行政院及所屬機關因公出國人員報告書
（出國類別：專題研究）

「油氣管線管理研究」報告

服務機關：中國石油股份有限公司
出國人　職　稱：一般工程師
姓　名：林明聰
出國地點：英　國
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摘要

本專題研究-「油氣管線管理研究」，係本公司八十八年下半年至八十九年度之國外專題研究計畫，主要目的在於研究先進國家油氣管線之管理制度、法規，並研究英國油氣公司在管線設計、營運操作、維護保養、監控及檢測上之相關管理制度、方法，與管線完整性管理之作法(Pipeline Integrity Management)，俾利引進，作為應用於本公司之參考，以改善、提升本公司管線管理能力，降低管線工安機率，減少損失。

本報告內容主要包括：英國管線法規 Pipelines Act 1962，管線實務準則 British Standard Code of practice for Pipelines 簡稱 BS8010，管線安全準則 Pipeline Safety Code 等有關之標準及規定，英國管線之相關權利與義務規定介紹，英、美、歐、俄等主要國家管線準則比較，英國 BPA 公司之 UKOP 管線系統完整性管理作法與相關技術探討，LICENERGY 公司之管線洩漏監控系統，與歐洲管線技術與管理相關論文。

油氣管線管理研究報告

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1. 目的

我國地狹人稠，而本公司長途輸油氣管線總長超過五千公里，遍佈台灣西部人口密集區域。管線一旦發生洩漏，極易造成百姓身家財產損失，為有效管理本公司長途輸油氣管線，強化本公司管線管理制度，故至先進國外油氣公司實地瞭解管線之設計、舖設、監控、營運管理及檢測等詳細之做法，俾利參考引進國外優良管理方法，以改善提升本公司管線管理能力，避免發生油氣外洩工安事故。

油氣管線之管理，公司十分重視，也是本處年度重點工作之一，本專題研究－「油氣管線管理研究」，研究重點主要在於蒐集英國政府管線管理法規，及至英國管線專業代營機構BRITISH PIPELINE AGENCY LIMITED（BPA）公司、管線監測技術廠商LICENERGY公司進行有關研究，以瞭解國外之制度及作法。核定之工作計畫採現場實務研究及資料蒐集研究等方式進行，並進行下列主要工作：

※ 蒐集英國政府管線管理有關之法令、標準。

※ 研究油氣公司管線管理在設計、建造、營運管理、監控及檢測等詳細之做法，並與當地公司技術人員討論。

※ 參觀、瞭解管線實地作業情形。

預估效益：

※ 瞭解先進國家及國外油氣公司管線管理作法及制度。

※ 獲取國外油氣公司管線之設計、建造、營運管理、監控及檢測等詳細之作法。

※ 瞭解國外管線管理作法，強化本公司管線管理制度，提升管線管理能力。

※ 建立優質管線管理制度，降低管線工安事故，減少損失，提升公司形象。

2. 行程

9月12日至9月13日	起程赴英國。
9月14日至10月13日	於英國管線專業代營機構BPA公司研習其UKOP管線系統完整性管理作法，並至輸油監控中心實地參

	訪、研究管線作業情形，並蒐集研究英國政府管線管理有關之法令及標準。
10 月 14 日至 10 月 23 日	於 LICENERGY 公司研究管線洩漏監控系統。
10 月 24 日至 10 月 25 日	返程回台北。

3. 管線法規

3.1 英國管線法

管線法【Pipelines Act 1962】-英國管線法早於 1962 年即頒布施行，經數次修訂條文，於 1996 年更名為管線安全法【Pipelines Safety Regulation 1996】。英國官方之衛生及安全執行部門（Health and Safety Executive HSE）另發行－管線安全法規指導書【A guide to the Pipelines Safety Regulation 1996】(詳附錄一)，該指導書係對管線安全法 1 至 31 條作補充說明，藉以幫助管線操作者、與管線有關業者瞭解、遵循與參考，或那些受法規影響而須了解法規者提供相關指導。

英國管線安全法適用於英國內陸及大陸棚裏所有陸上海上管線，並取代 1962 年早期的管線法，使更具完整性，接近目標背景及風險基礎。其主要內容在於規範管線之設計、建造、輸轉操作上的規定、管線經過處地主之權利義務、地方政府權限、民眾居住或工作於靠近管線之注意事項，用以降低環境風險指數，確保管線安全，法規並提供了管線安全完整的意義。

英國管線安全法共計 31 條 Regulations，內容主要分為 4 部份，概述如下：

Part 1. 介紹 Introduction

法規 1~ 4 條－法律引用，解釋說明，定義，應用。

Part 2. 總則 General

法規 5~17 條－管線設計，系統安全，安全檢查，輸運物質，建造安裝，管線操作，管線檢測，緊急應變處理，管線維護，報廢，毀損，預防危害，協力合作。

Part 3. 危險管線事故 Major accident hazard pipelines

法規 18~27 條－危險液體，緊急關斷閥，建造前通告，使用前通告，

其他通告，事故預防文件，緊急處理程序，事故應變計畫，過渡期條款。

Part 4.雜項 Miscellaneous

法規 28~31 條－防範措施，免除執照，1962 年管線法之廢除，法規廢止與修改。

3.2 英國管線實務準則

英國管線實務準則【British Standard Code of practice for Pipelines】，簡稱 BS8010，係英國國家標準局（British Standards Institution BSI）制定。該準則對管線提供實務上之相關標準規定，藉以幫助管線業者遵循與參考。英國管線實務準則共 4 冊，其中 2 冊與石油業管線有關，概述如下：

Part 1.Pipelines on land：general

陸管：總則

共六章節－原則，例行事務，土地徵用及其他權益，管線安裝及使用，操作、維護、修理及檢測，報廢。（詳附錄二）

Part 2.Pipelines on land：design, construction and installation

陸管：設計、建造與安裝

共九章節－原則，設計，材質，防蝕保護，中繼站，建造，品質保證，壓力測試，啟用。（詳附錄三）

3.3 英國管線相關法規彙整

(1)【Pipelines Act 1962】管線法

(2)【British Standard Code of practice for Pipelines】
英國管線實務準則

(3)【Requisitioned Land and War Works Act 1948】土地及工廠徵用法

(4)【The Land Powers Defence Act 1958】土地權益保障法

(5)【Shell-Mex and BP (London Airport Pipeline) Act 1959】
Shell 及 BP 石油公司（倫敦機場管線）法

(6)【Esso Petroleum Company Act 1961】Esso 石油公司法

英國石油工業管線業者，皆須遵照上述6種與管線有關之法律規定辦理。1960年代英國管線法，規定輸送油氣之鋼質管線，其設計標準須達使用20年之設計年限(design life)，近年已提高設計標準須達40年之使用年限。管線法規定埋設管線皆須依相關規定及標準辦理，並須向政府之管線建造權責單位Pipeline Construction Authorization （PCA）申請，取得同意後始可埋設。政府有權退回管線施設申請，尤其是在甲至乙地已有管線存在的情況，政府通常不會同意另一家業者重複鋪設管線，一般只會核准乙至丙路段，但依法律規定，後申請業者有權使用前業者甲至乙地管線，惟須經由協商方式簽立合約，支付甲至乙地管線泵輸費，再將油料由乙地輸運至丙地。

英國政府視油氣管線屬高危險管線，管線法規定須於管線上方安設警告標示，通過道路下之油氣管線，須於道路兩端安設警告標示外，另須於道路下鋪設混凝土面板來保護管線，因此多數油公司或管線業者基於安全與成本考量，管線多儘量埋設於低危險區之農地或牧場。業者一般於規劃埋設管線前，通常會先舉辦公聽會向附近民眾與地主說明，依土地法之規定與地主協商以取得管線通過權，並根據土地權益保障法之規定跟地主協議相關補償，法律規定採一次補償給付。補償範圍包括土地使用權利金，即地役權(easement)補償（慣例上以每公尺來計價)，地上物、作物等之損壞補償。工程損壞固定設施者另須加以修復，如圍牆、水溝、道路等。

英國法律另規定只要 70%之地主同意，業者即可申請埋設管線，政府相對地有義務協商其餘 30%之地主以解決管線通過問題，然而業者通常都不會這麼做，而是經由協商直到獲得全部地主同意，才會申請埋設管線，因此往往從管線規劃、協商至申請常須耗費數年之久，有時常因採繞道方式致建造費用過鉅，最後不得不放棄計畫。一旦取得地主同意，業者依法則擁有管線路徑兩旁各 3公尺土地之地役權，在此6公尺土地範圍內任何危害管線的活動皆受到管制。管線相關安全規定，概述如下：

(1) 所有工作應依照指導書之規定。

(2) 不可善自提升或降低管線地役權通過範圍地表高度。

(3) 混凝土保護面板是永久被要求安設於管線穿越道路處、泊車區及臨時工地，用以保護管線，管線業者應派代表在其監督下公佈管線位置，並定期作包覆檢查及修護。混凝土保護面板示意圖，詳如附錄四所示。

(4) 管線通過範圍應用標識樁明顯標出相關資料。

(5) 為防止過多穿越管線之物體或其他管線，如排水溝、電纜、水管等等，管線應盡可能集中共同交會於一處，或交會處儘量減少。

(6) 管線路徑應安設管線標識佈告，且由所有者（發啟者）支付此費用。管線標識須裝於穿越道路的兩邊及其它任何有必要的地方。

(7) 管線地役權範圍內不能有建築物、建築工事或不當挖掘。

(8) 管線地役權範圍應總是在空曠地區。

(9) 管線陰極防蝕會腐蝕鄰近地區的金屬構造，所有者有責任保護建築物避免受到腐蝕。

(10) 管線地役權範圍禁止種植樹木（灌木）。

(11) 未經獲得管線操作者或其代理業者事前之協議，不得於管線 400 米(1300 英尺)範圍內使用炸藥。

(12) 未經獲得管線操作者或其代理業者事前之協議，不得於管線 30 米(100 英尺)範圍內挖掘打樁。

英國石油協會（Institution of Petroleum IP）也發行一冊管線安全準則【Pipeline Safety Code】(詳附錄五)，該準則對石油工業所使用之油氣鋼質管線，提供管線在設計安全、建造與操作技術上的一般要求與說明，藉以幫助石油工業管線業者依循參考。

管線安全準則，內容分為十一章節，概述如下：

共十一章－適用範圍、土地調查、設備材質、管線設計、建造、中繼站、清洗測試啟用、防蝕保護、操作維護、緊急應變、海底管線。

3.4 主要國家管線準則比較

列表比較歐洲地區、英、美及俄國等國家，管線規定差異處如下：

Country 國 家	Code 準則	Title 標題
英 國	BS8010-Section 2.8 1992	Code of Practice for Pipelines -Steel for Oil & Gas 油氣鋼質管線之實務準則
英 國	IGE/TD/1－Ed3 1993	Steel Pipelines for High Pressure Gas Transmission 輸送高壓氣體之鋼質管線
美 國	ASME/ANSI B31.8－1995	Gas Transmission & Piping Systems 氣體輸運及管線系統
歐 洲	ISO/FDIS 13623－2000	Petroleum & Natural Gas Industries -Pipeline Transportation Systems 石油及天然氣業之管線運輸系統
俄 國	SniP 2.05.06-85－1988	Construction norms & Regulations -Trunk & Pipelines 油槽與管線之建造基準及規定

Code 準則	Design Factor 設計因子	Min. Cover Depth 最小埋設深度	Block Valve Space 關斷閥距離
BS8010	Max.0.72(rural)down to <0.3(urban)	0.9 m	16km maximum 最大距離 16km
IGE/TD/1	Max.0.72(rural)down to <0.3(suburban)	Typically 1.1 m	Not Specified 未明定
ASME/ANSI B31.8	Max.0.80(remote)-Min. undefined	0.6 m(remote)	32km maximum 最大距離 32km
ISO/FDIS 13623	Max.0.83(remote)-Min. undefined	0.6m(rural)to 1.2 m(urban/crossings)	Not Specified 未明定
SniP	Typically up to Max.0.90(remote)	1.0 m(rural)	Maximum 30km and either side of river crossings 最大距離30km及穿越河流之任一端

Code 準則	Classifications 分類	Testing 測試
BS8010	Class 1 (rural) Class 2 (intermediate) Class 3 (urban)	24 hours test between 90% & 150% Max operating pressure (MOP) or 2 hours test at min 1.25 x MOP 24 小時測試壓力介於 90%至 150%最大操作壓力之間或最小以 1.25 倍最大操作壓力測試 2 小時
IGE/TD/1	Type R (rural) Type S (suburban) Type T (town)	For design factor<=0.3, Mininum 1.5 x design pressure。 設計因子小於等於 0.3 者最小以 1.5 倍設計壓力測試 For design factor> 0.3, 1.5 x design pressure may be allowable 24 hours。 設計因子大於 0.3 者以 1.5 倍設計壓力測試 24 小時
ASME/ANSI B31.8	Class 1 (rural) Class 2 (intermediate) Class 3 (urban) Class 4 (city)	For design factor<=0.3, Mininum 1.5 x design pressure。 設計因子小於等於 0.3 者最小以 1.5 倍設計壓力測試 For design factor> 0.3, 1.5 x design pressure may be allowable 24 hours。 設計因子大於 0.3 者以 1.5 倍設計壓力測試 24 小時
ISO/FDIS 13623	Class 1 (remote) Class 2 (rural) Class 3 (intermediate) Class 4 (urban) Class 5 (city)	1 hour test at 1.2 ~ 1.4 x MOP (depending on location) then 8 hours at 1.1 x MOP 以 1.2 至 1.4 倍最大操作壓力測試 1 小時，之後以 1.1 倍最大操作壓力測試 8 小時
SniP	Not Specified	24 hours test at 1.1 x MOP then 12 hours at MOP 以 1.1 倍最大操作壓力測試 24 小時，之後以最大操作壓力測試 12 小時

4. BPA公司管線管理

4.1 簡介

BRITISH PIPELINE AGENCY LIMITED（BPA）公司為英國一管線專業代營公司，經英國國家標準局（BSI）註冊登記，具有執照之民營業者，負責營運管理取名為UKOP之輸油管線系統。該油管及相關泵站、儲槽、監控等設備，係BP、Shell、Texaco、Mobil、Fina 等5家油公司出資興建，同時並於1965年底合資成立BPA公司，聘請石油工業背景之專業人員代為營運管理與維護。其中BP及Shell 兩油公司為最大股東。BPA公司現有工作人員約100 人，其中行政管理、財會、工程技術與咨詢服務等工作團隊約30餘人於倫敦北郊總部上班，其餘60餘人於Kingsbury之輸油監控中心、部分泵站及terminal 等現場單位執行操作業務。

UKOP輸油管線系統經不斷更新及加裝設備，目前可以說已十分現代化、自動化。該管線於Kingsbury 輸油監控中心裝設有SCADA(Supervisory Control And Data Acquisition)輸油監控系統，該系統非常完整，配備有壓力計（pressure meters）、流量計（flow meters）、密度計（density meters）、顏色計（color meters）、溫度計（temperature meters）、管式迴路校驗器（prover loop）等幾種重要偵測儀器，經由電腦設定，定時自動收集輸油資料作分析處理，達到即時線上監控輸油狀況，並以完全自動化遙控（remote）方式來執行各項作業，可遙控泵浦、閥門作啟閉動作及能自動控制切換油槽，因而降低人為操作失誤之機率確保輸油安全與節省不少人力。六百多公里之管線年輸油量達1200萬噸，卻只須不到100人力即可完成操作管理等工作，可見該管線展現高績效、高效益。

UKOP管線目前幾乎24小時輸油以供應市場需要。主要替BP、Shell 等油公司，負責從英格蘭東南岸之Thames及西北岸之Mersey等煉油廠輸運成品油，以供應中部地區4行政區及都市使用，並肩負倫敦Heathrow和Gatwick二國際機場航空燃油輸運。

4.2 UKOP 管線系統介紹

※ 由 3 完整的管線系統組成，其中 Thames-Mersey 管線系統為多種油品輸運管線(multi-product pipeline)。

	Thames-Mersey	West London	Walton-Gatwick
長度	505km	62km	36km
建造年份	1965-68	1968(&84)	1984
管徑	10-14 吋	6-10 吋	10 吋
輸運油品類別	8 種	航空燃油	航空燃油
1999 輸油量	7538 千噸	3135 千噸	1485 千噸

※ 輸運 8 種油品（95、98 無鉛，高汽，高柴 diesel，普柴 gas oil，航空燃油 aviation，煤油 kerosene 等)。

※ 8 泵站。

※ 4 輸入口、17 個 terminal 供應英國 4 行政區域。

※ 由 Kingsbury 輸油監控中心完全自動監控操作，1990 年更新 SCADA 系統。

※ 5 油公司所有：BP、Shell、Texaco、Mobil、Fina。

※ 1999 年總輸油量 1215.8 萬噸。

4.3 管線完整性管理

科技上的檢定、評估計算與緩和惡化為方法學的一部分，現在一般已被接受成為管線管理實務上良好的作法，且被管線所有者及操作者認為屬完整性的管理，主要考量管線設計、建造、操作、維護與檢測等方面，其目的在於確保管線持續地運作安全。管理作法與步驟可分為許多行動，有些行動是被認為必須用於任何管線系統且定期實施，有些具特殊優點的方法則被考量用於特殊管線系統或特殊需求之時。

BPA 公司同時使用許多方法隨時確保管線的安全與完整，避免管線受到危害。這些方法主要包括：

(1) 即時線上洩漏監測，經由 SCADA 監控系統高精確度計量器，獲得準確輸油量資料作比對，微小油量不平衡時即產生警報，以確保輸油安全。

(2) 經常維護管線防蝕保護系統，包括執行管線包覆與陰極防蝕調查。

(3) 空中和地表週期性監視巡邏，尤其注意高風險地區管線。

(4) 有系統地與地主、地方主管機構、管線附近廠商密切聯繫，以確保其工作不會對管線造成危害。

(5) 使用高解析度管線檢測工具週期性地實施檢測，以提供管線詳細狀況，了解惡化情形並定出所需之修護工作。

BPA 公司管線管理哲學，基本要求完整系統、保證油料品質、合理計價、滿足需求與控制成本。首要考量在於系統完整，並須注重人員訓練、缺陷管理、外力聯繫、緊急應變、維護與檢測等工作之執行與落實。BPA 管線安全管理系統（pipeline safety management system）涵蓋層面極廣，主要包括下列 11 個管控因子：

(1) 風險評估 Risk Assessment
(2) 制訂計劃 Programme Planning
(3) 績效衡量與報告 Performance Measurement & Reporting
(4) 管理檢視 Management Review
(5) 部屬參與 Staff Involvement
(6) 事件/事故調查 Incident/accident Investigation
(7) 法令遵循 Legislative Compliance
(8) 系統發展 System Development
(9) 安檢訓練 HSEQ Training
(10) 員工溝通 Staff Communications
(11) 緊急應變準備 Emergency Preparedness

BPA 公司管線管理方式實務上著重：

※ 洩漏偵測(leak detection)
※ 腐蝕保護（corrosion protection）
※ 路徑管理（wayleave management）
※ 聯繫與教育（liaison and education）
※ 線上檢測（on-line inspection）
※ 壓力測試（pressure testing）

※ 緊急應變計畫（emergency planning）等方面，詳細內容與作法說明於下：

(A) 洩漏偵測(leak detection)：使用科技及目測。

a. 科技(technology)

在英國，監控及資料收集 Supervisory Control And Data Acquisition (SCADA) 系統，被要求應用於管線輸油洩漏監控已有數十年的歷史。雖然此技術與科技已相當成熟，然而電腦與通訊技術的進步仍促使 SCADA 系統不斷地改進。系統運作成功與否取決於設備使用的能力及儀器的準確度。體積質量平衡、壓力監視、管線模擬及統計等技術皆須應用在 SCADA 系統。洩漏偵測為管線完整性管理之一部份，管線系統規劃同時應考量洩漏監測功能。目前尚無完美的管線測漏儀器問世，也沒有某一種技術能夠完全地偵測出微小洩漏，市場上任何一種測漏儀器與技術皆有其極限，安裝 SCADA 系統的費用亦不便宜，不過良好、完整、穩定的 SCADA 系統以及建立合適的管線管理系統，有助於維護保養及確保輸油安全，環保要求高之國家尤其有其必要。

b. 目測(visual detection)

一般係於管線路徑上，步行目視地表或空中偵查地面有無油料洩漏跡象。小洩漏造成地表土壤有油跡，而經由巡查人員目測發現之機會極低，通常地主與居民是適時提供管線洩漏狀況消息的最大來源者。因此與地主或居民建立保持良好關係是必要的，常因而避免發生意外與減輕損失。

(B) 腐蝕保護 (corrosion protection)：使用管線包覆與陰極防蝕方法。

防止管線腐蝕係使用包覆將管線與土壤隔離來防止，加上使用陰極防蝕方法將腐蝕作用局限於聯結地床上來保護管線避免腐蝕。此兩種方法為互補的，任何一方失能，皆可依靠另一方的功能來保護管線，但是管線操作者仍須經常檢查系統，確保此兩種保護裝置功能正常，能提供足夠保護，否則萬一此兩種保護裝置同時失能，管線將會快速腐蝕。

a. 包覆(coatings)

包覆材質之優劣影響防蝕效果，隨著工業進步，管線包覆材料已由早期使用瀝青(bitumen)加亞麻布塗覆，後來使用PE防蝕帶包覆，最近則進步到使用環氧基樹脂(epoxy)作為包覆材料，使得防蝕效果大大提高。管線操作者通常須定期實施包覆劣化檢測，找出管線包覆劣化之處、迷失電流之處加以改善，或調整陰極防蝕系統。

b.陰極防蝕（cathodic protection）

陰極防蝕法是Himphrey Davy 先生於1820年代首次提出，直到1930年代才被普遍使用於輸運油氣之高壓鋼質管線。今日陰極防蝕技術仍大多被用來保護地下鋼管。常用的陰極防蝕方法有兩種：犧牲陽極法與外加電流法。犧牲陽極法是比較簡單的系統，以安設一金屬陽極讓其成為腐蝕端來保護管線本體，常用鎂金屬作為金屬陽極。外加電流法是比較複雜的系統，外加直流電的費用也比較高，但其保護的距離較遠，防蝕效果亦較好。

(C)路徑管理（wayleave management）：注重監視巡邏與教育。

a.地表巡邏（ground surveillance）

外力機具或地表狀況改變造成管線損壞之機率，通常可經由管理及路徑監視有效地加以降低。管線操作者須監視管線上任何可能影響管線的活動，通常經常性地監視管線狀況，實施道路巡邏。

b.空中監視（aerial monitoring）

使用直昇機或飛機巡查攝影，直昇機巡查機動性高可立即降落進一步作調查、處理或向控制中心報告請求支援。空中偵查通常採不定期實施。

(D)聯繫與教育（liaison and education）

道路開挖工程可概分為經授權與未經授權兩類，經授權作業之工程，管線操作者會得知且能與施工單位討論預防措施。未經授權者常因不知道有管線存在，使用重型機械挖掘而造成管線破損。因此管線操作者常須與地主、地方主管機構、附近廠商密切聯繫，進行教育宣導，經由介紹說明、錄影帶教育與提供宣導文件、管線有關資料，清楚告知管線路線、聯繫電

話、聯繫單位、失能後果與預防措施等，以避免管線受毀損。此行動須經常性實施，亦可使用有線電視來宣導。

(E) 線上檢測(on-line inspection)：使用智慧型 pig 檢測。

線上檢測是一種可直接量測管壁缺陷的非破壞性方法。所使用的儀器被稱為智慧型通管器(intelligent pig)，檢測方式係將 pig 置於管線內，以慢速輸油狀態下量測，藉由磁通漏或超音波原理，連續量測紀錄管壁狀況資料，經儀器判讀與電腦分析，可精確測出管線缺陷大小與位置、描繪缺陷情況，得知腐蝕深度、長度、軸向位置及有無機械性破壞，如凹陷、變形情況等。作智慧型 pig 檢測前，須先清管及作幾何變形調查，清管經由施打 clean pig 數次直到管內積垢清除為止，而幾何變形調查是經由施打 geometric pig 來查看管線內徑變化、彎曲度、真圓度等情況，以確認執行智慧型 pig 之適合度，避免卡管。pig 檢測須週期性實施，與前次檢測資料作比對，來計算管線腐蝕速率或了解腐蝕變化情況，評估缺陷影響程度，進而擬定開挖修護規模與計畫，及推估或修正下次檢測時程。

BPA 公司使用 intelligent pig 週期性地實施管線檢測，每年檢測一小段、7 年為一週期。該公司最近 3 年實施的檢測，有 2 次委託荷蘭 HROSEN(HRE)公司代為檢測服務，1 次委託英國 PII 公司檢測。BPA 公司管線專家對 pig 檢測服務廠商技術評比如下：

No.1 -英國 PII 公司，擁有 30 年檢測服務經驗與技術，近年另併購德國知名的 PIPETRONIX 公司，該公司檢測精確度最佳，惟其檢測費用亦最貴。

No.2 -荷蘭 HROSEN(HRE)公司、美國 TUBOSCOPE 公司、美國 T.D.WILSON 公司，其中 HRE 公司軟體分析資料技術強為其特色。

另挪威 A.G.R. 公司以專門提供大口徑管線檢測服務著名。

(F) 壓力測試(pressure testing)：使用加壓檢查。

管線是否正常、能否承受輸油壓力，最簡單的方法可經由壓力測試得

知。英國管線實務準則 BS8010 對壓力測試的規定為，以最大操作壓力的90%至150%間之壓力測試24小時，或最小須以1.25倍最大操作壓力測試2小時。加壓測試，管線恐有破裂之虞其風險較高，然而能確定管線處於良好狀況之下，能承受輸油壓力，較能放心使用。管線有無微小洩漏，亦可用保壓測試得知，保壓係以低於平時輸油之壓力作一長時間之監視，保壓測試管線無破裂之虞較無風險，惟其僅代表測試當時管線是處於良好狀況。

(G) 緊急應變計畫(emergency planning)

管線失能的危害程度可經由嚴密的緊急應變加以降低。事前察覺、預防與處理程序成為完整性管理步驟的一部分。為使應變計畫有效，必須經常對全體操作同仁、主管及支援服務者實施訓練，告知相關處理行動並落實應變能力。緊急應變能否有效成功，主要在於平時之訓練成果。

BPA公司管線管理例行維護之工作項目，表列如下：

項　目	頻 率	項　目	頻 率
臨海地區管線巡邏	每日	管線巡邏	每週
空中勘查及攝影	每月	步行巡邏	每年
臨海地區管線洩漏勘查	每年	管線標示維護	視需要
關斷閥系統檢查	每月	關斷閥完整功能測試	每年
外單位聯繫	每年	外單位管理	視需要
通告與報導	每月	緊急求助	視需要
陰極防蝕啟用測試	一次	陰極防蝕電位檢查	每月
陰極防蝕調查	每半年	陰極防蝕影響評估	2年
緊密電位測量	5年	智慧型pig檢測（7年一週期）	每年

BPA公司自豪在其30多年完整性管理之下，UKOP輸油管線系統呈現非常穩定(stable)之狀況，績效卓越非常令顧客滿意，具有高效率輸油能量與高精度計量能力，能達到小於 ± 0.1%管輸盈虧標準，優於官方 ± 0.15%盈虧標準。關於此點，BPA強調係將U型管式迴路校驗器（prover loop）常態使用於UKOP

管線，定時on-line校驗流量計準確度，經由所測得循環路徑（round trips）脈波數、壓力、溫度與密度等資料，利用電腦立即自動計算通過校驗器流量，即時校對Turbine流量計讀數並建立常態差異值。遇流量計讀數常態差異值過大時，SCADA 系統立即於終端機顯示異常並發出警告訊號，可自動或手動切換使用備用流量計，以隨時確保輸油量之準確性，使得UKOP輸油管線系統實務經驗上展現超水準之管輸績效。

5. LICENERGY公司管線洩漏監控系統

5.1 簡介

LICENERGY公司是一家丹麥公司，成立於1976年，並於1998年股票上市。其在油、天然氣、水等公用設施管線上為有名的廠商，以能提供即時操作動態模擬技術與洩漏偵測技術著名。該公司從事專業連接技術和商業應用，在即時環境下提供給操作員和管理者全盤信息，並且在技術極限內安全地操作系統。該公司在歐洲、中東、印度、美國、加拿大等地區設有辦事處，目前正進行成立中國北京辦事處，為中國當地客戶、油、氣公司等提供技術服務。整體而言，LICENERGY 公司涉及力學模擬技術的所有方面，專長從設計研究到複雜的即時系統技術及其供應、安裝與移交。許多國際的咨詢公司、工程承包商、管線營運公司、SCADA供應商、油、氣公司等均使用該公司的軟體，客戶遍及全世界，目前有125個線上用戶，具有成功豐富的線上執行經驗，包括世界上現存最複雜的管線系統，由於獲得眾多客戶的信任與評價，使得LICENERGY公司在任何領域，如油和天然氣、水供給系統、加熱管線等方面，都成為世界著名和經驗豐富的即時應用軟體供應廠商。

5.2 洩漏偵測

管線在操作使用後需隨時檢測管線狀態，早期找出可疑的地方，可防止嚴重的洩漏事故發生。偵測管線洩漏的方法，簡單的方法為目視檢查，複雜的方法是用儀器蒐集資料加上電腦分析系統來監視洩漏。偵測的目標在於能快速偵察出洩漏發生，並判定洩漏位置及洩漏量，以便立即處理防止嚴重的災害發生。

一個實用的洩漏偵測系統，需能兼顧系統適切性及經濟性，經由引用多種測漏方法，發揮各自特點來達到整體效能。

管線洩漏偵測的方式可區分為兩種，一種是管外偵測，如以眼睛審視管線外觀，或利用儀器偵測管線周圍或地下土壤是否有油、氣溢出，另外一種是管內偵測，包括量測管中油、氣壓力、流量、密度與溫度，與常態值比較以檢知管線是否有異常情況，利用電腦作力學模式模擬分析，求取整個管線內的動態情況，以找出洩漏可疑點，各種偵測方法分別敘述如下：

(A) 管外偵測方式

a. 目視法

目視法是最古老的一種方法，對地上管線較有效，管線變形彎曲甚至破裂、溢出都可藉目視檢視出來。目視法的成效與人員巡視管線的週期與用心程度有關，對於地下管線則只能依據地面上土壤或植物生態變化據以推斷。

b. 管線週圍量測法

利用可燃性氣體偵測儀器，量測管線週圍環境或土壤以測知洩漏。通常由巡邏人員攜帶偵測儀器及探棒，沿著管線經過地段檢測，藉以量測油氣濃度來判斷是否有洩漏發生。

(B) 管內偵測方式

a. 質量平衡法

這種方法主要是利用管線兩端進出量的量測計算來推斷是否有洩漏現象，基本上管線之出量若小於進量即表示有可能發生洩漏，精確的測漏必須加入溫度、壓力及密度的補償，以求取精確的質量平衡。

b. 保壓法

當管線有洩漏發生時管線兩端壓力會隨之降低，藉著能否保持管存壓力可檢測出是否有洩漏。惟此方法的缺點在於難於決定洩漏的位置。

c. 壓力變化法

當管線發生洩漏時管線壓力會快速下降，所以監視壓降速率可以偵測是否

有洩漏並計算推知洩漏可能位置。

d.音波測漏法

當有突然的管裂發生洩漏時會產生音波，這種波會由漏孔位置往管線兩端傳送。藉量測兩端音波到達的時間差，可以用來測知洩漏的位置，另外藉由測量音波振幅衰減程度，亦可測知洩漏尺寸大小。此種方法係將接收器安裝於同管線兩端，將測得的訊號經過濾波消除雜訊並計算時間延遲，以獲得洩漏位置。

e.動態模擬法

主要利用質量平衡法來作為洩漏偵測依據，加上精確的溫度、壓力及密度補償，並利用電腦程式來模擬整個管線系統，能在即時情況下了解管線輸運狀況。此方法須裝設多種精密儀器及電腦化設備，能即時蒐集訊號與處理，包括流量、壓力、溫度與密度值，經由流體力學模擬比較實際值與預測值，假如兩者差值超過某一個常態值則表示有洩漏的可能。動態模式將管線分成許多小段，應用流體力學原理逐次計算存量、流量、壓力值，這種計算方式包括解下列聯立方程式:

※ 質量平衡方程式(conservation of mass)

※ 動量平衡方程式(conservation of momentum)

※ 能量平衡方程式(conservation of energy)

※ 狀態方程式(equation of state)

動態模擬可補償管線因為管壁膨脹、高程變化及熱傳導所造成的影響，以及由於磨擦所造成的能量損失，用以正確估算流體動態。動態模式也會自動修正調整某些參數，使測量值與模擬預測值一致，並能提供有關洩漏孔大小及位置之資料，並降低誤警報機率有效的偵測洩漏。

LICENERGY 公司油、氣管網測漏系統"LICMONITOR"，主要即根據質量守衡原理和利用動態模擬法所發展出來之即時（real time）、線上（on-line）與動態（dynamic）測漏系統，具有回應快速、維護容易、高靈敏度、低誤報率、中文工作畫面編輯、輸出/入數據顯示、時序顯示視窗、流體狀態剖面顯示視窗等功能。其 PIPELINE STUDIO 軟體則為經工業界驗證有名的油、氣管網暫態（transient）、靜態（steady state）與離線（off-line）模擬分析工具。

就目前的測漏技術而言，並沒有任何一種單獨的技術能解決所有的問題，每種技術的測漏效能決定於管線本身的組態及功能要求，有時要考慮同時使用多重技術以達成目標。

6. 結論與建議

石油及其成品為重要能源與物資,同時也是各種石化產品的基本原料,英、美等先進國家對油料之輸運訂有相當安全的管理規則，其中使用管線來輸運油料是目前所知最安全的方法，它有良好的歷史記錄。近年來隨著時代的改變，科技的進步,管理管線的方法亦隨之改變,加上環保要求考量,如何管理管線？已成為很重要的議題。許多油氣公司董事會、經理階層基於安全顧慮與投資效益理由，經常質詢管線操作部門，你們如何管理管線？事實上，以英國為例，政府制訂有管線安全法，明確要求管線操作者須擁有安全的管理系統。此管理系統係指經公司最高管理階層核准之正式文件化形式，並施行於管線部門所有員工。

管線完整性管理作法，必須兼顧設計、建造、操作、維護管理等方面，才能確保管線安全。首先應從管線決定鋪設規劃設計開始就須考量，對建造施工階段的工程品質尤須注重，包括管線材質選擇、路徑選擇、焊接程序與技術、回填方式、新管啟用測試等。在管線施工安裝階段，所有的程序均須遵循標準工程規範並落實實務作法,尤須特別注重鋼管品質、焊道檢查、防蝕包覆施工、陰極防蝕施工、管線埋入及覆土施工等環節。管線在完成施工亦須確實試壓，確保管線的完整性。整體而言，在設計建造操作上，一般通常可經由使用制式的標準及程序來保障管線的品質，也就是依據公認的準則(code)來設計管線，例如 ASME B31、BS8010，因此管線很容易展現有效率和符合安全。然而在維護管理上，雖然有許多方法業已被使用了數十年，卻仍然很難訂定一套公認的準則來管理管線，因為沒有任何一種成熟的系統是完全有效的。不同性質公司應自行判斷，選擇適合自己的作法。

油氣管線所輸送的物質屬高危險性，這種管線在設計、施工、操作、維護上的安全係數要求較嚴格，不同於其他一般管線系統。本公司現有油料輸送管

線超過五千公里，管線皆依照美國機械工程標準 ASME B31 來設計施工，符合公認的安全規範，然台灣雨水多且地質環境差，管線容易腐蝕，所以基本上應特別注重施工品質的控制，以減緩腐蝕確保使用壽命。在操作、維護管理上嚴格來講，應該還有很大的改善空間，尤其在面對日趨嚴格的環保標準及油品自由化挑戰，為確保管線營運操作安全，有必要參考先進國家、油公司之經驗，並倣效 BPA 公司之管理理念與完整性作法，使用現代化的電腦、通訊、量測及應用軟體技術，以自動化方式來強化本公司管線操作管理技能，以建立優質之管線管理，提升輸運效能降低營運成本，並期能避免發生油氣外洩工安事故或降低危害程度減少公司損失。最後十分感謝長官給予出國機會及磨練，也謝謝家人的配合與支持，得以順利完成本專題研究。

7. 附錄(原文)

附錄一：【A guide to the Pipelines Safety Regulation 1996】
英國管線安全法規指導書

附錄二：【British Standard Code of Practice for Pipelines】part1.
英國管線實務準則 1

附錄三：【British Standard Code of Practice for Pipelines】part2.
英國管線實務準則 2

附錄四：混凝土保護面板示意圖

附錄五：【Pipeline Safety Code】管線安全準則

附錄六：BPA 公司管線管理資料

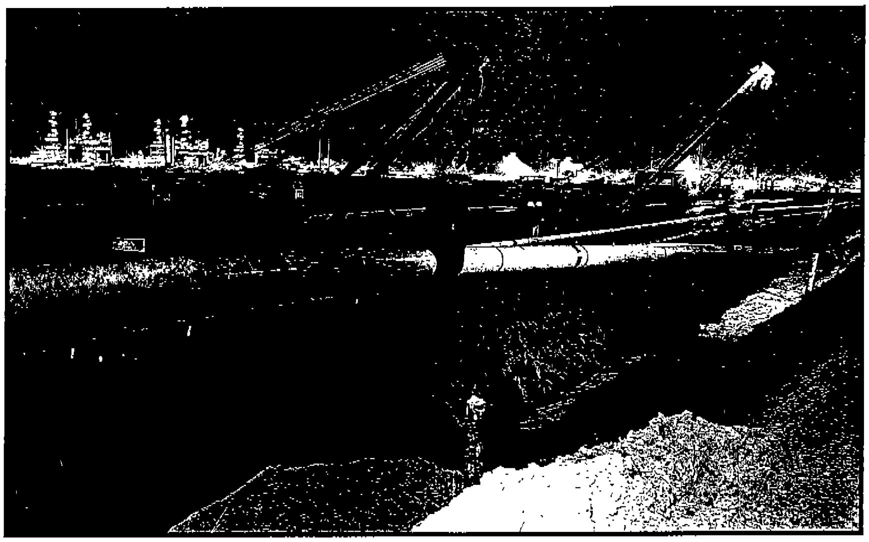
附錄七：LICENERGY 公司管線洩漏監控系統

附錄八：管線技術與管理相關論文

附錄一

HSE
Health & Safety
Executive

A guide to the Pipelines Safety Regulations 1996



GUIDANCE ON REGULATIONS

L82

HSE BOOKS

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This guidance is issued by the Health and Safety Executive (HSE). Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to ensure compliance with the law and may refer to this guidance as illustrating good practice.

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Preface

This guide to the Pipelines Safety Regulations 1996 (SI 1996/825) is intended to help pipeline operators and others involved with pipeline activities or who may be affected by the Regulations to understand what the Regulations require.

Environmental considerations

The Pipelines Safety Regulations 1996, made under the Health and Safety at Work etc Act 1974, do not cover the environmental aspects of accidents arising from pipelines. However the Regulations, by ensuring that a pipeline is designed, constructed and operated safely, provide a means of securing pipeline integrity, thereby reducing risks to the environment.

It is important that effects on the environment are considered at all stages in the life cycle of a pipeline.

Most large onshore pipeline projects require an assessment to be carried out which is designed to identify the likely impact of a project on the environment, to determine the significance of that impact and to establish mechanisms which will minimise any adverse impact. The Electricity and Pipeline Works (Assessment of Environmental Effects) Regulations 1990 apply to cross-country pipelines as defined under the Pipelines Act 1962 (PA62) and detail the procedures to be followed when considering the need for an environmental statement to accompany an application for a pipeline construction authorisation from the Secretary of State for Trade and Industry. The Town and Country Planning (Assessment of Environmental Effects) Regulations 1988 apply to PA62 local pipelines.

The Environment Agency (or its Scottish equivalent the Scottish Environment Protection Agency) issues good practice guidance on how the operators' responsibilities under duty of care can best be met. The Water Resources Act 1991 gives the agencies powers of prosecution in the event of any spillages resulting in the pollution of watercourses.

Environmental aspects of offshore pipelines are addressed in the Pipelines Works Authorisations, issued by the Department of Trade and Industry, through the provisions of the Petroleum and Submarine Pipelines Act 1975.

For offshore pipelines with a diameter greater than 800 mm and a length of more than 40 km an environmental impact assessment will soon need to be carried out once the Environmental Impact Directive is implemented.

Information on design and construction

The Health and Safety Commission (HSC) has issued an informal discussion document to consider ways of ensuring that pipeline operators can comply with their duties through the provision of design and construction information.

Introduction

1 This booklet gives guidance on the Pipelines Safety Regulations 1996, which came into force on 11 April 1996. For convenience, the text of each regulation is included in *italics,* with the appropriate guidance immediately below. Where regulations are self-explanatory, no comment is offered.

2 The Pipelines Safety Regulations (referred to as 'the Regulations' in this guidance) replace earlier prescriptive legislation on the management of pipeline safety with a more integrated, goal-setting, risk-based approach encompassing both onshore and offshore pipelines. They revoke various requirements which had become unnecessary.

3 The Regulations complement other onshore and offshore regulations. Offshore they complement the new regime for offshore health and safety legislation at the heart of which lies the Offshore Installations (Safety Case) Regulations 1992 (SI 1992/2885). Onshore they complement the regulations dealing with extending competition to the domestic gas market including the Gas Safety (Management) Regulations 1996 (SI 1996/551). The Pipelines Safety Regulations cover:

(a) the definition of a pipeline;

(b) the general duties for all pipelines;

(c) the need for co-operation among pipeline operators;

(d) arrangements to prevent damage to pipelines;

(e) consequential amendments to other regulations (eg repeal of sections of the Pipelines Act 1962 and the revocation of three sets of regulations and parts of three further sets of regulations);

and for major accident hazard pipelines they cover:

(f) the description of a dangerous fluid;

(g) the requirement for emergency shut-down valves (ESDVs) at offshore installations;

(h) the notifications structure;

(i) the major accident prevention document;

(j) the arrangements for emergency plans;

(k) the transitional arrangements.

Scope of the Regulations

4 The Regulations apply to all pipelines in Great Britain, and to all pipelines in territorial waters and the UK Continental Shelf. Schedule 1 lists the pipelines to which these Regulations do not apply. Detailed guidance to Schedule 1 is given in the commentary on the Schedule.

Regulation 1 Citation and commencement

Regulation 1

These Regulations may be cited as the Pipelines Safety Regulations 1996 and shall come into force on 11th April 1996.

Regulation 2 Interpretation

Regulation 2

(1) In these Regulations, unless the context otherwise requires -

"dangerous fluid" has the meaning given by regulation 18(2);

Guidance 2

5 The definition of dangerous fluid in the Regulations is widely drawn; the fluids covered are contained in Schedule 2 which lists the dangerous fluids by generic category and, where appropriate, the conditions under which they are conveyed.

Regulation 2

"emergency shut-down valve" means a valve which is capable of adequately blocking the flow of fluid within the pipeline at the point at which it is incorporated;

Guidance 2

6 Regulation 19 requires emergency shut-down valves (ESDVs) to be fitted to certain pipelines connected to offshore installations. An ESDV should be capable of stopping the flow of fluid within the pipeline. However, minor internal leakage past the ESDV may be accepted providing it does not represent a threat to safety. The rate of leakage should be based on the installation's ability to control safely the hazards produced by such a leak.

Regulation 2

"the Executive" means the Health and Safety Executive;

"fluid" includes a mixture of fluids;

"local authority" means -

- *(a) in relation to England, a county council, a council having the functions of a county council, the London Fire and Civil Defence Authority, a metropolitan county fire and civil defence authority, or the Council for the Isles of Scilly;*
- *(b) in relation to Scotland, the council for a local government area; and*
- *(c) in relation to Wales, a county council or a county borough council;*

Guidance 2

7 Regulations 25 and 26 relate to emergency plans to be prepared by local authorities. This duty falls to the local emergency planning authority; in the case of metropolitan authorities this rests with the appropriate metropolitan county fire and civil defence authority. In Scotland, where regional councils were replaced by unitary authorities on 1 April 1996, the preparation of emergency plans rests with the local unitary authority.

Regulation 2

"major accident" means death or serious injury involving a dangerous fluid;

Guidance 2

8 The term 'major accident' appears in a number of places in these Regulations. In particular, the judgement whether there is the potential to cause a major accident will determine the range of hazards identified, and the risks to be evaluated, under regulations 23(1)(a) and (b) and will determine the scope of emergency procedures and plans prepared under regulations 24 and 25.

Guidance

2

9 A major accident would cover death or serious injury from a fire, explosion or uncontrolled emission from a pipeline. This includes both events which have escalated beyond the control of the normal operating envelope of the pipeline and those resulting from third party interference. Whether an event leads to serious danger to people will depend on factors specific to the incident. Major accidents to people can be distinguished from other accidents by the severity of the injuries, the number of casualties, or by the physical extent of the damage in areas where people may be present. The risk strategy needs to address fully the potential for any major accident.

Regulation 2

"major accident hazard pipeline" has the meaning given by regulation 18(1);

Guidance 2

10 A 'major accident hazard pipeline' is one which conveys a dangerous fluid which has the potential to cause a major accident.

Regulation

2

"operator", in relation to a pipeline means -

(a) the person who is to have or (once fluid is conveyed) has control over the conveyance of fluid in the pipeline;

(b) until that person is known (should there be a case where at a material time he is not yet known) the person who is to commission or (where commissioning has started) commissions the design and construction of the pipeline;

(c) when a pipeline is no longer, or is not for the time being used, the person last having control over the conveyance of fluid in it.

Guidance

11 The operator of the pipeline is the person who has control of the pipeline at any time during all stages of its life cycle from the design stage through to final decommissioning.

12 Until the person who is to have control of the conveyance of fluid is known, the operator is the person who commissions the design of the pipeline or (where such work has started) the person who commissioned the design.

Regulation

2

"pipeline" shall be construed in accordance with regulation 3.

(2) Unless the context otherwise requires, any reference in these Regulations to -

(a) a numbered regulation or Schedule is a reference to the regulation or Schedule in these Regulations so numbered; and

(b) a numbered paragraph is reference to the paragraph so numbered in the regulation or Schedule in which the reference appears.

Regulation 3 Meaning of "pipeline"

Regulation

3

(1) Subject to the provisions of this regulation, in these Regulations "pipeline" means a pipe or system of pipes (together with any apparatus and works, of a kind described in paragraph (2), associated with it) for the conveyance of any fluid, not being -

(a) a drain or sewer;

(b) a pipe or system of pipes constituting or comprised in apparatus for heating or cooling or for domestic purposes;

Regulation

3

(c) *a pipe (not being apparatus described in paragraph (2)(e)) which is used in the control or monitoring of any plant.*

(2) *The apparatus and works referred to in paragraph (1) are -*

(a) *any apparatus for inducing or facilitating the flow of any fluid through, or through a part of, the pipe or system;*

(b) *any apparatus for treating or cooling any fluid which is to flow through, or through part of, the pipe or system;*

(c) *valves, valve chambers and similar works which are annexed to, or incorporated in the course of, the pipe or system;*

(d) *apparatus for supplying energy for the operation of any such apparatus or works as are mentioned in the preceding sub-paragraphs;*

(e) *apparatus for the transmission of information for the operation of the pipe or system;*

(f) *apparatus for the cathodic protection of the pipe or system; and*

(g) *a structure used or to be used solely for the support of a part of the pipe or system.*

Guidance

3

13 This regulation defines what is meant by a pipeline. Drains and sewers including liquid effluent outfalls which discharge into a river or estuary are not considered to be pipelines for the purposes of these Regulations.

14 These Regulations do not apply to pipelines which form part of control monitoring equipment such as small bore pipes or tubes normally bundled together with cables, wires, etc to form an 'umbilical' used for hydraulic control or signalling purposes.

15 However, new designs of 'umbilicals' are appearing with pipes within the bundle which are larger in diameter and are used for the conveyance of fluids for purposes other than control or monitoring. It is likely that future designs may include pipes of considerable diameter or even a number of 'large' diameter pipelines bundled together. Even though the basic design and structure of these new systems may be similar to umbilicals, they will be considered to be pipelines and will be subject to the requirements of these Regulations.

16 These Regulations cover pipelines used for the conveyance of fluid. Electrical equipment such as high voltage cable systems which utilise fluid under pressure for circuit integrity and are self-contained are excluded from the scope of these Regulations.

Regulation

3

(3) *For the purpose of sub-paragraph (c) of paragraph (2) a valve, valve chamber or similar work shall be deemed to be annexed to, or incorporated in the course of, a pipe or system where it connects the pipe or system to plant, an offshore installation, or a well.*

Guidance

3

17 Regulation 3(3) defines the interface between plant, an offshore installation or a well and the pipeline.

18 Figures 1 to 7 give examples of different interfaces and illustrate the limits of pipelines covered by these Regulations.

Note: The diagrams in Figures 1 to 7 are for illustrative purposes only – they are not proper representations of actual pipeline systems.

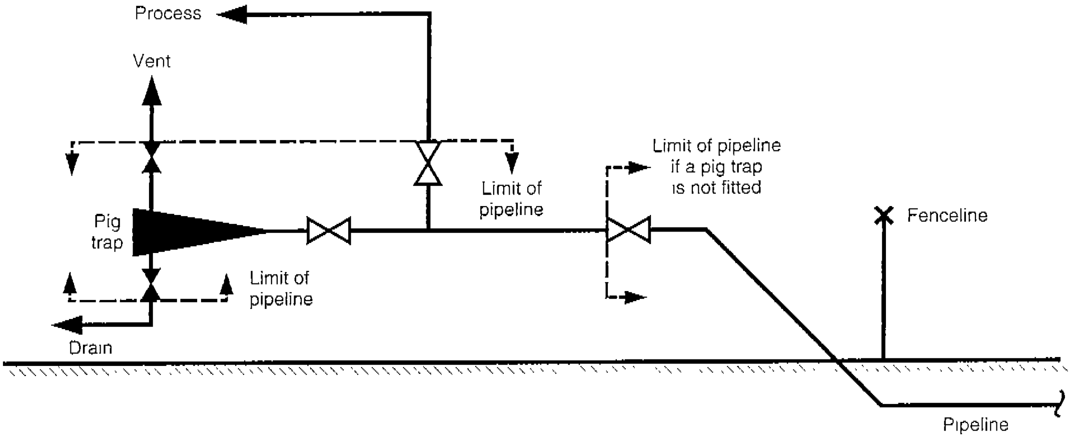

Figure 1 Limit of a pipeline at a factory, onshore terminal, refinery, etc

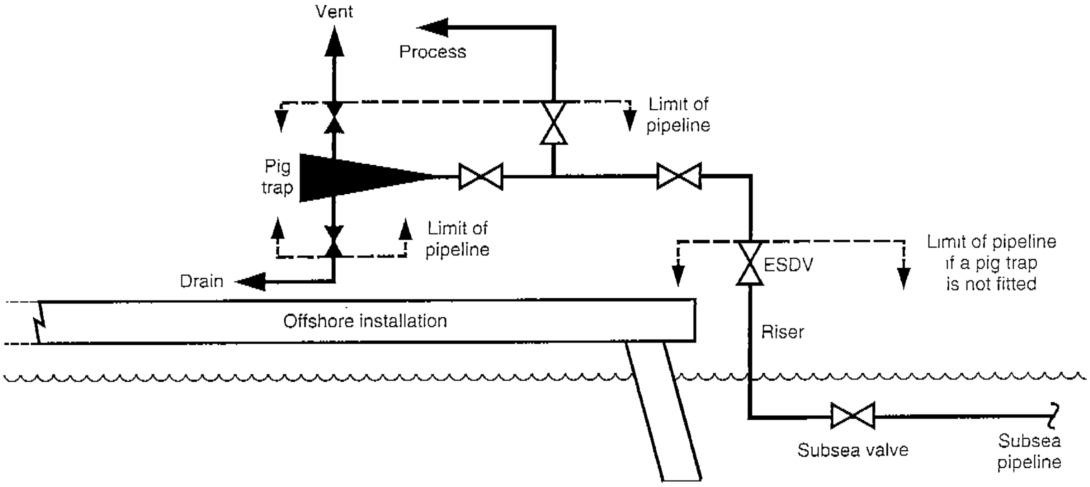

Figure 2 Limit of a pipeline at an onshore installation

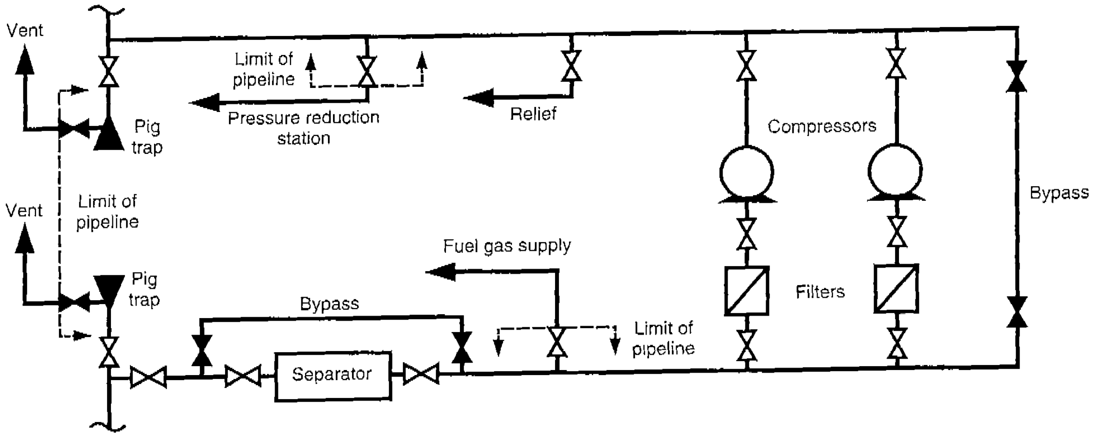

Figure 3 Limit of a pipeline at a mid-line gas compressor station

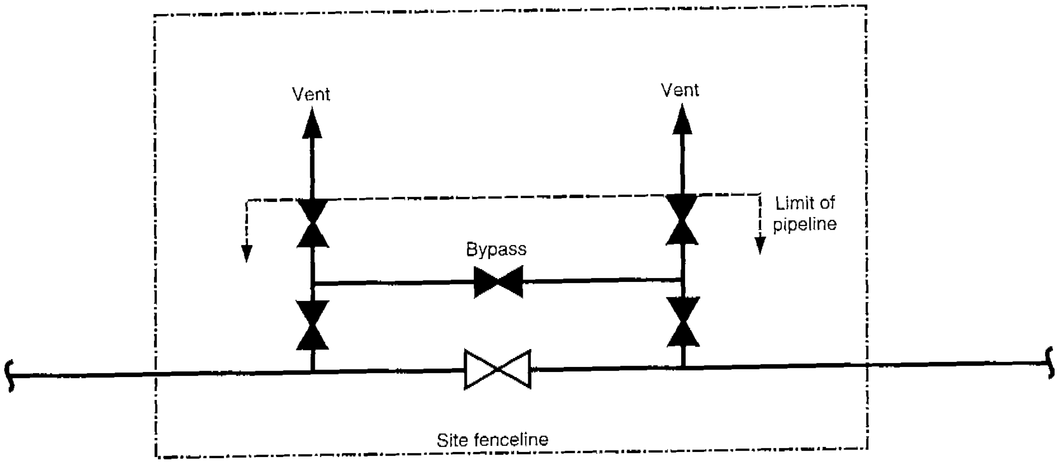

Figure 4 Limit of a pipeline at a block valve site

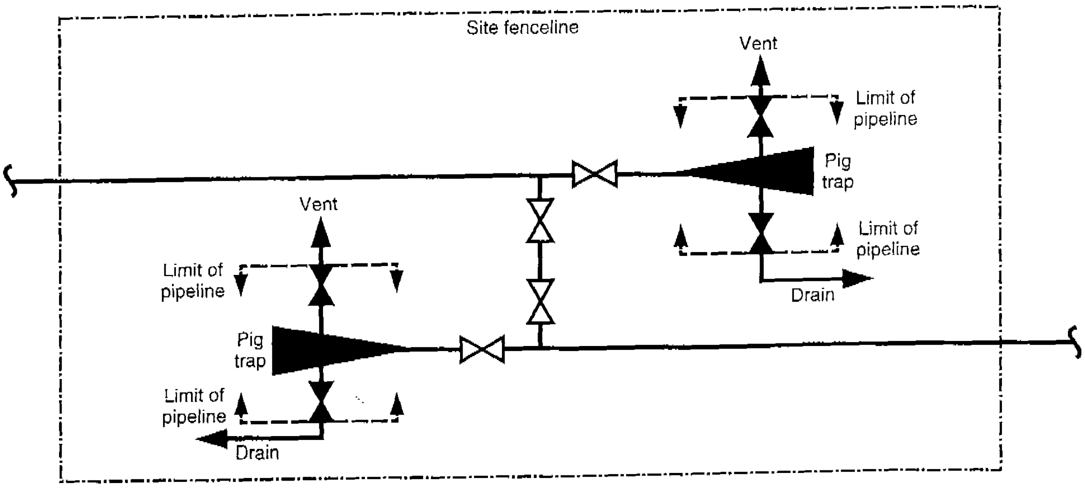

Figure 5 Limit of a pipeline at a mid-point pig trap site

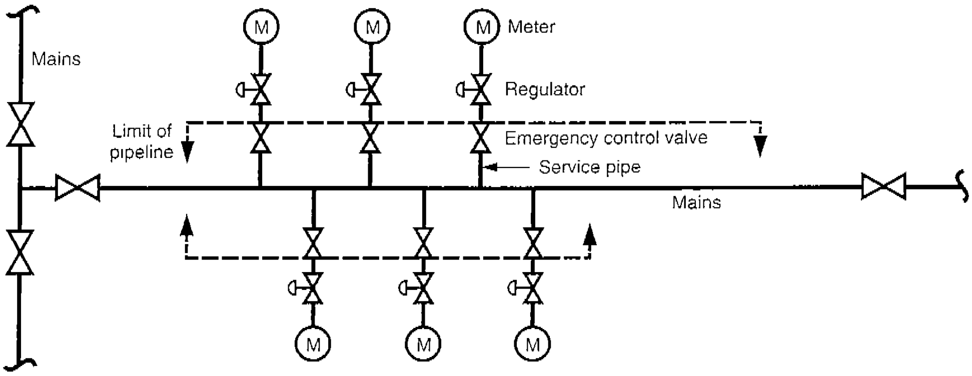

Figure 6 Limit of a pipeline for a gas distribution network

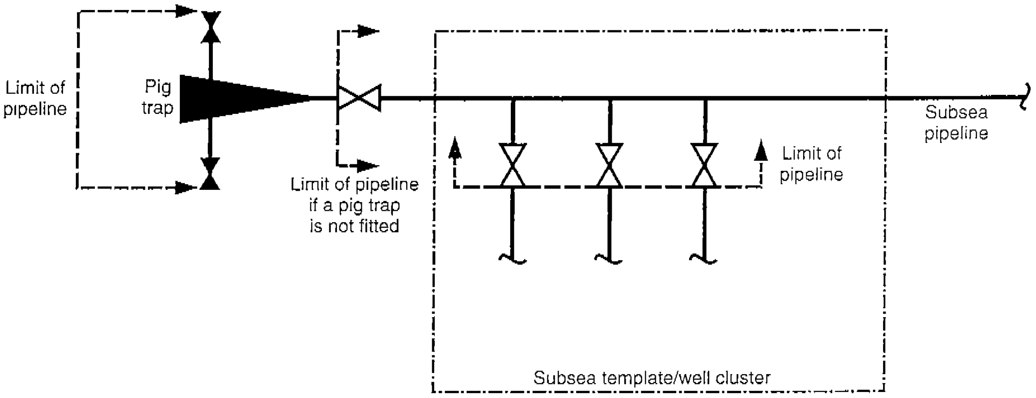

Figure 7 Limit of a pipeline at a subsea template or well cluster

19 Pig traps connected to a pipeline, used for either launching or receiving pigs or for facilitating other equipment to be run through a pipeline, are included within the scope of the Regulations. The pig itself, or other equipment run through a pipeline, is not considered to be part of the pipeline.

20 For pipelines connected to onshore plant, the limit of the pipeline is the primary shut-off valve which connects the pipeline to the plant or the primary valve(s) off the pig trap, where fitted, which connects the pipeline to the plant. Process plant facilities and pipework beyond the primary shut-off valve are not covered by these Regulations.

21 On an offshore installation the limit of the pipeline is up to and including the emergency shut-down valve or primary shut-off valve(s) off the pig trap, where fitted, which connects the pipeline to the installation.

22 Although apparatus for inducing or facilitating flow is included in the definition of a pipeline, where such apparatus is not incorporated in the pipeline system itself, for example compressors on an offshore installation, then such apparatus is not covered by these Regulations.

Regulation

3

(4) A pipeline for supplying gas to premises shall be deemed not to include anything downstream of an emergency control.

(5) In this regulation -

"emergency control" means a valve for shutting off the supply of gas in an emergency, being a valve intended for use by a consumer of gas;

"gas" has the same meaning as it has in Part I of the Gas Act 1986[a]*.*

[a] 1986 c.44.

23 For pipelines supplying gas as defined by the Gas Act 1986 to consumers, the limit of the pipeline in these Regulations is the emergency control.

Regulation 4 Application

Regulation

4

(1) Subject to paragraph (2), these Regulations shall apply -

(a) in Great Britain; and

(b) to and in relation to pipelines and activities outside Great Britain to which sections 1 to 59 and 80 to 82 of the 1974 Act apply by virtue of article 6 of the Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 1995[b]*.*

(2) These Regulations shall not apply to any pipeline or part of a pipeline which is described in Schedule 1.

[b] SI 1995/263.

Guidance

4

24 This regulation defines the scope of the requirements as pipelines in Great Britain, and all pipelines in territorial waters and the UK Continental Shelf. Schedule 1 lists the pipelines to which these Regulations do not apply. Detailed guidance to Schedule 1 is given in the commentary on the Schedule.

Regulation

4

(3) In the case of a pipeline to which the Pressure Systems and Transportable Gas Containers Regulations 1989[(a)] *apply, nothing in these Regulations shall require the taking of any measures to the extent that they are for the prevention of danger within the meaning of those Regulations.*

(a) SI 1989/2169.

