

GENERAL SPECIFICATION

CORROSION

GS EP COR 170

**Materials for sour service (upstream applications)
Specification for design**

08	10/2012	Modifications of various sections
07	01/2011	Reference document revised and limitations for the use of 17-4PH revised
06	10/2008	Modification of § 5.2 Testing requirements and categories
05	10/2006	Modifications of HIC testing requirements. Addition of testing for flexible wires
00	03/2001	First issue
Rev.	Date	Purpose of the revision

Owning entity: DEV/TEC

Managing entity: DEV/TEC/COR

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 2 of 39

Contents

1. Scope	4
2. Reference documents.....	4
3. General.....	6
3.1 Application	6
3.2 Other types of corrosion.....	7
3.3 Requirements	7
3.4 Materials concerned.....	7
3.5 Upgrading of equipment.....	7
3.6 General HIC requirement	7
4. Use of Carbon and Low Alloy Steels in the presence of wet H₂S	8
4.1 Definition of service conditions	8
4.2 Domains of sour service.....	8
4.3 Use of the diagram.....	11
5. Corrosion resistant alloys	11
6. Materials for sour service.....	11
6.1 General requirements	12
6.2 Testing requirements and categories	15
6.3 Downhole tubulars	18
6.4 Transmission pipelines.....	18
6.5 Flexible lines	18
6.6 Pressure vessels, heat exchangers, and process pipework	18
6.7 Rotating machinery	19
6.8 Centrifugal pumps.....	20
6.9 Reciprocating compressors.....	21
6.10 Centrifugal compressors	22
6.11 Rotary-type positive displacement compressors	22
6.12 Instrumentation	22
6.13 Bolting.....	23
6.14 Bellows	24

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 3 of 39

6.15	Springs and spring lock washers.....	24
6.16	Metallic coating and surface treatment.....	25
6.17	Low temperature plant	25
6.18	Sour service with alkalis/amines	25
7.	Fabrication and repair welding	26
7.1	General.....	26
8.	Identification, stamping, marking	26
8.1	H ₂ S Marking	26
8.2	Hard stamps	26
8.3	Marking paints, crayons, etc.....	26
9.	Inspection	27
9.1	General.....	27
9.2	Hardness checking	27
9.3	Hardness checking on small items.....	27
9.4	Hardness checking on welds.....	27
9.5	Corrosion resistant alloys.....	27
	Bibliography.....	28
Appendix 1	Definitions and abbreviations.....	29
Appendix 2	Hydrogen-related cracking phenomena.....	30
Appendix 3	Forms of Hydrogen Induced Cracking	31
Appendix 4	Factors affecting the resistance of materials to cracking in H ₂ S containing environments.....	33
Appendix 5	Use of the pH-P _{H₂S} sour service diagram.....	34
Appendix 6	Examples of how to use the pH versus P _{H₂S} Diagram.....	37

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 4 of 39

Foreword

Value of this General Specification

This Company General Specification clarifies certain requirements specified in [ISO 15156](#) and provides guidelines for the choice of materials for sour service duty applicable to upstream conditions, offering economy, safety and reliability of operation. The use of this Specification to its users will be significantly enhanced by their regular participation in its improvement and updating. For this reason, users are encouraged to inform Company of their experiences in all aspects of its application.

Application

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance with the specific application.

Principal features of this General Specification

This General Specification Revision 8 reminds of some of the requirements of [ISO 15156](#). It also provides additional information and/or guidance to apply the ISO Standard. Note that [ISO 15156](#) is also called [NACE MR0175/ISO 15156](#) Standard. **As a consequence, in all other Company General Specifications, [ISO 15156](#) document automatically applies when reference is made to [NACE MR0175](#) Standard.**

Feedback and further information

Users are invited to feed back any comments and to detail experiences in the application of this General Specification, to assist in the process of its continuous improvement.

