UNDERGROUND COAL GASIFICATION FIRST TRIAL IN THE FRAMEWORK OF A COMMUNITY COLLABORATION

CONTRACTS Nº: SF - 369/91 - ES/BE/UK
Nº: SF - 543/92 - ES/BE/UK

TECHNICAL REPORT
JULY 1993 - DECEMBER 1993

Management Group

A. BAILEY (DIRECTOR)

A. OBIS (DEPUTY DIRECTOR - OPERATIONS)

M. MOSTADE (DEPUTY DIRECTOR - TECHNICAL)

D. MARTINEZ (HEAD OF EXTERNAL AFFAIRS)

Underground Gasification Europe (UGE), AEIE
Calle Hermanos Nadal, 27 - 1º
44550 Alcorisa (Teruel), Spain

CONTENTS

Summary

The main activities during the period of this report have been the drilling and completion of the deviated injection well[IW1(ET4)], the completion of the basic engineering design of the surface plant, and most of the engineering design for the recovery well[RW(ET5)], the transverse injection well[IW2(ET6)] and the transverse monitoring well[MW2(ET2)].

The medium-radius deviated injection well[IW1(ET4)] was drilled and completed in October-November 1993. The objective of drilling an interval of length 100 metres in-seam was not fully realised because of the inability of the directional drilling company to achieve the required degree of directional control over the well trajectory. The well was completed successfully with the insertion of casing and liner in deviated and in-seam sections, and a length of approx. 90 metres is estimated to be available over which to achieve gasification.

Phase 1 of the Surface Plant Engineering was completed by JOHN BROWN SENER in August 1993. The final reports are two basic documents: the Process Data Book, and the Capital Cost Estimate and Project Time Schedule Book.

Two projects began in the supporting programme; a project at INSTITUTO DE CARBOQUIMICA on the pyrolysis and reactivity behaviour of the "El Tremedal" coal, and work at the TECHNICAL UNIVERSITY OF DELFT in the Netherlands on the thermo-mechanical behaviour of adjacent strata and modelling of the underground gasification process.

1. INTRODUCTION

This report is the fourth technical report of the Underground Coal Gasification project being conducted in North Teruel, Spain, with financial support under the EEC's THERMIE energy programme.

The drilling and completion of the deviated injection well in November 1993 was a key point in this reporting period. Although not achieving the total well objective in terms of the target length and location in the selected seam, an interval of approx. 90 metres of the well is estimated to be available over which to effect gasification.

The contract for the basic engineering of the surface plant was completed by JOHN BROWN SENER in August 1993. The results of this work will be used to define the requirements for the detailed engineering design of surface plant, and be followed by procurement/construction.

2. COAL ANALYSIS

Additional coal analysis was realised at INSTITUTO DE CARBOQUIMICA and INSTITUTO NACIONAL DEL CARBON.

INSTITUTO DE CARBOQUIMICA laboratory measured the ash composition of selected samples taken from the Upper Coal Seam in each exploratory well. Table I gives the average values per exploratory well.

INSTITUTO NACIONAL DEL CARBON laboratory realised the remaining Petrographic Analysis of samples from the exploratory wells ET2 and ET3. Table II presents the results.

3. DEVIATED INJECTION WELL[IW1(ET4)]

3.1 TARGET OBJECTIVES - DIRECTIONAL DATA

Gamma logs from the three exploratory wells ET1, ET2 and ET3 indicated a high gamma marker approx. 0.5 m above the Top of the Intermediate Limestone(see Figure 1) and it was decided to select this marker as the target horizon for the in-seam section, with the intention to try to use its detection by Measurement While Drilling(MWD) gamma as an additional in-seam locator. The following objectives were therefore set for the trajectory of the deviated injection well[IW1(ET4)]:

- First target location(target 1) at point 0.5 m above Top of Limestone, at expected seam inclination i.e. 59° 09´ to vertical.

Kick-Off Point(KOP)	+/- 396 m True Vertical Depth(TVD)
Inclination build-up rate	+/- 11.2 degrees / 30 metres
Target azimuth	+/- 184° 00´ relative to UTM North.
Horizontal displacement from spud to 1st target	+/- 75 metres
Well inclination in-seam	+/- 59° 09´
In-seam section length	+/- 100 metres

- Additional target positions 10 m(target 2), 40 m(target 3), 70 m(target 4) and 100 m(target 5) measured length along in-seam section from 1st target.

- Position of targets, base of coal seam with vertical error -0.5 m(Top Limestone), +0.5 m(1.0 m above Top Limestone).

- Azimuth range 182° - 186° relative to UTM North from spud location IW1(ET4).

- Target UTM co-ordinates(Target elevations 0.50 m above Top Limestone)

Spud	X: 718558.48	Y: 4532746.39	Z: 651.93(ref. sea level)
Target 1	X: 718553.26	Y: 4532671.59	Z: 123.90
Target 2	X: 718552.67	Y: 4532663.03	Z: 118.77
Target 3	X: 718550.87	Y: 4532637.34	Z: 103.38
Target 4	X: 718549.07	Y: 4532611.65	Z: 87.99
Target 5	X: 718547.28	Y: 4532585.96	Z: 72.60

The planned trajectory is shown in Figures 2a and 2b.

3.2 WELL DETAILS - CASING/COMPLETION PROGRAMME

Unless otherwise stated, all depths given in Sections 3.2 to 3.6 of this report are ***Depths from Ground Level****(i.e. from the concrete platform).*

In accordance with standard practice, the well was designed from the bottom up, the liner diameter and hole size in-seam controlling drilling and casing diameters in higher intervals. Although a 4.1/2" liner(6.1/8" diam. hole) was considered to be adequate for subsequent gasification, the required build rate was high(11.2° / 30 m, ~150 m radius) and it was considered prudent to incorporate an element of contingency into the drilling programme.

<u>Casing/Tubing Programme</u>

Hole (inches)	Casing/Tubing (inches)	Shoe TVD (m)	Shoe MD (m)	Inclination (degrees)
17.1/2	13.3/8	60	60	0
12.1/4	9.5/8	528	555	59
8.1/2	7 - 6.5/8	579	655	59
6.1/8(contin.)	4.1/2	579	655	59

The programme comprised 13.3/8" surface casing set at approx. 60 m True Vertical Depth(TVD)(below water table), 9.5/8" casing set at approx. 555 m Measured Depth(MD)(near to the floor of the coal seam), and a 7" tubing / 6.5/8" liner with control lines run to Total Depth(TD) at the end of the in-seam section. The planned completion of the well is shown schematically in Figures 3a, 3b and 3c.

First Contingency Programme (Inability to run 9.5/8" casing)

9.5/8" casing set high, 7" casing set into coal seam at 555 m, 6.1/8" hole drilled to 660 m, 4.1/2" instrumented liner set at 655 m.

Second Contingency Programme (Inability to run 7" tubing/ 6.5/8" liner)

7" tubing / 6.5/8" liner set in-seam before TD, in-seam hole re-drilled at 5.7/8" to 660 m, 4.1/2" liner set at 655 m with liner hanger in last joint of 6.5/8" liner.

Casing/Tubing Specification:

13.3/8"	54.5 PPF - K55 - BTC
9.5/8"	40 PPF - N80 - BTC
7" /	26 PPF - N80 - NEW VAM Special Clearance / cross over to
6.5/8"	20 PPF - L80/1 - NEW VAM Special Clearance /
	20 PPF - VS22 - NEW VAM Special Clearance for open hole section
4.1/2"	12.6 PPF - N80 - NEW VAM Special Clearance /) Contingency
	11.6 PPF - VS22 - NEW VAM Special Clearance) Programme

9.5/8" casing in base programme or 7" casing string in first contingency programme run with centralisers, float collar and float shoe.

7" tubing / 6.5/8" liner or 4.1/2" tubing / liner string in first contingency programme run with guide shoe, encapsulated instrumentation lines, protectors and centralisers.

4.1/2" liner string in second contingency programme run with guide shoe and liner hanger but without instrumentation.

3.3 DRILLING PROGRAMME, BITS AND FLUIDS

The selection and compatibility of rig and directional drilling equipment are important factors in successful high deviation drilling. The rig must have sufficient mast and drawworks capability, enough hydraulics to power the Down Hole Motor(DHM) and Measurement While Drilling(MWD) systems, and adequate mud control equipment to control mud quality for the desired combination of hole diameter, rate of penetration and strata. The assemblies for directional drilling must be predictable, controllable and reliable. The skill in directional control is the ability to predict the behaviour of assemblies over a range of operating parameters in different formations.

