OPERATIONAL PIPELINE INSPECTION

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The British Gas Corporation owns and operates 17,000 kilometres of high pressure gas transmission pipeline. Some sections of the system have already been in service for over 20 years and, based on current projections, most will be in regular use well into the next century.

Despite high standards of design, construction and operation, it must be anticipated that the integrity of a steel structure of this magnitude will be adversely influenced by many factors. It was recognition of this fact during the late 1960's that prompted British Gas to seek a means of monitoring the system's condition. After technical and economic studies, On-Line Inspection was chosen as the preferred method, and equipment developed to meet the required standards.

This equipment is now in routine use for the detection of metal loss from British Gas pipelines and more recently has been applied to similar needs in a number of overseas locations.

The paper describes operational aspects of on-line pipeline inspection.

1. INTRODUCTION

The British Gas Corporation owns and operates approximately 17,000 kilometres of high pressure pipeline to transmit bulk supplies of North Sea gas from its East Coast terminals around the country.

This transmission system is designed to operate at pressures up to 70 bar and, as a relatively new high pressure welded steel system, contrasts with the 250,000 kilometres of low pressure gas distribution system, mostly based in urban areas, that has grown slowly since Victorian times. A map of the system is shown in Fig. 1.

Notwithstanding its relative newness, some sections have now been in service for over 20 years and, based on current projections, most of it will be in use well into the next century. In the mid 1970's, therefore, once the construction standards for the new transmission system were well established, increasing attention within the Corporation's Engineering Research Station began to be paid to the methods that could be used for long term condition monitoring of the system.

I propose to describe the monitoring system and inspection equipment that has been developed by British Gas in response to this problem but, before doing so, it is worth enlarging a little on the limitations of the pre-existing methods of monitoring long pipelines.

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2. CONDITION MONITORING OF PIPELINES

A transmission pipeline which has been designed, constructed and tested in accordance with an adequate construction code and appropriate component manufacturing standards, should be free from significant defect at the time of commissioning.

To ensure its continued fitness for purpose requires:-

(a) that the pipeline continues to be operated within its design envelope (in which due regard should be given to the possibility of fatigue);

(b) that it is protected from any time-dependent degradation processes. These are primarily: corrosion, external interference and ground movement, either natural or man made.

For pipelines it is customary to check the performance of protective measures using inferential techniques such as monitoring the current flows in the cathodic protection system and by Pearson and electrical potential surveys. Potential sites of physical damage are monitored by regular aerial surveys of the pipeline and by regular liaison with farmers and others with access to the right of way.

Despite being useful, the effectiveness of such methods is certainly not total. As the operational life of pipelines increases, therefore, uncertainty over their actual structural condition will increase, possibly to the point where random failures start to occur. To prevent this condition actually being reached, it is necessary at intervals to have a fundamental 'audit' of the actual condition of the pipeline.

The normal means of carrying out such an audit for pressure vessels is, of course, by means of a hydrostatic pressure test.

However, the extension of this practice to buried high pressure pipelines is associated with severe practical, logistic and safety problems.

The problems of regaining access to the right of way for major works, restricting public access, decommissioning, sectioning, testing, disposing of contaminated water etc., are in themselves quite severe but, for an industry that has a statutory requirement to ensure continuity of supply, tend to be less significant than the problem of duplicating and reinforcing the network to permit this continuity to be maintained during testing.

When the development of an on-line inspection system was being considered in the mid 1970's, it was estimated that the capital cost of such a reinforcement of the transmission system would be in excess of £600 million.

In addition to the practical and financial aspects referred to above, there is also a more fundamental objection to the hydrostatic testing of pipelines. This is that a hydrostatic test gives no information on the population of sub-critical defects present at the time of the tests that survive and may continue to grow.

For a conventional vessel operating in a well controlled environment, and which will be given a visual inspection and manual NDT check of critical areas to supplement a hydrostatic test which will be repeated at intervals that are short compared to any growth mechanism present, this is not a major problem. However, for a buried pipeline with many factors that can affect the efficiency of even a well maintained CP system, the absence of this information is a significant limitation of hydrostatic testing.

These factors strongly indicate the desirability of using some type of on-line inspection or condition monitoring system provided it can reach an equivalent functional standard to that provided by a hydrostatic proof test.

The effectiveness of on-line inspection systems which can indicate the rate of deterioration of a pipeline goes beyond inspection. Such a method makes it possible to control deterioration by making adjustments to the CP system in affected areas at an early stage, removing artefacts inducing current drain from the pipe backfill, and repairing coating damage where it has occurred. The life of a pipeline may thus be prolonged considerably over its original design life.

In practice, the only type of system that will meet the on-line operating requirement is a free running inspection vehicle propelled by the product flow. These are known in the pipeline industry as 'intelligent pigs'. 'Pig' is the traditional generic term applied for many years to the simple cleaning, gauging and batching devices driven down a pipeline.

3. SPECIFYING THE PERFORMANCE OF AN NDT SYSTEM FOR PIPELINES

The basic requirements of an on-line inspection system for the revalidation of pipelines can be formulated as follows. It must:-

(a) Detect all significant defects;

(b) Accurately locate the defects;

(c) Determine the defect size;

(d) Distinguish between true defects, spurious signals and natural pipeline features;

(e) Avoid interference with pipeline operations.

Items (a),(b),(c) and (d) can be considered as functional requirements and (e) as an operational requirement.

Because of the high cost of pipeline excavations in 'off the road' locations and the rapid loss of credibility that would be occasioned by abortive 'digs', it is impossible to over-emphasise the importance of avoiding spurious indications or normal pipeline design features being interpreted as defects. The only method of achieving this aim is to produce a high resolution inspection system that will permit accurate characterisation of both defects and normal design features without further exploratory work to validate the indications.

The implications, both for equipment design and method of operation, of avoiding interference with pipeline operations are far reaching. The national transmission system is designed for automatic operation by modern computer and telemetry equipment from a single control room and is therefore quite frugally manned. The 12 operating regions take gas from this system into their own high pressure network in a carefully programmed manner in accordance with their individual load predictions, again using automatic control equipment. The consequences of interfering with this carefully optimised network, with its enormous associated cash flows, must therefore be minimised.

The engineering and organisational implications of (e) can be summarised as follows:-

(i) Engineering

- The operating range must equal the distance between insertion points (pig traps) on the transmission network.
- The inspection equipment should gather all the information necessary in a single pass of the pipeline.
- The equipment should be physically compatible with the existing network and require no extensive modifications to the system to permit operation.
- The equipment should be operationally compatible with the network, i.e. it should be suitable for running at the normal pipeline operating pressure and temperature, at normal product speeds, and have a very low probability of causing an interruption to supply.