1. Scope

This Specification specifies Company general requirements on materials of construction for equipment handling fluids containing water and hydrogen sulfide in upstream conditions. It supplements or modifies [ISO 15156](#) International Standard. Note that Technical Corrigenda published between two publications of [ISO 15156](#) are part of the Standard. Other documents such as [EFC Publication No. 16](#) and [EFC Publication No. 17](#) and [NACE TM0177](#) and [NACE TM0284](#) Standards are also referenced in the present specification.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
API 5CT	Specification for Casing and Tubing
API RP 945	Avoiding Environmental Cracking in Amine Units
API STD 619	Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries
ASTM A 193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
ASTM A 194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
ASTM A 307	Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM A 320	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
ASTM A 370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 439	Standard Specification for Austenitic Ductile Iron Castings
EFC Publication No. 16	European Federation of Corrosion Publication No. 16; Guidelines on Material Requirements for Carbon and Low Alloy Steels for H ₂ S - Containing Oil and Gas Field Service
EFC Publication No. 17	Corrosion Resistant Alloys for Oil and Gas Production: Guideline on General Requirements and Test Methods for H ₂ S Service
EN 10204	Metallic Products - Type of Inspection Documents
ISO 6892-1	Metallic Materials - Tensile testing - Part 1: Method of test (at ambient temperature)
ISO 15156 (Parts 1; 2; 3)	Petroleum and Gas Industries-Materials for Use in H ₂ S-containing environments in oil and gas production - Parts 1; 2; 3
NACE Standard TM0177	Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H ₂ S Environments
NACE Standard TM0284	Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 6 of 39

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP MEC 251	Supply of Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services according to API Standard 617
GS EP MEC 261	Packaged Reciprocating Compressors for Oil and Gas Production Services According to ISO 13631
GS EP MEC 271	Packaged Reciprocating Compressors for Oil and Gas Production Services According to ISO 13631
GS EP MEC 273	Supply of Centrifugal Pump class II according to ISO 5199
GS EP MEC 281	Lubrication, Shaft Sealing, and Oil Control Systems and Auxiliaries according to ISO 10438 / API Standard 614
GS EP PLR 109	Design, fabrication and testing of submarine unbonded flexible pipes and risers
GS EP PLR 211	Fabrication of seamless pipes for pipelines (mild, intermediate and severe sour service)
GS EP PLR 212	Fabrication of longitudinally submerged arc welded pipes for pipelines (mild, intermediate and severe sour service)
GS EP PVV 612	Piping and equipment subject to severe sour service. Metallurgical and welding requirements
GS EP PVV 613	Valves materials requirements for use in sour service
GS EP PVV 622	Piping and equipment subject to intermediate sour service. Metallurgical and welding requirements

Note: In the listed Company General Specifications when [NACE MR0175](#) Standard is referenced, [ISO 15156](#) Standard automatically applies.

3. General

3.1 Application

All installations for fluid containing hydrogen sulfide shall meet the requirements of this Specification. These include:

- (i) All wetted parts which are in direct contact with the H₂S containing fluid
- (ii) All attachments which are not freely ventilated to the atmosphere (insulated, buried, shielded equipment, etc.) and are liable, in case of a leak, to be exposed to H₂S.

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 7 of 39

3.2 Other types of corrosion

This Specification does not cover all general requirements for chloride, alkali or amine services without H₂S, and should not be used for such purposes, but does provide guidance on avoiding environmental cracking in the presence of H₂S. Also it does not provide materials requirements due to other corrosion mechanisms than environmental cracking: e.g. general corrosion (weight loss) or localised corrosion (pitting, crevice). The materials suitability with respect to those other forms of corrosion will have to be established separately. These requirements are of special concern for stainless steels or other so called CRAs.

3.3 Requirements

This Specification defines the requirements for new sour service conditions equipment for oil and gas fields, transmission lines and oil and gas treatment plants and it is applicable whenever the purpose design conditions are such that sour service, as defined within the Specification, may be encountered.

According to [ISO 15156](#) a material can be qualified if one of the three following options is fulfilled:

- The material is listed in the Standard and fulfills the metallurgical requirements of the Standard and it is used within the limits stated by the Standard,
- The material passed the appropriate sour service test under the worst case field conditions,
- The material shall be used under the same conditions for which positive experience was acquired for 2 years as long as these conditions are documented.

3.4 Materials concerned

Reference is made in this Specification to various items of equipment, such as pressure vessels, process pipework, well tubing and casing, pipelines, rotating machinery and instrumentation, for which specific Company Specifications exist. The requirements of such Specifications apply in all respects, except as modified by this Specification for sour service.

3.5 Upgrading of equipment

In some cases, it may be possible to upgrade existing equipment so that the requirements of this Specification are met. Advice on this should be sought from Company.

3.6 General HIC requirement

The various forms of hydrogen internal pressure damage are explained in Appendix 2 and illustrated in Figure A.1.

