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GP 41-01

Flow Assurance (Overview Document)

Group Practice

**BP GROUP
ENGINEERING TECHNICAL PRACTICES**

Foreword

This is the first issue of Engineering Technical Practice (ETP) GP 41-01.

This Group Practice (GP) is not a standalone document. It should be used with other documents referenced within that provide details of flow assurance issues and mitigation techniques.

There are no industry standards covering the scope of this document.

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Introduction

There is a long history to the understanding of the flow of materials in conduits. The simplest systems are those with pure (i.e. single component) fluids that exhibit Newtonian behaviour (viscosity is a simple function of temperature/pressure), with no phase change or chemical reactions occurring at the operating conditions of pressure and temperature. In these systems there are well-defined equations and methods for predicting the relationship between pressure change, temperature change, and nature of the flow along the conduit as a function of flowrate and fluid properties (thermo-hydraulic behaviour).

In the oil industry such simple systems can include dry gas flow, water flow (in inert pipes), and the flow of many refined products.

However, there are many other systems with a significantly greater level of complexity, which have far greater uncertainties in the equations and methods for predicting their behaviour – systems in which the fluid properties over the operating pressure and temperature ranges are such that more than one phase, complex rheology, chemical reactions, and the deposition of solids from the fluid stream may occur (physico-chemical behaviour). Such complex systems include any pipe containing flow of more than one phase (e.g. gas and liquid, immiscible liquids, gas and immiscible liquids and solids). Also included are single phase liquid lines when the fluid exhibits complex rheological behaviour, or in which chemical reactions (such as corrosion) or solid deposition may occur.

In the oil industry the production of oil and gas - for which liquid and gaseous hydrocarbons are usually flowing together, often with water and solids - is the main example. It is with such hydrocarbon production systems that the term 'flow assurance' originated.

Flow assurance embraces a wide variety of thermo-hydraulic and physico-chemical phenomena, and the mitigation measures required to manage these phenomena. These phenomena and mitigation measures are introduced in this document, together with a high-level summary of the key requirements for the development of sound designs and operational procedures. Whilst the emphasis is on E&P hydrocarbon production activities, some of the guidance contained herein will be beneficial to designers and operators of other complex fluid transportation systems.

Formal definitions of terms are given in section 3 of this GP.



1. Scope

This GP establishes group practice for the design and operation of flow assurance systems - see section 3 for definition of a flow assurance system.

This GP specifies requirements primarily related to E&P for the design and operation of hydrocarbon production systems comprising a hydrocarbon reservoir, wells, flowlines, and processing facilities. If the production system is offshore, then such systems also include the risers connecting the flowlines to the processing facilities. In these systems the uncertainties in the predictive equations and methods, and in the characterisation of the fluids, are usually also compounded by the level of uncertainty in predicting the behaviour of source of the flow, the hydrocarbon reservoir. This leads to the requirement for highly experienced staff to make engineering judgements on flow assurance based on their understanding of the risks and uncertainties. Such systems usually also include water injection from processing facilities back down into the reservoir. Figure 1 shows a representation of a typical offshore hydrocarbon production system with water injection.

This GP is primarily for the management team and technical leaders of any BP entity responsible for such systems throughout their development and operation. It is also relevant to staff working on any aspect of a flow assurance system, whether they are employees of BP, agency staff, or employees of companies engaged by BP. It serves as a key reference document when establishing agreements with partners or contractors as it sets out many of the responsibilities and actions needed to design and operate a safe and reliable complex fluid transportation system.

Full application of this document will usually require close cooperation with a wide variety of other different disciplines in addition to those implied by the normative references - notably reservoir engineering, wells/drilling/completions engineering, process/facilities engineering, and midstream/refining.

A thorough understanding of the flow assurance issues, and of the limitations of the current design and mitigation techniques, is necessary in order to develop an informed view of CAPEX versus OPEX spends, and risks to production.

2. Normative references

The following normative documents contain requirements that, through reference in this text, are particularly relevant to the requirements of this document, and should be consulted alongside it.

BP

GP 41 series	Flow Assurance (see Annex A for plan of ETP section 41 document development; prior to publication of these documents, please refer to the Flow Assurance guideline documents currently available via Flow Assurance CoP website).
GP 06-14	Erosion Control.
GP 10-35	Well Operations.
GP 10-80	Well Testing.
GP 36-15	Materials Selection for Surface (Topsides) Equipment in Oil and Gas Production Facilities.
GP 36-20	Materials Selection and Specification for Subsea Systems.
GP 43-00	Pipeline Philosophy (Overview Document).
GP 43-19	Pipeline Integrity Management Systems.
GP 44-70	Overpressure Protection Systems.
GP 44-80	Relief Disposal Systems.



GP 64-05	Implementing Measurement Aspects of Multiphase and Wet Gas Meters.
GP 78-00	Principles of Subsea Design and Execution.
GP 78-08	Design and Installation of Deepwater Pipelines and Flowlines.
GP 78-12	Well Jumpers and Flowline Connections.
GP 78-25	Integrity Management of Subsea Systems.

3. Terms and definitions

Flow assurance

The integration of thermo-hydraulic modelling of flow in pipes with the detailed understanding of the physico-chemical behaviour of the fluids, to develop a design, and operational procedures, that will deliver the required flow rate of the fluids in a way that is compatible with the upstream source and the facilities downstream.