The main change from the drilling programme proposed in the previous report (period January - June 1993) concerned the drilling of the build(deviated) section of the well - the initial proposal for this section being to drill at 8.1/2" and to open the hole to 12.1/4" prior to setting and cementing 9.5/8" casing. The selected directional drilling contractor recommended that the hole be drilled directly in 12.1/4" to avoid the long duration and high cost of hole opening. It was appreciated that this recommendation would impose a greater demand on the rig's hydraulics and mud system, but the directional drilling company considered that the capability of the selected rig should be sufficient.

Method of drilling

The planned drilling programme was as follows:

17.1/2" to 60 m	-	Rotary
13.3/8" plug/casing shoe	-	Rotary
12.1/4" to KOP 60 m - 396 m	-	8" DHM/MWD(With rotation)
12.1/4" 396 m - 560 m	-	8" DHM/MWD(Oriented)
9.5/8" plug/casing shoe	-	Rotary
8.1/2" 560 m - 660 m	-	6.3/4" DHM/MWD(Oriented/Rotation)

A 4.3/4" Down Hole Motor(DHM) would be used to drill the 6.1/8" in-seam section in first contingency programme or to drill out the 6.5/8" liner guide shoe in second contingency programme.

Bits

Conventional rock roller bits were considered to be adequate for the drilling service, the lengths of each diameter hole interval being too short to merit the use of longer life PDC bits.

Standard tooth bits were selected for the vertical section, protected insert bits for the deviated section, and protected tooth bits for drilling in-seam. Table III presents the detailed bit specification related to the drilling programme.

Fluids

Simple Bentonitic spud mud was proposed for the initial 17.1/2" interval from surface to 60 m depth.

From the 13.3/8" casing shoe, the vertical and deviated sections would be drilled with a non-dispersed KCl polymer mud, to which would be added a lubricant for drilling the in-seam section. The target KCl mud properties were:

Density	1.08 - 1.12 kg / l
Funnel Viscosity	$>$ 45 s / qt
Plastic Viscosity	As low as possible
Yield Point	$>$ 15 lb / 100 ft^2
Filtrate	5 cm^3 / 30 min API
Sand content	$<$ 0.5%

In coal, the yield point would be maintained at a high level(approx. 18 lb / 100 ft^2), to assist cuttings removal.

3.4 SERVICE CONTRACTORS

The following contractors were selected for the operations, services and equipment involved in the realisation of the Deviated Injection Well[IW1(ET4)]:

• Civil works Concrete platform for the derrick Cellar and guide tube Channels to drain mud	MAURICIO VENTURA
• Drilling(Rig & Crew) Drilling 17.1/2" Casing and cementing 13.3/8" Drilling 12.1/4"	COFOR
Casing 9.5/8" installation Drilling 8.1/2"	+ WEATHERFORD
Tubing 7" / 6.7/8" installation Instrumentation installation Wellhead installation	+ WEATHERFORD/ VALLOUREC
• Directional Drilling & MWD	BAKER HUGHES
• Fluids(Mud) Provision of drilling fluids Fluids engineering	DOWELL IDF
• Casing/Tubing Supply of 13.3/8" and 9.5/8" casing Supply of 7" tubing / 6.5/8" liner Tubing installation assistance	VALLOUREC
• Cementing 9.5/8" casing	HALLIBURTON
• Wellhead supply	MALBRANQUE
• Logging Cement Bond Log(CBL)	SCHLUMBERGER
• Bits	SMITH / REED

3.5 OPERATIONS

3.5.1 Site Preparation, Procurement and Mobilisation

The site was prepared to accept the COFOR rig, a MASSARENTI 7000 MR Trailer rig with double derrick capacity, 300,000 LB hookload, Triplex pumps.

Although all instrumentation, materials and equipment for the well were procured and the site was ready to receive the rig by end-September 1993, unforeseen operational factors in a well being drilled by the rig in France prior to IW1(ET4) delayed the mobilisation to Teruel until late October.

3.5.2 Rig operations

The rig arrived on site 20 October 1993. The rig, pumps, tanks, shale shaker, desander, etc. were installed in the following days and the well was spudded 23 October.

From 23 October to 6 November 1993, the following operations were performed:

- Drilling	17.1/2"	0 - 62.8 m	23 Oct.- 24 Oct.
- Casing/cementing	13.3/8"	0 - 62.8 m	25 Oct.
- Drilling	12.1/4"	62.8 - 556.0 m	25 Oct.- 1 Nov.
- Casing/cementing	9.5/8"	0 - 551.55 m	2 Nov.
- CBL log		0 - 9.5/8" shoe	3 Nov.
- Drilling	8 1/2"	551.55 - 675.5 m	4 Nov.
- Tubing/liner insertion	7" / 6.7/8"	0 - 628.0 m	5 Nov.
- Wellhead Installation			6 Nov.

Table IV presents the Operating Time Distribution.

Actual depth/time progress is compared to the pre-spud estimate in Figure 4. The time required for 13.3/8" casing and cementing was much less than foreseen but this time saving was subsequently lost mainly due to MWD problems. The total time from spud to completion was 15 days compared to the estimated 14 days.

3.5.3 Vertical Interval 0 m - 62.8 m MD, 17.1/2" diam. (see trajectory in Figures 5a and 5b)

This interval was drilled in rotary mode with a standard pendulum assembly:

17.1/2" Bit
Bit Sub
17.1/2" Stabiliser
8" Drill Collar
X-Over
17.1/2" Stabiliser
8" Drill Collar to surface

Drilling parameters were:

Weight On Bit(WOB)	1 - 7 tonnes
Revolution Per Minute(RPM)	80 - 90
Flow rate	1500 - 2000 l / min
Injection pressure	35 kg / cm^2

Tertiary sands were encountered throughout the interval with which the shaker screens of the rig were unable to cope. Large overflows of mud were tolerated with drilling frequently suspended on nearing minimum active fluid volume. The mud was then pumped back through the screens before drilling was resumed. Inclination was 1/4° from vertical by TOTCO survey. 13.3/8" casing was installed and cemented.

3.5.4 Vertical Interval 62.8 m - 296.3 m MD, 12.1/4" diam. (see trajectory in Figures 5a and 5b)

Arrival of the directional drilling equipment was delayed by bad weather/snow conditions and after drilling out the 13.3/8" collar and shoe, it was decided to begin the drilling of the vertical section(through the Tertiary clays/marls and sands) with a rotary assembly, at least until the directional tools arrived. The following conventional two-stabiliser assembly was used:

12.1/4" Bit
Bit Sub
12.1/4" Stabiliser
8" Drill Collar
12.1/4" Stabiliser
8" Drill Collar(5 joints)
X-Over
6.1/2" Drill Collar(2 joints)
X-Over
5" Drill Pipe to surface

Drilling parameters were:

WOB	5 - 8 tonnes
RPM	100 - 110
Flow rate	1800 - 2000 l / min
Injection pressure	75 - 110 kg / cm^2

Flow rates and Rate Of Penetration(ROP) were limited by screen overflows in several parts of the interval. Bottom Tertiary red marls appeared at 293.0 m. At 296.3 m, it was decided to Pull Out Of Hole(POOH) and to complete the remaining vertical section to KOP with a DHM / MWD Bottom Hole Assembly in rotation mode. This decision was taken to prove operational ability of the DHM / MWD combination and to obtain MWD survey data for this section of the well.

Several parts of the hole were very tight on POOH requiring circulation and overpull up to 15 tonnes, possibly a consequence of the use of full gauge 12.1/4" stabilisers. After POOH, it was also observed that the two stabilisers were completely balled with clay, probably due to the insufficient inhibition. As a consequence, it was decided to improve the rheology of the mud by increasing the KCL content and by adding more polymer products. TOTCO inclination surveys were run every 50 m and gave 1/4° - 1/2° inclinations from vertical.

3.5.5 Vertical Interval 296.3 m - 393.0 m MD(KOP), 12.1/4" diam. (see trajectory in Figures 5a and 5b)

This interval was drilled vertically with the Down Hole Motor(DHM) used in rotation mode with the following Drill String Assembly(DSA):

12.1/4" Bit
12.1/8" Motor Stabiliser
8" Navidrill Mach 1 AKO motor - 0.6° bent housing
11.1/2" Nortrak Stabiliser
X-Over
6.3/4" NMHWDP(with MWD)
6.3/4" Pulser Sub
6.3/4" NMHWDP
5" HWDP(25 joints)
5" Drill Pipe to surface

Drilling parameters were:

WOB	6 - 14 tonnes
Bit RPM	215 - 250
Table RPM	~100
Flow rate	1800 - 2200 l / min
Injection pressure	75 - 110 kg / cm^2

MWD surveys were taken during Run In Hole. Drilling from 296.3 m MD was effected with DHM assembly in combination with drill string rotation to achieve verticality. A decrease of ROP at 314.7 m MD indicated the Top of Cenomanian; a sudden increase at 370.0 m MD indicated the Cenomanian-Albian boundary at exactly the expected depth. Drilling continued to KOP at 393.0 m MD. The MWD system failed to operate throughout the whole of this interval; on POOH the system was inspected and inlet ports to the pulser unit were found to be completely blocked with a material thought to be pipe scale. The bit used for the interval was completely worn out on POOH.

