptable for service.                     |
| Dimensional change                | Shrinkage, loss of sealing at end-fitting leading to pull-out of sheath and subsequent leakage into the annulus <sup>3</sup> .                                                                          | Temperature<br>Liquid absorption<br>Sheath constraint<br>Extrusion                                                                                                                                                                      | Large change<br>High<br>Low<br>High                                                                       | Thermal expansion coefficient,<br>Dimensional stability<br>Extrusion/creep resistance<br>Liquid compatibility                     | Could have change for thermal reasons; shrinkage due to leaching (e.g. of plasticizer); swelling due to liquid uptake; processing stresses often exist in extruded pipes; extrusion in service will alter sheath shape.                                                                                                                      |
| Permeation (of hostile chemicals) | If permeant is chemically hostile to the sheath polymer, degradation will result.<br>Gas pressure build-up in annulus unless vented.<br>Tensile armour corrosion with some gases.                       | Temperature<br>Pressure (for gases)<br>Sheath wall thickness<br>Permeation coefficient<br>Local armour geometry<br>Chemical attack<br>Sheath constraint<br>Extrusion                                                                    | High<br>High<br>Low<br>High<br>Large g/r <sup>4</sup><br>High<br>Low<br>High                              | Permeation coefficient,<br>Liquid compatibility,<br>Extrusion/creep resistance                                                    | Certain chemical species may not degrade the sheath but attack the surrounding metal layers once they have permeated the sheath polymer; in extreme cases, gas build-up could cause cover damage.                                                                                                                                            |
| Stress relaxation                 | Loss of sealing force at end fitting leading to pull-out of sheath and subsequent leakage into the annulus <sup>3</sup> .                                                                               | Stress relaxation rate<br>Extrusion<br>Temperature<br>Dimensional stability<br>Liquid absorption<br>Chemical attack<br>End fitting design                                                                                               | High<br>Low<br>High<br>Low<br>High<br>High<br>Poor                                                        | Stress relaxation,<br>Liquid compatibility,<br>Extrusion/creep resistance,<br>Dimensional stability                               | Swelling and/or chemical ageing may affect stress relaxation rate. Liquids may not have access to end-fitting region due to the metal flange. Stress relaxation can affect main pipe body during storage/service.                                                                                                                            |

Notes: 1. These potential failure modes are based on the assumption of existing flexible pipe cross-section configurations.

2. Not every failure driver on its own is sufficient to bring about particular types of sheath failure; in other words, drivers can interact. For instance, high temperature alone is insufficient to allow permeation of a hostile gas through the sheath. However, when high temperature

is combined with high gas pressure, a thin sheath wall, a high permeation coefficient, low chemical resistance (i.e., the gas does not interact chemically with the sheath polymer, but may be hostile to the armour layers), small armour gaps (i.e., the sheath does not deform and present, locally, an increased travel path for the gas) and a low level of constraint (meaning the gas can permeate widely into the annulus), then the conditions for permeation of hostile gas through the sheath have been "optimised".

3. Once the internal pressure sheath of a flexible pipe has ruptured, a flexible pipe is considered to be at the end of its life.

4. g/r is the pressure armour gap-to-fillet radius ratio.

## 5 EVALUATION METHODOLOGY

### 5.1 GENERAL

This section describes the methodology employed for the evaluation of polymeric materials for high temperature flexible pipe applications. This methodology involves the evaluation of a *candidate polymer material* against a set of *performance criteria*, which are identified from application-specific service conditions.

### 5.2 APPROACH

An overview of the evaluation methodology is presented in Figure 2.

#### 5.2.1 Candidate Materials

A *candidate polymer* is initially identified as being suitable for use as an internal pressure sheath on the basis of available property information. The relevant material characteristics have been categorised in [API Spec 17J](#) [1] as follows:

- c. Mechanical
- d. Physical/thermal
- e. HP permeation characteristics
- f. Compatibility and ageing

The cost, availability and processability of candidate polymers are also relevant in determining their suitability for flexible pipe service.

#### 5.2.2 Service Application

**5.2.2.1** The *service application* for the pipe will be characterised by the internal temperature and pressure, transported fluids and the mechanical loading environment.

**5.2.2.2** The service application can consist of:

- a) the service loads specific to a particular pipe application, or
- b) a set of envelopes which may relate to predicted service conditions.

**5.2.2.3** The parameters that will be used during the evaluation test programme will be defined from the service conditions that the pipe is expected to experience

during its service life. Where no specific application has been identified, a generic service application for the flexible pipe may be developed based on a global design base case or field experience and projected service conditions.

