

GENERAL SPECIFICATION

CORROSION

GS EP COR 004

**Limiting flow velocities calculations for erosion
corrosion purpose**

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1. Scope

This specification defines the design criteria for calculating limiting flow velocities to prevent liquid erosion-corrosion phenomena, i.e. limitations to high velocities. Its application limits are as follows:

- Applicable for all produced fluids, from single phase to 3 phases, as well as injection water
- Applicable to pipelines and to piping systems
- Carbon steel and stainless steels are addressed, as well as copper alloys (used for aerated sea water).

This specification does not address flow velocity limitations:

- For other causes than erosion-corrosion (vibrations, noise). In some cases, these limitations may be more severe than the ones given in this GS. They are covered by **GS EP ECP 103**
- Related to pure mechanical erosion by solid particles, or to solid erosion-corrosion
- Specific to particular equipment such as pumps, valves, compressors etc. also covered by **GS EP ECP 103**
- Regarding the low velocity side, i.e. minimum flow velocities (e.g. for Top of Line Corrosion, solid accumulation, etc.).

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 RP 14E	Recommended Practice for Design and Installation of Offshore Production Platform Piping Systems

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 COR 001	Corrosion control on production facilities: Design and construction
GS EP ECP 103	Process sizing criteria

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3. Definitions

3.1 Liquid erosion-corrosion (L E-C)

Liquid erosion-corrosion is defined in this document as a specific process where final degradation results from corrosion reactions. The liquid flow contributes to a mechanical and/ or enhanced chemical removal of a protective layer (by fatigue cracking, shear stress effect, etc). No solid particle is involved. On the other hand free liquid water is mandatory for erosion-corrosion, as well as some corrosive components in it (CO₂, oxygen, H₂S, etc.).

3.2 Solid Erosion-Corrosion (S E-C)

Solid Erosion-Corrosion is defined in this document as a specific process where final degradation results from corrosion reactions but where solid particles promote the physical/ mechanical removal of a protective corrosion layer. This corrosion mode is not exclusive of the previous L E-C (both being possible). However the presence of solid particles enhances the damage to corrosion layers, i.e. S E-C may occur at lower velocities than L E-C. This corrosion mode is considered as a possible issue when the flow rate of solid particles is higher than limits given in § 5.

As for L E-C, S E-C damages result from a corrosion effect. As such the occurrence of S E-C requires a corrosive water in contact with the pipe wall. It also only concerns non-passive materials. Passive stainless steels are not concerned by this S E-C phenomenon.

3.3 Potential Corrosivity

The "Potential Corrosivity" of a water represents the uniform corrosion rate that this water should induce on bare carbon steel if no protective effects from corrosion product nor any localized corrosion effect should occur over time. This potential corrosivity represents the worst erosion-corrosion rate because corrosion layers may be completely removed under erosion-corrosion conditions.

3.4 Flow velocity calculations

All flow velocity limitations given in this document refer to the sum of superficial velocities (labeled as "total velocity") of all liquid and gas phases at the point under consideration (Oil + water + gas): $V = V_{sl} + V_{sg} = V_{so} + V_{sw} + V_{sg}$.

The superficial velocity of any phase i is the ratio of its actual flow rate Q_i by the total section A of the pipe ($V_{si} = Q_i/A$).

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3.5 Solid free fluid

The sizing criteria in this GS are limited to erosion-corrosion produced by liquid water at the pipe surface in a solid-free environment. **The absence of solid particles is defined as follows:**

- for gases (liquid fraction lower than 5%volume in actual conditions) considering that all sand is present in the gas phase:
 - Particle size below 30 microns (less than 5% mass > 30 microns)
 or
 - Sand flow rate lower than 1 kg/Million Sm³ of gas.
- for multi-phase fluids or liquids (liquid fraction higher than or equal to 5%volume in actual conditions) considering that all sand is present in the liquid phase:
 - Particle size below 30 microns (less than 5% mass > 30 microns)
 or
 - sand concentration less than 3 kg/1000 m³ of liquid.

4. Flow velocity limiting criteria, for solid free fluids

4.1 Acceptance criteria

The following criteria apply to "solid free fluids" as defined in § 3.5, i.e. to conditions where only L E-C is possible.

Two criteria are applicable for carbon steel:

1. Criterion related to the API C value (using the equation given in chapter 4.2)
2. Criterion related to the maximal total velocity V_{max} .

Both criteria must be fulfilled, i.e. the sum of superficial velocities (V) must be less than:

1. The critical velocity (V_{API}) defined by API RP 14E using the C values found in Table 2, chapter 4.3
2. The maximal total velocity (V_{max}) found in Table 2, chapter 4.3.