Guidance

25 The Pressure Systems and Transportable Gas Container Regulations 1989 (PSTGCR) apply to onshore pipelines which constitute a 'pressure system' where the operating pressure is greater than 3 bar absolute (2 bar gauge) and conveying a relevant fluid. The regulations address in some detail pipeline hazards resulting from the stored energy of the fluid conveyed. Where measures are taken in compliance of PSTGCR to prevent danger within the meaning of those regulations, there will be no requirement for duplication of these measures through the Pipelines Safety Regulations.

Part II General

Regulation 5

Design of a pipeline

Regulation

5

The operator shall ensure that no fluid is conveyed in a pipeline unless it has been so designed that, so far as is reasonably practicable, it can withstand -

(a) forces arising from its operation;

(b) the fluids that may be conveyed in it; and

(c) the external forces and the chemical processes to which it may be subjected.

Guidance

5

26 The purpose of this regulation is to ensure that the design of a pipeline, or any modification to it, takes into account the operating regime for the pipeline, the conditions under which the fluid is to be conveyed as well as the environment to which the pipeline will be subjected.

27 The pipeline, or any modification to it, should be designed so that it is safe within the range of operating conditions to which it could be reasonably subjected. In the pipeline design, account should be taken of the maximum and minimum operating temperatures and of the maximum operating pressure of the pipeline. Account should also be taken of the nature of the fluid being conveyed, for example, corrosive, abrasive or chemical effects. The possibility of any subsequent changes in the fluid to be transported, or in the condition under which it is to be transported should be considered at the design stage.

28 The external forces and the chemical processes to which the pipeline will be subjected will need to be identified and evaluated. Account should be taken of the pipeline location and its susceptibility to damage. This may include consideration of the physical and chemical actions of the environment in which the pipeline is to be located and the terrain, subterrain or seabed conditions. Account should be taken of foreseeable mechanical and thermal stresses and strains to which the pipeline may be subjected during its operation.

29 It is also important that the forces to which the pipeline is to be subjected during its construction are taken into account in its design.

30 Any change to the fluid conveyed will need a reassessment of the pipeline design to ensure that the pipeline is capable of conveying the fluid safely.

31 The design and location of the pipeline should take account of the hazard potential of the fluid being conveyed. Consideration should be given to routes which will minimise the possibility of external damage. Extra protection may be required to prevent damage from other conditions such as road and river crossings, long self-supported spans and structural movements.

32 In general, British Standards provide a sound basis for the design of pipelines. Other national or international standards (eg a relevant standard or code of practice of a national standards body or equivalent body of any member state of the European Union) are likely to be acceptable provided the proposed standard, code of practice, technical specification or procedure provides equivalent levels of safety.

33 For low pressure natural gas polyethylene pipelines (operating below 8 bar absolute), technical guidance in the form of recommendations from the Institution of Gas Engineers offers standards recognised across the industry in IGE/TD 3: 1992 Edition 3: *Distribution mains* and IGE/TD 4: 1994 Edition 3: *Gas services*. The design of gas service pipelines is specifically addressed in the HSE Approved Code of Practice and guidance entitled *Design, construction and installation of gas service pipes* (ISBN 0 7176 1172 8).

Regulation 6

Safety systems

Regulation
6

The operator shall ensure that no fluid is conveyed in a pipeline unless it has been provided with such safety systems as are necessary for securing that, so far as is reasonably practicable, persons are protected from risk to their health or safety.

34 The pipeline should be provided with such safety systems, as necessary, to protect people from risk. Safety systems cover means of protection such as emergency shut-down valves and shut-off valves which operate on demand or fail safe in the closed position, so minimising loss of containment of the pipeline inventory. Safety systems also include devices provided which prevent the safe operating limits being exceeded, for example pressure relief valves.

35 Safety systems are not meant to cover all control or measuring devices. However, safety systems do include control or monitoring equipment, such as flow detectors and pressure monitors, which have to function properly in order to protect the pipeline or to secure its safe operation.

36 Safety systems also include leak detection systems where they are provided to secure the safe operation of the pipeline. The method chosen for leak detection should be appropriate for the fluid conveyed and operating conditions.

37 Interlock arrangements may be provided as safety systems, particularly where they prevent inadvertent operation. For example, valve interlocks may be used in conjunction with bleed devices on pig trap door mechanisms to prevent opening up under pressure.

Regulation 7

Access for examination and maintenance

Regulation 7

The operator shall ensure that no fluid is conveyed in a pipeline unless it has been so designed that, so far as is reasonably practicable, it may be examined and work of maintenance may be carried out safely.

38 The design of the pipeline should take due account of the need to facilitate examination and maintenance. Consideration should be given at the design stage to any requirement to provide suitable and safe access and operation for in-service inspections, such as pigging.

Regulation 8

Materials

Regulation 8

The operator shall ensure that no fluid is conveyed in a pipeline unless it is composed of materials which are suitable.

39 This regulation requires that all materials of construction specified in the design of, and in any subsequent modifications to, the pipeline should be suitable for the intended purpose. This requirement applies not only to the pipeline but also to the associated equipment.

40 The material of construction should be able to withstand the physical and chemical conditions of the fluid to be conveyed under the operating conditions for which the pipeline has been designed. Any changes to the fluid conveyed or the operating conditions of the pipeline, including an extension of the pipeline design life, will warrant a reassessment of the pipeline material to ensure it is capable of conveying the fluid safely.

41 Changes in operating conditions include changes to the corrosion protection system which may well affect corrosion rates and therefore the design life of the pipeline.

Regulation 9

Construction and installation

Regulation 9

The operator shall ensure that no fluid is conveyed in a pipeline (save for the purpose of testing it) unless it has been so constructed and installed that, so far as is reasonably practicable, it is sound and fit for the purpose for which it has been designed.

42 The purpose of this regulation is to ensure that a pipeline which has been properly designed, is fabricated, constructed and installed in a manner to reflect that design. During the installation, design considerations such as the location of the pipeline, depth of cover, need for supports or anchors, and extra protection at vulnerable locations should be adhered to.

43 Suitable procedures should be developed for the construction and installation of the pipeline. Pipe-laying techniques, appropriate to both the location of the pipeline and the type of pipeline being laid should be used.

44 The regulation recognises that before a pipeline is brought into operation it is common to allow the introduction of a fluid, commonly water, into the pipeline to pressure test as part of the demonstration of its soundness and fitness for purpose. Testing in this regulation includes precommissioning work such as pressure testing, flushing or cleaning the pipeline, or other activities which introduce fluids into the pipeline, prior to bringing it into use and the use of intelligent pigs in carrying out a baseline inspection.

Relationship with other Regulations

Onshore Regulations

45 The Construction (Design and Management) Regulations 1994 (CDM) cover the health and safety management of construction projects by those who contribute to the avoidance, reduction and control of health and safety risks faced by construction workers, and others, when engaged on or affected by new construction works. CDM covers the design of the pipeline in so far as the design should take into account the safety of those carrying out the construction (and any subsequent) maintenance work. Similarly, CDM covers the safety management of those involved in the construction during the construction stage, but does not cover the design and construction of the pipeline for safe operation and use. This is covered by the Pipelines Safety Regulations 1996.

46 The CDM Rgulations only apply to the actual construction work of a pipeline. Prefabrication work on a pipeline in a fabrication workshop or yard is outside the scope of CDM.

Offshore Regulations

47 Offshore pipelines and pipeline works are subject to the general provisions of the Health and Safety at Work etc Act 1974 (HSW Act) and HSW Act Regulations, such as the Management of Health and Safety at Work Regulations 1992 (MHSWR), which extend outside Great Britain.

48 This legislation is applied offshore by the Health and Safety at Work etc Act 1974 (Application outside Great Britain) Order 1995. The activities covered include: pipe-laying operations and associated work such as trenching; the inspection, testing, maintenance, repair, alteration or renewal of pipelines; and diving operations in connection with such works. MHSWR also extends to the connected activities of loading, unloading, fuelling or provisioning vessels engaged in pipeline works.

49 Employers of workers engaged in pipelines works or connected activities, for example on pipelay barges, are also required under regulation 15(2) of the Offshore Installations and Pipeline Works (Management and Administration) Regulations 1995 to ensure that their workers know or have ready access to the address and telephone number of the HSE office covering the sector in which the pipeline works are taking place.

50 Thus, all occupational risks connected with offshore pipeline construction works are subject to the HSW Act and the associated inspection and enforcement regime.

Regulation 10

Work on a pipeline

Regulation

10

The operator shall ensure that modification, maintenance or other work on a pipeline is carried out in such a way that its soundness and fitness for the purpose for which it has been designed will not be prejudiced.

51 The purpose of this regulation is to ensure that any subsequent modification, maintenance or other work, such as inspection, of a pipeline should be carried out in such a way as not to affect detrimentally the pipeline's continuing fitness for purpose.

Regulation 11 Operation of a pipeline

Regulation 11

The operator shall ensure that -

(a) no fluid is conveyed in a pipeline unless the safe operating limits of the pipeline have been established; and

(b) a pipeline is not operated beyond its safe operating limits,

save for the purpose of testing it.

52 In order to operate the pipeline in a safe manner, the operator will need to draw up safe operating limits, which reflect the pipeline design, its operating history and its current and future condition, and ensure that it is operated and controlled within these limits.

53 For pipelines, safe operating limits may be specified in terms of maximum operating pressure and maximum and minimum temperature. In some cases safe operating limits will also take into account such matters as fluid velocities and any limits set on the composition of the fluid.

54 The regulation recognises that for the purposes of proof testing a pipeline to ensure that it is sound and fit for purpose, it is often necessary to test the pipeline to pressures beyond its maximum allowable operating pressure, the safe operating limit.

Regulation 12 Arrangements for incidents and emergencies

Regulation 12

The operator shall ensure that no fluid is conveyed in a pipeline unless adequate arrangements have been made for dealing with -

(a) an accidental loss of fluid from;

(b) discovery of a defect in or damage to; or

(c) other emergency affecting,

the pipeline.

55 This regulation requires that adequate arrangements are in place in the event of an incident or emergency relating to the pipeline. In particular arrangements should be in place for loss of containment and for discovery of damage to, or a defect in, the pipeline which requires immediate attention or action. The detail and scope of the arrangements will vary according to the type of pipeline, its location and the fluid being conveyed. Where a defect in, or damage to, a pipeline is found which could affect the safety of the pipeline, but not requiring immediate attention, then consideration will be needed of appropriate action in such circumstances.

56 In some circumstances it may be necessary for arrangements to be in place for emergencies which may have an affect on the pipeline. For example, arrangements should be in place covering an emergency on an offshore installation which may affect connected pipeline(s).

Relationship with other Regulations

Onshore Regulations

57 In the case of gas pipelines subject to the Gas Safety (Management)

Regulations 1996, these arrangements for incidents and emergencies may be referred to in the gas transporter's or network emergency co-ordinator's safety case.

Offshore Regulations

58 Regulation 8 of the Offshore Installations (Prevention of Fire, Explosion and Emergency Response) Regulations 1995 requires the installation operator to draw up an emergency response plan for the installation and this should cover the arrangements in place for emergencies which may affect the connected pipeline.

Regulation 13

Maintenance

Regulation 13

The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair.

59 This regulation deals with the requirement to maintain the pipeline to secure its safe operation and to prevent loss of containment. Maintenance is essential to ensure that the pipeline remains in a safe condition and is fit for purpose.

60 The operator needs to consider maintenance and inspection requirements for the pipeline. Examination and monitoring of the pipeline are part of routine maintenance. The operator needs to consider both how and when the pipeline should be surveyed and examined to validate and maintain it in a safe condition.

61 The extent of the work done to maintain a pipeline will depend on its material of construction, its location, the fluid conveyed and the condition under which it is operated. For example, for low pressure gas distribution and service pipelines onshore, the operator should monitor the pipeline to secure its safe operation. For major accident hazard pipelines, the maintenance plan should form part of the pipeline's safety management system.

62 It is important to recognise that a pipeline includes associated equipment such as valves, bridles and other primary attachments. It may also include launch and reception pig traps. These should be maintained, as necessary, to ensure that they are kept in efficient working order. Maintenance under this regulation also includes maintaining any safety system associated with the pipeline which has been provided to secure its safe operation.

63 A pipeline which is out of service should also be maintained in a safe condition; if it has been out of service for a significant period of time, detailed assessment of the condition of the pipeline will be necessary to ensure fitness for purpose before returning it to service.

Regulation 14

Decommissioning

Regulation 14

(1) The operator shall ensure that a pipeline which has ceased to be used for the conveyance of any fluid is left in a safe condition.

64 Pipelines should be decommissioned in a manner so as not to become a source of danger. Once a pipeline has come to the end of its useful life, it should be either dismantled and removed or left in a safe condition. Consideration should be given to the physical separation and isolation of the pipeline. It may be necessary to purge or clean the pipeline; due consideration should be given to the hazardous properties of any fluid conveyed in the pipeline or introduced during the decommissioning.

65 Depending on the physical dimensions of an onshore pipeline and its location, under the general provisions of the HSW Act, it may be necessary to consider the risk of the pipeline corroding and causing subsidence or acting as a channel for water or gases.

66 Offshore, pipelines should be either dismantled and removed or left in a condition where they will be not become a source of danger to people. It is likely that the riser section of an offshore pipeline will be dismantled. However, the extent of the obligation to remove the remainder of the pipeline will depend on the diameter of the pipeline, its location on the seabed, its stability and on subsea conditions. It should be noted in this context that the decommissioning (in statutory language, abandonment) of offshore pipelines is also subject to and regulated by the Petroleum Act 1987 and should be discussed with the Department of Trade and Industry, whose formal approval for decommissioning programmes is required before they can be implemented.

Regulation 14

(2) The operator of pipeline shall ensure that work done in discharge of the duty contained in paragraph (1) is performed safely.

67 Work done in carrying out the final decommissioning of a pipeline should be done in a safe and controlled manner.

Regulation 15 Damage to pipeline

Regulation 15

No person shall cause such damage to a pipeline as may give rise to a danger to persons.

68 This regulation applies to the operator of the pipeline, for example when carrying out maintenance on the pipeline, to ensure that the pipeline does not sustain damage through his actions which could give rise to danger to people. Equally this regulation applies to the actions of third parties since interference is the main cause of damage to pipelines leading to loss of containment.

69 In many cases the damage to a pipeline by a third party is accidental; it is important that such damage is reported to the pipeline operator. Failure to notify damage to a pipeline which ultimately affects the safety of others could be a breach of the HSW Act. Some third party incidents may not appear to have caused obvious or serious damage, however, these incidents should still be reported to the pipeline operator as the pipeline may have been weakened or its integrity impaired in some other way, eg damage to its corrosion protection coating.

70 It is important that the location of onshore pipelines, and in particular underground pipelines, is considered when carrying out building, excavation or dumping or other such work, as such activities may either cause damage to pipelines or deny access to them for maintenance purposes.

71 Similarly, when carrying out vessel or anchoring activities offshore the location of offshore pipelines should be considered. Information regarding the location of offshore pipelines is normally available from the Hydrographer of the Navy and included on Admiralty charts.

Regulation 16 Prevention of damage to pipelines

Regulation 16

For the purpose of ensuring that no damage is caused to a pipeline, the operator shall take such steps to inform persons of its existence and whereabouts as are reasonable.

72 It is important that third parties are made aware of the presence of a pipeline, and that information is available, where appropriate, regarding the location of the pipeline. For instance, where street work is to be undertaken information on the location of underground services including pipelines will be required. On request, pipeline operators should be able to give approximate locations of pipelines, usually in the form of plans.

73 Because of the problems associated with identification of underground pipelines, parallel running of similar pipelines in the street should be avoided; where it is unavoidable, consideration should be given to means of identifying each pipeline such as with coloured plastic marker tape or indicator tape incorporating a metallic tracer wire. A colour coded identification system used by utilities and local authorities is set out in the National Joint Utilities Group publication No 4 *The identification of small buried mains and services* April 1995.

74 The operator shall take reasonable steps to inform people of the existence of the pipeline and its whereabouts, and for major accident hazard pipelines there should be regular contact with owners/occupiers and tenants of the land through which the pipeline passes. This should include supplying information on the route of the pipeline.

75 Depending on the fluid conveyed, the pipeline location and the conditions under which it is conveyed, it may be appropriate to consider periodic surveying of its route to check on activities which might affect the pipeline.

76 Offshore, damage to pipelines may arise from fishing activities and anchoring. Consideration should be given to reducing the potential for damage to offshore pipelines by use of concrete coating, trenching, burial, protection structures or mattresses etc.

Relationship with other Regulations

77 As part of the offshore Pipeline Works Authorisation issued by the Department of Trade and Industry under the Petroleum and Submarine Pipelines Act 1975, information regarding the location of offshore pipelines is normally passed to the Hydrographer of the Navy for inclusion on Admiralty charts.

Regulation 17

Co-operation

Regulation 17

Where there are different operators for different parts of a pipeline, each operator shall co-operate with the other so far as is necessary to enable the operators to comply with the requirements of these Regulations.

78 This regulation places a duty on operators of different parts of a pipeline or a pipeline system to co-operate with other operators of that pipeline or system, where appropriate, to enable each of them to fulfil their duties under these Regulations. It does not mean that an operator of part of a pipeline can evade his own responsibilities by seeking to pass them to others. If an operator is capable of complying with a duty unaided, then the co-operation duty does not come into play. However, it is likely that where a pipeline or pipeline system has different operators for different parts of it, co-operation between each operator will be required in ensuring the health and safety of people or activities involving the pipeline.

Regulation 18

Dangerous fluids

Regulation 18

(1) The provisions contained in regulations 19 to 27 shall apply in relation to a pipeline in which a dangerous fluid is being, or is to be conveyed (in these Regulations referred to as a "major accident hazard pipeline").

Guidance 18

79 This regulation defines the pipelines with the potential to cause a major hazard accident which attract the additional duties under these Regulations: emergency shut-down valves, notifications, the preparation of a major accident prevention document, the preparation of emergency procedures and the preparation of an emergency plan by the local authority.

Regulation 18

(2) For the purpose of these Regulations a fluid is a dangerous fluid if it falls within a description in Schedule 2.

Guidance 18

80 Dangerous fluids which are brought within these requirements are listed in Schedule 2. Detailed guidance about which fluids are described as dangerous is given in the commentary on the Schedule.

Regulation 19

Emergency shut-down valves

Regulation 19

(1) The operator of a major accident hazard pipeline which -

(a) is connected to an offshore installation; and

(b) has an internal diameter of 40 millimetres or more,

shall ensure that the requirements contained in Schedule 3 are complied with in relation to the pipeline.

Guidance 19

81 Emergency shut-down valves (ESDVs) are required to be fitted to all risers of major accident hazard pipelines of 40 mm or more in diameter at offshore installations. Schedule 3 sets out the requirements for these ESDVs.

Regulation 19

(2) The duty holder in relation to an offshore installation to which a pipeline described in paragraph (1) is connected shall afford, or cause to be afforded, to the operator of the pipeline such facilities as he may reasonably require for the purpose of securing that the requirements contained in Schedule 3 are complied with in relation to the pipeline.

(3) In this regulation -

"duty holder", in relation to an offshore installation, means the person who is the duty holder as defined by regulation 2(1) of the 1995 Regulations in relation to that installation.

"the 1995 Regulations" means the Offshore Installations and Pipeline Works Management and Administration) Regulations 1995(a)*.*

(a) SI 1995/738.

Guidance 19

82 This regulation places a duty on the duty holder in relation to the offshore installation to provide the operator of the pipeline with such facilities as he requires to fulfil his duties as set out in Schedule 3.

Regulation 20

Notification before construction

Regulation

20

The operator shall ensure that the construction of a major accident hazard pipeline is not commenced unless he has notified to the Executive the particulars specified in Schedule 4 at least 6 months, or such shorter time as the Executive may approve, before such commencement.

83 This regulation requires the operator to notify HSE of certain details of a proposed new pipeline prior to its construction. The intention is that this notification should be made at the 'end of the concept design' stage, which will normally be at least 6 months prior to the start of construction. The notification must contain the information contained in Schedule 4. This regulation only requires a notification to HSE; this does not place any constraint on the operator to proceed to detailed design and construction.

84 This notification may form the first contact between the pipeline operator and HSE; earlier contact may be helpful. This notification should be made at a point where the design is sufficiently advanced to be able to set out, in general terms, the particulars required in Schedule 4 but not so late that the company has already committed itself to major expenditure. Once a pipeline has been built, it is very difficult and extremely costly to make changes.

85 Only a limited amount of information about the pipeline is required at this notification stage. Where some of the information cannot, at the time of notification, be fully specified, notification to HSE should go ahead, together with details of when the further information may be provided, by agreement between the operator and HSE.

86 This notification is aimed at triggering HSE's inspection arrangements and it will provide the basis for the start of a dialogue between the pipeline operator and HSE about arrangements to secure the proper construction and safe operation of the pipeline. The intention behind the notification is to ensure that HSE is made aware of the proposed pipeline before major expenditure has been committed, since it is at this early stage that the most recent and best practice of design, and use of materials, can be applied at least cost. The information that is supplied will help HSE to form a view on appropriate inspection arrangements.

87 The information to be supplied need only represent the particulars as far as they have been developed by this stage. It is likely that there may be minor changes to the information, however, where the changes are significant to the level of risk of the pipeline, these further details should be supplied to HSE.

88 Although for major projects, this notification will be made at an early stage and at least 6 months prior to the start of construction, there may be cases when a shorter notification period will be appropriate. HSE will be sympathetic to requests for shorter notification periods where good reason is demonstrated.

89 This may apply offshore to shorter lengths of pipeline or small projects, such as pipeline network extensions. There will also be cases which are a result of operational demands such as where there is a requirement to construct a pipeline from an installation for the purposes of well testing or evaluation. Cases when shorter notification is appropriate need the approval of HSE.

90 A reduced period of notification may be approved for short onshore pipelines, eg local pipelines to be built under section 2 of the Pipelines Act

1962, which may be viewed as relatively small projects where construction may be required to start over a shorter scale than six months.

91 Notification shall contain the details listed in Schedule 4. Notification should be sent to the appropriate office of HSE's Chemical and Hazardous Installations Division (CHID) in Aberdeen or Norwich (addresses below). As a general guide, pipelines located in Scotland or in Scottish waters are covered by the Aberdeen office, all other pipelines are covered by the Norwich office. Fax or other electronic transmission arrangements are acceptable.

Health and Safety Executive (CHID)
Lord Cullen House
Fraser Place
Aberdeen AB25 3UB
Tel: 01224 252500
Fax: 01224 252555

Health and Safety Executive (CHID)
122A Thorpe Road
Norwich
Norfolk NR1 1RN
Tel: 01603 275000
Fax: 01603 275055

Relationship with other Regulations

92 This notification does not form part of the role HSE undertakes as a consultee on the route of the pipeline for planning purposes. However, since HSE is consulted on, and assesses the route of, major accident hazard pipelines, both onshore and offshore, in practice the information required in the notification under this regulation will also be required for HSE to assess the route as a consultee.

Onshore pipelines

93 HSE is a consultee on the route of a land pipeline attracting the additional duties. The Department of Trade and Industry consults HSE on the route of cross-country pipelines and local planning authorities consult HSE on the route of local pipelines under the Pipelines Act 1962.

94 Through the licence condition of a public gas transporter under the Gas Act 1995, the route of high pressure gas pipelines need to be notified to HSE. In cases where the route does not comply with specific guidelines, HSE should be consulted on the proposed route.

Offshore pipelines

95 HSE is a consultee of the Department of Trade and Industry on the route of a proposed new pipeline under the Petroleum and Submarine Pipelines Act 1975.

Regulation 21

Notification before use

Regulation

21

The operator shall ensure that no fluid is conveyed in a major accident hazard pipeline, or conveyed following a period in which it has been out of commission (other than for routine maintenance), until the expiration of 14 days, or of such shorter period as the Executive may in that case approve, from the receipt by it of a notification of the date on which it is intended to convey or, as the case may be, resume the conveyance of fluid in the pipeline.

96 This notification, of the intention to bring the pipeline into use, is required so that HSE is made aware that the dangerous fluid is to be introduced into the pipeline.

97 A notification period of 14 days is required; though in exceptional circumstances a shorter notification period may be permissible if agreed by HSE.

98 This notification applies to the first introduction of the dangerous fluid into the pipeline. However, this regulation also applies to circumstances where the pipeline may have been taken out of commission (other than for routine maintenance, planned or emergency repair) and is to be brought back into use.

99 It is not intended that notification of bringing back into use will be required after it has been shut down for routine maintenance. Routine maintenance includes work such as valve lubrication, maintenance of pig traps, maintenance and replacement of cathodic protection equipment, function testing of pipeline equipment and instrumentation, running repair work (slight surface damage repairs, coating and wrapping repairs, rectification of spans etc). However, in cases where the pipeline has been subject to major modifications or remedial work which has been notified to HSE under regulation 22, notification of bringing back into use is required.

100 Notification can be made in writing, by fax or by telephone to the appropriate office of HSE's Chemical and Hazardous Installations Division (CHID) in Aberdeen or Norwich. Other electronic transmission arrangements are also acceptable. Information should include the pipeline identification, name of the operator/point of contact and date the pipeline is to be used for the first time or reused.

Regulation 22

Notification in other cases

Regulation 22

(1) Where there is a change of operator of a major accident hazard pipeline, or of his address, the operator shall notify any such change to the Executive within 14 days thereafter.

(2) Subject to paragraph (3), in the case of a major accident hazard pipeline the construction of which has commenced, or has been completed, the operator shall ensure that no event of a kind described in Schedule 5 takes place until the expiration of 3 months, or such shorter time as the Executive may in that case approve, from the receipt by the Executive of particulars specified in that Schedule in relation to such event.

(3) Where an event of a kind described in Schedule 5 takes place in an emergency, the operator shall notify to the Executive the particulars specified in that Schedule as soon as is reasonably practicable.

22

101 This regulation concerns any significant changes to the pipeline which affect the level of risk. Notification to HSE is required of certain changes such as changes in the operating regime, major modifications to the pipeline, changes in fluid and cessation of use of the pipeline.

102 Schedule 5 sets out instances when notification is required; detailed guidance is given in the commentary to the Schedule.

103 The notification should be made to HSE at completion of the concept design for the change. The intention behind the 3-month notification period is to ensure that HSE is made aware of the proposed changes to a pipeline once the details have been established but before major expenditure has been committed. The information that is supplied will help HSE to form a view on appropriate inspection arrangements. However, urgent works may be carried out with shorter notification periods with the approval of HSE.

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104 Notification of change of the pipeline operator, or his address, should be made within 14 days of the change being known.

105 Notification should be sent to the appropriate office of HSE's Chemical and Hazardous Installations Division (CHID) in Aberdeen or Norwich. Notification in writing, by fax or other electronic transmission arrangements is acceptable.

Regulation 23

Major accident prevention document

Regulation

(1) The operator shall, before the design of a major accident hazard pipeline is completed prepare, and thereafter revise or replace as often as may be appropriate, a document relating to the pipeline containing, subject to paragraph (2) sufficient particulars to demonstrate that -

(a) all hazards relating to the pipeline with the potential to cause a major accident have been identified;

(b) the risks arising from those hazards have been evaluated;

(c) the safety management system is adequate; and

(d) he has established adequate arrangements for audit and for the making of reports thereof.

(2) Paragraph (1) shall only require the particulars in the document referred to in paragraph (1) to demonstrate the matters referred to in that paragraph to the extent that it is reasonable to expect the operator to address them at the time the document is prepared or revised.

(3) Where the document referred to in paragraph (1) describes any health and safety arrangements or procedures to be followed, the operator shall ensure that those arrangements or procedures are followed unless in particular circumstances of the case it is not in the best interests of the health and safety of persons to follow them, and there has been insufficient time to revise or replace the document to take account of those circumstances.

(4) In this regulation -

"audit" means systematic assessment of the adequacy of the safety management system, carried out by persons who are sufficiently independent of the system (but who may be employed by the operator) to ensure that such assessment is objective; and

"safety management system" means the organisation, arrangements and procedures established by the operator for ensuring that the risk of a major accident is as low as is reasonably practicable.

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Guidance

23

106 This regulation deals with the operator's overall aims and principles of action for the control of the aspects of design, construction and installation, operation, maintenance and final decommissioning which have a bearing on the health and safety arrangements with respect to the control of major accident hazards.

107 The major accident prevention document (MAPD) initially shall be prepared during the design of the pipeline. Where there is a change in the fluid conveyed which results in an existing non-major accident hazard pipeline falling within the definition of a major accident hazard pipeline, then this will

require a reassessment of the pipeline design. The MAPD should be prepared at this reassessment stage.

Major accident prevention document

108 The MAPD is a management tool to ensure that the operator has assessed the risk from major accidents and has introduced an appropriate safety management system to control those risks. The aim is that the document will explain how the operator has established satisfactory management systems to control the major accident hazards of the pipeline or pipeline system.

109 The MAPD can be made up of a number of documents. A covering document may be prepared which need only be a short statement setting out the health and safety arrangements with respect to the control of the major accident hazards. This covering document should, however, refer to more detailed documents which make up the MAPD. These will include the safety management system detailing arrangements such as training procedures, management responsibilities and auditing arrangements which set down how that operator's policy to control major accident hazards will be put into action. It is important to recognise that safety management is an integral part of the normal business management of an organisation.

110 The MAPD should contain sufficient information to demonstrate that all hazards relating to the pipeline with the potential to cause a major accident have been identified and the risks arising from those hazards have been evaluated.

111 This requires the operator to identify the ways in which a major accident may occur and to evaluate the risks arising from those hazards. Account will need to be taken of hazards during the various stages of the life cycle of the pipeline including commissioning, excursions from normal operating limits, maintenance and any other activity which may affect the pipeline. This also requires consideration of matters such as the nature of the dangerous fluid being conveyed, the conditions under which it is conveyed and the susceptibility of the pipeline system to damage.

112 Where appropriate, an operator can produce a single MAPD for all his pipeline systems, rather than produce a separate MAPD for each individual pipeline. The MAPD must reflect the hazards and risks associated with all the major accident hazard pipelines covered by it and the supporting safety management system should be applicable to all those pipelines.

Safety management system

113 The pipeline MAPD should be supported by the safety management system which is in place for the control of the safety of the pipeline throughout its life cycle from its concept design through to decommissioning. The safety management system will need to consider the interfaces between the pipeline design, construction, operation and maintenance. Key elements of safety management are management's leadership, commitment and accountability. Both an adequate organisation and sufficient resources are necessary to implement the operator's policy with respect to the control of major accident hazards effectively.

114 It will be necessary for the MAPD, and the associated management arrangements, to be updated at various stages throughout the life cycle of the pipeline. It is recognised that, for example, at the concept design stage, it may not be practicable to describe future management procedures for controlling risks to people during the operation of the pipeline.

115 A clear line of responsibility and accountability for the control of health and safety needs to be established from the highest management down. As a pipeline moves through the various stages of its life cycle, the line of command and accountability might change; the basis for change and arrangements for bringing it about should be set out in the safety management system.

116 The safety management system should cover the organisation and arrangements for preventing, controlling and mitigating the consequences of major accidents. These include specific attention to management competencies and procedures necessary to minimise the possibility of these events and if they occur, to limit their potential for causing harm. The safety management system is likely to set out the management control and monitoring procedures to be followed in critical areas such as:

- ensuring that systems are in place to provide for the satisfactory co-ordination of all those involved in the safety of the pipeline;
- establishment of operating procedures for normal operation of the pipeline as well as abnormal operation and non-routine operations;
- communication of those procedures to relevant personnel, eg through instructions, operating manuals, permits to work;
- establishment of adequate systems for the selection, control and monitoring the performance of contractors so that their working methods and standards are such as to ensure the safety of their activities;
- establishment of standards for training, for all people with a significant role to play in the safety of the pipeline. This is likely to extend to the highest levels of management and will also deal with training of those in supporting roles such as engineers and contractors;
- the procedures adopted for the systematic appraisal of the major accident hazards associated with the pipeline and evaluation of the risks arising from those hazards;
- procedures for the planning of modifications to be made to the pipeline.

117 The importance of the arrangements for achieving the initial and continuing safety of the pipeline requires that the safety management system pay particular attention to these arrangements. These include the arrangements for ensuring the soundness and fitness for purpose at the various stages in the life cycle of the pipeline.

118 It will be necessary that suitable and sufficient records of a pipeline are kept, including the design, construction, operation, and maintenance, so as to be able to demonstrate that the pipeline is safe.

119 Specific arrangements for dealing with emergencies form part of the safety management system. The emergencies to be addressed will result from the hazard identification and risk assessment process. Having identified all types of emergency events, plans and procedures should be prepared for dealing with these. The preparation of emergency procedures is covered in regulation 24.

Audit

120 Once a systematic and formalised management approach to safety has been implemented, it becomes necessary to audit the system performance. This regulation requires that arrangements are in place for audits to be made of the safety management system which address its adequacy in achieving the safety of the pipeline. This requires a demonstration that there are clearly defined

systems for audit of the quality of the design, construction, operation, maintenance and finally decommissioning of the pipeline. As for other aspects of the safety management system, performance standards for the audit and review process should be set and monitored. The people carrying out the audits should be sufficiently independent to ensure that such an audit is objective.

121 Auditing is referred to in HSE's publication *Successful health and safety management* as 'the structured process of collecting independent information on the efficiency, effectiveness and reliability of the total safety management system and drawing up plans for corrective action'.

122 In order to provide the necessary independent perspective and to maximise the benefits from the auditing process, audits should be carried out by competent people outside the line management chain of the areas or activities being audited.

123 Performance standards should be established to identify responsibilities, timings, and systems for reviewing. To ensure effectiveness, those responsible for implementing any remedial action should be clearly identified and deadlines set for the completion of such action. Audit should be viewed by all within the organisation as an opportunity to identify weaknesses in management control or procedures.

Relationship with other Regulations

Offshore Regulations

124 The definition in the Offshore Installations and Pipeline Works (Management and Administration) Regulations 1995 excludes pipelines, nevertheless there is a provision for any part of a pipeline connected to an installation and within 500 metres of the installation to be 'deemed' to be part of that installation, which is appropriate when considering the safety of people on the installation and possible consequences of a pipeline failure.

125 For the same reasons, offshore pipelines fall partly within the scope of the offshore safety case regime. Under Schedules 1 and 2 of the Offshore Installations (Safety Case) Regulations 1992 (SCR), the safety case must demonstrate that full account has been taken of risks to the installation, and to the people on it, arising from the pipeline. This entails, for any pipeline connected to an installation, giving a description of the design and hydrocarbon inventory of the pipeline demonstrating that an integrated approach will be taken to the management of the installation and the pipeline so risks from a major accident are at the lowest level that is reasonably practicable. The SCR provisions regarding pipelines at the interface are not enough in themselves to ensure the safe operation and integrity of offshore pipeline systems as a whole. However, work done in the safety case to identify the safety critical elements of a pipeline can be used in the pipeline MAPD.

Onshore Regulations

126 The Gas Safety (Management) Regulations 1996 (GS(M)R) are concerned essentially with the safe management of the flow of gas through public gas transporters' networks. Those Regulations require a safety case to be prepared which should contain sufficient information to demonstrate that the transporter's operation is safe, and that the risks to the public and employees are as low as is reasonably practicable. Schedule 1 of those Regulations lists the particulars to be included in the safety case. It is not intended that the requirements of Schedule 1 of GS(M)R should duplicate those in the Pipelines Safety Regulations 1996 (PSR).

Guidance

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127 There are some areas of unavoidable overlap between these two sets of regulations, in particular the duties dealing with safety management systems (the MAPD in PSR and the safety case in GS(M)R). Although PSR covers safety management systems, such systems are concerned solely with pipeline integrity and the consequences of its loss. In contrast GS(M)R is concerned with the safe management of the supply of gas to users and the management of the flow of gas. To minimise duplication, those parts of any documents which are prepared under the requirements in PSR can be referenced in the GS(M)R safety case.

Regulation 24

Emergency procedures

Regulation

(1) The operator shall ensure that no fluid is conveyed in a major accident hazard pipeline unless -

(a) such appropriate organisation and arrangements as shall have effect; and

(b) the procedures which shall be followed in different circumstances,

in the event of an emergency relating to the pipeline have been established and recorded.

(2) The operator shall revise or replace the record of the organisation, arrangements and procedures referred to in paragraph (1) as often as may be appropriate.

(3) The operator shall ensure that the organisation, arrangements and procedures referred to in paragraph (1) are tested, by practice or otherwise, as often as may be appropriate.

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Guidance

128 This regulation requires that adequate emergency procedures are prepared for dealing with the consequences of a major accident involving a pipeline. The detail and scope of a major accident will vary according to the pipeline, its location and the fluid conveyed and the operator will need to consider these aspects when drawing up the emergency procedures.

129 The emergency procedures for an offshore pipeline should cover the pipeline, as an entity, as well as the interface with offshore and onshore installations. The plan should cover the procedures needed to respond to all foreseeable major accidents involving a pipeline, ie it should set out who does what, when and how and to what effect, in the event of an emergency. It should describe arrangements at the interfaces with onshore and offshore installations to ensure that they dovetail.

130 For onshore pipelines, it is important that the pipeline operator and local authorities liaise to ensure that the emergency procedures and the local authorities' emergency plans are dovetailed in order to provide a comprehensive and effective response to emergencies.

131 The emergency procedures should be kept in an up-to-date operational state. They should be revised as necessary to ensure that they cater for any changes in operation that might have a significant effect on the procedures.

132 Although this regulation does not specify the frequency at which tests should be carried out, it is important that the procedures are exercised and tested with sufficient frequency and depth so that they can be relied upon to work effectively in an emergency. The procedures should be monitored and

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reviewed in the light of exercises and tests and of any practical experiences gained from operating the plan in a real emergency, and remedial action identified and taken.

Relationship with other Regulations

Offshore Regulations

133 Regulation 8 of the Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (PFEER) requires the owner or operator of an installation to prepare an emergency response plan for the installation after consulting with people likely to become involved in emergency response. Consultees will include the pipeline operator, operators and owners of other installations as necessary, for the plan to reflect agreement about shutting down pipelines for emergency response. The relevant parts of the pipeline emergency procedures required by the Pipelines Safety Regulations 1996 and the emergency response plan prepared through the requirement in PFEER should be compatible.

Regulation 25

Emergency plans in case of major accidents

Regulation

(1) A local authority which has been notified by the Executive that there is, or is to be a major accident hazard pipeline in its area shall before the pipeline is first used or within 9 months of such notification, whichever is later, and subject to paragraph (5), prepare an adequate plan detailing how an emergency relating to a possible major accident in its area will be dealt with.

(2) In preparing the plan pursuant to paragraph (1) a local authority shall consult the operator of the pipeline, the Executive and any other persons as appear to the authority to be appropriate.

(3) A local authority which has prepared a plan pursuant to paragraph (1) shall, as often as is appropriate and, in any case, at least every three years review the plan and make such revision as is appropriate.

(4) The operator of a major accident hazard pipeline shall ensure that every local authority through whose area the pipeline will pass is furnished promptly with such information as it may reasonably require in preparing the plan referred to in paragraph (1).

(5) It shall be deemed to be sufficient compliance with the requirement in paragraph (1) as to the time by which a plan is to be prepared, where such time is exceeded by reason of waiting for information referred to in paragraph (4) which has been promptly required.

(6) Where a pipeline passes or is to pass through the areas of two or more local authorities the duties under this regulation may be discharged by them where they prepare a single plan.

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134 Local authorities at county or equivalent level, once notified of a pipeline by HSE, are required by this regulation to prepare an emergency plan for each major accident hazard pipeline passing through their area. The requirement under these Regulations is for emergency plans which should specifically relate to the protection of the health and safety of people, not environmental damage.

135 Though local authorities will already have general emergency plans, it will be necessary to have either pipeline specific plans or to include specific reference to each major accident pipeline and how their emergency

arrangements are integrated into the existing emergency provisions in the area covered by the authority.

136 It is intended that emergency plans should only be drawn up or amended after consultation with bodies who may be able to contribute information or advice. In all cases this will include the emergency services (fire, police and ambulance), hospitals, the pipeline operators and HSE. Other bodies to be consulted will depend on circumstances and could include adjacent local authorities through whose area the pipeline passes, government departments dealing with agriculture, the Environment Agency or its Scottish equivalent, the Scottish Environment Protection Agency, and companies providing water services.

137 Full liaison and effective two-way flow of information is required between the pipeline operator and the local authority. Information from the pipeline operator is needed to enable the authority to draw up the emergency plan, and information from the authority should be available to the pipeline operator to assist in the preparation of the pipeline emergency procedures so as to achieve dovetailing between the pipeline emergency procedures and the local authority's emergency plan.

138 The pipeline operator should provide information about the type and consequences of possible major accidents and the likely effects. Information should also be provided on the route of the pipeline, the fluid conveyed and the operating conditions, location of shut-off valves and emergency control arrangements.

139 In the event of an incident involving a pipeline, it is important there is effective communication between the emergency services and pipeline control centre.

140 The emergency plan should be a written document, in a format which can be used readily in emergencies, and kept up to date to reflect changes in risk, procedures, hardware and personnel. The authors of the plan must address all relevant aspects including the following:

(a) the types of accidents to people to be taken into account;

(b) organisations involved including key personnel and responsibilities and liaison arrangements between them;

(c) communication links including telephones, radios and standby methods;

(d) special equipment including fire-fighting materials, damage control and repair items;

(e) technical information such as chemical and physical characteristics and dangers of the fluid conveyed;

(f) information about the pipeline including route of the pipeline, location of shut-off valves and emergency control arrangements;

(g) evacuation arrangements;

(f) contacts and arrangements for obtaining further advice and assistance, eg meteorological information, transport, first aid and hospital services, water and agricultural information;

(i) arrangements for dealing with the press and other media interests.

141 Since an incident involving a pipeline could occur at any point along its length, it is often inappropriate to provide location specific advice along the

whole length of the pipeline. The plan is likely to focus on those parts of the pipeline which are vulnerable to damage such as road, rail and river crossings and other areas of higher risk. Pipeline plans for this reason are likely to be generic and flexible in nature.

142 In discharging their duties, local authorities must take reasonable steps to ensure that they are preparing plans which will prove adequate in the event of major accidents. This will involve checking and testing the various components of each plan during its development.

143 The local authority shall review, and where necessary, revise and update the plan at suitable intervals so that it can be relied upon to work effectively in an emergency. The maximum interval for review should be every three years.

144 For existing pipelines, local authorities are allowed 18 months from notification of the pipeline to prepare the major accident hazard emergency plans (see regulation 27(6)).

145 For all new pipelines, the plan is required before the pipeline is brought into use, or within 9 months of notification of the pipeline to the local authority by HSE, whichever is the later.

Regulation 26

Charge by a local authority for a plan

Regulation 26

(1) A local authority which prepares, reviews or revises a plan pursuant to paragraph (1) or (3) of regulation 25 may charge a fee, determined in accordance with paragraphs (2) to (4), to the operator of the pipeline to which the plan relates.

(2) A fee shall not exceed the sum of the costs reasonably incurred by the local authority in preparing, reviewing or revising the plan and, where the plan covers pipelines of which there are more than one operator, the fee charged to each operator shall not exceed the proportion of such sum attributable to the part or parts of the plan relating to his pipelines.

(3) In determining the fee no account shall be taken of costs other than the costs of discharging functions in relation to those parts of the plan which relate to the protection of health or safety of persons and which were costs incurred after the coming into force of these Regulations.

(4) The local authority may determine the cost of employing a graded officer for any period on work appropriate to his grade by reference to the average cost to it of employing officers of his grade for that period.

(5) When requiring payment the local authority shall send or give to the operator of the pipeline a detailed statement of the work done and costs incurred including the date of any visit to any place and the period to which the statement relates; and the fee, which shall be recoverable only as a civil debt, shall become payable one month after the statement has been sent or given.

146 This regulation enables the local authorities who are responsible for preparing and keeping up-to-date emergency plans required under regulation 25 to recover the cost of undertaking this work from the pipeline operator.

147 The local authority may only recover costs that have been reasonably incurred. There may be locations where several pipelines are co-located, so the local authority may decide to prepare one emergency plan covering all the pipelines. In such an event each pipeline operator should be charged for only that part of the costs which can be attributed to the pipeline under his control.

Guidance

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148 The charge made may only be for the cost of preparing the plan itself and of any changes necessary to keep it up to date. It does not cover the cost of emergency equipment (eg fire appliances) considered necessary for the operation of the plan. Furthermore, the charge should relate only to those parts of the emergency plan concerned with the health and safety of people, not with environmental damage.

149 The charge made may be based on the time spent by officers of appropriate grades. The average costs of their employment overheads as well as salary may be taken into account.

150 In presenting a charge to a pipeline operator, the local authority should provide an itemised, detailed statement of work done and cost incurred. Any dispute arising over the charge has to be decided in the civil courts. HSE has no enforcement role for the recovery of cost incurred by a local authority in respect of emergency planning.

Regulation 27

Transitional provision

Regulation

27

(1) In the case of a pipeline, the construction of which is commenced within 6 months after the coming into force of these Regulations, it shall be sufficient compliance with regulation 20 if the particulars specified in Schedule 4 are notified to the Executive within 3 months after the coming into force of these Regulations.

Guidance

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151 For major accident hazard pipelines where the construction is commenced within 6 months of these Regulations coming into force, the information required in regulation 20 and Schedule 4 should be notified to HSE within 3 months.

Regulation

27

(2) Subject to paragraph (3), in the case of a major accident hazard pipeline, the construction of which was commenced (and whether or not completed) before the coming into force of these Regulations the particulars specified in Schedule 4 (or, in the case of paragraphs 3, 4, 5, 6 and 8 particulars, where appropriate, of the actual route of the pipeline or of the riser, materials used, fluid conveyed, and the temperature and pressure, and maximum rate of flow of that fluid) shall be notified to the Executive within 6 months after such coming into force.

(3) Paragraph (2) shall have effect where, pursuant to regulation 3(1) of the Notification of Installations Handling Hazardous Substances Regulations 1982(a), the particulars relating to that pipeline specified in Part II of Schedule 2 to those Regulations have been supplied before such coming into force.

(a) SI 1982/1357.

Guidance

27

152 For existing major accident hazard pipelines, or ones under construction, the information required by regulation 18 of Schedule 4 should be notified to HSE within 6 months of the Regulations coming into force, unless the pipeline has been notified to HSE through the notification requirement in the Notification of Installations Handling Hazardous Substances Regulations 1982.

Regulation

27

(4) In the case of a pipeline, the design of which was completed before the coming into force of these Regulations, or within 12 months after such coming into force, regulation 23 shall have effect as if, for the words "before the design of a major accident hazard pipeline is completed" in paragraph (1) of that regulation there were substituted the words "within 12 months after the coming into force of these Regulations".

Guidance

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153 Where a major accident prevention document (regulation 23) is required for existing major accident hazard pipelines and for proposed new pipelines, where the concept design will be completed within 12 months of the Regulations coming into force, the MAPD should be in place by 11 April 1997.

Regulation

27

(5) In the case of a pipeline which was first used before the coming into force of these Regulations it shall be sufficient compliance with the requirement in regulation 24(1) where the matters referred to therein are recorded within 6 months after the coming into force of these Regulations.

Guidance 27

154 For existing major accident hazard pipelines, the emergency procedures should be in place within 6 months of the Regulations coming into force.

Regulation

27

(6) Where a local authority receives a notification referred to in paragraph (1) of regulation 25 within 6 months after the coming into force of these Regulations, that regulation shall have effect in relation to the pipeline notified as if the reference in that paragraph to 9 months were a reference to 18 months.

Guidance 27

155 For existing pipelines a local authority, once notified of a major accident hazard pipeline, is allowed 18 months to prepare its emergency plan.

Part IV Miscellaneous

Regulation 28

Defence

Regulation

28

(1) In any proceedings for an offence for a contravention of any of the provisions of these Regulations it shall, subject to paragraphs (2) and (3), be a defence for the person charged to prove -

(a) that the commission of the offence was due to the act or default of another person not being one of his employees (hereinafter called "the other person"); and

(b) that he took all reasonable precautions and exercised all due diligence to avoid the commission of the offence.

(2) The person charged shall not, without leave of the court, be entitled to rely on the defence in paragraph (1) unless, within a period ending seven clear days -

(a) before the hearing to determine mode of trial, where the proceedings are in England or Wales; or

(b) before the trial, where the proceedings are in Scotland,

he has served on the prosecutor a notice in writing giving such information identifying or assisting in the identification of the other person as was then in his possession.

(3) For the purpose of enabling the other person to be charged with and convicted of the offence by virtue of section 36 of the 1974 Act, a person who establishes a defence under this regulation shall nevertheless be treated for the purposes of that section as having committed the offence.

Guidance

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156 It shall be the operator's responsibility to ensure that any other person contracted to perform work does what is required in helping to meet the legal obligation set by these Regulations. The operator will therefore need to put in place suitable arrangements to ensure proper performance of functions required under these Regulations. Regulation 28(1) offers a defence in legal

Guidance

proceedings, if it can be shown that a contravention of the Regulations is due to an act or default of another person and the operator exercised all due diligence. It should be noted that where the commission of an offence is due to the act or default of another person, HSE has powers, through section 36 of the Health and Safety at Work etc Act 1974 (HSW Act), to prosecute the other person.

Regulation 29

Certificates of exemption

Regulation 29

(1) Subject to paragraph (2) and to any of the provisions imposed by the Communities in respect of the encouragement of improvements in the safety and health of workers at work, the Executive may, by a certificate in writing, exempt any person, pipeline or class of persons or pipelines from any requirement or prohibition imposed by these Regulations and any such exemption may be granted subject to conditions and with or without limit of time and may be revoked by a certificate in writing at any time.

(2) The Executive shall not grant any such exemption unless, having regard to the circumstances of the case and, in particular, to -

(a) the conditions, if any, which it proposes to attach to the exemption; and

(b) any other requirements imposed by or under any enactments which apply to the case,

it is satisfied that the health and safety of persons who are likely to be affected by the exemption will not be prejudiced in consequence of it.

Regulation 30

Repeal of provisions of the Pipe-lines Act 1962

Regulation 30

Sections 20 to 26, 27 to 32 and 42 of the Pipe-lines Act 1962(a) are hereby repealed.

(a) 1962 c.58; section 24 was repealed by SI 1974/1986; and section 26A was inserted by section 26 of the Petroleum Act 1987 (1987 c.12).

Guidance 30

157 This regulation sets out the sections of the Pipelines Act 1962 (PA62) which are repealed by these Regulations. These sections are relevant statutory provisions of the HSW Act. Safety notices served by HSE under PA62 do not apply after these Regulations come into force.

158 Section 37 of PA62 which requires notifications of certain pipeline accidents to the emergency services etc. is not being repealed by these regulations since this section covers notifications which may include environmental effects such as pollution of water.

Regulation 31

Revocation and modification of instruments

Regulation 31

(1) The instruments specified in column 1 of Part I of Schedule 6 shall be revoked to the extent specified in column 3 of that Part.

(2) The Notification of Installations Handling Hazardous Substances Regulations ("the 1982 Regulations") shall have effect subject to the modifications of those Regulations specified in Part II of Schedule 6.

Guidance

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159 This regulation sets out the revocations and modification of statutory instruments associated with these Regulations and also listed in Schedule 6.

160 The Notification of Installations Handling Hazardous Substances Regulations 1982 have been modified to remove the requirement to notify certain pipelines to HSE contained in those Regulations.

BS 8010 : Part 1 : 1989
UDC 621.644 : (21) :.001.8

附錄二

British Standard Code of practice for

Pipelines

Part 1. Pipelines on land: general

Canalisations. Code de bonne practique
Partie 1. Canalisations aériennes — Généralités

Leitfaden für Rohrleitungen
Teil 1. Überlandrohrleitungen; Allgemeines

Foreword

This Part of BS 8010 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee. The standard is to be published in four Parts to form a complete revision of all Parts of CP 2010 as follows.

Part 1	Pipelines on land: general
Part 2	Pipelines on land: design, construction and installation
Part 3	Pipelines subsea: design, construction and installation
Part 4	Pipelines on land and subsea: operation and maintenance

This Part 1 (which supersedes CP 2010 : Part 1 : 1966 which is withdrawn) contains general information which is relevant to pipeline construction for a variety of transported substances. It deals with those aspects of pipeline development which affect the owner and occupier of land through which the pipeline passes.

Part 1 is divided into six sections. Definitions and general details are given in section one. Section two gives recommendations on the routing of pipelines and section three on the acquisition of the land and rights of way, compensation and legal documents. Section four deals with the construction of pipelines and the reinstatement of the land. The aspects of operation, maintenance and inspection are briefly examined in sections five and six and are to be dealt with fully in Part 4.

A list of principal Acts of Parliament and Statutory Instruments is included in appendix A.

A flow chart for implementation of a pipeline project is included as appendix B.

Part 2 is to be divided into several Sections each of which contains information on the design, construction and installation of a pipeline in a particular material. These Sections are to be published as separate documents as follows.

Section 2.1	Ductile iron*
Section 2.2	Steel for water and associated products
Section 2.3	Asbestos cement
Section 2.4	Prestressed concrete*
Section 2.5	Glass reinforced thermosetting plastics
Section 2.6	Thermoplastic (under consideration)
Section 2.7	Precast concrete
Section 2.8	Steel for oil, gas and associated products

These Sections are not intended to replace or duplicate hydraulic, mechanical or structural design manuals.

Part 3 will include information relevant to the design, installation and commissioning of subsea pipelines in steel and other materials.

Part 4 will contain advice on the operation and maintenance of pipelines and will be in Sections related to the conveyed material.

Until such time as each Part and Section of BS 8010 is published the relevant Part of CP 2010 will remain the applicable code.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

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* Published

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Section one. General

1.1 Scope

This Part of BS 8010 gives recommendations on the installation of pipelines on land. It deals with those aspects of acquisition of land and other rights, construction, operation and maintenance, which affect land, and which are common to all applications and materials on land.

Principal Acts of Parliament are listed in appendix A. These Acts enable pipelines to be constructed and regulate procedures. A flow chart for the implementation of a pipeline project given in appendix B relates the required procedures.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

1.2 Definitions

For the purposes of this Part of BS 8010 the following definitions apply.

1.2.1 pipeline. A line of pipes, of any length, without frequent branches. It does not include piping systems such as process plant piping within refineries, factories or treatment plants.

1.2.2 on land. Refers to a pipeline laid on or in land whose surface is above high water mark, including those sections laid under inland watercourses.

1.2.3 subsea. Refers to a pipeline laid under maritime waters and estuaries, and the shore below high water mark.

1.2.4 promoter. An organization that seeks to install, operate and maintain a pipeline under statutory powers.

1.2.5 lease. A legally binding agreement granted by a landowner to the promoter, for a determinable period of time, whereby essentially the ownership of the land is transferred to the promoter for use during that period.

1.2.6 easement. A legally binding agreement granted by a landowner to the promoter of a pipeline, either in perpetuity or for a long term, which sets out the rights and obligations of both parties, (and their respective successors in title) in relation to the matter, but under which ownership of the land remains with the landowner.

1.2.7 wayleave. An agreement (similar in nature but less specific than an easement) granted by a landowner to the promoter, permitting the promoter to execute works on the terms specified.

1.2.8 statutory notice. A notice issued under an Act of Parliament by the promoter to a landowner, occupier or relevant authority stating the statutory powers which the promoter will exercise in surveying, installing, operating and maintaining a pipeline. Such notice is sometimes required to be displayed for public comment.

1.2.9 working width. A strip of land, usually wider than that covered by an easement, lease or wayleave, which is used by the contractor for the purpose of installing a pipeline.

1.2.10 pipeline spread. A continuous length of sequential pipeline installation on which the contractor is currently working.

1.2.11 header drain. A length of land drainage pipe, usually installed parallel to a pipeline, for the purpose of conveying sub-surface water from existing land drainage systems severed by a pipeline.

1.2.12 cathodic protection. A system to reduce the rate of corrosion of ductile iron and steel pipes, and the ferrous compounds of pipelines in other materials, by regulating the electrical potential between a pipeline and the surrounding ground.

1.3 Safety

Specific safety matters are dealt with at appropriate places in the text of this and the other Parts of this standard.

There is a statutory requirement to provide for the health, safety and welfare of all employees and members of the public in connection with the design, construction, operation and maintenance of pipelines under the Factories Act 1961, the Factories Act (Northern Ireland) 1965, the Health and Safety at Work etc. Act 1974, the Health and Safety at Work (Northern Ireland) Order 1978, and Regulations enacted under these. Attention is also drawn to guidance notes published by appropriate Authorities.

Compliance with the Acts and Regulations requires knowledge of the relevant statutory notices, registers, records and forms. There are also British Standards which are particularly directed to health and safety considerations, and these will be referred to in this and other Parts of BS 8010, as appropriate.

1.4 Insurance

Promoters should ensure that there is adequate third party insurance in force during design, installation and subsequent operation of pipelines.

2.1 General

2.1.1 Economic, technical and safety considerations are the primary factors governing the choice of pipeline routes. The shortest route may not be the most suitable, and physical obstacles, environmental and other factors should be considered.

2.1.2 The main factors influencing routing are:

- (a) contents of the pipeline and operating conditions;
- (b) terrain and subterranean conditions;
- (c) hazards;
- (d) existing and future land use;
- (e) permanent access;
- (f) transport facilities and utility services;
- (g) agricultural practice;
- (h) environmental impact.

2.1.3 Other considerations apply to underwater pipelines, namely:

- (a) underwater environment;
- (b) waterborne traffic;
- (c) fishing;
- (d) underwater development;
- (e) bed conditions.

NOTE. Subsea pipelines will be covered in detail in BS 8010 : Parts 3* and 4*.

2.1.4 Consultations should be held as early as possible during route selection, with appropriate organizations, in respect of their existing and future developments. These organizations include:

British Coal
British Geological Survey
British Pipeline Agency
British Railways Board and other statutory Railways
British Telecom and other telecommunications operators
British Waterways Board
Civil Aviation Authority
Country Landowners' Association
Council for the Preservation of Rural England
County, District and Parish Councils and London Boroughs
Electricity, Gas and Water Authorities
Government Departments
Independent pipeline operators
Independent developers of mineral rights
Internal Drainage Boards
Landowners and occupiers
Local Trusts for nature conservation and archaeology
National Farmers' Union
National Park Authorities
Nature Conservancy Council
Navigation: Harbour Authorities

or the equivalent national and local organizations which in Scotland include:

South of Scotland Electricity Board
North of Scotland Hydro Electric Board
Regional and Islands Councils
Scottish River Purification Boards
National Trust for Scotland
National Farmers Union of Scotland
Scottish Landowners' Federation
Scottish Woodland Owners' Association

In appropriate circumstances detailed consultation may be required with local and/or specialized organizations.

2.2 Operating conditions and hazards

2.2.1 The operating conditions in pipelines affect route selection. The main parameters concerned are:

- (a) the nature of the contents;
- (b) maximum working pressure;
- (c) peak flow rate;
- (d) pipeline material and diameter.

2.2.2 For a given pipeline material, diameter and duty consideration should be given to:

- (a) the probability of fracture and its consequences;
- (b) the maximum possible size of fracture;
- (c) the consequent maximum rate of release of contents;
- (d) any change of state of the contents under atmospheric conditions;
- (e) the total volume that can escape under emergency conditions.

2.2.3 Where pipelines convey flammable or toxic substances or those liable to cause contamination, the routes selected should, wherever reasonably practicable, avoid built-up areas. Consideration should be given to routing that will minimize the possibility of external damage, which could lead to incidents and attendant damage to third parties. A safety evaluation may be requested by the approving authority, and this requirement should be checked before a preliminary route is put forward. Fire authorities should be consulted in appropriate cases in order that they may take into account the risk categories of the areas being traversed, to determine measures required to deal with accidents.

2.3 Terrain and subterranean conditions

2.3.1 An important consideration in pipeline routing is the geography of the terrain traversed. On land, this can be broadly separated into surface topography and subterranean geology, and it is usually convenient to consider both natural and man-made geographical features under these two headings.

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* In preparation.

2.3.2 The principal geographical features which are likely to be encountered include the following.

Land surface

Agricultural:	crops, livestock, woodlands
Heritage:	natural beauty, archaeological, ornamental
Natural barriers:	rivers, mountains
Natural resources:	water catchment areas, forestry
Occupation:	population, communications, services
Physical:	contouring, soil or rock type, water, soil corrosivity

Subterranean

Earthquake zone category
Geological features
Land infill
Mining and quarrying
Old mine and quarry workings
Pipelines and underground services
Possible land slippage
Tunnels
Water table limits

2.3.3 Surveying

An essential prelude to pipeline projects is to acquire from records, maps and physical surveys a complete set of data on each of the geographical and geological features that are relevant to the safe, reliable and economic operation of the pipeline.

The adoption of a tentative route should be preceded by a desk study, making use of all available material. In addition to current editions of maps and records, reference should be made to superseded editions. Before a route is finally adopted for construction, a physical survey should be made, aided as necessary by aerial photography, soil surveys and underwater observations.

Maps and plans used for land surveys are obtainable from the Ordnance Survey. Geological information may be obtained from the British Geological Survey. For information on mining, application should be made in the first instance to British Coal, or to the owners of mineral rights in the case of privately owned mines and quarries.

Many independent sources of specialist information exist which may assist in route determination. The pipeline promoter should employ professional advisers as early as possible on those aspects requiring expert knowledge.

2.3.4 Adverse ground conditions

The following adverse ground conditions should be considered during the route planning stage:

(a) the proximity of past, present and future mineral extractions, including uncharted workings;

(b) areas of geological instability including faults and fissuring;

(c) soft or waterlogged ground;

(d) soil corrosivity;

(e) rock and hard ground;

(f) flood plains;

(g) earthquake zones;

(h) existing or potential areas of land slippage and subsidence;

(i) infilled land and waste disposal sites including those contaminated by disease or radioactivity.

British Coal, private mine owners and the owners of mineral rights should be consulted to determine the extent of present and possible future mining operations and the existence of tips and old workings. These bodies should be consulted on possible projected subsidence.

Local authorities, local geological institutions and mining consultants are available for consultation on general geological conditions, slippage areas, tunnelling and other possible adverse ground conditions.

Where there is a possibility that any of these conditions might arise during the lifetime of pipelines, observations leading to their detection should be incorporated in the regular surveillance procedures adopted. This will include measurement of local ground movement and of indicative changes in pipeline stresses.

2.4 Existing and future land use

Existing areas of development should be avoided as far as possible, but at locations where this is unavoidable, the proximity of pipelines to structures should be related to design parameters for particular contents. In exceptional circumstances it may be advantageous to override normal design limitations, and provide alternative installation methods or additional protective measures giving the same degree of reliability and safety.

Areas designated for future development require careful consideration, to reduce the incidence of expensive diversions or alternative works at a later date.