(ii) Organisational

- Except for planning and liaison, the entire operation should proceed with minimal support from pipeline operating staff.
- The launch into and retrieval of equipment from the pipeline should be a simple, self-supporting and routine operation.
- The turn-round time for data analysis should be short and the report to the operators made in straightforward engineering terms requiring no specialised interpretation or preliminary excavations.

4. SELECTING AN NDT SYSTEM

A review of the types of defect which occur in pipelines indicates that they fall into three main categories:-

(a) Geometric Damage - dents, ovality, wrinkles

(b) Metal Loss - due to corrosion and mechanical impact

(c) Crack-like Defects - plate rolling laminations, fatigue and stress corrosion cracks

No single NDT system will detect all three categories of defect.

Before embarking on an in-house development, a considerable review was undertaken of existing pipeline inspection tools, and a test loop was constructed for evaluation purposes. None of the equipment evaluated came near to meeting the five objectives outlined in Section 3 for most types of defect, and discussions with the manufacturers indicated that they were unlikely to be developed to the extent required in a reasonable timescale.

To minimise in-house development, however, it was necessary to make the best possible use of external expertise and it was decided to utilise a hybrid development strategy.

Accordingly, we have utilised, as far as possible, an existing commercial tool for the detection of geometric damage. The main thrust of in-house development was concentrated on producing a tool to detect and size metal loss defects, which were expected to constitute the major population. A magnetic flux leakage system was the technique chosen for this problem. Although a major factor in the choice of technique was ease of engineering implementation, the production of a serviceable system still presented a considerable engineering challenge.

A longer range development programme based on ultrasonics was also commenced, particularly targeted at stress corrosion cracks. The specialised NDT aspects of this programme were subcontracted to AERE Harwell, with the British Gas engineering involvement concentrating on ensuring that as much as possible of the pipeline vehicle and data collection equipment was common to the two inspection systems. This paper concentrates on the design and use of the magnetic metal loss system.

My colleague in his paper, Reference 1, has described the technical factors underlying the standards that must be achieved by an efficient pipeline inspection system. These have been related to the standards of defect detection achieved by hydrostatic testing. It is therefore possible to treat the detection standards as a performance specification for a non-destructive testing system that will be equivalent, from the point of view of ensuring structural integrity, to a hydrostatic test.

This inspection performance specification is given in Table 1. The defects are grouped into the categories listed above and thus cover the requirement for each type of inspection tool.

The design features of the pipeline network translate into a physical performance specification which a pipeline vehicle must meet if it is to survive and operate. The physical performance specification is given in Table 2.

TABLE 1

INSPECTION PERFORMANCE SPECIFICATION
(For Seam Welded Pipelines operating
at Stress Levels up to 0.72 SMYS)

INSPECTION SYSTEM	FEATURE	DETECTION SENSITIVITY	SIZING ACCURACY
Geometry Tool	Dent Depth	0.05D	±0.02D
	Ovality $\frac{D_{Max} - D_{Min}}{D_{Nom}}$	0.10D	±0.02D
	Wrinkling $\frac{D_{Max} - D_{Min}}{D_{Nom}}$	0.10D	±0.02D
Magnetic Metal Loss Tool	Pitting Corrosion*	0.4t	±0.1t
	General Corrosion	0.2t	±0.1t
	Circumferential Gouging	0.4t	±0.1t
	Axial Gouging	0.2t	±0.1t
	Repaired Damage	0.2t	±0.1t
Elastic Wave Tool	Depth of Cracking	0.2t	±0.1t
	Length of Cracking	0.2D	±0.02D
All Systems	Spuria	None to be classified as a significant defect	
	Defect Location	All defects to be located within ±1.5m irrespective of pipeline length	

t = Nominal pipe wall thickness
D = Nominal pipe diameter
*Corrosion affecting a surface area of pipe contained within a square of dimensions 3t x 3t is termed pitting

TABLE 2

PHYSICAL PERFORMANCE SPECIFICATION FOR INSPECTION VEHICLES

Pressure	Bar	7 - 70 (144)
Temperature	°C	0 - 40 (70)
Velocity	m/sec	1 - 4
Cup Blow over Pressure - Gas	Bar	3.5
Cup Blow over Pressure - Liquid	Bar	14 - 21
Debris (Liquid/Particulate)		To be assumed present
Minimum Pipeline Bore		95% of (smallest) nominal value
Maximum Step Change in Pipeline Radius		12.7mm subject to compliance with minimum pipeline bore
Valve Protrusion		Maximum 20mm on 60° segment
Minimum Bend Radius		3 pipe diameters on centre line
Back to Back Bend Segments		All combinations without mitres
Maximum Angle of Mitre Joints		11¼°
Branch Connections		Unbarred tees up to 60% pipeline diameter Barred tees up to 100% pipeline diameter
(Length of Vertical Sections)		(Unlimited)

() Offshore Requirements

5. INSPECTION VEHICLE DESIGN FOR THE MAGNETIC FLUX LEAKAGE SYSTEM

The inspection system is mounted on a vehicle designed to pass through the pipeline driven as a free piston by the product flow (gas or oil). Insertion and reception points (pig traps) are provided in the system at convenient points. These are not normally more than 80 kilometres apart on the British Gas system, although much greater distances may be encountered offshore or in continental systems. A typical pig trap installation is shown in Fig. 2.

The inspection vehicle must accommodate three main payloads:-

(a) The basic NDT sytem;

(b) The on-board electronics associated with signal processing and data recording;

(c) Power supplies.

These payloads have to be accommodated in a vehicle configuration that will pass down a transmission main, traverse forged bends and changes in bore up to 5% of diameter, without violent changes in speed. A protected environment is provided for the primary electronic packages. The rest of the vehicle must be suitable for either a pressurised gas or hydrocarbon liquid environment. The interior surfaces of the line are usually contaminated with a sludge composed of paint scale, corrosion product and sand that can give severe wear problems on components in sliding contact with the pipe. The constraints on equipment volume are quite severe. Although the vehicle can be subdivided into a number of linked modules, the overall length must fit into launch and receive traps of reasonable dimensions.

Great care is taken, both in preparation of the pipelines and in the vehicle design, to minimise the possibility of the vehicle blocking the line. Pipelines of a given nominal diameter vary significantly in their bore, partly because of design variations in wall thickness and partly because of normal manufacturing tolerances. Components of the vehicle contacting the pipe must therefore be sufficiently resilient, or on a resilient suspension, to cope with the bore variations mentioned above plus a safety margin.