In cases where Hydrogen Blistering, SWC or SOHIC may occur, Company may specify steel with increased resistance to these cracking mechanisms. Alternatively, carbon steel internally clad with stainless steel may be specified.

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 8 of 39

4. Use of Carbon and Low Alloy Steels in the presence of wet H₂S

4.1 Definition of service conditions

The guidance is based on severity of corrosive medium as characterized by the in-situ pH and the H₂S partial pressure, and representing the risks connected with any equipment damage. This concept is associated with that of the severity of operating conditions, related to the type and function of the equipment concerned in terms of personnel and equipment safety (risk of damage, cost of repair or replacement, etc...).

4.2 Domains of sour service

4.2.1 Background

The presence of wet H₂S promotes and exacerbates many types of environmental cracking, involving a range of mechanisms. For SSC to occur, a combination of susceptible material (metallurgical factors), an aqueous environment containing H₂S and a tensile stress (applied or residual) are required. The service conditions within which these types of cracking may become an integrity concern and hence require metallurgical design or operational precautions are known as "sour service". This is in contrast to "sweet service" where no metallurgical design or operational precautions are normally required in order to avoid environmental cracking.

4.2.2 Severity of operating conditions

The [ISO 15156-2](#) diagram has been adopted in this Specification but with additional constraints related to the unknown behavior of some materials in specific areas, as described below.

Hence, four sour service "domains" are identified on the graphical presentation of Figure 1. Each domain characterizes materials' suitability, indicated by decreasing susceptibility to cracking with increasing severity of corrosive conditions. In the context of these domains, severity of sour service is enhanced by decreasing pH and/or increasing H₂S partial pressure.

4.2.3 Domains of sour service

Domains of sour service are defined in Figure 1, showing four Regions characterizing materials suitability for sour service applications. These are:

Region 0: "Sweet Service" (only negligible traces of H₂S): the domain within which no specific metallurgical precautions are needed except for very high strength steels

Region 1: "Mild Sour Service" The domain within which minor and inexpensive precautions are required. An example of materials which can be used within Region 1 includes carbon steel tubing and casing up to [API 5CT](#) grade P110. This Region applies to any material of similar sensitivity to SSC.

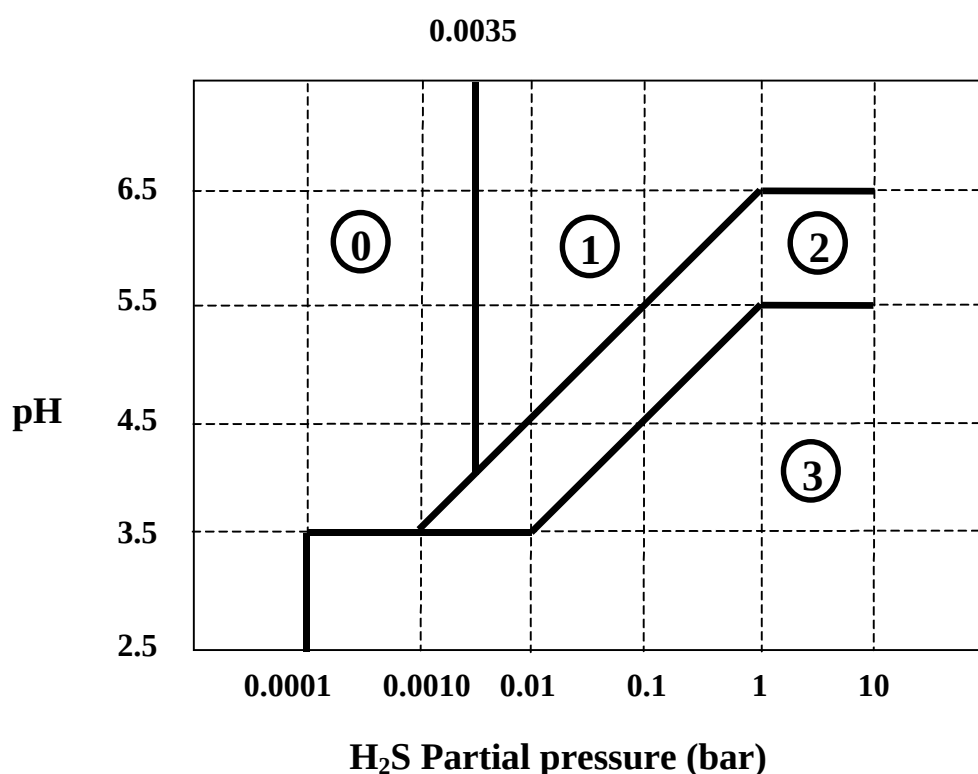
Region 2: "Intermediate Sour Service" The domain within which increasing precautions are required. An example of materials, which can be used within Region 2, includes carbon and low

alloy steel tubing and casing up to the [API 5CT](#) grade N80. This Region applies to any material of similar sensitivity to SSC.