The routes of pipelines conveying substances which may cause contamination of water supplies should, wherever reasonably practicable, avoid crossing exposed aquifers or land immediately upstream of waterworks intakes or impounding reservoirs. Where avoidance is not possible, statutory water undertakers and private abstractors may require additional precautions to be taken.

Water authorities should be consulted about all watercourse crossings particularly in relation to future widening and deepening. The larger watercourses are classed as 'main rivers' and are directly controlled by water authorities; lesser watercourses draining low level areas may come within the control of internal drainage boards. In other cases the riparian owners and occupiers should be consulted. The jurisdiction of water authorities includes river embankments, sea and tidal defences and secondary works to reduce the spread of flood water. Where pipelines cross or are laid adjacent to any such embankments, it is essential that the agreement of the relevant water authority be sought.

In Scotland, Regional Councils and River Purification Boards should be consulted about all watercourse crossings. Riparian owners and occupiers may also need to be consulted. As regards sea and tidal defences and works to reduce the spread of flood water, where pipelines cross or are laid adjacent to any such works, the agreement of the appropriate Regional Council should be sought. In Northern Ireland the relevant authority is the Drainage Division of the Department of the Environment.

Consideration should be given to the availability and suitability of water for hydrostatic test purposes and its subsequent discharge.

2.5 Permanent access

The final route should permit ready and adequate access from public highways for the equipment and materials necessary to carry out planned inspections, maintenance and emergency repairs. This aspect should be taken into account at the time pipeline routing is being negotiated with landowners and occupiers. Access may have to be negotiated with parties other than those through whose land pipelines will be laid.

Access facilities should be determined by the frequency of use, the testing and repair equipment likely to be required, and the anticipated urgency of repairs.

2.6 Transport facilities and utility services

Particular regard should be given to the layout and levels of existing transport facilities and utility services, and enquiries made regarding their foreseeable development. It is essential that pipeline routes accommodate the special conditions imposed by the authorities concerned.

Normally pipelines should be routed to minimize disruption to existing facilities and services. However at locations where this is not possible, the most appropriate solution may be to relocate existing services rather than divert the pipelines.

All relevant authorities should be approached in good time requesting details of their facilities and services. In certain cases they may arrange to excavate exploratory trial holes, or will carry out other locational tests on site in order to provide plans of the actual positions.

The number and lengths of crossings under or over transport facilities should be minimized, and the recommendations of the relevant transport authorities should be taken into account. Pipelines laid in highways are subject to legislation related to public utilities street works.

2.7 Agricultural practice

Pipelines should be located to produce minimum disturbance to established agricultural practice.

Permanent above ground apparatus, located on or adjacent to the line of pipelines, should be sited with the agreement of the land owners and occupiers concerned to minimize future obstruction.

Consideration should be given to terminating sewer manholes below the surface of agricultural land. Chambers which terminate at ground level should be sited at field boundaries.

2.8 Environmental impact

Among environmental factors to be considered should be the possible effects on the following.

(a) Sites of Special Scientific Interest.

(b) National Parks: Country Parks.

(c) Areas of outstanding natural beauty.

(d) Ancient monuments and archeological sites.

(e) Tree preservation orders.

(f) Noise and vibration.

(g) Odour and dust.

Early reference should be made to the relevant planning authorities to determine whether an Environmental Impact Assessment (EIA) will be required for a pipeline and its associated above ground installations. If required, an EIA should cover the effect of pipeline works on local amenities and future developments. Pipeline promoters should also ascertain at the planning stage whether they are or are likely to be subject to Directives of the European Communities.

Where there is a possibility of pipeline construction and permanent facilities giving rise to noise complaints, an environmental noise survey should be carried out by suitably qualified persons before the pipeline route is established, so that a prior noise assessment can be made. Particulars of previous noise complaints may be obtained from relevant local authorities.

Section three. Acquisition of land and other rights

3.1 General

The responsibility for acquiring the necessary land, easements and ancillary rights for the pipeline rests with the promoter. These should be obtained wherever possible by private negotiation. If statutory powers are necessary, the procedure to be followed has been established by legislation.

Promoters should, at the earliest stage, consult the owners and occupiers concerned, as well as statutory organizations, and other representative associations such as the Country Landowners' Association and National Farmers' Union or their equivalent counterparts in Scotland, Wales and Northern Ireland.

Promoters should make full use of other advice from land agents, surveyors and engineers in all negotiations with owners and occupiers. Promoters should make full use of legal advice although this may not be necessary in the case of wayleave orders acquired by Statute.

The practical considerations and aims in 3.2 to 3.7 apply, irrespective of whether the land is acquired by private treaty or by statutory powers.

3.2 Access for survey and route selection

Although much can be done from plans and geological and aerial surveys, route selection requires access to the land, and may often necessitate on site ground investigations. The consent of owners and occupiers should be sought individually for any such access.

The promoter will normally obtain temporary rights which will lapse after the survey is completed. A prior undertaking should be given to landowners and occupiers to make good damage done or loss sustained during the survey and to pay compensation for any damage not made good.

An unnecessarily large number of entries on to land can be avoided by prior consultation with planning and other local authorities, as described in section two.

3.3 Types of rights

3.3.1 Rights granted directly by Acts of Parliament

Statutory Authorities and Government bodies have powers under Acts of Parliament to lay, use and maintain pipelines. Reference should be made to the Act or Order which grants those powers, as to the procedure to be adopted by the Authority concerned.

3.3.2 Rights granted by agreement between landowner and promoter

Where a promoter is not granted rights directly by Act of Parliament, he will require the agreement of the landowner, conferring some interest in or over the land concerned, to lay and maintain a pipeline. The agreement may take any of a variety of names (such as easement or lease) but legally the interests which may be conferred, and the associated degrees of security to the promoter, are, in the order of magnitude:

(a) a freehold of the land;

(b) a leasehold interest in the land for a term of years corresponding to the likely life of the pipeline;

(c) an easement over the land;

(d) a wayleave from the landowner to place the pipeline on his land.

The acquisition of these rights is similar in all parts of the UK although the legal terms are different in Scotland. The Scottish terms are described in the final paragraph of this clause.

The interests in land which the promoter will require are:

(a) *Freeholds.* Generally, the only freeholds which need to be purchased outright will be for land on which buildings are to be constructed (e.g. pumphouses), or land which it will be necessary to fence (e.g. where there are valves) but, as these may sometimes be set back from a public highway, specific provision for permanent rights of access to and from the plots should be made.

(b) *Easements and leases.* It will not usually be appropriate to purchase land for laying the pipeline itself and, where possible, easements or leases should be obtained.

If it is the promoter's own land which will be served by the pipeline (i.e. a dominant tenement, such as a refinery at one or other end of the pipeline) easements may be acquired. These may be for a term of years or in perpetuity and, as they run with the land, they will not be extinguished by a change of ownership; thus, if the landowner dies or sells his land or if the pipeline changes hands, the pipeline easement will continue automatically, provided it continues to serve the dominant tenement.

Where the promoter needs to obtain rights for a pipeline, but is not entitled to obtain an easement, a different form of grant (such as long leases of subterranean strips) will need to be acquired. Leases of subterranean strips are subject to the provisions of the Land Registration Acts as to registration of leases.

An easement or a lease will cover pipeline works (including surface obstructions) and, where necessary, rights of way, cathodic protection beds and other apparatus. The document will specify the rights and liabilities of each party, the width of an easement and the terms under which the rights are granted.

The width of an easement is not necessarily as large as the temporary working width. It is essential that the temporary working width be agreed before work commences. Any amendment to the working width has to be agreed between promoter and occupier. The promoter's rights and obligations incorporated in the document should include the number of pipelines, associated cables, etc., permitted to be laid, their depth and provision for inspection, maintenance, operation, repair or relaying, the future use of the surface of the land and procedure on abandonment (see section six).

The restrictions on the grantor in respect of the protection of the pipeline should also be included.

Where an easement is acquired through registered land, notice of the grant of the easement or lease, together with notice of any ancillary covenants restricting the use of the land, should be registered at the Land Registry by the pipeline promoters against the title of the land affected. For unregistered land restrictive covenant and equitable easements (e.g. informal grants) should be registered.

(c) *Wayleaves.* The wayleave will confer no interest in the land as such, the contractual rights being binding only on the original contracting parties, and will thus confer no security on the promoter if the original landowner sells his land. Care should therefore be taken by the promoter not to obtain only a wayleave when a greater interest in land is required.

(d) *Additional rights.* Additional rights could be for construction, reconstruction and rights of way to and from the pipeline and provision for the installation and maintenance of cathodic protection outside the easement strip. In the case of a permanent installation, an additional grant of easement may be required for works not covered by the grant for the pipeline.

(e) *Mineral rights.* It should be ascertained if any mineral rights are owned or leased separately from the surface ownership. Suitable arrangements will generally need to be made to safeguard rights of support and to negotiate compensation to mineral owners and operators. An adaption of one of the statutory mining codes may need to be incorporated in the deed of grant.

In Scotland, while the acquisition of these rights is similar in its practical effect, the separate statutory and legal system means that generally rights will be acquired under the appropriate Scottish statutes, although rights may be acquired through agreement with the landowner by the following:

(1) Acquisition of the dominium utile (similar to freehold purchase in England).
(2) Leasehold.
(3) Deed of Servitude (similar to easement in England).
(4) Wayleave.

3.3.3 Rights granted indirectly by Acts of Parliament

A promoter wishing to lay and maintain a pipeline over land may fail to obtain the agreement of a landowner. The promoter may then have to seek the right compulsorily under appropriate legislation.

3.4 Financial consideration and compensation

3.4.1 Payments to owners

Owners are generally entitled to receive payment for granting an easement or lease, or sale of freehold interest, or where rights are acquired by statute.

3.4.2 Compensation for damage and loss

Owners or occupiers or both are entitled to compensation for any land which cannot be fully reinstated. Compensation is therefore payable for damage to crops, loss of profits, loss of residual manurial value, loss of or damage to sporting rights. Negotiations over compensation for land covered by rights described in **3.3** are the responsibility of the promoter.

Landowners and occupiers should be made aware that occupation of land by a contractor is permitted only within the designated working area.

Landowners and occupiers concerned should avoid entering into independent negotiations with the contractor executing the work.

In cases where the promoter is exercising statutory powers, owners and occupiers have a duty to mitigate any losses which may arise.

Shooting and fishing rights are often sub-let but may still be subject to compensation for loss. Before construction it should be determined to whom compensation should be paid.

Delay in payment of compensation should be avoided and, where appropriate, payment on account should be made for matters not in dispute.

3.4.3 Professional costs

The professional fees reasonably incurred by the owners and/or occupiers of any interest in land through which the pipeline may be routed should normally be reimbursed by the promoter. Costs may be based on the Ryde's scale of Professional Charges as appropriate for pipeline work.

3.5 Planning permission

Except where exemption has already been provided for by statutory powers, pipeline construction may not be commenced until either planning permission has been obtained from the local planning authorities or, where appropriate, authorization has been obtained from relevant Government Departments. Investigation with the local planning authorities should be carried out to determine if other construction related areas (e.g. construction camps, pipe storage areas) require planning permission.

3.6 Consultation with other interests

3.6.1 General

A pipeline will usually cross the routes of roads, railways, canals and water courses. It is also likely to cross or lie adjacent to existing underground or overhead services operated by water, gas and electricity undertakings, telecommunication, drainage and sewerage authorities and other pipeline operators. Construction drawings of the relevant sections of the project should be submitted to each appropriate authority in sufficient detail to enable proper consideration to be given.

It is always the responsibility of the pipeline promoter to ensure that all bodies or persons whose duties or interests are likely to be affected by the construction and operation of the pipeline are provided with sufficient information to enable them adequately to carry out their duties or safeguard their interests.

3.6.2 Railways

When pipelines are to be laid across or adjacent to tracks the appropriate railway authority should be consulted well in advance. In the case of main lines a year or more notice of works may be necessary. A complete closure of all tracks for a 24 h period is unlikely to be available. Appropriate administrative and operational costs should be paid by the promoter.

British Rail has produced a handbook, entitled 'Engineering recommendations for pipelines constructed on or adjacent to railway property' to which reference should be made.

3.7 Plans

3.7.1 Preliminary routing plans

For preliminary routing plans, maps of either 1 : 25000 or 1 : 50000 scale should be used, according to the complexity of the terrain.

3.7.2 Field reconnaissance plans

For field reconnaissance plans, Ordnance Survey maps of either 1 : 10000 or 1 : 25000 scale should be used. The use of 1 : 10000 maps may obviate duplication, since this is the smallest scale acceptable for applications under the Pipelines Act.

3.7.3 Final field survey plans

For final field survey plans, Ordnance Survey sheets of 1 : 2500 scale with field numbers should be used.

3.7.4 Strip plans

Strip plans should be prepared from Ordnance Survey sheets of 1 : 2500 scale. In built-up areas, consideration should be given to the use of plans of 1 : 1250 scale. Any alteration to land drainage works should be detailed on these plans. Any vertical section or profile along the pipeline route should be shown to a scale appropriate to the variations in ground elevation. Special crossings should be detailed on separate drawings which should be cross-referenced to the appropriate strip plan; the scale should be between 1 : 250 and 1 : 25 depending on the complexity of the work.

3.7.5 Plans for attachment to legal documents

Plans for attachment to legal documents should be based on the Ordnance Survey sheets, preferably the 1 : 2500 scale. It may be necessary to prepare these plans on a larger scale where the areas of land are very small or complex or, conversely, to a smaller scale where large areas of land are involved.

3.7.6 As built plans

If, during construction of the pipeline, there are any changes or deviations from any plans which have been issued in accordance with **3.6.1**, as built plans, to the same scale as the original plans, should be issued to all original recipients on completion of the work. If found more convenient the strip plans detailed in 3.7.4 may be used for this purpose.

3.7.7 Digital mapping

Consideration should be given to the method in which the horizontal and vertical alignments of a pipeline are recorded in digital form, known as the Coordinated Method.

Detailed design of the route by the Coordinated Method is based on a land survey, and the alignment of the pipeline related to the Ordnance Survey grid. Setting out of the pipeline for construction is controlled by permanent ground markers, established by the survey. These ground markers should be retained on site with the agreement of the landowner and occupier to enable subsequent pipeline location.

Using this method, the above plans can be recorded on stable film, showing Ordnance Survey grid lines and location of the pipeline for use in conjunction with conventional maps. Alternatively pipeline details can be recorded electronically for use in Digital Mapping systems.

NOTE 1. Ordnance Survey Maps and Sheets may not be reproduced or copied without the permission of the Director-General of Ordnance Survey.

NOTE 2. A publication 'Coordinated Pipelines Practice' is available from the Institution of Civil Engineering Surveyors.

Section four. Pipe installation and reinstatement

4.1 Entry upon land

4.1.1 Preparation

The promoter should arrange for representatives, e.g. agricultural liaison officers, to maintain close personal contact with occupiers, beginning well before construction is to commence and continuing until reinstatement is complete and compensation for damage has been paid.

The promoter's representatives should discuss with the occupiers the implications of the work and the construction programme. The representative should advise occupiers whether the work will be completed in one operation or if return will be necessary after the main pipelaying has been completed; also whether night and/or weekend work will be involved. The representative should keep occupiers informed of any significant changes in the programme, and should advise owners of any changes affecting their interests.

Before the land is entered for construction, as much notice as possible over and above any statutory period should be given to individual owners and occupiers and to any authority affected. Each of these should be given the address and telephone number of the representatives of the pipeline promoter to whom any complaints or requests are to be made.

As far as practicable, the working width should have been determined and documented with owners and occupiers as part of the overall land acquisition process.

Advance provision should also be made for any land required for storing pipes and other materials, for parking and maintaining equipment, and for the siting of temporary offices, camps, sanitary facilities, etc.

4.1.2 Working width

Consultation should be undertaken by the promoter with occupiers at the earliest possible stage so as to determine the width of the working area for construction. Any later amendment to the working width should be negotiated by the promoter. In deciding upon the extent of any extra working width there should be recognition of the ground terrain and conditions at the following locations:

(a) at major road, rail, river and canal crossings;

(b) where deep pipelines are being installed;

(c) where it is necessary to go beneath existing underground services;

(d) where it is necessary to go beneath ditch and stream crossings and land drainage;

(e) where it is necessary to stack separately various subsoil bands and topsoil to ensure correct order of replacement.

4.1.3 Infected areas

Wherever an area has been declared an infected area on account of foot and mouth disease, swine vesicular disease, fowl pest, swine fever or other notifiable disease, entry on the land for any purpose should be suspended except with the approval of the Ministry of Agriculture, Fisheries and Food or the Department of Agriculture and Fisheries for Scotland or Department of Agriculture for Northern Ireland. Entry will be governed by such conditions as may be stipulated or agreed. Promoters in conjunction with owners and occupiers directly affected by the pipeline should take such reasonable precautions as may be necessary to avoid the spreading of soil borne pests and diseases, e.g. Rhizomania.

Infected areas are not necessarily declared when a notifiable disease outbreak is confirmed, although this action is invariably taken with foot and mouth disease. Precautions should therefore be taken when there are outbreaks in an area or when individual infected farms are declared to have animals infected with notifiable disease.

4.1.4 Record of condition

Before work starts, a record should be made of the state of the land including photographs where appropriate. Particular note should be made of the depth of the topsoil and any special features, so that they may be adequately reinstated if disturbed. This record should be agreed with the occupier and, wherever possible, the owner. The cost of preparing it will be borne by the promoter. The method of dealing with any trees growing within the working width should be agreed at this time. Where trees are not to be felled, it may be necessary to make slight deviations in the alignment of the pipeline or require additional working width to allow the passage of equipment. Where special protective works exist or are required on account of a notifiable disease, the fact should be noted in the record.

4.2 Working season

Wherever possible the construction period for pipelines laid through agricultural land should be limited to the period in each year when climatic conditions are such that pipeline construction will cause least harm to the soil condition. In England this is generally between the spring and late October with an additional period of one moth for reinstatement works. Arrangements should also be made where possible for construction works in agricultural land to stop if extreme adverse weather conditions are encountered which could seriously affect the final condition of the land.

4.3 Pipeline spread

It is recommended that the promoters restrict the total length of each pipeline spread from the start of the temporary fencing, to the point of the sub-soil backfilling operations. Where the spread exceeds 15 km it may be advisable to appoint additional Agricultural Liaison Officers

4.4 Trespass

Construction personnel should not trespass outside the working limits of the pipeline route or other agreed areas. Goodwill should be maintained with owners, occupiers and representatives of authorities, by respecting their rights and causing the least possible damage or interference.

4.5 Preparation of the working width

4.5.1 Clearing and grading

Preliminary work in pipeline construction should include pegging out, erection of temporary fencing, the clearing and disposal of all scrub, hedges and debris from the route, together with the proper and adequate fluming or bridging of ditches and streams. These operations should be planned from the outset to cause the least possible disturbance to owners and occupiers.

Trees should not be felled unless absolutely necessary and special precautions will need to be taken where any tree within the working width is subject to a preservation order.

Where trees have been felled, any resulting timber will, in the absence of any arrangement to the contrary, remain the property of the landowner. The removal of any roots of trees felled should be agreed with the occupier.

In good agricultural land, unless agreed otherwise by the occupier, topsoil should be stripped from the whole of the working width apart from that area used for the stacking of the topsoil. The width and depth of stripping of top soil will be governed by individual circumstances. The depth will not normally exceed 300 mm (12 in) unless otherwise agreed with the occupier. Special arrangements should be made for moor and heathlands.

All topsoil should be deposited separately, ready for replacement in its original position without contamination. Where possible turf on lawns, sports and ornamental grounds, etc. should be carefully cut, rolled and kept in moist condition for subsequent replacement.

The height of stacked top soil should be limited to avoid compaction. If reinstatement of land is delayed beyond the current season then precautions should be taken to try to avoid loss of topsoil through erosion. This may necessitate the grassing over of the stacked topsoil. In addition if prolonged exposure is encountered it may be necessary to carry out spraying of the stacked topsoil for weed control.

The land should be restored to its original contours and the topsoil replaced, unless otherwise arranged with the landowner.

Care should be taken to avoid earth slippage out of the working width. Travel along the working width should be minimized to avoid increasing compaction of the soil.

4.5.2 Temporary fencing

In agricultural land, appropriate stock-proof fencing should be provided along each side of the working width to exclude animals kept on adjoining land. This is normally the first operation after pegging out. Where no stock is kept, the limits of the working width should be adequately marked in agreement with the occupier. All temporary fences should be maintained until work on the section is completed, the ground fully restored and permanent walls, fencing, or hedges reinstated. In no case should nails or staples be driven into trees. In areas where special (e.g. anti-vermin) fencing has been erected, precautions should be taken at all times during construction not to nullify the purpose for which the fencing was provided.

Gaps in hedges or walls at field and road boundaries should, where necessary, be temporarily closed during construction. Temporary fencing for this purpose should be to a standard equivalent to the adjoining boundary hedge, wall or fence. A removable section or gates should be provided for contractors' plant access.

Temporary bridging and widening of access roads for the passage of plant and equipment may be required.

All temporary fencing, access bridges and access roads should be to a reasonable standard agreed with the occupier. Additional precautions may need to be undertaken where infectious disease is encountered.

The removal of temporary fencing should be carried out in consultation with the occupiers.

4.5.3 Public safety

The contractor should ensure at all times that the general public is protected from any danger arising from the installation and testing of pipelines.

Fencing should be provided to prevent free access to the site with particular attention be given to excavations, open pits and boreholes. Care should be taken to avoid accidents to children who may trespass on the site. If the entrance to a site crosses a public road or footpath this should be kept clear of obstructions, mud and spoil.

4.5.4 Emergency services

The promoter should advise all of these services of the works in hand prior to commencement. This notification should include the supply of maps and plans of any temporary access points.

4.6 Pipe distribution

Stringing of the pipes end to end along the working width should be done in such a manner that the least interference is caused in the land crossed. Gaps should be left at intervals to permit the passage of farmstock and equipment across the working width. Pipes should be laid out carefully to prevent damage to the pipe or coatings and in a manner to ensure that they remain safely where placed until incorporated in the pipeline. If straw is used for protecting pipes, etc., in transit, it should all be collected and burnt in a safe area immediately after use so as to avoid any possible agricultural contamination.

4.7 Trenching

Trenching includes all excavation which is carried out by trenching machine, excavator, or by hand, to prepare the trench to the required dimension for the pipeline.

Special consideration should be given to the depth of the trench. In agricultural land the depth of cover should not be less than 900 mm (3 feet).

It may be necessary to increase the depth of trench for pipelines following hydraulic gradients, to avoid land drains, drainage systems, roads, railways or other crossings or for other special reasons such as fenlands, peat and marsh areas and for improved pipeline security.

In rocky ground, rough grazing, or by special arrangement, the cover may be reduced, provided the contents of the pipeline are not liable to be adversely affected by frost and the pipe material is strong enough to withstand the loading of any anticipated vehicular traffic.

Temporary underpinning, supports and other protective measures for supporting building structures or apparatus in or adjacent to the trench should be of proper design and sound construction.

If the backfilled pipeline trench is likely to act as a drain, precautions should be taken to prevent loss of any fine material.

4.8 Support of excavations

An excavation should be properly supported, or the sides sloped back to a safe angle, before the excavation reaches a depth of 1.2 m. At this depth persons working in it would be buried or trapped if there were a collapse. An adequate store of suitable supports should be kept on the site to provide immediate shoring and strutting as found necessary. No timbering or other support for any part of an excavation should be erected or substantially added to, altered or dismantled, except under the direction of a competent person with adequate experience of such work. All material for such work should be inspected by a competent person on each occasion before being taken into use, and material found defective in any respect should not be used.

The condition of the ground being excavated may necessitate the sides of the excavation being closely supported. This is particularly important when temporary spoil heaps, material stacks, excavating plant, pipe handling devices, cranes, or pile-driving apparatus are positioned adjacent to an excavation. The shoring and strutting of excavations in proximity to a railway or a highway, whatever its use, will need to take into account the support of services such as gas and water mains, sewers and underground tunnels, in addition to the loading on the highway from foot and vehicular traffic.

The stability of the excavation should be investigated in relation to the safety of the services, their structural condition and likely movement. Likewise, structures on adjacent lands may necessitate an appraisal of the live and dead loads, and whether the resultant of the loads will cause a loading on the sides of the excavation, or whether the excavation will affect the stability of the neighbouring structure. It may be necessary to provide temporary shoring, strutting, ground treatment or other support to the structure to safeguard its stability. Detailed information may be found in BS 6031 and Report 97 'Trenching Practice' published by the Construction Industry Research and Information Association. Attention is also drawn to the Statutory Instrument 1961 No. 1580 the Construction (General Provisions) Regulations 1961.

4.9 Explosives

If it is proposed to use explosives, regulations regarding their storage and use should be strictly observed and agreement obtained from the owners, occupiers, authorities and all others affected concerning their use and the timing of blasting operations. Attention is drawn to the danger of unexploded charges. The promoter's as built records should indicate where explosives were used. Detailed guidance may be found in BS 5607 on the use of explosives in the construction industry.

4.10 Avoidance of other services

It will generally be advantageous to lay the pipeline below most existing services, such as water and gas pipes, cables, cable ducts and drains, but not necessarily sewers. Sufficient clearance between the pipeline and other services should be agreed between the parties and adequate arrangements should be made to protect and support the other services. Where thrust or auger boring or pipe jacking methods are used, the clearances required should be the subject of consultation between the parties concerned. The pipeline should be laid so as not to obstruct access to the other services for inspection, repair and replacement.

Particular care should be taken when operating under or near overhead services. In such cases, the authority concerned should be asked to give advice on the clearances which should be maintained between the overhead services and any equipment which is employed, together with the use of height gauges on each side of the overhead service. In addition, in the case of overhead power lines, the possibility of induced voltage should be discussed with the relevant authority in order that appropriate safety measures may be taken.

Warning slabs, tape, tiles or other markers should be placed over and close to pipelines and any associated cables at their points of intersection with other services.

4.11 Land drains

The method of restoring disrupted land drains in any particular case should be agreed with the owner and occupier concerned at the time of negotiating easements. In the event of a dispute, the advice of an agreed drainage expert with knowledge of local conditions should be taken and followed.

Information regarding the location of land drains in agricultural land should be obtained wherever possible from local sources or from the Divisional Office of the Ministry of Agriculture, Fisheries and Food or the Department of Agriculture and Fisheries for Scotland or the Department of Agriculture for Northern Ireland.

It is essential that the course and general condition of all land drains which are located during pipeline construction be marked and recorded at the time.

Section two. Routing

Before backfilling is commenced, the landowner or occupier should be given adequate notice of the reinstatement of drains to enable the landowner or occupier to inspect if they so wish.

The repair of land drains should keep pace with the progress of pipelaying to ensure that drainage systems are out of action for the shortest possible time. However such repairs should only be carried out in suitable ground conditions.

Prior to or immediately after the pipeline is commissioned the drainage of the land affected should be restored to a condition as efficient as that before the work was started. This will usually consist of laying one or more header drains parallel to the pipeline trench. In the case of a single header drain it should be laid on the uphill side of the trench to collect water from all the disturbed drains, and graded to a free outfall. The drains on the downhill side of the trench should be properly sealed to prevent the intake of soil into the drains. Arrangements may be required to drain the working width.

In the case of narrow trenches it may be possible to reconnect the existing drains across the pipeline. For wide trenches reconnection across the pipeline should only be considered where no suitable outfalls are available for header drains.

Where existing drains are reconnected, they should be first cleaned out at the junctions as far as possible, and then connected across the pipeline trench and supported in such a way as to be protected against displacement or settlement.

The backfilled pipeline trench itself will usually collect water and may act as a drain. In some cases this water will not drain away, but collect, e.g. at a low point or where the backfill is impermeable. Arrangements should be made to drain these points to a free outfall. It should be recognized that defects in the system may not become apparent for a number of years.

It is recommended that the promoter provides the landowner/occupier with a set of records relative to the drainage system as installed and modified.

4.12 Ditches

Where a pipeline passes underneath a trench, ditch or culvert, it should be suitably protected with concrete or other similar material, having a minimum cover of 300 mm (12 in) from the hard cleaned bottom of the ditch or culvert to the top of the protection. Ditches, drains, culverts and watercourses which are in any way interfered with by the pipeline operations should be maintained in effective condition during the construction period and be restored finally to as good condition as before the commencement of work.

Where a crossing has to be made above the bed of a ditch, but below the level of the banks, or across a culvert, the underside of the pipe should be at such a level above the bed of the watercourse that it will not obstruct any flow which can reasonably be expected. In such a case reasonable cover adjoining the ditch should be provided: normally 450 mm (18 in) cover at a distance of 900 mm (36 in) from the edge of the ditch is considered reasonable.

Where a pipeline runs parallel to a ditch, the edge of the pipeline trench nearest to the ditch should be kept at a distance from the edge of the ditch at least equal to the depth of the ditch, or the depth of the trench, whichever is the greater.

4.13 Maintenance of services

It is essential that services such as water, gas and electricity supplies, sewerage and telephones be maintained during the progress of work. Pipes, cables and other apparatus belonging to statutory undertakers should not be interfered with or altered without the consent of the undertakers. Undertakers may require to carry out alterations themselves at the expense of the promoters.

Private pipes, cables and other service apparatus should not be interfered with or altered without the consent of the owner, and any alterations should be carried out so that interruption to the service is kept to a minimum. It should be noted that privately owned apparatus may be subject to byelaws, regulations or other control.

Private water supplies affected by pipeline operations should be maintained during the progress of the work, protected from pollution and permanently restored as soon as possible after the pipeline is laid. If necessary, they should be replaced during the progress of the work by water from another suitable source. Where fields containing animals are split, consideration should be given to the need for additional drinking troughs.

4.14 Fishing and sporting rights

Fishing and sporting rights should at all times be protected. Where a watercourse is frequented by migratory fish, the flow should be maintained during the progress of the works in such a manner as will allow the passage of the fish. The local fisheries official should be consulted over the periods suitable for the execution of works in order to take into account the needs of migratory Salmonids and freshwater fish.

4.15 Pollution

Steps should be taken to prevent pollution of watercourses by chemicals, fuels, oils, excavated spoil, silt laden discharges or other materials. The disturbance of bed deposits should be minimized as far as practicable.

4.16 Maintenance of access

Where the trench and pipeline interfere with any normal access an alternative access or a bridge should be constructed and maintained, together with access ways to provide adequate temporary communications across the works until normal access has been restored. The temporary access across the working width should, where necessary, be provided with properly hung swing gates which effectively prevent livestock straying on to the working width.

4.17 Canal, river, road and rail crossings

Special methods of construction may be required when pipelines cross canals, roads and railways. Agreements reached with the appropriate authorities may be conditional upon approval of the design, construction, timing, and issue of statutory notices. These vary according to the size of the pipeline, the material conveyed and the nature of the crossing. Consideration should be given to the use of pre-tested pipe in crossings.

4.17.1 Roads

Where a pipeline crosses or passes along a highway the exact siting and constructional details should be agreed with the highway authority, who may also specify the manner in which trenches should be backfilled and compacted, and the nature of reinstatement of the road surface. In the event of a road closure being considered necessary, agreement with the highway authority should be sought at an early stage as statutory periods of notice are required for such closures.

Where the highway authority considers that the road affected is of such importance as to justify the avoidance of traffic disruption, or the disturbance of the carriageway pavement, they may require the use of pipelaying techniques which do not necessitate open trench excavation.

Where work is being carried out adjacent to or on any public or private road, warning signs — and at night warning lights — should be provided and maintained as required by the body having jurisdiction over the road.

Particular care should be taken to avoid damage to drains, sewers and all other services laid within the highway. Where these services are disturbed they should be reinstated in accordance with the highway and appropriate service authority requirements.

4.17.2 Railways

The appropriate railway authority should be approached before any works are carried out on or adjacent to any railway property.

Private level crossings are provided only for the landowner and tenant of the adjacent land. There is seldom any warning given of approaching trains, and the profile may be unsuitable for the equipment being used. The appropriate railway authority should be approached before the crossing is used as access to the worksite.

4.17.3 Watercourse crossings

Where a pipeline crosses a watercourse, the design and method of construction require consent from the drainage or water authorities concerned, and in Scotland from the appropriate river purification board. The design and method of construction should take into account the characteristics of the watercourse. Consideration should be given to the suspended solids generated and the particular requirements of the water authority under the Control of Pollution Act. It may be necessary to plan the work to take advantage of seasonal variations and to make arrangements to take action on receipt of flood warnings in order to prevent damage to the works or the surrounding country.

4.18 Backfilling, cleaning-up and reinstating

Backfilling operations should follow as closely as possible the laying of the pipe. The backfill should be compacted to suit the type of bedding and the type of pipeline material. Neither topsoil nor material harmful to the pipeline should be used. Safe working practices should be adopted to avoid damage to the pipeline.

The trench should be backfilled with selected material from the excavation to preserve as far as possible the original soil sequence and should be compacted to minimize subsequent settlement. The backfill should not contain any perishable material including scrub or vegetable growth. If the owner or occupier so requires, the top 300 mm (12 in) or any agreed greater depth of subsoil should be loosened by an agreed method before reinstatement of topsoil and where possible the land restored to its original contours. Unless otherwise arranged with the landowners or occupiers the topsoil should be replaced. Top soiling and reinstatement work should only be carried out when ground and weather conditions are suitable.

The topsoil of agricultural land should be left in a loose, friable and workable condition to its original full depth and over the whole working width and should be as free from stones as the adjacent land. Any additional topsoil imported will be subject to the reasonable requirements of the occupier as to the testing of the suitability of the imported soil. Arrangements for final reinstatement and seeding of any land should be agreed in advance with the owner or occupier.

Disposal of any surplus material from the site should be by agreement with the landowner, and such surplus should not include topsoil.

The permanent reinstatement of gaps made in fences, hedges, walls, etc., should be agreed with the landowner or occupier. Where hedges have to be re-planted, they should be protected on both sides by a fence together with wire netting turned out or buried at the bottom for protection against rabbits. The fencing and netting should be maintained until the hedge is fully established. All wire fences should be well strained when reinstated.

All constructional debris, tools, equipment and any temporary works should be removed and the working width reinstated so that the route of the pipeline may be restored as nearly as possible to its original condition and handed back to the occupier without delay. Debris should not be buried without the consent of the landowner or occupier.

The reinstatement should include all permanent walls, fencing, hedges, footpaths, private roads and temporary accesses.

Any certificate presented to the occupier for signature relating to the completed reinstatement should be limited to the condition ascertained at the time.

About one year after the completion of the work, the promoter should make a survey to check the adequacy of the reinstatement. Where possible, this should be done by reference to the agreed record of condition (see **4.1.4**).

4.19 Pipeline markers

Distinctive markers should be erected at all road, rail, river and canal crossings and elsewhere as required to identify the pipeline and to indicate its position and other details. Markers should be placed at field boundaries and not in fields, preferably in such a way that they are not obscured by vegetation and do not interfere with agricultural operations.

Where aerial surveillance is intended, sufficient markers should be visible from the air to indicate the pipeline route. At all valve installations plates should be provided to give the same information as on the markers. Groups of marker posts can be avoided by the use of special marker plates bearing engraved dimensioned diagrams of the layout.

Markers should not be treated with any substance likely to be harmful to livestock.

4.20 Cathodic protection

Where a pipeline is to be cathodically protected the promoter should establish liaison with owners of other pipelines, cables, sheetpiling and other buried metallic structures likely to be affected so that these may be safeguarded.

Further information on this matter is contained in BS 8010 : Part 2* and in CP 1021.

4.21 General supervision

The pipeline promoter should provide competent and adequate supervisory staff and be satisfied that contractors employed do likewise.

4.22 Safety during testing

The safety precautions required when pipelines are being pressure tested are detailed in other parts of this code. These may involve the temporary closure of highways. (including footpaths and bridleways). The highway authority should be consulted regarding the procedure to be adopted. Other statutory authorities should be consulted as appropriate. Notices warning the general public should be clearly displayed.

4.23 Records

Records should be kept by the promoter of all tests and inspections carried out on the pipeline.

Copies of as built plans indicating the pipeline's size, depth and location related to surface features should be provided for each owner and occupier by the promoter.

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*Published in Sections.

Section five. Operations, modifications, maintenance, repair and inspection

5.1 General

It is essential that procedures for the operation, modification, repair, maintenance and inspection of pipelines are formulated and adhered to so that a pipeline continues to function safely whilst in use. This standard encompasses the transportation of widely differing fluids and it is not practicable to specify in Part 1 a detailed set of procedures covering the many cases involved. Until BS 8010 : Part 4* is available operating bodies should develop procedures for operating, modifying, maintaining, repairing and inspecting pipelines based upon the recommendations given here and upon best industry practice.

5.2 Operations

All matters of operation, maintenance, repair and modification of an operating pipeline are properly the concern of the operating body. Correct operating procedures are those which ensure that the operating demands upon the system at any particular time can be achieved safely. All maintenance works and modifications should be coordinated with operating needs. Operating bodies should take account of these inter-relating factors when drawing up their procedures. Particular care should be taken in differentiating between routine procedures and emergency procedures.

5.3 Route inspection

Routine visual inspection of land pipelines should be made to check on the condition of the pipeline easement. Any third party activity on, or adjacent to the pipeline easement and which could affect the integrity of the pipeline should be investigated. The frequency of such inspection may vary dependent upon local conditions. Urban areas and intensively farmed agricultural land are likely to require more frequent and closer inspection than heathland. Particular attention should be paid to areas where problems may occur, for example, disused underground workings and river and watercourse crossings. Any excavation or development occurring near buried pipelines should be monitored.

Arrangements should be made with owners and occupiers to permit a routine programme of inspection of the route. In the absence of any such arrangement, except in cases of emergency, prior written notice of all pipeline inspections involving entry on land should be given to the occupiers.

All persons carrying out inspections should carry and produce on request adequate means of identification.

Where air patrols are used, aircraft should fly at a suitable height to avoid nuisance or harm to poultry or livestock.

5.4 Infected areas

Certain areas may be declared an infected area on account of foot and mouth disease, fowl pest, swine fever, or other notifiable disease including soil borne pests and diseases. Where this occurs, routine pipeline inspections involving entry on such land should be suspended unless there are exceptional circumstances. If there is a clear necessity to enter land, approval of the Ministry of Agriculture, Fisheries and Food, or the Department of Agriculture and Fisheries for Scotland or the Department of Agriculture for Northern Ireland should be obtained, and entry should be governed by such conditions as may be stipulated.

5.5 Emergencies

Emergency procedures should be drawn up for each pipeline by the operating body. The purpose is to ensure that all operations staff and other parties involved are adequately informed regarding the action to be taken in the event of an emergency. Other parties likely to be involved include personnel not normally involved with the routine operations, the public emergency services, local authorities and utility service authorities. Procedures should be developed to meet the needs of each individual pipeline and should include for periodic emergency exercises to be carried out in conjunction with the public emergency services.

All occupiers of land traversed by a pipeline should be requested by the pipeline operators to assist by speedy notification of any abnormal occurrences which may affect, or may have been caused by the pipeline. Pipeline operators should provide land occupiers with current telephone numbers for contact in an emergency. Similarly pipeline operators should notify occupiers and any authority concerned of incidents which might affect their interests.

5.6 Maintenance

Complementary to the operating procedures, and mindful of operational constraints, maintenance procedures should be developed to ensure that the system retains its integrity and that all safety devices are in working order. The rights acquired for the construction of a pipeline usually include rights necessary to maintain and repair the line. Except in emergencies, maintenance and repair work should follow the same procedures as those for the original construction particularly in relation to notices to landowners and occupiers.

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*In preparation.

Section six. Abandonment

6.1 Disused pipelines

A pipeline may be considered disused when it has been abandoned or when the owners cease to inspect it regularly and are no longer prepared to maintain it in an operable condition.

When the owners are no longer prepared to maintain a disused pipeline in an operable condition they should take precautions to prevent the pipeline from becoming a source of danger or nuisance or an undesirable watercourse.

6.2 Precautions

Before being abandoned, the pipeline should be completely disconnected at both ends and if necessary divided into sections. All open ends should be capped and sealed. In certain areas, e.g. those subject to subsidence or where heavy external loads may occur, it may be necessary to close the pipeline at both ends and to fill the abandoned line with a suitable filler. Where the abandoned pipeline cannot be made safe by the above method, it should be removed. In all cases where the fluid conveyed is considered an environmental or safety hazard, or could become so after contact with the soil, it will be necessary to remove completely the fluid from the pipeline. In other cases, it may be possible to permit the fluid to remain in the disused pipeline.

All surface chambers should be removed to not less than 900 mm (36 in) below ground level. Backfilling and land reinstatement should be in accordance with **4.18**.

6.3 Records

A record should be kept by the owners of a pipeline to indicate that they have taken the necessary precautions. A record plan showing the size and depth of the pipeline and its location related to surface features should also be prepared and a copy given to the owners and occupiers of the land concerned.

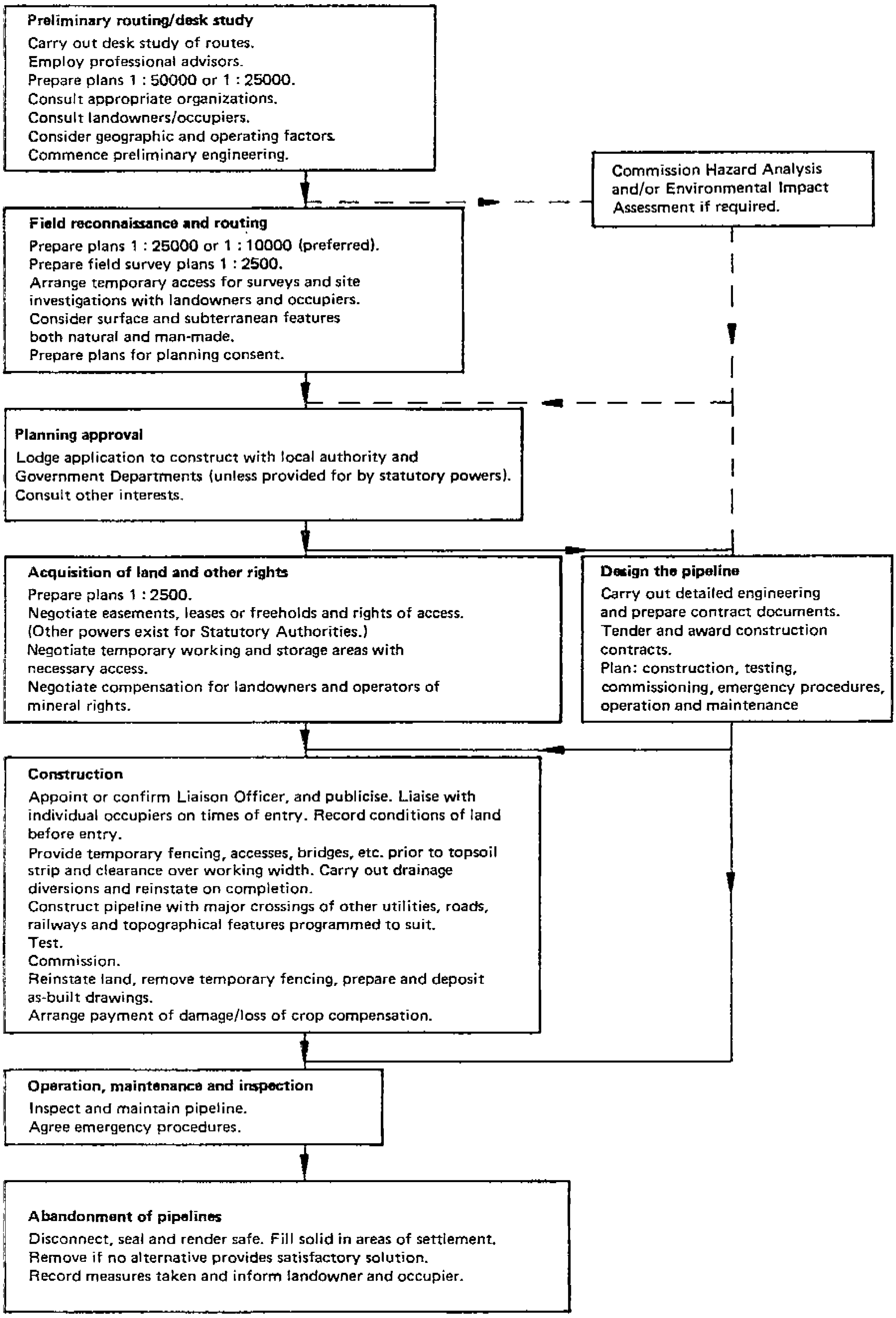
Appendices

Appendix A. UK Statutes

The following list of principal Acts of Parliament and Statutory Instructions is given in alphabetical order and the dates quoted are the years in which the Acts were passed. This list should not be assumed to include all relevant statutes.

Acquisition of Land Act 1981
Ancient Monuments and Archaeological Areas Act 1979
Atomic Energy Authority Act 1954
Coast Protection Act 1949
Compulsory Purchase Act 1965
Construction (General Provisions) Regulations 1961
Control of Pollution Act 1974
Countryside Act 1968
Countryside (Scotland) Acts 1967, 1981
Customs and Excise Act 1952
Factories Act 1961
Fire Precautions Act 1971
Gas Acts 1965 and 1972
Health and Safety at Work etc. Act 1974
Health and Safety at Work (Northern Ireland) Order 1978
Highways Act 1980
Historic Buildings and Ancient Monuments Act 1953
Housing Acts 1961 and 1974
Land Compensation Act 1961 and 1973
Land Drainage Act 1976
Land Powers (Defence) Act 1958
Lands Clauses Consolidation Act 1845
Local Government Act 1972
Oil and Gas (Enterprise) Act 1982
Petroleum and Submarine Pipelines Act 1975
Pipelines Act 1962
Public Health Acts 1936 and 1961
Public Health (Ireland) Act 1978
Public Health (Drainage of Trade Premises) Act 1937
Public Health (Recurring Nuisances) Act 1969
Public Utilities Street Works Act 1950
Radioactive Substances Act 1960
Requisitioned Land and War Works Act 1945 and 1948
Rivers (Prevention of Pollution) Acts 1951 and 1961
Sewerage (Scotland) Act 1968
Town and Country Planning Act 1971
Town and Country Planning General Development Order 1977
Water Acts 1945, 1948, 1973, 1976, 1981 and 1983
Water Act (Northern Ireland) 1972
Water Resources Acts 1963, 1968 and 1971
Water Scotland Act 1946, 1949, 1967 and 1980
Water Supplies and Sewerage Act (Northern Ireland) 1945
Water Supply and Sewerage Services (Northern Ireland) Order 1973
Wild Life and Countryside Act 1981

Appendix B. Flow chart for implementation of a pipeline project



Preliminary routing/desk study
Carry out desk study of routes.
Employ professional advisors.
Prepare plans 1 : 50000 or 1 : 25000.
Consult appropriate organizations.
Consult landowners/occupiers.
Consider geographic and operating factors.
Commence preliminary engineering.

Commission Hazard Analysis and/or Environmental Impact Assessment if required.

Field reconnaissance and routing
Prepare plans 1 : 25000 or 1 : 10000 (preferred).
Prepare field survey plans 1 : 2500.
Arrange temporary access for surveys and site investigations with landowners and occupiers.
Consider surface and subterranean features both natural and man-made.
Prepare plans for planning consent.

Planning approval
Lodge application to construct with local authority and Government Departments (unless provided for by statutory powers).
Consult other interests.

Acquisition of land and other rights
Prepare plans 1 : 2500.
Negotiate easements, leases or freeholds and rights of access.
(Other powers exist for Statutory Authorities.)
Negotiate temporary working and storage areas with necessary access.
Negotiate compensation for landowners and operators of mineral rights.

Design the pipeline
Carry out detailed engineering and prepare contract documents.
Tender and award construction contracts.
Plan: construction, testing, commissioning, emergency procedures, operation and maintenance

Construction
Appoint or confirm Liaison Officer, and publicise. Liaise with individual occupiers on times of entry. Record conditions of land before entry.
Provide temporary fencing, accesses, bridges, etc. prior to topsoil strip and clearance over working width. Carry out drainage diversions and reinstate on completion.
Construct pipeline with major crossings of other utilities, roads, railways and topographical features programmed to suit.
Test.
Commission.
Reinstate land, remove temporary fencing, prepare and deposit as-built drawings.
Arrange payment of damage/loss of crop compensation.

Operation, maintenance and inspection
Inspect and maintain pipeline.
Agree emergency procedures.

Abandonment of pipelines
Disconnect, seal and render safe. Fill solid in areas of settlement.
Remove if no alternative provides satisfactory solution.
Record measures taken and inform landowner and occupier.

Publications referred to

BS 1722	Fences
BS 5607	Code of practice for safe use of explosives in the construction industry
BS 6031	Code of practice for earthworks
BS 8010	Code of practice for pipelines *Part 2. Pipelines on land: design, construction and installation
CP 1021	Code of practice for cathodic protection
CP 2010*	Code of practice for pipelines

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*Published in Sections.

†Referred to in the foreword only.

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Civil Engineering and Building Structures Standards Committee (CSB/-) to Technical Committee CSB/10, upon which the following bodies were represented:

Association of Consulting Engineers
British Compressed Gases Association
British Gas plc
British Plastics Federation
British Precast Concrete Federation Ltd.
Concrete Pipe Association
Country Landowners' Association
County Surveyor's Society
Department of Energy (Petroleum Engineering Division)
Ductile Iron Producers' Association
Electricity Supply Industry in England and Wales
Engineering Equipment and Materials Users' Association
Federation of Civil Engineering Contractors
Health and Safety Executive
Home Office
Institute of Petroleum
Institution of Civil Engineers
Institution of Gas Engineers
Institution of Mechanical Engineers
Institution of Water and Environmental Management (IWEM)
Ministry of Agriculture, Fisheries and Food
National Farmers' Union
Pipeline Industries Guild
Royal Institution of Chartered Surveyors
Society of British Gas Industries
Water Authorities' Association
Water Companies' Association
Water Research Centre

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Institution of Civil Engineering Surveyors
United Kingdom Offshore Operators' Association

Amendments issued since publication

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BS 8010 : Part 1 : 1989

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Amendment No. 1
published and effective from 15 August 1993
to BS 8010 : Section 2.8 : 1992

Pipelines
Part 2. Pipelines on land: design, construction and installation
Section 2.8 Steel for oil and gas

Corrections

AMD 7799
August 1993

Clause 2.9.2 Hoop stress

Delete the existing formula for hoop stress thin wall and substitute the following.

$$S_h = \frac{pD}{20t}$$

AMD 7799
August 1993

Figure 2 Minimum distance from normally occupied buildings for methane (a category D substance)

Delete the existing figure 2 and substitute the attached new figure 2.

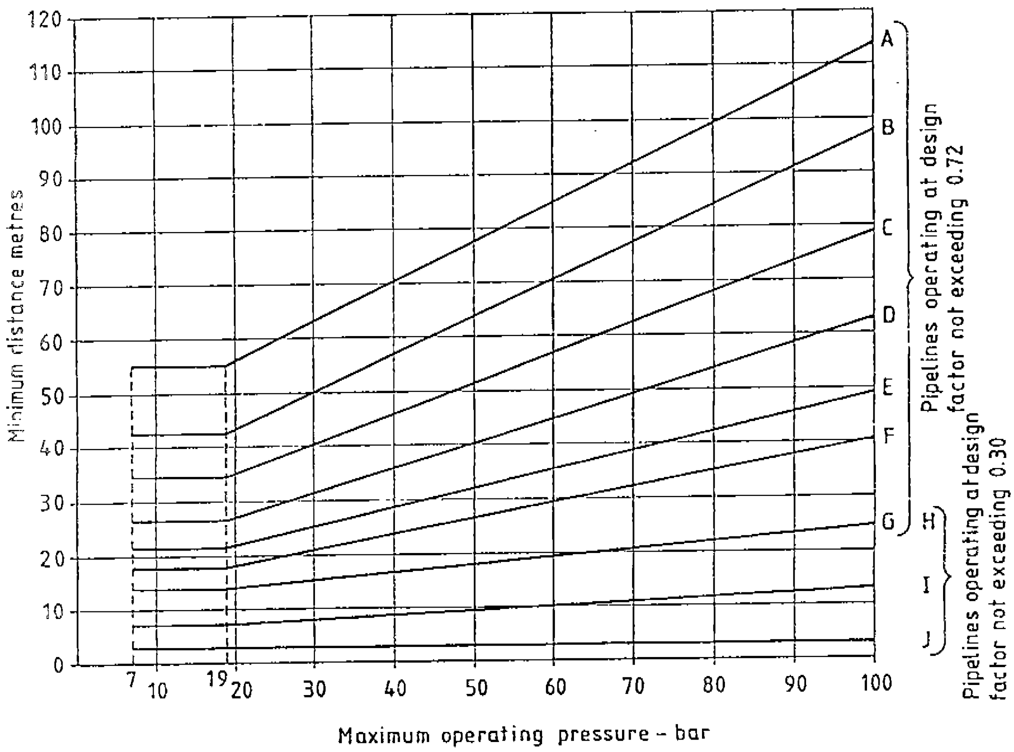
NOTE. The drawing is unchanged but a key to the pipe diameters and two notes to the figure have been inserted.

AMD 7799
August 1993

List of references

In the informative references, list of IGE publications, insert the following new reference after the reference to IGE/TD/1 : 1984.

' IGE/TD/3 : 1993 *Gas distribution mains (3rd edition)*'



Key to pipe diameters

A Exceeding 914.4 mm (36") but not exceeding 1066 mm to 1068 mm (42")

B Exceeding 762.0 mm (30") but not exceeding 914.4 mm (36")

C Exceeding 609.6 mm (24") but not exceeding 762.0 mm (30")

D Exceeding 457.2 mm (18") but not exceeding 609.6 mm (24")

E Exceeding 323.8 mm (12 ¾") but not exceeding 457.2 mm (18")

F Exceeding 168.3 mm (6 ⅝") but not exceeding 323.8 mm (12 ¾")

G Not exceeding 168.3 mm (6 ⅝")

H All diameters, wall thickness < 9.52 mm

I All diameters, wall thickness ≥ 9.52 mm or impact protection

J All diameters, wall thickness ≥ 11.91 mm

NOTE 1. Pipelines designed to operate between 7 bar and 19 bar should have an internal design pressure of 19 bar.

NOTE 2. For pipelines designed to operate at less than 7 bar, guidance may be obtained from IGE/TD/3.

Figure 2. Minimum distance from normally occupied buildings for methane (a category D substance)

BS 8010 :
Section 2.8 :
1992

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Code of practice for

Pipelines

Part 2. Pipelines on land: design, construction and installation

Section 2.8 Steel for oil and gas

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Committees responsible for this British Standard

The preparation of this British Standard was entrusted by Technical Committee B/203 Pipelines, to Subcommittee B/203/2, Pipelines for oil and gas on land, upon which the following bodies were represented:

Association of Consulting Engineers
British Compressed Gases Association
British Gas plc
British Steel Industry
Department of Environment (Property Services Agency)
Federation of Civil Engineering Contractors
Health and Safety Executive
Institute of Petroleum
Pipelines Industries Guild
PSE/17 Materials and equipment for petroleum and natural gas industries
  PSE/17/1 Linepipe

This British Standard, having been prepared under the direction of Technical Committee B/203, was published under the authority of the Standards Board and comes into effect on 15 September 1992

The following BSI references relate to the work on this standard:
Committee reference B/203/2
Draft for comment 92/10703 DC

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Foreword

This Section of BS 8010 has been prepared under the direction of Technical Committee B/203. BS 8010 is a complete revision of all five Parts of CP 2010. BS 8010 is to be published in four Parts as follows.

Part 1. *Pipelines on land: general*

Part 2. *Pipelines on land: design, construction and installation*

Part 3. *Pipelines subsea: design, construction and installation*

Part 4. *Pipelines on land and subsea: operations and maintenance*

Part 1 (which supersedes CP 2010 : Part 1 : 1966) contains general information which is relevant to a variety of pipelines and a variety of transported materials. It deals with those aspects of pipeline development which affect the owner and occupier of land through which the pipeline passes.

Part 2 is divided into several Sections which will be published as separate documents as follows:

Section 2.1 *Ductile iron*

Section 2.3 *Asbestos cement*

Section 2.4 *Prestressed concrete pressure pipelines*

Section 2.5 *Glass reinforced thermosetting plastics*

Section 2.6 *Thermoplastics*

Section 2.7 *Precast concrete*

Section 2.8 *Steel for oil and gas*

Each Section will contain information on the design, construction and installation of a pipeline in the particular material. These Sections will supersede the existing Parts 2, 3, 4 and 5 of CP 2010.

Part 3 will include the general information relevant to subsea pipelines and the particular information on design, construction and installation of a pipeline in specific materials.

Part 4 will contain advice on the operation and maintenance of pipelines and will probably be in sections related to conveyed material.

This Section of BS 8010 supersedes part of CP 2010 : Part 2 : 1970. This Section of BS 8010 deals with oil, gas and other substances which are hazardous by nature of being explosive, flammable, toxic or reactive, generally classified as category B, category C and category D substances (see **2.2**).

The guidance given on the design of pipelines for the transmission of methane is based directly on the philosophy and guidance contained in the Institution of Gas Engineers *Recommendations on transmission and distribution practice* IGE/TD/1 : 1984 *Steel pipelines for high pressure gas transmission*. The Institution's guidance is specific to 1st and 2nd family gases and can be supported by experimental data. Copies of the Recommendations are available from the Institution and should be consulted.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

Attention is drawn to the principal Acts of Parliament, which enable pipelines to be constructed and regulate procedures. These are listed in appendix A of BS 8010 : Part 1 : 1989.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Section 1. General

1.1 Scope

This Section of BS 8010 : Part 2 provides guidance on the design, construction and installation of steel pipelines on land for oil, gas and toxic fluids. It is not intended to replace or duplicate hydraulic, mechanical or structural design manuals.

The extent of pipeline systems on land for conveying oil, gas and toxic fluids which are covered by this Section is shown in figure 1.

Reference should be made to BS 8010 : Part 1 : 1989 for those aspects of land acquisition, routing, installation, operation, maintenance and abandonment of pipelines which affect land.

1.2 References

1.2.1 Normative references

This Section of BS 8010 incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on page 46. Subsequent amendments to, or revisions of, any of these publications apply to this Section of BS 8010 only when incorporated in it by updating or revision.

1.2.2 Informative references

This Section of BS 8010 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on page 48, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this Section of BS 8010 the definitions given in BS 8010 : Part 1 : 1989 apply together with the following.

1.3.1 availability

The probability that a system will be in the operational state.

1.3.2 coating

A durable material of high electrical resistance applied to the external surface of steel pipes and fittings to protect the metal from corrosion.

1.3.3 component

A general term for any item that is part of a pipeline other than a straight pipe or field bend.

NOTE. Also referred to as a fitting.

1.3.4 design temperature

The design temperature is the maximum or minimum temperature which determines the selection of material for the duty proposed and should represent the most arduous conditions expected.

1.3.5 holiday

A flaw in the coating or lining.

1.3.6 holiday detector

A device for detecting flaws in the coating or lining.

1.3.7 insulation joint

A fitting having high electrical resistance which can be inserted in a pipeline to insulate electrically one section of pipeline from another.

1.3.8 intermediate station

A pump, compressor, valve, pressure control, heating or metering station, etc. located along the pipeline route between the pipeline terminals.

1.3.9 internal design pressure

The pressure selected as the maximum sustained pressure exerted by the pipeline contents for which a pipeline is to be designed.

1.3.10 lining

A durable material applied to the internal surface of steel pipes and fittings to protect the metal from corrosion, erosion or chemical attack.

1.3.11 maximum operating pressure

The sum of the static head pressure, the pressure required to overcome friction loss and any required back pressure.

1.3.12 maximum allowable operating pressure (MAOP)

The MAOP is that pressure, excluding surge pressure or other variations, for which a pipeline is qualified.

1.3.13 night cap

A temporary closure at the end of a section of pipeline.

1.3.14 pig

A device propelled through a pipeline by fluid pressure, for cleaning, swabbing, inspection or batch separation.

1.3.15 pig trap

A device allowing entry to the pipeline for the launching and receiving of pigs and other equipment to be run through the pipeline.

1.3.16 pipe

A hollow cylinder through which fluid can flow, as produced by the manufacturer prior to assembly into a pipeline.

NOTE. Also known as linepipe.

1.3.17 pipeline

A continuous line of pipes of any length without frequent branches used for transporting fluids. It does not include piping systems such as process plant piping within refineries, factories or treatment plants.

A pipeline on land is a pipeline laid on or in land, including those sections laid under inland water courses.

A pipeline subsea is a pipeline laid under maritime waters and estuaries and the shore below the high water mark.

NOTE. Certain aspects of both on land and subsea Parts of BS 8010 are relevant to the shore area and should be consulted for landfalls.

1.3.18 pipeline system

An interconnected system of pipelines including piping within terminals and intermediate stations as shown in figure 1.

1.3.19 pup

A short made-up piece of pipe.

1.3.20 redundancy

The incorporation of components in parallel in a control system in which the system fails to operate only if all its components fail to operate.

1.3.21 reliability

The probability of a device or system performing in the manner desired for a specified period of time.

1.3.22 tie-in welds

Tie-in welds are welds carried out between two sections of pipe already welded together and installed in the ground.

1.3.23 voting systems

Systems incorporating parallel components which operate only if a predetermined proportion of the components indicate that the system should operate.

1.4 Units

The International System of Units (SI) (see BS 5555) is followed in this Section. Exceptions are pipeline diameters which are also given in inches and the unit used for pressure which is the bar.

NOTE. 1 bar = 10^5 N/m^2 = 10^5 Pa.

1.5 Application

1.5.1 General application

The steel pipelines covered by this Section should be constructed with butt welded joints and are generally suitable for conveying oil, gas and toxic fluids. The choice of steel, components, coating and lining (if necessary) will depend on the service conditions and the particular environment. The major application of this Section will be the transmission of substances for which low alloy carbon steel pipe will meet the service conditions required. Service conditions include maximum operating pressure, maximum and minimum temperatures, extent of chemical and physical reaction between the substance conveyed and the pipe, and the flammability and/or toxicity of the substance conveyed. Environmental factors are described in BS 8010 : Part 1 : 1989.

Pipelines are unlikely to be required to operate outside the temperature range − 25 °C to + 120 °C. In the event of pipelines being required to operate outside this range reference should be made to specifications such as ANSI B31.3 or BS 806 where design stresses for pipe materials at other temperatures are given.