3.5.6 Build Interval 393.0 m - 556.0 m MD, 12.1/4" diam. (see trajectory in Figures 5a and 5c)

The bent housing of the motor was set to 2.35° to achieve kick-off and the required build rate, a new MWD was installed in the NMHWDP, and 12 joints of standard drill pipe were run behind the BHA for spacing. The initial BHA/DSA to drill this interval was therefore:

12.1/4" Bit
12.1/8" Motor Stabiliser
8" Navidrill Mach 1 AKO motor - 2.35° bent housing
(11.1/2" Nortrak Stabiliser)
X-Over
6.3/4" NMHWDP(with MWD)
6.3/4" Pulser Sub
6.3/4" NMHWDP
5" DP(12 joints)
5" HWDP(25 joints)
5" Drill Pipe to surface

Drilling parameters were:

WOB	3 - 20 tonnes
Bit RPM	140 - 155
Flow rate	2000 - 2200 l / min
Injection pressure	90 - 125 kg / cm^2

Drilling from KOP at 393.0 m MD was in oriented mode with Tool Face oriented to achieve the target azimuth. Tool Face stability required high WOB, resulting in relatively high ROP and flow, and these requirements(together with the fact that the whole of the build section was located in the Albian with extensive sands and clays) led to screen overflows even greater than those experienced in the vertical part of the well. Drilling had to be stopped at intervals of only 1.1/2 hours in order that the active tank be refilled by pumping mud from the pit back through the screens. MWD surveys were taken every joint.

ROP decreased almost to zero at 440.5 m MD and a motor failure was suspected. A further MWD fault appeared as soon as drilling resumed with a new motor and another trip was performed to change again the MWD unit. ROP with this assembly(second motor - third MWD) remained extremely slow and it was decided(at 445.0 m MD) to POOH to remove the upper stabiliser(Nortrak Stabiliser), it being suspected that the BHA was unable to flex sufficiently at the upper stabiliser location due to a bad distribution of forces between the stabilisers and the bit(the upper stabiliser was probably ledging within the soft formation). The stabiliser was removed, the motor bent housing reset to 2.2° and drilling resumed with expected ROP, albeit with screen overflows.

Drilling progressed smoothly for the remaining part of the build interval. First coal appeared on the shakers at approx. 510 m MD after only some metres of sand, and continued until the end of the build interval at 556.0 m MD, suggesting that the coal is 4 - 5 m thicker than expected(in vertical section) at the entry point of the well into the coal. A uniform combined thickness of overlying sand and coal seam can be explained on the basis of Paleochannel erosion. The required elevation, and azimuth were achieved at the first target at 556.0 m MD on a line parallel to and ~ 5 m to the west of the target trajectory. Well inclination of ~ 58° (extrapolated to bit) at the end of the build section was a little less than that of the target trajectory.

9.5/8" casing with centralisers was installed without difficulty, only the last two joints being a little difficult to introduce(probable caving conditions in the final coal section) and requiring circulation/weight to assist introduction. A total of 17 centralisers were used, the majority being in the deviated section.

The casing string was cemented by HALLIBURTON. Two types of cement were used - a lead slurry of 1.5 kg / l for the upper part of the well and a tail slurry of 1.9 kg / l with 40% silica for the lower part to give some protection against the high temperatures foreseen at the lower part of the well. The plug failed to bump, and surface cementing was carried out down to a pre-located cement basket installed as a precaution to overcome such an eventuality. The cementing plugs and float collar were drilled out, the hole was cleaned and a CBL log was run by SCHLUMBERGER which confirmed an excellent quality cementing of the bottom section of the well(556 - 400 m MD), a medium quality cementing of the intermediate section(400 - 75 m MD) and a poor quality cementing near to surface. The bottom section corresponds to the section cemented with the refractory tail slurry. Gamma markers within the Albian/Aptian were visible from the Gamma Log with the exception of the gamma marker at the floor of the seam not crossed at the maximum depth of the Log.

3.5.7 In-seam Interval 556.0 m - 675.5 m MD, 8 1/2" diam. and Completion (see Figures 5a and 5d)

The float shoe and in-seam section were drilled with the following BHA/DSA:

8.1/2" Bit
8.3/8" Motor Stabliser
6.3/4" Navidrill Mach 1 AKO motor - 0.80° bent housing
X-Over
8" Nortrak Stabiliser
6.3/4" NMHWDP(with MWD)
6.3/4" Pulser Sub
6.3/4" NMHWDP
5" DP(27 joints)
5" HWDP(25 joints)
5" Drill Pipe to surface

Drilling parameters were:

WOB	2 - 14 tonnes
Bit RPM	90 - 210
Table RPM	~ 100(rotation mode)
Flow rate	1200 -1400 l / min
Injection pressure	45 - 70 kg / cm^2

On resumption of drilling from the 9.5/8" shoe at 551.55 m MD, Tool Face was oriented to drill up to recover the difference in inclination with the coal seam and coal continued to arrive on the shaker screens during the first 10 m of drilling but was then replaced by marls/limestone, suggesting that the hole had entered the immediate floor of the upper seam. MWD gamma and cuttings indicated a minimum of 8.45 m in coal from the 9.5/8" shoe before entering the seam floor.

At this point, it was decided to continue to drill with Tool Face oriented up to return to the seam. Although inclination began to increase, the build rate was inadequate to return rapidly to the coal and the well remained just into the carbonaceous limestone below the seam floor for a length of approx. 56 m, to 618.0 m MD. Subsequent MWD surveys showed that the gamma marker within the coal was crossed close to this location with an increase of build rate probably due to the coal/limestone interface(a major change of strata hardness). On the return of coal on the shakers and a high MWD survey inclination of 64.4°, some 5.25° greater than the theoretical seam inclination(both events being detected with delay because of bit - MWD sensor spacing and cuttings return time respectively), Tool Face was oriented down to attempt to stay within the coal seam. The response of the assembly proved to be inadequate to enable sufficient build in the downward direction, inclination of the hole continued to be excessive and after remaining in seam for approx. 24 m the hole entered the seam roof at approx. 642 m MD .

Drilling continued with toolface oriented down until 675.5 m MD, and although inclination decreased, the fall off was insufficient to bring the hole back into the coal. At this point it was decided to stop drilling and to assess the value of the hole for subsequent gasification operations.

Side-tracking was considered to be undesirable, increasing the potential difficulty for subsequent liner insertion. The location of the trajectory just into the floor of the seam was considered not to be a serious impediment to gasifier development provided that the CRIP points of ignition/injection were within or very close to the floor of the seam. Over 30 m of the well behind the 9.5/8" shoe is located in coal and it was considered a possibility that part of this section could be utilised for gasification.

A revised gasification plan was proposed in which the product well/liner shoe would be located at approx. 628 m MD(injection well in the coal) and in which there would be only two CRIP injection points(at approx. 600 m MD and 540 m MD), resulting in a gasifier of total length approx. 90 metres.

To achieve this configuration, the 6.5/8" liner string(with instrumentation and centralisers/protectors) was installed to 628.0 m MD with a revised sequence of segmented liner to achieve the newly designated CRIP locations and provision for igniter protection(see Figure 6). The insertion of tubing/liner was realised without difficulty, only the last joint being difficult to introduce and requiring circulation/weight to assist introduction as required for the 9.5/8" casing. Again, caving conditions inside the coal section may explain these difficulties.

Cleaning was effected by circulation, a 10 m^3 viscous pill, and 15 m^3 of clean water. Finally the water was replaced by water with added inhibitor.

The wellhead was installed and the well was closed.

3.5.8 Bits and Mud

Due to the importance of the drilling and completion of the deviated injection well ET4 for the future of the project, it was decided to give careful attention to definition of the mud programme. This was prepared on the basis of the previous drilling and completion experience of the exploratory wells and the technical advice of the main international mud engineering companies.

The mud programme comprised basically a simple Bentonitic mud for the 17.1/2" surface hole drilling phase and a non-dispersed KCL polymer mud for all following drilling and completion phases(12.1/4", 8.1/2").

