Advances in
Underwater Technology,
Ocean Science and
Offshore Engineering

Volume 24

Advances in Subsea Pipeline Engineering and Technology

ADVANCES IN UNDERWATER TECHNOLOGY
OCEAN SCIENCE AND OFFSHORE ENGINEERING

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Advances in Subsea Pipeline Engineering and Technology

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edited by

C. P. Ellinas

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PART III – PIPELINE DESIGN, FABRICATION AND INSTALLATION

Preface

Dr C P Ellinas
Advanced Mechanics & Engineering Ltd

Major advances have been achieved in recent years in subsea pipeline design and installation. Inspection, maintenance and repair have also received much attention. The development of marginal fields has brought with it special problems, which have necessitated novel methods and solutions. In the meanwhile interest in the development of deepwater fields continues with the development of new technology.

This Conference has placed emphasis in addressing developments in pipeline technology under four main headings:

- pipeline/seabed interaction;
- flexible pipelines;
- pipeline design, fabrication and installation;
- deepwater applications.

Advances in North Sea technology over the last few years have been concerned mostly with marginal fields, small diameter pipelines and new materials, which are well covered in the first three topics.

Economic development of marginal fields requires processing of oil and gas to take place not at the wellhead but at existing facilities, usually some distance away. Hydrocarbons are thus often transported at high pressure and temperature in small diameter pipelines, which need to be protected through trenching. However, such operational practice has brought to the fore a problem that in the past was of little concern namely, upheaval buckling. This phenomenon has been the subject of extensive research and novel techniques have been developed to overcome it. Three of the papers presented in this Conference report on the findings of such work and on the successful application of prevention methods. A fourth paper examines the application and behaviour of anchor reinforcement used to stabilise offshore pipelines.

Some of the problems of upheaval buckling can be overcome to a certain extent through the use of flexible pipelines. Their use, however, has increased in recent years in the form of catenary and flexible risers, used in more novel processing installations, such as SWOPS, converted semi-submersibles, etc, and in loading terminals. This increased demand in flexible pipe has been matched by the development and marketing of new products and novel forms of construction. However, one major area which limits the wider application of flexibles, and which still requires further development is their non-destructive testing and the detection of defects and localised damage at an early stage which ensures the initiation of repairs before failure occurs. Work on this and other related subjects is reported in four detailed papers.

Development of marginal fields also often requires that new pipelines are tied into existing facilities, and frequently there is the additional requirement that the lines are piggable. The development, design and implementation of technology which allows pipelines to be tied in while maintaining full piggability has the advantage of eliminating the need for intervention. This is the subject of a paper which also discusses valuable test results.

New materials, higher strength steels, welding and requirements for operation of pipelines at high pressure and temperature are covered in some detail in a number of papers, and facets of these developments are encompassed in the paper reporting on the retrofit installation of risers in Central Brae.

Recent considerations of safety, especially following Piper Alpha, have led to the Department of Energy to initiate a process that will eventually lead to formal safety assessments of offshore installations. These assessments will be required to address installation hardware, human factors, operating practices, procedures and safety management. The implications of these on pipeline design are considered in a wide-ranging review paper, which also discusses major hazards to pipelines and risers in the North Sea. Hazard and protection concepts are examined also with regard to deepwater pipelines. In a session on deepwater applications there is a detailed report on developments in hyperbaric welding technology for pipeline repairs and on techniques and technology developed for pipelaying.

The depressed market in deepwater technology in the North Sea will not last for long, and as the more accessible fields become depleted developments such as covered by papers in this Conference will become central to the economic exploitation of deepwater fields.

The advances in pipeline technology and engineering covered by this Conference, and the technical complexity, diversity and sophistication of the novel concepts and techniques are evidence of exciting progress in what seems to be an inexaustible search for new and more economic ways of fabricating, constructing and maintaining subsea pipelines. As demand grows, it seems that offshore engineers rise successfully to the challenge of responding to an evermore demanding technical and economic climate.

Society for Underwater Technology

The Society was founded in 1966 to promote the further understanding of the underwater environment. It is a multi-disciplinary body with a worldwide membership of scientists and engineers who are active or have a common interest in underwater technology, ocean science and offshore engineering.