For other materials than carbon steel, such as stainless steel, copper-nickel, titanium, GRP, etc., there is only one criterion, which is the maximal total velocity (V_{max}) given in Table 1. The C values and the API equation are only applicable to carbon steel.

4.2 API RP 14E equation

The **critical flow velocity** is defined by API RP 14E as follows:

$$V_{API} = C / \rho^{0.5}$$

Where:

V_{API} : API limiting velocity

C: constant

ρ : average density of the total fluid at the point considered. This is the average density of all fluids present at the temperature and pressure of the considered calculation, without accounting for any slippage between the present phases

The limiting velocity of [API RP 14E](#) equation is sometimes expressed using the ρV^2 criterion:

$$V < C / \rho^{0.5} \implies \rho V^2 \leq C^2$$

In short, the API RP 14E equation or the ρV^2 equation express a limiting kinetic energy, above which corrosion products or even the steel itself in case of a pure erosion may be mechanically damaged.

C values given in Table 2 are in US units (V in ft/s and ρ in lbs/ft³). Table 1 indicates equivalent C values with other units, as well as corresponding ρV^2 limiting values.

Table 1: Conversion table for C and ρV^2 values

Units for V Units for ρ	C value ft/s lbs/ft ³	C value m/s kg/L	C value M/s kg/m ³	ρV^2 value ft/s lbs/ft ³	ρV^2 value m/s kg/l	ρV^2 value m/s kg/m ³
	100	3.86	122	10000	15	15000
	130	5.0	159	17000	25	25000
	160	6.2	195	25600	38.5	38500
	200	7.73	245	40000	60	60000
	250	9.66	305	62500	93.3	93300

4.3 Detailed acceptance criteria

Acceptance criteria values based on the philosophy outlined in chapter 4.1 are given in table 2 below as a function of type of fluid, material, corrosion control and fluid corrosivity.

Table 2: Velocity limitation criteria (no solid particles)

Fluid	Material & corrosion control	Corrosive behaviour	C max (US units)	V max (m/s)	Comments
3Φ produced fluid	CS, no inhibition CS, inhibited SS	High/Medium/Low High/Medium/Low N/A	100/130/160 130/160/160 N/A	20 30 50	3 Φ flow is defined as an oil based fluid (GOR < 2 000 Sm ³ /m ³)
2 Φ Oil + water	CS, no inhibition CS, inhibited SS	High/Medium/Low High/Medium/Low N/A	100/130/160 130/160/160 N/A	20 30 50	Gas phase limited to residual amounts, with no significant impact on flow regime
Wet sweet gas	CS, no inhibition CS, inhibited SS	High/Medium High/Medium N/A	100/130 160 N/A	20 30 50	Gas based fluid, (GOR ≥ 2000 Sm ³ /m ³) H ₂ S / CO ₂ < 0.05
Wet sour gas, condensed water only	CS, no inhibition CS, inhibited SS	N/A N/A N/A	130 160 N/A	20 30 50	Gas based fluid, (GOR ≥ 2000 Sm ³ /m ³) H ₂ S / CO ₂ ≥ 0.05
Wet sour gas, with reservoir water	CS, no inhibition CS, inhibited SS	N/A N/A N/A	100 130 N/A	20 20 50	Same as above with reservoir water
Dry or non condensing gas	CS, no inhibition SS	Low	≥ 250	50 100	T higher than T _c or T > T _c + 15 °C (see note 3)
Injection water	CS, no inhibition Inhibited CS if CO ₂ in produced gas	De-aerated by produced gas	150 250	6 10	
	CS, no inhibition	De-aerated by vacuum stripping	200 to 250	8 to 10	Depending on long term de-aeration performance
Natural sea water	GRP Copper alloys Highly alloyed SS Ti alloys	N/A N/A N/A N/A	N/A N/A N/A N/A	8 3 N/A N/A	N/A Erosion above this limit N/A N/A