Operation of inspection vehicles (or any other type of pig) in gas pipelines becomes progressively more difficult at low gas pressures. Variations in bore, surface condition and pipe inclination invariably produce variations in drag which, by interaction with the elastic driving medium, produce variations in speed. Although every effort is made to minimise the fluctuations, the inspection system must cope with quite large variations. A speed range of 1 to 4 m/sec can in fact be handled. At gas pressures below about 20 bar, the speed fluctuations may exceed this range and a vehicle with a servo-controlled braking system is used where necessary to minimise speed fluctuations.

The general configuration of the magnetic circuit for the flux leakage system is shown in Fig. 3. Steel bristles are used to couple the flux into the pipe wall and provide a smooth coupling over girth welds and other bore steps. To obtain a consistent, defect specific, signal that can form the basis for accurate sizing, it is desirable for the flux levels in the pipe wall to approach saturation. A circumferential ring of sensors to measure the leakage flux is positioned between the magnet poles. Consistency of signal strength makes it desirable to have all the sensors in a single plane and the optimum position is rather to the rear of the magnet centre line. Careful design of the sensor carrier is necessary to ensure a bounce free ride along the pipe surface and minimum lift at girth welds. The zone close to the girth weld is necessarily site wrapped with corrosion protection tape rather than factory protected and is thus the area that may be most vulnerable to corrosion. The sensor carrier design must therefore be such as to avoid a 'weld shadow' that is not inspected.

A typical configuration of an inspection vehicle is shown in Fig. 4. The vehicle shown has two modules. Three or four modules may be necessary on small pipe diameters and the overall vehicle length is largely governed by the volume of protected environment necessary to accommodate the on-board electronics and power supplies.

6. DATA COLLECTION AND RECORDING

Considerable effort has been given throughout the engineering design of the magnetic flux leakage hardware to produce a system capable of generating repeatable high resolution data with the potential to permit the characterisation of defects with sufficient confidence to replace hydrostatic testing. This data must be collected and recorded by a system of equal quality.

The volume of data generated is very large. In a typical inspection or 80 kilometres of 24 inch pipeline, a surface area of 3.2×10^9 sq cm must be scanned (considering both surfaces). Features of the order of one square centimetre are significant and several discrete readings may be required to size each feature. Additional data is required to record the axial and circumferential position of each feature. When operating at its maximum inspection speed, some 5 million bits of data per second are generated by the main inspection sensors and the axiliary position measuring systems.

To cope with both the absolute quantity of data and the data generation rate, some degree of on-board data reduction is required and a purpose designed microcomputer is carried by the vehicle to carry out this function. Fortunately, much of the pipe surface is free of either defects or structural features that generate significant signals. The on-board computer therefore is designed to digitise and temporarily store the signals arriving from the flux leakage sensors and test them for significance before passing the data in orderly batches to the tape recorder, whose speed it controls. During lengths of 'clean' pipe, the tape recorder may be held at 'zero speed' by the on-board computer, thus effecting a great economy in tape and a proportionate increase in inspection range.

This feature of the inspection system makes the inspection range to some extent a function of the condition of the pipe that is being inspected. Clean, featureless pipe will give a longer inspection range than corroded pipe. Increasing the sophistication of the on-board data discrimination programmes also gives scope for continuous increases in inspection range using essentially the same hardware.

Notwithstanding the data reduction carried out by the on-board computer, approximately 5×10^7 inspection readings remain to be stored to achieve the operating range specified for the inspection system. This data is recorded on a magnetic tape and special measures have to be taken to maximise the amount of data that can be recorded on a tape spool of limited size.

The On-Line Inspection Centre has funded the development of special environmental recorders with 42 tracks of data across 25 mm wide tape, in which each recording track is only 0.4 mm wide. Data is deposited along these tracks at a constant linear density irrespective of tape speed (rather than at a constant rate) to give a maximum packing density measured in thousands of bits per centimetre. Constant packing density is achieved even during the start, speed change and stop transients of the recorder when the tape is accelerating under the control of the on-board computer.

The on-board computing and recording equipment is energised by a system of rechargeable batteries. Although commercially available secondary cells are packaged into cylindrical assemblies compatible with the modular construction of the other electronic modules, the power supplies have still required a significant amount of development.

Protective systems are incorporated to automatically de-energise the rest of the electronics, particularly external harnessing and sensors, during the launch and receive operation when the vehicle could be, under fault conditions, in an incendive atmosphere. Also incorporated are systems which permit the on-board processing and recording units to be maintained in a standby mode during any desired portion of the journey through a long transmission pipe. This enables very long lengths of pipeline to be inspected by a multiple pass operation. Switching to the recording mode can be initiated by time, distance travelled or by low frequency radio pulse from a transmitter coil positioned above the pipeline.

The on-board data processing and recording units are shown in Fig. 5.

7. DATA ANALYSIS TECHNIQUE

At the On-Line Inspection Centre, the data recorded on tape during the inspection run is replayed via a process control type of computer on to standard computer tapes, which can then be analysed using one of the Centre's three main computers. These machines reformat and reorganise the data so that information from the various types of sensor is properly aligned and correlated with positional data.

The next process is to reject signals from normal, defect-free pipeline fittings such as welds and bends. Each fitting gives a particular shape of signal which can be identified, checked and then eliminated. If existing pipeline maps resulting from previous inspection runs are available, these are also used to verify and reject data. Significant sensor data is then presented in summary form on an electrostatic plotter for interpretation by trained operators. This form of output allows many parallel sensor traces to be plotted and quickly assessed. During this stage of the analysis, a detailed map of the pipeline is compiled showing the position of every weld and fitting. This is used to pinpoint the position of defects and to update the pipeline engineer's records.

Finally, a mathematical sizing model, used in conjunction with a computer graphics terminal, is employed to obtain a direct estimate of the size and shape of metal loss defects. This system is complemented by a comparative sizing technique based on an automatic search through a large library of known signals.

The data reduction techniques employed are designed to operate in a cascade fashion so that only the simplest operations are applied to the bulk of the inspection data, more complex steps being reserved for later stages in the analysis sequence. Using various software tools, the operator may search for particular types of feature, manipulate images on graphics terminals, and test new signal processing algorithms to identify any misclassification errors.

Inspection data must be preserved for comparison with subsequent inspection logs and as a historical record. Following the complete survey of the British Gas transmission network, a library of many thousands of computer tapes will have been built up, together with a corresponding back-up library.