Committees

The Society has a number of Committees to study such topics as:

Diving and Submersibles
Offshore Site Investigation and Geotechnics
Environmental Forces and Physical Oceanography
Ocean Mineral and Energy Resources
Subsea Engineering and Operations
Education and Training

Conference and Seminars

An extensive programme is organized to cater for the diverse interests and needs of the membership. An annual programme usually comprises four conferences and a much greater number of one-day seminars plus evening meetings and an occasional visit to a place of technical interest. The Society has organized over 100 seminars in London, Aberdeen and other appropriate centres during the past decade. Attendance at these events is available at significantly reduced levels of registration fees for Members or staff of Corporate Members.

Publications

Proceedings of the more recent conferences have been published in this series of *Advances in Underwater Technology, Ocean Science and Offshore Engineering.* These and other publications produced separately by the Society are available through the Society to members at a reduced cost.

Journal

The Society's quarterly journal *Underwater Technology* caters for the whole spectrum of the inter-disciplinary interests and professional involvement of its readership. It includes papers from authoritative international sources on such subjects as:

Diving Technology and Physiology

Civil Engineering
Submersible Design and Operation
Geology and Geophysics
Subsea Systems
Naval Architecture
Marine Biology and Pollution
Oceanography
Petroleum Exploration and Production
Environmental Data

An Editorial Board has responsibility for ensuring that a high standard of quality and presentation of papers reflects a coherent and balanced coverage of the Society's diverse subject interests; through the Editorial Board, a procedure for assessment of papers is conducted.

Endowment fund

A separate fund has been established to provide tangible incentives to students to acquire knowledge and skills in underwater technology or related aspects of ocean science and offshore engineering. Postgraduate students have been sponsored to study to MSc level and subject to the growth of the fund it is hoped to extend this activity.

Awards

An annual President's Award is presented for a major achievement in underwater technology. In addition there is a series of sponsored annual awards by some Corporate Members for the best contribution to diving operations, oceanography, diverless intervention technology and the best technical paper in the Journal.

FURTHER INFORMATION

If you would like to receive further details, please contact
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Part I

Pipeline/Seabed Interaction

UPHEAVAL BUCKLING MITIGATION BY HOT WATER FLUSHING

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INTRODUCTION

The Glamis Field in UK North Sea Block 16/21a is operated by Sun Oil Britain Ltd as a subsea step out from the Balmoral Field, 8km to the North East.

The relationship between Balmoral and Glamis is shown in Figure 1. Dedicated single flowlines tie the two production wells and the one water injection well back to the Balmoral template. For process reasons, the production flowlines are heavily insulated to maintain fluid arrival temperatures at the separator above 25°C (Reference 1).

Volume 24: C. P. Ellinas (ed.), Advances in Subsea Pipeline Engineering and Technology, 3–32.

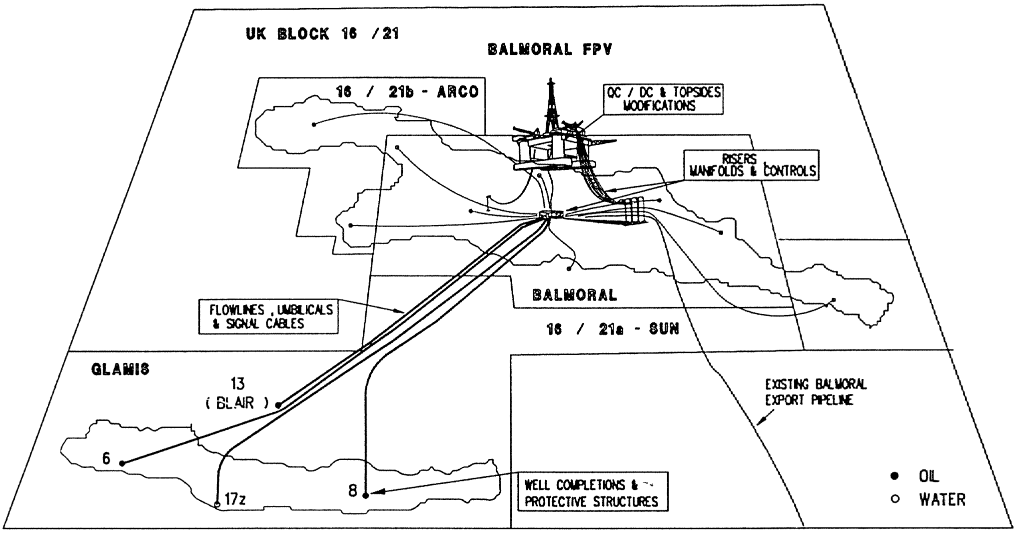

Fig 1: GLAMIS DEVELOPMENT

Pipeline surveys had revealed that an existing Balmoral insulated flowline had been subject to upheaval buckling movements. Similar but more widespread movements were expected on the Glamis lines unless steps were taken to prevent or alleviate the conditions causing the movements . Theoretical predictions based on published analytical techniques confirmed these expectations.