The services of a full-time mud engineer of DOWELL IDF were contracted to supervise the provision, preparation and maintenance of mud and additives during all drilling and completion activities.

The drilling and completion phases of the 17.1/2" surface hole were realised with a simple Bentonitic mud without problems. The mud properties did not suffer any important change during this phase. After drilling the plug/cement shoe, a viscous pill of approx. 4 m^3 was introduced to avoid contamination of the subsequent KCL polymer mud.

The non-dispersed KCL polymer mud had the following composition at the beginning of the 12.1/4" drilling phase:

Soda Ash	0.8 kg / m^3
Caustic Soda	1.6 kg / m^3
Bentonite OCMA	9 kg / m^3
KCL	76 kg / m^3
IDFLO LT	0.8 kg / m^3
IDPAC REG	6 kg / m^3
Defoamer	0.4 l / m^3
IDBOND	2.4 kg / m^3(added progressively after first circulation)

The initial mud properties were set to:

Density	1.05 kg / l
Funnel Viscosity	42 s / qt
Plastic Viscosity	12 cps
Yield Point	17 lb / 100 ft^2
Gel(0 - 10 min)	4 - 16 lb / 100 ft^2
pH	10
Filtrate	6 cm^3 / 30 min API

The first problem encountered was that of large overflows at the shale shakers installed with 100 mesh screens. To decrease the overflow, the screens were changed to 60/40 mesh with the result that mud density and solid content increased considerably. Eventually, mud density was controlled in the range of 1.15 to 1.17 kg / l and sand content to below 1 % by frequent partial dumping and corresponding make-up/addition of new mud. This procedure was applied throughout all drilling phases because of the high sand/clay content of the formations crossed.

With the 60 mesh screens, large overflows continued, particularly in the sand and coal parts of the deviated section. On reaching minimum active fluid volume, drilling had to be stopped in order that the active tank be refilled by pumping mud from the pit back through the screens.

The second problem encountered was a higher than expected absorption of K+ ions by the formation with consequent difficulty to inhibit clay activity. On POOH from 296.3 m, several parts of the hole were very tight and overpull up to 15 tonnes was necessary. The stabilisers were balled with clay, probably due to insufficient inhibition and it was decided to re-inforce the rheology of the mud by increasing the KCL content and the addition of more IDBOND and IDVIS polymer products. The subsequent POOH at 393 m was realised without problem, and was considered to be a consequence of the improvement in mud quality.

At the approach to the coal in the deviated interval, following the advice of the DOWELL IDF engineer, 6.7 kg / m^3 of THUSLICK was added to the mud. This material is a graphite and silicone powder and was used to minimise coal caving caused by drill string vibration and to improve the filtrate by the formation of a uniform and consistent cake. Also, the lubricant properties of the product reduced drilling torque.

As the consequence of all corrective measures, the composition of the mud at the end of the 12.1/4" drilling phase was:

Soda Ash	0.8 kg / m^3
Caustic Soda	1.6 kg / m^3
Bentonite OCMA	1.2 kg / m^3
KCL	93 kg / m^3

IDVIS	0.7 kg / m^3
IDFLO LT	7.9 kg / m^3
IDPAC REG	5.9 kg / m^3
Defoamer	0.1 l / m^3
IDBOND	2.4 kg / m^3
THUSLICK	6.7 kg / m^3

The 8.1/2" drilling phase began with a slightly different mud composition:

Soda Ash	1.2 kg / m^3
Caustic Soda	1.2 kg / m^3
Bentonite OCMA	7 kg / m^3
KCL	70 kg / m^3
IDVIS	1.2 kg / m^3
IDFLO LT	8.6 kg / m^3
IDPAC REG	4.3 kg / m^3
THUSLICK	13.3 kg / m^3

With the exception of density, mud properties did not change significantly during the short time period of the 8.1/2" drilling phase. A rapid increase of density from 1.08 to 1.12 kg / l was attributed to the tendency of the coal to be dispersed in fine particles in the mud. These fine particles were difficult to eliminate due to their very low specific weight($\approx$ 1.15). At the end of the drilling phase, a viscous pill of 5 m^3 was injected to clean the in-seam section of the well.

The bit report is presented in Table V. In general, the bits performed satisfactorily with the exception of the REED MHP13G bit which was used with drilling parameters outside the recommended range(excessive WOB and RPM) during the last vertical section before KOP. At POOH, this bit was observed to be completely worn out and the bearings nearly at their breakage point. The SMITH M1S bit used during the build section gave good results.

3.5.9 Main Operational Difficulties and Result Inconsistencies

Whilst rig hydraulics were adequate for efficient operation of the DHM and MWD systems employed, it was clear that the solids control equipment was less than adequate for the required service. In some formations, high ROP(in directional control as a result of the need for adequate WOB for BHA assembly performance and stability) resulted in the production of large quantities of sand/coal-laden drilling fluid. When this occurred, drilling was stopped on reaching minimum active fluid volume in order to avoid damage to the pumps. The initial design(8.1/2" + 12.1/4" hole opening) would have resulted in lower flows more able to have been handled by the system; another solution would have been to install additional mud equipment and pits to maintain a sufficiently high and clean active fluid volume.

The MWD system failed on three occasions and resulted in a significant loss of drilling time, the failures being attributed to:

(i) blocked inlet ports on pulser unit - cause unidentified but most likely to be a failure of the mud cleaning system or drill pipe condition/preparation.

(ii) lower part of MWD unit separated during operation, subsequently recovered from the motor dump valve - attributed to assembly error.

(iii) data transmission fault attributed to software configuration error.

The target trajectory of ET4 was designed on the basis of a planar seam disposition defined by the three seam locations in the logs of exploratory wells ET1, ET2 and ET3. On drilling ET4, surveyed TVD of the coal seam at in-seam Target 1(near to ET1) was in good agreement with the expected TVD on the basis of the ET1 Log.

Surveyed seam TVD in Vertical Section further along the in-seam interval of ET4(in the areas of ET2 and ET3) does not correlate well with that determined on the basis of seam location in ET1, ET2 and ET3(see Figure 5d). The distance of approx. 56 m drilled just below the coal seam(between entry to seam floor and re-entry to the seam) is greater than that expected for the seam dip of 30.85° derived from exploratory well logs. Vertical Section seam dip on the basis of the ET4 survey is 28.5° .

The inconsistencies of seam location can be explained on the basis of inaccuracy of trajectory information in the exploratory wells, the azimuth data obtained by dipmeter being relatively inaccurate for near-vertical trajectories. Non-uniformity of seam dip is also a possible cause of the apparent dip inconsistency.

The inclination of the well at the end of the build section was 58°, a little less than that of the Top Limestone(dip angle 59.15°). This factor, together with the knowledge that the hole had entered the floor of the seam, contributed to the decision to continue drilling with tool face up for perhaps too long an interval and to the excessive inclination(64.4°) on re-entry to the seam.

However, the most important problem in drilling operations was the inability to achieve the required degree of directional control to attain the desired target trajectory in the in-seam interval of the well. The reasons are (i) that the directional and gamma sensors in the(conventional) MWD tool were located 14.30 m and 11.64 m respectively behind the drill bit which always led to the late application of corrective action, and (ii) that the response of BHA´s is difficult to predict on crossing formation interfaces. The delay in application of corrective action would have been significantly reduced by the use of recently developed near-bit MWD tools, but only a few of these tools existed world-wide and none was available for this well.

3.5.10 Well Costs

The actual costs involved in drilling and completion of the well are compared with the pre-spud estimate in Table VI.

3.6 WELL COMPLETION

The completion of the deviated injection well ET4 was realised in three main phases: (i) the installation and cementing of the 9.5/8" casing string, (ii) the installation of the 7" tubing / 6.5/8" liner string and (iii) the wellhead christmas tree installation.

The final stage of well completion will be the coiled tubing string and head installation which will be realised prior to gasification operations. This equipment will be designed to fulfil the requirement for Controlled Retraction Injection Point(CRIP) manoeuvre use of the well.

9.5/8" casing installation and cementing

The casing string is a classical oil/gas well design, and comprises one float shoe, two joints of casing, one float collar and forty-one casing joints(the last joint is a pup joint) to cover the remaining length to the surface. Each joint is 9.5/8" - 40 PPF - N80 - Range3 with Buttress Thread Coupling. Seventeen centralisers and a cement basket near to surface were installed on the casing string. The positions of centralisers were determined by HALLIBURTON to optimise centralisation particularly in the build section of the well. The cement basket was used to carry out surface cementing because of the lack of cement in this interval during normal cementing operations(the plug failed to bump).