8. DETERMINING INSPECTION FREQUENCY

Having developed an inspection system, it is necessary to have a rational method of determining how often it is to be used. British Gas operates a scheduling scheme to place pipelines in order of priority for initial inspection and to determine inspection frequency thereafter. The scheme is based on an algorithm for computing a 'priority number' for each element of the network that can be separately inspected.

The priority number is the product of factors contributing to probability of failure and factors contributing to the consequences.

Thus:-

$$\text{Priority Number} = (\text{Probability}) \times (\text{Consequences})$$

Each term on the RHS is determined by summing several individual factors that are separately assessed.

Thus we have:-

$$\text{Priority Number} = \left[(A+B+C) \times D\right] \times \left[(E+F)\right]$$

The individual factors are defined as follows:

A is the factor representing the probability of damage due to external interference. This is determined by a simple matrix combining three different wall thickness ranges and three types of ground use, with points allocated accordingly.

B is the factor for corrosion. This is obtained by summing points allocated to four factors, viz. cathodic protection system voltage, protection of the CP system against electrical interference and the effects of corrosive backfill, standard of protection within pipe sleeves at road crossings etc.

Each factor is classified into three standards: good, adequate or poor.

C is the factor for ground movement. The probable effects of mining subsidence, geological faults and river bed stability (for river crossings) are assessed and categorised as severe, moderate, light or none.

D is the factor for age and standard of construction. This factor is concerned with time related effects which might lead to failure and is applied as a multiplier to factors A, B and C. It also takes account of the improvement in standards of construction which have occurred as the British Gas grid has been constructed. Points are allocated according to the date when the pipeline was given a hydrostatic test and whether a proof test or a yield test was given at that time.

E is the factor for safety. This is dependent on the probable quantity of gas released in the event of a pipeline failure and the number of people likely to be affected. Factors are calculated according to the operating stress in the pipeline and the maximum population density along its length.

F is the factor for security of supply. Points are allocated according to the quantity of gas not supplied as the result of a failure on a typical cold winter's day or the number of domestic consumers cut off.

All these factors are combined as illustrated in Fig. 6, which also indicates the number of points allocated to each factor. A more complete definition of each factor, and the method of calculation, is given in Reference 2.

When computed, the priority numbers are ranked into three groups, as shown in Table 3. A high priority number indicates a high priority for the initial on-line inspection and a shorter interval between repeat inspections.

Priority Group	Priority Number	Maximum Inspection Interval (Years)
High	>900	2
Middle	300 to 900	6
Low	<300	10

Table 3: Current Maximum Inspection Intervals for On-Line Inspection

Feedback from the system can, of course, be used to adjust the priority number of any individual pipeline element or the overall inspection intervals applied to the system. Pipelines subject to special influences, such as a period of active mining, may also be given additional inspections.

9. FIELD OPERATIONS (PREPARATION)

Before running the inspection vehicle, a significant number of preparatory operations are carried out on the pipeline to clean it and prove that the line geometry is compatible with that of the inspection vehicle.

The first pig to be run is a simple single module tool with very flexible drive cups and a body with a high obstacle passing capacity. This ensures that there are no major buckles or obstacles in the line.

A commercial geometry measuring tool is then run to give an indication of the minimum bore existing in the pipeline. It is necessary to demonstrate that the bore is at least 95% of the nominal bore for which the inspection vehicle was designed.

A cleaning pig is then run to clear gross amounts of debris or liquids from the line. This pig is fitted with magnets to pick up any ferrous debris that could interfere with the operation of the magnetic inspection system. Several passes of the cleaning pig may be necessary to clear the line.

Two specially developed geometry checking tools are then run. The first is a single module tool with a deformable plate designed to indicate the presence of bends with radii tighter than those for which the inspection vehicle is designed. Any such bends must, of course, be removed before any further operations. The final proving run is carried out with a multi-module profile tool designed to represent each module of the inspection vehicle system. Deformable plates represent critical diameters. Undamaged passage of this tool, not longer than one week before the actual inspection operation, is the final check that ensures safe passage of the inspection vehicle. Both of these tools are designed to deform but continue to run if an obstruction is encountered.

Some of the preliminary operations can be omitted on well documented lines that are regularly pigged for normal operating reasons.

The tools used for these line preparation operations are illustrated in Fig. 7.

10. FIELD OPERATIONS (INSPECTION)

The inspection operations are mounted from the On-Line Inspection Centre's base at Cramlington, Northumberland. Self-contained teams of two or three technicians, led by an engineer, transport the inspection vehicle and launch equipment to a temporary base local to the launch site for a final physical and electronic check. A HGV, fitted with an integral hydraulic crane, is used for transport and off-loading.

The vehicles are loaded into the traps from specially designed adjustable stands containing a support tray and a hydraulically powered cross-head driven off the HGV power pack. Several tons thrust is required on the larger sizes of inspection vehicle to overcome the magnetic drag of the pig and the mechanical interference of the drive cups in the pipe.

Once the inspection system is launched, the launch equipment is transported to the other end of the inspection length and re-erected for vehicle retrieval, which is essentially a mirror image of the launch operation. A typical set of launch equipment is shown in Fig. 8.

The field crew is provided with an instrument van containing electronic diagnostic equipment to enable them to carry out pre- and post-run functional checks on the NDT and data recording systems. They are also equipped to carry out a quality check on the magnetic tape record and verify the distance inspected. The tape record is sent back to Cramlington for analysis and the field crew can then move on to the next operation.

Since both the launch and receive operations involve a potentially incendive gas/air interface, considerable attention has been given to ensuring safety during these operations.

The traps are purged with nitrogen after blow down for vehicle loading and again before repressurisation with gas. The electronics on the inspection vehicles are de-energised during the launch and receive operations by pressure switches which return power to the system when it is at full line pressure.

11. REPORTING AND RECTIFICATION

On receipt of the inspection tape at Cramlington, the recorder tape is replayed and reformatted on to computer tape for detailed analysis. Any potentially significant features are reported to the pipeline engineer by telex within seven days of inspection and a full report is despatched within 30 days.

Each significant feature is described separately and accompanied by a map giving precise locations. A computer produced pipe tally is also forwarded with the report as an aid to defect location. This tally lists all the fittings and pipe welds present in the line and constitutes an updated 'as built' record.

The report format and an example of a section of pipe tally are illustrated in Figs. 9 and 10.