Flowlines buckle when the net compressive load in the pipe exceeds the bending stiffness and the frictional restraining force. Vertical movements occur if the pipe's preferential lateral mode of movement is restrained and the compressive load is able to overcome the weight of the pipe and cover weight/resistance. The compressive load is a combination of the internal pressure effects and the temperature induced expansion forces.

There are several methods for preventing or stabilising buckling movements. Only a limited number were relevant to Glamis and of those only the most appropriate are described in this paper.

The preferred solution was the hot water flushing technique which was developed specifically for this project. The essence of the method is artificially raising the flowline effective installation temperature so that the differential with the operating temperature is reduced to a value which will not cause compressive loads high enough to result in buckling.

Theoretical aspects of the hot water flushing procedure are described in conjunction with details of the offshore operation. The effectiveness of the technique is discussed in terms of the observed pipe movements recorded during the post lay, post hot water flush and post first oil surveys.

SOLUTIONS

Containment or alleviation of upheaval buckling movements can be achieved using either of the two general concepts of cure or prevention. By definition, those techniques based on prevention reduce the compressive loads to below the buckling threshold whereas the cure approach contains the pipe movements when the loads occur.

The important difference between the two approaches is that a well designed prevention method should resolve the issue for the full design life. However a cure method may require regular survey and refurbishment work.

Before discussing the alternative methods considered for Glamis the general conditions under which upheaval buckling can occur are described briefly.

Figure 2 is a diagrammatic presentation of the flowline loads which are caused by the pipe heating up during operation and expanding towards the free ends. At each end of the flowline the load in the pipe is limited by the mobilised soil frictional restraint. Current theories generally assume that once the pipe displacement is greater than about 5-10mm the friction force remains constant as represented by the straight lines in the figure.

Along the central section of the flowline, where sufficient end restraint has been mobilised, the pipe load is governed by the temperature (and pressure) differential between installation and operation. The higher the differential the greater the compressive load. This part of the flowline load diagram is represented in Figure 2 by the line between points A and B. It should be noted that the thermal load line assumes full flowline restraint.

In theory, the load may be calculated directly from the predicted temperature profile. However local lateral pipe movements including a degree of acceptable vertical movement will lower the temperature difference load line appreciably. It should be noted that even though pressure does have an effect on the results it is only marginal and it has been ignored in this discussion.

Superimposed on the flowline load diagram in Figure 2 is the minimum upheaval buckling load line above which unacceptable vertical pipe movements can be expected to occur. For Glamis, unacceptable movements were defined as those that would result in the pipe becoming exposed above the level of the natural seabed.

Close inspection of Figure 2 shows that there are at least four different ways of reducing the Buckling Zone to zero.

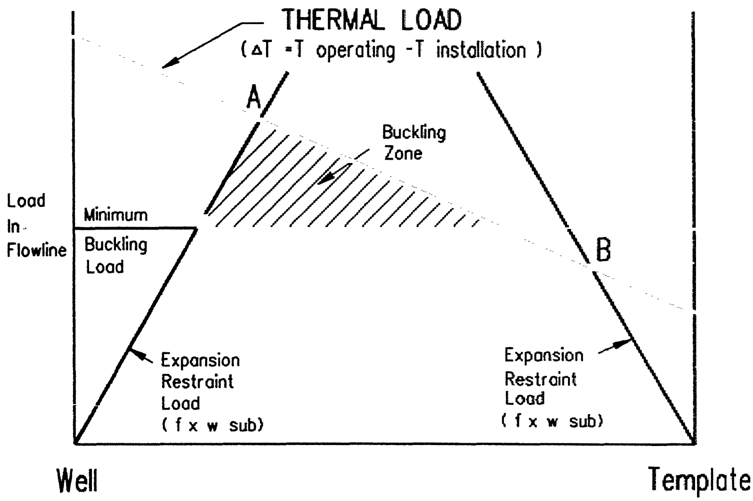

FIG 2 : TYPICAL BUCKLING LOAD DIAGRAM

1. The minimum buckling load line is raised until it exceeds the load represented by point A, e.g. the pipe movement is contained by dumping rock over the line.