The installation was realised by COFOR with the services of WEATHERFORD for casing connection(screwing/make-up manoeuvre and torque control). After installation and cementing, the casing head was screwed onto the last casing joint/coupling. This casing head formed the base for the subsequent wellhead christmas tree installation.

Table VII gives the 9.5/8" casing components and the corresponding levels/positions in the well.

7" tubing / 6.5/8" liner installation

The installation of the 7" tubing / 6.5/8" liner was much more complicated than the 9.5/8" casing installation. The reasons for this complexity were twofold (i) an instrumentation cable was fixed/clamped to the external side of the tubing string during installation and (ii) NEW VAM Special Clearance couplings of the string necessitated special tools/tongs to make-up and control torque during installation. The total time to realise the installation was approx. 24 hours.

The instrumentation cable was designed to measure the temperature and the liner/cavity growth during CRIP manoeuvres and gasification phases. The cable is composed of four 1/8" type-K thermocouples and two single ended fibre optic cables. The fibre optics are Polyimide coated 50/125 optical fibre installed in 1/8" Stainless Steel protection sheets. Prior to delivery to site, the six 1/8" cables were encapsulated in plastic to form a flat cable(8 mm x 28 mm) for ease of installation.

The thermocouples will measure temperatures inside the underground reactor at four pre-determined points(positions: liner end and ≈ 33 m , ≈ 66 m and ≈ 100 m from liner end). The fibre optic cables will act as sensors in an innovative technique to measure the distributed temperature and cable length.

The optical fibre distributed temperature and cable length sensing is based on Optical Time-Domain Reflectometry(OTDR) in which laser light is pulsed inside the fibre and the backscattered light analysed. The Rayleigh component of the backscattered light is practically independent of temperature and will be used for measurement of the light decay curve and cable length. The Raman backscattered component is caused by thermally influenced molecular vibrations and will be used to obtain information on the temperature distribution along the fibre.

The installation was realised by COFOR with the services of WEATHERFORD and VALLOUREC for tubing/liner connections (screwing / make-up manoeuvre and torque control). A cable guide gooseneck, drum support, liner cable fixation/guiding shoe and protectors/clamps were specially designed and used for the instrumentation cable installation.

Attention was given to the material selection of liner joints. Normal L80 joints were installed in the foreseen reaction zones where the liner will be destroyed by combustion. VS22 joints were installed behind the foreseen CRIP locations to avoid back burning from these ignition/injection points, duplex alloy having the properties to withstand auto-ignition/reverse combustion in the presence of high pressure oxygen.

Table VIII gives the 7" tubing / 6.5/8" liner components and the corresponding levels/positions in the well. Figure 6 presents a schematic view of the in-seam installation.

Wellhead christmas tree installation

When the tubing/liner string was set in place, the wellhead spacer(previously suspended below the rig platform during string installation) was moved down onto the casing head while simultaneously pulling in the instrumentation cable. After spacer installation, the tubing was suspended on a tubing hanger(slip type) placed in the top of the spacer. The last tubing joint was then cut ~ 10 cm above the top level of the spacer, and a control line pack-off system and wellhead top spacer/flange completed the installation. The wellhead assembly is shown in Figure 7.

4. ENGINEERING

4.1 WELLS

Product well design continued, the results of analyses carried out by the Universities of Louvain-la Neuve and Liège in the supporting programme being taking into account. A preferred configuration of casing/tubing for the well has been established and materials availability/manufacturing capability are under investigation via technical enquiries to potential suppliers. KAWASAKI THERMAL SYSTEMS based in the United States may be the only supplier of insulated tubing to the desired specification. Initial estimates of delivery times for items in special alloys are 6 months or more.

4.2 SURFACE PLANT BASIC ENGINEERING

The contract for Phase 1 of the Surface Plant Engineering(Basic Design) was completed by JOHN BROWN SENER in August 1993.

The work comprised a review of the initial UGE surface plant design, and its progression in sufficient detail to obtain a cost estimate of detailed design, equipment selection and the procurement, installation and operation of all necessary plant and equipment.

The contract covered the following activities:

(a) Finalise PFD´s including mass balances.
(b) Compile utilities and effluents schedule.
(c) Prepare an agreed first issue of the plant Engineering Line Diagrams showing all equipment, instruments, pipelines, etc.
(d) Complete preparation of process data sheets and specification of package items, where necessary a first issue of mechanical data sheets.
(e) Prepare site plot plan and preliminary general arrangements.
(f) Prepare a plant equipment list including electrical, plant control, and other ancillary items.
(g) Prepare outline specifications for ancillary structures and other civil works, electrical facilities and a preliminary SLD, plant control, data collection, and safety instrumentation.
(h) Prepare outline specifications for piping, valves and other line fittings.
(i) Prepare a project plan for the design, procurement, installation and commissioning of the surface plant equipment.
(j) Prepare any drawings or documentation required for planning permission or by any other statutory bodies.

(k) Identify and progress critical plant items that need to be urgently progressed to meet the requirement of availability by the target start-up date.
(l) Prepare a cost estimate to an accuracy of ± 15% for the purchase or lease of all equipment.
(m) Prepare estimates for the detailed design, procurement, and construction of the surface works.
(n) Prepare detailed scopes of work for Phases 2 and 3 of the surface plant engineering (Detailed engineering, and Construction)

At the completion of the works, JOHN BROWN SENER produced two basic documents: the Process Data Book, and the Capital Cost Estimate and Project Time Schedule Book.

Process Data Book

The Process Data Book establishes the basis for the design of all the surface facilities required for the UCG trial at the "El Tremedal" site and includes all the standard sheets/drawings required to begin the detailed engineering(mass balance, PID's, process data sheets, site plot plan and preliminary arrangement, equipment list/specification, piping specification, instrumentation list, hazardous areas and fire water system).

The facility is designed to operate for approx. 6 months, 7 days per week, 24 hours per day, for a UCG reactor of about 10-15 MW thermal. The main gasification agent will be a mixture of oxygen and foamy water.

The surface plant will comprise four major areas(see Figure 8). These are the injection/utility area, the product gas disposal/sampling area, the office/control area, and the well area.

The injection/utility area, the largest area, will comprise nitrogen and oxygen tanks, pumps, vaporisers and surge vessels, argon storage, water/foam tanks and pumps, instrument air compressors and dryers, propane tanks, steam boiler and associated equipment, and utility/fire water plant. This area will include the plant and unloading facilities for propane, water, oxygen and nitrogen and will be situated on the lowest platform of the site.

The main components of the product gas disposal area will be the flare, incinerator, low flow vent package, foul water tank and the 2-stage product gas letdown system(low and high flow lines). The main component of the gas sampling area will be the product gas sampling/analysis trailer providing continuous sampling/analysis of the gas streams. In addition to this, a particle sampling unit will be installed for intermittent sampling of the gas stream. The product gas disposal/sampling area will be situated on the upper platform close to the recovery well location.

In the office/control area will be the Data Acquisition System/Control trailer, staff accommodation trailer and storage/working containers. This area will be located on the intermediate platform with direct access from the main field road. The location will offer good sight lines from the control room to all the functional areas. Platform crosswalks will allow personnel easy access from the office/control area to the injection/utility area and the product gas disposal/sampling area.

The well area is distributed throughout the site and will be composed of three process wells - the deviated in-seam injection well[IW1(ET4)], the transverse vertical injection well[IW2(ET6)], the recovery well[RW(ET5)], and two monitoring wells, the vertical well[MW1(ET1)] and the deviated well [MW2(ET2)]. All the process/monitoring wells will be serviced by process/utility pipe racks and/or instrument cabling racks. Each process well will also be surrounded by a flow control/metering unit to facilitate the control of fluids injection during all process phases.

The basic parameters of the surface plant are shown in Table IX and the process flow diagram is given in Figure 9.

Capital Cost Estimate and Project Time Schedule Book

The cost of detailed design, Phase 2, and the total investment cost of procurement, purchase/rental, construction and installation of all surface plant and equipment, Phase 3(excluding well and wellhead equipment) is estimated by JOHN BROWN SENER to be approx. 850 MPTA. A breakdown of the estimate is given in Table X.

With regard to the time schedule, JOHN BROWN SENER foresee a period of approx. 3 months required to carry out the detailed design work and to prepare final specifications and requisition sheets for purchasing. A procurement period of 3 to 6 months is estimated. The critical path at this stage covers the procurement of the cryogenic plants, the incinerator, the Data Acquisition System/Control unit and the product gas sampling/analysis unit. Construction is estimated to require approx. 3-4 months.