1.5.2 Categorization of substances

Substances to be conveyed by pipelines should be placed in one of four categories according to the hazard potential of the substance. (See **2.2.**)

The provisions of this Section apply to pipelines conveying category B, category C and category D substances (see **2.2**).

1.6 Pipeline and plant area demarcations

This Section applies to pipeline systems connecting production plants, process plants, refineries, and storage facilities, including any section of pipeline constructed within the boundaries of such facilities for the purpose of connecting it to a pumping station or process piping.

This Section does not necessarily apply to other piping systems within such facilities and for which other British Standards are available.

Figure 1 illustrates the extent of pipeline systems to which this Section applies.

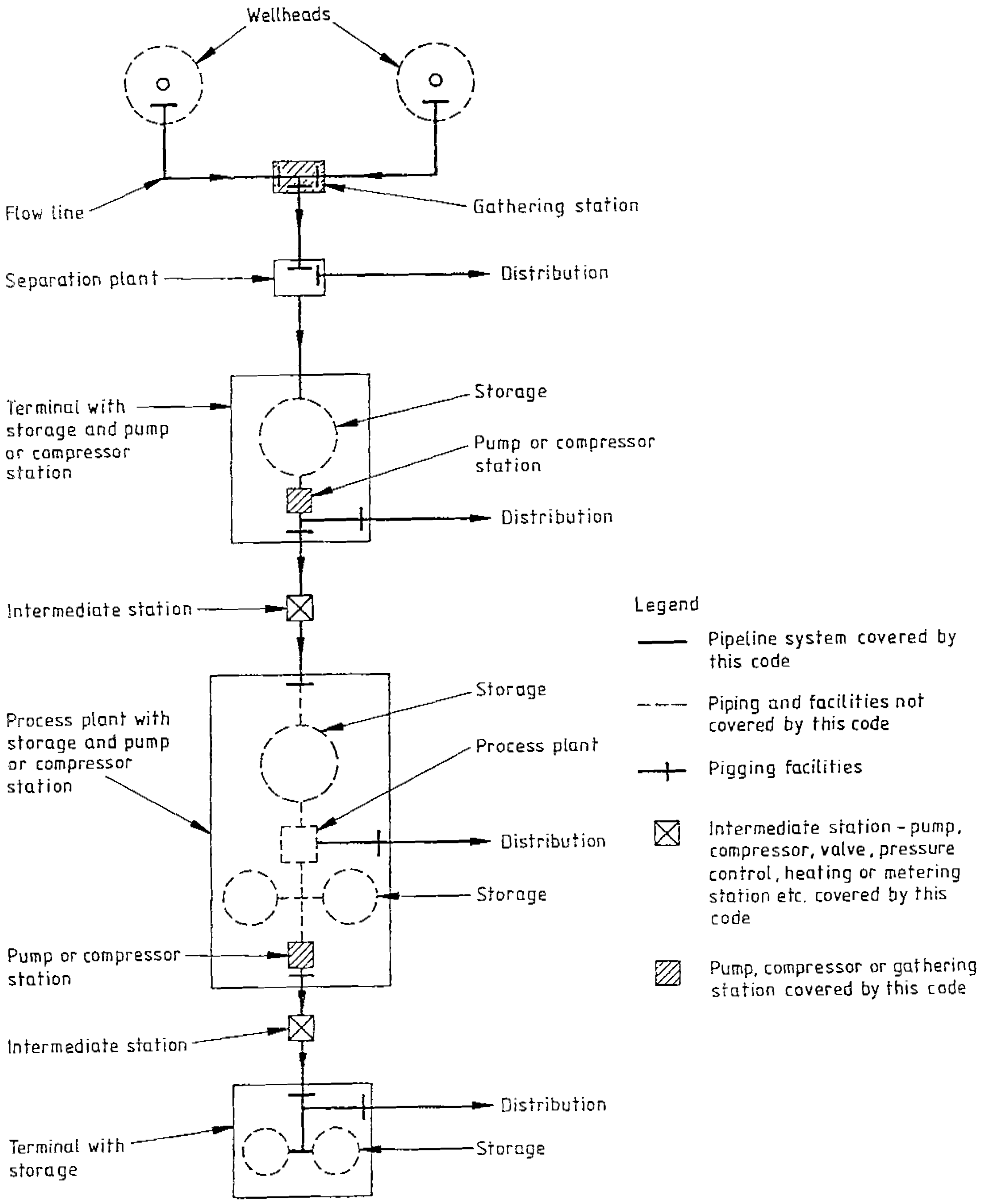


Figure 1. Extent of pipeline systems for conveying oil and gas which are covered by this Section

1.7 Safety

Safety considerations affecting the design, construction and installation of pipelines are covered generally in BS 8010 : Part 1 : 1989 and specific recommendations for the extra protective measures which may be provided for pipelines are given in appropriate clauses in this Section.

1.8 Environmental protection

Environmental factors to be considered in the design, construction and installation of steel pipelines are covered in BS 8010 : Part 1 : 1989.

1.9 Quality assurance

The safety and reliability of a pipeline system may be improved by the introduction of quality assurance procedures. These procedures should be used in the application of the whole of this Section including design, procurement, construction and testing.

In this respect reference should be made to BSI Handbook 22 *Quality Assurance*, BS 5750 and section 7 of this document.

NOTE. Other recognized quality assurance codes may be specified and in this case section 7 should be referred to.

1.10 Statutory requirements

BS 8010 : Part 1 : 1989 gives recommendations for compliance with the requirements of all authorities whose duties or interests may be affected by the construction of a pipeline. Appendix A of BS 8010 : Part 1 : 1989 lists the principal Acts of Parliament regulating the construction of pipelines.

1.11 Documentation

BS 8010 : Part 1 : 1989 gives recommendations for the types and scales of plans to be used in routing surveys and construction of pipelines. In addition, the following records should be maintained by the promoter.

a) Materials specifications and test results.

b) Equipment manufacturers and suppliers.

c) 'As built' route alignments generally of 1 : 2500 scale (in built-up areas 1 : 1250 scale should be considered).

d) Detailed larger scale drawings of crossings and installations, etc.

e) Land drainage drawings.

f) Pressure test records.

g) Factory and construction inspection records.

h) Welding records showing the location of each pipe and component giving pipe number, grade, wall thickness, coating type, coating thickness and weld number.

The use of computerized records systems should be considered for these records.

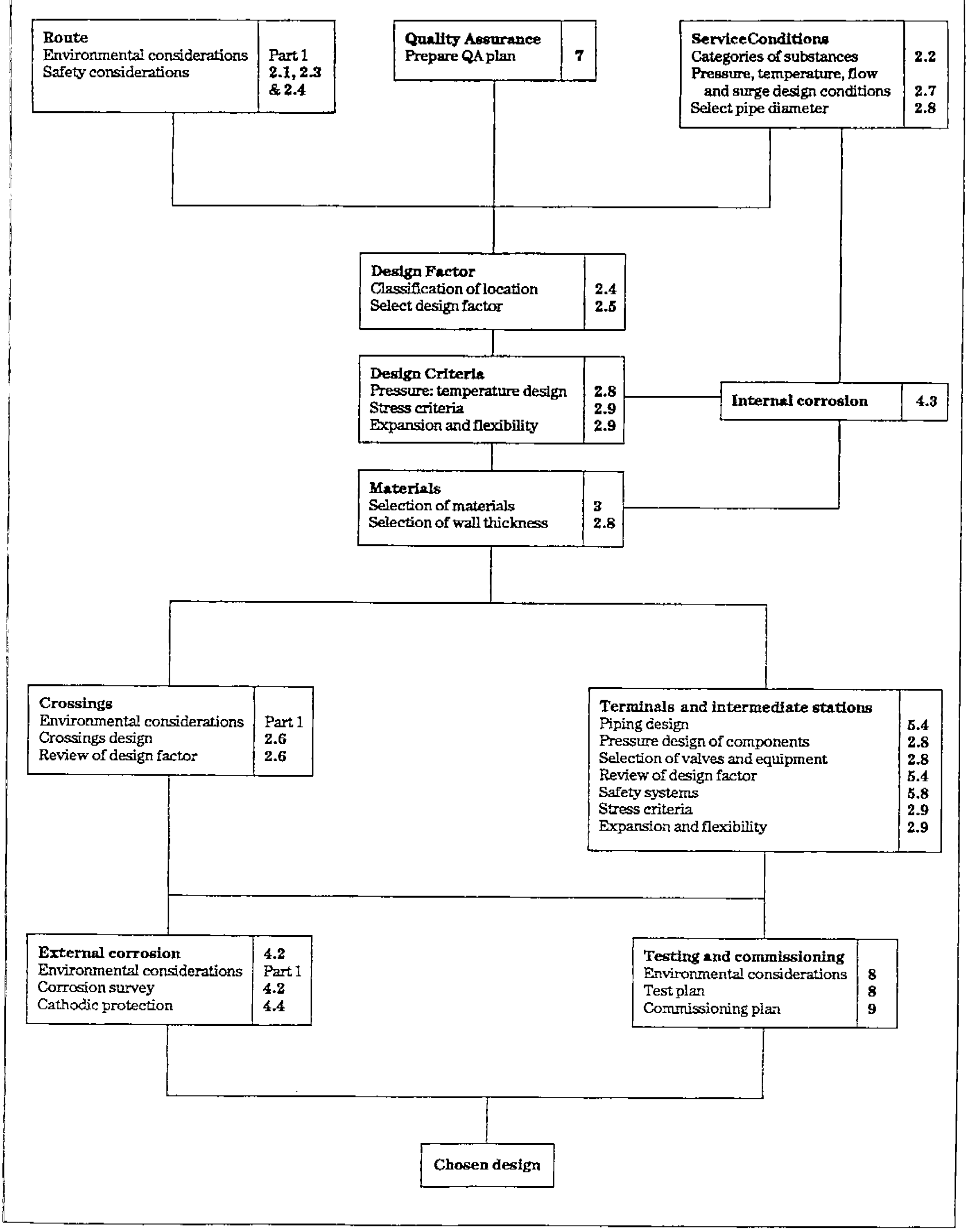
1.12 Abandonment

BS 8010 : Part 1 : 1989 gives recommendations for the steps to be taken on abandonment of a pipeline.

1.13 Pipeline design flowchart

The pipeline design flowchart shown in table 1 may be used by the pipeline designer as a guide through the design process as it relates to this Section. The flowchart does not attempt to show all the various pathways required to arrive at the chosen design. The numbers shown in the flow chart boxes refer to the sections and clauses within this Section.

Table 1. Pipeline design flowchart



Section 2. Design

2.1 Safety considerations

2.1.1 General

The recommendations of this Section are considered to be adequate for public safety under conditions usually encountered in pipelines including those within towns, cities, water catchments and industrial areas. The Section is not intended to be a design handbook and although it contains certain recommendations it does not replace the need for appropriate experience and competent engineering judgement. Fundamental principles should be followed throughout and materials and practices not recommended in the Section may be used providing they can be shown to achieve comparable safety standards.

The design and location of a pipeline should take account of the hazard potential of the substance to be conveyed, the proximity of the pipeline to normally occupied buildings and the density of population in the areas through which the pipeline passes. Potential causes of pipeline damage which may lead to subsequent failure include the activities of third parties carrying out agricultural or construction works along the route of the pipeline such as those associated with deep working of the land, drainage, installation and maintenance of underground services and general road works.

Consideration should be given at the design stage to any requirement to provide suitable and safe access for in-service inspection.

The safety and reliability of a pipeline system may be improved by the application of quality assurance procedures in design. In this respect reference should be made to section 7.

2.1.2 Extra protection

The design of a pipeline should take into account the extra protection which may be required to prevent damage arising from unusual conditions such as may occur at river crossings and bridges, or due to exceptional traffic loads, long self-supported spans, vibration, weight of special attachments, ground movement, abnormal corrosive conditions, any other abnormal forces and in areas where the depth of cover is less than recommended.

Typical examples of extra protection are:

a) increased pipe wall thickness;

b) additional protection above the pipe;

c) application of concrete or similar protective coating to the pipe;

d) use of thicker coatings to improve corrosion protection;

e) increased depth of cover;

f) use of extra markers to indicate the presence of the pipeline;

g) provision of a sleeve to protect from live loads;

h) provision of impact protection for above-ground pipelines.

2.2 Categorization of substances

2.2.1 General

Substances to be conveyed by pipelines should be placed in one of the following four categories according to the hazard potential of the substance. If the category is not clear the more hazardous should be assumed.

Category A	Typically water based fluids.
Category B	Flammable and toxic substances which are liquids at ambient temperature and atmospheric pressure conditions. Typical examples would be oil, petroleum products, toxic liquids and other liquids which could have an adverse effect on the environment if released.
Category C	Non-flammable substances which are gases at ambient temperature and atmospheric pressure conditions. Typical examples would be oxygen, nitrogen, carbon dioxide, argon and air.
Category D	Flammable and toxic substances which are gases at ambient temperature and atmospheric pressure conditions and are conveyed as gases or liquids. Typical examples would be hydrogen, methane, ethane, ethylene, propane, butane, liquefied petroleum gas, natural gas liquids, ammonia, and chlorine.

Mixtures of gases and liquids should be placed in relation to their composition. Other gases or liquids not specifically included by name should be placed in the category containing substances most closely similar in hazard potential to those quoted (see **2.2.2**). Guidance on this may be found in publications such as *A guide to the Notification of Installations Handling Hazardous Substances Regulations* 1982 [1], published by HSE and *Hazard definition: nomenclature for hazard and risk assessment in the process industries* [2] published by the Institution of Chemical Engineers.

2.2.2 Hazard potential

2.2.2.1 *General*

In the unlikely event of a rupture of a pipeline conveying a gas, the blast effect owing to stored energy is an important factor in the hazard potential of the substance. The rupture of a pipeline conveying a liquid will have a much lower blast effect owing to the relatively incompressible nature of liquids. Gases conveyed as liquids will have an intermediate effect. The characteristics of some hazardous substances commonly conveyed in pipelines have been included in **2.2.2.2** to **2.2.2.4**, to assist the designer in determining the category into which hazardous substances should be placed.

2.2.2.2 *Substances conveyed as a liquid*

Crude oil and refined petroleum products (heavier than butane) are flammable and will be released as a liquid which may infiltrate ground water and migrate from the point of release along the ground or in water courses. Toxic liquids will behave in a similar manner. Crude oil and petroleum products radiate a high level of heat on ignition.

2.2.2.3 *Substances conveyed as a gas*

Nitrogen and carbon dioxide readily mix with air but may form a heavier than air cloud on release (due to temperature reduction) increasing the risk of asphyxiation in the immediate vicinity. In addition carbon dioxide has a degree of toxicity (see the latest issue of HSE Guidance Note EH40/92 *Occupational exposure limits* [3]).

Oxygen readily mixes with air, supports combustion and will increase the flammability of combustible materials in the immediate vicinity of a release.

Hydrogen is flammable, lighter than air and easily ignited. When ignited it radiates heat and may produce a vapour cloud explosion.

Methane is flammable, lighter than air, radiates heat on ignition and can form a vapour cloud which may migrate from the point of rupture.

Ethane is flammable, slightly heavier than air, radiates a high heat on ignition and can form a vapour cloud at low level which may migrate from the point of rupture.

2.2.2.4 *Substances conveyed as liquid or gas or in dense phase*

Ethylene is flammable, slightly lighter than air but may form a heavier than air cloud on release due to temperature reduction. Ethylene radiates a high heat on ignition and can form a vapour cloud which may migrate from the point of rupture. Ethylene has the lowest critical pressure of commonly transported gases, can decompose exothermally and is capable of detonation.

Natural gas liquid (NGL) will on release behave in relation to its constituents, ethane, propane and butane etc., depending on its particular composition. NGL is flammable, will radiate a high heat on ignition and form a vapour cloud at ground level which may migrate from the point of rupture.

Liquefied petroleum gas (LPG) is flammable and, although conveyed in pipelines as liquid or gas, will be released as a heavier than air gas (propane and butanes) which can migrate some distance at ground level. LPG will radiate a high level of heat on ignition. The behaviour of gases and associated liquids in two phase flow pipelines will depend upon their particular composition on release.

Ammonia is flammable and toxic, and will be released as a heavier than air gas which can migrate some distance at ground level. Ammonia will radiate heat if ignited; the gas has a toxic effect.

2.3 Safety evaluation

2.3.1 General

The pipeline designer should give consideration to the preparation of a safety evaluation for pipelines designed and constructed in accordance with this Section. The evaluation should include the following:

a) critical review of the pipeline route;

b) description of the technical design of the pipeline system including potential hazards of the substance to be conveyed and design and construction aspects of the pipeline system;

c) details of pressure control, monitoring and communications systems, emergency shutdown facilities and leak detection (where incorporated);

d) proposals for pipeline monitoring and inspection during operation together with emergency procedures.

2.3.2 Risk analysis

Where a risk analysis is required as part of the safety evaluation it should include the following:

a) the identification of all potential failure modes;

b) a statistically based assessment of failure mode and frequency;

c) a detailed evaluation of the consequences of failure from small holes up to full bore rupture including reference to population density;

d) prevailing weather conditions;

e) time taken to initiate a pipeline shutdown.

The risk analysis should culminate in an evaluation of risk along the pipeline.

2.4 Classification of location

2.4.1 General

The location of category C and category D substance pipelines should be classified in relation to population density along the route of the pipeline to determine the operating stress levels and proximity distances from normally occupied buildings. The location of category B substance pipelines need not be classified in relation to population density but may require extra protection or be subject to a safety evaluation.

Class 1 location	Areas with a population density less than 2.5 persons per hectare.
Class 2 location	Areas with a population density greater than or equal to 2.5 persons per hectare and which may be extensively developed with residential properties, schools and shops etc.

Class 3 location	Central areas of towns and cities with a high population and building density, multi-storey buildings, dense traffic and numerous underground services.

The measurement of population density is described in **2.4.3**. Additional factors should be considered when classifying pipeline location such as future development, topographical features in the area through which the pipeline passes and watercourses crossed or adjacent to the pipeline leading to areas of higher population density. In these and other comparable cases a more stringent classification of location may be considered where the effects of a pipeline failure could be experienced by population centres outside the immediate vicinity of the pipeline.

2.4.2 Proximity to occupied buildings

2.4.2.1 The minimum distance between a pipeline conveying category B substances and normally occupied buildings should be determined by the designer taking into account both access requirements during construction and access requirements for maintenance and emergency services during operation.

2.4.2.2 At the pipeline feasibility study stage the initial route and population density assessment for pipelines conveying category C and category D substances (excluding methane) should be established by taking account of the proximity to occupied buildings. The minimum distance (in metres) for routing purposes between a pipeline having a design factor (see **2.5**) not exceeding 0.72 and normally occupied buildings should be determined from the following formula:

$$\text{Minimum distance} = Q\left(\frac{D^2}{32000}+\frac{D}{160}+11\right)\left(\frac{P}{32}+1.4\right)$$

where

D is the pipe outside diameter (in mm);

P is the maximum operating pressure (in bar);

Q is the substance factor (see table 2).

The proximity distances for pipelines conveying category C substances at pressures less than 35 bar should be the same as those for the substance calculated at 35 bar.

Table 2. Substance factors

Substance	Substance factor, Q
Ammonia	2.5
Ethylene	0.8
Hydrogen	0.45
LPG	1
NGL	1.25
Category C	0.3

Substances not specifically listed by name in table 2 should be given the substance factor most closely similar in hazard potential to those quoted.

For pipelines conveying category C substances and having a design factor not exceeding 0.3, the initial route may be established by allowing a minimum distance of 3 m between the pipeline and normally occupied buildings. For pipelines conveying category D substances and having a design factor not exceeding 0.3 and a wall thickness greater than 11.91 mm the initial route may be established by allowing a minimum distance of 3 m between the pipeline and normally occupied buildings.

The minimum distances should finally be determined by taking into account factors including the hazardous nature of the particular substance being conveyed and the pipeline inventory in conjunction with a safety evaluation of the pipeline (see **2.3**).

2.4.2.3 The minimum distance between a pipeline conveying methane (a category D substance) and normally occupied buildings should be determined in accordance with figure 2.

2.4.2.4 Pipelines designed to operate outside the range of maximum operating pressure and pipe diameters shown in figure 2 may be acceptable provided a more detailed assessment of potential additional hazard is made in conjunction with a safety evaluation (see **2.3**).

2.4.3 Population density

2.4.3.1 For category C substance pipelines the population density should be calculated as the total of the average number of persons normally occupying buildings within a strip centred on the pipeline of width three times the minimum distance given in **2.4.2.2** for any 1.5 km length of pipeline.

2.4.3.2 For methane (a category D substance) pipelines the population density should be calculated as the total of the average number of persons normally occupying buildings within a strip centred on the pipeline of width 10 times the minimum distance shown by lines A to G in figure 2 for any 1.5 km length of pipeline.

2.4.3.3 For category D substance pipelines (excluding methane) the population density should be calculated as the total of the average number of persons normally occupying buildings within a strip centred on the pipeline of width eight times the minimum distance given in **2.4.2.2** for any 1.5 km length of pipeline.

2.4.3.4 The population density is expressed in terms of number of persons per hectare. Measurement of population density should be based on a survey of normally occupied buildings including houses, schools, hospitals, public halls, and industrial areas. The population should be estimated following consultation with local authorities to assess the population level in the area concerned.

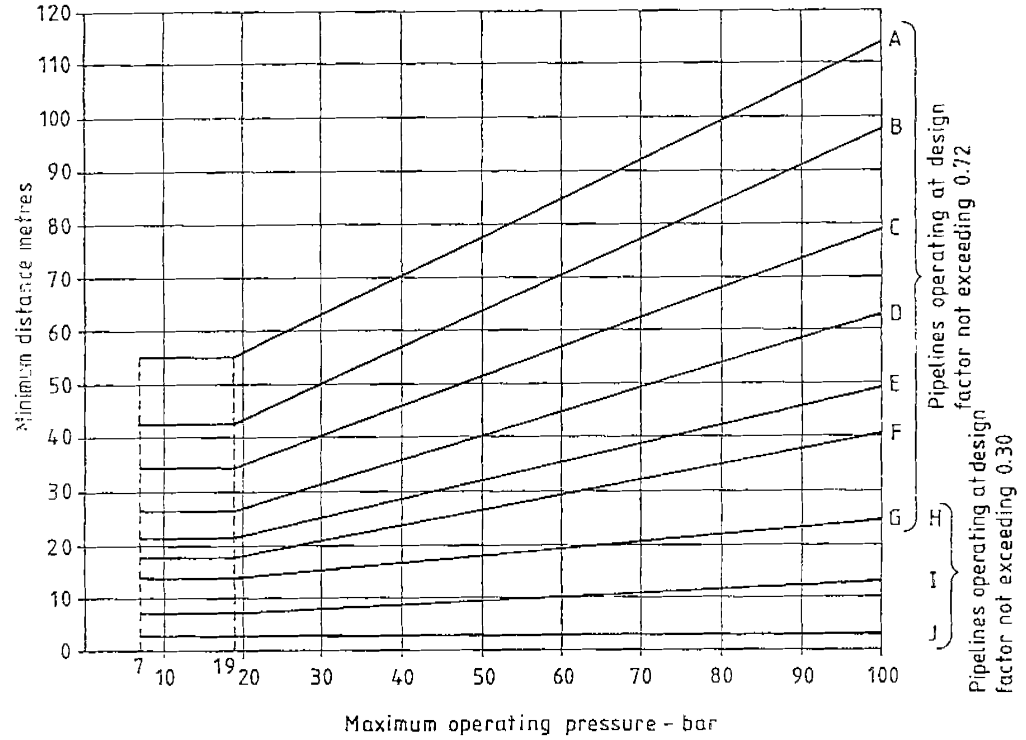


Figure 2. Minimum distance from normally occupied buildings for methane (a category D substance)

The point at which the required degree of protection changes adjacent to the boundary between class 1 and class 2 areas should be one-half of the appropriate strip width from the boundary of the higher density area.

Occasionally the method of population density assessment may lead to an anomaly in classification of location such as may occur in a ribbon development area or for pipelines conveying toxic substances. In such cases consideration should be given to a more stringent classification than would be indicated by population density alone.

2.5 Selection of design factor

2.5.1 Design factor

The maximum design factor a to be used in the calculation of allowable stress for pipelines (see **2.10.2**) should be as described in **2.5.2** and **2.5.3**.

2.5.2 Category B substances

The design factor a should not exceed 0.72 in any location. In areas of high population density extensively developed with residential properties, schools, shops, public buildings and industrial areas consideration should be given to providing extra protection to the pipeline as described in **2.1.2**.

2.5.3 Category C and category D substances

The design factor a should not exceed 0.72 in class 1 and 0.30 in class 2 and class 3 locations. However the design factor may be raised to a maximum of 0.72 in class 2 locations providing it can be justified to a statutory authority by a risk analysis carried out as part of a safety evaluation for the pipeline (see **2.3.2**).

Pipelines designed to convey category D substances in class 2 locations should have either a nominal wall thickness of 9.52 mm or be provided with impact protection in accordance with **2.6.8** to reduce the likelihood of penetration from mechanical interference.

It is essential that pipelines designed to operate in class 3 locations be limited to a maximum operating pressure of 7 bar.

2.6 General design considerations

2.6.1 Road crossings

2.6.1.1 *General*

The design of pipeline road crossings and parallel encroachments to roads should take account of daily and seasonal traffic density and risk of external interference in the area. For category C and category D substance pipelines, roads should be classified as major roads or minor roads for allocation of design factor and wall thickness. Major roads would normally include motorways and trunk roads. Minor roads would normally include all other public roads. Private roads or tracks should only be classified as minor roads if there is reason to believe that they may be used regularly by heavy traffic. Assessments of traffic densities should be carried out by consultation with the Department of Transport and local highway authorities concerned.

Road crossings should be installed by open-cut, boring or tunnelling methods following consultation with the relevant highway authorities. Particular care should be exercised in the consideration of ground conditions and temporary works design. The minimum distance between the road surface and the top of the pipe or sleeve should be 1.2 m.

2.6.1.2 *Category B substances*

For pipelines designed to convey category B substances no revision to design factor or wall thickness is required at road crossings. Consideration should be given to the provision of impact protection at open-cut crossings of major roads.

2.6.1.3 *Category C substances*

For pipelines designed to convey category C substances no revision to design factor or wall thickness is required at road crossings. However, impact protection should be provided at open cut crossings of major roads.

2.6.1.4 *Category D substances*

For pipelines designed to convey category D substances the design factor *a* should be 0.30 for both major and minor road crossings. However, the design factor may be raised to a maximum of 0.72 if this can be justified to a statutory authority by a risk analysis carried out as part of a safety evaluation for the pipeline (see **2.5.3**).

Pipeline crossings of major roads should be carried out using either:

a) pipe with a nominal wall thickness of 11.91 mm or greater without impact protection; or

b) pipe with a wall thickness appropriate to the design factor and with impact protection in accordance with **2.6.8**.

For major roads the design factor, wall thickness or impact protection requirements should extend for a distance equal to the minimum distance shown in figure 2 for methane or the final minimum distance (see **2.4.2.2**) for other category D substance pipelines, measured at a right angle from the edge of the carriageway.

Pipeline crossings of minor roads should be carried out using either:

1) pipe with a nominal wall thickness of 9.52 mm or greater without impact protection; or

2) pipe with a wall thickness appropriate to the design factor and impact protection in accordance with **2.6.8**.

For minor roads the design factor, wall thickness or impact protection requirements should extend between highway boundaries on each side of the crossing.

2.6.2 Rail crossings

Pipeline rail crossings should be designed and classified in the same manner as described in **2.6.1** for road crossings. Major rail routes would normally include inter city and high density commuter routes. Minor rail routes would normally include all others. The minimum distance between the top of the pipe or sleeve and the top of the rail should be 1.4 m for open cut crossings and 1.8 m for bored or tunnelled crossings. Assessment of traffic densities and crossing requirements should be carried out by consultation with the appropriate railway authority.

2.6.3 River crossings

Pipelines crossing rivers and estuaries which cannot be designed and constructed using normal land pipeline methods should be classified as submarine pipelines and designed and constructed in accordance with BS 8010 : Part 3 : 1992.

2.6.4 Canal, ditch, dyke and other water crossings

Pipelines crossing rivers and canals should be designed in consultation with the water and waterways authorities to determine the minimum depth of cover and additional protection required. In considering additional protection, account should be taken of potential pipeline damage by ship's anchors, scour and tidal effects, flood defences and any future works such as dredging, deepening and widening of the river or canal. (See **6.14**.)

2.6.5 Pipe bridge crossings

The preferred design for pipeline crossings is for buried installation of pipe. Where it is necessary to utilize pipe bridges these should be designed in accordance with good structural engineering practice and with a design factor in accordance with **2.6.1** or **2.6.2** as appropriate. Pipe bridge design should consider thermal and structural stresses, pipe carrier stresses and foundation loadings. Sufficient headroom should be provided to avoid possible damage from the movement of traffic or shipping beneath the pipe bridge. Account should be taken of accessibility requirements for maintenance and of restrictions on access to the general public. Potential cathodic protection interference between the pipeline and bridge supporting structure should be considered.

2.6.6 Sleeved crossings

The preferred design for pipeline crossings is for installation of pipe without the use of sleeves to reduce the likelihood of corrosion and for ease of maintenance. Where particular circumstances indicate the need for a sleeved crossing, reference should be made to section 7.2 of the Institution of Gas Engineers IGE/TD/1 : 1984 and BS 7361 : Part 1 : 1991.

2.6.7 Parallel encroachments

Pipelines running parallel to major roads or major rail routes should have design factors appropriate to major road crossings if they encroach within the minimum distance shown in figure 2 for methane or the final minimum distance (see **2.4.2.2**) for category C and other category D substance pipelines.

2.6.8 Impact protection

At some crossings and in areas where the likelihood of third party activity leading to interference with the pipe is increased, the use of impact protection is recommended.

Impact protection may take the form of increased cover, concrete surround, concrete slab over or similar construction.

Unless otherwise recommended in this standard impact protection should extend between the highway or railway boundary at each side of the crossing.

2.6.9 Adverse ground conditions

Reference should be made to **2.3.4** of BS 8010 : Part 1 : 1989.

Where pipelines are unavoidably located in such areas, appropriate protective measures should be taken to counter any potential harm to the pipeline. These may include increased wall thickness, ground stabilization, erosion prevention, installation of anchors, provision of negative buoyancy, etc. as well as the surveillance measures advised in BS 8010 : Part 1.

2.6.10 Depth of cover

In agricultural land the depth of cover should be not less than 900 mm. For the depth of cover in other areas reference should be made to BS 8010 : Part 1.

2.6.11 Location of cathodic protection stations

The selection of sites for cathodic protection stations should take account of the distance from the pipeline route, ground resistivity, ease of access for maintenance, proximity to other buried metallic services and railways, proximity to power supplies, existing ground beds for other pipelines and minimum interference with agricultural operations. Cathodic protection systems should be designed in accordance with BS 7361 : Part 1 : 1991.

2.6.12 Location of section isolating valves

2.6.12.1 Section isolating valves should be installed at the beginning and end of the pipeline and at a spacing along the pipeline appropriate to the substance being conveyed to limit the extent of a possible leak. The spacing of section isolating valves should reflect the conclusions of any safety evaluation prepared for the pipeline and should preferably be installed below ground. In the locating of section isolating valves account should be taken of topography, ease of access for operation and maintenance, protection from vandalism and proximity to normally occupied buildings. Section isolating valves should be installed at either side of a major river or estuary crossing where the pipeline could be damaged by ship's anchors or scouring of the river bed.

2.6.12.2 For pipelines designed to convey category B substances, section isolating valves should be installed at locations which would limit drain down of pipeline contents at any low point to not more than the volume contained in a 16 km length of the pipeline.

2.6.12.3 For pipelines designed to convey category C and category D substances, section isolating valves should be installed at intervals of about 16 km along the pipeline. This distance may be increased if it can be justified to a statutory authority as part of a safety evaluation of the pipeline.

2.6.12.4 For pipelines designed to convey category D and toxic Category B substances, automatic or remotely controlled section isolating valves should be installed unless non-installation can be justified to a statutory authority as part of a safety evaluation for the pipeline. Consideration should be given to similar installation on pipelines conveying category C and non-toxic category B substances.

2.6.13 Use of internal inspection devices

Consideration should be given to the design of pipelines to accommodate internal inspection devices (intelligent pigs).

Important factors to be considered include:

a) minimum radius of bends;
b) changes of internal diameter;
c) length of and access to pig traps;
d) design of branch connections.

2.6.14 Leak detection

Consideration should be given to the incorporation of a leak detection system into the design of a pipeline. The method chosen for leak detection should be appropriate and effective for the substance to be conveyed. Typical leak detection methods include continuous mass balance of pipeline contents, detection of pressure waves, monitoring of rate of change of pressure and flow, and dynamic modelling by computer. The leak detection system should be part of the overall pipeline management system which should incorporate route inspection in accordance with BS 8010 : Part 1 : 1989.

2.7 Design conditions

2.7.1 General

This clause covers the pressures, temperatures and forces applicable to the design of pipeline systems. Pipeline systems should be designed for the most severe coincident conditions of pressure, temperature and loading which may occur during normal operation or testing.

2.7.2 Internal design pressure

The internal design pressure used in design calculations should never be less than the maximum operating pressure at that point. The maximum operating pressure is the sum of the static head pressure, the pressure required to overcome friction losses and any required back pressure. The internal design pressure used in design calculations may be modified by taking into account the difference in pressure between the inside and outside of any pipeline component. Allowances for pressure rises above maximum operating pressure due to surges are described in **2.8.2.4** and **2.8.2.5**. (See figure 3 for a review of pressure definitions.)

Where pipelines are connected to wells, consideration should be given to well kill pressure in the assessment of maximum operating pressure.

2.7.3 Maximum allowable operating pressure (MAOP)

The MAOP is related to the test pressure established by carrying out a hydrostatic or pneumatic test on the pipeline in accordance with section 8. It is essential that the MAOP does not exceed the internal design pressure.

2.7.4 Temperature considerations

2.7.4.1 ***Design temperature***

The design temperature should be established by considering temperature variations resulting from pressure changes and extreme ambient temperatures, but should not include post rupture conditions or emergency blow-down conditions.

NOTE. Consideration should be given to possible fault conditions which may give rise to low temperature.

2.7.4.2 ***Solar gain***

Where piping is exposed to the sun, consideration should be given to the metal temperature rise resulting from solar gain.

2.7.4.3 ***Fluid expansion effects***

Provision should be made to withstand or relieve increased pressure caused by heating of static fluid in a pipeline system or component.

2.7.4.4 ***Cooling effects***

The cooling of vapour or gas may reduce pressure in a pipeline system to vacuum and account should be taken of this in pressure design.

2.7.4.5 ***Pneumatic testing***

Consideration should be given to minimum test temperatures when pneumatic testing is applied (see **3.3.2** and **8.4.2**).

2.7.5 Dynamic effects

2.7.5.1 ***Shock effects***

Effects caused by sudden changes in external or internal pressure shall be considered in the pipeline system design.

2.7.5.2 ***Wind***

The effects of wind loading should be taken into account in the design of exposed pipeline systems.

2.7.5.3 ***Discharge reactions***

The pipeline system should be designed to withstand reaction forces and temperature changes which may occur during discharges or pressure release.

2.7.5.4 ***Vibration***

The pipeline system should be designed to minimize stresses induced by vibration and resonance.

2.7.5.5 ***Earthquake***

Consideration in the design should be given to pipelines located in regions of known earthquake activity.

2.7.5.6 ***Subsidence***

Consideration in the design should be given to pipelines located in mining areas, made up ground or other areas where subsidence is known to occur or likely.

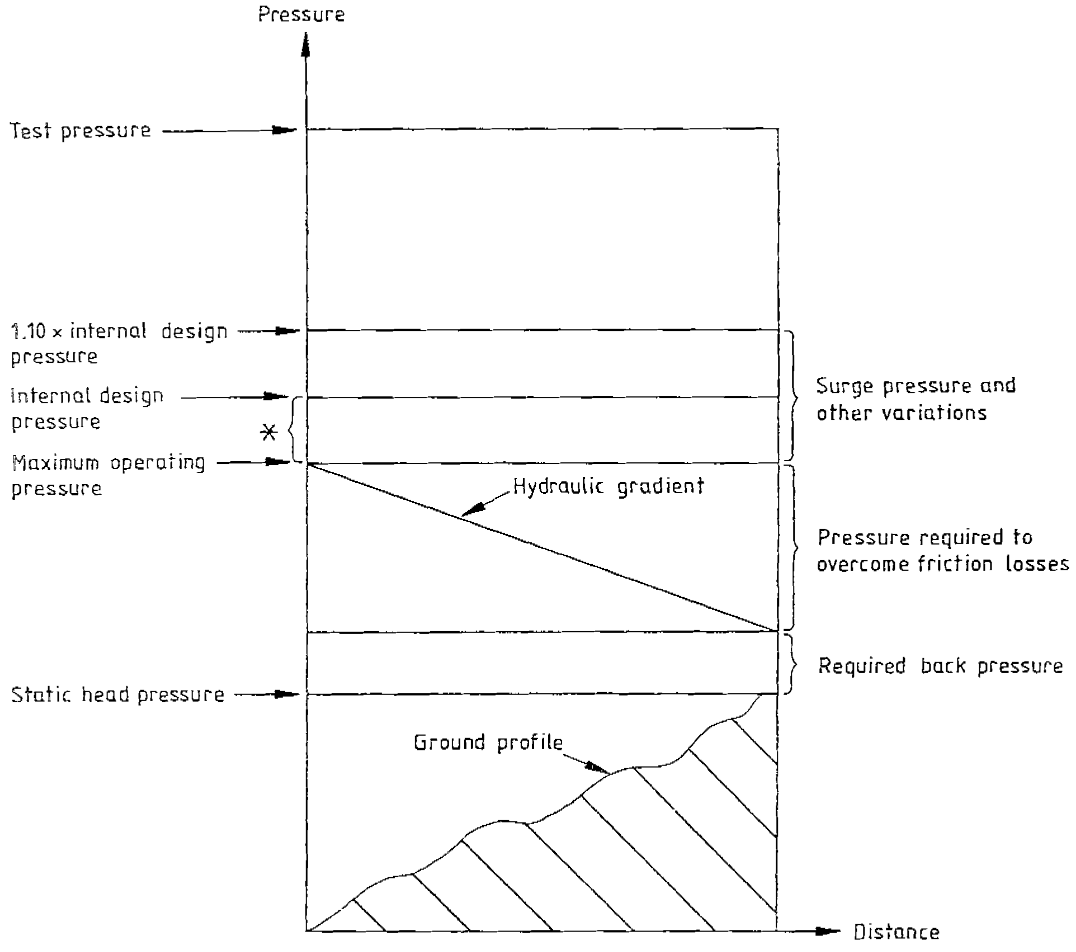
2.7.6 Weight effects

2.7.6.1 ***General***

The weight effects described in **2.7.6.2** and **2.7.6.3** combined with loads and forces from other causes should be taken into account in the design of pipeline systems.

2.7.6.2 ***Live loads***

Live loads are varying loads such as weight of the substance being conveyed, the weight of test liquid, the weight of snow and ice and traffic loads.



* The MAOP may vary between these limits dependent upon the test pressure.

Figure 3. Pressure definitions

2.7.6.3 ***Dead loads***

Dead loads are constant loads such as the weight of the pipe, components, coating, backfill and unsupported attachments to the pipeline system.

2.7.7 Thermal expansion and contraction loads

Provision should be made for the effects of thermal expansion or contraction in the design of pipeline systems. Account should be taken of stresses induced as a result of restriction of free thermal movement owing to restraints.

2.7.8 Pressure expansion

The effects of longitudinal expansion due to internal pressure should be taken into account in the design of pipeline systems.

2.7.9 Relative movement of connected components

The effects of relative movement of connected components or buried piping should be taken into account in the design of pipeline systems and pipe supports.

2.8 Design criteria

2.8.1 General

This clause covers the ratings, design allowances, minimum design values and variations permissible in the design of pipeline systems.

2.8.2 Pressure : temperature ratings

2.8.2.1 ***Components having specific ratings***

The pressure ratings for components should conform to those standards listed in section 3.

2.8.2.2 *Components not having specific ratings*

Piping components not having specific ratings may be used if the pressure design is based on sound engineering analysis supported by proof tests, experimental stress analysis or engineering calculations as appropriate.

2.8.2.3 *Normal operating conditions*

For normal operation the maximum operating pressure should not exceed the internal design pressure and pressure ratings for the components used.

2.8.2.4 *Allowance for variations from normal operation*

Surge pressures in liquid pipelines may be produced by sudden changes in flow which occur for example following valve closure, pump shutdown, pump start-up or blockage of the moving stream. Surge pressure calculations should be carried out to assess the maximum positive and negative surge pressures in the piping system. Account should be taken of surge pressures produced within the pipeline affecting piping systems outside the scope of this standard such as upstream of pumping stations or downstream of pipeline terminals.

2.8.2.5 *Over-pressure protection*

Adequate controls and protective equipment should be provided to ensure that the sum of the surge pressure, other variations from normal operations and the maximum operating pressure does not exceed the internal design pressure at any point in the pipeline system and equipment by more than 10 %. (See **5.8.2**.)

2.8.2.6 *Consideration for different pressure conditions*

When two pipeline systems operating at different pressure conditions are connected the valves or components separating the two pipeline systems should be designed for the more severe design conditions.

2.8.3 Pressure design of pipeline and pipeline components

2.8.3.1 *Straight pipe under internal pressure*

The nominal thickness of steel pipe minus the specified manufacturing tolerance on wall thickness, should not be less than the design thickness, t, used in the calculation of hoop stress in 2.9.2. A nominal pipe wall thickness should be selected to give adequate performance in construction handling and welding. For treatment of corrosion allowance see **2.11**.

2.8.3.2 *Straight pipe under external pressure*

The pipe wall thickness should be adequate to prevent collapse under conditions during construction or operation when the external pressure exceeds the internal pressure taking into account pipe mechanical properties, bending stresses, dimensional tolerance and external loads.

2.8.3.3 *Flanges*

Flanges should be designed and manufactured in accordance with BS 1560 : 1989, BS 3293 : 1960, ANSI B16.5 : 1988 or MSS SP-44 : 1991, as appropriate for the pressure and temperature ratings. Flanges exceeding or departing from standard dimensions may be used provided they are designed with reference to BS 5500 : 1991 or ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1, appendix II : 1989 [4].

2.8.3.4 *Fittings*

Fittings should be designed and manufactured in accordance with BS 1640 : 1962, BS 1965 : 1963, BS 3799 : 1974, ANSI B 16.9 : 1986 or MSS SP-75 : 1988 as appropriate and should have pressure and temperature ratings based on stresses for pipe of the same or equivalent material.

2.8.3.5 *Non-metallic components and gaskets*

Non-metallic trim, packing, seals and gaskets should be manufactured in materials compatible with the substance being conveyed in the pipeline system and should be capable of withstanding the design pressures and temperatures.

Gaskets should be designed in accordance with BS 1832 : 1991, BS 2815 : 1973, BS 3381 : 1989 or ANSI B 16.20 : 1973, as appropriate. Special gaskets may be used providing they are suitable for the pressures, temperatures and substances to which they may be subjected.

2.8.3.6 *Bolting*

Bolting should be designed and manufactured in accordance with BS 4882 : 1990 or ANSI B 16.5 : 1988. Bolts or studbolts should extend completely through the nuts.

2.8.3.7 *Valves*

Steel valves should be designed in accordance with recognized industry standards such as those listed in section **3**. Valves having pressure-containing components such as body, bonnet, cover, end flange or gate manufactured in cast iron or ductile iron should not be used in pipeline systems covered by this Section.

Special steel and non-ferrous valves may be used providing their design, including material strength, structural features, tightness and test procedures, is in accordance with the standards listed in section **3**.

Consideration should be given to the installation of valves to a fire safe design in safety critical areas.

2.8.3.8 *Branch connections*

The design and fabrication of welded branch connections and reinforcement, where appropriate, should be in accordance with ANSI B31.3 : 1987 or ANSI B31.8 : 1989. Where welded or forged branch connections are installed in pipelines designed for pigging, special branch connections should be used to ensure that the pig is not damaged whilst passing the connection, allowed to enter the branch or become stuck.

2.8.3.9 *Bends*

Changes in direction may be made by bending pipe or installing factory-made bends or elbows. All bends should be free from buckling, cracks or other evidence of mechanical damage. The nominal internal diameter of a bend should not be reduced by ovality by more than 2.5 % at any point around the bend. Sufficient tangent lengths should be left at each end of bends to ensure good alignment. Pipes bent cold should not contain a butt weld within the bent section.

The wall thickness of finished bends, taking into account wall thinning at the outer radius, should be not less than the design thickness, t, shown in **2.8.3.1**. An indication of wall thinning as a percentage may be given by the following empirical formula:

$$\text{wall thinning} = \frac{50}{n + 1}$$

where

n is the inner bends radius divided by pipe diameter.

This formula does not take into account other factors which depend on the bending process and reference should be made to the bend manufacturer where wall thinning is critical.

Reference should be made to **3.5.2** for materials aspects of bending and to **6.6** for field bending during construction.

Mitred, wrinkle or gussetted bends should not be used in pipeline systems covered by this Section. Account should be taken of the use of cleaning, scraper and internal inspection devices when specifying the radius of bends intended for installation in pipelines.

Factory-made bends and factory-made wrought steel elbows may be used provided they comply with **2.8.3.6** and this clause.

2.8.3.10 ***Closures***

Closure fittings, including those designed for repeated opening and closing, except blind flanges, should be designed in accordance with BS 5500 : 1991 or ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1 : 1989 [4] and **2.8.3.6** for bolting.

End closures for components including pig traps, filters and prover loops should incorporate an interlocked vent to prevent the closure being opened before the release of pressure from the component. The design should ensure that the hinges and locking mechanism are sufficiently robust to withstand repeated use.

Flat, ellipsoidal, spherical and conical closure heads should be designed in accordance with BS 5500 : 1991 or ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1 : 1989 [4].

2.8.3.11 ***Threaded joints***

All pipe threads on piping components should be taper pipe threads in accordance with BS 3799 : 1974 or ANSI B16.11 : 1980. The installation of threaded joints (including compression fittings) should be discouraged on buried piping systems.

2.8.3.12 ***Special joints***

Special joints, such as insulation joints, may be used provided they are designed in accordance with good engineering practice and applicable requirements of this section. The design of special joints should take account of vibration, fatigue, cyclic conditions, low temperature, thermal expansion and construction installation stresses. Before installation into the pipeline, the joint should pass a hydrostatic pressure test without end restraint at a pressure equal to the pipeline test pressure.

2.8.4 Pig traps

Pig traps should be designed according to the provisions of this Section. However, reference may be made to BS 5500 for fabrication, and for design of details such as nozzle reinforcement, saddle supports and other items not classed as standard pipeline sections. Welding and inspection requirements should be supplemented by BS 4515 : 1984. Pig traps should be tested at pressures not less than those required for the associated pipeline.

2.8.5 Slug catchers

2.8.5.1 ***General***

Slug catchers should be installed upstream of stations, terminals and other plant to remove slugs of liquid from multi-phase flow pipelines. The design pressure should be equal to the internal design pressure of the pipeline system (see **2.7.2**).

Consideration should be given to thermal relief, pipeline and process-related relief requirements and measures to reduce fire exposure. The design should take account of static loading, transients during slug arrival, anchor and support requirements and the provision of sample points to evaluate the build up of solids. When carrying out flexibility and stress analysis calculations account should be taken of momentum and dynamic effects.

2.8.5.2 *Vessel-type slug catchers*

The design of vessel-type slug catchers should be in accordance with BS 5500 : 1991 or ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1 : 1989 [4].

2.8.5.3 *Multipipe-type slug catchers*

For buried multipipe-type slug catchers the pressure design should be in accordance with this Section with an appropriate design factor. For above-ground multipipe-type slug catchers the pressure design should be in accordance with ANSI B31.3 : 1987.

In both cases reference should be made to BS 5500 : 1991 or ASME *Boiler and Pressure Vessel Code* Section VIII, Division 1 : 1989 [4] for nozzle reinforcement and saddle support design and for construction quality requirements.

2.8.6 Anchor blocks

Design of anchor blocks to prevent axial movement of a pipeline should take into account the pipeline expansion force and any pipe to soil friction preventing movement. The axial compressive force required to restrain a pipeline should be calculated as follows.

Thin wall

$$F = A(Ea\ (T_2 - T_1) + 0.5\ S_h - vS_h)$$

Thick wall

$$F = A(Ea(T_2 - T_1) + \frac{S_h}{k^2 + 1} - v(S_h - \frac{p}{10})$$

where

F is the axial force (in N);

A is the cross sectional area of the pipe wall (in mm^2);

E is the modulus of elasticity (in N/mm^2) (2.0×10^5 at ambient temperature for carbon steel);

a is the linear coefficient of thermal expansion (per °C) (11.7×10^{-6} per °C up to 120 °C for carbon steel);

T_1 is the installation temperature (in °C);

T_2 is the maximum or minimum metal temperature (in °C);

S_h is the hoop stress calculated in **2.9.2**, but using the nominal pipe wall thickness (in N/mm^2);

k is the ratio of outside diameter to inside diameter, D/D_i (see **2.9.2**);

v is the Poissons ratio (0.30 for steel);

p is the internal design pressure (in bar).

NOTE. Additional forces may need to be considered.

2.9 Pressure, thermal and other stress criteria

2.9.1 General

This clause covers the calculation of hoop stress (**2.9.2**) and the calculation of expansion and flexibility stresses (**2.9.3**). The allowable hoop stress is given in **2.10.1** and the allowable stress for expansion and flexibility design (equivalent stress) is given in **2.10.2**.

2.9.2 Hoop stress

The hoop stress (S_h) developed in the pipe wall at the internal design pressure should not exceed the allowable hoop stress (S_{ah}) given in **2.10.1**. The hoop stress should be calculated by using either the thin wall or thick wall design equations.

Thin wall

$$S_h = \frac{pD}{20_t}$$

Thick wall

The thick wall formula may be used when the D/t ratio is ≤ 20. This gives the maximum hoop stress encountered at the inside face of the pipe wall.

$$S_h = \frac{p(D^2 + D_i^2)}{10(D^2 - D_i^2)}$$

where

S_h is the hoop stress (in N/mm^2);

p is the internal design pressure (in bar) (see **2.7.2**);

D is the outside diameter (in mm);

t is the design thickness (in mm);

D_i is the inside diameter ($D - 2t$) (in mm).

The thick wall design equation gives a more accurate calculation of hoop stress and always gives the smallest value of maximum stress. When the D/t ratio is greater than 20, the difference between the stresses calculated from the two formulae is less than 5 %.

2.9.3 Expansion and flexibility

2.9.3.1 *General*

2.9.3.1.1 Pipelines and piping should be designed with sufficient flexibility to prevent expansion or contraction causing excessive forces or stresses in pipe material, joints, equipment, anchors or supports.

Expansion calculations should be carried out on buried and above-ground pipelines where flexibility is in doubt and where significant temperature changes are expected such as occur in heated oil or refrigerated pipelines. Thermal expansion or contraction of buried pipelines may cause movement at termination points, changes in direction or changes in size. The necessary flexibility should be provided if such movements are unrestrained, by anchors. Account should be taken of buckling forces which may be imposed on pipelines laid in active mining areas.

The effect of restraints, such as support friction, branch connections and lateral interferences should be considered.

Calculations should take into account stress intensification factors found to be present in components other than plain straight pipe. Account may be taken of any extra flexibility of such components. In the absence of more directly applicable data, the flexibility factors and stress intensification factors shown in BS 806 may be used.

Above ground pipelines and piping may be restrained by anchors so that the longitudinal movement owing to thermal and pressure changes is absorbed by direct axial compression or tension of the pipe. In such cases expansion calculations should be carried out taking into account all the forces acting on the pipeline. Consideration should be given to elastic instability due to longitudinal compressive forces.

Where movement is unrestrained, flexibility should be provided by means of loops, offsets or special fittings.

2.9.3.1.2 The total operating temperature range should be the difference between the maximum and minimum metal temperatures for the operating cycle under consideration and should be used in calculating stresses in loops, bends and offsets.

The temperature range used in the calculation of reactions on anchors and equipment should be the difference between the maximum or minimum metal temperatures and the installation temperature, whichever gives the greater reaction.

2.9.3.1.3 Where there is a likelihood of repeated stress changes (including thermal stress) giving rise to fatigue conditions, reference should be made to ANSI B31.3 : 1987 or IGE/TD/1 : 1984 for the assessment of stress range reduction factors.

2.9.3.1.4 Nominal pipe wall thickness (including any corrosion allowance) and nominal outside diameter should be used for expansion and flexibility calculations.

2.9.3.2 *Longitudinal stress*

The total longitudinal stress should be the sum of the longitudinal stress arising from pressure, bending, temperature, weight, other sustained loadings and occasional loadings (see **2.7**).

A pipeline should be considered totally restrained when axial movement and bending resulting from temperature or pressure change is totally prevented.

For totally restrained sections of a pipeline, the longitudinal tensile stress resulting from the combined effects of temperature and pressure change alone should be calculated as follows.

Thin wall

$$S_{L1} = vS_h - Ea(T_2 - T_1)$$

Thick wall

$$S_{L1} = v\left(S_h - \frac{p}{10}\right) - Ea\,(T_2 - T_1)$$

where

S_{L1} is the longitudinal tensile stress (in N/mm^2);

v is the Poissons ratio (0.30 for steel);

p is the internal design pressure (in bar);

S_h is the hoop stress calculated in **2.9.2**, but using the nominal pipe wall thickness (in N/mm^2);

E is the modulus of elasticity (in N/mm^2) (2.0×10^5 at ambient temperature for carbon steel);

a is the linear coefficient of thermal expansion (per °C) (11.7×10^6 per °C, up to 120 °C for carbon steel);

T_1 is the installation temperature (in °C);

T_2 is the maximum or minimum metal temperature (in °C).

For unrestrained sections of a pipeline, the longitudinal tensile stress resulting from the combined effects of temperature and pressure change alone should be calculated as follows.

Thin wall

Use $k = 1$

Thick wall

$$S_{L2} = \frac{S_h}{k^2 + 1} + \frac{1000\,M_b i}{Z}$$

where

S_{L2} is the longitudinal tensile stress (in N/mm^2);

M_b is the bending moment applied to the pipeline (N·m);

i is the stress intensification factor (see BS 806);

k is the ratio D/D_i (see **2.9.2**);

Z is the pipe section modulus (in mm^3).

2.9.3.3 *Shear stress*

The shear stress should be calculated from the torque and shear force applied to the pipeline as follows:

$$\tau = \frac{1000\,T}{2Z} + \frac{2S_F}{A}$$

where

τ is the shear stress (in N/mm^2);

T is the torque applied to the pipeline (in N·m);

S_F is the shear force applied to the pipeline (in N);

A is the cross sectional area of the pipe wall (in mm^2);

Z is the pipe section modulus (in mm^3).

2.9.3.4 ***Equivalent stress***

The equivalent stress (S_e) should not exceed the allowable equivalent stress (S_{ae}) given in **2.10.2**. The equivalent stress should be calculated using the von Mises equivalent stress criteria as follows:

$$S_e = (S_h^2 + S_L^2 - S_h S_L + 3\tau^2)^{½}$$

where

S_h is the hoop stress calculated in **2.9.2**, but using the nominal pipe wall thickness (in N/mm^2);

S_L is the total longitudinal stress (as defined in **2.9.3.2**) (in N/mm^2);

τ is the shear stress (in N/mm^2).

NOTE. The von Mises equivalent stress has been derived from the full equation by assuming that the third principal stress is negligible.

2.10 Limits of calculated stress

2.10.1 Allowable hoop stress

The allowable hoop stress (S_{ah}) should be calculated as follows:

$$S_{ah} = aeS_y$$

where

S_{ah} is the allowable hoop stress (in N/mm^2);

a is the design factor (see 2.5);

e is the weld joint factor (see below);

S_y is the specified minimum yield strength of pipe (in N/mm^2), (see table 3).

Table 3. Pipe specified minimum yield strength (S_y)

Pipe specification	Type of grade of pipe	Specified minimum yield strength N/mm^2
API 5L : 1991	B	241
	X42	289
	X46	317
	X52	358
	X56	386
	X60	413
	X65	448
	X70	482

The weld joint factor e should be 1.0 for pipe conforming to API 5L when supplied as seamless, longitudinally welded or spirally welded pipe. If the pipe history is unknown, the weld joint factor e should not exceed 0.60 for pipe of 4.5 in (114 mm) outside diameter or smaller, or 0.80 for pipe larger than 4.5 in (114 mm) outside diameter.

2.10.2 Allowable equivalent stress

The allowable equivalent stress (S_{ae}) should be calculated as follows:

$$S_{ae} = 0.9\ S_y$$

where

S_{ae} is the allowable equivalent stress (in N/mm^2);

S_y is the specified minimum yield strength of the pipe (in N/mm^2), (see table 3).

2.11 Corrosion allowance

A corrosion allowance on design thickness need not be included providing the substance to be conveyed is non-corrosive or measures are taken to prevent corrosion. Where internal corrosion, external corrosion or erosion is expected, a corrosion allowance may be made following an appropriate study, taking into account the type of corrosion expected and the required life of the pipeline. No external corrosion allowance is required if both an anti-corrosion coating system and a cathodic protection system are installed. Where a corrosion allowance is applied it should be added to the value of the design thickness (see **2.8.3.1**).

2.12 Fatigue life

Consideration should be given to the fatigue life of pipelines to ensure that minor defects do not grow to a critical size under the influence of cyclic pressure. The maximum daily variation in hoop stress should not exceed 125 N/mm^2 to ensure a life of 15000 stress cycles (equivalent to one stress cycle per day for 40 years). Reference should be made to ANSI B31.3 : 1987 or IGE/TD/1 : 1984.

The maximum number of stress cycles expected for a pipeline should be evaluated by multiplying the number of daily cycles occurring within a given stress range by C in table 4. More complex daily stress cycles should be evaluated by multiplying the number of individual stress cycles, within the daily cycle, by C in table 4. The sum of factored and unfactored cycles should not exceed 15000.

Table 4. Factors for hoop stress variations

Stress range N/mm^2	Stress range lbf/in^2	Value of constant C
0 to 35	0 to 5000	0.0
35 to 70	1000 to 10000	0.2
70 to 105	10000 to 15000	0.6
105 to 125	15000 to 18000	1.0

2.13 Thermal insulation

Where pipelines are designed to convey substances which are either heated or refrigerated, thermal insulation may be required in addition to an anti-corrosion coating. Account should be taken of the differences between installation and operating temperatures in relation to axial stresses (see **2.9.3**) and movement. Thermal insulation systems should be designed to retain the substance being conveyed within its process design limits at the lowest design flow rates. Reference should be made to CP 3009 : 1970 and BS 4508 for the design of thermally insulated underground pipelines.

Thermal insulation may be built up from layers of different materials selected according to the temperature gradient through the system. Differences in coefficient of thermal expansion of the various materials and the pipe should be considered. Vapour barriers should be installed to prevent the migration of moisture within the insulation and subsequent damage to the pipeline material.

Careful consideration should be given to the maximum design operating temperature for anti-corrosion coatings. Since the risk of external corrosion at elevated temperatures is higher than at ambient temperatures and since above ground coating damage inspection techniques are ineffective, the pipeline system should be designed to accommodate internal inspection devices (intelligent pigs).

Consideration should be given to the depth of cover of heated or refrigerated pipelines in agricultural land in respect of thermal effects on crop growth. For refrigerated pipelines the possibility of frost heave should be considered.

2.14 Supports and anchors

The forces and moments transmitted to connected equipment such as valves, strainers, tanks, pressure vessels and pumping machinery should be kept within safe limits.

Supports should be designed to support the pipe without causing excessive local stresses in the pipe. Friction forces at the supports should be considered in evaluating the flexibility of the system. Braces and damping devices may be required to prevent vibration of piping.

Attachments to the pipeline should be designed to keep within safe limits the additional stresses in the pipe wall caused by the attachment. Non-integral attachments such as pipe clamps are preferred where they will perform the supporting or anchoring functions.

Where a piping system or pipeline is designed to operate at, or close to, its allowable stress, all connections welded to the pipe should be made to an anchor flange incorporated in the pipeline with full penetration butt welds or to a separate cylindrical member which completely encircles the pipe. The encircling member should be welded by continuous circumferential welds.

Section 3. Materials

3.1 General requirements, materials and dimensional standards

Pipeline materials and components should conform to the specifications listed in table 5 or should meet the recommendations of this Section for materials not listed.

Table 5. Standards for materials

Subject	Number
1 *Pipe*	
Specification for line pipe	API 5L : 1991
Steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties	BS 3601 : 1987
Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties	BS 3602 : Part 1 : 1987 and Part 2 : 1991
Specification for steel pipes and tubes for pressure purposes: carbon and alloy steel with specified low temperature properties	BS 3603 : 1991
2 *Flanges, fittings and gaskets*	
Steel pipe flanges and flanged fittings	ANSI B16.5 : 1988
Factory-made wrought steel butt-welded fittings	ANSI B16.9 : 1986
Ring joint gaskets and grooves for steel pipe flanges	ANSI B16.20 : 1973
Steel pipe flanges and flanged fittings for the petroleum industry	BS 1560
Steel butt-welded pipe fittings for the petroleum industry	BS 1640
Oil resistant compressed asbestos fibre jointing	BS 1832 : 1991
Butt-welded pipe fittings for pressure purposes	BS 1965 : 1963
Compressed asbestos fibre jointing	BS 2815 : 1973
Carbon steel pipe flanges (over 24 in) for the petroleum industry	BS 3293 : 1960
Metallic spiral wound gaskets for use with flanges to BS 1560	BS 3381 : 1989
Steel pipe fittings, screwed and socket welded, for the petroleum industry	BS 3799 : 1974
Steel pipeline flanges	MSS SP-44 : 1991
Specification for high test wrought welded fittings	MSS SP-75 : 1988
3 *Bolting*	
Bolting for flanges and pressure containing purposes	BS 4882 : 1990
4 *Valves*	
Pipeline valves	API 6D : 1991
Steel venturi gate valves, flanged and butt-welded end	API 597 : 1991
Steel plug valves	API 599 : 1988
Steel gate valves, flanged or butt welded ends	API 600 : 1991
Small carbon steel gate valves, compact design	API 602 : 1985
Steel wedge gate valves (flanged and butt welded ends) for the petroleum, petrochemical and allied industries	BS 1414 : 1975
Steel check valves (flanged and butt-welded ends) for the petroleum, petrochemical and allied industries	BS 1868 : 1975
Steel globe and globe stop and check valves (flanged and butt welded ends) for the petroleum, petrochemical and allied industries	BS 1873 : 1975
Steel ball valves for the petroleum, petrochemical and allied industries	BS 5351 : 1986
Specification for steel wedge gate, globe and check valves 50 mm and smaller for the petroleum, petrochemical and allied industries	BS 5352 : 1981
Specification for plug valves	BS 5353 : 1989
Safety valves	BS 6759 : Part 3 : 1984

Table 5. Standards for materials (*concluded*)

Subject	Number
5 ***Structural materials and pressure vessels***	
Steels for fired and unfired pressure vessels. Plates	BS 1501
Steels for use in chemical, petroleum and allied industries	BS 1501 to BS 1504, BS 1506
Steels for fired and unfired pressure vessels. Sections and bars	BS 1502 : 1982
Specification for steel forgings (including semi-finished forged products) for pressure purposes	BS 1503 : 1989
Specification for steel castings for pressure purposes	BS 1504 : 1976
Specification for weldable structural steels	BS 4360 : 1990
ASME boiler and pressure vessel code section II : Part A : Materials specifications-ferrous	None
Unfired fusion welded pressure vessels	BS 5500 : 1991

NOTE. In any of the standards listed where the pressure rating is specified at 38 °C it is acceptable to use the component in the range − 25 °C to 120 °C.