The On-Line Inspection Centre's report limits itself to a neutral description of the features found. Classification of the feature into a defect requiring remedial action or otherwise is the responsibility of the pipeline engineer. British Gas has a comprehensive standard (Reference 3) to assist the responsible engineer in classifying the defect, prescribing remedial action and the method of implementation. Records of all repair actions are stored on a computerised data base maintained at the Corporation's Engineering Research Station.

12. CURRENT STATUS, FUTURE DEVELOPMENTS AND EXTERNAL OPERATIONS

To date, the On-Line Inspection Centre has inspected over 6,000 kilometres of pipeline and had over one thousand features confirmed by excavation.

Equipment is available to inspect 12, 18, 24, 30 and 36 inch pipelines, which represent the major mileage in the British Gas network. Production of intermediate sizes to inspect the remainder of the network is well in hand. About 90 operations per year are required to inspect the existing network.

British Gas now owns and operates offshore pipelines associated with the Morecambe Bay and Rough Fields. Special versions of existing inspection vehicles have been produced to cope with the somewhat different design conditions in these offshore pipelines.

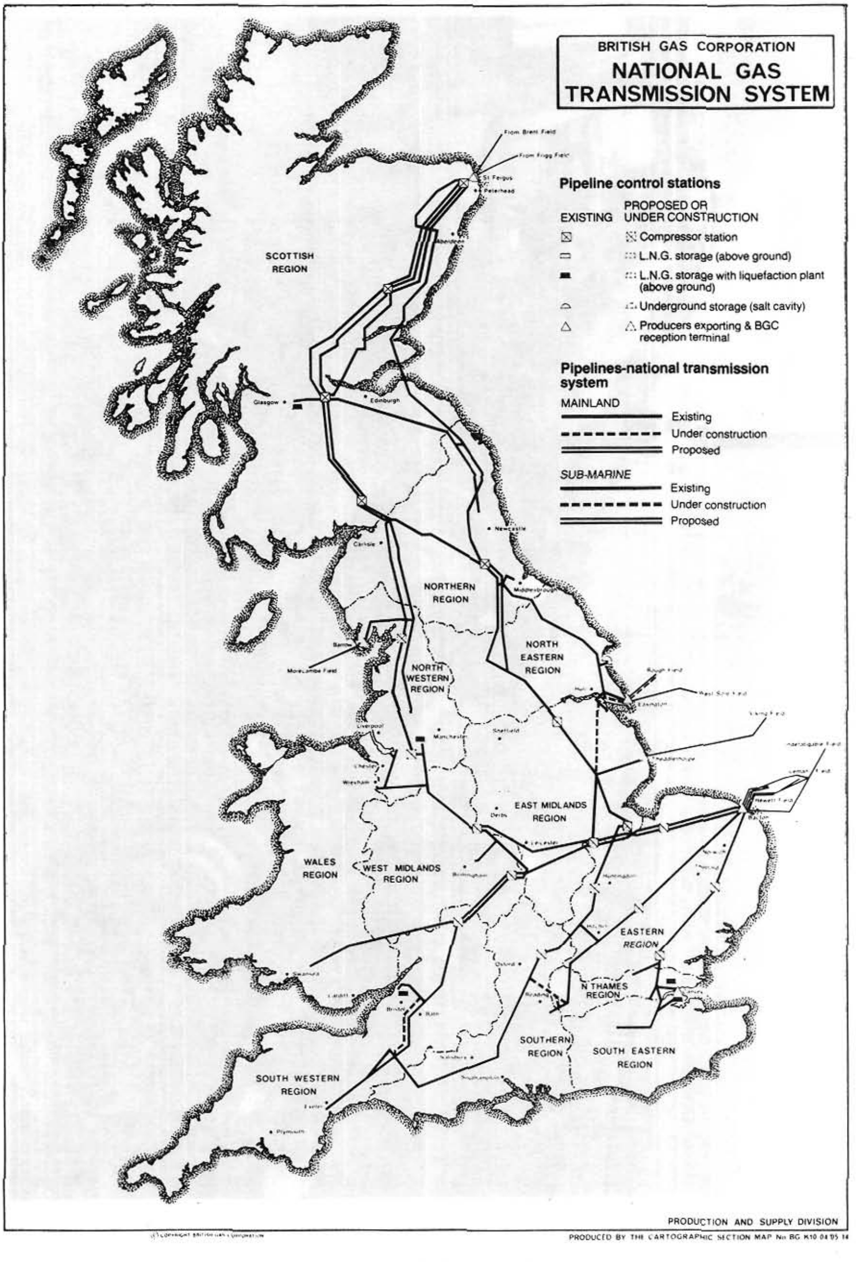
Although optimised for the inspection of the British Gas network, the equipment is suitable for operation in any high pressure gas or hydrocarbon liquid pipeline.

An inspection service is now being offered on a commercial basis to other pipeline operators and utilities. Gas pipelines in North America and Continental Europe have been inspected, together with crude oil and liquid product lines in the United Kingdom. Small changes to the vehicles have sometimes been necessary to ensure satisfactory operation in lines constructed to different design standards, but the basic technology has proved very adaptable.

