



Document No.	GP 06-14
Applicability	Group
Date	11 February 2009

GP 06-14

Erosion Control

Group Practice

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This issue of Engineering Technical Practice (ETP) GP 06-14 includes key learnings from the erosion technology program (in particular the JIP at the University of Tulsa). Revisions are identified by a bar in the margin.

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Table of Contents

	Page
Foreword	2
1. Scope	5
2. Normative references.....	5
3. Terms and definitions.....	5
4. Symbols and abbreviations.....	6
5. Erosion	6
5.1. General.....	6
5.2. Liquid droplet erosion.....	7
5.3. Erosion-corrosion.....	7
5.4. Cavitation - erosion	7
5.5. Flow regime and its effect upon erosion.....	8
6. BP approach to designing against erosion via erosion modelling.....	8
6.1. General.....	8
6.2. BP erosion model.....	8
6.3. Full erosion rate models.....	9
6.4. Accuracy of erosion models	11
6.5. Erosion modelling of flexible pipes/risers	11
6.6. Use of CFD to assess erosion.....	12
7. External standards for assessing erosion.....	13
7.1. General.....	13
7.2. API RP 14E (ISO 13703)	13
7.3. DNV RP-O501	13
8. Material selection to minimise erosion and erosion-corrosion	13
8.1. General.....	13
8.2. Use of hard materials.....	14
8.3. Use of soft materials	15
8.4. Use of CRAs to avoid the corrosion element of erosion-corrosion.....	16
9. Equipment design to minimise erosion.....	16
9.1. Piping sizing, layout, and routing.....	16
9.2. Piping bend points	17
9.3. Choke valves	18
9.4. Isolation (block) valves.....	19
9.5. External standards and recommended practices for minimising erosion	20
10. Designing against erosion in refining operations	21
11. Monitoring/assessment of erosion damage and/or solids production	23
11.1. General.....	23
11.2. Inspection	23
11.3. Sampling for solid particles	25



11.4. Solid particle detectors.....	26
12. Existing guidance documents	26
12.1. Inhouse erosion guidelines and solid particle management guidelines.....	26
12.2. Inhouse guidance on erosion management.....	26
Bibliography	28

List of Tables

Table 1 - Alternative material relative erosion resistance performance.....	14
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List of Figures

Figure 1 - Example of a flanged tee (flow tee with blind flange).....	17
Figure 2 - Example of a capped tee (ordinary tee with weld cap)	18
Figure 3 - Lead filled target blind flange	18
Figure 4 - Potential erosion mechanism for the inside of elbows/bends	25



1. Scope

This GP provides requirements for modelling erosion, material selection, and equipment design to minimise erosion and monitor erosion damage.

2. Normative references

The following referenced documents may, to the extent specified in subsequent clauses and normative annexes, be required for full compliance with this GP:

- For dated references, only the edition cited applies.
- For undated references, the latest edition (including any amendments) applies.

BP

GN 06-001	Erosion Guidelines.
GN 06-007	Guidelines on the Use of CFD Modelling for Erosion Prediction.
GP 26-10	Heat Exchangers.
GP 32-48	In Service Inspection and Testing of Heat Exchangers.
GP 36-12	Amine Services.
GP 42-10	Piping Systems (ASME B31.3).
GP 62-01	Valves.

American Petroleum Institute (API)

API RP 14E	Design and Installation of Offshore Production Platform Piping Systems.
API RP 17B	Flexible Pipe.

Det Norske Veritas (DNV)

DNV RP-O501	Erosive Wear in Piping Systems.
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International Organization for Standardization (ISO)

ISO 10420	Petroleum and natural gas industries - Flexible pipe systems for subsea and marine riser applications.
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Note: ISO 10420 is currently being revised and is due to be replaced by ISO/DIS 13628-2.

ISO 13703	Petroleum and natural gas industries - Design and installation of piping systems on offshore production platforms.
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NORSOK

NORSOK Std L-002	Piping design, layout and stress analysis.
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3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

Erosion

The mechanical loss of material by the impact of solid particles and/or liquid droplets.



Solid particles

Particulate inorganic matter that can cause erosion damage. Examples include sand (silica), certain hard scales (e.g., magnetite, mill scale), proppants, and catalysts.

4. Symbols and abbreviations

For the purposes of this GP, the following symbols and abbreviations apply:

CFD	Computational fluid dynamics.
CRA	Corrosion resistant alloy.
CO ₂	Carbon dioxide.
CVD	Chemical vapour deposition.
FCCU	Fluid catalytic cracking units.
GRP	Glass reinforced plastic.
JIP	Joint industry project.
SPPS	Sand production pipe saver.
ToFD	Time of flight diffraction.