3.2 Limitations on materials

Materials should be selected to ensure suitability for service under the intended operating conditions. Consideration should be given to the significance of temperature on the performance of materials. Those materials exposed to low temperatures should have adequate fracture toughness at the design temperature. Where the substance to be transported requires that special materials should be used, selection should be based on the particular requirements and relevant recognised specifications and recommendations, e.g. BS 3605, ASTM A790 M and NACE MR-01-75.

Cast iron should not be used for pressure-containing components.

Limitations on gasket materials are given in **2.8.3.5**.

Limitations on bolting materials are given in **2.8.3.6** and BS 4882 : 1990.

3.3 Pipe

3.3.1 Specification

Linepipe should be supplied as seamless, longitudinally welded or spirally welded pipe. Butt-welded pipe should not be supplied. (Refer to API 5L).

Consideration should be given to the completion of a manufacturing procedure qualification test on linepipe to be specially manufactured for a specific pipeline. This should be carried out before significant quantities of linepipe are produced to ensure compliance with the chemical and mechanical properties in the specification.

3.3.2 Fracture toughness

To ensure resistance against brittle or ductile running fracture, linepipe should be impact tested if required in accordance with ANSI B31.3 : 1987/EEMUA 153/89 : 1987 or IGE/TD/1 : 1984. Where pipelines are required to be pneumatically tested, reference should be made to appendix D of BS 5500 : 1991 with regard to minimum ambient temperature for carrying out the pneumatic test. The value of f in appendix D should be interpreted as defined by appendix K of BS 5500 : 1991.

3.3.3 Hardness

Hardness testing requirements should be agreed between the purchasers and the manufacturer.

3.3.4 Post weld heat treatment

The seam weld of electrically welded line pipe should be heat treated to ensure compliance with the mechanical and fracture toughness requirements in the specification.

3.3.5 Weldability

Consideration should be given to the completion of a weldability trial on pipe selected during line pipe production for each size and supplier of pipe.

3.4 Pipe without full certification

Pipe without full certification may not be used unless each pipe has been subjected to testing in accordance with all appropriate sections of the relevant material standards for pipe in table 5 to establish chemical and mechanical properties, dimensions, non-destructive testing properties and visual acceptability. The pipe should also comply with the additional recommended requirements in **3.3** and should be hydrostatically pre-tested in accordance with the relevant materials standard before installation.

3.5 Pipe fittings, components and bends

3.5.1 Pipe fittings and components

Fittings and components should be subject to similar testing to linepipe in respect of fracture toughness, hardness and weldability.

3.5.2 Pipe bends

Pipe intended for manufacture into bends should be selected to take account of changes in mechanical properties and wall thickness after bending. Advantage may be taken of pipe delivered with certified mechanical properties better than the specified minimum values and measured wall thickness greater than the design thickness.

Traditional methods of bend manufacture by the hot-forming process (furnace bends) may differ in their effect upon the pipe mechanical properties when compared with more modern methods (e.g. induction bends). Unless the method is well established with a continuous history of successful manufacture in the range of bend materials and dimensions concerned, the process should be subjected to a manufacturing procedure qualification test. The level of testing and acceptance criteria should be similar to that required in the manufacturing procedure qualification test for the parent pipe (see **3.3**).

Particular care should be taken with methods which involve quenching as part of the process.

3.6 Quality assurance

For quality assurance aspects of materials refer to section 7.

Section 4. Corrosion protection

4.1 General

Buried pipes may be affected by external corrosion arising from the formation of corrosion cells in the surrounding ground or from stray electrical earth currents and should be protected by a combination of anti-corrosion coatings and cathodic protection. Above-ground pipes should be protected from atmospheric corrosion by a suitable coating or paint system. Internal corrosion may be caused by the corrosive effect of the substance being transported and may be controlled by a combination of corrosion inhibitors, internal lining, dehydration or frequent pigging.

4.2 External corrosion

4.2.1 General

Pipelines should be designed and routed to take account of the possible corrosive effects of industrial waste ground, parallel encroachments to high-voltage overhead a.c. power lines and stray d.c. earth currents. Anti-corrosion coatings should be selected to reflect the varying ground conditions found during a soil and resistivity survey carried out along the pipeline route.

4.2.2 External coatings for buried pipelines

External coatings should have suitable mechanical and electrical properties in relation to the pipe size, environment and operating conditions. Coatings should also exhibit strong adhesion and resistance to cathodic disbondment at holidays. A factory-applied coating is preferred for all pipeline components to ensure adequate surface preparation and coating application under controlled conditions.

Factory-applied external coating materials may be glass-reinforced coal-tar or bitumen in accordance with BS 4164 and BS 4147, polyethylene, epoxy powders, two component resin systems or other proven materials. Coal tar protective coatings should be applied in accordance with AWWA C203. When selecting an external factory-applied coating, consideration should be given to the safety and effectiveness of a repair system that can be efficiently applied in the field.

Field-applied coatings for bare pipe, fittings and joints should be selected and applied to reproduce as far as possible the properties of factory-applied coatings. If a spirally-applied tape wrapping system is used, care should be taken to ensure mechanical and electrical compatibility with other factory-applied coatings on the pipeline and with the cathodic protection system.

Particular attention should be given to compatibility between the field coating and the original pipe coating. The external coating of other below ground components forming part of the pipeline system should be designed in conjunction with the cathodic protection system and other coatings on the pipeline. For components of irregular shape, external coating materials such as two component resin system or mastic combined with tape wrapping may be used.

Consideration should be given to the use of a hard abrasion-resistant compatible external coating such as a polyurethane or two component epoxy resin system where coated pipe is to be installed by thrust boring or similar methods.

4.2.3 External coatings for above-ground pipelines

Above-ground pipelines should be protected against corrosion by the use of suitable coating systems in accordance with BS 5493 : 1977. Above-ground sections of pipelines should be electrically isolated from the buried sections and should not carry cathodic protection currents. (See 4.4.)

4.3 Internal corrosion

4.3.1 General

The design of pipelines should include an assessment of the corrosive nature of the substance being transported. Consideration should be given to the control of corrosion as described in **4.3.2** and **4.3.3**.

4.3.2 Internal coating

Where internal coatings are used to control corrosion they should be applied in accordance with the quality specifications and dry film thickness requirements established for suitable protection of the pipe material from the substance being conveyed. Reference should be made to API RP 5L2 for recommended practice for internal coating of pipelines.

If pipes are joined by welding such that metal is exposed, consideration should be given to internal coating of the joint area or the use of a suitable inhibitor. Account should also be taken of the internal coating in the selection of pigs to prevent damage during pigging.

4.3.3 Corrosion inhibitor

Where corrosion inhibitors are used to control internal corrosion, sufficient corrosion coupons or other monitoring equipment should be installed in suitable locations to monitor the effectiveness of corrosion control. Inhibitor injection equipment should be included in the design, and corrosion monitoring equipment should be designed to permit passage of pigs if required. The corrosion inhibitor selected should not cause deterioration of any components in the piping system or of the substance being conveyed. The effects of high turbulence in the performance of inhibitors should be considered.

4.4 Cathodic protection

Defects in the external coating systems enable the ground water to come in contact with the pipeline steel and allow electric corrosion currents to flow, resulting in pipeline corrosion, often in the form of pitting at small coating defects. A cathodic protection system should be installed to reduce this corrosion.

Cathodic protection may be applied by the sacrificial anode or impressed current method and should be designed and constructed in accordance with BS 7361 : Part 1 : 1991.

The cathodic protection system should be brought into operation as soon as possible following pipeline construction and where delays are unavoidable the use of temporary sacrificial anodes should be considered, particularly in areas with corrosive ground conditions. The application of cathodic protection to a pipeline may cause adverse effects on other buried metallic structures close to the protected pipeline and the procedures of BS 7361 : Part 1 : 1991 should be followed.

Section 5. Terminals and intermediate stations

5.1 General

A typical schematic layout of facilities included as terminals and intermediate stations is shown in figure 1.

5.2 Location

Pipeline design and economic influences will determine the approximate location of intermediate stations. Consideration should be given to topography, ease of access, availability of services, ground conditions, safety and environmental factors in the more precise location of intermediate stations. The precise location of intermediate stations should be considered as part of any safety evaluation.

Terminals and intermediate stations should be located and securely fenced to ensure adequate safety conditions exist for the protection of third parties, buildings and areas of public access.

An assessment of noise levels should be made for a proposed intermediate station and account taken of predicted noise levels compared with existing background noise levels in the choice of sites.

5.3 Hazardous area classification

Plant and equipment should be specified in accordance with its hazardous area classification. Guidance on hazardous area classification may be obtained from appropriate recognised codes such as *IP Model Code of Safe Practice, Part 15, Area Classification Code for Petroleum Installations* [5] and BS 5345 : Part 1.

5.4 Piping

Above and below-ground piping should be designed in accordance with the design conditions (see **2.7**) and design criteria (see **2.8**) of this Section. Design factors should follow the recommendations of **2.5**. However, consideration should be given to reducing these design factors where special conditions exist at the particular location.

Consideration should be given to the preparation of a detailed stress analysis of piping for the design conditions (see **2.7**) to ensure that stresses within piping and forces and displacements exerted on equipment comply with the design criteria (see **2.8**).

For piping design, reference may be made to ANSI B31.3 and IGE/TD/12 : 1985.

5.5 Vibration resonance and noise

The effects of vibration and resonance on piping and equipment should be considered in the design of intermediate stations. Particular attention should be given to the analysis of piping vibrations caused by connections to vibrating equipment or by gas pulsations associated with reciprocating pumps or compressors.

Account should also be taken of noise generated by piping and equipment in the design of station piping. Where noise levels cannot be further reduced by design or equipment selection, consideration should be given to the use of acoustic cladding or enclosures.

5.6 Heating and cooling stations

The design of some pipeline systems may require heating or cooling of the substance being conveyed to maintain the design flow conditions. Temperature indication and controls should be provided on the pipeline system to ensure that the temperature is maintained within the design temperature range (see **2.7.4**). For heating stations trace heating may be required on pipework, pump bodies, drains and instrument lines to ensure satisfactory flow conditions following shutdown

Account should be taken of expansion and contraction stresses within piping between above-ground and below-ground sections.

5.7 Interface detection

Interface detection equipment should be installed on pipelines designed to convey different substances in sequence through the pipeline to detect the interface between different batches.

5.8 Safety systems

5.8.1 Design

Terminals and intermediate stations should be located at a sufficient distance from adjacent property and areas of public access to minimize fire hazards and allow free movement of firefighting equipment around the site.

Fences erected around intermediate stations which may prevent escape of personnel in an emergency should be provided with a sufficient number of gates conveniently located to provide escape to a place of safety. Gates should open outwards and be unlocked or able to be opened from the inside without a key when the area within the fenced enclosure is occupied.

Terminals and intermediate station buildings containing pumps or compressors should be ventilated such that personnel are not endangered by accumulations of hazardous concentrations of flammable or noxious vapours or gases under normal operating conditions and abnormal conditions such as blown gaskets or glands. Consideration should be given to the installation of gas detection and warning devices.

Station piping should be designed to enable personnel to gain clear access to and around equipment for maintenance without trip or overhead hazards. Hot or cold piping should be suitably insulated or protected to prevent injury to personnel.

5.8.2 Pressure control and pressure relief

Piping within terminals and intermediate stations may be subjected to overpressure or vacuum conditions as a result of surge following a sudden change in flow during valve closure or pump shutdown, excessive static pressure, fluid expansion, connection to high-pressure sources during a fault condition or as a result of a vacuum created during shutdown or drain-down of the pipeline.

Protective devices such as relief valves, pressure-limiting stations or automatic shutdown equipment of sufficient capacity, sensitivity and reliability should be installed to ensure the conditions of **2.8.2.5** are met. Where high reliability of automatic shutdown equipment is required high integrity protective systems which rely upon instrumentation to protect against overpressure may be used. Where high integrity protective systems are proposed, a comprehensive reliability study of the system should be carried out in which consideration should be given to hazard rate, redundancy, voting systems and the design of equipment for on-line testing and maintenance.

5.8.3 Vent and drain lines

Vent and drain lines to atmosphere should be extended to a location where the substance may be discharged without hazard. Account should be taken of the relief valve capacity in the sizing of vent lines.

5.8.4 Monitoring and communication systems

A monitoring and communication system should be installed on pipelines to provide an indication and record of pressure, temperature, flow rate and physical characteristics of the substance being conveyed. The system may also be used to provide information on pumps, compressors, valve positions, meters, and tank levels together with alarm conditions such as power supply failure, high temperature of electric motor windings and rotating machinery bearings, excessive vibration levels, low suction pressures, high delivery pressures, seal leakage, abnormal temperatures and the detection of fire and hazardous atmospheres.

Telemetry based systems may be used for controlling equipment.

An assessment should be carried out to determine the required availability of monitoring and communication systems, the need for redundant components and the necessary provisions for secure power supplies to ensure that the required performance is met.

5.8.5 Emergency shutdown facilities

Pump or compressor stations should be provided with emergency shutdown systems to prevent major hazards in the event of process faults or equipment failures.

Push buttons or switches to initiate an emergency shutdown should be provided in at least two locations outside the area of hazard, preferably close to the exit gates.

5.8.6 Fire-fighting facilities

Terminals and intermediate stations should be provided with fire-fighting facilities which are appropriate to the size and nature of the site following consultation with the local fire authorities. Fire-detection outdoors should be by the use of flame-detection instrumentation. For indoor fire-detection, heat and smoke detectors should be provided. For protection of control rooms consideration should be given to inert gas systems (see BS 5306 series).

Fire detection equipment should be installed to BS 5839 : Part 1 : 1988 recommendations. Fixed fire-fighting equipment should be to BS 5306 series.

Portable fire equipment should be to BS 5423 : 1987 and installed to the provisions of BS 5306 : Part 3 : 1985.

Reference should be made to the *IP Model Code of Safe Practice, Part 2, Marketing Safety Code* [6].

Section 6. Construction

6.1 General

Reference should be made to BS 8010 : Part 1 : 1989 which considers the aspects of pipeline projects which affect land owners and occupiers along the route of the pipeline. Account should be taken of the procedures and recommendations in BS 8010 : Part 1 : 1989 to be followed before any work on land commences.

The safety and reliability of a pipeline system may be improved by the application of quality assurance procedures in construction. In this respect reference should made to section 7.

6.2 Construction supervision

The pipeline designer and construction contractor should ensure that competent and experienced staff are appointed to supervise the full range of pipeline construction activities. Particular attention should be given to environmental matters, quality assurance and public safety aspects of pipeline construction.

6.3 Safety

High standards of safety should be maintained at all times and reference made to the Health and Safety at Work Act 1974 [7]. Safety training should be given to all employees engaged in supervision and construction of pipelines.

Particular provisions of the Factories Act 1961 [8] apply to pipeline construction and account should be taken of the Construction (Lifting Operations) Regulations [9]. Reference should also be made to the Ionising Radiations Regulations 1985 [10] and The Pressure Systems and Transportable Gas Containers Regulations 1989 [11].

6.4 Setting out and surveying for bends

At each particular location the pipeline should be set out by the contractor and checked by supervisory staff before construction commences.

Following setting out and right-of-way preparation a survey should be carried out along the pipeline route to determine the pipe bend requirements taking into account the changes in direction in both horizontal and vertical planes and allowing for any grading which might be carried out.

NOTE. The number of bends may be reduced by judicious grading of the trench at approaches to crossings and other obstacles.

6.5 Handling and storage of pipe

Care should be taken to prevent damage to pipes, fittings and coating during handling. Slings or equipment used for handling pipes should be designed to prevent pipe or coating damage. Reference should be made to IGE/TD/6 : 1985. Where minor damage to coating has occurred repairs should be carried out. Where extensive coating damage has occurred there should be a complete recoating of the area affected.

6.6 Pipe stringing, field bending and swabbing

Pipes should be strung along the pipeline route and placed on suitable cushioned packing to prevent damage to the coating.

Pipe may be flexed to a radius of curvature which does not induce a bending stress exceeding 85 % of the specified minimum yield stress. Cold bends of 40 pipe diameters minimum radius may be made from the pipe specified for straight lengths. Such bends should be made on a suitable field bending machine manned by trained operators.

Cold bends of a radius less than 40 pipe diameters may be made in the field providing:

a) the quality control conditions are equivalent to those applicable to an established bending shop;

b) the finished bends comply with **2.8.3.9**;

c) pipe material is selected to comply with **2.5.2**.

Cold bends should be checked for ovality, wall thinning and location of longitudinal seam. Pipes and bends should be swabbed before alignment and welding to ensure that all dirt and other objects likely to cause obstruction are removed. A gauging plate should be pulled through each bend before installation to ensure compliance with the specification for ovality.

6.7 Pipe inspection

All pipes should be visually inspected for possible damage in transit and rectified before stringing. Gouges, grooves, notches and arc burns imparted to pipe during construction may cause subsequent pipeline failure in service. These may be carefully ground out providing that the resulting wall thickness is not less than the design thickness given in **2.8.3.1**. If the wall thickness is reduced below the design thickness the damaged area should be cut out as a cylinder of length not less than one pipe diameter.

In pipelines designed for category B or for category C substances, and subject to hydrostatic testing, any dent which contains a scratch, sharp edge, groove or arc burn should be removed. All dents which affect the curvature of the pipe at the longitudinal weld or any circumferential weld should be removed. The removal of dents should be carried out by cutting a cylinder of length not less than one pipe diameter. Insert patching or knocking out of the dent is not permitted.

After stringing, but before alignment for welding, pipe ends should be inspected for bevel damage and dimensional errors and repaired by grinding or rebevelling.

NOTE. Guidance on allowable defects is contained in API 5L and IGE/TD/1.

6.8 Welding

6.8.1 General

The welding of pipeline systems should be carried out in accordance with BS 4515 : 1984.

Prefabricated and interconnecting pipework in terminals may alternatively be welded in accordance with ANSI B31.3, BS 2633, BS 4677, BS 4870, BS 4871 or API 1104 as appropriate.

6.8.2 Night caps

Suitable night caps should be placed on the open ends of welded sections of pipeline at the end of each day's production or when no work is in progress to prevent the ingress of dirt or other objects, small animals and water. If there is a likelihood of trench flooding, appropriate action should be taken to prevent flotation of the pipeline section.

6.8.3 Welding inspection

Welding inspection and non-destructive testing should be appropriate to the welding standard used.

In pipelines designed for category B substances and for category C substances subject to hydrostatic testing, welding quality should be established by 100 % radiographic inspection. After satisfactory welding quality has been achieved the level of radiographic inspection may be progressively reduced to a minimum of 10 % of field welds. If welding quality falls, the level of inspection should be increased back to 100 % radiography until welding quality is restored. In locations where possible leakage could cause pollution or other hazards, all welds should be subjected to 100 % radiography.

In pipeline systems designed to convey category C substances and tested by pneumatic rather than hydrostatic methods, or systems designed to convey category D substances, field welds should be subjected to 100 % radiographic inspection. If this is impracticable, ultrasonic testing should be performed instead.

All tie-in welds and all welds made in road, rail and watercourse crossings for pipelines carrying any category of substances should be subject to radiographic examination. In addition, all tie-in welds made following any hydrotest should be subject to ultrasonic inspection.

6.9 Joint wrapping and trench excavation

Welded joints between pipes should be protected against corrosion in accordance with **4.2.2**. Trench excavation should be carried out in accordance with BS 8010 : Part 1 : 1989.

6.10 Coating inspection and holiday detection

Pipe coating and tape wrapping should be visually inspected at the time of application to ensure compliance with the quality plan. Particular attention should be given during tape wrapping to ensure correct adhesion, tension and overlap between tapes. After field bending the coating or wrapping should be inspected and any damage or disbondment repaired. Whilst lowering the pipe into the trench the areas under skid, cradle or belt supports should be inspected for damage and repaired.

Immediately before lowering the pipe into the trench the whole of the coating should be inspected by use of a holiday detector set to the correct voltage applicable to the coating. Any defects should be marked and repaired before the pipe is lowered. Where disbondment of the coating has occurred the coating should be removed, replaced and retested.

6.11 Lowering

Before the pipe is lowered care should be taken to ensure that the bottom of the trench is clean, free from objects likely to cause coating damage and able to provide even support to the pipeline. Where the trench contains rock or stones a 150 mm thickness of sand or other suitable material should be placed beneath the pipe. Alternatively the pipe may be protected by a suitable coating.

Roller cradles or wide belt slings should be used to lift and lower the pipe into the trench using sideboom tractors or similar machinery. Such machinery should be certified in accordance with the Factories Act 1961. All equipment in contact with the pipe coating should be suitably padded to prevent coating damage. Account should be taken of the stresses in the pipeline during the lifting and lowering operation to prevent overstressing of the pipe.

6.12 Backfilling and reinstatement

Backfilling and reinstatement should be carried out in accordance with BS 8010 : Part 1 : 1989. The first 150 mm of cover to the pipe should comprise a carefully compacted finely graded material free from sharp-edged stones or other deleterious material. Backfilling should be controlled to prevent damage to the pipe coating by large stones. Trench barriers may be used in steeply sloping ground to prevent the loss of backfill material by land slip or washout.

Backfilling should be carried out before hydrostatic testing. In the event of work being necessary within the working width after hydrostatic testing the position of the pipeline should be clearly marked and precautions taken to ensure that heavy plant crosses the pipeline at properly constructed and defined crossing places only.

Reinstatement in roads should be carried out in consultation with the local highways authority.

6.13 Coating survey following construction

On completion of pipeline construction a suitable combination of the following should be carried out to locate any areas of coating damage on the buried pipeline:

a) signal attenuation coating survey;

b) Pearson type survey;

c) close-interval potential survey.

Any coating damage found should be repaired.

6.14 Crossings

Road and rail crossings may be constructed by open-cut, boring or tunnelling methods. Open cut road crossings should be carried out in a manner which minimizes the disruption to normal traffic flow. Particular attention should be given to the statutory and local authority requirements for warning signs and lights during the construction of road crossings.

Where water crossings are installed by the open-cut method temporary flume pipes or overpumping should be considered to ensure that there is no disruption to water flow during construction. To achieve stability of the pipeline at water crossings consideration should be given to the application of a weight coating such as concrete to maintain negative buoyancy of the pipe during both construction and in service. Attention should be given to maintaining the integrity of flood or tidal barriers at river crossings during construction.

Consideration should be given to the possibility of future cleaning and deepening operations on drainage ditches. Where such operations are likely and where the pipeline is installed by open cut methods, protective slabs should be provided. For large drainage ditches and dykes a reinforced concrete slab of adequate dimensions should be placed above the pipe and below the hard bottom of the ditch, bedded on firm ground either side of the pipe trench. For smaller ditches precast concrete marker slabs should be adequate. The top of the slab should be at least 300 mm below the cleaned bottom of the ditch.

6.15 Cleaning and gauging

Following construction, the pipeline sections should be cleaned in lengths of several kilometres by the passage of swabbing pigs to remove dirt and other matter.

Gauging pigs having a soft metal disc of diameter not less than 95 % of the least-specified internal diameter of pipeline up to 508 mm nominal, or with 25 mm clearance for larger pipes, should be passed through each completed section before testing to ensure that it is free from internal obstruction. The progress of pigs through the pipeline should be carefully monitored.

Where temporary pig launchers or receivers are used for pigging operations during construction they should be welded or bolted to the pipeline and not attached by friction clamps.

6.16 Tie-in welds

Tie-in welds also include closure welds made to connect installed crossings to adjacent ditched sections of pipeline. Particular attention should be given to ensure the proper alignment of pipes at tie-in welds without the use of jacks or wedges to ensure that the welds remain in a stress free condition during backfilling and subsequent operation. Tie-in welds between long lengths of exposed pipe should not be made when the ambient temperature is above 30 °C or below 5 °C.

6.17 Pups

Pipe pups or off-cuts produced during construction may be welded into the pipeline but should not be shorter than twice the diameter of the pipe or 600 mm long whichever is the lesser. When a pipe is cut the pup should be given a suffix number to trace its inclusion elsewhere in the pipeline. All cut ends should be non-destructively examined for laminations.

Section 7. Quality assurance

7.1 General

Quality assurance procedures should be applied throughout design, procurement, construction and testing of a pipeline system to ensure compliance with specifications, procedures, standards and safety requirements. An efficient document control system is essential. Reference should be made to BS 5750 when setting up the procedure.

7.2 Basic terms

7.2.1 Quality assurance

Quality assurance embraces all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements of quality.

7.2.2 Quality plan

The quality plan should set out specific quality procedures, resources and activities which are appropriate and relate to the particular project including the required written certificate inspection and hold points. It should include procedures for:

Environmental controls	(BS 8010 : Part 1)
Design auditing	(section **2**)
Material source and identification	(section **3**)
Corrosion controls	(section **4**)
Pipe coating	(**4.2.2**)
Welding operations	(**6.8**)
Welder qualifications	(**6.8**)
Welding inspection and acceptance	(**6.8**)
Testing	(section **8**)
Commissioning	(section **9**)

7.2.3 Inspection

Inspection is the process of controlling quality by examining, measuring, testing, gauging or otherwise comparing the material or item with the specified requirements. The level of inspection should be such as to satisfy the requirements of the quality plan. Inspection activities should be certified by appropriately qualified personnel.

7.3 Design quality assurance

7.3.1 Design basis

A design basis manual should be prepared, taking account of the process illustrated in table 1.

7.3.2 Supervision

The design and construction of the system should be carried out under the supervision of a suitably experienced chartered engineer.

7.4 Materials quality assurance

7.4.1 Pipe

The quality plan should specify the tests and documented evidence required to ensure that the pipe as delivered meets with the specification against which it has been ordered. Each heat of steel should be certified. Pipe mill inspection should be specified. Each accepted pipe should be given a unique identification number, cross-referenced to the inspection certification so that it can be identified and its quality verified. Each pipe used for the construction of the pipeline should be clearly marked with the unique pipe identification number which should be maintained and transferred to any pipe off cuts.

7.4.2 Stock material

Where material is purchased from stockholders, it is essential that the supplier provides satisfactory documentary certification (either of original manufacture or by appropriate testing) that the material supplied is in accordance with the required specification.

7.4.3 Shop fabricated equipment

Shop-fabricated or manufactured equipment (such as pig traps, manifolds, slug catchers, valves, flanges, insulation joints, meters and meter provers) should be constructed only from material which can be identified and verified as to quality and specification. Fabrication should not commence until written certification is available.

7.5 Construction quality assurance

The construction quality plan should detail the procedures to be employed so as to control the construction process and the means of ensuring compliance with them. The method of recording and accepting or rejecting non-conformities should be fully developed.

It should also identify the organisation and responsibilities of those controlling the workmanship criteria. The procedures should include instructions for training, qualifying and periodic re-examination of personnel. Where the quality of workmanship is dependent on highly skilled or specially trained personnel, only those qualified to perform the work should be used.

The construction quality plan should also identify the inspection, certification and construction records and reports required to confirm the quality and safety of the constructed pipeline.

7.6 Records and document control

7.6.1 General

All documents, specifications, drawings, certificates and change orders relating in any way to project quality should be retained, cross-referenced and filed in accordance with the quality plan.

7.6.2 Design documentation

The following documents should be included:

a) design basis manual;

b) design audits, resultant change instructions and their implementation;

c) calculations relating to construction and operation;

d) materials and construction specifications;

e) drawings and sketches.

7.6.3 Procurement documentation

The following documents should be included:

a) certificates of compliance, testing and identification of material;

b) Non-destructive testing (NDT) results and radiographs;

c) inspection reports;

d) weld procedure qualification certificates;

e) welder and NDT inspector qualification certificates;

f) manufacturing and fabrication procedures;

g) heat treatment certificates;

h) quality plans and manuals.

7.6.4 Construction documentation

The following documents should be included:

a) weld procedure qualification certificates;

b) welder and NDT inspector qualification certificates;

c) NDT inspection reports and radiographs;

d) weld repair reports and radiographs;

e) land drainage plans and alterations;

f) records of geographic location of pipe lengths and pipe joints by unique identification number;

g) coating inspection records;

h) field inspectors' records covering such items as pipe condition, field joint wrapping, trench condition and depth, coating repairs, and sand padding;

i) inspection records relating to special constructions, e.g. crossings of watercourses, railways, roads and services, thrust bores, valve sites, cathodic protection bonding;

j) coating survey results and repair records;

k) field bending reports.

7.6.5 Pressure testing and pre-commissioning documentation

The following documents should be included:

a) selection of test sections with respect to hydrostatic head between high and low points;

b) filling procedure and records of pig run;

c) test procedure;

d) instrument calibration certificates;

e) test records including calculation of air content, half-hourly pressure log and pressure and temperature charts.

f) pre-commissioning records.

7.6.6 Retention of documents and records

All construction documentation should be retained for at least 3 years following start-up of the pipeline.

All design, procurement, testing and survey documentation should be prepared for retention for the life of the pipeline.

Section 8. Pressure testing

8.1 Introduction

8.1.1 General

It is essential that pipelines are pressure tested after construction work and backfill to prove their strength and leak tightness prior to commissioning. Testing may be carried out in suitable sections as work progresses (see **8.4.1**). Where topography or other considerations require testing in a number of sections, consideration should be given to a final tightness test. Pipelines should be tested hydrostatically, except that in the case of pipelines designed to carry category C substances and to operate at a design factor of not more than 0.3, pneumatic testing may be considered using dry, oil free air or nitrogen (see **8.4.2**).

8.1.2 Procedures

A written procedure for the test should be prepared detailing the acceptance criteria, and all testing should be carried out under the supervision of an experienced test engineer.

NOTE. It may be necessary to give notice to a statutory authority of the intention to carry out the pressure test.

8.2 Safety precautions

8.2.1 Precautions to be taken during a test

Reference should be made to the Health and Safety Executive Guidance note, General series 4 *Safety in pressure testing* [12]. When formulating safety procedures it should be recognised that pneumatic testing will store far greater energy in the pipeline than the equivalent hydrostatic testing.

The following safety precautions should be adopted during pressure testing.

a) All crossings and areas of public access should be patrolled during the period of the test.

b) Warning notices should be erected indicating that testing is in progress.

c) Boundaries should be clearly marked around the test equipment at each end of the section to deter persons not involved with the testing from approaching closer than the recommended safety distances. The typical safety distance for hydrostatic testing is 15 m. For high-level or pneumatic testing, greater distances should be considered.

8.2.2 Cold weather

In cold weather, after the completion of hydrostatic testing all lines, valves and fittings should be drained completely to prevent frost damage.

8.2.3 Use of temporary pig traps

Care should be taken in the operation of temporary pig launchers and receivers during the test and these should not be opened unless the pressure in launcher or receiver is zero.

It is essential that any temporary pig traps attached to a pipeline under test are isolated from the pipeline unless they are designed and fabricated to the same standard as the pipeline.

8.3 Test equipment

8.3.1 General

Instruments and test equipment used for measurement of pressure, volume and temperature should be certified for accuracy, repeatability and sensitivity. Gauges and recorders should be checked immediately prior to each test. Dead weight testers and other equipment should have been certified within the 12 months preceding the test.

8.3.2 Measurement of pressure

Hydrostatic test pressure should be measured by a dead weight tester having an accuracy better than ± 0.1 bar and a sensitivity of 0.05 bar.

8.3.3 Measurement of volume

The volume of liquid added or subtracted during a hydrostatic test should be measured by equipment having an accuracy better than ± 1.0 % and a sensitivity of 0.1 % of the calculated volume of a liquid to be added after line filling has been completed to produce in the test section the required test pressure (see **8.4.1**). Where pump strokes are used to determine the added volume an automatic stroke counter should be used.

8.3.4 Measurement of temperature

Temperature-measuring equipment should have an accuracy of ± 1.0 °C and a sensitivity of 0.1 °C.

8.3.5 Other measuring equipment

Pressure and ambient temperature recording equipment should be used to provide a graphical record of test pressure and above ground ambient shade temperature for the duration of the test.

8.3.6 Test end design

Test ends should be designed and fabricated to the same or higher standard as the pipeline and pre-tested to 10 % above the specified test pressure of the pipeline.

8.4 Test pressure

8.4.1 Hydrostatic pressure test

The hydrostatic test pressure in any part of the system under test should be not less than the lower of:

a) 150 % of the maximum operating pressure; or

b) that pressure which will induce a hoop stress as defined in **2.9.2** of 90 % of the specified minimum yield stress of the pipeline material in the system under test.

NOTE. Provided that in no case should the hydrostatic test pressure be less than the sum of the maximum operating pressure plus any allowance for surge pressure and other variations likely to be experienced by the pipeline system during normal operation.

The pressure at the point of application should be such that the test pressure as calculated in this clause is generated at the highest point in the section under test. The additional static head at any point in the section should not cause a hoop stress in excess of the specified minimum yield stress of the material at that point.

8.4.2 Pneumatic test pressure

Pneumatic testing should only be carried out on pipelines designed to convey category C substances which are to be operated at a design factor of not more than 0.3. The pneumatic test pressure should not be less than 1.25 times the maximum operating pressure (see **8.5.2** and note to **8.4.1**). However, the pneumatic test pressure should not exceed that pressure which, when substituted into the formulae in **2.9.2** and **2.10.1**, gives a design factor greater than 0.375. The pneumatic test should be carried out at an ambient temperature not less than that given by appendix D of BS 5500 : 1991 with the value of *f* in accordance with appendix K of BS 5500 : 1991.

8.5 Test procedure

8.5.1 Hydrostatic testing

8.5.1.1 *Water quality*

Water for testing and any subsequent flushing should be clean and free from any suspended or dissolved substance which could be harmful to the pipe material or internal coating where applied or which could form deposits within the pipeline. Consideration should be given to using water from a public utility supply and where this is not practicable water may be taken from other sources. In the latter case samples should be analysed and suitable precautions taken to remove or inhibit any harmful substances. Special care is needed in dealing with water sources containing potentially harmful chemicals or bacteria; it is advisable to take specialist advice and the local water authority should be notified. (See also BS 8010 : Part 1.)

8.5.1.2 *Line filling*

During filling, one or more pigs or spheres should be used to provide a positive air/water interface and to minimize air entrainment. All spaces in which air could be trapped, such as valve bodies, bypass pipework, etc. should be vented and sealed.

Where the fill rate is slow and there are steep downhill sections it may be necessary to maintain an air pressure to inhibit pigs running ahead of the linefill. A safe limit of any such air backpressure should be established and carefully maintained.

The use of pig location devices to track the pig, and hence the interface position, is recommended

8.5.1.3 *Air content*

The measurement of air content should be carried out by constructing a plot of pressure against volume (see figure 4) during the initial stage of pressurization until a definite linear relationship is apparent. By extrapolating this linear curve back to the volume axis, the air volume may be assessed, and compared with the total volume of the test section.

A comparison should also be made between the linear slope of the pressure/volume relationship for 100 % water content. If these two slopes differ by more than 10 %, the test section should be refilled. The theoretical slope may be calculated from the following formula:

$$\frac{\Delta V}{\Delta P} = V(0.044 \frac{D}{t} + 4.50)10^{-5}$$

where

ΔV is the incremental volume of water added (in m^3);

V is the volume of test section (in m^3);

ΔP is the incremental pressure change (in bar);

D is the nominal pipe diameter (in m);

t is the nominal wall thickness (in m)

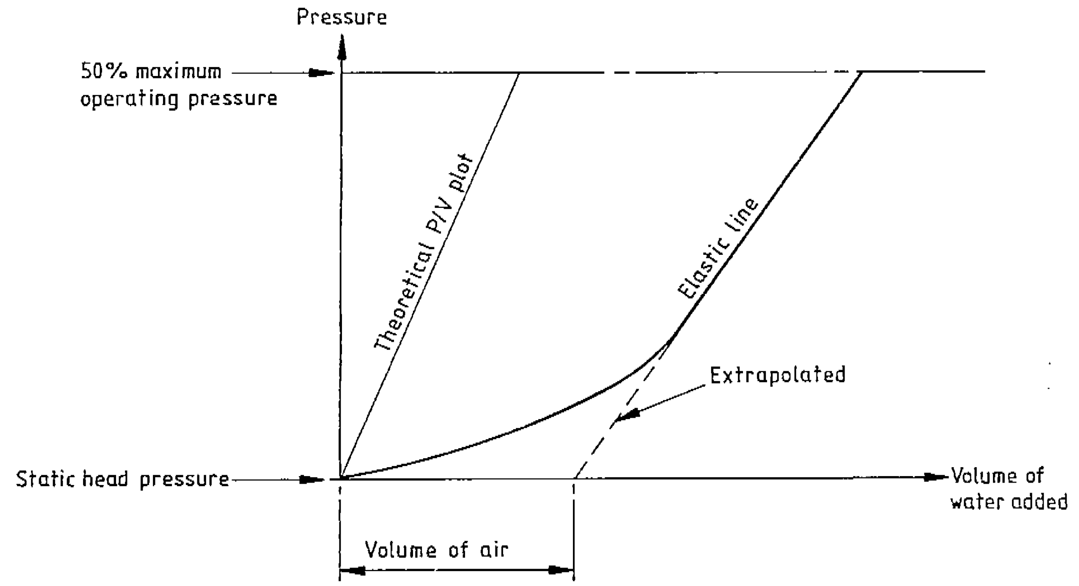


Figure 4. Measurement of air content

8.5.1.4 *Thermal stabilization*

Time should be allowed after filling for the temperature of the water in the pipeline to stabilize with the ground temperature at pipeline depth.

8.5.1.5 *Pressurization*

The pressure in the test section should be raised at a controlled rate to the test pressure calculated according to **8.4.1**. The volume of water added, the corresponding pressure rise and the time should be logged during this operation, and the air content calculated according to **8.5.1.3**. A period should be allowed for stabilization. During this period residual air will continue to go into solution and time-dependent straining of the pipe can take place. Test pressure should then be held for a period of 24 h. Pressure and temperatures should be recorded every $\frac{1}{2}$ h, and the volume of any water added to maintain test pressure noted.

NOTE. **Cyclic testing.** As an alternative, a cyclic testing procedure may be followed, which accentuates time-related straining. Pressure is initially raised to test pressure for a period of 2 h, then reduced to half the value and then raised again to test pressure for a further 2 h. Pressure is again reduced to half the test pressure, then raised again and the test pressure held for 24 h. Pressure, temperature and volume are logged throughout the test as in **8.5.1.5**.

8.5.2 Pneumatic testing

A pneumatic pre-test should be carried out on the pipeline section at a pressure of 1.5 bar before commencing the full pneumatic test. At this stage the pipeline section should be carefully inspected for signs of leakage.

The full pneumatic test should be carried out by raising the pressure in the test section at a controlled rate in increments of 7.0 bar to the test pressure specified in **8.4.2** for a strength test and held for a period of $\frac{1}{2}$ h. The pressure should be lowered at a controlled rate in similar decrements to 110 % of the maximum operating pressure of the pipeline and held for a period of 24 h as a leak test.

A pressure-relieving device should be fitted to compressors used in pneumatic testing to prevent overpressurizing the pipeline.

8.5.3 Test data recording

A record of pressure, volume change, underground and ambient temperature should be compiled over the full duration of a pipeline pressure test. The record of pressure and temperature should be monitored and recorded every $\frac{1}{2}$ h throughout the test. For hydrostatic testing, underground temperature measuring equipment should be installed at least 2 days before commencement of the pressure test to establish an underground temperature trend over several days including the 24 h hold period.

NOTE. Temperature trends can be measured to a sensitivity of better than 0.1 °C if plotted graphically over several days. A graphical plot of pressure, underground temperature and ambient temperature against time prepared during the test period will assist in the interpretation of test results.

8.6 Test acceptance criteria

8.6.1 General

The pressure test should be considered as satisfactory if no observable pressure variation occurs which cannot be accounted for by temperature change taking into account the accuracy and sensitivity of the measuring equipment.

8.6.2 Method of assessment for hydrostatic test

The relationship between pressure and temperature should be calculated in accordance with the following formula:

$$\Delta P = \frac{264.7\ T_f}{D/t + 100}$$

where

ΔP is the pressure change (in bar/°C);

T_f is the temperature factor change (from figure 5);

D is the nominal pipe diameter (in m);

t is the nominal wall thickness (in m).

The temperature factor change T_f should be read from figure 5 at the mean test temperature. ΔP should be multiplied by the temperature change during the test to find the pressure correction.

Account should be taken of both ambient and underground temperatures (see **8.5.3**) according to the respective lengths of pipeline involved, when calculating the pressure/temperature relationship.

NOTE 1. It has been observed that a significant time lag may occur between a change in ground temperature and a corresponding change in pressure in the test section.

NOTE 2. Chill or heat factors on exposed pipe may have an effect on pressure readings.

8.6.3 Method of assessment of pneumatic test

The relationship between pressure and temperature should be calculated in accordance with the Gas Laws. However, owing to the difficulty in assessing the actual gas temperature within the test section, inconclusive results of such calculations may occur. In this event consideration should be given to extending the pneumatic test hold period to obtain more conclusive results.

8.7 High level testing

High-level hydrostatic testing may be carried out. During high-level testing a detailed pressure/volume graph should be maintained throughout the test. The test pressure should be specified as the lesser of either:

a) the pressure given by the formulae in **2.9.2** and **2.10.1** in which the design factor is 1.14 for seam welded pipe and 1.02 for seamless pipe (but see note); or

b) the pressure at which the pressure/volume graph reaches the point at which twice the volume of water is required to raise the pressure 1.0 bar compared to the volume required to raise the pressure 1.0 bar at the commencement of the linear section of the pressure/volume graph (double stroking).

In other respects high-level testing should follow the hydrostatic test procedure in **8.5** with similar acceptance criteria as **8.6**. Account should be taken of fabricated items incorporated into a pipeline subjected to high level testing and their suitability to withstand the test pressure.

NOTE. High-level testing can cause damage to coatings particularly of coal tar enamel or bitumen. For seamless pipe with such coatings a design factor in a) above of 0.97 is recommended.

8.8 Disposal of test water

Arrangements should be made for the disposal of test water from the pipeline section after completion of pressure testing, bearing in mind that it may be heavily discoloured with rust particles. Consents should be obtained from landowners and occupiers, and from river, drainage and water authorities (see BS 8010 : Part 1).

8.9 Repairs to test failures

Any pipeline which fails a pressure test should be repaired and retested. The failed portion should be replaced and the welds subjected to both radiographic and ultrasonic inspection in accordance with BS 4515 : 1984.

For pipelines subjected to high level testing repairs should be carried out using pre-tested pipe. The pipeline or section should then be re-tested for an aggregate period of not less than 24 h.

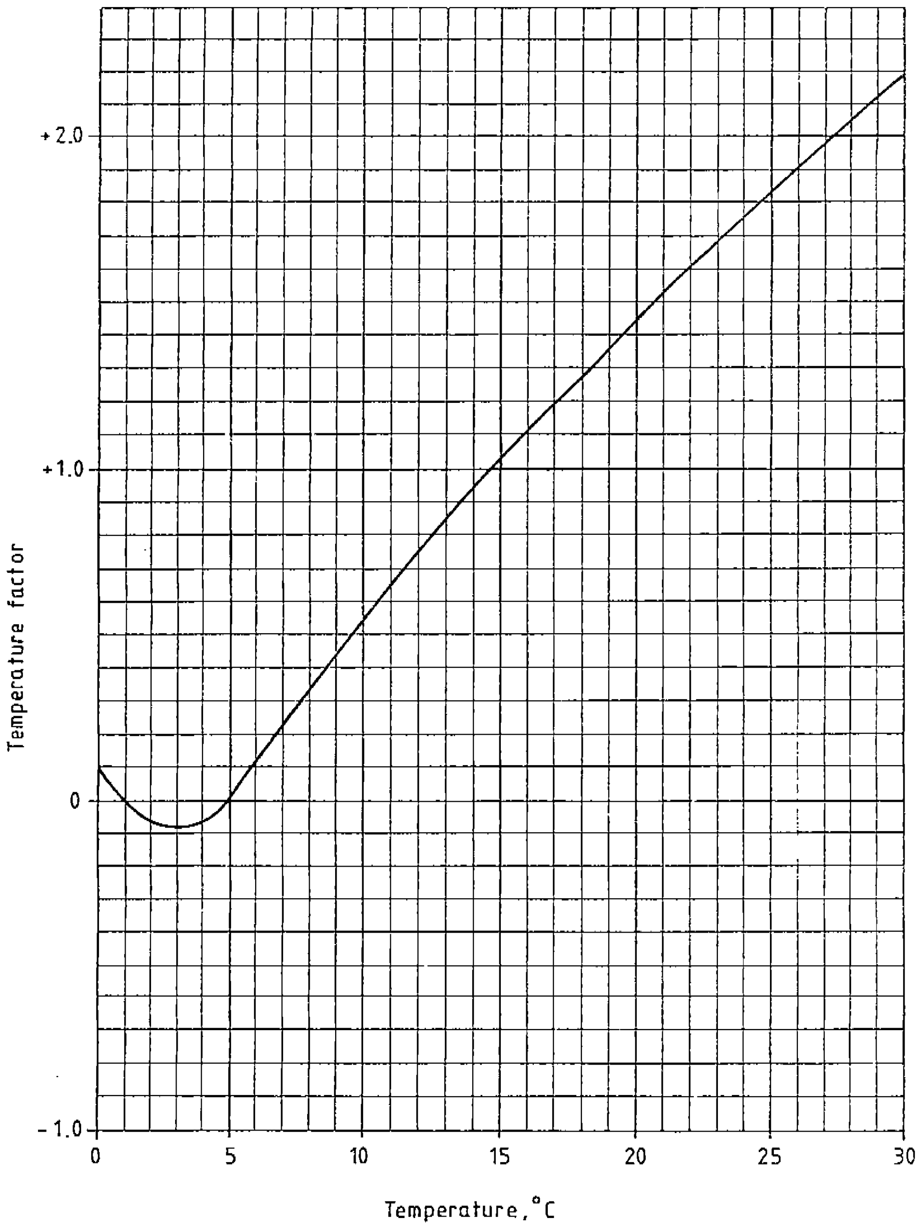


Figure 5. Effect of temperature on pressure

8.10 Tie-in welds

Consecutive test sections should be constructed to overlap so that the tie-in can be made with a single weld. If the tie-in cannot be made without using a length of pipe, this length of pipe should be pretested in accordance with **8.5.1** or **8.5.2** before installation. All tie-in welds not subject to subsequent pressure testing should be subject to radiographic inspection supplemented by ultrasonic testing.

8.11 Pre-testing of crossings

Road and rail crossings classified as major crossings, river crossings, canal crossings and bridge crossings (see **2.6**) should be fabricated from pre-tested pipe or should be pre-tested after fabrication but before installation and final test. Pre-testing of pipe or fabrications should be carried out in accordance with **8.5** except that:

a) the pre-test pressure should be at least 1.05 times the test pressure appropriate to the section into which the crossing is to be installed taking into account the elevation of the crossing within the test section; and

b) the duration of the final hold period should be not less than 3 h.

The test should be considered acceptable if no leaks are detected on visual examination.

8.12 Testing of fabricated components

Fabricated components (such as pig traps, slug catchers, insulation joints or manifolds) should be pressure tested to limits equal to those required for the completed pipeline. If the components are also to be tested out as part of the completed system they should be designed in accordance with test procedures and pressure in **8.4** and **8.5**.

Fabricated components and fittings should be tested to the test pressures not in excess of the flange rating of the particular item.

8.13 Test records

All certificates and records produced in connection with pressure testing a pipeline should be retained by the registered operator for the lifetime of the pipeline.

Section 9. Commissioning

9.1 General

Commissioning refers to the work required to bring a pipeline system into operation after completion of construction. A commissioning procedure document should be prepared which systematically sets out the commissioning operation.

9.2 Precommissioning

9.2.1 Integrity test

On completion of pressure testing consideration should be given to carrying out an integrity test on the completed pipeline system to demonstrate its integrity by proving that all tie-ins between test sections have been completed and that all equipment has been correctly installed into the system. This is particularly important where previously untested mechanical joints have been incorporated into the systems. When the integrity test medium is not compatible with the substance to be conveyed in the pipeline, it should be displaced by a compatible substance.

9.2.2 Test pressure

The test pressure for the integrity test should not be less than the maximum operating pressure plus any allowance for surge pressure and other variations likely to be experienced by the pipeline systems in normal operation subject to an upper limit of 1.1 times the design pressure (see **2.8.2.5**).

9.3 Cleaning

Consideration should be given to the degree of cleanliness required in the operating pipeline both at the design stage and before the introduction of the substance to be conveyed during commissioning. A cleaning method appropriate to the substance being conveyed should be employed.

9.4 Commissioning

9.4.1 Commissioning of category B substance pipelines

Commissioning of category B substance pipelines should comprise the displacement of test medium, if necessary, by pumping the substance to be conveyed into the pipeline. Pigs or spheres may be used to minimize interface mixing and to monitor progress of the interface along the pipeline. Care should be taken to clear trapped test medium from valves, fittings and instruments.

9.4.2 Commissioning of category C substance pipelines

Commissioning of category C substance pipelines should comprise the displacement of the test medium, if necessary, by the substance to be conveyed. This should be undertaken at a continuous and carefully controlled rate to reduce the mixing of test medium and substance to be conveyed. At the end of the pipeline, venting arrangements should consist of a valved connection to a vertical vent pipe discharging into a safe area, a valved sampling connection and a pressure gauge connected to the pipeline.

Suitable detection equipment to monitor the change from test medium to conveyed substance should be used.

9.4.3 Commissioning of category D substance pipelines

Prior to the introduction of category D substances into the pipeline system, removal of the test medium, if necessary, and drying of the pipeline should be carried out. Initial removal of the test medium should be by the use of swabbing pigs and draining down at valve locations. Drying should be achieved by a method appropriate to the dryness required. Drying may be carried out by the use of drying agents such as methanol conveyed along the pipeline between pigs and may be followed by purging with dry nitrogen. Other drying methods such as dry air, nitrogen purging or vacuum drying may be considered. Where vacuum drying is proposed the suitability for vacuum conditions of seals incorporated into pipline components such as pig-trap doors and valves should be established.

Commissioning should comprise the introduction of an inert gas such as nitrogen followed by the introduction of the substance to be conveyed at a continuous and controlled rate immediately following the inert gas. For lighter-than-air substances, venting arrangements at the end of the pipeline should consist of a valved connection to a vertical vent pipe not less than 2.5 m high, a valved sampling connection and a pressure gauge connected to the pipeline. Suitable detection equipment to monitor the change from test medium to conveyed substance should be used.

For the commissioning of category D substance pipelines designed to convey methane, reference should be made to section 11 of the Institution of Gas Engineers IGE/TD/1 : 1984.

9.5 Deferred commissioning

When a significant time lag is expected between completion of testing and commissioning, consideration should be given to filling the pipeline with a suitable fluid to reduce the likelihood of internal corrosion of the pipe. Suitable fluids should be selected from dry inert gas, gas oil and water. If water is used care should be taken to ensure that all air is excluded from the pipe line and that the water is free of corrosive material. The pipeline should remain under a small positive pressure, which should be periodically checked, until commissioning commences.

9.6 Communications

During all phases of cleaning, testing, purging and commissioning, a reliable communications system should be in operation between field personnel. Consideration should be given to the use of trackable pigs during initial swabbing operations.

9.7 Handover procedures

Arrangements should be made to ensure that the completed pipeline is handed over to the pipeline operator with all the necessary records and as-built information to enable the pipeline to be safely operated. The information should also include as-built route maps of the completed pipeline.

List of references (see clause 1.2)

Normative references

BSI standards publications

BRITISH STANDARDS INSTITUTION, London

BS 1414 : 1975	*Specification for steel wedge gate valves (flanged and butt-welding ends) for the petroleum, petrochemical and allied industries*
BS 1501	*Steels for pressure purposes: plates*
BS 1502 : 1982	*Specification for steels for fired and unfired pressure vessels: sections and bars*
BS 1503 : 1983	*Specification for steel forgings for pressure purposes*
BS 1504 : 1976	*Specification for steel castings for pressure purposes*
BS 1506 : 1990	*Specification for carbon, low alloy and stainless steel bars and billets for bolting material to be used in pressure retaining applications*
BS 1560	*Circular flanges for pipes, valves and fittings (Class designated)*
BS 1640	*Specification for steel butt-welding pipe fittings for the petroleum industry*
BS 1832 : 1991	*Specification for compressed asbestos fibre jointing*
BS 1868 : 1975	*Specification for steel check valves (flanged and butt-welding ends) for the petroleum, petrochemical and allied industries*
BS 1873 : 1975	*Specification for steel globe and globe stop and check valves (flanged and butt welded ends) for the petroleum, petrochemical and allied industries*
BS 1965 :	*Specification for butt-welding pipe fittings for pressure purposes*
BS 1965 : Part 1 : 1963	*Carbon steel*
BS 2815 : 1973	*Specification for compressed asbestos fibre jointing*
BS 3293 : 1960	*Specification for carbon steel pipe flanges (over 24 inches nominal size) for the petroleum industry*
BS 3381 : 1989	*Specification for spiral-wound gaskets for steel flanges to BS 1560*
BS 3601 : 1987	*Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes*
BS 3602 :	*Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties*
BS 3602 : Part 1 : 1987	*Specification for seamless and electric resistance welded including induction welded tubes*
BS 3602 : Part 2 : 1991	*Specification for longitudinally arc welded tubes*
BS 3603 : 1991	*Specification for carbon and alloy steel pipes and tubes with specified low temperature properties for pressure purposes*
BS 3799 : 1974	*Specification for steel pipes fittings, screwed and socket-welding for the petroleum industry*
BS 4360 : 1990	*Specification for weldable structural steels*
BS 4508	*Thermally insulated underground pipelines*
BS 4515 : 1984	*Specification for welding of steel pipelines on land offshore*
BS 4882 : 1990	*Specification for bolting for flanges and pressure containing purposes*
BS 5306 :	*Fire extinguishing installations and equipment on premises*
BS 5306 : Part 3 : 1985	*Code of practice for selection, installation and maintenance of portable fire extinguishers*
BS 5306 : Part 6 :	*Foam systems*
BS 5306 : Part 6 : Section 6.1 : 1988	*Specification for low expansion foam systems*
BS 5306 : Part 6 : Section 6.2 : 1989	*Specification for medium and high expansion foam systems*

BS 5345	*Code of practice for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture)*
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BS 5351 : 1986	*Specification for steel ball valves for the petroleum, petrochemical and allied industries*
BS 5352 : 1981	*Specification for steel wedge gate, globe and check valves 50 mm and smaller for the petroleum, petrochemical and allied industries*
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BS 5423 : 1987	*Specification for portable fire extinguishers*
BS 5493 : 1977	*Code of practice for protective coating of iron and steel structures against corrosion*
BS 5500 : 1991	*Specification for unfired fusion welded pressure vessels*
BS 5839 :	*Fire detection and alarm systems for building*
BS 5839 : Part 1 : 1988	*Code of practice for system design installation and servicing*
BS 6759	*Safety valves*
BS 6759 : Part 3 : 1984	*Specification for safety valves for process fluids*
BS 7361 :	*Cathodic protection*
BS 7361 : Part 1 : 1991	*Code of practice for land and marine applications*
BS 8010 :	*Code of practice for pipelines*
BS 8010 : Part 1 : 1989	*Pipelines on land: general*
BS 8010 : Part 3 : 1992	*Pipelines subsea: design, construction and installation*
CP 3009 : 1970	*Thermally insulated underground piping systems*

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AMERICAN NATIONAL STANDARDS INSTITUTE, New York

ANSI B16.5 : 1988	*Pipe flanges and flanged fittings*
ANSI B16.9 : 1986	*Factory-made wrought steel butt welded fittings*
ANSI B16.11 : 1980	*Forged steel fittings, socket welded and threaded*
ANSI B16.20 : 1973	*Ring joint gaskets and grooves for steel pipe flanges*
ANSI B31.3 : 1987	*Chemical plant and petroleum refinery piping*
ANSI B31.8 : 1989	*Gas transmission and distribution piping systems*

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AMERICAN PETROLEUM INSTITUTE, USA

API 5L : 1991	*Specification for line pipe*
API 6D : 1991	*Specification for pipeline valves*
API 597 : 1991	*Steel venturi gate valves, flanged and butt-welded end*
API 599 : 1988	*Steel and duefile iron plug valves*
API 600 : 1991	*Steel gate valves, flanged or butt welded ends*
API 602 : 1985	*Compact steel gate valves*
API RP 5L2	*Recommended practice for internal coating of line pipe for non-corrosive gas transmission service*

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ENGINEERING EQUIPMENT AND MATERIAL USERS ASSOCIATION, London

EEMUA 153/89 : 1987	*Supplement to ANSI/ASME B.31.3*

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[1] All publications are available from BSI Publications.

IGE publication

INSTITUTE OF GAS ENGINEERS, London

IG/TD/	*Recommendations on transmission and distribution practice*
IG/TD/1 : 1984	*Steel pipelines for high pressure gas transmission, Edition 2*

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BS 806 : 1990	*Specification for design and construction of ferrous piping installations for and in connection with land boilers*
BS 2633 : 1987	*Specification for Class I arc welding of ferritic steel pipework for carrying fluids*
BS 3605 :	*Austenitic stainless steel pipes and tubes for pressure purposes*
BS 3605 : Part 1 : 1991	*Specification for seamless tubes*
BS 4147 : 1980	*Specification for bitumen-based hot-applied coating materials for protecting iron and steel, including suitable primers where required*
BS 4164 : 1987	*Specification for coal-tar-based hot-applied coating materials for protecting iron and steel, including a suitable primer*
BS 4677 : 1984	*Specification for arc welding of austenitic stainless steel pipework for carrying fluids*
BS 4870	*Specification for approval testing of welding procedures*
BS 4871	*Specification for approval testing of welders working to approved welding procedures*
BS 5555 : 1981	*Specification for SI units and recommendations for the use of their multiples and of certain other units*
BS 5750	*Quality systems*
BSI Handbook 22 : 1990	*Quality assurance*

API publication[1]

AMERICAN PETROLEUM INSTITUTE, USA

API 1104 : 1988	*Welding of pipelines and related facilities*

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[1] All publications are available from BSI Publications.

ASTM publication[1]

AMERICAN SOCIETY FOR TESTING AND MATERIALS, USA

ASTM A790M : 1985	*Standard specification for seamless and welded austenitic/ferritic (Duplex) stainless steels*

AWWA publication[1]

AMERICAN WATERWORKS ASSOCIATION, USA

AWWA C203 : 1986	*Standard on coal for protective coatings and linings for steel water pipelines*

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INSTITUTE OF GAS ENGINEERS, London

IG/TD/	*Recommendations on transmission and distribution practice*
IGE/TD/1 : 1984	*Steel pipelines for high pressure gas transmission, Edition 2*
IGE/TD/6 : 1985	*Transport handling and storage of steel pipe, valves and fittings*
IGE/TD/12 : 1985	*Pipework stress analysis for gas industry plant*

NACE publication[1]

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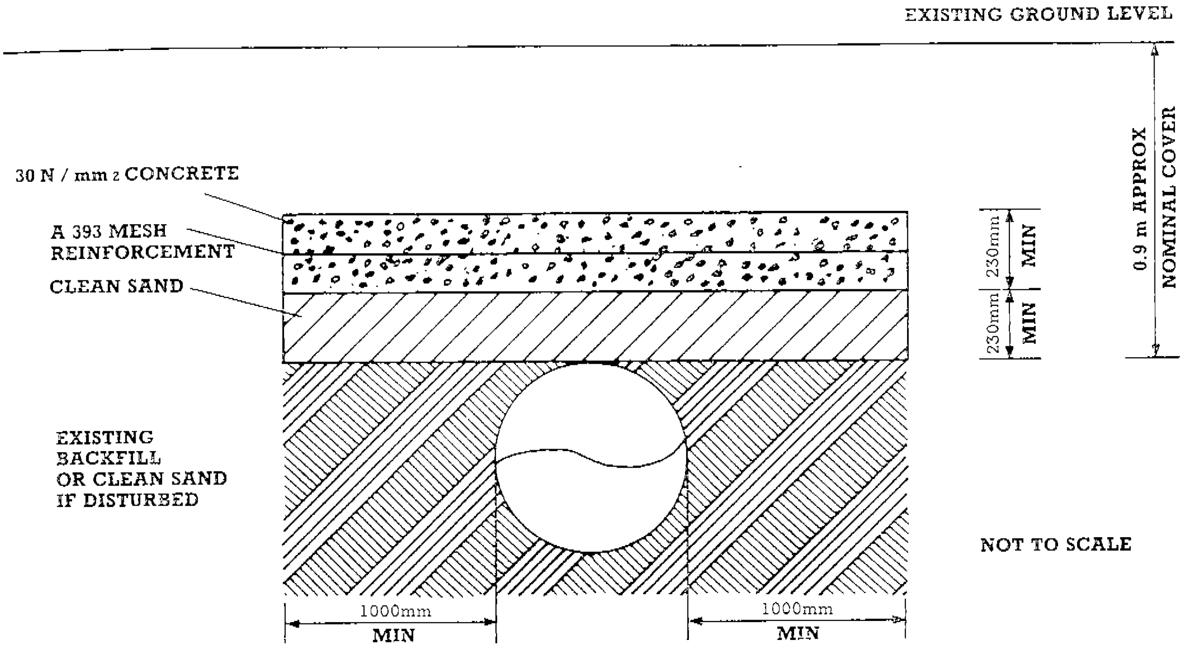
B/203

Typical sectional drawing and specification for protection of Pipelines under carriage ways.