#### 5.2.3 Performance Criteria

**5.2.3.1** In order to assess the performance of a candidate polymer in relation to the required service application, it is necessary to identify a set of performance requirements or *performance criteria* which should define the material properties required of the candidate polymer. Performance criteria are defined in Section 7 of this document.

#### 5.2.4 Evaluation Test Programme

**5.2.4.1** Depending on the quality of available validated test data, and the service application under consideration, a decision has to be made as to whether a low cost *preliminary evaluation test programme* is required as a precursor to the *full evaluation test programme*. The full evaluation programme will typically involve more extensive longer-term testing. Further guidance on preliminary and full evaluation test programmes is presented in Section 6.

**5.2.4.2** With agreement between relevant parties, the information used for preliminary evaluation of a candidate polymer does not have to originate from test methods described in this standard. However, such data may not be used as a substitute for validated test data in the full evaluation test programme.

#### 5.2.5 Material Evaluation

The final step in the evaluation process is the comparison of test results with the performance criteria. This will indicate whether the candidate material is suitable for the proposed pipe application. Even if the material fails at this stage it is not automatically precluded from future pipe service: design modifications to the pipe cross-section and/or a reduced qualification envelope are situations which may justify its future consideration. The material evaluation process is described in more detail in Section 7.

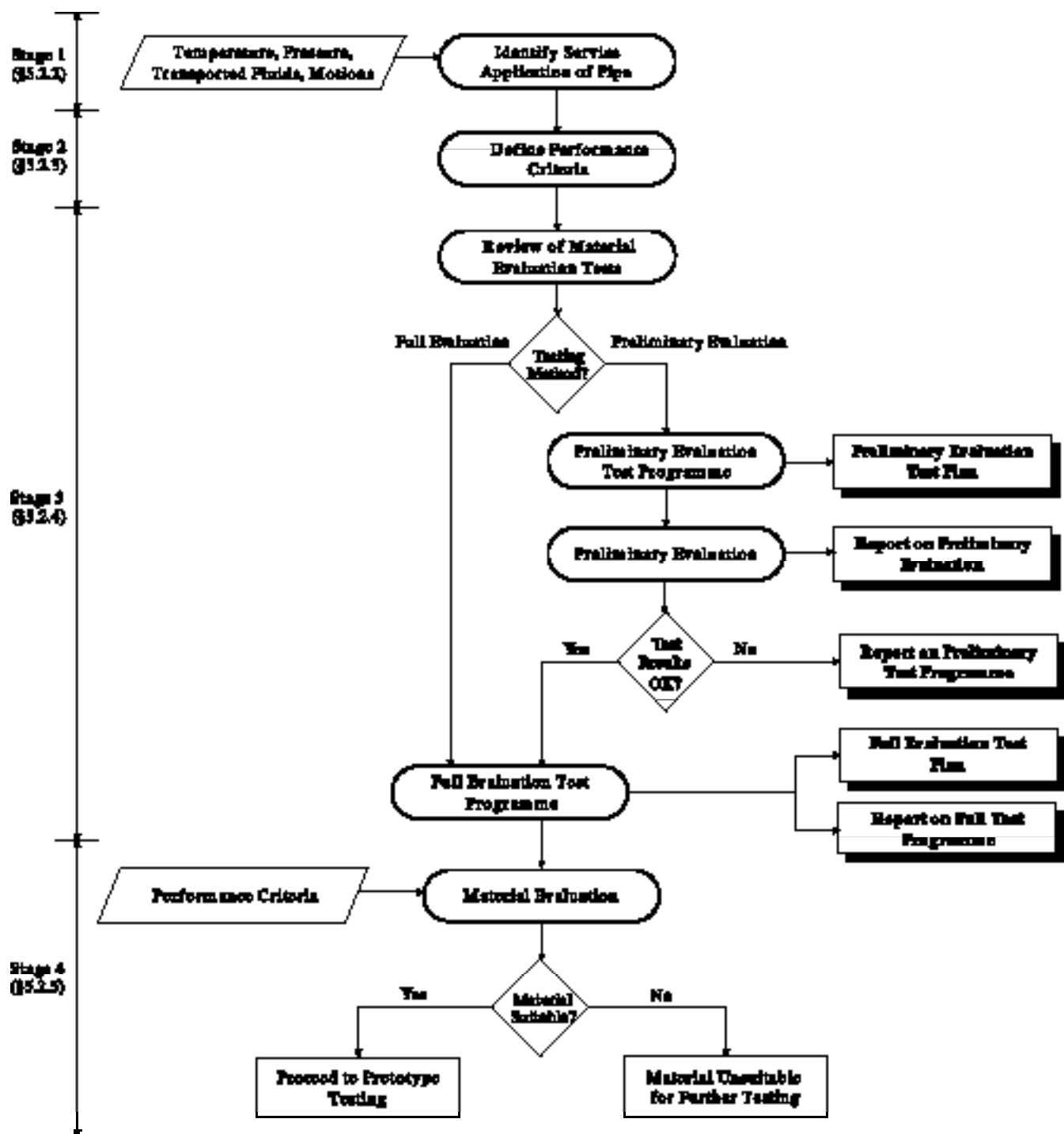


Figure 2—Overall Material Evaluation Methodology.

## 6 EVALUATION TEST PROGRAMMES

### 6.1 OVERVIEW

The evaluation of a candidate polymer may be performed on two levels; *preliminary evaluation* and *full evaluation*. Annexe B contains the general test protocols for the evaluation test programme. Mechanical, time-dependent and physico-chemical test methods which are applicable to this standard are fully described in Annexes C and D; standard test procedures are referred to where relevant.

### 6.2 TEST METHODS

**6.2.1** Evaluation of material performance will involve using appropriate tests to quantify material properties and performance-related characteristics which are relevant to the application. This involves the definition of a set of material tests and the identification of the critical properties to be measured. The test methods required for materials evaluation include both published international standard tests and other relevant performance-related tests.

**6.2.2** Table 4 lists the test methods which are used in the preliminary and full stages of evaluation. For all tests, the measured properties on which performance is evaluated are also presented. Pertinent information about each test is presented briefly in the sections below.

**6.2.3** Testing over a range of temperatures requires that sample temperature be equal to test temperature. Accordingly, the temperature sensor should be located as close as possible to the testpiece failure site; see Annexe B.