4.3 SURFACE PLANT DETAILED ENGINEERING AND CONSTRUCTION

Phase 2 of Surface Plant Engineering covers the completion of all detailed design work and includes equipment selection, data sheets, package unit specifications and requisition sheets for purchasing. Phase 3 comprises the procurement, construction and installation of equipment and plant, and extensive pre-commissioning.

Engineering companies will be invited to tender for Phases 2 and 3 of the Surface Plant Engineering now that the deviated in-seam well [IW1(ET4)] has been completed. Invitation to Tender will be issued in January - March 1994.

4.4 SUPPORTING PROGRAMME

Collaboration began with T.U.DELFT, the Netherlands, on three projects concerning UCG process behaviour. The projects are:

1. Thermo-mechanical stability of the overburden rock of a UCG cavity
2. Formation and behaviour of rubble
3. Channel gasification modelling

A contract was placed with INSTITUTO DE CARBOQUIMICA at Zaragoza to measure pyrolysis and coal char reactivities of the "El Tremedal" coal in laboratory experiments, and to model the combustion/gasification process to predict maximum in-seam temperatures as a function of operating conditions.

Determination of coal reactivities

Char samples will be obtained from a thermogravimetric analyser with the following pyrolysis conditions:

Heating rate	5° C / min
Max. Temperature	1000° C
Time at 1000° C	1 hour
Gas	Nitrogen
Gas velocity	8 cm / s

Reactivity experiments with O_2, CO_2 and H_2O will be realised with the char samples obtained in the previously mentioned conditions. Char granulometry will be in the range of 100 to 200 μm. Appropriate temperatures and gas mixtures will be used to facilitate the fitting of results to existing reactivity models.

A total of 36 tests will be realised.

Maximum temperature modelling

Maximum in-seam temperatures will be predicted for a range of operating conditions in a model which will take into account the kinetics of the different combustion/gasification reactions and the thermal properties of the char and surrounding rocks.

The model to be used will be the shrinking unreacted core model with char heating by conduction and radiation from the reaction front. The following set of reactions will be considered with their corresponding kinetics:

$$C + O_2 \Rightarrow CO_2$$
$$C + CO_2 \Rightarrow 2\,CO$$
$$C + H_2O \Rightarrow CO + H_2$$
$$C + 2\,H_2 \Rightarrow CH_4$$
$$CO + H_2O \Leftrightarrow CO_2 + H_2$$

The set of differential equations for the mass balance of each reactant and the heat balance of solid and gas will be set out and solved for different initial conditions, providing temperature profiles for gas and solid, and gas composition. The effect of operating variables on temperature profiles and the maximum temperature achieved in the solid will be simulated to determine the window of operating variables to avoid ash softening and melting.

Coal pyrolysis tests

Pyrolysis behaviour of the coal will be studied in a fixed bed reactor with coal samples of 100 - 250 g crushed to 4 mm. A heating rate of 10° C / min will be used. Heating will be in the absence of carrier gas in order to increase the residence time of volatiles in the coal bed. An additional isothermal period of 30 min will be applied at the maximum temperature.

A total of 15 tests will be realised.

The pyrolysis behaviour will be evaluated by the measurement of the following outputs:

- Product distribution
    - Char Yield
    - Tar Yield
    - Gas Yield
    - Water Yield
    - H_2, CH_4, CO, CO_2, C_2H_4, C_2H_6, H_2S, COS
- Calorific value distribution between tar, char and gases
- Sulphur distribution between char, gases and liquid
- Empirical correlation between char and gas yield depending on temperature and pressure

5. PROJECT DIRECTION

5.1 ADMINISTRATION

Vacancies for three additional staff were advertised in the press and at Universities in Spain in November. Interviews will be held in January 1994. The posts are in :

- Process control and modelling
- Data acquisition & control
- Field co-ordination

The conversion of the second floor of the office building was completed in October 1993.

5.2 PROBLEMS/DIFFICULTIES

The most important technical problem was the inability to achieve the required degree of directional control to attain the desired target trajectory in the in-seam interval of the deviated injection well[IW1(ET4)].

The objective of drilling an interval of length 100 m in-seam was not fully realised. However, over 30 m of the well behind the 9.5/8" shoe is located in coal and it is considered that part of this section can be utilised for gasification, resulting in a length of approx. 90 m being available over which to achieve gasification.

An issue which could affect future progress is the expected long delivery time for the procurement of some items of equipment for the product well.

5.3 CHANGES IN TECHNICAL STRATEGY

The location of part of the trajectory just into the floor of the seam should not present a serious impediment to gasifier development provided that the CRIP points of ignition/injection are located close to the floor of the seam. To achieve this configuration, it is proposed to realise only two ignition(CRIP) points in the gasification phase(in place of three in the initial plan).

5.4 FUTURE WORK

Engineering companies will be invited to tender for Phases 2 and 3 of the Surface Plant Engineering now that the deviated in-seam well[IW1(ET4)] has been completed. The invitation to tender is prepared and will be issued in January - March 1994. The work should commence in April - May 1994.

Invitations to Tender will be issued for the detailed design and construction of the Data Acquisition/Control Unit and the Gas Sampling/Analysis Unit. These Units will be separated from Phases 2 and 3 of the Surface Plant Engineering because they require specialist expertise, knowledge and resources.

Work on the pyrolysis and reactivity behaviour of the El Tremedal black lignite will continue at the INSTITUTO DE CARBOQUIMICA as part of the supporting programme.

Orders for special alloy and insulated tubings for the production well will be placed following technical advice and final analysis.

5.5 CONFERENCES, PUBLICATIONS AND REPORTS

- "Informe Geológico y de Perforación del Sondeo Tremedal 4"(80/IN/94/S)
  Internal report prepared by C. BARAT, A. OBIS.

- "Informe de Analisis de Cenizas"
  (UGE ref. 29/03.09.93)
  Report prepared by INSTITUTO DE CARBOQUIMICA, Zaragoza

- "Caracterización Microscópica y Ensayos de Hinchamiento y Carbonización de cuatro muestras de carbón"
  (UGE ref. 32/15.12.93)
  Report prepared by INSTITUTO NACIONAL DEL CARBON, Oviedo

- "ET4 Drilling and MWD Summary"
  (UGE ref. 33/13.12.93)
  Report prepared by BAKER HUGHES

- "Well Summary for Underground Gasification Europe Well: ET4"
  (UGE ref. 43/05.01.94)
  Report prepared by DOWELL IDF