Similarly, resistance to HIC and SOHIC can be achieved by the use of moderately low sulphur, clean and microstructurally homogeneous steels.

Region 3: "Severe Sour Service" The domain within which the most stringent precautions are necessary. Examples include materials taken from the [ISO 15156](#) reference list. Similarly, resistance to SWC requires steels with very low sulphur and other impurity contents, and/or calcium treatment, and qualified by laboratory testing in the expected service conditions.

Figure 1 - Limits of sour service



Note that this diagram is slightly different from the one adopted in [ISO 15156-2](#). While the dashed lines in the ISO document have disappeared into Region 0, the following rules have been adopted in this Specification:

- The severe "sour service" region (Region 3) **includes the area below 3.5 down to 0.1 mbar of H₂S partial pressure**
- The small triangular region above pH 3.5 and below 3.5 mbar of H₂S remains in the intermediate "sour service" region (Region 2) until precise data are available.

Note that, in practice, if P_{H₂S} is < 0.1 mbar or below the detection limit regardless of pH, the conditions are considered sweet or in Region 0. Between 1 and 0.1 mbar H₂S below pH 3.5 the SSC severity decreases as the P_{H₂S} decreases.

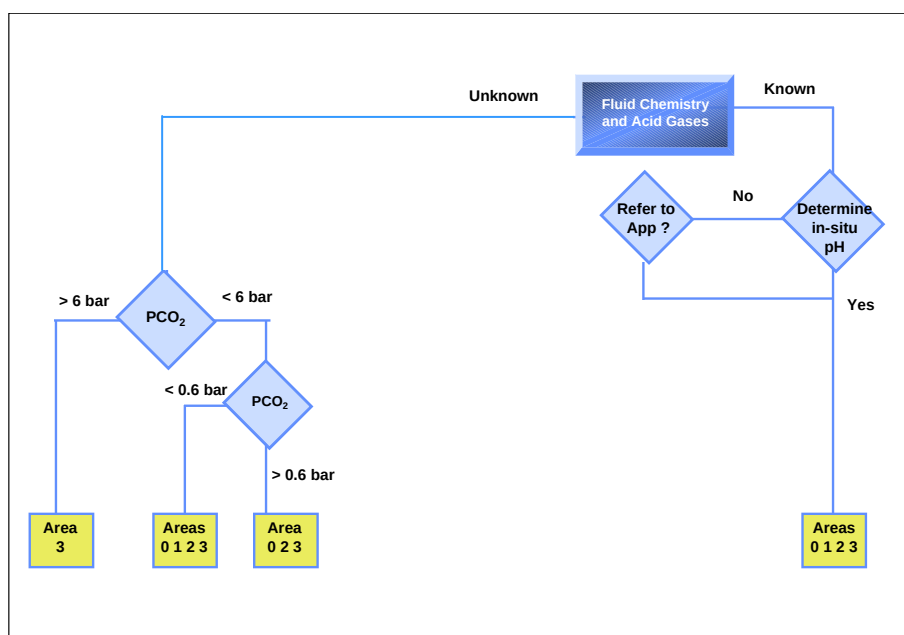
4.2.4 Characterization of materials

Except for the very high strength steels all components and materials which have not been qualified for sour service duty can be used in Region 0 (Sweet Service) without any metallurgical precaution. Materials and components that have been qualified in Region 3 according to the procedures defined in this Specification can be used in Regions 1, 2 and 3.

4.2.4.1 Strategic materials

For the most strategic materials, such as steels for tubing, casing or linepipe, the metallurgical precautions necessary for their use in sour service are generally well known and the application domains are well established. Nevertheless, reference to the four Regions of Figure 1 conveniently simplifies the reporting of individual performance.

Figure 2 - A decision tree defining domains of sour service for carbon and low alloy steels



4.2.4.2 Non-strategic materials

For less strategic materials, or where usage is small, the limits of resistance to sour service may not be available. However, the performance can be determined on a case by case basis, provided that testing conditions are appropriate for the expected service conditions. A successful test at a given pH and P_{H_2S} value will qualify the use of the material for any higher pH or lower P_{H_2S} . This allows a test matrix to be tailored to the expected application of each material.