Flow assurance system

Any system designed for flow of fluids from one location to another (such as hydrocarbon production systems, export pipelines, or transfer lines between vessels in processing plants) in which the fluids comprise more than one phase and/or have the potential for complex rheology, chemical reaction or solid deposition over the operating pressure and temperature range.

Multiphase flow

The commonly used term associated with the modelling and management of the thermo-hydraulic aspects, with 'multiphase flow engineers' as the specialists in this activity.

Production chemistry

The commonly used term associated with the modelling and management of the physico-chemical aspects, with 'production chemists' as the specialists in this activity.

Flow assurance engineers

Engineers from a multiphase flow or production chemistry background who have developed a broad understanding across a wide range of thermo-hydraulic and physico-chemical aspects, are experienced in the integration of all aspects with related disciplines, and call on the subject matter experts in multiphase flow and production chemistry as appropriate.

4. Symbols and abbreviations

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

BOD	Basis of design.
CMS	Chemical Managed Services.
E&P	Exploration and Production.
EPT	Exploration and Production Technology.
ESP	Electric submersible pump.
ETP	Engineering Technical Practice.
HSSE	Health, Safety, Security, and Environment.
IM	Integrity management.



MDT	Modular Formation Dynamics Tester.
MEG	Mono-ethylene glycol.
MoC	Management of change.
MPcp	Major projects common process.
NGL	Natural gas liquids.
PSCM	Procurement and supply chain management.
PVT	Pressure, volume and temperature (fluid properties).
SETA	Segment engineering technical authority.
SME	Subject matter expert.
SoR	Statement of requirements.
SPA	Single point of accountability.
SPM	Supplier performance management.
SPU	Strategic performance unit.
SSSV	Subsurface safety valve.
TA	Technical authority.
TAN	Total acid number.

5. Application of this document

5.1. Application by BP E&P entities

- a. This document shall be applied by BP E&P entities designing and/or operating complex fluid transportation ('flow assurance') systems.

Whilst the greatest impact of flow assurance issues is usually felt in hydrocarbon production systems in the high cost and difficult to intervene arena of subsea (particularly deepwater) production, it does however apply more widely, to any well-flowline system, and is also relevant to other complex fluid transportation systems (including some pipelines and some aspects of refineries and chemical plants). Therefore a new ETP section, 41 Flow Assurance, has been created.

The wider context for design of pipeline and subsea systems is given in ETPs GP 43-00 Pipeline Philosophy (Overview Document) and GP 78-00 Principles of Subsea Design and Execution (note especially 9.2.3).

- b. Where BP has partial ownership, but does not have operational control, the responsible BP staff should make the operator and other owners aware of the requirements of this document, and should ensure that BP is consulted on any divergences.
- c. Subject to existing contractual constraints (to the extent that they cannot be renegotiated), the requirements of this document should be applied to contractors working under BP's control during design, procurement, construction, operations, and maintenance of BP's assets and during the BP funded development of technology.



5.2. SPA for flow assurance issues

For hydrocarbon production systems in E&P, the Engineering Authority for the SPU or Major Project, should appoint an SPA for flow assurance issues (usually a Flow Assurance TA), who in turn shall ensure that appropriate activities and reviews are put in place to meet the requirements of this document.

Depending on the balance of activities in an SPU, it may be appropriate to have an overall Flow Assurance TA for the SPU, or both a Project Flow Assurance TA and an Operations Flow Assurance TA.

A Flow Assurance TA should have a broad appreciation across the thermo-hydraulic and physico-chemical aspects, and be experienced in the integration of all aspects with related disciplines. They will call on the subject matter experts in multiphase flow and production chemistry as appropriate.

In some SPU operations it may be appropriate to have a specialist Production Chemistry TA instead of a Flow Assurance TA if the principal risks are physico-chemical and the mitigation measures are largely chemical based.

In systems where the principal risks are thermo-hydraulic then a specialist Multiphase Flow TA may be appropriate instead of a Flow Assurance TA.

Corrosion may be included in the responsibilities of the flow assurance SPA.

For some SPU projects or operations with few flow assurance issues, the Process Engineering TA may be a suitable SPA for flow assurance.

6. Flow assurance system design

- a. Flow assurance issues shall be evaluated for the overall complex fluid transportation system end to end, considering the interactions with both the upstream fluid sources (e.g. hydrocarbon reservoirs) and the downstream processing facilities, and ultimately through to point of sale.

It is important that the flow assurance evaluation is in turn part of a holistic analysis with other disciplines to maximise operability, reliability, BP value, and ultimately shareholder value. There are often opportunities to do things 'smarter', in adjusting the approach to flow assurance, which can significantly affect project viability/economics.

System limits extend from a source of fluid and pressure (e.g. oil and gas reservoirs; process facilities such as compressors and pumps) to a point of discharge (e.g. process facilities; tanks, vessels, or other storage; export pipelines).

Given the complexity of flow assurance issues, and inherent uncertainties in the data and methods to predict these issues, the design process is iterative through the MPcp stages. An MoC system should be in place to track the iterations. It is, however, important to state that the project should not be changing the approach to flow assurance during late define and execute.

Illustration of work required in different MPcp stages is attached as Figure 2. However, it should be noted that the emphasis varies greatly between different projects, depending on how the particular flow assurance risks and their mitigation affect the feasibility and economics of the project.

Any work involving design or operation of wells should also refer to ETP GP 10-35 Well Operations.

Any work involving design of subsea flow assurance systems should also refer to ETP GP 78-08 Design and Installation of Deepwater Pipelines and Flowlines, particularly section 6.