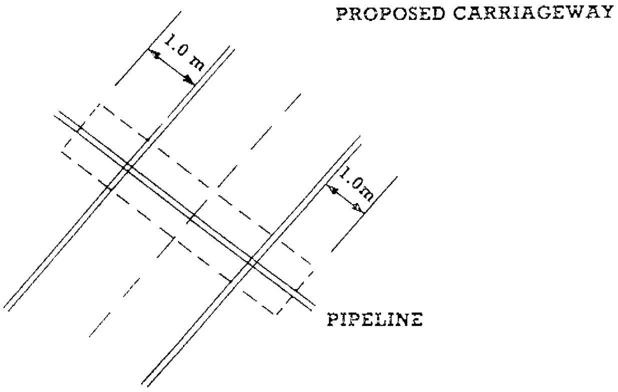
附錄四

(Each case will be treated separately)



Notes:

1. Backfill between pipeline and concrete slab to be;
   Either existing backfill (undisturbed)
   Or sand clean of any inclusions.
2. The concrete slab is to extend a minimum of 1.0 metre (3′3″) beyond the proposed crossing area, i.e.



附錄五

Model Code of Safe Practice

Part 6

SPECIMEN COPY

For your inspection only
Please do not take away

Fourth Edition

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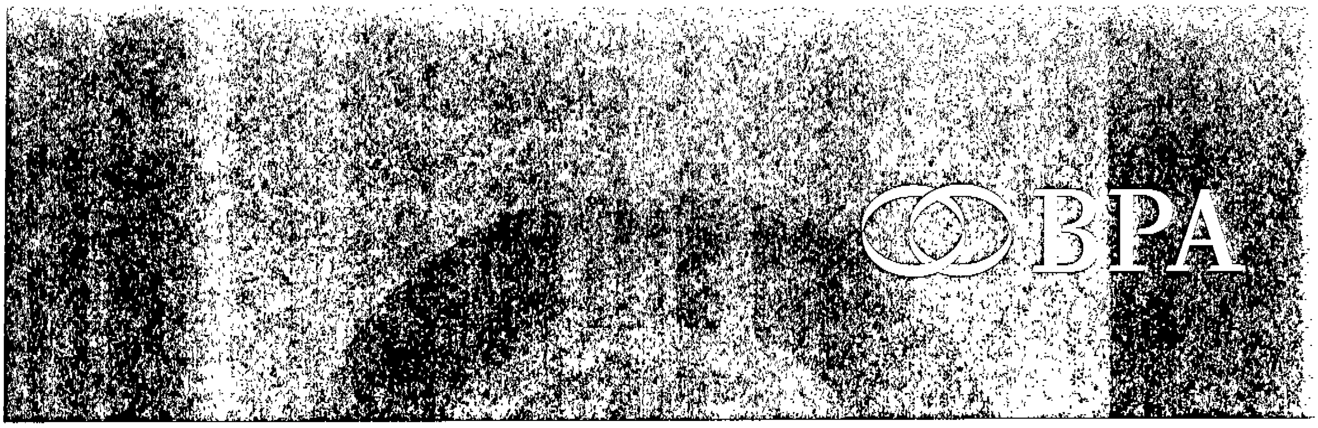

附錄六

PIPELINE MANAGEMENT

PARTICULARLY RELATING TO INTEGRITY MANAGEMENT ISSUES

Lord Alexander House, Waterhouse Street
Hemel Hempstead, Herts. HP1 1EJ, UK
Tel: +44 (0) 1442 242200 Fax: +44 (0) 1442 214077
E-mail: business@bpa.co.uk
Website: www.bpa.co.uk

Certificate of Registration

BSI

REGISTERED

Certificate Number FS 14375

B P A
LORD ALEXANDER HOUSE
WATERHOUSE STREET
HEMEL HEMPSTEAD
HERTFORDSHIRE
HP1 1EJ

operate a Quality Management System which complies with the requirements of BS EN ISO 9001:1994

J Thomas

Signed on behalf of BSI

Accredited by the
Dutch Accreditation Council RvA

Originally registered 24 January 1992 Amended on 19 September 2000

UKAS
QUALITY
MANAGEMENT
003

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To be read in conjunction with attached Appendix.

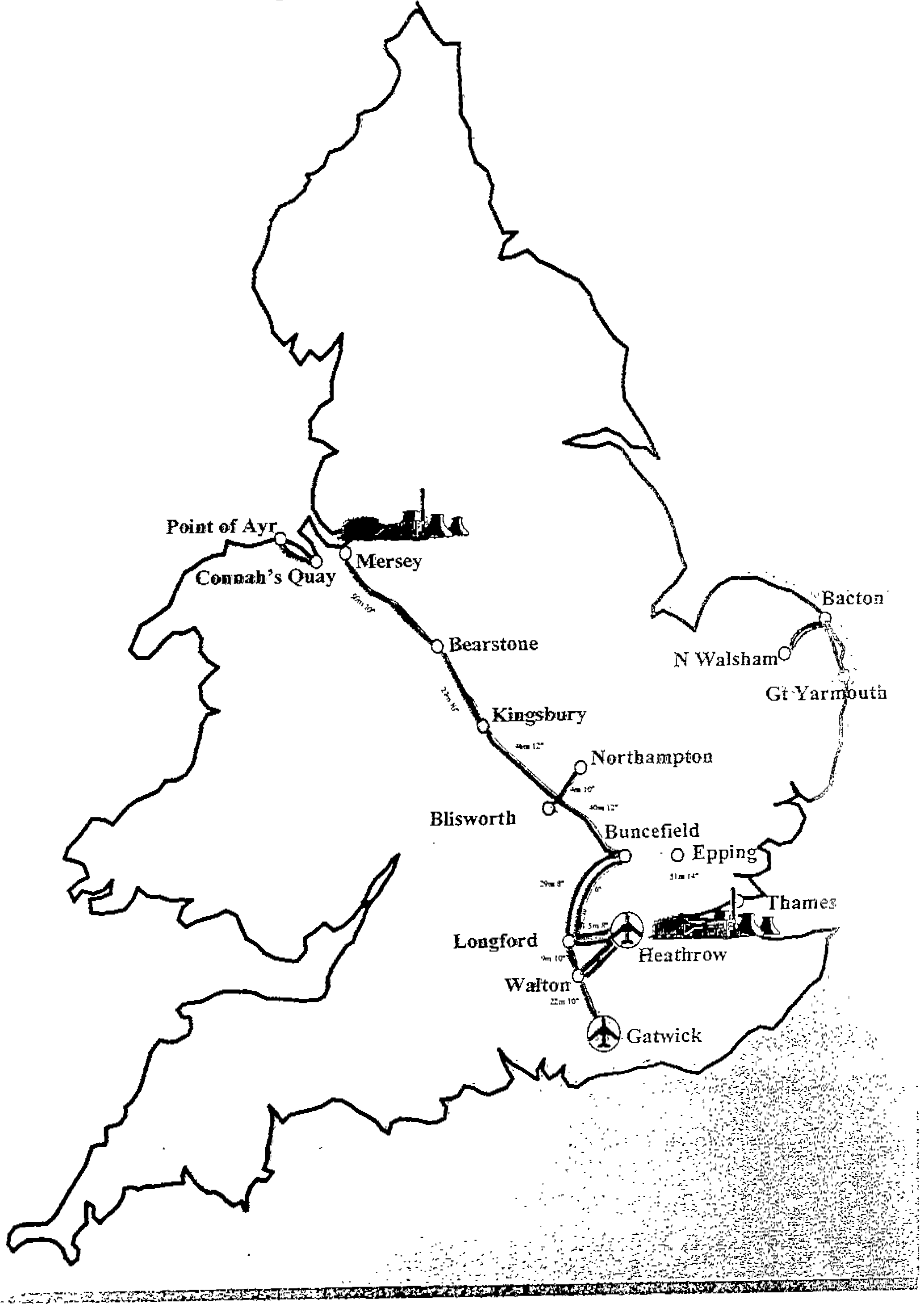
The British Standards Institution is incorporated by Royal Charter.

BSI 389 Chiswick High Road London W4 4AL

BPA 'UKOP' Operations

	THAMES - MERSEY	WEST LONDON	WALTON - GATWICK
LENGTH	505km	62km	36km
CONST'N	1965-68	1968 (&84)	1984
DIAMETER	10-14"	6-10"	10"
PRODUCTS	8 GRADES	Aviation	Aviation
OWNERS	BP, Shell, Texaco Mobil, Fina	BP, Shell, Texaco Mobil, Fina	BP, Shell Texaco, Mobil
REP 'T COST	C£125M	C£25M	C£10M
1999 TH'PUT	7538kT	3135kT	1485kT

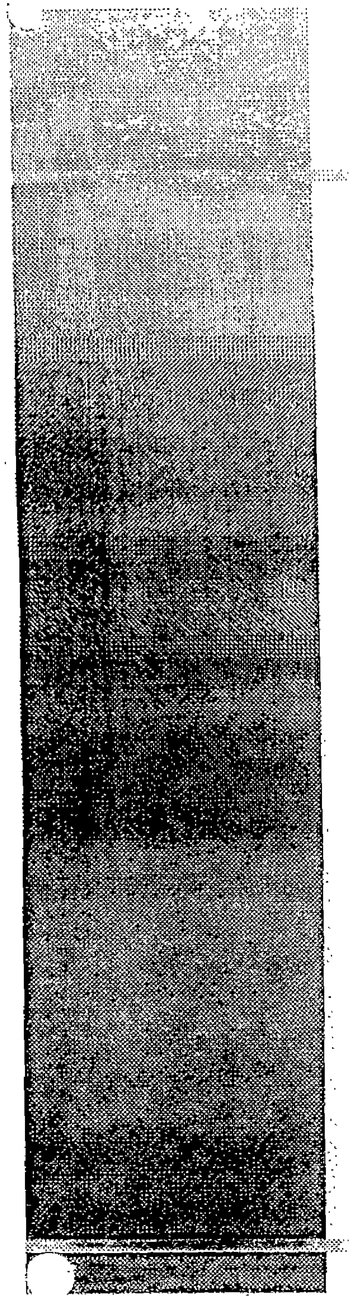
Commercial pipeline systems managed by BPA



BPA, Lord Alexander House, Waterhouse Street, Hemel Hempstead Hertfordshire, HP1 1EJ. UK.
Tel: +44 (0) 1442 242200 Fax: +44 (0) 1442 214077

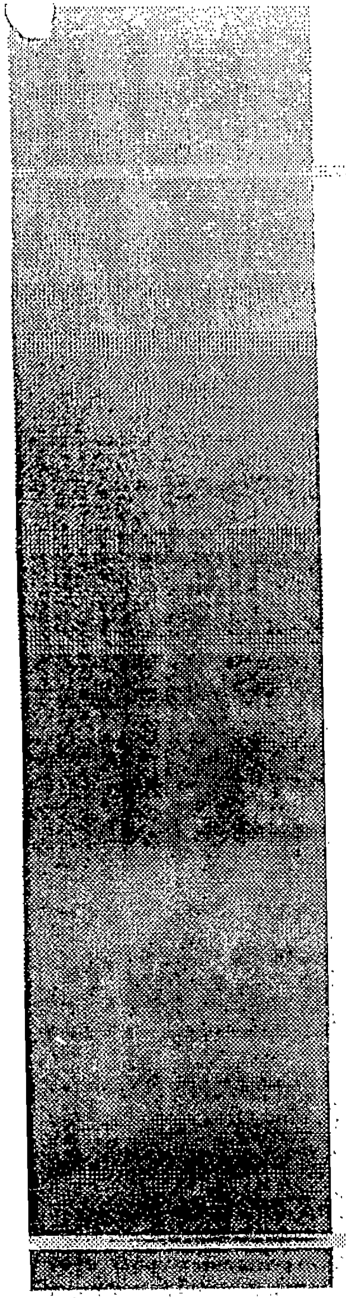
THE PEOPLE

- Total staff of 100 - UK wide
- Management team with diverse oil industry background
- Professional engineering and technical staff
- Drawing office utilising latest CAD technology
- Over 50 pipeline and storage operating staff around UK
- Hemel Hempstead based management, administration, finance, IT, and business support
- Shareholder support resources available



Description of the UKOP Pipeline System

- Built in the 1960's and extended in the 1980's
- Owned by a consortium of 6 companies
- 510 kilometres, diameters in the range 10 - 14 inch
- Max operating pressure 1200 psi, flowrates to 850m3/hr
- Multiproduct - up to 8 different grades
- Utilisation 80 - 100%
- Batch sizes 1,100 - 48,000m3
- Transportation speed typically 4mph, M-B - 48hrs



Operation of the UKOP Pipeline

- Product scheduled many days in advance
- Pipeline parcel order arranged to reduce critical interfaces
- Centrally controlled from Kingsbury
- New SCADA system installed in 1990

U.K. products pipeline installs new scada system

Chris Giles *SD-Scicon Ltd. Milton Keynes, U.K.*
Ian Neilson *British Pipeline Agency Ltd. Hemel Hempstead, U.K.*

Design of the supervisory control and data acquisition (scada) system recently installed on the United Kingdom Oil Pipelines Ltd. (UKOP) multiproduct pipeline system provides a high level of automation and system availability.

UKOP is trustee and agent for BP Oil (U.K.) Ltd., Chevron International Oil Company Ltd., Fina plc, Mobil Oil Co. Ltd., Shell U.K. Oil, and Texaco Ltd.

The project to replace the existing control system was managed by British Pipeline Agency Ltd. (BPA) which designs and operates liquid petroleum pipelines for several third-party clients, including UKOP.

The scada system was designed and built by SD-Scicon, a U.K.-based subsidiary of EDS, which supplies systems integration services for the oil and petrochemical industries.

Hybrid system

The UKOP pipeline system (Fig. 1) consists of two pipelines. One originates from the Stanlow refinery on the river Mersey and delivers to terminals at Uttoxeter, Kingsbury (near Birmingham), Northampton, and Buncefield. The second draws product from refineries and tank farms in the Thames Haven area and delivers to terminals at Buncefield, Northampton, and Kingsbury.

The system, which consists of some 470 km (292 miles) of 6-14 in. pipeline, ships eight grades of white oil for several shipping companies and transports approximately 2,000 parcels of fuel per year; individual parcels may be split between several different delivery destinations.

Before this project, the pipeline was controlled by a hybrid 1960s and 1970s control system which had evolved as the pipeline system expanded. It was nearing the end of its useful life, primarily through hardware obsolescence.

It had also become apparent that the system would be unable to satisfy new requirements expected to arise during the 1990s:

- BPA would need improved process monitoring and leak-detection facilities, to be able to maintain safety and environmental performance.
- Limitations of the existing control system meant that the pipeline system had to be controlled from three sites. Significant cost savings could be realized if it could be controlled from a single, centralized control system.

Providing a range of automation facilities would be necessary if the existing control center personnel at Kingsbury were to be able safely to operate the increased length of pipeline and number of sites which would come under their control.

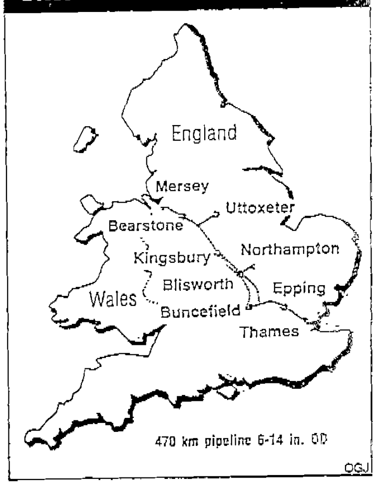
- The pipeline system plays a critical role in the distribution strategies of the shipping companies and operates close to its maximum capacity. Shutdowns caused by control system malfunctions or failures were therefore becoming even more unacceptable.
- Increasing implementation of new computer systems for planning and product accounting within the shipping companies was causing demands for more process-related data, at increasingly frequent intervals, to be placed on the pipeline operations staff.

It was clear that these demands would grow further and that they could only be met if such data were

A BPA engineer adjusts the control unit for an hydraulic valve at Buncefield, northwest of London. The valve is operated and controlled via the new scada system from Kingsbury near Birmingham, 100 miles north. (Photograph by John D. Elton.)

Fig. 1

UKOP MULTIPRODUCT PIPELINE



Reprinted from the March 30, 1992 edition of **OIL & GAS JOURNAL**

BPA

UKOP 1:50,000 Route Maps

1) These maps are supplied only to indicate the existence of the pipelines; they should not be copied, enlarged, scaled or digitised.

2) The pipelines must be located on site by a BPA representative before any excavations commence.

3) These pipelines carry refined petroleum products at extremely high pressure.

4) Nominal cover is only 3' (0.9m) and no special warning tape or protection is usually found.

5) All excavations (including hand trial holes) within 3 metres of the pipelines must be supervised by a BPA representative.

6) Please give us 7 days notice of your intention to work near the pipelines and a minimum of 2 days to arrange supervision.

BPA Land & Wayleaves Office – Normal Consultations
and requests for supervision
Tel: 01442 218911
Fax: 01442 214077

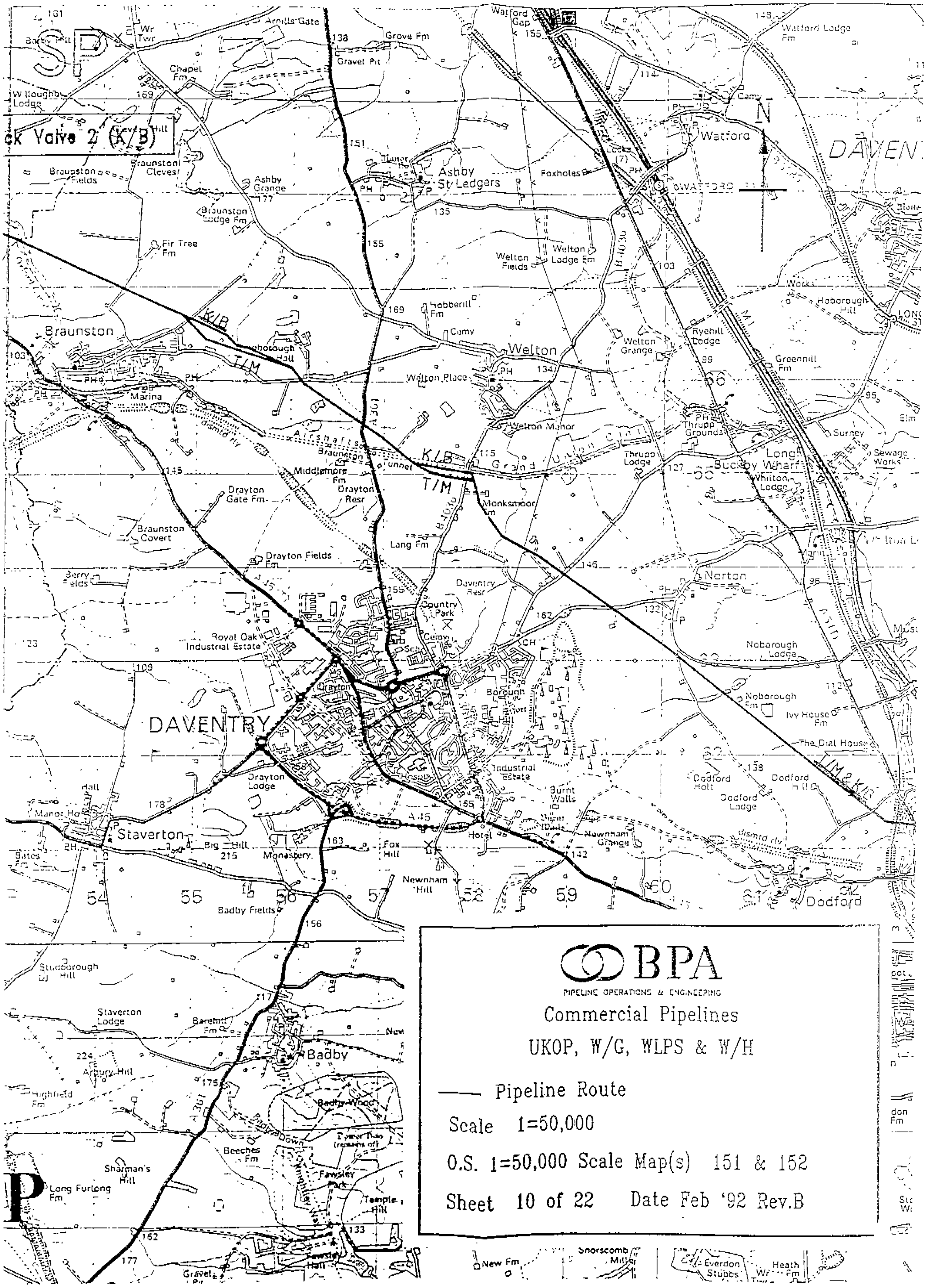
BPA 24 Hr Control Room – Out of Hours urgent works
Tel: 01827 63744

BPA Emergency Tel: 01827 63708

HM/Map Covers 2000

Lord Alexander House, Waterhouse Street
Hemel Hempstead, Herts, HP1 1EJ, UK
Tel: +44 (0) 1442 242200 Fax: +44 (0) 1442 214077
E-mail: business@bpa.co.uk
Website: http.www.bpa.co.uk

BPA is a business name of British Pipeline Agency Limited
Registered office as above. Registered in England No 1228157



BPA

PIPELINE OPERATIONS & ENGINEERING

Commercial Pipelines

UKOP, W/G, WLPS & W/H

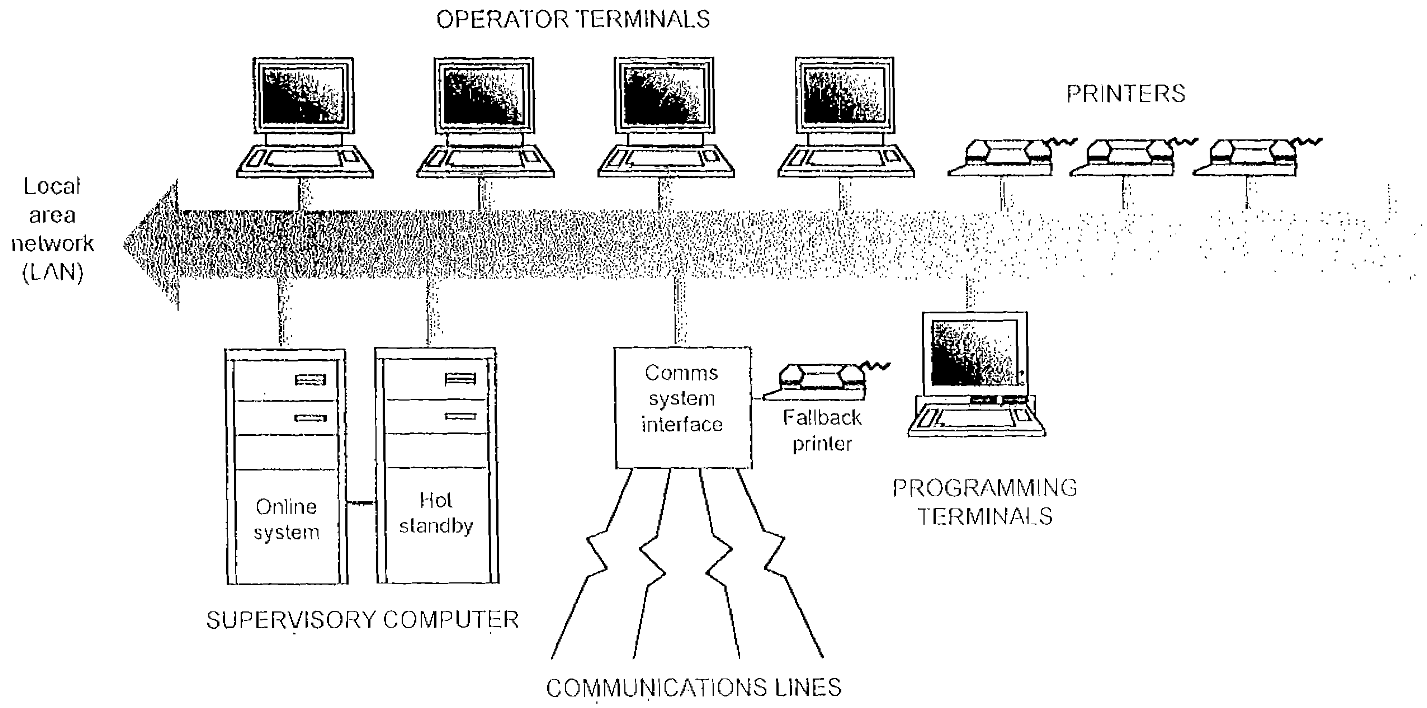
—— Pipeline Route

Scale 1=50,000

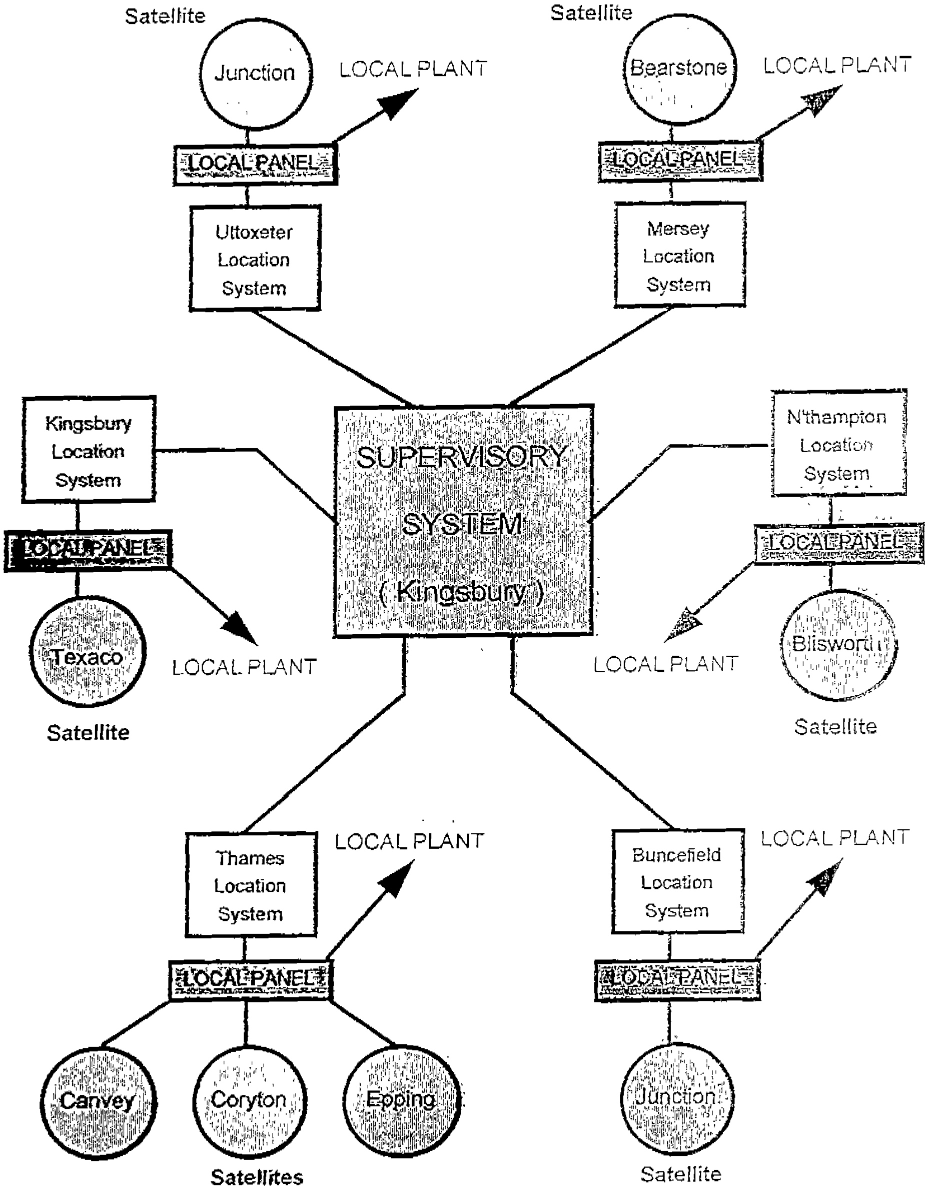
O.S. 1=50,000 Scale Map(s) 151 & 152

Sheet 10 of 22 Date Feb '92 Rev.B

CENTRAL SUPERVISORY SYSTEM SCHEMATIC

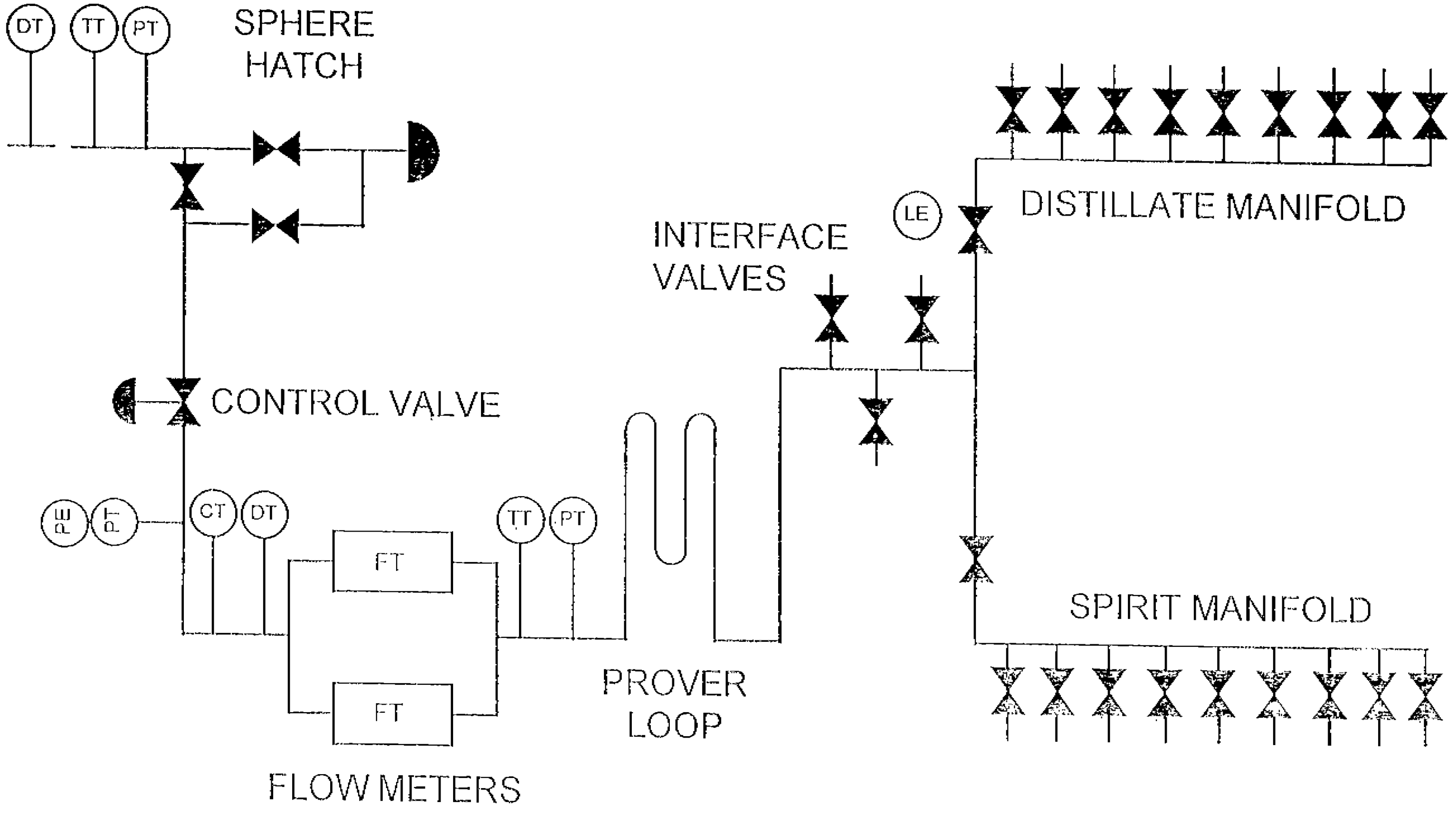


UKOP CONTROL SYSTEM SCHEMATIC

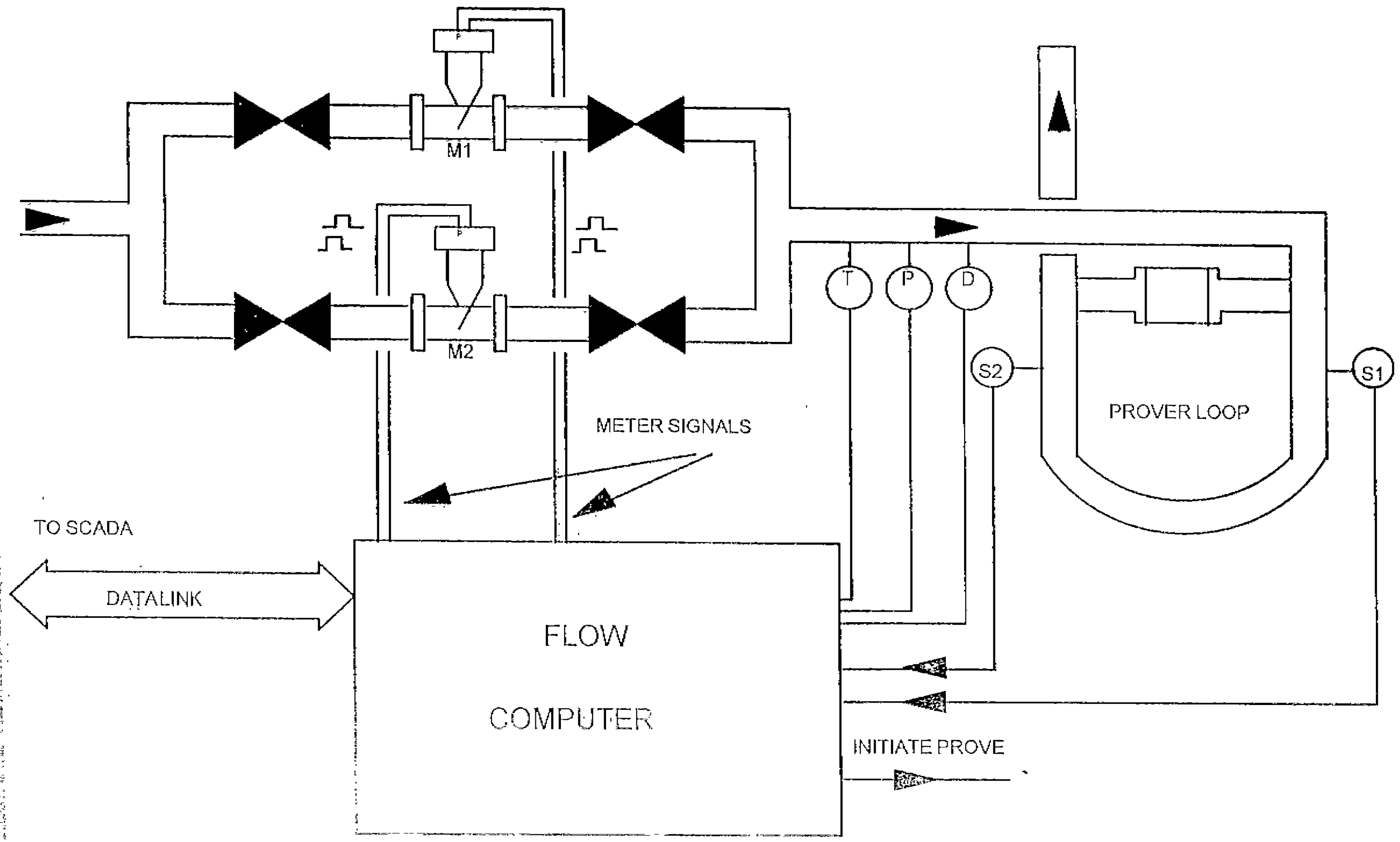


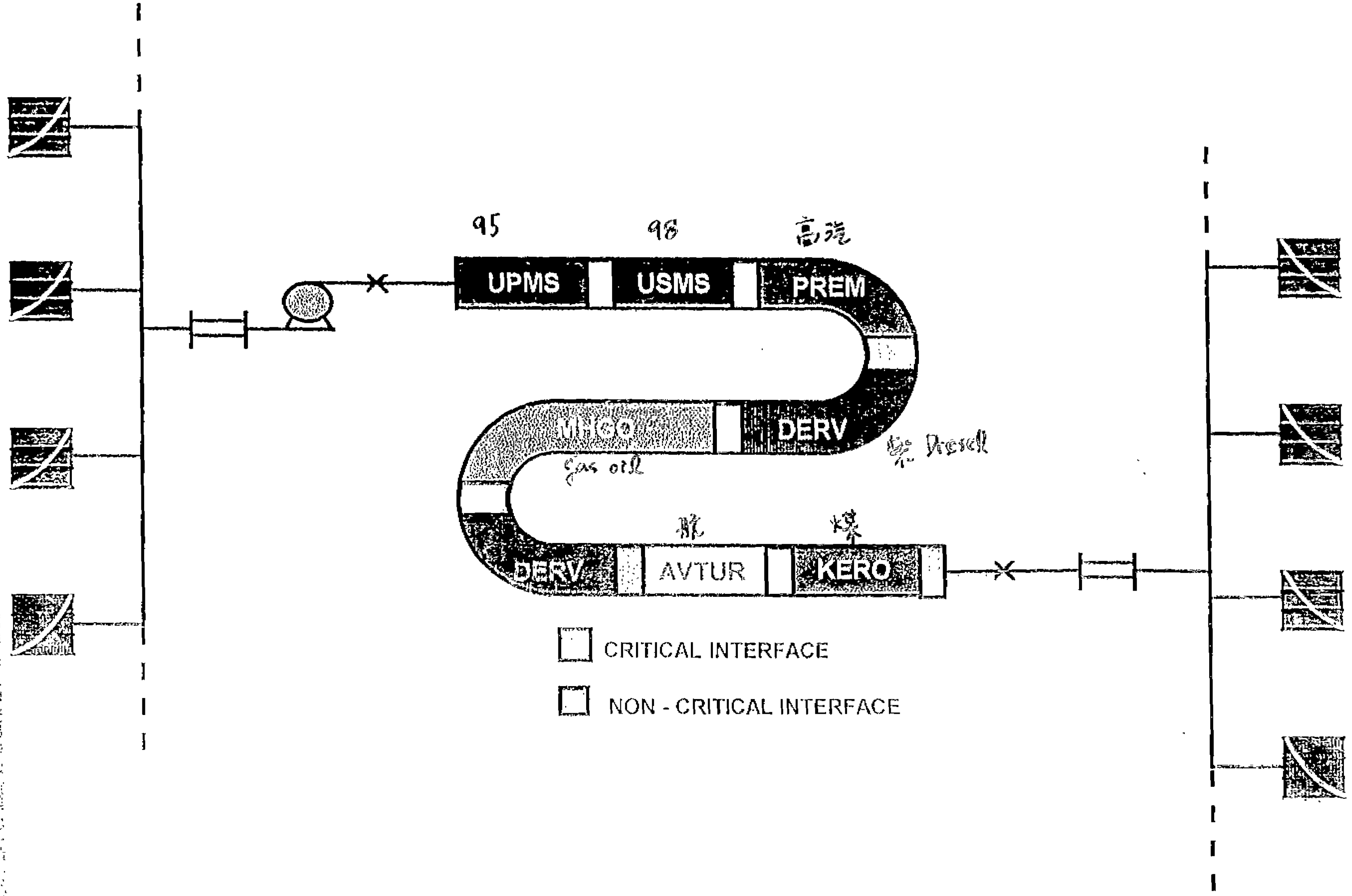
BPA
PIPELINE OPERATIONS & ENGINEERING

RECEPTION INSTRUMENTATION

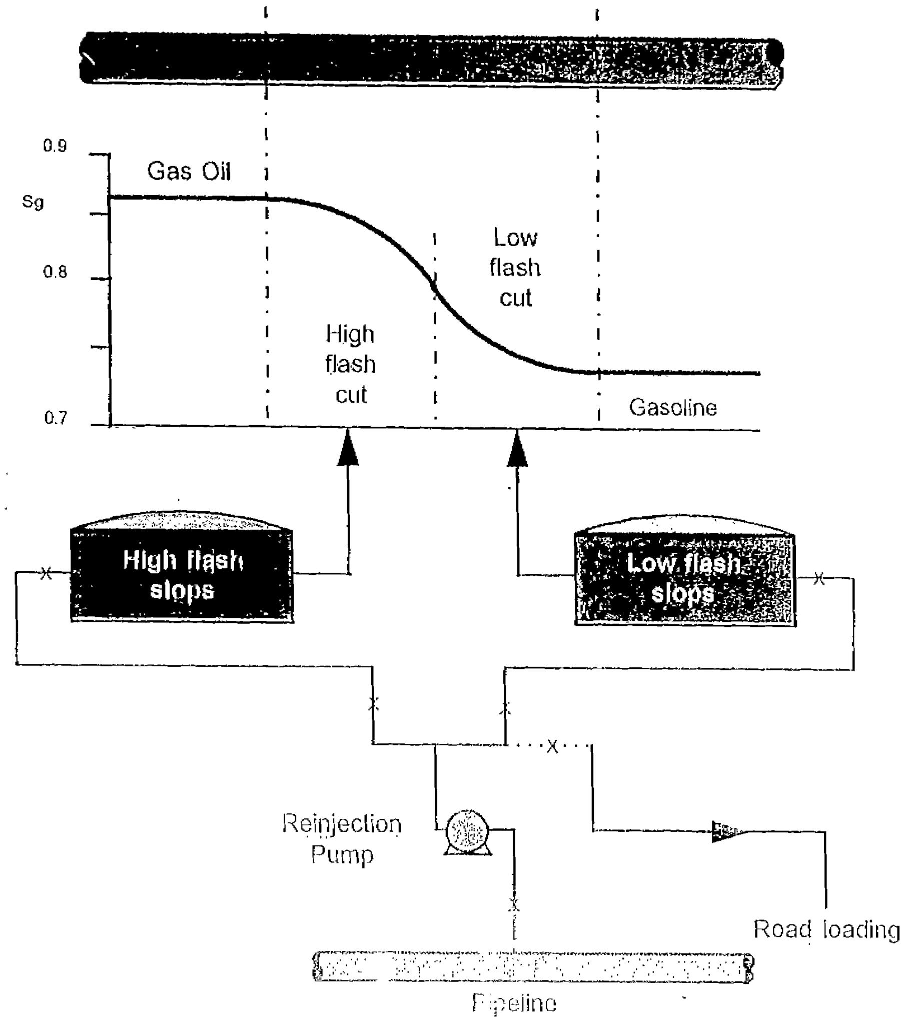


TYPICAL FLOW METERING ARRANGEMENT




95
98
高汽
UPMS
USMS
PREM
DERV
柴 Diesel
MHGO
Gas oil
航
煤
DERV
AVTUR
KERO
☐ CRITICAL INTERFACE
☐ NON - CRITICAL INTERFACE

TWO - WAY INTERFACE CUTTING

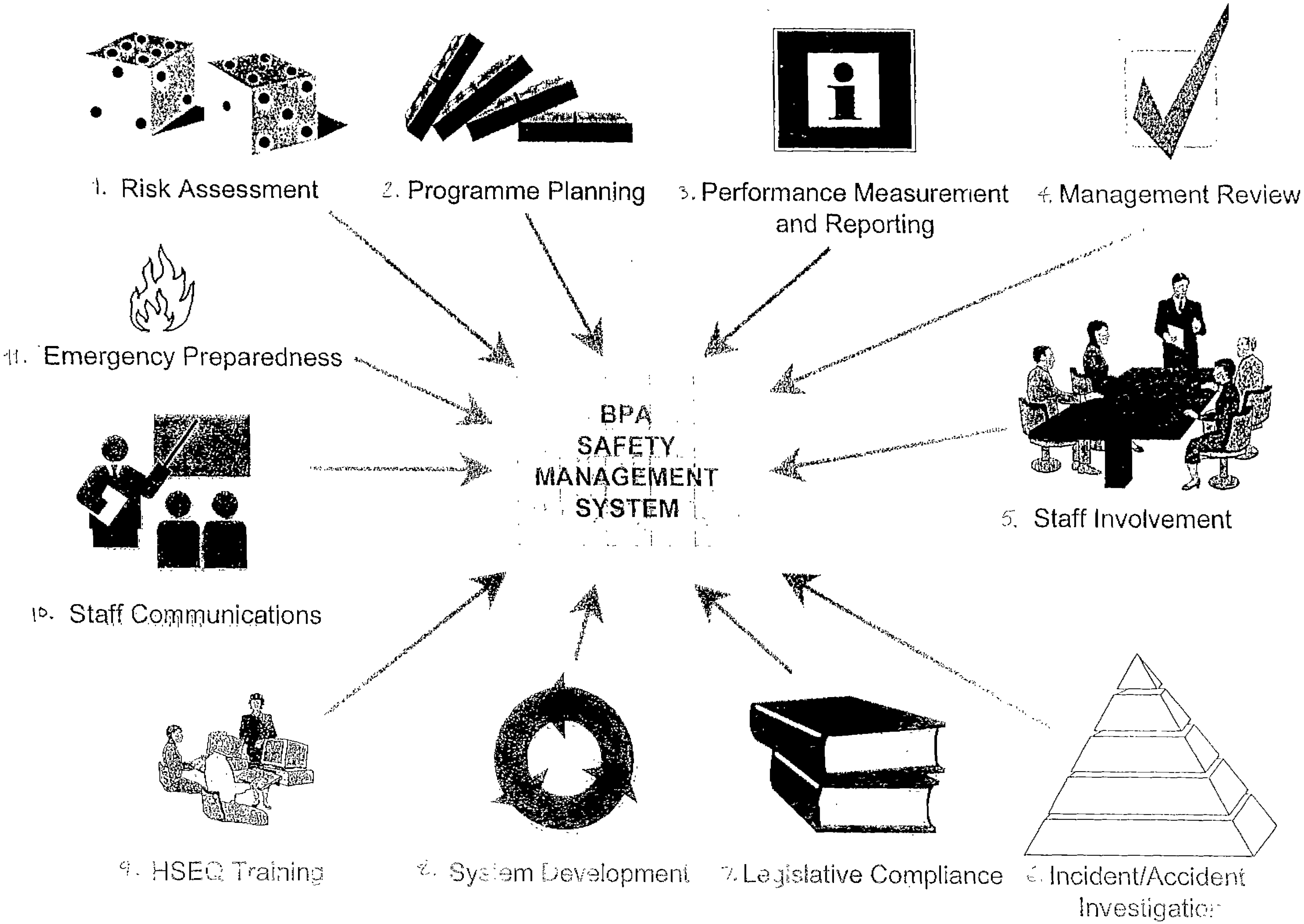


PIPELINE INTEGRITY MANAGEMENT

APPLICABLE TO

- DESIGN
- CONSTRUCTION
- OPERATION
- INSPECTION
- MAINTENANCE

11 Elements



BPA
SAFETY
MANAGEMENT
SYSTEM

1. Risk Assessment

2. Programme Planning

3. Performance Measurement and Reporting

4. Management Review

5. Staff Involvement

6. Incident/Accident Investigatio

7. Legislative Compliance

8. System Development

9. HSEQ Training

10. Staff Communications

11. Emergency Preparedness

BACTON GREAT YARMOUTH PIPELINE

BPA
PIPELINE OPERATIONS & ENGINEERING

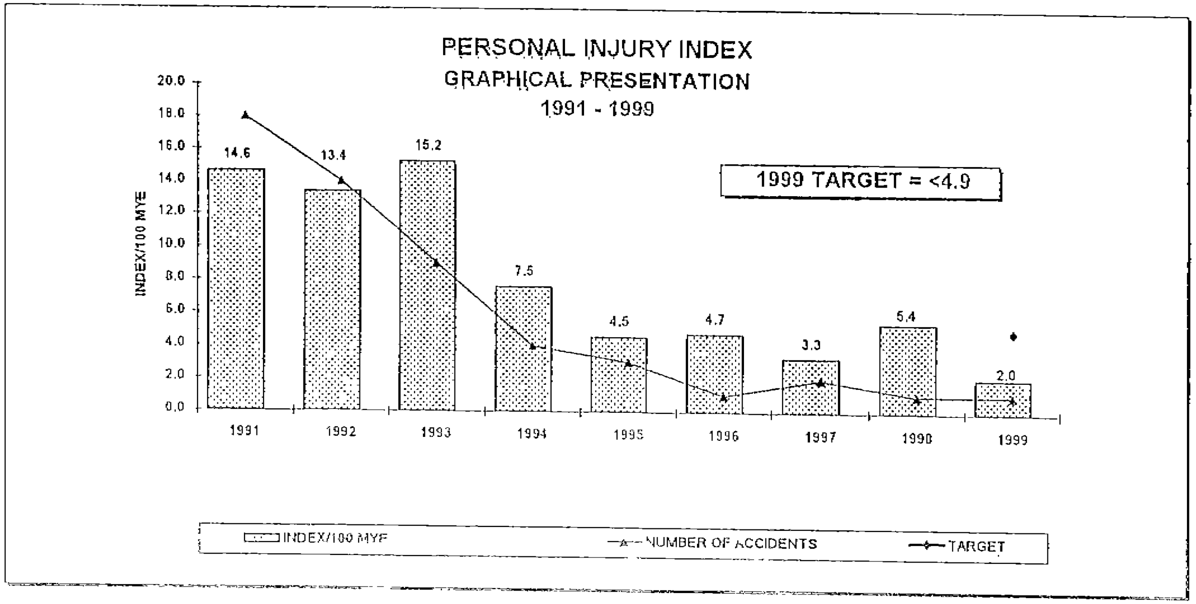
INSPECTION AND MAINTENANCE PROGRAMME

Activity	Frequency	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02	Foreseen
Seafront Road Patrol	Daily	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Road Patrol	Weekly	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Air Survey	Monthly	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Videotape Survey	6 Monthly		▨						▨						▨						▨						▨						
Line Walk	Annual			▨												▨												▨					
Seafront Road Leakage Survey	Annual			▨												▨												▨					
Marker Maintenance	As Required			▨						▨			▨			▨						▨			▨			▨					
BVS System Checks	Monthly	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
BVS Full Function Test	Annual		▨												▨												▨						
Third Party Liaison	Annual	▨									▨												▨										
Third Party Management	As Required																																
Notification & Reporting	Monthly	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
Emergency Call-Outs	As Required																																
CP Commissioning	Once	▨	▨																														
CP Checks	Monthly	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	
CP Survey	6 Monthly				▨						▨			▨						▨						▨							
CP Interaction Tests	2 Yearly																									▨							Summer 2004
Close Interval Protection Survey	5 Yearly																																Winter 2004/2005
Provision of Land Agency Services	As Required																																

BPA PERSONAL INJURY REPORTING 1999

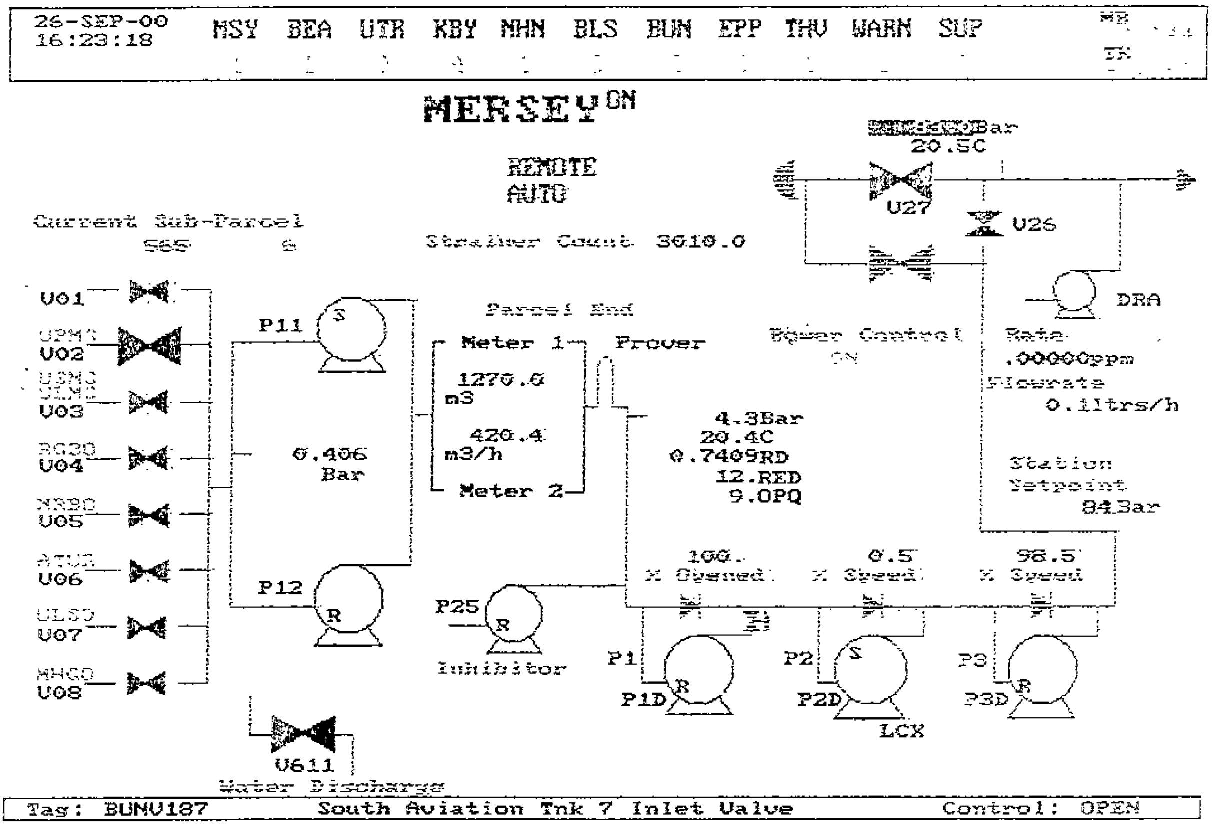
TOTAL ACCIDENT INDEX
1991 - 1999

	SEVERITY FACTOR	1991 JAN-DEC	1992 JAN-DEC	1993 JAN-DEC	1994 JAN-DEC	1995 JAN-DEC	1996 JAN-DEC	1997 JAN-DEC	1998 JAN-DEC	1999 JAN-DEC
FATALITY	100	0	0	0	0	0	0	0	0	0
>20 DAY LTA	20	1	1	0	0	0	0	0	0	0
6-20 DAY LTA	10	0	0	0	0	0	0	0	0	0
3-5 DAY LTA	8	1	1	1	1	0	0	0	0	0
<3 DAY LTA	6	2	1	0	0	0	1	0	1	0
REPORTABLE DISEASE	4	0	0	0	0	0	0	0	0	0
RESTRICTED WORKING	6	0	0	0	0	0	0	0	0	0
MAJOR NON LTA *	10	0	0	3	0	0	0	0	0	0
MINOR NON LTA *	2	14	11	5	3	3	0	2	0	1
TOTAL ACCIDENTS	▨	18	14	9	4	3	1	2	1	1
TOTAL ACCIDENT INDEX	▨	68	56	48	14	6	6	4	6	2
MANYEAR EQUIVALENTS (MYE)	▨	465	419	315	186	133	127	122	112	98
INDEXx100/ MYE (%)	▨	14.6	13.4	15.2	7.5	4.5	4.7	3.3	5.4	2.0

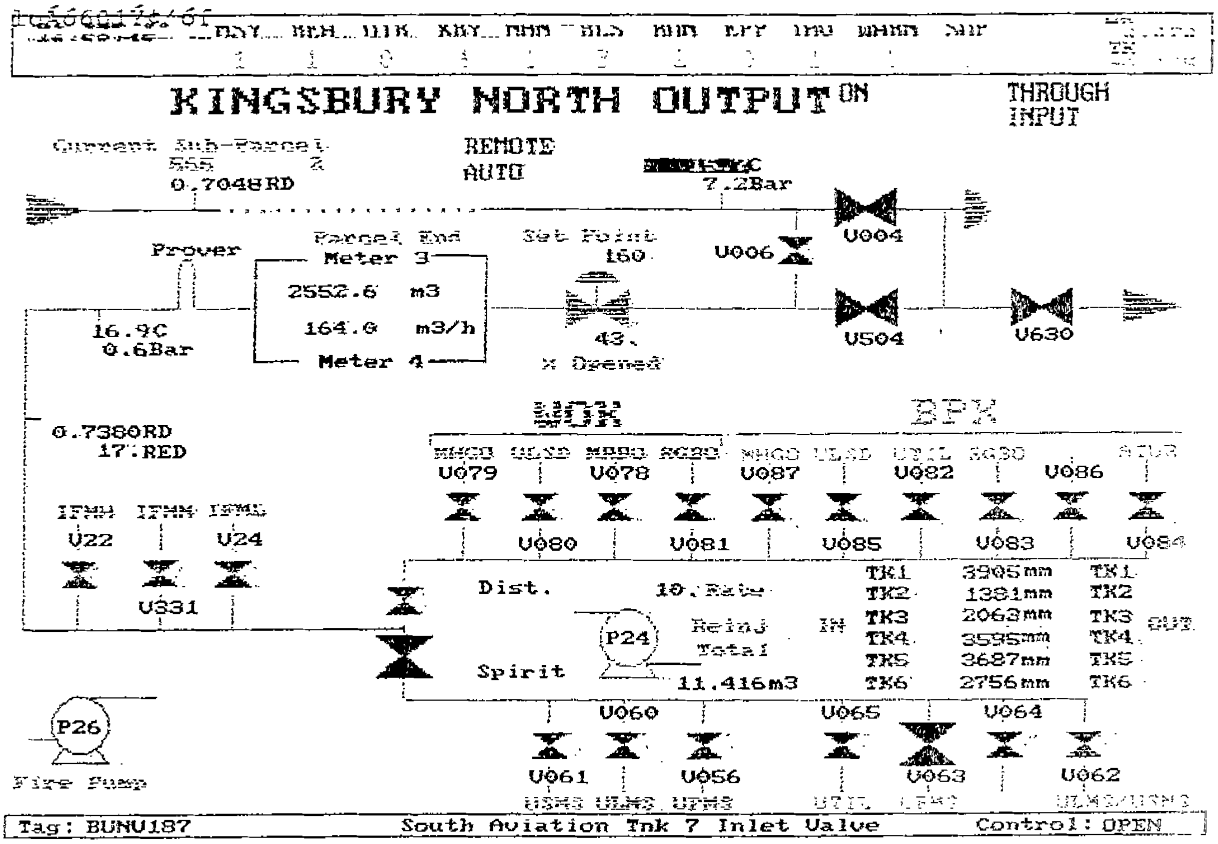


PERSONAL INJURY INDEX
GRAPHICAL PRESENTATION
1991 - 1999

1999 TARGET = <4.9

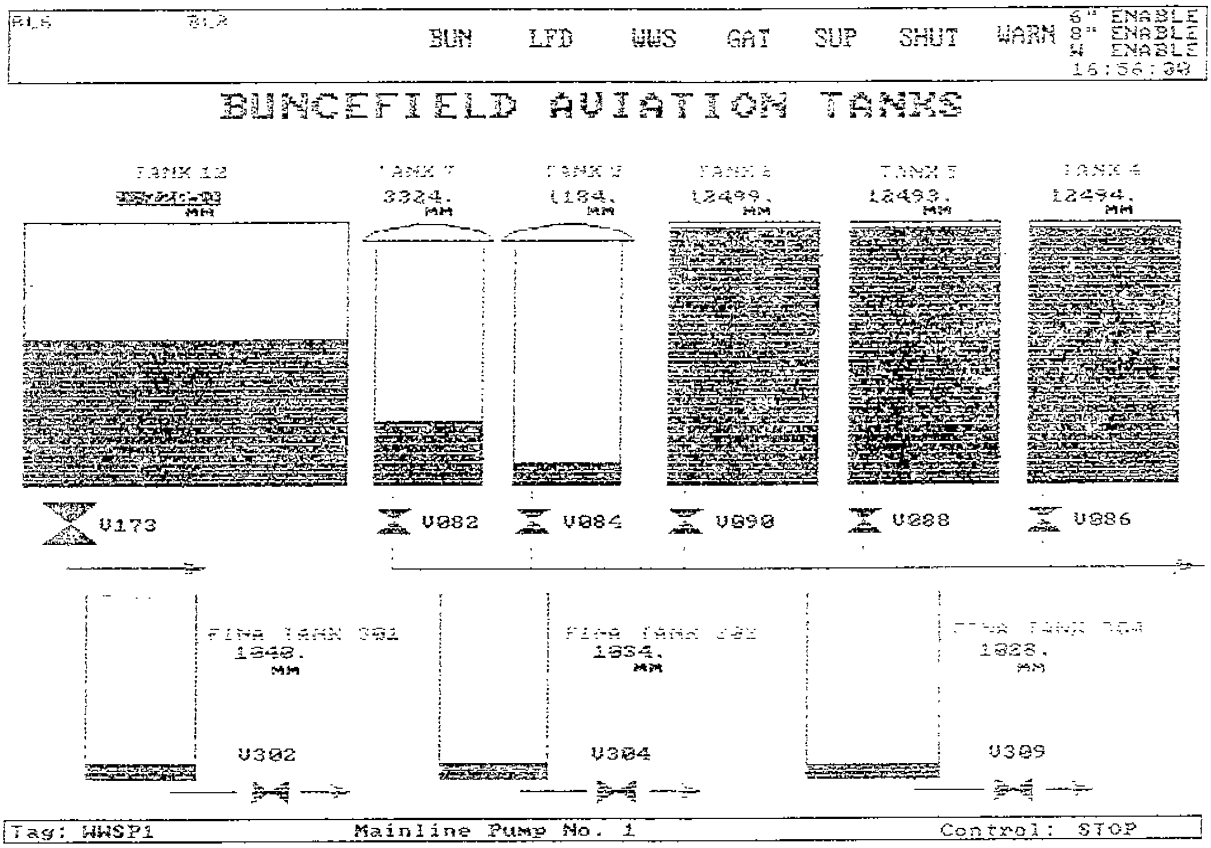


Tag: BUNV187 South Aviation Tnk 7 Inlet Valve Control: OPEN



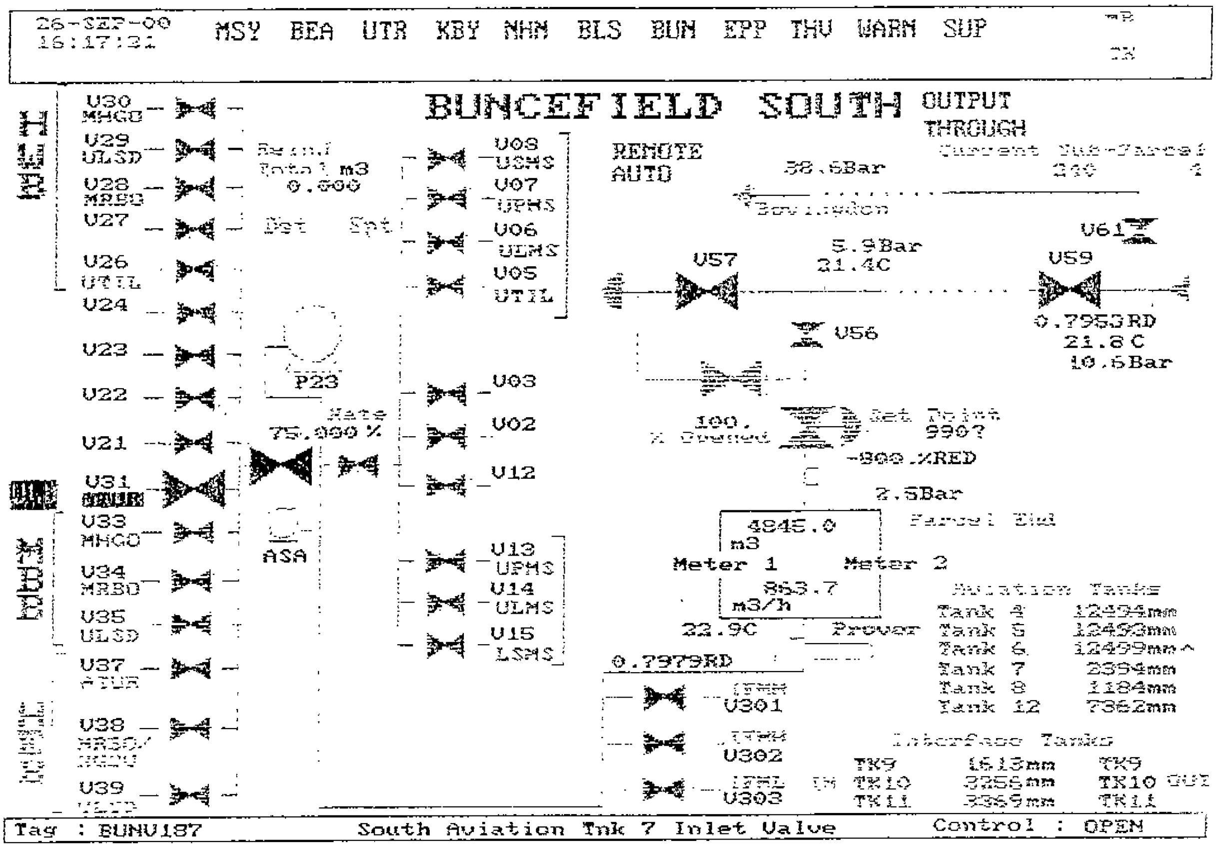
KINGSBURY NORTH OUTPUT

Tag: BUNU187 South Aviation Tnk 7 Inlet Valve Control: OPEN



BUNCEFIELD AVIATION TANKS

Tag: WWSP1 Mainline Pump No. 1 Control: STOP



Aviation Tanks

Tank	4	12494mm
Tank	5	12493mm
Tank	6	12499mm^
Tank	7	2394mm
Tank	8	1184mm
Tank	12	7362mm

Interface Tanks

TK9	1613mm	TK9
TK10	3255mm	TK10
TK11	3369mm	TK11

Tag : BUNV187 South Aviation Tnk 7 Inlet Valve Control : OPEN

1.0 INTRODUCTION

Pipelines can be considered as the safest and most cost effective means of transporting large quantities of hydrocarbons over long distances. From an environmental point of view pipelines have less of an impact than transportation by road or rail.