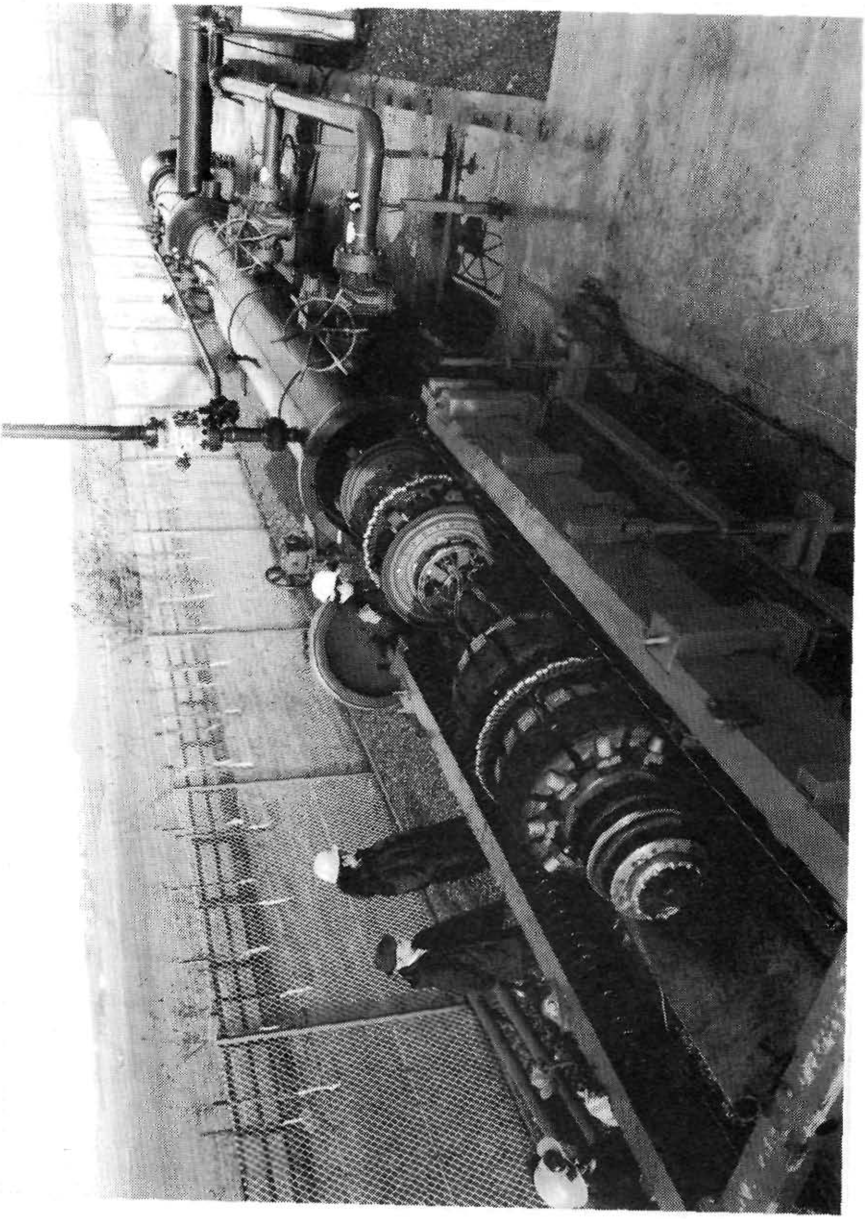
Combined development and inspection contracts are also being undertaken to produce equipment to customers' special requirements in pipe sizes not operated in the British Gas system.

LIST OF REFERENCES

Reference 1	Fearnehough G D Symposium on Assessment and Control of Major Hazards Manchester 22-24 April 1985
Reference 2	British Gas Corporation Engineering Standard BGC/PS/OLI1 February 1980
Reference 3	British Gas Corporation Engineering Standard BGC/PS/P11 December 1983



British Gas National gas transmission system **Fig. 1**



Typical pig trap installation

Fig.2

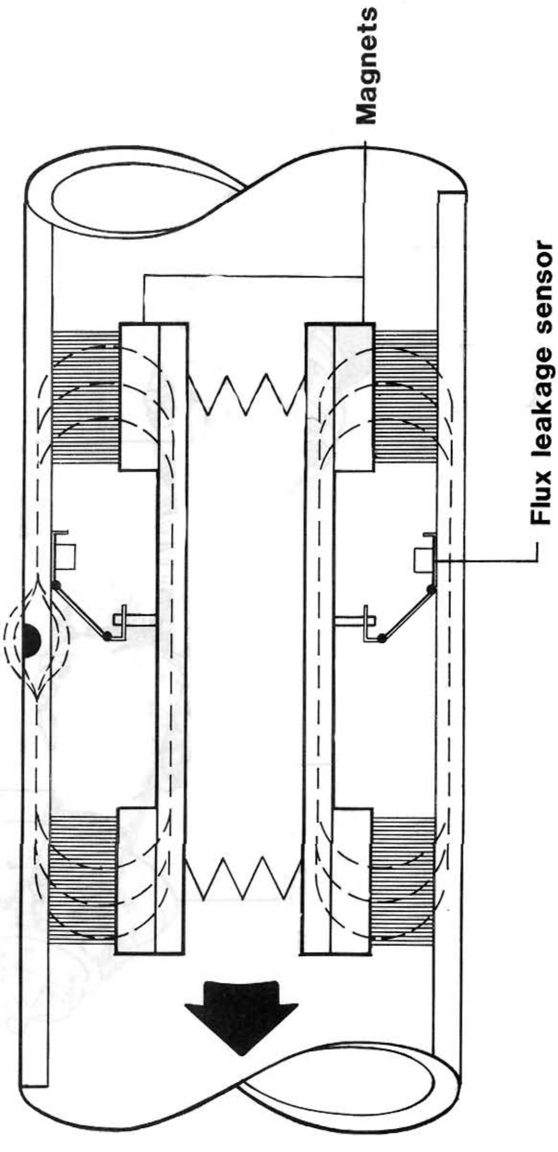
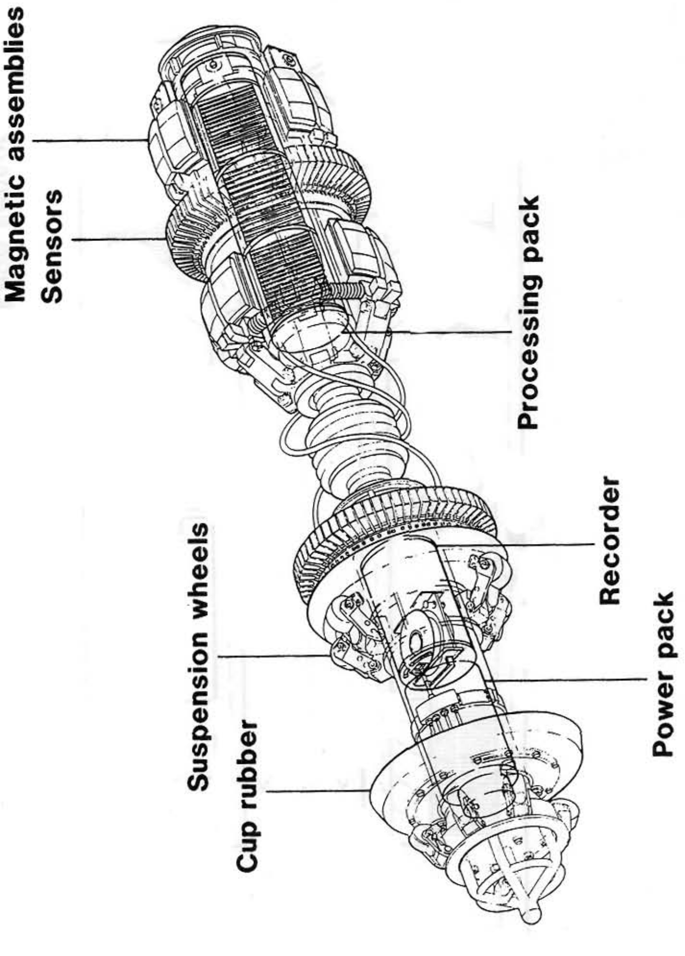