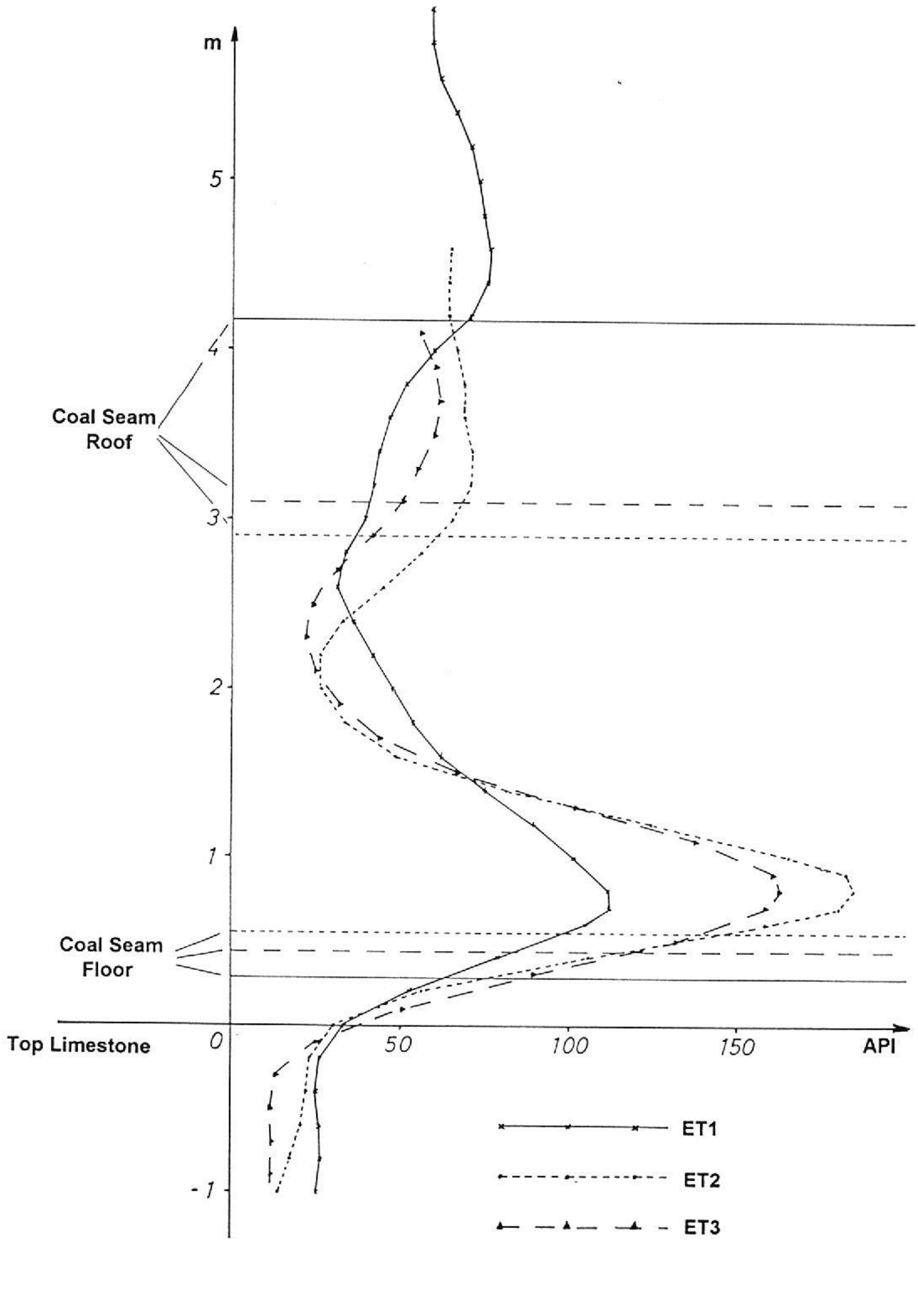


Figure 1 . Exploratory Well Gamma Profiles
(Elevation relative to Top Limestone)

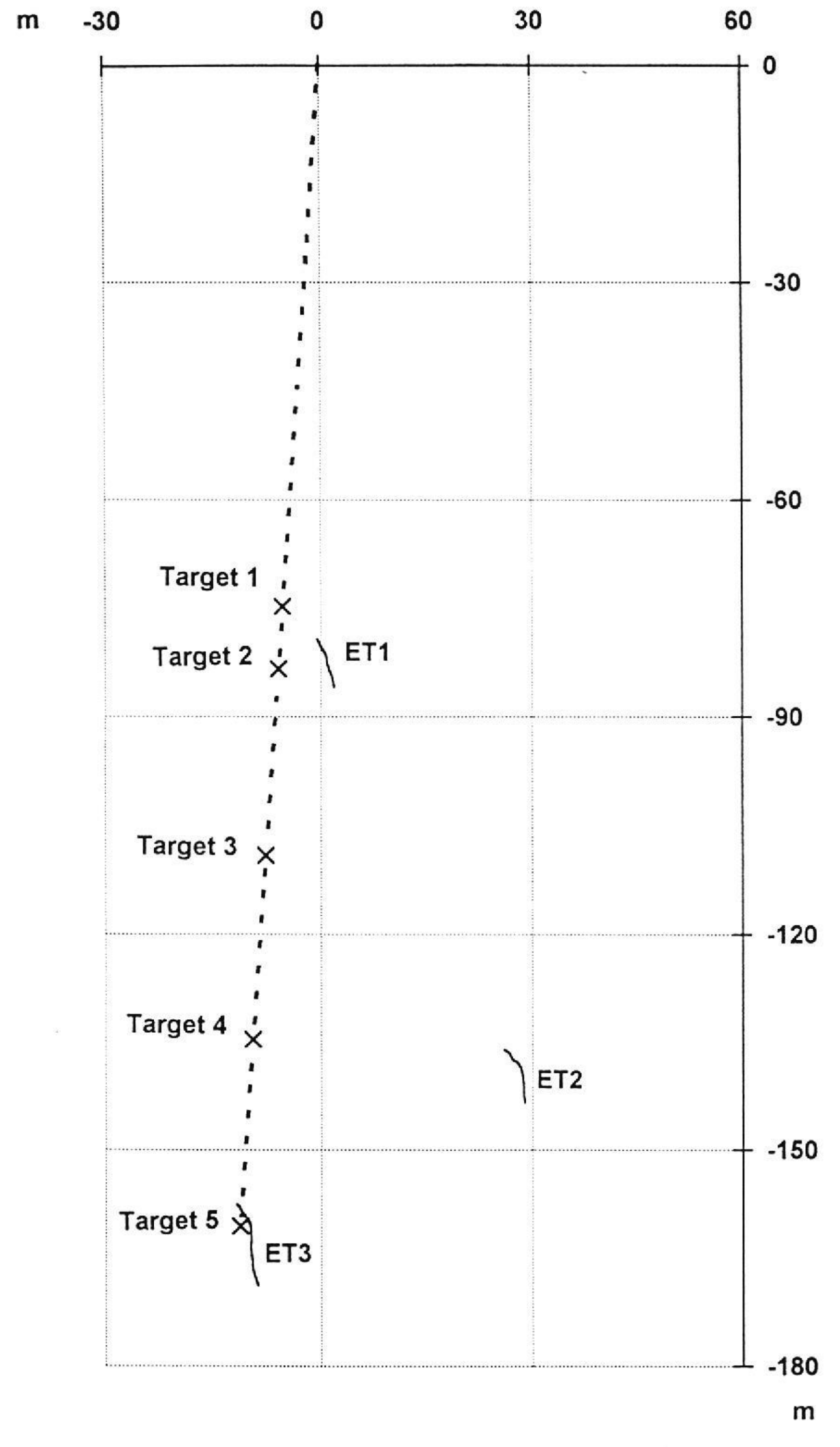


Figure 2a . ET4 Planned Trajectory(Horizontal Section)

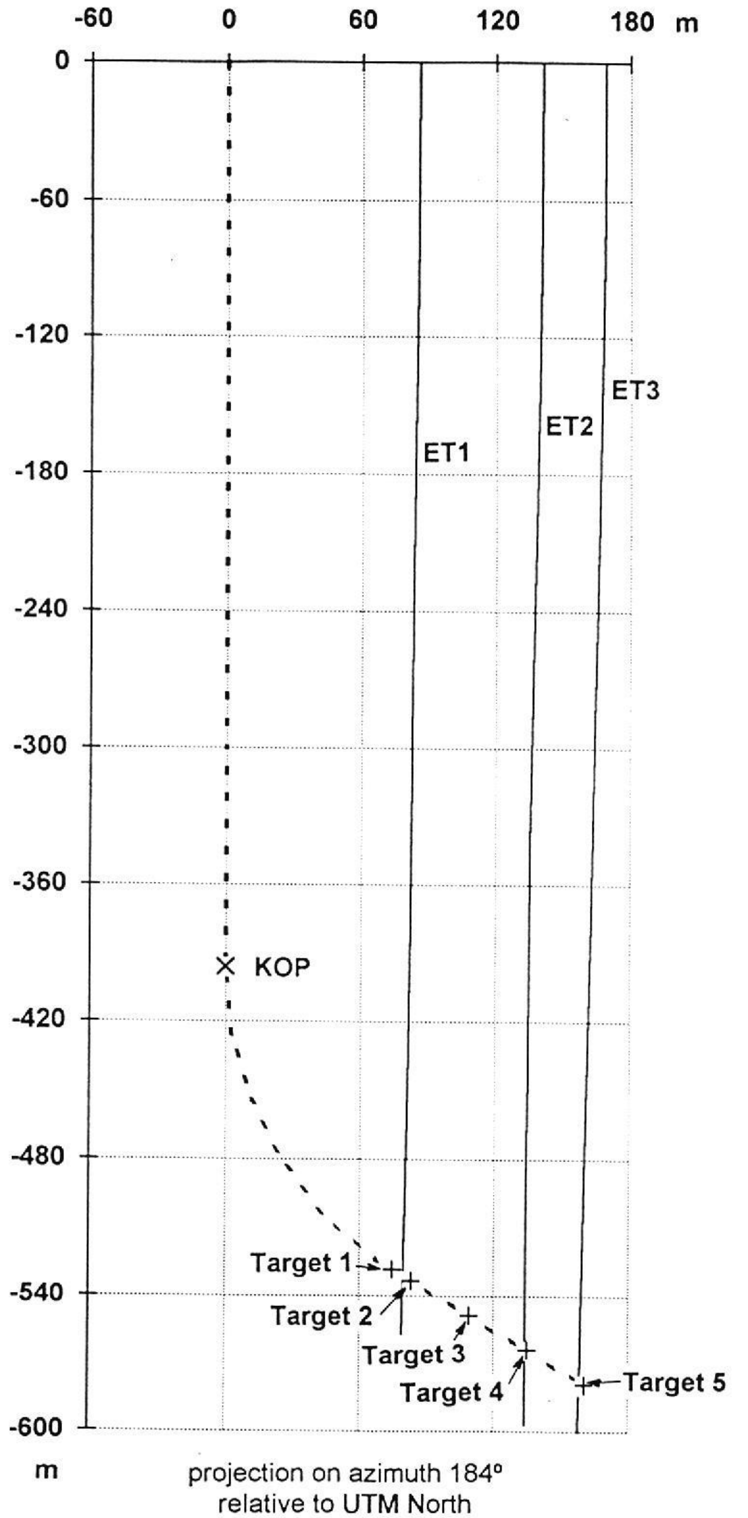


Figure 2b . ET4 Planned Trajectory(Vertical Section)