5. Erosion**5.1. General**

- a. Erosion is the mechanical loss of material by the impact of solid particles and/or liquid droplets, other forms of flow-related damage are not covered in this GP.
- b. For the purposes of this GP solid particles are defined as particulate inorganic matter that can cause erosion damage, examples include sand (silica), certain hard scales (e.g. magnetite, mill scale), proppants, and catalysts.

Under certain flowing conditions, erosion damage can be very rapid. There have been countless examples of highly concentrated erosion damage of the topsides components of drilling rigs and offshore production platforms. Many of these failures have occurred over very short timescales (a few hours, for example, during well cleanup operations).

Many flow dependent wastage mechanisms are termed “erosion”. The majority of the reported “erosion” failures can be subdivided into one of the four main erosion mechanisms that may be encountered:

- *Erosion by noncorrosive fluids through liquid droplet impact.*
- *“Pure” solids erosion by noncorrosive fluids carrying solid particles.*
- *Erosion-corrosion by a corrosive medium in the absence of solids.*
- *Erosion-corrosion by a corrosive, solids containing medium.*



5.2. Liquid droplet erosion

- a. This form of erosion is produced by the formation of very high pressures and shear stresses at the point where the liquid droplets contact the pipe wall.

Droplet impact is possible in annular mist flow (e.g., wet gas), but in general, liquid droplet erosion is only considered to be a potential problem in very high velocity systems.

- b. For mist flow conditions (e.g., in gas condensate systems), a mixture superficial velocity of 70 m/s (230 ft/s) should not be exceeded.

5.3. Erosion-corrosion

- a. Erosion-corrosion occurs in environments that have the potential to be both erosive and corrosive. Erosion and corrosion can be either independent, in which case the total wastage is the wastage produced by each mechanism in isolation, or synergistic, in which case the total wastage is greater than the sum of the independent mechanisms of erosion and corrosion.

In solids containing flows, the synergy between the erosion and corrosion rates (e.g., due to the removal of protective corrosion scales or inhibitor films) can be such that the resultant damage is enhanced. The most damaging situation occurs where any corrosion scale is only removed over a small area. Wall loss is likely to appear in the form of pitting corrosion. Under these conditions, the rate of wall loss in the location where the scale has been removed is dictated by the ratio of the scale coated pipe wall to the area of the bare pipe wall. For example, erosion studies at Tulsa University have shown that, where a protective iron carbonate scale is formed but becomes damaged due to erosion, rapid, highly localised corrosion can result.

- b. Erosion-corrosion is not pure erosion and this GP does not address this phenomenon in detail. Nevertheless, potential interactions between the erosion and corrosion mechanisms shall be considered. Further guidance on dealing with erosion-corrosion is given in [GN 06-001](#).

The approach has been to set a maximum allowable erosion rate of 0,1 mm/yr (approximately 4 mpy) for materials that are prone to synergistic erosion-corrosion (i.e., carbon/low alloy steels and lower chromium content stainless steels, such as 13Cr steel). It is believed that, as long as the erosion rate is maintained below this limit, the risk of synergistic erosion-corrosion is acceptably low.

In the case of duplex stainless steel and higher CRAs (e.g., highly alloyed austenitic stainless steels, nickel alloys), no maximum allowable erosion rate has been set. Rather, in these cases, the maximum allowable erosion rate will be determined by the equipment design and the wastage tolerance available.

5.4. Cavitation - erosion

- a. If the potential for cavitation exists, control valve types that result in a high pressure recovery downstream (such as ball valves and butterfly valves) should be avoided, as well as piping features that cause a high local pressure reduction (such as sharp bends). Multistage pressure drop devices, long radius bends, etc., should be used.

Cavitation is caused by the high energy collapse of vapour bubbles (or cavities) in a liquid flow stream as a result of pressure recovery following pressure reduction to a value below the vapour pressure of the liquid at the flowing temperature. Solid boundaries in the vicinity are likely to be eroded. This is a complex phenomenon, and as with other forms of erosion, it can exacerbate corrosion effects on materials that are susceptible.



Cavitation erosion is not caused by the impact of solid particles or liquid droplets but by the impact of a very high velocity liquid pulse onto the solid boundary from a collapsing bubble. Cavitation emits a characteristic noise, by which its presence and severity (incipient or full cavitation) can be recognised.