Fig.3

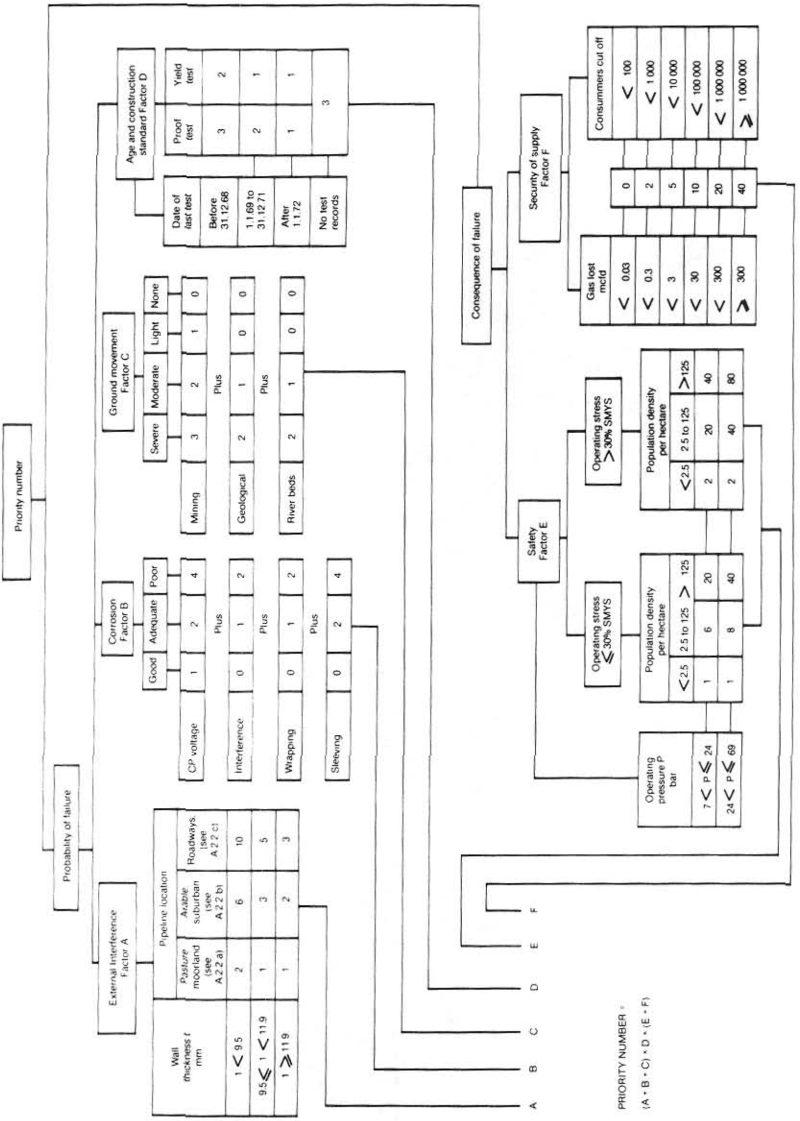
Magnetic circuit configuration for flux leakage system



Inspection vehicle configuration

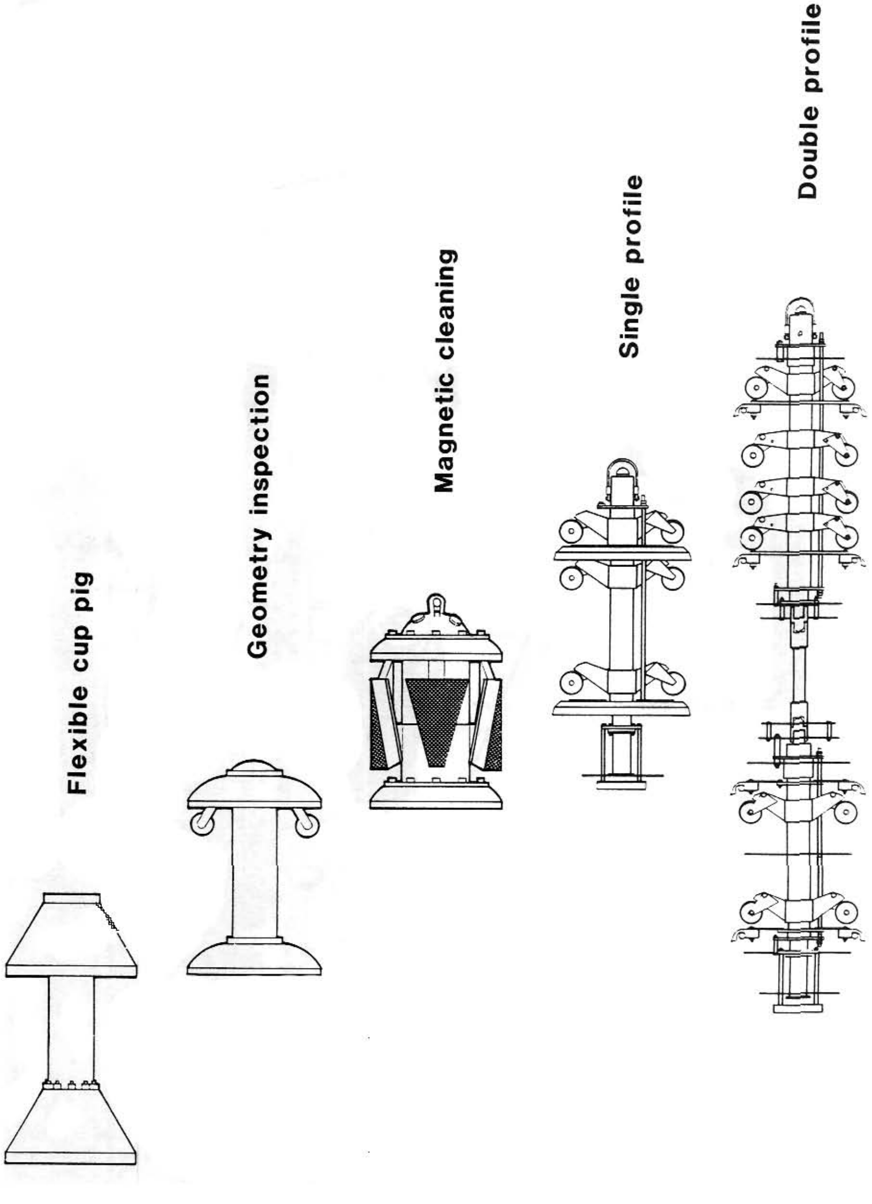
Fig.4

Fig.5 On board electronic processing and recording units



Priority rating scheme algorithm

Fig.6



Line preparation pigs

Fig.7

Launch / receive equipment

Fig.8

On Line Inspection Centre

PIPELINE INSPECTION SHEET NO: 1

FEATURE TYPE:	EXTERNAL METAL LOSS	RECORD REF:	
ORIENTATION: (O'CLOCK)	6.00	WELD COUNT:	2560 (+ 3.5m)

FEATURE DIMENSIONS (mm)

Axial	250 mm
Circumferential	450 mm
Depth	15% average with pitting up to 25%

LOCATION: OS Map Ref: OT 159 472 Sheet: 78 Strip Map No: WG 879

Reference:-

1. This reference is the centre of the 90° left side bend comprising 2 × 45° forged bends located on the north side of the A74 road crossing.
2. This reference is the downstream end of the sleeved B2403 road crossing.