The operation of pipeline systems are continually under review to minimise the costs. BPA has, in recent years, achieved considerable efficiency improvements for the pipelines that it operates, with plans in place to further increase the efficiency.

This has resulted in a period of considerable change but throughout a prime consideration has been the integrity of the pipeline system, with an excellent record being maintained.

Any company operating a pipeline system has a moral obligation to protect the people and the environment of the country in which it operates, in addition to any existing national statutory requirements currently in force. This is especially important in the UK. as the pipeline systems tend to supply product to the more densely populated areas of the country with the pipeline routes crossing over and under numerous river and other water courses.

The financial implications of an in-service failure for any pipeline system of high usage would be significant for the pipeline owner/operator. In addition to the cost associated with the repair of a defect, loss of throughput, arranging alternative supply, and the associated clean-up operation, the operator would suffer an immeasurable setback in public opinion in the use of high pressure hydrocarbon pipelines.

To ensure that the pipelines systems continue to perform their duty without loss of product the operator is responsible for putting in place systems to prevent failure or damage to the pipeline. Additionally systems must be put in place to reduce the consequence of any loss should this occur. The term given to this process is Pipeline Integrity Management.

2.0 TYPES OF PIPELINE FAILURE

Pipeline performance data shows that the volume of product lost from pipeline systems is very low. However it must be recognised that pipeline failures do occur. In recent years, net spillage, that is the volume remaining after recovery, has amounted to 0.00042% of total oil transported through oil industry pipeline networks in Western Europe (ref. Concawe Report 5/94).

The types of pipeline failure can be divided into five main categories:

- **Mechanical failure**

  These occur when stresses in the system exceed allowable limits. These can be caused by poor material quality or faulty construction. Mechanical failure represents 25% of the number of spillage incidents and 27% of product lost.

- **Operational failure**

  These can occur due to excessive pressurisation or malfunctions of equipment such as pressure relief or control valves. They can also occur due to human error. Operational failure represents 6% of the number of spillage incidents and 4% of product lost.

- **Corrosion**

  Pipelines can be subject to both internal and external corrosion. Internal corrosion generally occurs when corrosive products are present in the pipeline in addition to water. External corrosion is the predominant type of corrosion experienced with hydrocarbon pipelines (in particular refined hydrocarbons) and usually occurs due to failure of the pipeline protective coating and/or the cathodic protection system. Corrosion represents 33% of the number of spillage incidents but only 18% of the product lost.

- **Natural hazards**

  These occur due to localised natural phenomena such as ground movements. The possibility of the phenomena are taken into account during the design and planning phases and therefore the occurrence of failure due to these is low resulting in 5% of the spillage incidents and 3% of the product lost.

- **Third Party Activity**

  The majority of these occur due to accidental damage by third party excavations. A small number of spillages are caused deliberately.

  The consequences of the pipeline damage equates to 31% of the number of incidents and 51% of the product lost.

3.0 PIPELINE INTEGRITY MANAGEMENT PROCESS

The Pipeline Integrity Management process is applicable during the whole life of a pipeline system including design, construction, operation, inspection and maintenance.

The Pipeline Integrity Management process can be segregated into various activities. There are certain activities which should be considered as a necessity for all systems, and carried out on a regular basis, and additional activities which should be considered on their merits for each particular pipeline or following other works upon the pipeline system.

3.1 Regular Activities

3.1.1 Wayleave Management

The possibility of mechanical damage to the pipeline by third parties or changing ground conditions can be reduced by effective management and monitoring of the wayleave in which the pipeline runs. This can be broken down into several categories:

- **Monitoring**

  The pipeline operator monitors the wayleave to identify any activities which may affect the pipeline. This is carried out during his normal day to day requirements to travel along the pipeline route for maintenance works etc. and is also carried out by a regular aerial surveillance (usually helicopter) along the route. The aircraft will carry an observer familiar with the pipeline route who will be looking for any activity within the wayleave or encroaching close and likely to enter into it which may affect the pipeline. Subject to the nature of the activity the helicopter will either immediately land to investigate further or report the incident to the pipeline control centre who will despatch a vehicle to investigate. The aerial surveillance is usually carried out at fortnightly intervals.

- **Education**

  The works within the wayleave fall within two categories, either authorised or unauthorised. The authorised works are those of which the operator is aware and has therefore been able to discuss all the necessary requirements and precautions with the third party. The activities that provide the concern are those that are unauthorised and which the operator has no prior knowledge of. The greatest concern is that the third party may not even know of the existence of the pipeline and be excavating down to the pipeline depth in ignorance with heavy machinery which is quite capable of causing rupture of the pipe.

  In order to combat this, pipeline operators within the UK have embarked upon a process of education for all those companies that may, at some time, need to carry out works within the pipeline wayleave, together with the landowners. These companies include all the utility services, local authorities and contractors. The education is in the form of presentations, videos and printed literature providing details of the pipelines and their routes, contact points, the consequences of failure and the precautions to be taken to prevent damage.

  This process is a continuing one as the pipeline data is updated and the list of third parties grows. This has been particularly the case recently as cable TV companies continue to appear.

  The sharing of the burden for these works between the participating companies results in the most cost effective solution for each in terms of financial and manpower resources.

- **Supervision**

  Prior to any works taking place within the wayleave the pipeline operator will locate and mark the exact position of the pipeline. The operator will stipulate the protective measures that must be undertaken near to the live pipeline. In most cases the operator will maintain a presence on site until the work is completed to ensure that the working practices used will not put the pipeline at risk.

3.1.2 Corrosion protection

External pipeline corrosion is prevented by the application of a protective coating, which insulates the pipeline from the soil, and by cathodic protection which ensures that current only flows from the soil to the pipeline and that corrosion occurs at the associated ground beds where it can be tolerated. The two measures are complementary, failure of one, most commonly the coating, being compensated by the presence of the other.

The pipeline operator must ensure that both the systems are functional and providing the protection required.

- **Pipeline coatings**

  The performance of the coating will depend upon the coating materials, the standard of workmanship when applied, its age and any damage caused during pipeline construction or subsequent. The standard of pipeline coatings has improved over the years and coatings of pipelines currently in service range from site applied hot poured bitumen to factory applied epoxy.

  Specialist sub-contractors are employed to carry out coating surveys. The exact nature of the survey will depend upon the contractor employed but generally will involve the walking of the pipeline route and the measurement of current loss from the pipeline.

  The operator must decide upon the types of surveys to be undertaken and the frequency of those surveys. The rectification of coating defects identified by the surveys can be made by excavation and re-coat of the pipeline and in certain circumstances by adjustment of the cathodic protection system.

- **Cathodic protection**

  The pipeline operator must maintain the cathodic protection system to a standard at which the desired level of protection is given. Routine monitoring involves taking regular readings at test posts to ensure that current levels within the pipeline are maintained above specified limits. When indications are received that the current levels are not being maintained the operator must investigate further into the performance of the transformer rectifiers and groundbeds. Failure of any of these items invariably involves the operator in further expense for rectification works.

3.1.3 On-Line Inspection

On-line inspection is a non-destructive method of detecting defects in the metal wall of a pipeline. The vehicle (commonly known as an intelligent pig) is passed through the pipeline, propelled by the product, continually monitoring the wall by means of either a magnetic flux leakage or ultrasonic technique. The vehicle provides an accurate method for locating any defects and for describing the defect in terms of axial and circumferential length and pipe wall penetration depth. The most common defect that the vehicle will be expected to identify is corrosion but will also identify mechanical damage and material defects such as laminations.

The use of on-line inspection tools has now widely been accepted within the pipeline industry and is in some circumstances a statutory requirement dictated by the pipeline Safety Notice.

From the information received from the inspections the operator can carry out calculations to determine whether the remaining strength of the pipeline material is sufficient to operate at the required pressures. If this is found not to be the case the operator must decide whether to put into place remediation works to repair the defective section of pipeline or accept that the pipeline must operate at lower pressure and therefore lower flow rate.

As the on-line inspection produces an accurate assessment of defect size, repeat inspections mean that all data can be compared with previous inspection data to provide an assessment of any defect growth rate, or other changes in pipeline condition. With this information, and a general knowledge of the general condition of the system, the operator can make a judgement as to the re-inspection interval. This is one of the decisions required to be taken by the operator; others include:

- What information is required from the tool? How sensitive does the pig have to be? What accuracy is required?
- What type of vehicle should be run, magnetic-flux or ultrasonic?
- Can the flow conditions required for a particular vehicle be achieved?
- Is the pipeline suitable for running the vehicle? Are there any bend or bore restrictions? Are temporary facilities required for launching and receiving the vehicle?
- Is it necessary to run gauge, bend or calliper pigs before the inspection vehicle?
- Are there facilities and systems in place to handle the "dirty" product generated by the vehicle?

All of the above must be considered by the operator before embarking on an on-line inspection programme. Any one of the items will affect the investment level required As with all items the operator is striving to achieve the lowest possible, most suitable service at the optimum cost. The confidence of achieving this can only be obtained by experience of the varying tools and techniques and the verification of the results provided.

3.1.4 Validation pressure testing

The integrity of a pipeline system can be demonstrated by carrying out a pressure test. It should be noted that a pressure test can only provide confirmation of the pipeline integrity at the time of the test.

The requirement to carry out a regular pressure test may be the subject of the pipeline Safety Notice.

The validation pressure test would normally be carried out by increasing the product to a pressure equating to 110% of the normal maximum operating pressure and held for 24 hours.

The operator must allow for the pipeline to be out of service for a total of 60 hours to facilitate the test which equates to 6 hours for preparing the pipeline for the test, 24 hours for pipeline temperature stabilisation, 24 hours for pressure test and 6 hours to return the pipeline to a condition suitable for operation.

A satisfactory result from a pressure test will provide the operator with the confidence to continue pipeline operations for a limited period.

3.1.5 Leak Detection

The detection of pipeline leaks falls into two main categories:

- **Visual Detection**

  This relies upon the detection, above ground, of the presence of product, visible on the ground or a water course. From the operator this information will be received during line walking or during the aerial surveillance. However, the main source of information will be from landowners or the public who, if they know of the presence of the pipeline, will immediately assume that it is the source for any oil found. This can instigate numerous false alarms as, unfortunately, the dumping of old oil cans etc. in ditches and other water courses is becoming increasingly more common. Therefore the operator must have in place systems to check the authenticity of any report efficiently and effectively.

- Technology

  Application of SCADA system based leak detection has been a requirement of UK pipeline Safety Notices for a number of years. Although the basic technology and techniques are relatively mature, continuing advances in computer and communication technology provides improvements. The success of the systems are largely dependent upon the accuracy and repeatability of the instruments available on the pipeline.

A number of techniques are available to the pipeline operator including volume/mass balance, pressure monitoring, pipeline modelling and statistical techniques. Each technique has its merits and shortfalls. The selection of the most appropriate and cost effective technique is greatly influenced by a number of factors including the complexity of the pipeline network, the pipeline operating modes, the instrumentation available and the available SCADA system. The key element in the selection process is the assessment of the available techniques in the context of the relevant pipeline. This assessment should be carried out by someone with a detailed knowledge of the technology and also of the pipeline's operating characteristics.

The operator must remember that leak detection is only one element within the Pipeline Integrity Management process and must therefore ensure that the level of investment in this high technology and therefore high cost aspect reflects the real benefits.

Having installed a leak detection system the pipeline operator should have a policy of verifying their performance. This can be carried out by initiating controlled removal of unmetered product from the pipeline. When this is carried out with the operator's prior knowledge, this can be used as the trigger for an emergency response exercise.

3.1.6 Emergency planning

The risk of pipeline failure can be reduced but can never be eliminated from pipeline operations. For this reason, safety awareness is an important part of any integrity management process in order that the effects of incidents and accidents can be substantially reduced. Emergency plans and procedures should be developed with the relevant authorities and emergency services.

A properly developed plan:

- reduces the thinking time when an incident occurs
- defines responsibilities
- help contain the incident and minimises the extent of damages
- speeds up rehabilitation

To develop a plan it is first necessary to identify the hazard and the risk, and then identify the means by which the hazard can be controlled. For a pipeline the risks, consequences and method of dealing with failure can vary along the route. For example, the consequences of a pipeline failure in the centre of a field with no aquifer close by is vastly different than that of a failure at a crossing of a fast flowing river. Therefore, an essential part of the plan is an environmental audit of the pipeline route.

For the plan to be effective it is necessary for all the operating staff and others likely to get involved, including the public services, to be adequately informed regarding the actions to be taken in the event of an emergency. Therefore the success of the plan is linked to the training given.

Together with the plan and the trained staff the operator also requires other resources available.

- equipment suitable for the cessation of the leak, the containment of the spill and the recovery of the oil. At certain geographic locations industrial cooperatives have been formed with stockpiles of equipment, materials and supplies to provide a communal response to oil spills.
- contracted services to carry out specialised activities outside the fields of the operator or other emergency service. Each operating location will maintain an up-to-date list of local and national contractors.

Periodically, procedures and facilities are tested by emergency exercises carried out in conjunction with the relevant authorities. These exercises check operators' preparedness and provides guidance towards modifications required.

3.2 Additional Activities

Particularly during the design and construction phase of a pipeline, and following any subsequent modifications to the pipeline, the operator must consider the application of the following:

- review of operating philosophy
- review of maintenance philosophy
- design reviews
- surge analyses
- procedure reviews
- safety audits
- pigging programmes
- hydrostatic pressure tests

4.0 SUMMARY

Pipeline Integrity Management is a large investment item in terms of financial and manpower resources. The operator has to decide on how much to invest in each of the activities within the Pipeline Integrity Management process. These decisions have to be made after considering and quantifying all of the risks and consequences associated with the particular system.

Each pipeline operator must develop a Pipeline Integrity Management programme to meet the pipeline system requirements. This programme must be continually reviewed as the pipeline conditions change and particularly as the age of the pipeline increases.

The decisions become increasingly difficult as the continuing pressure is always for reduced operating costs. The operator is always looking for more cost effective ways to carry out the activities. These may include activity sharing with other operators, contractorisation and sub contracting.

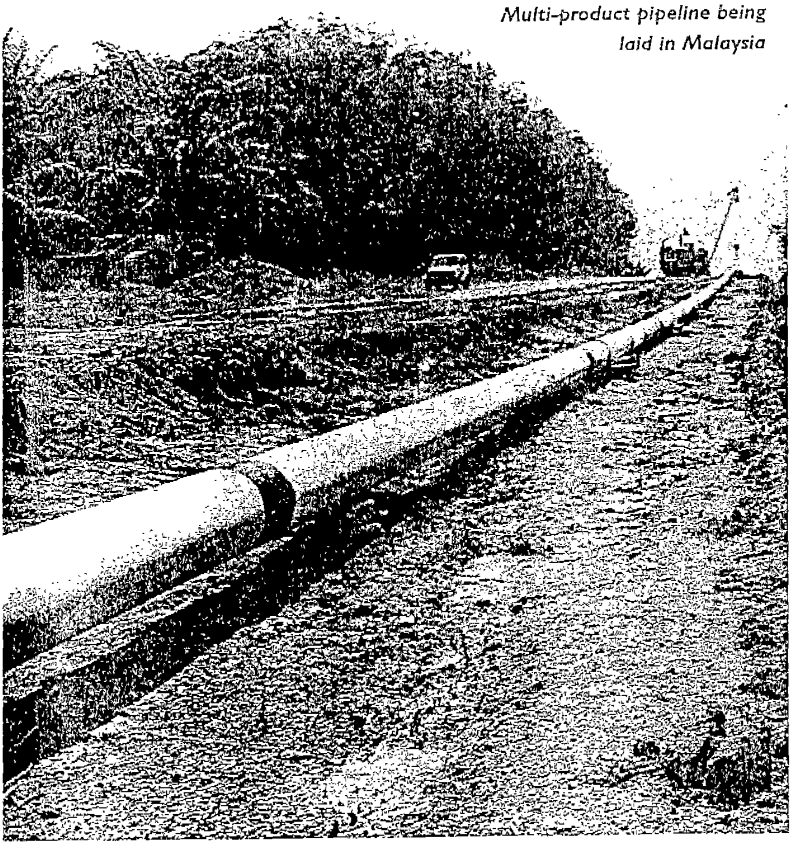
The overall objective for all pipeline operators is to achieve the correct balance among safety, cost efficiency and throughput availability to ensure that pipelines remain the safest and most efficient way of supplying the inland market.

ig pipeline integrity

by David Whitman, Project Manager, BPA

The existence of a 510 km pipeline carrying hydrocarbon products from coastal refineries and storage terminals to inland population centres is not well-known. Owned by several consortia of international oil companies, the line is operated by BPA, whose David Whitman writes here on maintaining the integrity of major pipelines.

Multi-product pipeline being laid in Malaysia



The cost and the environmental impact of energy transportation may seem to be two very different issues but they are often inseparably linked. Pipelines are a very good example. Pipelines can be considered the safest and most cost effective means of transporting large quantities of hydrocarbons over long distances. From an environmental point of view they have less of an impact than transportation by road or rail.

Any company operating a pipeline system has a moral obligation to protect the people and the environment of the country in which it operates, in addition to any existing national statutory requirements currently in force. This is especially important in the UK, as the pipeline systems tend to supply product to the more densely populated areas of the country with the pipeline routes crossing over and under numerous river and other water courses.

The financial implications of an in-service failure for any high pressure hydrocarbon pipeline system of high usage would be significant. In addition to the costs of repairing the defect, loss of throughput, arranging alternative supply, and the associated clean-up operation, the operator would suffer an immeasurable setback in public opinion.

To ensure that the pipelines systems continue to perform their duty without loss of product the operator is responsible for putting in place systems to prevent failure or damage to the pipeline. Additionally systems must be put in place to reduce the consequence of any loss should this occur. The term given to this process is pipeline integrity management.

TYPES OF PIPELINE FAILURE

The volume of product lost from pipeline systems is very low. However pipeline failures do occur. In recent years, net spillage, the volume remaining after recovery, has amounted to 0.00042% of total oil transported through oil industry pipeline networks in Western Europe.

There are five types of pipeline failure.

Mechanical

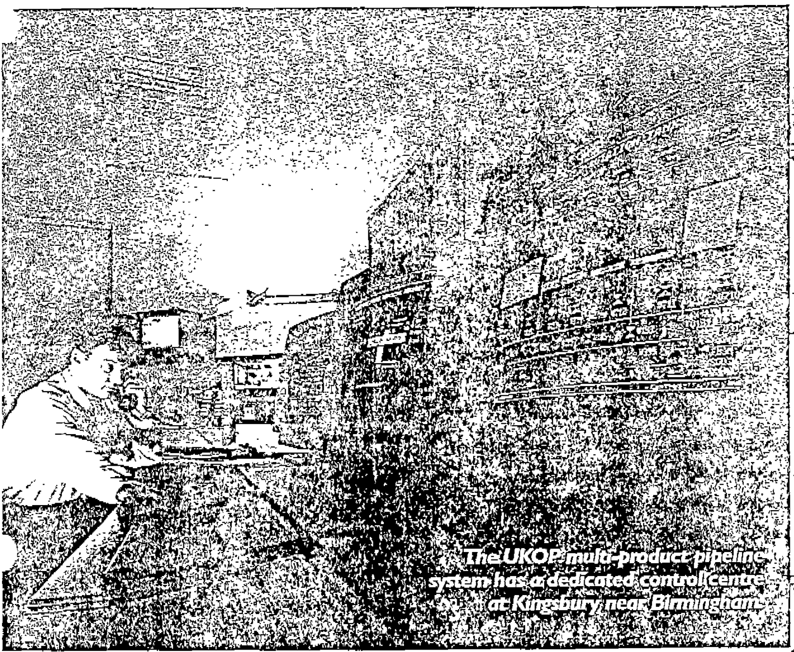
These occur when stresses in the system exceed allowable limits. These can be caused by poor material quality or faulty construction. Mechanical failure represents 25% of the number of spillage incidents and 27% of product lost.

Operational

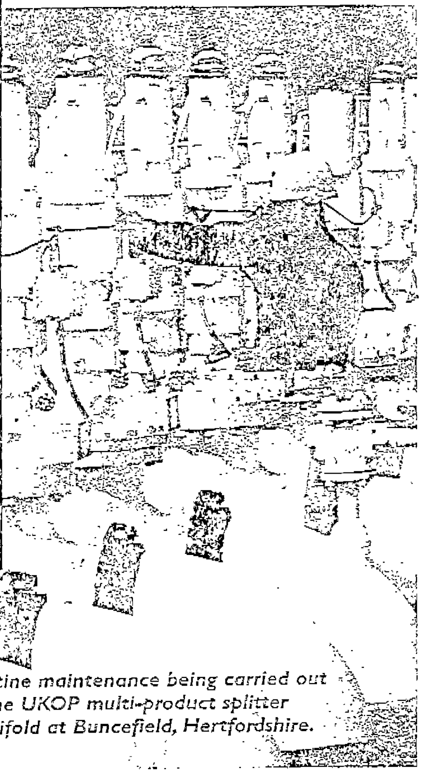
These can occur due to excessive pressurisation or malfunctions of equipment such as pressure relief or control valves. They can also occur due to human error. Operational failure represents 6% of the number of spillage incidents and 4% of product lost.

Corrosion

Pipelines can be subject to both internal and external corrosion. Internal corrosion generally occurs when corrosive products are present in the pipeline in addition to water. External corrosion is the predominant type experienced with hydrocarbon pipelines (in particular refined hydrocarbons) and usually occurs due to failure of the pipeline protective coating and/or the cathodic protection system. Corrosion represents 33% of the number of spillage incidents but only 18% of the product lost.



The UKOP multi-product pipeline system has a dedicated control centre at Kingsbury near Birmingham.



Routine maintenance being carried out at the UKOP multi-product splitter manifold at Buncefield, Hertfordshire.

The UKOP pipeline network is one of the most complex and highly loaded oil products pipeline systems in the world. The main system was built between 1965 and 1968 and connects the Stanlow refinery on Merseyside with two refineries on the river Thames; Thames Haven and Coryton, as well as serving Heathrow Airport. A second leg between Kingsbury and Buncefield, together with an extension to supply Gatwick Airport, was added in 1984.

Oil movements through the network are controlled remotely from the Kingsbury pipeline terminal in the Midlands by means of a supervisory and control and data acquisition (SCADA) system.

Overall, the system transports more than 10% of the total volume of clean oil products consumed in the UK, including more than half the aviation fuels supplied to aircraft at London's main airports.

Natural hazards

These occur due to localised natural phenomena such as ground movements. The possibility of the phenomena are taken into account during the design and planning phases and therefore the occurrence of failure due to these is low resulting in 5% of the spillage incidents and 3% of the product lost.

Third party activity

The majority of these occur due to accidental damage by third party excavations. The consequences of the pipeline damage equates to 31% of the number of incidents and 51% of the product lost.

PIPELINE INTEGRITY MANAGEMENT

The pipeline integrity management process is applicable throughout the life of a pipeline system including design, construction, operation, inspection and maintenance. Some elements of the process are a necessity for all systems, and carried out on a regular basis. Others are additional activities to be considered for each particular situation.

WAYLEAVE MANAGEMENT

The possibility of mechanical damage to the pipeline by third parties or changing ground conditions can be reduced by effective management and monitoring of the wayleave, the channel in which the pipeline runs. Three ways of achieving this are:

Monitoring

The pipeline operator monitors the wayleave to identify any relevant activities. This is carried out during his normal day-to-day requirements to travel along the pipeline route for maintenance works etc and is also carried out by a regular aerial surveillance (often by helicopter) usually at fortnightly intervals.

Education

The works within the wayleave are either authorised or unauthorised. Authorised works are those of which the operator is aware and has therefore been able to discuss all the necessary requirements and precautions with the third party. The activities that provide concern are those that are unauthorised and of which the operator has no prior knowledge

To combat this, pipeline operators within the UK have embarked upon a process of education for all those companies that may, at some time, need to carry out works within the pipeline wayleave, together with the landowners. It takes the form of presentations, videos and printed literature.

Supervision

Prior to any works taking place within the wayleave the operator will mark the exact position of the pipeline. The operator will stipulate the protective measures that must be undertaken near to the live pipeline. In most cases the operator will maintain a presence on site until the work is completed.

CORROSION PROTECTION

External pipeline corrosion is prevented by a protective coating, and by cathodic protection. This ensures that current only flows from the soil to the pipeline and that corrosion occurs at the associated ground beds where it can be tolerated. The two measures are complementary, failure of one, most commonly the coating, being compensated by the other.

Pipeline coatings

Coatings of pipelines currently in service range from site applied hot poured bitumen to factory applied epoxy. Specialist sub-contractors carry out surveys of the condition of the coating. The operator must decide upon the types of surveys to be undertaken and their frequency.

Cathodic protection

The pipeline operator must maintain the cathodic protection system to a standard at which the desired level of protection is given.

ON-LINE INSPECTION

On-line inspection is a non-destructive method of detecting defects in the metal wall of a pipeline. The vehicle (commonly known as an intelligent 'pig') is passed through the pipeline, propelled by the product, continually monitoring the wall by means of either a magnetic flux leakage or ultrasonic technique. The vehicle provides an accurate method for locating any defects and for describing the defect in terms of axial and circumferential length and pipe wall penetration depth. The most common defect that the vehicle should identify is corrosion but it will also highlight mechanical damage and material defects.

On-line inspection tools are in some circumstances a statutory requirement dictated by the pipeline Safety Notice.

From the information received the operator can make a judgement as to the re-inspection interval, what should be covered and how. This is one of the decisions required to be taken by the operator before embarking on an on-line inspection programme.

VALIDATION PRESSURE TESTING

The integrity of a pipeline system at a particular moment can be demonstrated by carrying out a pressure test. A regular pressure test may be the requirement of the pipeline Safety Notice.

The validation pressure test would normally be carried out by increasing the product to a pressure equating to 110% of the normal maximum operating pressure and held for 24 hours.

The operator must allow for the pipeline to be out of service for a total of 60 hours for the test. A satisfactory pressure test result will provide the operator with the confidence to continue pipeline operations for a limited period.

LEAK DETECTION

The detection of leaks falls into two main categories.

Visual

This relies upon the detection, above ground, of the presence of product, visible on the ground or in a water course. This information will be received during line walking, during aerial surveillance, from landowners or the public.

Technology

Application of SCADA system based leak detection has been a requirement of UK pipeline Safety Notices for a number of years.

A number of techniques are available to the pipeline operator including volume/mass balance, pressure monitoring, pipeline modelling and statistical techniques. The key element in the selection process is the assessment of the available techniques relevant to the particular pipeline.

EMERGENCY PLANNING

Safety awareness is an important part of any integrity management process because the risk of pipeline failure can be reduced but can never be eliminated.

For a pipeline the risks, consequences and method of dealing with failure can vary along the route. For example, the consequences of a pipeline failure in the centre of a field with no aquifer close by are vastly different than that of a failure at a crossing of a fast flowing river. Therefore, an essential part of the plan is an environmental audit of the pipeline route.

In conclusion, the financial and manpower resources required make pipeline integrity management a large investment. But the management process is not an option, and ensuring that it is continually effective is vital.

PIPELINES '98

BPA is among the 90 or so companies on show at an exhibition devoted to the onshore and offshore pipeline business to be held at the National Exhibition Centre in Birmingham from 19 to 21 May. Supported by the Pipeline Industries Guild, the event will cover petrochemical, utility, water and drainage pipelines and also includes a programme of seminars. Entry to the exhibition is free - contact the organisers on 01203 426467 for further details.

BPA has 30 years experience of managing, operating and maintaining a wide range of hydrocarbon product pipeline and storage systems on major schemes worldwide. Related consultancy services are provided to clients worldwide. Operations and engineering services are available across a range of fluid handling systems from multi product, gas, gas condense, black oil and LPG pipelines through storage and pumping facilities to road, rail and sea loading facilities.

BPA provides expertise on any aspect of the project cycle, from conceptual studies through FEED and detail design, to construction management, commissioning and start up, and then all aspects of pipeline system operation and management.

Contact: Rhys Davies, BPA, Lord Alexander House, Waterhouse Street, Hemel Hempstead, Herts HP1 1EJ, tel: 01442 242200, fax: 01442 214077.

附錄七

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SYSTEM CONCEPTS

31 July 2000

ENERGY SOLUTIONS INTERNATIONAL LTD
Dunedin House | Riverside Quay Stockton-on-Tees TS17 6BJ UK
Tel +44 1642 677755 | Fax +44 1642 606604

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1. INTRODUCTION

Overlaying open communications with the ability to integrate legacy applications with new operations and business management applications is the theme of this document. As pipelines move from being pure merchants to transporters/merchants and eventually to pure transporters, the need becomes stronger for better information facilitating improved decision-making. Such information must be easily disseminated to clients throughout the organisations as well as externally. Clients can easily leverage the valuable experience that has been gained in managing this transformation in the United States.

1.1 ENERGY SOLUTIONS INTERNATIONAL (ESI)

The ENERGY SOLUTIONS INTERNATIONAL Group results from the merger between the **LIC***ENERGY* Group and Wright Logue & Associates of Houston. ESI combines the global experience of **LIC***ENERGY* in simulation and optimisation of gas pipelines with the WLA suite of Java based application modules and middleware. The Message Broker (NECTAR) is the middleware system by which ESI integrates applications and makes all data easily shared. Full Internet accessibility is assured with this leading edge technology. Through the ESI technology, Clients will be able to continue to use legacy systems, develop new applications (available through ESI or third parties) and insure seamless interaction between systems!

2. SYSTEM CONCEPTS

2.1 INTRODUCTION

The most striking aspect of modern computing is its heterogeneity and fast pace of development. Gas companies as well as other enterprises wrestle with a wide variety of operating systems, third- and fourth-generation languages, RDBMS, networking protocols and management tools. It is in this challenging context that users demand an ever-growing level of application integration.

To accommodate the complex and fast-changing nature of the gas business, the need exists to reduce or eliminate the boundaries between applications, to re-use data and processing logic more effectively within the enterprise and to create 'virtual enterprises' by linking applications together.

Traditional methods of integration via database centric frameworks cannot meet these requirements. It costs too much and takes too long to modify applications to work with each other. Too few tools exist to reconcile redundant and inconsistent data.

At ESI, we believe that gas pipeline companies must rethink the problem of interoperability and consider drastic revisions in the customary design process. Supporting our position is the fact that leading-edge gas companies in the USA are deriving interesting benefits from integrated gas management systems utilising the *message broker centric.*

Strategies that rely on making all application systems compatible through database centric systems will not survive. A message broker strategy, on the other hand, is based on the premise that distributed heterogeneity and changes are inescapable.

Message brokers are another step in the gradual evolution of moving logic out of the application program and into a reusable system-wide function. The flow control (workflow) service of a message broker is key to the success of this concept. Message brokers enable Business Process Reengineering by re-engineering only those application programs, databases and other parts of the infrastructure.

2.2 THE APPROACH

ESI secure, Internet enabled integrated systems for gas pipeline management are providing optimised decision support data to and from its clients' corporate operations and business units, throughout their organizations, and across the world - NOW.

The products are written in the Java language, making them machine independent, web ready, and extremely easy to maintain.

ESI products communicate internally and externally via the Internet and intranet, using message brokering, browser based graphical user interfaces, and employing highly detailed security for users and developers alike.

THE PRODUCTS

TIE PACK

J-AM J-AR	Rapid Application and Configuration environment
Nectar	Event Management Message Broker
Common Model	Rules, Procedures, Connectivity and Data
RDBMS Bridge	Link to any RDBMS
SCADA Bridge	Link to any SCADA or Data Historian

GAS PACK

RTM	On-line real time transient hydraulic model
PM	On-line predictive simulator
LAM	On-line look ahead simulator
CSO	Compressor Station Optimiser
MCA	Marginal Cost Analysis
LDS	Leak Detection System
Gas SCOPE	Simulation Control and Operations Planning Environment
Gas Nominations	Internet based gas nominations processing
Smart alarm	Intelligent operational alarm processing
Gas Forecaster	Neural Network based gas load forecaster

BUSINESS SOLUTIONS

GTS	Gas Contracts, Nominations and Allocation Management Systems.
Hedger	
Gasman	

These products accelerate, control and save costs in the implementation of large, complex optimisation and simulation projects. This combination of general-purpose implementation and integration tools and industry specific products is used to deliver completely integrated gas or liquids pipeline management systems. The system architecture comprise 4 main types of components

- *Message brokers* responsible for any communication between other components
- *Graphical configurators* used to build the system in a fast and efficient visual way
- *Graphical user interfaces* used to operate the system
- *Application modules* providing a variety of data processing, data storage and external interfaces.

The generic characteristics of these elements are described below.

2.3 TIE - PACK

2.3.1 MESSAGE BROKER (NECTAR)

At the hub of the gas management system the message broker acts as a broker between many target or source entities (such as network, middleware, applications, and systems), letting them share information more easily than with traditional techniques.

The message broker is a CORBA compliant publish/subscribe technology embedded with the graphical configurator for use by all the ESI products and legacy client applications included in the integration. The message broker allows the integration of traditional operations based systems with business systems, providing vital decision support data in real time. To this end, a message broker's purpose is to integrate multiple activities (applications, objects, or databases), whether they're new, old, legacy, centralized, or distributed. The message broker will allow electronic information to flow from user to user and application-to-application the same way paper was flowing in the traditional organisation. Data flow will be much faster, more efficiently and as soon as needed.

Traditional integration employs database – centric architectures that focus on the location of stored data. Changes in the way an application reads or writes data, requires changes to the database, and to the other applications using the data. This is called "tightly coupled", and while relatively easy to implement, when only one or two applications are being integrated it is very difficult to use where a number of new and legacy products are being integrated.

Integration using a message broker focuses upon the dissecting of data. Making the architecture Broker centric is a fundamental shift in thinking, and is needed before an integrated suite of systems can truly be called Web Enabled.

In this paradigm, changes in the way applications read or write data to the database or among themselves, requires only that changes need to be made to the broker. This is called loosely coupled, and is ideal for multiple application integration.

The message broker technology ties many different platforms and application development solutions together and it can also use any number of middleware and API mechanisms to connect and route information to each application. It routes information between applications.

You can separate message broker services into several distinct categories. These include message transformation services, rules processing, intelligent routing, message warehousing, flow control, repository services, directory services, APIs, and adapters.

Message Transformation Layer

The message broker has a message translation layer that understands the formats of every message being passed among applications and changes their formats as required. The message broker restructures the data from one message into a new message that makes sense to the receiving application (or applications). The message translation layer provides a common dictionary with information on how each application communicates and which information is relevant to each application.

Intelligent Routing

Intelligent routing (sometimes known as flow control) builds on the capabilities of both the rules and the message transformation layer. The message broker can identify messages dynamically coming from a target application and route that information to the proper source application, translating the messages if required.

If a message comes to a message broker, it is analysed and identified as coming from a particular system or subsystem—for instance SAP. Once the message broker identifies and understands its message's origin and schema, it processes the message. By applying applicable rules and services, including message transformation.

Once the message is processed, the message broker routes the message to the subscribing system. This may take less than a second, and up to 1,000 of these operations may occur simultaneously.

Rules Processing

The rules processing engine allows system architects and developers to create rules governing control of the message processing and distribution. The message broker enables an application development environment to support the special application integration requirements.

The rules engine will let you implement intelligent message routing and transformation. For example, in some instances a message may be required by one other receiving application. In other instances, you may have to route a message to two or more applications. Solving each problem required the ability to route the message to any number of applications that are extracting and translating data from other applications.

Message Warehousing

The message warehouse is a database that store messages flowing through the message broker. In general, message brokers provide a message persistence facility to meet several requirements, including message mining, message integrity, message archiving, and auditing.

Message mining uses the message warehouse as a quasi-data warehouse, allowing extraction of business data to support decisions. Message warehousing can provide services such as message integrity, since the warehouse provides a natural persistent state of message traffic.

If a server goes down, the message warehouse is a persistent buffer or queue to store messages that otherwise would be lost. The message warehouse is used to resend or compare messages with other message warehouses on the network thus ensuring message transfer integrity. This is much the same principle as the persistent message queuing that other message-oriented middleware products support.

2.3.2 J-AM J-AR

J-AM J-AR™ (Java based Application Monitoring and Application Reporting) is a rapid application development environment used for developing the GMS.

J-AM J-AR™ contains a sophisticated event management system, graphical user interface and internet/intranet communication capability. All applications comprising GMS are accessible from J-AM J-AR™ for user interaction.

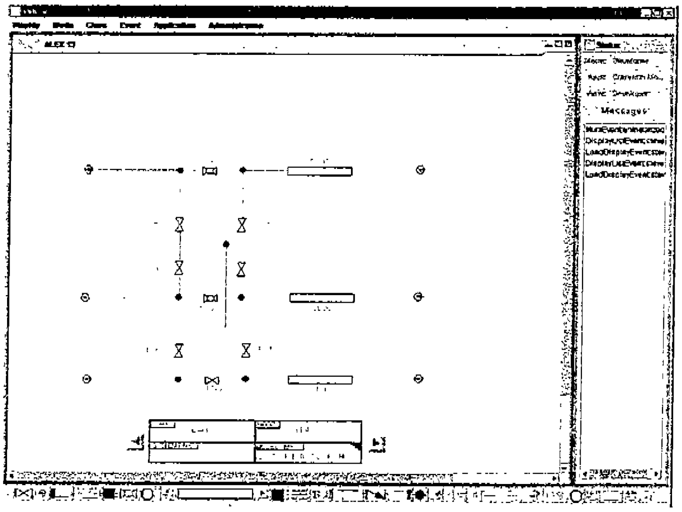
Standard Microsoft Windows functionality is provided on high-resolution graphical displays. Standard object and symbol libraries are provided allowing data to be displayed in both graphical and textual form.

The message broker is embedded with the graphical configurator and enables the system to be implemented as a distributed Intranet/Internet tool serving the widest of user communities.

Realising that implementation delays were the real money loser for the client community, ESI concluded that the design of an easy-to-use, "point-and-click" Rapid Application Configuration Environment (RACE) greatly improves profitability.

From a work-screen (schematic), the user builds the system by simply selecting objects from a palette and placing them on the schematic, connecting them to other objects and editing alphanumeric properties through dialogs. With no work, additional objects with default attributes are defined in the RDBMS and included in the Common Model for use by the rest of the system, see below. The connectivity between the objects is established as they are added to the schematic, quickly building a system ready for flow.

Figure 7



The icons and schematics are easily user definable. The schematics can take on any look that the user desires, including SCADA screen emulation. The schematics, thus configured by the user, become the GUI for the complete suite of products.

Adapters

Message brokers adapters are, generally speaking, a layer between the message broker interface and the source or target application. An adapter can adapt to differences between source or target and the message broker's native interfaces

In addition to adapters, message brokers use APIs to access the message broker's services from an application. These are similar to the API of a traditional message-oriented middleware product except that the message broker lets you integrate many applications.

The application of an integrated gas management system with an architecture based on message broker communications fully integrated with the Internet provides the only solution for the gas company of today who wants to remain ahead of the competition in the future.

2.3.3 COMMON MODEL

Large distributed web-based systems yield plenty of benefits including improved user access and faster data availability, but keeping control of their implementation is very difficult. Recurring problems with large, distributed systems include redundancy of data definitions and even more common, redundancy of attributes, business rules, and procedures. Part of the development of these systems, is the control of the definitions used to build them.

Description

The Common Model is ESI's mechanism for ensuring that data, rules, and procedures occur only once across the entire gas management system.

When the rapid application configuration environment is used to add a valve to a schematic, that valve is written to the RDBMS and becomes part of the Common Model. Any application using the valve in that location along the line uses this single definition: there is no possibility for divergence or confusion regarding that valve, its state, its operation, or its place in the rules built using the Expert System capabilities of the system.

Every distributed developer or user sees the same definition of that valve. If the value is deleted, it vanishes from the entire system. As a result, there are no vestiges to clear up and the valve never returns to haunt the application in the future as some difficult to find error in a calculation.

The Common Model contains the entire definition of all of the objects, rules and procedures used by the entire system. It can also be interfaced to distribute legacy systems outside the system (such as the Geographical Information System) ensuring that all the systems in the suite remain in data synchronization.

This approach provides a number of benefits:

- Eliminates the need for multiple definitions and consequent interface development.
- Consistent answers from all applications using the same data.
- Robust implementation.
- Unique data definition.
- Saves time and money on support and maintenance.

Another advantage of having both the application and the I/O web based is multiple-user system access from different locations simultaneously. This enables the end user to be much more actively involved in the configuration process. On a recent project with Transcanada pipeline, the client had more configuration personnel working on the project than ESI.

2.3.4 BRIDGES

A number of standard bridges between ESI application modules and common applications such as SCADA and databases have been developed.
Corporate RDBMSs are ubiquitous throughout the industry, and any system claiming to be capable of integration must be capable of integration with any RDBMS.

The point where the gas management system integrates with the corporate RDBMS is the Common Model. Actually, the Common Model, going further than integration, becomes part of the corporate RDBMS. As the rapid development application is used to configure the Common Model, J-AM J-AR is actually configuring tables in the RDBMS, behind the scenes and away from the direct attention of the developer or the user.

Supervisory Control and Data Acquisition (SCADA) systems are used to monitor and control oil and gas transmission pipelines. These systems normally have their own data storage mechanisms and have to be extremely "safe". This means that it must be impossible for control logic to go wrong, and for the SCADA system to enact dangerous equipment operational sequences. Further, if anything does go wrong, the SCADA system must be able to shut down the pipeline in an orderly and safe manner. Bridges with numerous SCADA systems have been developed.

2.4 GAS - PACK

The application modules integrate gas nominations, gas demand forecasts, and market data with current and future hydraulic states, enabling the user to build an operational plan in a single graphical environment where all data may be shared securely and reliably with the rest of the organization. This significantly enhances the quality of decision support information throughout the organization, enabling key staff to make fast and profitable decisions, closing the gap between operations and business.

North America's leading natural gas transmission companies have utilised these products to build the foundation for their gas pipeline management systems. These are just a selection of the application modules available.

- Real Time Model	On-line real time fully transient model
- Predictive Model	On-line automatic predictive simulator
- Look Ahead Model	On-line automated look ahead simulator
- CS Optimiser	Compressor station optimiser
- LDS	Leak detection system
- MCA	Marginal Cost Analyser
- Scope	Simulation Control and Operations Planning Environment
- Nominations	Internet based on-line gas nominations processing
- Gas Forecaster	Neural network based gas load forecaster
- Storage Manager	Gas storage optimiser

2.5 GAS PACK APPLICATIONS

The gas simulation software is one of the key requirements in providing an integrated gas pipeline management system. And it can be only through the use of the worlds leading pipeline simulation software from ESI that the ARAMCO's vision can be realized.

2.5.1 REAL TIME MODEL

The core of any network simulation is the simulation model; ESI is able to supply the Worlds leading Real Time Fully Transient Dynamic Model. Many world-class energy companies have successfully proved this model on similar applications.

The real time model provides real time data on gas Flows, Pressures and compositions throughout the network. This provides an accurate starting point for Predictive and Look Ahead simulations.

The real time Pipeline Simulation Software makes use of ESI' mathematical hydraulic models. These models provide the state estimation based on real-time measurements provided from the field. It is from this state estimation that all the "application" modules derive data, either using it as a comparison to measured data or as input to other calculations. The flexible design of the system allows the addition of extra levels of sophistication to any functionality stated below.

- Data Supervision - The continuous evaluation of the validity of acquired data based on physical interrelations and limitations rather than the ordinary range checks provided by most SCADA systems.
- Information Concentration - The reduction of groups of data by means of the model into a few characteristic values thus reducing the mass of data an operator needs to monitor in order to supervise the process.
- Operational Supervision - The monitoring of process phenomena that are not normally continuously available to the operator, e.g. monitoring a pressure at a location where measurement is not possible.
- Operational Planning - The prediction of process changes under various operational modes based on the current state and simulation of future process conditions much faster than real time.
- Automatic State Estimation - A few measurements are applied to provide detailed results for pressure, flow, temperature, and quality throughout the pipeline.
- Line Pack Calculation - The pipeline model provides real time line pack data. At any instant, it is possible to determine total gas volume. Gas temperature and pressure profiling is automatically applied to the line pack calculations to compensate for the effect of temperature and pressure.
- Automatic Tuning - The differences between measured and calculated data are used to tune the model to actual pipeline conditions resulting in improved performance of application modules.

- Gas Composition Tracking - The gas composition tracking software determines the movement of the different gas components or properties through the transportation system, thus forming the basis to accurately assess gas properties (i.e. BTU, degradation, contamination, etc.) as function of space and time. Composition and property measurements of product entering the pipeline are being periodically updated and passed to the pipeline model. Composition is tracked down the pipeline noting times of arrival of critical or new composition at the gas terminal.

- Fuel Consumption - This module calculates required power, torque, and fuel consumption per compressor unit. Using calculated and measured fuel consumption; compressor efficiency can also be calculated. In addition to this, the module can keep track of accumulated fuel consumption at each compressor unit.

- Over/Under Pressure and Flow Detection - Maximum and minimum pressure and flow limits can be defined separately for different modules. An alarm will be issued when the model calculates pressure or flow below or above the set boundaries anywhere in the pipeline network.

- Compressor Analysis - The compressor analysis module continuously monitors the energy consumption of the compressor units. This monitoring is based on the fuel consumption and efficiency parameters of each compressor unit.

- Survival Analysis - The purpose of survival analysis is to assist the operator in determining operation of the pipeline in the case of a major loss of flow into the pipeline. Based on calculated current line-pack, pipeline flow in, and pipeline flow out, the survival-time analysis module will provide information on how long the pipeline can continue to operate.

2.5.2 LOOK AHEAD MODEL

This tool provides forecasting of near future pipeline conditions. The look ahead tool performs a faster than real time flow analysis to discover the consequences of controlled adjustments, independent but based on real time pipeline operations.

2.5.3 PREDICTIVE MODEL

The predictive model tool is a simulation facility capable of performing "What if?" scenarios based on realistic modelling of equipment, product, and pipeline. The predicative model provides the capability to simulate pipeline operational strategies independently without disturbing normal pipeline operations. The model utilises any combination of measured, calculated, artificial process measurements or equipment status. It is executed in time steps and provides a simulation of pipeline conditions. The output is differentiated from the primary pipeline model data and presented to the system operator for analysis.

The various standard ESI application modules have been described above, as the ARAMCO philosophy has been to use standard applications where possible to meet the requirements of the project.

Within the ESI modelling environment, the network simulation will be carried out in real time at a frequency dependant upon the update time of field data from the SCADA system this is typically 10 to 20 seconds Therefore real time data is available for any of the defined parameters for any point in the network at any time with historical data archived as required. Predictive, Look Ahead and Survival time simulations will provide the additional simulations required from the list above. The results of the simulations will be presented through the GUI.

All of the simulation data will be available in the central database for access by other applications within the gas management system. As with all aspects of the ESI system the data is available to be displayed wherever necessary, via web technology or other means to any authorised user.

All of the simulation functionality required by ARAMCO can be accomplished with standard ESI software modules. However where required, bespoke configuration of the existing modules will provide the additional functionality required.

2.5.4 GAS LOAD FORECASTER

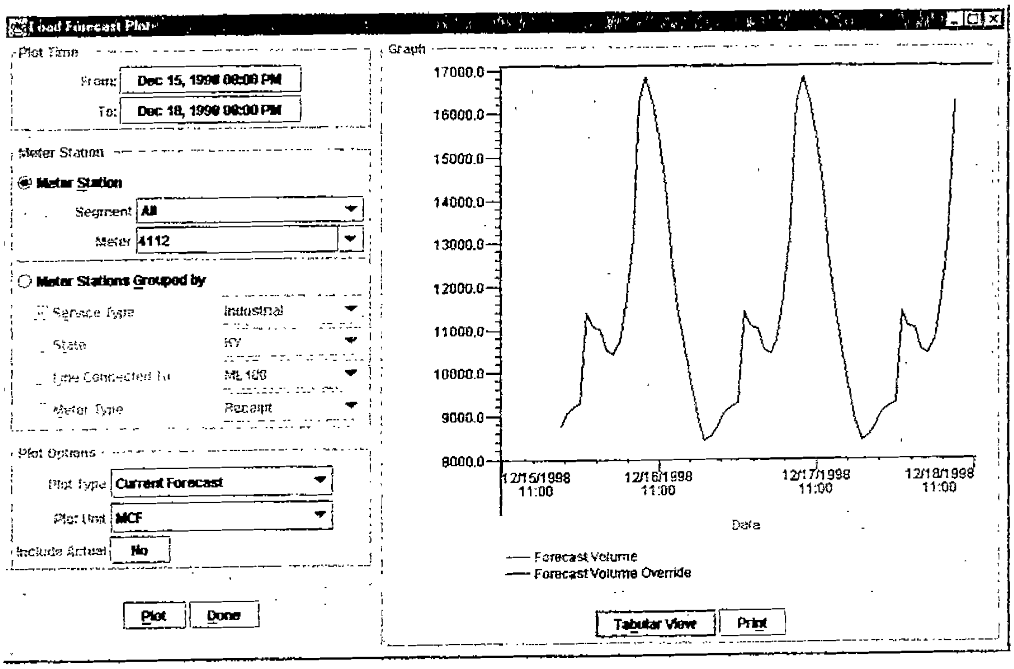
ESI' neural net-based Gas Load Forecasting system (GLF) is being used in the USA by clients operating extremely complex delivery systems, and is saving them hundreds of thousands of dollars by providing their predictive simulation models with forecasts accurate to within 5% of actual demand.

Some estimate of predicted load is the very first step in the marketing and operations cycle, without it marketing can't project, capacity sellers don't know the cost of their capacity or its availability, operations can't plan to run safely and profitably, and the system will not work at full efficiency.

The forecast engine is based on a general-purpose neural network. The neural network is trained using historical characteristics such as weather data, calendar information, and economic information such as competing energy costs.

Forecasts are generated automatically according to a set schedule, or whenever trigger events occur. Typically, events such as the arrival of new weather data or new nominations data will initiate a new load forecast. Whenever the differential between the forecasted loads and the actual loads vary by more than a defined threshold, the particular neural networks that are associated to that load will automatically retrain in-order to provide a better fit for the available data.

A typical display from the gas load forecaster can be seen below:-



Plot Time

From: Dec 15, 1998 08:00 PM

To: Dec 18, 1998 08:00 PM

Meter Station

● Meter Station

Segment: All

Meter: 4112

○ Meter Stations Grouped by

Service Type: Industrial

State: KY

Line Connected To: ML 100

Meter Type: Receipt

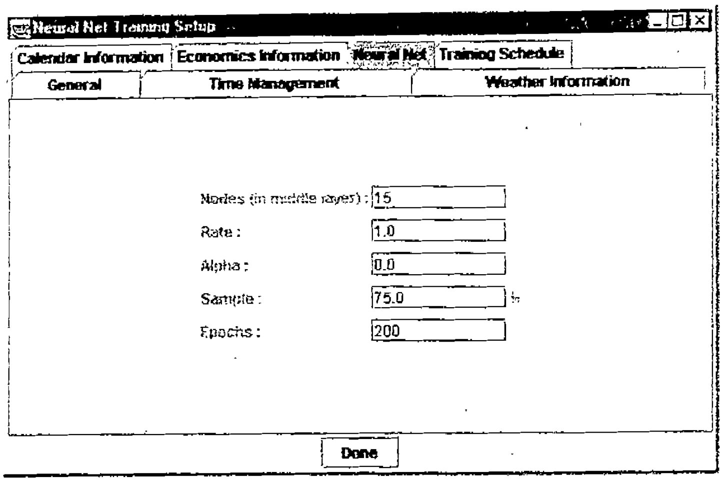
Plot Options

Plot Type: Current Forecast

Plot Unit: MCF

Include Actual: No

All of the data from the Load forecaster will be available in the central database for other applications that subscribe to it. Modifications to the set-up of the forecaster can be handled directly through associated dialogue boxes, as seen below.



Nodes (in middle layer) : 15

Rate : 1.0

Alpha : 0.0

Sample : 75.0 %

Epochs : 200

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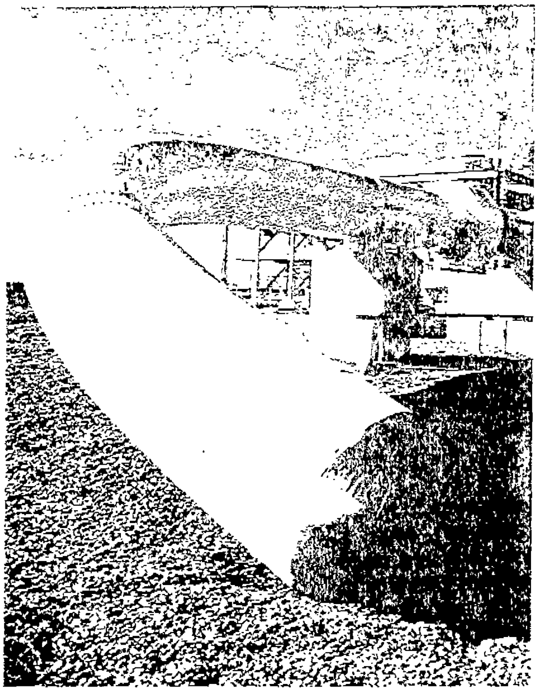
Pipeline Management Modules

This leaflet is one of a series containing examples of Energy Solutions Consultancy and Project work.



This data sheet outlines just some of the management modules developed and used by Energy Solutions engineers in the modelling of pipeline networks to maximise the business benefits of our software systems on behalf of Clients.

BATCH MANAGEMENT

Comprises Scheduling, Movements and Transfer Distribution; batch tracking is a pre-requisite for the scheduling and/or transfer distribution modules, and the combination of all three management modules enables an Operator to implement batch scheduling and to supervise transportation in accordance with an established schedule.

BATCH TRACKING

Determines the movement of product interfaces through a pipeline system, and the progress of batch fronts, together with the expected time of arrival at downstream locations is regularly updated via the pipeline model.

CATHODIC PROTECTION

This software monitors the cathodic protection parameters collected by the SCADA system in order to display and analyse trends and generate alarms.

COMPOSITION TRACKING

Enables the determination of movements in product composition and heating value. The parameters at mixing points are calculated and treated as an inflow to a pipeline section; the software regularly updates the position of the parameters based on the velocity profile of the base pipeline model, and the system then calculates the actual parameters in the delivery points.

COMPRESSOR OPTIMISATION

An optimisation model is generic, enabling detailed specification of compressor, engine and local control characteristics within a station to facilitate optimisation on the basis of current flow patterns and distribution in real-time, or on a scenario derived from the predictive model.

The results of an optimisation define the set point for individual compressor stations, together with an optimum compressor configuration that will minimise the energy required for compression and cooling within each station.

DRAG REDUCTION

This module simulates the effects of pipeline additives by adjusting friction values in the flow calculations; the module can be applied to drag reducing agents and corrosion inhibitors.

Refs/Pipeline Management Modules/05-09-00/HT/jc

MANAGEMENT, NOMINATION AND ALLOCATION

This gas management software comprises:

- A Nomination Computer System - which tracks energy levels in the pipeline to ensure that the participating fields are maintaining their individual share of the line stock.
- An Allocation Computer System - which allocates the gas transported from the originating fields to the gas shippers on the basis of data provided by the nomination system, the measured gas supply and the measured Customer demand.
- The Maintenance Scheduler - designed to improve the efficiency of warehouse handling, purchasing, work orders and preventive maintenance.
- The Energy Solutions Geographical Information System (LIGS) - which is used for the management of objects that have a geographical relationship to each other; different types of information can be assigned (for example, geographical, technical, administrative, or operational data, as well as damage and failure reports).

PIPELINE EFFICIENCY

Defined via the friction factor (determined from the pipeline roughness and its actual diameter), which is calculated on a per-section basis from pressure drops and flows. The friction factor enables an Operator to modify system parameters in order to accommodate less efficient conditions, or to implement pig cleaning of the pipeline.

PIPELINE INVENTORY

This module calculates the product mass within the pipeline on the basis of pressure, temperature and density profiles in order to determine the amount of product available. From the profiles, the actual line pack and rate of change is determined for each pipeline segment and for the total system.

PRESSURE MONITORING

A real-time pressure profile is calculated from the hydraulic model, and compensation for the effects of temperature (including diurnal solar energy changes) is automatically applied to these calculations; pre-configured safety limits applied to the pressure profile provide over- and under-pressure warnings.

PRODUCT TRACKING

This software determines the movement of product batch interfaces throughout a pipeline system.

The system parameters are derived from the pressure, temperature and composition equations and from the product properties.

PUMP OPTIMISATION

This module calculates the optimum pump configuration with regard to fuel consumption in those pipelines with multiple booster stations.

The optimisation is based on the flow pattern/distribution characteristics, availability of pumps, pump system efficiency curves and on the specified operational constraints of the pipeline.

SCRAPER TRACKING

Facilitates tracking of the position and type of any pig(s) in a pipeline as a basis for warning an Operator that a pig is approaching a receiver station, for avoiding false rupture alarms, and for the initial locating of a blocked pig.

STATE ESTIMATION

This is the process through which all known and estimated pipeline information is integrated in order to enable system software tools to produce outputs that will be useful to a system Operator and to a pipeline operating company.

SURVIVAL TIME ANALYSIS

ESIlds provides real-time line pack data that can be plotted against distance by the SCADA system, and at any instant in time, it will be possible to determine total product volume and the distribution along the pipeline. Based on current line pack, pipeline flow IN and pipeline flow OUT, and on customer demands, the Survival Time Analysis provides information on the length of time that a plant will continue to operate when a leak or other cut-off occurs.

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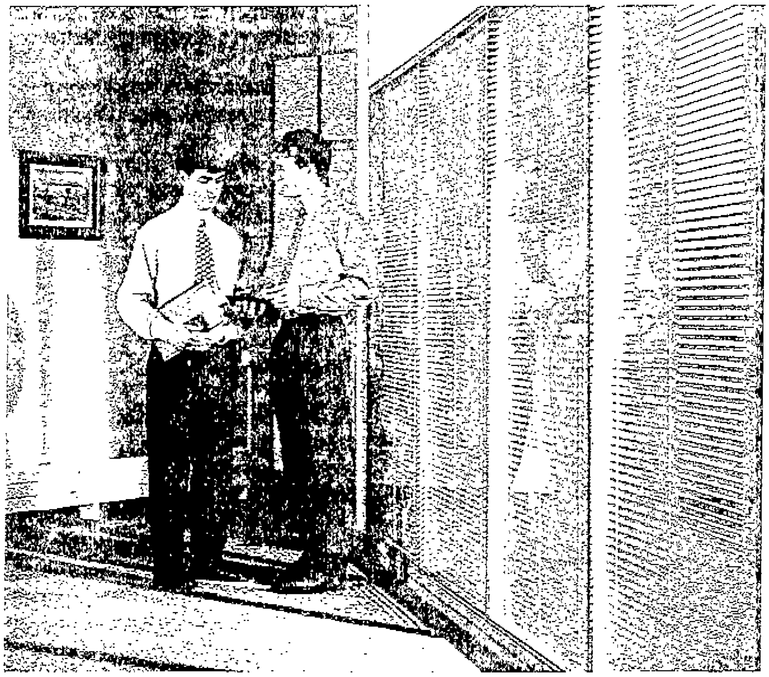
Leak Detection Design, Sensitivity and Performance Studies

This leaflet is one of a series containing examples
of Energy Solutions Consultancy and Project work.