Also, ranking of non-strategic materials in specific test conditions representative of particular field conditions allows extrapolation of their domains of application beyond those already documented.

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 11 of 39

Whatever the method used for the characterization of materials, the responsibility of the materials selection should be endorsed by the end user. The purpose of this document is to standardize the acquisition and release of this information on the comparative resistance of materials or their limits of use in sour service.

4.3 Use of the diagram

Whatever the application, the procedure to use the diagram shall be as follows.

Consider and compile the data relative to the fluid present in the equipment at the most severe operating conditions as follows:

- Design (absolute) pressure
- Maximum operating (absolute) pressure
- Minimum possible operating temperature
- H₂S and CO₂ contents in the gas phase
- Water composition.

Determine the minimum possible pH (Figures A5.1 and A5.2 of Appendix 5 or Corplus Software) according to the **minimum operating temperature**, the H₂S and CO₂ partial pressures at the **maximum operating (absolute) pressure**, or the lowest local alkalinity of water.

Determine the point corresponding to the service conditions which refers to Region of severity 0, 1, 2, or 3. Regions 3 and 2 correspond to the metallurgical requirements set forth in this Specification which must be satisfied. In Region 1, the requirements of this Specification are applicable; as such any standard grade is accepted in this Region except particularly sensitive steels (tool or spring steels, etc.).

Examples that explain how to use the above diagram are given in Appendix 4.

5. Corrosion resistant alloys

The SSC severity diagram does not apply to CRAs. The worst case service conditions shall be assessed in order to identify which CRAs can be used. This means that the selected CRA shall be used within its limits for each specific component in contact with the H₂S containing fluid.

The use of CRAs shall be in accordance with [ISO 15156-3](#). The limits given in [ISO 15156-3](#) may be extended in some cases according to recommendations by Company HQ corrosion specialist.

6. Materials for sour service

All Materials for sour service as defined in this Specification shall comply fully with the [ISO 15156](#) Standard except as modified or extended below. To put the requirements into context, modifications are divided into three Regions:

- General requirements
- Testing requirements
- Requirements for specific equipment.

General Specification		GS EP COR 170
Materials for sour service (upstream applications) Specification for design		
Rev.: 08	Effective date: 10/2012	Page: 12 of 39

The Supplier shall exercise special care in the selection and supervision of the fabrication conditions and heat treatment conditions, in order to eliminate heterogeneous structures, such as banded pearlite structures and aggregates of bainite and untempered martensite.

6.1 General requirements

6.1.1 Materials selection

The selection of materials for a particular sour duty shall take into account:

- Requirements arising from Section 6.1 of this Specification
- Resistance to general corrosion
- Mechanical properties, including low temperature toughness requirements where necessary, shall be given specific attention.

6.1.2 Carbon and low alloy steels for sweet service conditions

No specific requirements in Region 0 except for very high strength steels.

6.1.3 Materials for mild sour service conditions

The requirement for Region 1 is limited to the avoidance of particularly sensitive materials (e.g. tool or spring steels). For non welded construction steels or OCTG, a yield strength below 900 MPa (130 ksi) is acceptable.

6.1.4 Carbon and low alloy steels for intermediate sour service conditions

In case of strong economic stakes, it is possible to define the requirements for Region 2 by relaxing those for Region 3 in example through reduced quality control (e.g. nominal API L80 grade) or extended acceptance values (e.g. API N80 grade). This must be made in agreement with Company, and may require application specific testing.

In case of doubt, or without specific economic impact, the materials requirements for Region 2 will be similar to those of Region 3.

6.1.5 Carbon and low alloy steels for severe sour service conditions

Materials for the "Severe Sour Service" conditions (Region 3) shall be selected from those permitted in [ISO 15156-2](#).

6.1.6 Castings

All castings shall be suitably heat treated after any welding operation has been performed, and this requirement also applies to the weld repair of defects, irrespective of size. **All casting repair welds shall be heat treated** as follows:

- Carbon and carbon manganese steel: Post Weld Heat Treatment
- Martensitic stainless steel e.g. 11-13% chromium steel: Re-heat treat completely or double temper (see [ISO 15156-3](#) Section A.6 for details of heat treatments)