2. The temperature difference (thermal) load line is lowered until it is below the minimum buckling load line, e.g. the produced fluid is cooled at the well thereby lowering the maximum operating temperatures.

3. The expansion restraint load lines are manipulated so that they intersect below the minimum buckling load line or where the thermal loads are insufficient to cause buckling e.g. the flowline is divided into shorter lengths with mid line expansion spoolpieces.

4. A combination of two or more of these options.

Prevention Methods

Flowline Cooling

As already indicated in the previous paragraphs the effect of flowline cooling is to lower the thermal load curve below the minimum buckling load line.

To cool the produced fluids down before entering the flowline a number of pipework loops could be mounted within a protective structure and connected in series with the tree and the flowline. The exposed pipework continuously cooled by the surrounding seawater would lead to significant reductions in produced fluid temperatures.

However, low temperatures are often not tolerable for operational reasons. Risk of hydrates, problems with breaking down emulsions in the separators and possible wax deposition in the flowlines and pipework, may require a minimum level of fluid temperatures to be maintained. This was the case for Glamis where a minimum fluid inlet temperature at the separator of 25°C was specified. The option of installing a heater upstream of the separator would not have completely solved the problem.

Mid Line Spoolpieces

Figure 3 shows the effect of introducing mid line spoolpieces. It should be noted however that, for the long Glamis flowlines, more than two flowline sections would have been required.

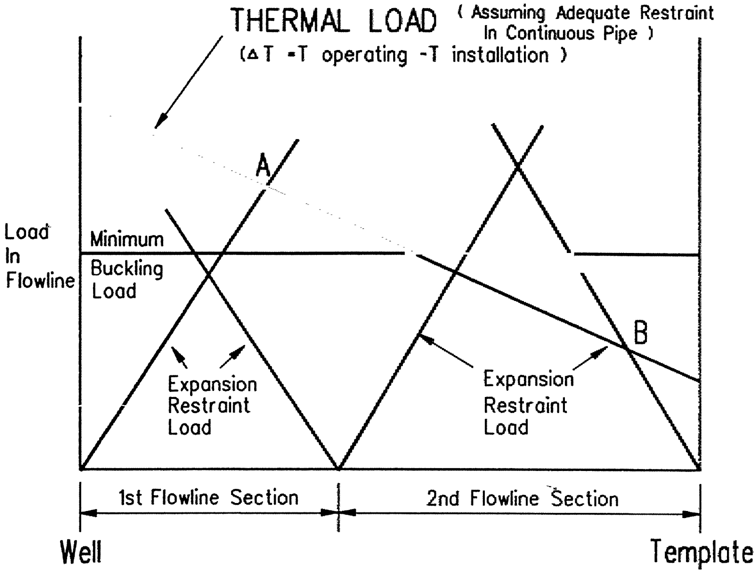

FIG 3 : LOAD DIAGRAM FOR FLOWLINE WITH MID LINE SPOOLPIECE

The spoolpieces are spaced so that at no time does the mobilised soil frictional restraint on the pipe exceed the minimum buckling load. The importance of the effective soil friction factor is evident. To be sure of selecting the optimum spoolpiece spacing a comprehensive soil survey would be necessary.

Although a satisfactory design was feasible there were a number of practical issues which led to this option being dropped.

° Space is required to allow the flowline to expand and the spoolpieces to move. This space could be created by excavating a wide trench or depression in the seabed at right angles to the flowline alignment. Some means of preventing natural backfill to allow unrestricted spool movements is also necessary. Alternative ways of providing space for the spool are feasible but not without increasing costs.

- The flowline installation would take longer with the interruptions to laying. Similarly, the trenching and diving durations would be extended.

- The spoolpieces introduce additional points of potential flowline leakage. Their remote location complicates inspection and maintenance.

Flowline pre-stressing during Installation

Creating a pre-stress in the flowline during installation requires the flowline to be subject to extension (or expansion) displacements which are locked in by soil friction or other mechanical means to prevent the installed pipe from regaining its neutral stress position.

If sufficient tensile pre-stress was applied during installation, it could reduce the operating compressive stress to a level below the minimum buckling stress.

Prestressing the flowline has the same effect as raising the installation temperature and thereby reducing the all important temperature differential between installation and operation. Referring to Figure 2, this is graphically equivalent to the flowline cooling case where the temperature difference load line is reduced so that point A is below the minimum buckling load line.

Initial flowline displacements can be generated by applying a tensile load to the pipe or by heating it so that it expands. Both alternatives have been considered here.