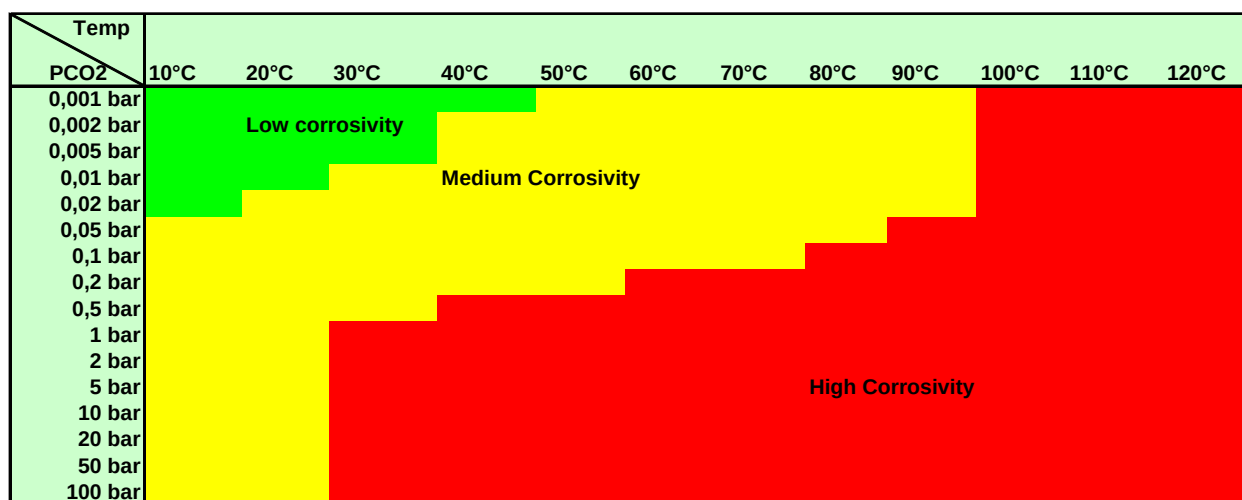
Notes:
1. Approximate classification of Corrosive behavior:

- HIGH: High Potential Corrosivity (> 1 to 2 mm/y without corrosion inhibition) and no likelihood of a highly protective corrosion layer under high flow velocities.

- MEDIUM: Moderate Potential Corrosivity (< 1 to 2 mm/y without inhibition) or "flow resistant" corrosion layer.
- LOW: Low Potential Corrosivity (< 0.1 to 0.2 mm/y without inhibition), or no risk of metal/water contact, or highly "flow resistant" corrosion layer.

The Potential Corrosivity shall currently be evaluated with the CORPLUS tool (Ref. **GS EP COR 001**). However if this tool is not available, the figure 1 here after can be used to determine the worst case corrosivity of current reservoir waters as a function of temperature and partial pressure of CO₂. Any use of less severe corrosivity not based on Corplus calculations has to be approved by TEC/COR.

Figure 1: Corrosivity for 2 and 3 phase production. Worst case



2. For gas process equipment (e.g. gas compression circuits)

Gas is considered as "Wet" unless the gas temperature T at the considered point is higher than T_c + 15°C, T_c being the water dew point of the gas at the same point, unless:

- The piping is thermally insulated or traced to prevent water condensation,
- The outside temperature is higher or equal to the gas temperature, i.e. preventing any water condensation by a cooling effect.

In these 2 cases the margin is reduced to 5°C.

5. Limiting flow velocities with solids

As long as the considered fluid is no longer a "solid free fluid" as defined in § 3.4, flow velocity limitations are calculated in 2 successive steps:

1. Flow velocity limitations by pure mechanical erosion

A dedicated calculation shall be performed with SPSS (Sand Production Pipe Saver) software or equivalent. Evaluation criteria are given in **GS EP COR 001**. Limiting flow velocities/ flow rates are determined to assure an erosion rate below 0.1 mm/y. The use of higher limiting

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erosion rates (e.g. 1 mm/y) is limited to situations of short duration and is subject to the approval of Total.

Note: as long as a significant amount of solid particles is present, erosion limits are generally more conservative than erosion-corrosion limits.

2. Flow velocity limitations by solid Erosion- corrosion

Limiting flow velocities are determined with a similar approach as for solid free fluids, with following particularities:

- No change for stainless steels,
- No change for water free fluids,
- $C = 100$ under all non inhibited conditions for C Steel.
- $C = 130$ under all inhibited conditions for C Steel.

6. Managing erosion-corrosion conditions

Flow velocity situations exceeding erosion-corrosion situations (either S E-C or L E-C) can be accepted during transient periods, subjected to the following conditions:

- No water present which could wet the pipe wall (e.g. during the first period of production of oil fields): BSW < 0.1% for condensate and light crudes (density < 0.85 kg/m³). BSW < 0.5% for heavy crudes (density > 0.85 kg/m³),
- Acceptable erosion-corrosion damage during the period of too high flow velocity: This situation is evaluated as follows:
 1. Determine the worst erosion-corrosion rate, i.e. the Potential Corrosivity, as defined in § 4.3,
 2. Evaluate an acceptable corrosion of the considered piping/ pipeline (e.g. 1, 2 or 3 mm, depending on the available corrosion allowance and total thickness),
 3. From these 2 values, determine the time allowance under erosion-corrosion situations,

The acceptance of such conditions shall be subject to the approval of TEC/COR.

These rules do not apply to pure erosion situation as the damage is not related to the presence of water.