### 6.3 PRELIMINARY EVALUATION

**6.3.1** Preliminary evaluation (“screening”) tests are optional and are typically low cost tests of short duration. Properly selected preliminary evaluation tests provide screening to highlight, at an early stage, any serious deficiencies in the performance of a candidate polymer; failure may immediately exclude the material from further consideration.

**6.3.2** A preliminary evaluation on its own is not sufficient to qualify a candidate material for service—it must be followed by a successful full evaluation if it is to be qualified. However, screening can save time and costs by removing non-contenders at an early stage.

**6.3.3** The approach to preliminary evaluation of candidate polymers is shown schematically in Figure 3. However, if information is already to hand (e.g., from technical literature of polymer supplier) it can be used. Otherwise appropriate tests from Table 4 are employed. The approach involves the following stages:

#### a) Review and Identification

Review of available literature data and identification of tests required to provide missing property information. Hence test selection will be based on available material data, particular performance requirements for the application (and their respective priority ratings) and cost. The emphasis will be on performing tests which are likely to highlight any gross inadequacies in material performance. The tests in Table 4 are of nominally equal importance but in reality some are overriding (e.g., RGD resistance); hence the value of RGD as a screening test.

#### b) Definition of Test Parameters

These will depend on the transported fluids, operating temperatures and pressures, etc.

### 6.4 FULL EVALUATION

**6.4.1** Full evaluation of a candidate polymer involves application of the set of materials tests identified as essential for obtaining critical property information. Some of these tests are longer term (e.g., accelerated chemical ageing). The purpose of the full evaluation test programme is to comprehensively assess the suitability of a candidate polymer for the high temperature flexible pipe application. The information necessary to determine whether or not a material has the characteristics necessary to justify manufacture and testing of a prototype flexible pipe will come from the evaluation of these test results. The tests required to assess performance are listed in Table 4 and the overall approach shown in Figure 4.

**6.4.2** The emphasis in full evaluation testing is on realism; that is, as far as possible, tests are tailored to the pipe application. One important requirement is that all testpieces originate from extruded pipe; samples processed in other ways (e.g., injection moulded) are unacceptable for full evaluation testing. As in the preliminary testing stage, test parameters need to be defined.

### 6.5 TENSILE TESTING

**6.5.1** Tensile testing is a basic means of obtaining material data such as the full stress-strain curve, Young's modulus, tensile (ultimate) strength at break and percent elongation (strain) at break for design criteria for use in Global and Local analyses, and for assessing ageing-induced changes. Tensile tests should be carried out according to [ASTM D638M](#) (or ISO equivalent), modified if necessary as described in Annexe C.