Energy Solutions experts conduct studies of leak detection system capabilities and requirements on behalf of Clients.

The dynamic pipeline response to leaks and ruptures are assessed through a Leak Detection Design Study.

Implementation of the on-line leak detection system implies requirements for instrumentation and data transmission, both of which are of key importance to the overall functioning of the leak detection system.

Knowledge of the practical operation of the pipeline is also essential to establish the correct design of the leak detection system software package; and evaluation is needed as to the extent that the system will be able to model the different conditions within the pipeline. The points to be considered include:

- Normal, maximum and minimum pipeline flow and pressure operating conditions
- Transient flow conditions (pump start\stop, valve operation, etc.)
- The effect of temperature variations
- Multiple products within the pipeline
- The effects of scraping
- The relevance of shut-in leak detection

The quality of the data and the design of the software in relation to pipeline operations will define the capability of the leak detection system.

PERFORMING A DESIGN STUDY

This type of study can produce input to a Client's own spill analysis and safety study, and generally results in a set of documents detailing the capabilities of alternative detection methods. The objectives of a study are to assess the leak detection capability in terms of the overall system specification and pipeline operations, i.e.:

- Minimum leak size
- Leak size/detection time
- Leak location accuracy

For existing systems, this work can include an assessment of potential problems and "bottlenecks".

BENEFITS TO THE CLIENT

Design studies form the basis for a Client's leak detection philosophy for a particular pipeline project, and the report prepared by the Energy Solutions Engineers will include a system description under the following headings:

- Description of the leak detection software package
- Detection capability
- Requirements assessment and recommendation of available\additional instrumentation update time
- Computer H\W requirements

A Design Study may include the implementation of a pipeline model, so that simulations can be used to determine the responses to leaks and operational changes. In this way, simulations of the time series of pressure, flow and temperature (comparable to the real measurements on the actual pipeline) can be obtained. From these simulations, a detailed assessment of the leak detection algorithm responses can be performed in order to determine the detection time and the effect of transient flow conditions.

Design studies performed on existing pipeline installations assess the requirements for the total information relevant to successful leak detection, including:

- Instrumentation accuracy and availability
- A/D conversion
- Communications
- SCADA requirements

SENSITIVITY STUDIES

So that both the Client and Energy Solutions can be fully aware of the capabilities of a leak detection system, and also to assess the accuracy and benefits provided by a pipeline management system, a pipeline sensitivity study is recommended.

A Sensitivity Study will analyse leak sensitivity thresholds and pipeline operating conditions as a standard initial step to determining the achievable leak detection performance before installing leak detection software.

Due to the requirements of pipeline safety regulations and the economic consequences of a leak through loss of product, clean up costs, pipeline and equipment downtime and repair costs, etc., fast, effective and accurate leak detection methodologies are needed.

Energy Solutions recognises the complexity of dynamic leak detection software, and therefore has developed its own software tool for analysis and study of leak detection sensitivity. This software can be used in the engineering design phase, or can be utilised for an existing pipeline.

Through a Energy Solutions leak sensitivity study, the pipeline operating company gains the following benefits:

1. Defining the characteristics of those leaks that could be masked by instrumentation errors, telemetry problems, and by inconsistencies in fluid property parameters.
2. The operating company will gain an understanding of where additional or improved instrumentation should be installed to assist in leak detection.

3. Evaluation of the benefits and costs of a leak detection system implementation.

4. Establishing leak sensitivity thresholds in order to provide realistic expectations and targets.

When the sensitivity study is completed, the Client will thoroughly understand the problems identified by the Energy Solutions Engineers, and will appreciate the benefits that can be provided. Both the Client and Energy Solutions can then develop a close working relationship during the implementation of the leak detection system.

PERFORMANCE STUDIES

A Leak Detection Performance Study includes an assessment of the Energy Solutions LDS detection capability in relation to the overall network and to the operation of the pipeline and will evaluate:

- Minimum detectable leak size
- Relationship between leak size and detection time
- Achievable leak location accuracy

The Final Study Report from the Energy Solutions Engineering Team will include a description of the available instrumentation enhancements, together with indications of the anticipated improvements in the leak detection capabilities for the Client's designated network.

Karamay and Dushanzi to Wang Jia Gou

Multi Product Pipeline

克拉瑪依，獨山子至王家溝混輸管線

```
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```

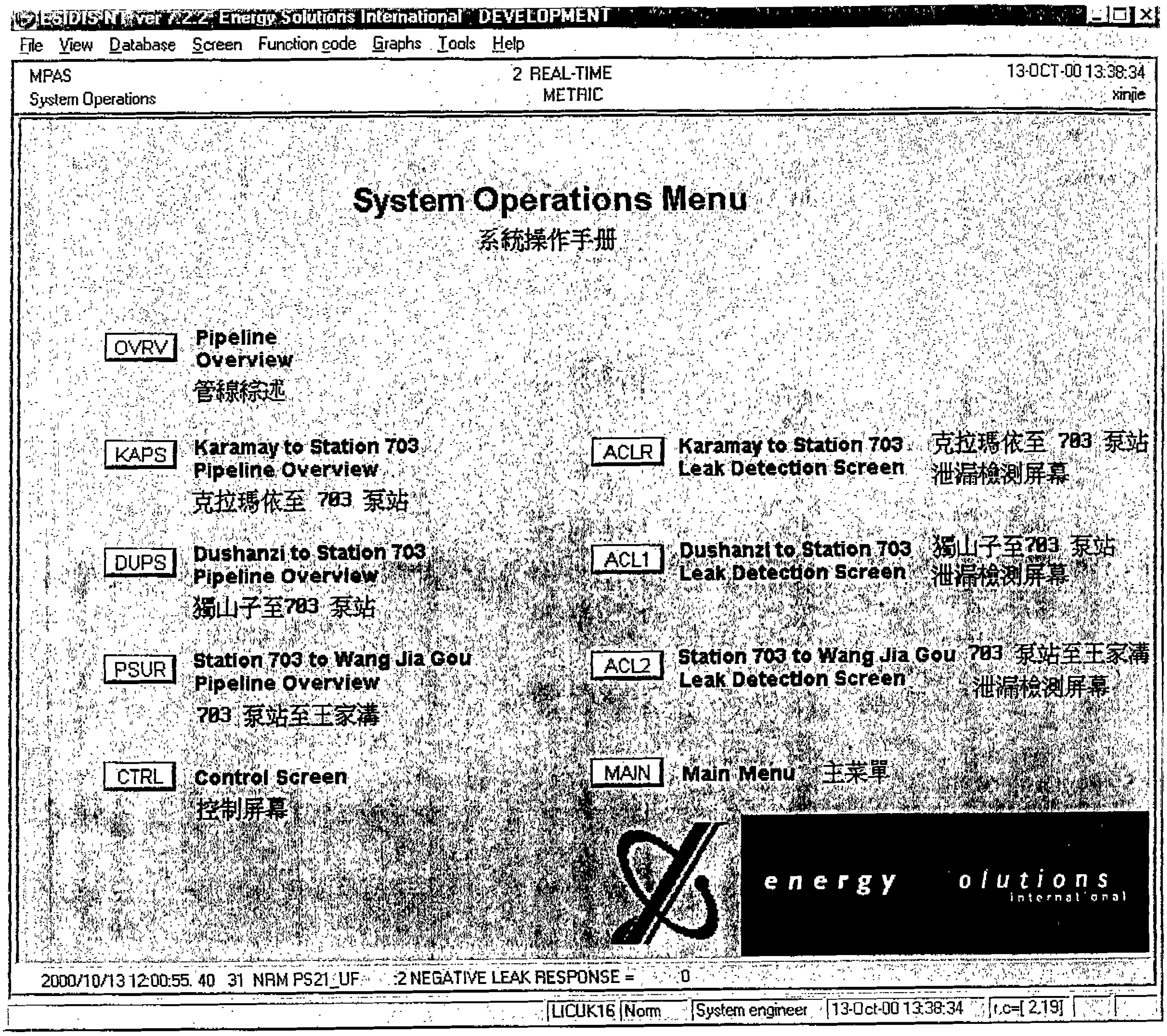

MPAS
System Operations

2 REAL-TIME
METRIC

13-OCT-00 13:38:34
xinjie

System Operations Menu

系統操作手册

OVRV **Pipeline Overview**
管線綜述

KAPS **Karamay to Station 703 Pipeline Overview**
克拉瑪依至 703 泵站

ACLR **Karamay to Station 703 Leak Detection Screen** 克拉瑪依至 703 泵站 泄漏檢測屏幕

DUPS **Dushanzi to Station 703 Pipeline Overview**
獨山子至703 泵站

ACL1 **Dushanzi to Station 703 Leak Detection Screen** 獨山子至703 泵站 泄漏檢測屏幕

PSUR **Station 703 to Wang Jia Gou Pipeline Overview**
703 泵站至王家溝

ACL2 **Station 703 to Wang Jia Gou Leak Detection Screen** 703 泵站至王家溝 泄漏檢測屏幕

CTRL **Control Screen**
控制屏幕

MAIN **Main Menu** 主菜單

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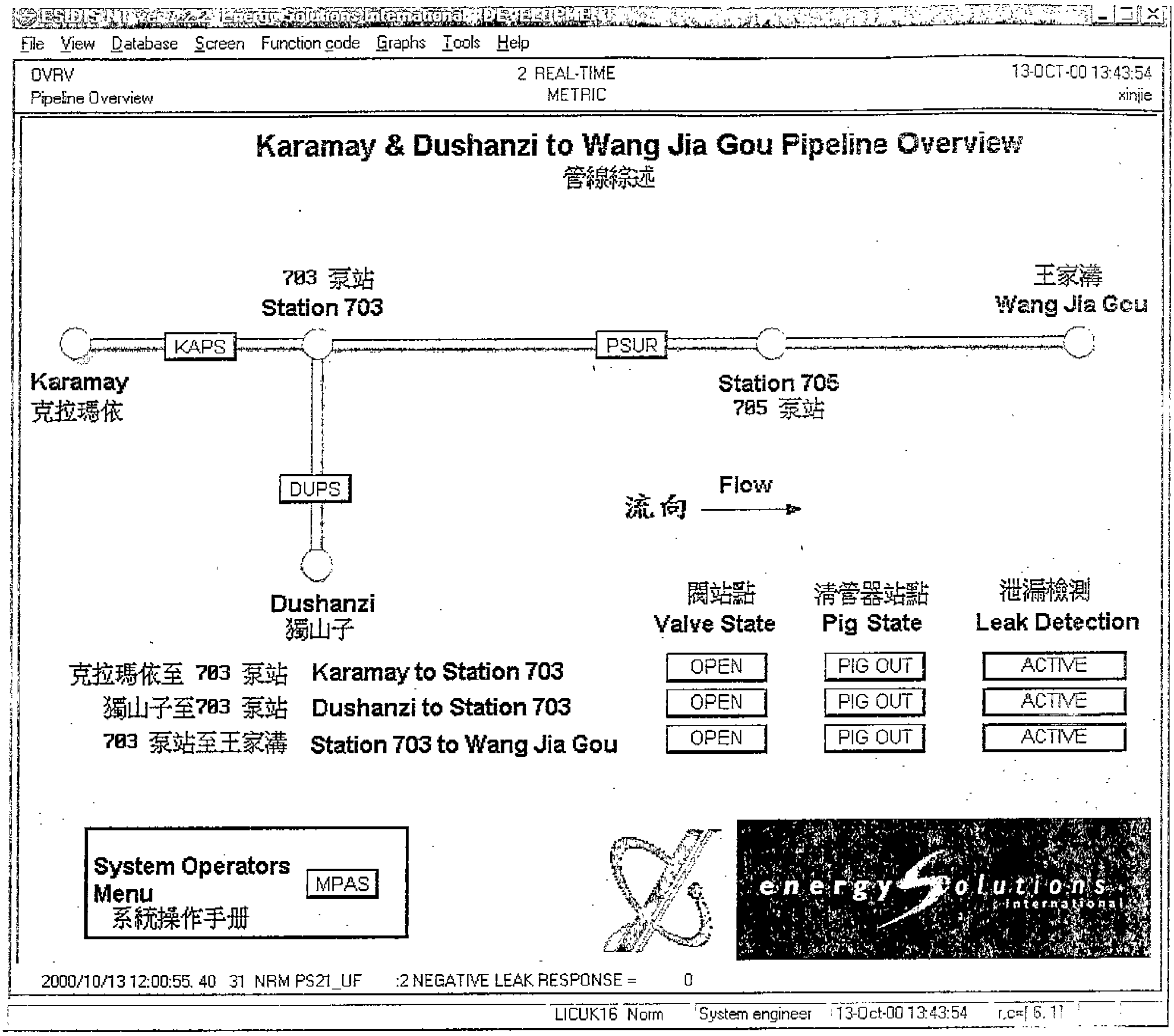


OVRV
Pipeline Overview

2 REAL-TIME
METRIC

13-OCT-00 13:43:54
xinjie

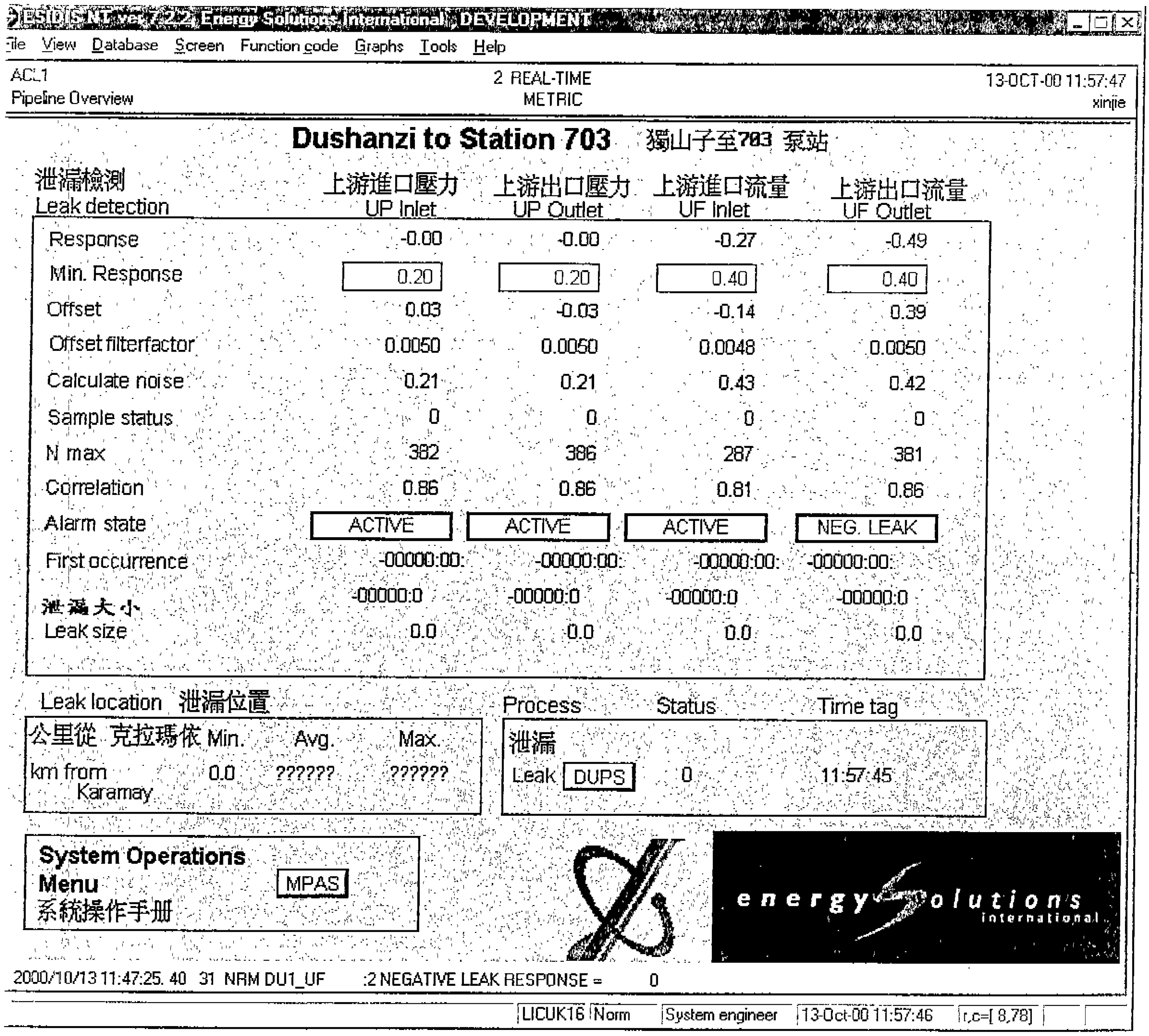
Karamay & Dushanzi to Wang Jia Gou Pipeline Overview
管線綜述

	閥站點 Valve State	清管器站點 Pig State	泄漏檢測 Leak Detection
克拉瑪依至 703 泵站 Karamay to Station 703	OPEN	PIG OUT	ACTIVE
獨山子至703 泵站 Dushanzi to Station 703	OPEN	PIG OUT	ACTIVE
703 泵站至王家溝 Station 703 to Wang Jia Gou	OPEN	PIG OUT	ACTIVE

System Operators Menu
系統操作手冊

```
2000/10/13 12:00:55. 40   31  NRM PS21_UF      :2 NEGATIVE LEAK RESPONSE =        0
```

LICUK16 Norm | System engineer | 13-Oct-00 13:43:54 | r,c=[6, 1]



ACL1
Pipeline Overview

2 REAL-TIME
METRIC

13-OCT-00 11:57:47
xinjie

Dushanzi to Station 703 獨山子至703 泵站

泄漏檢測
Leak detection

	上游進口壓力 UP Inlet	上游出口壓力 UP Outlet	上游進口流量 UF Inlet	上游出口流量 UF Outlet
Response	-0.00	-0.00	-0.27	-0.49
Min. Response	0.20	0.20	0.40	0.40
Offset	0.03	-0.03	-0.14	0.39
Offset filterfactor	0.0050	0.0050	0.0048	0.0050
Calculate noise	0.21	0.21	0.43	0.42
Sample status	0	0	0	0
N max	382	386	287	381
Correlation	0.86	0.86	0.81	0.86
Alarm state	ACTIVE	ACTIVE	ACTIVE	NEG. LEAK
First occurrence	-00000:00:	-00000:00:	-00000:00:	-00000:00:
	-00000:0	-00000:0	-00000:0	-00000:0
泄漏大小 Leak size	0.0	0.0	0.0	0.0

Leak location 泄漏位置

公里從 克拉瑪依	Min.	Avg.	Max.
km from Karamay	0.0	??????	??????

Process	Status	Time tag
泄漏 Leak DUPS	0	11:57:45

System Operations Menu
系統操作手册

2000/10/13 11:47:25. 40 31 NRM DU1_UF :2 NEGATIVE LEAK RESPONSE = 0

LICUK16 Norm System engineer 13-Oct-00 11:57:46 r,c=[8,78]

How do you manage your pipeline?

附錄八

by Dr P Hopkins and A Cosham
Andrew Palmer & Associates (A Division of SAIC), Newcastle upon Tyne, UK

TRANSMISSION PIPELINES are the safest method of transporting energy. They have an excellent safety record, mainly due to their proven design and operating practices. These practices have changed little since the early days of pipelines. Similarly, the methods used to manage a pipeline system have changed little over the years.

However, pipeline operators are now being asked the simple question "How do you manage your pipeline?" by board members, regulatory authorities, etc. The reasons for this question can range from cost-effectiveness to safety considerations. Indeed, in the UK, pipeline safety regulations require a pipeline operator to have a safety management system in place.

Consequently, pipeline operators are now producing and working to management systems. This paper presents an overall pipeline management system that can be used on an offshore or onshore, oil or gas pipeline. The system is in the form of a formal, structured document, that is authorized by top management, and implemented by all staff in all departments of a pipeline company.

Introduction

Good management of any company or asset is vital to its success, both in terms of profit and safety. There are many examples of poor management causing major disasters: the fire in the London Underground in 1988 which cost 31 lives was attributed to 'blinkered' management who believed they were self sufficient, and were unwilling to take advice or criticism [1].

Pipeline companies are going through major changes, ranging from 'downsizing', to franchising maintenance and operation activities. These changes, and increasing pressure from regulatory authorities to have auditable management processes in place, mean that pipeline operators are now producing, and working to, management systems.

The methods and systems they adopt vary significantly, which is in contrast to their assets. Pipeline companies design and operate their assets using detailed, prescriptive, codes and procedures that are both well-documented and recognized. This means that most companies design and operate their pipelines using identical codes and procedures. However, the management of these assets is left to the discretion of individual companies, and many use differing methods and structures that have been in place for decades. Consequently, it is easy to design a pipeline and show that is safe and efficient, by simply saying it is designed to a recognized code, e.g. ASME B31. However, it is not possible to say the same thing about the pipeline management because no formal or agreed systems are available.

This can lead to problems. For example, how is the competence, efficiency, and cost-effectiveness of the management of a pipeline system measured and recorded? Is the management 'good', is it efficient, is it operating the pipeline safely, etc.? How can an operator assess the performance of its management, and how can it show regulatory authorities that it has a top-quality management system, with suitable benchmarks?

What is needed is a systematic and formal appraisal of all aspects of the managers and management, and this can be achieved through a management system.

This paper was first presented at the Pipeline Risk Management and Reliability *conference held in Houston in November, 1997, organized by* Pipes & Pipelines International *and* Clarion Technical Conferences.

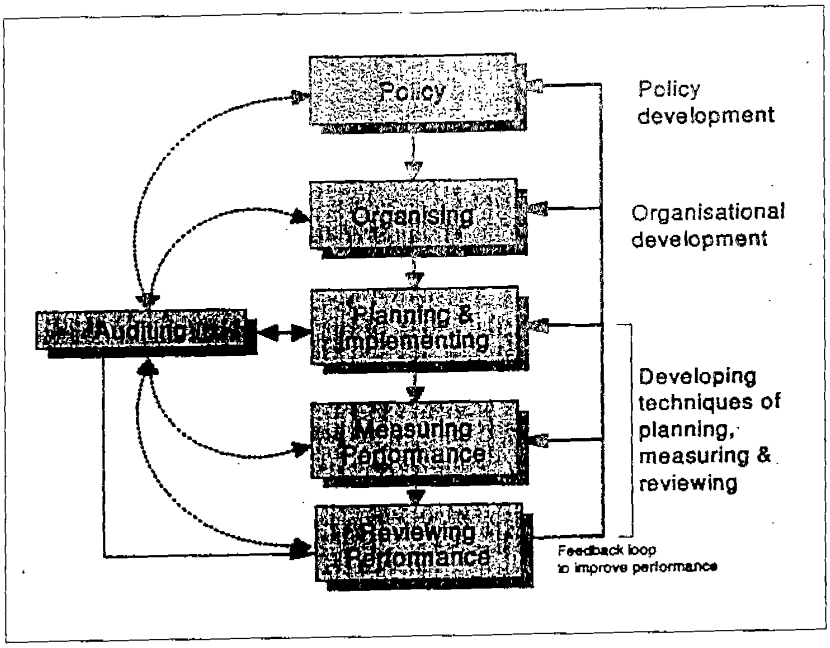


Fig.1. An overview of the key elements of a safety-management system [4].

What is a management system?

First of all, we need to know what a management system is, and what it can do. Unfortunately, management systems are often confused with management structures; they are completely different, although the latter is contained in the former.

A 'management system' is a management plan, in the form of a document that explains to company staff, customers, regulatory authorities, etc., how the company and its assets are managed, by stating:

- who is responsible for each aspect of the asset and its management;
- what policies and processes are in place to achieve targets and goals;
- how they are implemented;
- how performance is measured; and finally
- how the whole system is regularly reviewed and audited.

The document is agreed at board level, constantly and systematically reviewed and updated, and all levels of management comply with its contents.

Many companies operate such a system in a piecemeal, or unstructured, manner. It is the production of a single, detailed document that encompasses all the above aspects that creates the 'system'. The next question is, "why have a management system?". Some of the reasons are given above, but numerous examples can be given that show the importance and usefulness of formal pipeline management systems, i.e.:

- A board member, shareholder, or regulatory authority can ask how your pipeline is designed and operated, and is it cost-effective, safe, and efficient? It is easy to say, for example, "The pipeline is to BS 8010, so everything is OK", and this should satisfy any possible query or concern easily. If the same questioner asked the question "How is your pipeline managed?", what would your answer be, and how would you justify and show the effectiveness of the current management?

- You can imagine the problems a pipeline operator would have if he/she was to decide to franchise all pipeline operations to a contractor. The first thing the contractor would ask for is a formal document stating how the pipeline operator wanted the pipeline to be operated, the processes to be followed, the measures used to assess performance, etc. It is relatively easy to hand over several filing cabinets full of codes of practice, and specifications that tell a contractor how many times to inspect a pipeline, or how often to check valve operation, etc., but these will not tell the contractor how this is all managed, or how an operator wants it to be managed to satisfy corporate goals, measures of performance, safety-management criteria, etc.

continued on page 21 after Pipeline Report

How do you manage your pipeline?

(continued from page 20)

- In pipeline companies undergoing sweeping changes, including downsizing and management rotation and rationalization, it is essential that new managers can easily and quickly be informed of the management techniques, structures and processes in place, that will allow him/her to achieve company goals and objectives quickly.

- Regulatory authorities are increasingly asking operators for formal and documented management systems. In the UK, the Pipeline Safety Regulations [2] require a pipeline operator of a major accident hazard pipeline [3] to have a safety-management system documented and in place.

Simple management systems

A simple management system is a safety-management system; Fig.1 gives an outline [4]. This is one part of a pipeline-management system. However, it does show the components of a management system. If any of these components are missing, it is not a complete system. The key elements are:

- corporate, departmental, and local policies are stated, agreed, and undersigned by senior management. These policies will also include objectives/goals.

- the organization of these policies is stated, in terms of organization structure and strategy. This will usually include the name of the person/department who takes ownership of this part of the business. Ownership can be divided into accountability (who decides on the policies and plan, and selects those responsible), and responsibility (who carries out the policies and plan).

- how policies are realized is contained in a detailed plan. This plan can be anything from a simple flowchart, to a detailed framework.

- how this plan will be implemented is stated. The plan and its implementation will be achieved by written processes.

- wherever a policy is being implemented, it should have some performance measure that allows management to assess its effectiveness and value.

- the organization, plan, implementation, processes utilized, and performance measures in place, should be regularly reviewed against specified criteria. The review must have 'teeth', i.e. where deficiencies are identified, procedures must be in place and implemented to ensure rectification. Indeed, a performance measure for the whole system is the speed of the review and implementation of recommendations and changes.

- finally, the whole system, and all its elements should be subject to regular audit. This audit should not be a 'compliance audit', that merely checks that the paperwork is in place, and the people are following all the policies, etc.. The audit should be a 'critical audit' that appraises both the system in place, and each element, to ensure it is performing its stated function effectively.

A simple example of how this system would work is in environmental safety:

- The *corporate policy* states that all company pipelines will comply with all environmental legislation, and present an 'as low as reasonably practicable' risk to the surrounding environments. This policy is likely to be in the form of a mission statement, and itemized in terms of objectives.

- The *organization of this policy*, in terms of those persons/departments responsible and accountable, is detailed, with a listing of individual responsibilities. It is useful to specify one 'owner' of the policy, such as a board director.

- The *plan* outlining how environmental protection, and compliance with legal requirements, is to be achieved, i.e. how the corporate objectives are to be achieved, is summarized, but not detailed.

- The *methods and procedures* in place to achieve these objectives should be listed and how they will be implemented detailed. These will include measures in place to avoid environmental damage,

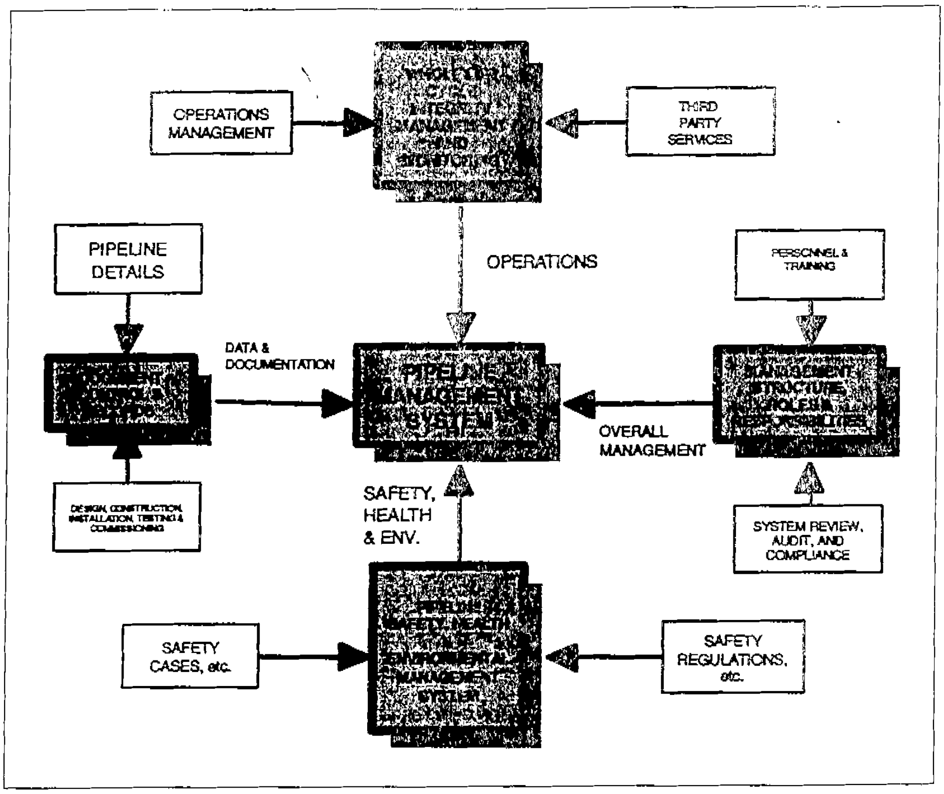


Fig.2. A pipeline-management system [5].

emergency plans and procedures in place to mitigate leakages, etc.

- *Implementation* of the plan should be outlined, but this is not sufficient; a list of...

- *Performance criteria* must be agreed with all levels of management before implementation. These criteria constitute the 'success factors'. Performance measures could be number and scale of leakages, response time to leakages, etc.

- *Review* of these elements is essential. The review would start with an assessment of the objectives (are they reasonable and achievable?), the organization, and the plan in place to realize these objectives. Then the performance measures are assessed, and the whole system reviewed using them.

- *An audit* by an independent person/department of the whole system will need to be performed at regular intervals. Part of this audit may use an environmental agency/consultant to appraise performance measures, etc.

Pipeline management system

An example of a pipeline management system is shown in Fig.2 [5]. This is a suggested format; different companies require different formats, and different priorities. However, this overall format should satisfy the needs of most companies, and also satisfy requirements of regulatory authorities.

Each arm of the management system in Fig.2 should contain all the elements of Fig.1. Therefore, it is not sufficient to have in place an integrity-monitoring programme (however good it may be); this programme must be constantly reviewed, and audited to test its adequacy, and check that it is being applied correctly and completely.

One of the key components of the management system is measuring performance (Fig.1). This is important in pipeline engineering, as it can allow early detection of problems, and can also allow relaxations in operational practices, that can allow reductions in operating costs. Fig.3 gives an example of how measuring performance can achieve this.

In this example, in-service inspection is reduced at the start of 1997 because the pipeline has a very low incidence of leakage, and the inspections in place are considered excessive.

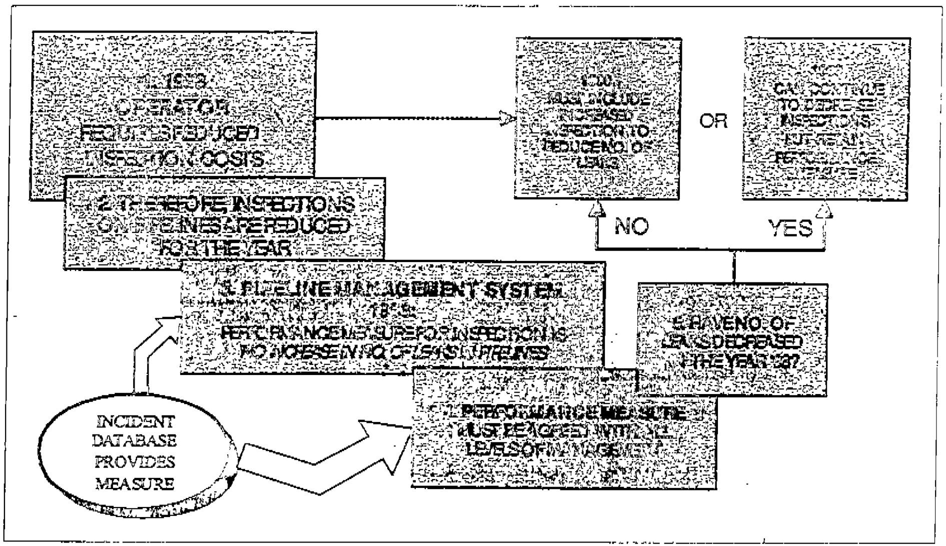


Fig.3. Performance measures in a pipeline-management system [5].

However, as a competent operator, management sets a performance measure that insists that an increase in the number of leaks is unacceptable. Management agrees that 'unacceptable' will be deterioration or leaks over and above accepted or past levels (from an in-house database). During the year all pipeline incidents and leaks are monitored. If they go above the agreed levels, they have failed the performance criterion, and therefore inspections would have to be increased in the following year to achieve the same performance criterion. This example shows the flexibility of a management system.

Producing a management system

Detail

A management system can be as detailed as a company requires. It can range from a few pages that outline a company's overall strategy for its pipeline network, and its management structure, responsibilities and review process, to an in-depth document that itemizes all aspects of a pipeline's management.

Fig.4 presents a summary of the types of level of detail that can be included in a management

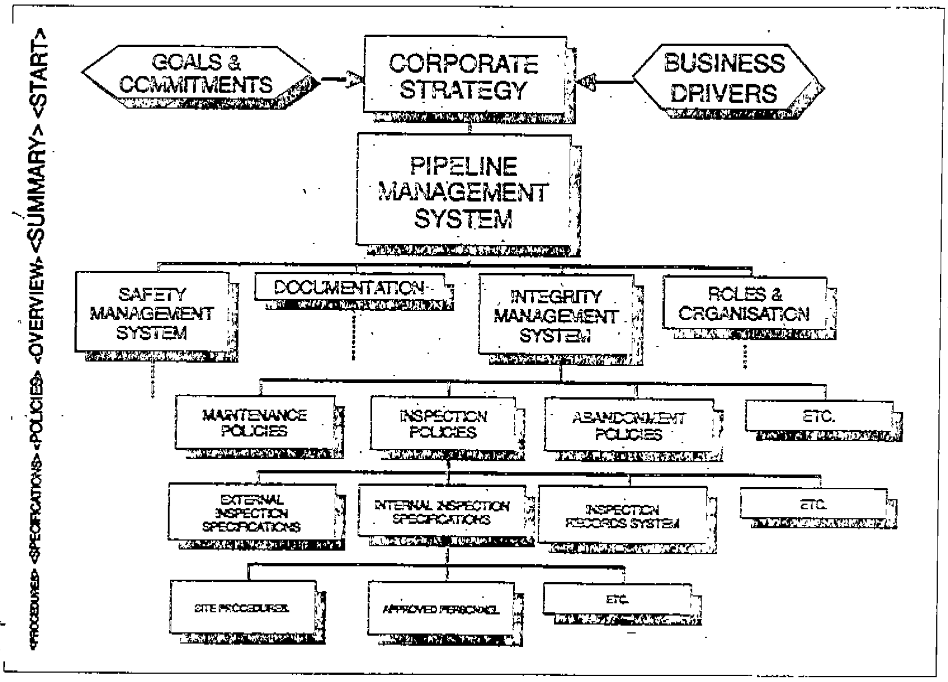


Fig.4. Differing levels in a management system.

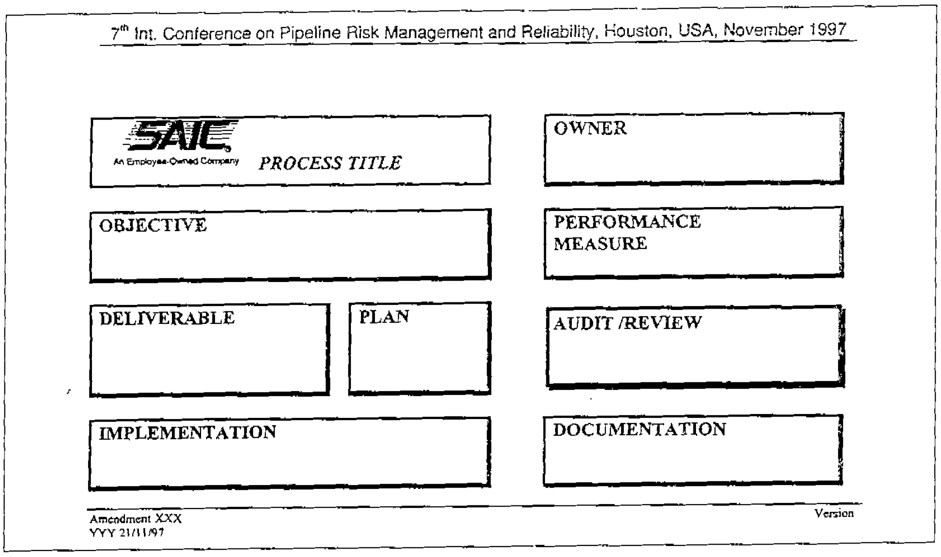


Fig.5. Typical Andrew Palmer & Associates management system chart.

system. It should always be recognized that a management system will be driven by the corporate strategy, which will take account of business drivers, profit goals, safety issues, etc. This is the starting point of the system.

A variety of differing levels of detail can be included in a pipeline management system. It does not necessarily have to include everything that is needed to manage a pipeline effectively and safely, as it can refer to more-detailed documents such as site procedures.

Most companies will have the policies, procedures, and specifications summarized in Fig.4 available, and usually there will be long-serving staff who will be applying them, and be able to present summaries of them all, and locate them. These staff are pivotal in the efficient management of a pipeline, and - in effect - are the management system. However, this reliance on 'corporate memory' can be dangerous, particularly if there are regular changes in a company, and staffing reorganizations. A major purpose of a management system is to eliminate this reliance on corporate memory, by ensuring that all management roles, policies, etc., are documented, with regular and systematic updates and reviews.

Structure

The management system will be in the form of a document that includes all the elements of Figs 1 to 3. A typical system will consist of an overview of the management of a company or asset, with a chart detailing individual aspects.

Fig.5 shows the chart layout used by Andrew Palmer and Associates to assist companies produce a management system. The overall management of a company is divided into 'processes', including emergency planning, pipeline operation, document handling, etc. The company can produce as many processes as required, depending on the detail required. Senior management would only require a single chart for 'pipeline operation', but those departments involved in pipeline operation would want to produce many more detailed charts, such as those dealing with pipeline maintenance, pipeline inspection, pipeline flow control, etc., (see Fig.4).

Production

The whole management system is produced as follows:

- management (up to board level) agrees to produce and work to a formal management system;
- management agrees on the contents of the management system document. This will dictate the degree of detail (and number of processes) to be incorporated;
- management agrees on the format of the system (for example, Fig.5), including those responsible for audit and review;
- the first part of the system (overview, objective, and mission statement) are approved at board level;
- the second part of the system (contents, definitions, and text to explain the system and how it is to be applied) is agreed by senior management;
- the final part of the system (all the charts) is drafted and agreed with all levels of management;

- the management system is produced, and authorized at board level;
- the management system is applied for a full year. The first annual review and audit may involve extensive changes (including additions or withdrawals of charts).

Conclusions

Pipeline operators are now producing and working to management systems. These pipeline-management systems can be used on an offshore or onshore, oil or gas pipeline. The systems are in the form of a formal, structured document, that is authorized by top management, and implemented by all staff, in all departments of a pipeline company.

It serves as a benchmark document for all managers in a company, and is a means of monitoring management performance, and assessing its effectiveness.

The system explains to company staff, customers, regulatory authorities, etc., how the company and its assets are managed, in a safe and cost-effective manner. It specifies roles and responsibilities, how the company achieves stated corporate objectives, regulatory requirements, etc., including the overall plans and methods of implementation.

Because it is a formal, structured document, it can easily be updated as the company changes, or made available to franchisees who may operate parts of the company's assets. This ensures that all parts of the company's assets are managed in an agreed, consistent, effective, and formal manner.

Acknowledgements

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Designing a cost-effective and reliable pipeline leak-detection system

by Dr Jun Zhang
REL Instrumentation Ltd, Manchester, UK

ATMOS PIPE is a statistical pipeline leak-detection system, incorporating advanced pattern-recognition functions. Real-time applications and field tests show that it is cost-effective and has a very low false alarm rate. Leaks with sizes from 0.5% to 55% were detected on liquid propylene, ethylene gas, natural gas, and natural gas liquid (NGL) pipelines. In this paper, the performance of the system is reported after the comparison of different leak-detection methods.

Introduction

With increasing public awareness and concern for the environment, recent pipeline leak incidents have shown that the cost to a company can be far more than the downtime and clean-up expenses. As more stringent statutory regulations are introduced, cost-effective and reliable leak-detection systems are in demand.

In this paper various pipeline leak-detection methodologies are reviewed. These include biological, hardware- and software-based methods. Each method has its advantages and disadvantages. To compare the performance of these methods, seven key attributes are defined: leak sensitivity, location estimate capability, operational change, availability, false alarm rate, maintenance requirement, and cost. Unfortunately, none of the existing methodologies can offer good performance for all the attributes. A common problem for most of these methods is high false alarm rate, i.e. generating a leak alarm when the pipeline is under normal operation. False alarms are undesirable because they generate extra work for operational personnel, they reduce the confidence operators have in a system, and a real leak may be overlooked.

Therefore it is essential to design a cost-effective and reliable leak-detection system. Such a system has been developed by Shell after intensive research and field tests over several years. The system applies advanced statistical techniques and its trademark is ATMOS PIPE. Examples of real-time applications and field tests are presented in this paper.

Review of leak-detection methods

Different leak-detection methods are applied to monitor the integrity of a pipeline (Bose 1993, Carlson 1993, Turner 1991). Broadly speaking, they can be classified into three categories (Fig.1):

- Biological methods - experienced personnel or trained dogs can detect and locate a leak by visual inspection, odour, or sound.
- Hardware-based methods - different hardware devices are used to assist the detection and localisation of a leak. Typical devices used include acoustic sensors and gas detectors, negative-pressure detectors, and infra-red thermography.
- Software-based methods - various computer software packages are used to detect leaks in a pipeline. The complexity and reliability of these packages vary significantly. Examples of these methods are flow/pressure change detection and mass/volume balance, dynamic model-based system, and pressure-point analysis.

This paper was first presented at the Pipeline Reliability conference held in Houston on 17th-20th November, 1996, and organized by Pipes & Pipelines International.

In the following sections, a brief description of the above methods will be given followed by a comparison of their key attributes.

Biological methods

A traditional leak-detection method is to use experienced personnel who walk along a pipeline looking for unusual patterns near the pipeline, smelling substances which could be released from the pipeline, or listening to noises generated by product escaping from a pipeline hole. The results of such leak-detection methods depend on individuals' experience and whether a leak develops before or after the inspection.

An additional leak-detection method is to use trained dogs which are sensitive to the smell of substances released from a leak.

Hardware-based methods

The hardware-based methods can be divided into four types according to the principles on which the devices are designed:

- visual devices
- acoustic devices
- gas-sampling devices
- pressure-wave detectors

Visual devices

Some leaks can be detected through the identification of temperature changes in the immediate surroundings. Infra-red thermography was used to detect hot water leaks as the surrounding temperature increases after a leak develops (Weil 1993). This method can be used from moving vehicles, helicopters, or portable systems, and is able to cover several miles or hundreds of miles of pipeline per day.

The recent development of advanced wide-area temperature sensors makes the temperature profile technique more practical. Temperature sensors such as multi-sensor electrical cable and optical time-domain reflectometry using fibre-optic cables are used to detect changes of temperature in the neighbourhood of a leak (Turner 1991).

Ground-penetrating radar (GPR) uses a radar transmitter and receiver to accurately pinpoint buried pipeline leaks without digging. The leaking substances can be 'seen' at the source by the radar via the changes in the surrounding soil's electrical parameters. A 'colourgraphic' data format then displays the leak (Graf 1990, Hennigar 1993).

Acoustic devices

When a leak occurs, noise will be generated as the fluid escapes from the pipeline. The wave of the noise propagates with a speed determined by the physical properties of the fluid in the pipeline. The acoustic detectors detect these waves and consequently the leaks (Hough 1988, Klein 1993, Kurmer 1993, Turner 1991).

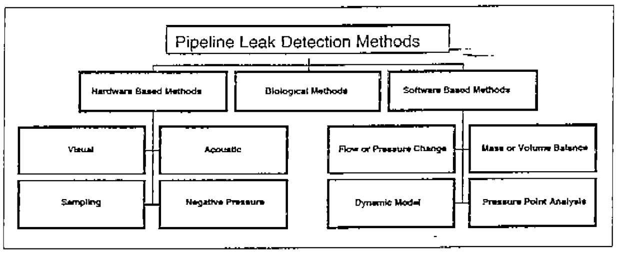


Fig. 1. Review of leak-detection methods.

Due to the limitation of the detection range, it is usually necessary to install many sensors along the line. These sensors detect acoustic signals in the pipeline and discriminate leak sounds from other sounds generated by normal operational changes.

Sampling devices

If the product inside a pipeline is highly volatile, a vapour-monitoring system can be used to detect the level of hydrocarbon vapour in the pipeline surroundings. This is usually done through gas sampling (Sperl 1991).

The sampling can be done by carrying the device along a pipeline or using a sensor tube buried in parallel to the pipeline. The response time of the detection system is usually from several hours to days. For application to offshore pipelines, a hydrocarbon detector can be used with a ROV (remotely operated vehicle) with swimming and sea bed crawling capacity. Pipeline leaks result in hydrocarbon anomalies in surrounding sediments and sea water, which can then be detected by the hydrocarbon detector.

Negative pressure

When a leak occurs a rarefaction wave is produced in the pipeline contents. The wave propagates both upstream and downstream from the leak site. The wave travels with speed equal to the speed of sound in the pipeline contents. Pressure transducers can be used to measure pressure gradient with respect to time (Turner, 1991). Usually two sensors are used for each pipeline segment to help discriminate between noise and externally-caused pressure drops.

Software-based methods

Software-based methods use flow, pressure, temperature, and other data provided by a SCADA (supervisory control and data acquisition) system (Bose 1993, Turner 1991); they can be divided into four types:

Method	**Leak sensitivity**	**Location estimate**	**Operational change**	**Availability**	False alarm	Maintenance requirement	Cost
biological	YES	YES	YES	NO	LOW	MEDIUM	HIGH
visual	YES	YES	YES	NO	MEDIUM	MEDIUM	HIGH
acoustic	YES	YES	NO	YES	HIGH	MEDIUM	MEDIUM
sampling	YES	YES	YES	NO	LOW	MEDIUM	HIGH
negative pressure	YES	YES	NO	YES	HIGH	MEDIUM	MEDIUM
flow change	NO	NO	NO	YES	HIGH	LOW	LOW
mass balance	NO	NO	NO	YES	HIGH	LOW	LOW
dynamic model	YES	YES	YES	YES	HIGH	HIGH	HIGH
PPA	YES	NO	NO	YES	HIGH	MEDIUM	MEDIUM

- flow or pressure change
- mass or volume balance
- dynamic model-based system
- pressure-point analysis

Flow or pressure change

This technique relies on the assumption that a high rate of change of flow or pressure at the inlet or outlet indicates the occurrence of a leak. If the flow or pressure rate of change is higher than a predefined figure within a specific time period, then a leak alarm is generated (Mears 1993).

Mass or volume balance

If the difference between an upstream and downstream flow measurement changes by more than an established tolerance, a leak alarm will be generated. This method allows the detection of a leak which does not necessarily generate a high rate of change in pressure or flow. The methods can be based on flow difference only, which would generate a simple mass or volume balance scheme, or on flow difference compensated by pressure/temperature changes and inventory fluctuations in a pipeline (Liou 1993, Parry 1992).

Dynamic model-based system

In its various forms this technique attempts to mathematically model the fluid flow within a pipeline. Leaks are detected based on discrepancies between calculated and measured values (Griebenow 1988, Hamande 1995, Liou 1994, Mears 1993).

The equations used to model the fluid flow are:

- conservation of mass
- conservation of momentum
- conservation of energy
- equation of state for the fluid

The partial differential equations are solved by a variety of computational techniques, depending on the choices of suppliers. The alternative methods currently in use in commercial software packages include:

- finite difference
- finite element
- method of characteristics
- frequency response/spatial discretisation

The method requires flow, pressure, and temperature measurements at the inlet and outlet of a pipeline and, ideally, pressure/temperature measurements at several points along the pipeline.

Pressure-point analysis (PPA)

This method is based on the assumption that if a leak occurs in a pipeline, the pressure in the line drops. Using simple statistical analysis of the pressure measurements, a decrease in the mean value of a pressure measurement is detected. If the decrease is more than a predefined level, then a leak alarm is generated.

Comparison of key attributes of different methods

Each leak-detection method has its advantages and disadvantages. To compare the performance of different methods, it is necessary to define the key attributes of a leak-detection system:

- leak sensitivity - can small leaks be detected?
- location estimate capability - is location estimate given?
- operational change - can the method work if pipeline experiences operational changes, e.g. throughput change, pigging?
- availability - can the method monitor a

  pipeline continuously, i.e. 24 hours a day?
- false-alarm rate - frequency of leak alarms generated during leak-free operations.
- maintenance requirement - level of technical expertise required to maintain the system.
- cost - capital expenditure (CAPEX) and on-going operating costs (OPEX).

Based on these definitions, Table 1 shows the comparison of the above methods. Note that the above attributes are common features of the leak-detection methods. In practice, the performance of each method varies considerably depending on the vendors, pipeline operating conditions, and quality of the hardware/instrumentation system available.

Table 1 shows that there is no method which is rated "good" for all the attributes. In particular, false alarm appears to be a common problem for all the techniques except the biological and sampling methods, which cannot monitor a pipeline continuously.

Comparison of the four software-based methods shows that flow change, mass or volume balance, and pressure-point analysis methods are easy to maintain and inexpensive to install, but they cannot estimate leak location and are not suitable for pipelines with operational changes.

The dynamic model-based method works during operational changes and can provide location estimate, but it requires a high level of expertise to maintain and is expensive to install.

To overcome the deficiencies of the above systems, research and development have been carried out to design a reliable and cost-effective leak-detection system. The result of this development work is a statistical pipeline leak detection system known as ATMOS PIPE.

ATMOS PIPE technology

ATMOS PIPE is a statistical pipeline leak-detection system, incorporating advanced pattern recognition functions. It has been developed at Shell by applying advanced statistical techniques to flow and pressure measurements of a pipeline. Variations generated by operational changes are registered and a leak alarm is generated only when a unique pattern of changes in flow and pressure exists (Zhang, 1993).

This statistical method does not use mathematical models to calculate flow or pressure in a pipeline, but it detects changes in the relationship between flow and pressure using measurement data available. As the system monitors a pipeline continuously it learns about continual changes in the line and flow/pressure instruments.

An optimum sequential analysis technique (sequential probability ratio test) is applied to detect changes in the overall behaviour of the inlet and outlet flow and pressure. It works based on the observation that although the control and operation may vary from one pipeline to another, the relationship between the pipeline pressure and flow will always change after a leak develops in a pipeline. For example a leak could cause the pipeline pressure to decrease and introduce a discrepancy between the inlet and outlet flow-rate. This leak-detection system is designed to detect such changes, i.e. pattern recognition.

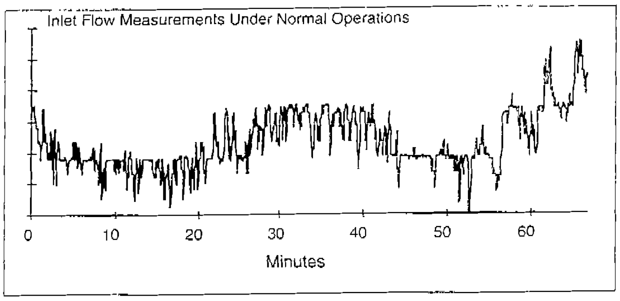
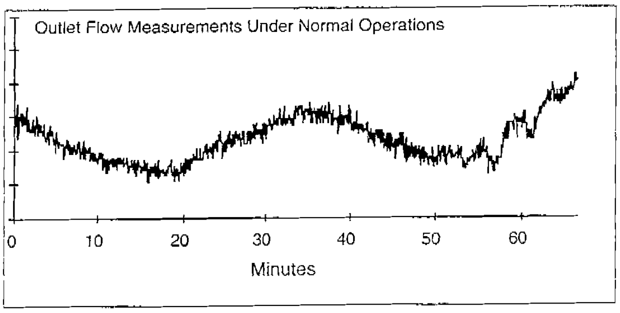


Fig.2 (above). Example of inlet flow measurement under normal pipeline operations.
Fig.3 (below). Outlet flow measurement correspondong to the conditions in Fig.2.



Field tests and real-time applications show that ATMOS PIPE is superior to the above methods. Some examples of the field tests are given below.

Liquefied propylene pipeline

Two 4-in diameter, 37-km long, liquefied propylene pipelines (lines A and B) run in parallel through a hilly area. The initial leak detection system was implemented in 1991 for line A only. In the summer of 1992 due to pipeline maintenance and pigging, line B was commissioned to transport propylene as well. Investigations showed that the system designed for line A was readily applicable to line B. Therefore with little effort the system was tailored to monitor either or both of the lines, including switching from one line to the other. Such flexibility has proven to be a major advantage of the system, compared with the conventional model-based systems. Significant time and money were saved by applying the Shell system to these pipelines.

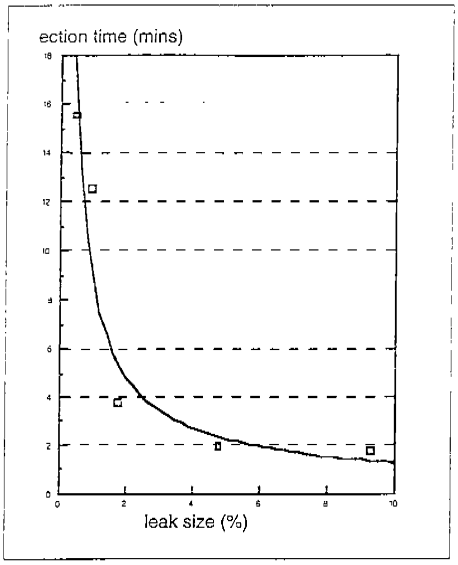


Fig.4. Leak detection time vs. leak size for propylene pipelines.

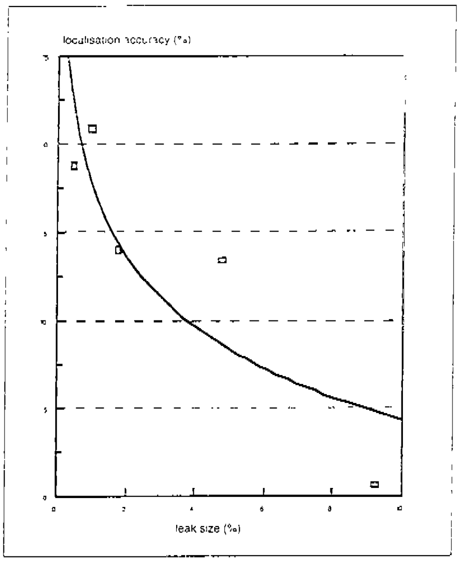


Fig.5. Localization accuracy vs. leak size for propylene pipelines.

Pipeline operational changes take place continuously as a result of upstream plant variations. As shown in Figs 2 and 3, both the inlet and outlet flow fluctuate significantly and the difference between them is non-zero. However no false alarm is generated by such operational changes or discrepancy between the instruments. Over the past five years of operation, a number of changes have been made in both the plant and pipeline operation, e.g. throughput increase by maximizing the plant's production, pigging, but the system has been running satisfactorily without any modification or false alarm.

Leaks with sizes from 0.5% to 9.3% were generated during field tests. The tests show that as the leak size increases, both the detection time and localization error decrease exponentially (Figs 4 and 5).

Low-pressure ethylene pipeline grid

The leak-detection system was installed on a low-pressure ethylene pipeline grid with diameters of 6in/8in and a total length of 40km. It was the first time the system was applied to a pipeline network. There are two possible suppliers to the pipeline and ethylene can be taken out of the line at two delivery points.

A number of controlled leaks have been generated on purpose to test the system since its installation. The minimum leak generated was 3% of the total throughput in the pipeline and was detected in 3 hours.

Note that this application was carried out without updating the old instrumentation system and the only additional equipment was a personal computer. Flow and pressure meters were available at the supply and delivery points but they were of poor quality. For example, the resolution of the pressure meter at supply 1 was 0.5 bar (Fig.6). Such low resolution did decrease the sensitivity of the system and hence leaks lower than 3% were not created during the tests.

Frequent operational changes took place in the pipeline and usually there was no 'steady-state' operation. As an example, Figs 6 and 7 show the flow and pressure measurements over an 18-hr period. No false alarm was generated during such operating conditions.

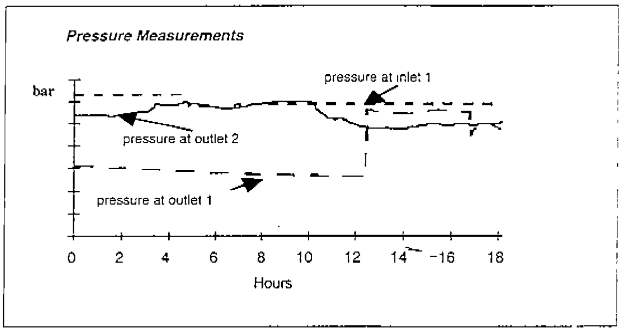


Fig.6. Pressure measurements during normal pipeline operating conditions.

Sour gas pipeline

The system implemented on the sour gas pipeline was intended for field tests only. The total pipeline length is 73km and the line diameter is 18in. In addition to the pressure and flow measurements at the inlet and outlet of the pipeline, pressure measurements are available at the five valve stations along the pipeline.

During the field tests, ten leaks were generated at two locations: 45km and 60km from the inlet.

The minimum leak generated was 0.7% of the throughput and the maximum detection time was two hours. The system was successful in detecting all the leaks and the leak-size estimate was satisfactory. The field tests illustrate that only marginal changes occur in the detection time as the leak location changes from 45km to 60km.

Natural gas liquid pipeline

A study was carried out for a natural gas liquid pipeline. The pipeline is 220km long with a diameter of 22in. In total, 107 days of pipeline operating data were collected including flow and pressure at the inlet and outlet, and pressure at 21 valve stations along the line. During the data-collection period, ten leaks were generated with sizes ranged from 0.5 to 1.7kg/s. The leaks were generated at different sites: inlet end, outlet end, and middle of the line.

From the collected data, it can be seen that the pipeline experiences a lot of operational changes. Fig.8 illustrates that although the flow has changed by more than 20% between 18:00 and 21:00 hrs, the corrected mass imbalance term has a relatively-constant mean as a result of the inventory change corrections.

The test of ATMOS PIPE on the 107 days' data demonstrates that the system can detect leaks greater than 1.6kg/s without generating false alarms. The main conclusions of the study are:

- The same leak detection results have been achieved with or without any intermediate measurements between the inlet and the outlet.
- Significant reduction in capital investment and maintenance costs is expected by reducing the number of instruments required. It is not realistic to detect leaks lower than 1kg/s without false alarms, due to the relatively-low repeatability of the existing instruments.
- It is more cost effective to install high-quality flow and pressure instruments at the inlet and outlet only than to have poor-quality instruments at all valve stations as well as at the inlet and outlet.

Conclusions

Statutory regulation demands that automated leak-detection systems are installed for new and upgraded pipelines. To design a cost-effective system, it is necessary to improve the performance of existing techniques. Intensive research and development at Shell have produced a novel statistical leak-detection system, which is marketed as ATMOS PIPE. Operational experience and a number of field tests illustrate that this new technology is cost efficient in terms of capital investment (CAPEX) and operating costs (OPEX), it is reliable to run, and requires a low level of expertise for maintenance.

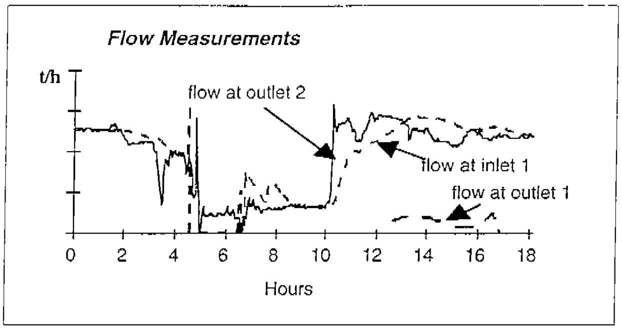
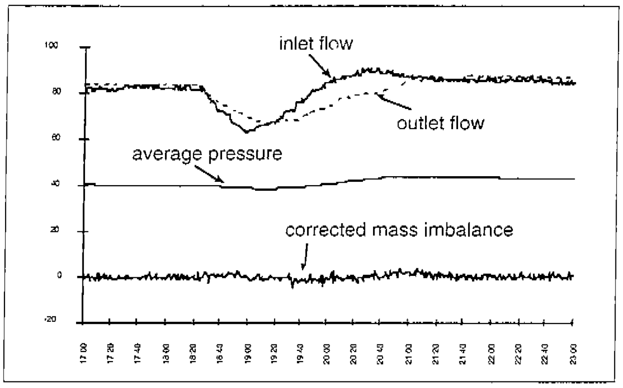


Fig.7 (above). *Flow measurements during normal pipeline operating conditions.*
Fig.8 (below). *Corrected mass imbalance dervied from flow and pressure measurements.*



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