Feature:-

Girth weld 2560 is located 51.6 m upstream from reference 1 and 98.4 m downstream from reference 2.

The feature is 3.5 m downstream from this girth weld.

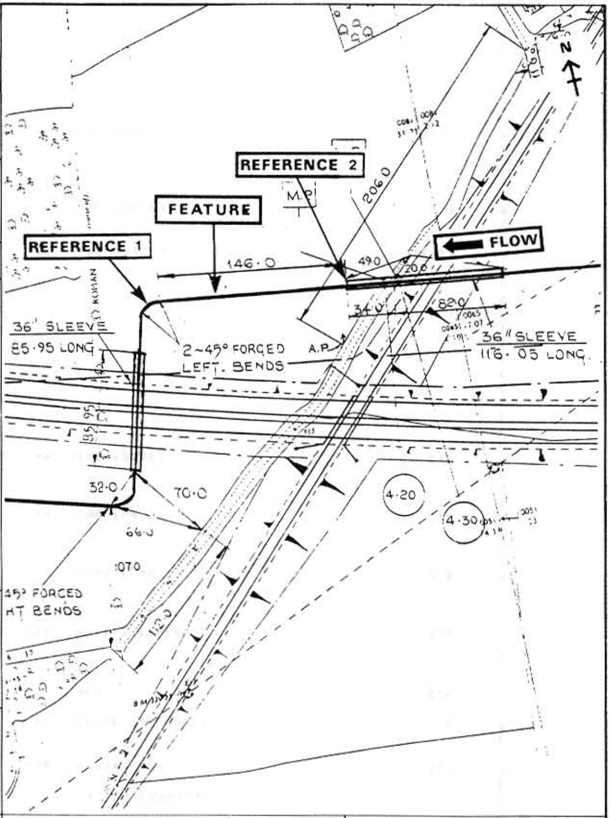
	← REFERENCE 2			FEATURE		REFERENCE 1 →					
Girth Weld No:	2540		2550		2560		2570		2580		2590
Seam Weld (o'clock)		10.30		1.30		10.00		2.00		10.00	
Pipe Section Length (m)		11.7		11.7		12.00		10.3		11.7	

FLOW →

COMMENTS:

The feature is characteristic of an area of corrosion containing some pitting.

OLI SR



DRG NO.

Reporting format

Fig.9

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PAGE   2        FILE: DEMO.PMS                                                                  MAP REF   SM 1/1

 REC   WELD  RELDIS          ABSDIS   CODE  DESCRIPTOR   COMMENT                    REFDIS    FEATDIS   SRCE

   1     10          0.0        2.3                       ASTON COMPOUND                                 C
   2     20          1.0        3.3                                                                      C
   3                 0.5        3.8   OFFT          450  OFFTAKE-FORGED                          1.5      M
   4     30          1.0        4.3                                                                      C
   5     40          1.3        5.6                                                                      C
   6                 0.3        5.9   OFFT           75  OFFTAKE-WELDOLET                        2.1      M
   7     50          0.7        6.3                                                                      C
   8                 0.0        6.3   VAL                VALVE                                   0.4      M
   9     60          1.3        7.6                                                                      C
  10     70          0.4        8.0                                                                      C
  11     80          1.3        9.3                                                                      C
  12                 0.5        9.8   OFFT          250  OFFTAKE-FORGED                          3.5      M
  13     90          1.0       10.3                                                                      C
  14    100          1.0       11.3                                                                      C
  15    110          1.3       12.7                                                                      C
  16                 0.0       12.7   JNT                JOINT FLANGED                           2.8      M
  17    120          0.6       13.3                                                                      M
  18    130          1.1       14.4                                                                      C
  19    140          1.7       16.0                                                                      C
  20                                  BD F  OVER     45  BEND-FORGED                             3.4      M
  21    150          1.3       17.4                                                                      C
  22    160          0.7       18.0                                                                      C
  23    170          0.7       18.7                                                                      C
  24                                  BD F  UNDER    45  BEND-FORGED                             2.7      M
  25    180          1.3       20.0                                                                      C
  26    190          1.3       21.4                                                                      C
  27    200          7.3       28.7                                                                      C
  28    210         13.3       42.0                                                                      C
  29    220         12.3       54.4                                                                      C
  30    230         12.0       66.4                                                                      C
  31    240          9.0       75.4                                                                      C
  32    250         11.0       86.4                                                                      C
  33    260         12.3       98.7                                                                      C
  34    270         12.0      110.7                                                                      C
  35    280         12.0      122.7                                                                      C
  36    290         11.0      133.7                                                                      C
  37    300         11.7      145.4                                                                      C
  38                                  BD F  LEFT     23  BEND-FORGED                           126.7      M
  39    310          1.0      146.4                                                                      C
  40    320          1.3      147.7                                                                      C
  41                                  BD F  LEFT     45  BEND-FORGED                             2.3      M
  42    330          1.3      149.0                                                                      C
  43    340          7.3      156.4                                                                      C
  44    350         12.0      168.4                                                                      C
  45    360         12.3      180.7                                                                      C
  46                                  BD F  RIGHT    45  BEND-FORGED                            33.0      M
  47    370          1.3      182.0                                                                      C
  48    380          6.3      188.3                                                                      C
  49    390          9.0      197.3                                                                      C
  50    400         12.0      209.3                                                                      C
  51    410         12.0      221.3                                                                      C
  52    420         12.0      233.3                                                                      C
  53    430         12.3      245.7                                                                      C
  54    440         12.0      257.7                                                                      C
  55    450         12.0      269.7                                                                      C
```

Computerised pipe tally

Fig.10