Cavitation may be caused by other features of the flow passage causing a sharp change in the flow direction (e.g., a tight radius or no radius) 90 degree elbow in which the pressure falls below the vapour pressure. Pump impellers may also initiate cavitation.

Pipe fittings and valves can be allocated a “cavitation index” by the manufacturer that is a measure of their propensity to cause cavitation in a particular flow regime. Cavitation-erosion can also be caused by surface roughness (e.g., poor internal surface condition of a pipeline), and the damage often appears in the form of “peening”.

- b. Appropriate erosion resistant materials (stellite, tungsten carbide, etc.) should be used locally in the area where cavitation is expected to occur.

Austenitic stainless steels, martensitic stainless steels, and nickel alloys are not significantly more resistant than carbon steel. Materials that are highly resistant to other forms of erosion, such as satellite, are many times more resistant to damage.

- c. This GP does not provide any further requirements in evaluating the potential for, or extent of, cavitation erosion. Cavitation erosion should be avoided by appropriate design and equipment selection.

5.5. Flow regime and its effect upon erosion

- a. Flow regime is an important parameter in determining the erosion damage in a flow stream and should be considered.
- b. Guidance on the consideration of flow regime is given in [GN 06-001](#).

One of the main difficulties of predicting the level of erosion damage in multiphase piping systems is due to the fact that numerous flow patterns of widely different geometry and mechanics can coexist.

6. BP approach to designing against erosion via erosion modelling

6.1. General

- a. Under aggressive operating conditions, velocity limits (and hence production limits) shall be set to avoid unacceptable levels of erosion. Guidance on evaluating the aggressivity of conditions in terms of erosion is given in [GN 06-001](#) and this clause.
- b. Design against erosion shall:
 1. Evaluate the likely erosion rate in the system using appropriate erosion model(s).
 2. Determine if the predicted levels of erosion are acceptable.
- c. Appropriateness of erosion models should be determined based on 6.2 through 6.6.

6.2. BP erosion model

- a. The BP erosion model should be used as a “first pass” assessment tool to determine whether it is necessary to undertake a more thorough assessment using the full erosion model (i.e., the SPPS [preferred for use within BP]). For third party work when SPPS is not available DNV RP-O501 model should be used as an alternate, subject to benchmarking against SPPS.
- b. The BP erosion model should be used in place of the API RP 14E equation.



- c. The BP erosion model is available in [GN 06-001](#).

The BP erosion model is available as a spreadsheet in [GN 06-001](#) and is capable of predicting the erosion rate in mm/yr (mpy) based upon input of:

- *Pipe internal diameter (assumed geometry is 1,5 D elbow).*
- *Superficial gas and liquid velocity.*
- *Gas and liquid density under process conditions.*
- *Process temperature and pressure.*
- *Solid particle size and content.*

The BP erosion model:

- *Is a simplified erosion model compared with the “full erosion rate models” (SPPS and DNV RP-O501 model).*
- *Does not account for all the parameters known to affect the erosion rate (e.g., system geometry, flow regime, fluid viscosity).*
- *Has purposely been set toward the upper (conservative) end of the erosion rate prediction spectrum.*
- *Is not intended for use in detailed studies on the effects of various production parameters on erosion.*

- d. The BP erosion model should only be used for the following:

1. Predicting solids erosion rate (it cannot predict droplet erosion damage levels).
2. For solid particle sizes in the range 50 μm to 500 μm (2 mil to 20 mil).

- e. It has been shown that the erosion rate under slug/churn can be 5 times to 10 times higher than that predicted by the BP model. Therefore, if using the BP erosion rate model for such flow regimes, the predicted erosion rate shall be multiplied by a factor of 10.

6.3. Full erosion rate models

6.3.1. General

- a. The two main full erosion rate models that are approved for use for BP are:

1. University of Tulsa Erosion/Corrosion Research Center (E/CRC) sand production pipe saver (SPPS) that is the preferred model for use within BP.
2. DNV RP-O501.

These models quantify the erosion rate as a function of:

- *Flow (velocity, gas liquid ratio).*
- *Fluid properties (density, viscosity).*
- *Properties of the solid particles (density, size, shape).*
- *Geometry of the piping components (radius of curvature, fitting type).*
- *Material of piping component.*

Each model in a. uses a set of equations to extrapolate from the limited set of test results to the process conditions for which the erosion rate is required.

- b. It is important to be aware that limits of applicability exist for the models, due to the fact that they are based on experimental test work.

