ABSTRACT
The utilisation of flexible pipe has gained ever increasing prominence over the past decade. Improvements in pipe design, construction quality, strength, and overall reliability have resulted in an increased industry confidence. Increasing confidence has permitted flexible pipe technology to become a key factor enabling the safe and reliable exploitation of marginal and deepwater hydrocarbon fields. Founded largely on early flowline and riser experience gained in shallow waters offshore Brazil, flexible pipe has evolved to become the composite material technology for the 1980s. However during this same period due to increased competition among manufacturers, reduced industry activity levels, and low margins there has been a reduction in both the number of manufacturers and overall production capacity. This change may have been somewhat mitigated by greater R&D activities during this decade resulting in advances in analysing pipe stresses and loads, and in determining fatigue lifetime. Greater awareness and levels of offshore industry activity have lead to increased applications of flexibles particularly in dynamic riser service for floating production. Some lessons have of course been learned from the use of simple catenary and multi-riser configurations. This paper reviews both the early flexible pipe experience with particular emphasis on the Brazilian experience and it charts the course of the main applications throughout the 1990s giving particular emphasis to several pertinent North Sea examples. The paper identifies important considerations for future designs of riser systems and outlines the trends the flexible pipe industry is likely to pursue during the 1990s.
Introduction

The concept of using flexible, reelable pipe to transport liquids, gases, and vapours is not a new one. As early as the 1940s a steel braided elastomeric pipeline was developed for the Allied Forces in order to transport fuels to support the Normandy Beachheads. In fact, the longest flexible pipeline ever constructed is likely to be that laid across the English Channel as part of 'Operation Pluto'. The methodology used to handle and instal such pipe is also not new. Ellis (1943, London) in an early patent specification identifies three basic objectives for a flexible pipelining method. These are: prefabrication of the pipe onshore; coiling of the pipe on suitable drums or reels; and using such reels to lay pipe from anchored or motorised barges.

The design concept for flexible pipe is also not a new invention given that flexible hoses and umbilicals have been in service for more than sixty years. A break-through was however achieved by the French Institute of Petroleum in the early 1970s when they developed an improved steel reinforced pipe structure having a high axial loading capacity which utilised corrosion and hydrocarbon resistant polymers to extend pipe service lifetime. This early pipe design utilised established cable making techniques to apply steel armour and axially and radially reinforce alternating layers of polymer sheaths. The pipe was primarily developed as a flowline for use in static seabed applications. Such flexible pipe had obvious advantages over rigid pipe laid at that time by conventional lay barges primarily in the manufacturer's ability to prefabricate and test the structure as a whole onshore and to assemble it onto readily transportable reels. The necessary installation equipment and offshore vessel sizes consequently were reduced and significant savings in overall installation time and costs were realised. To date more than 1700 km of flexible pipe have been similarly installed.