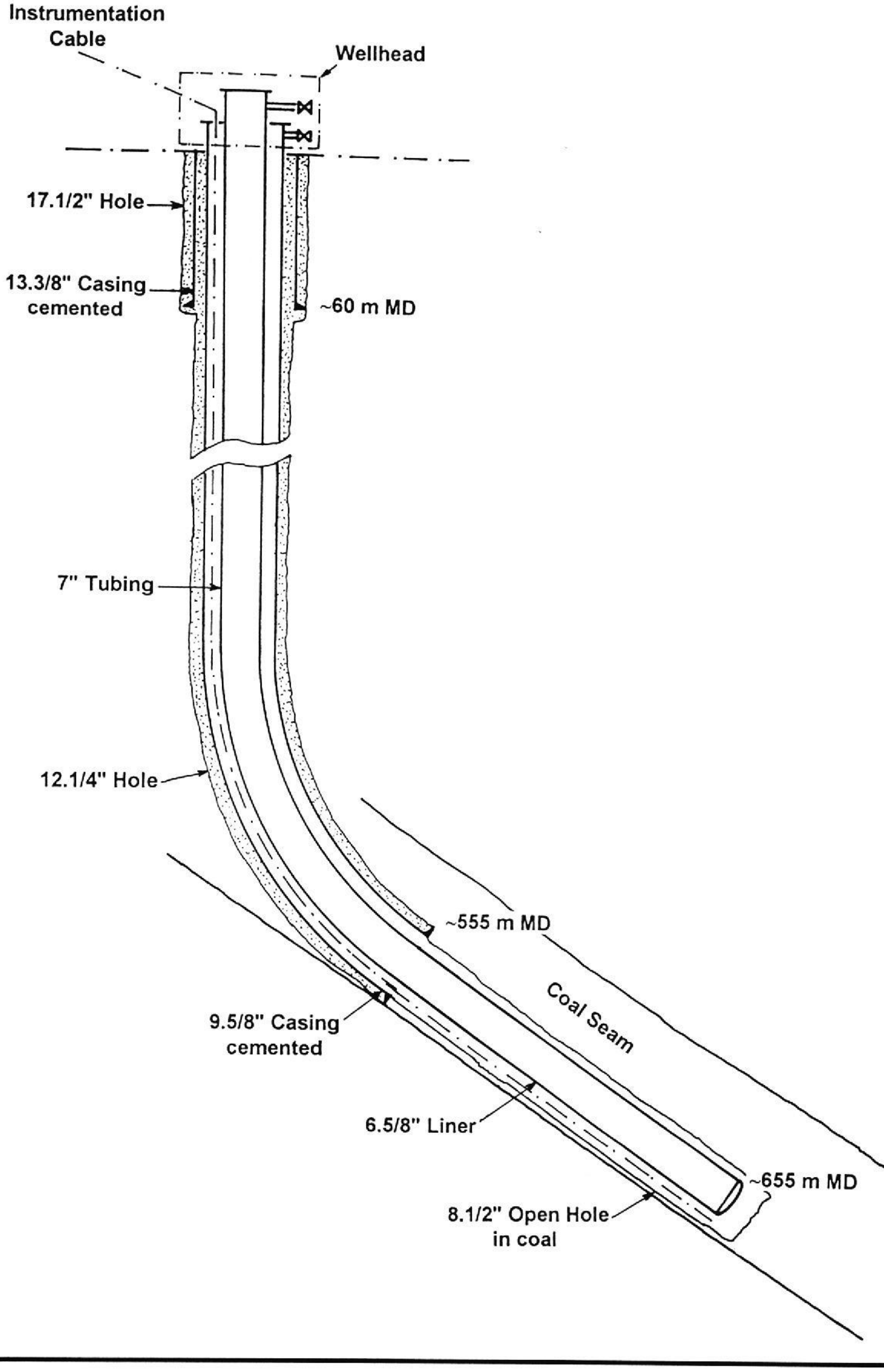


Figure 3a . ET4 Planned Completion(Basic Programme)

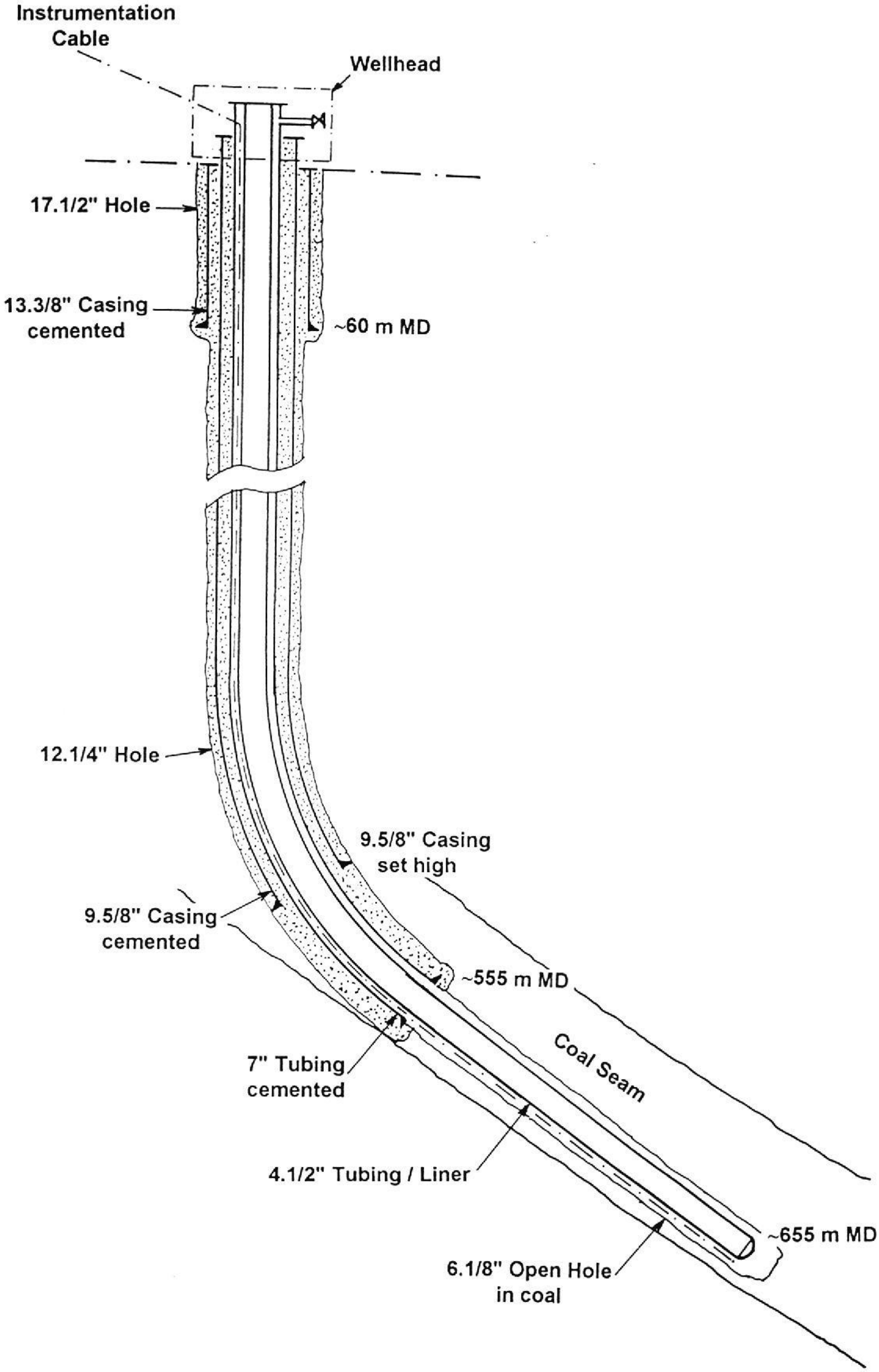


Figure 3b . ET4 Planned Completion(First Contingency Programme)

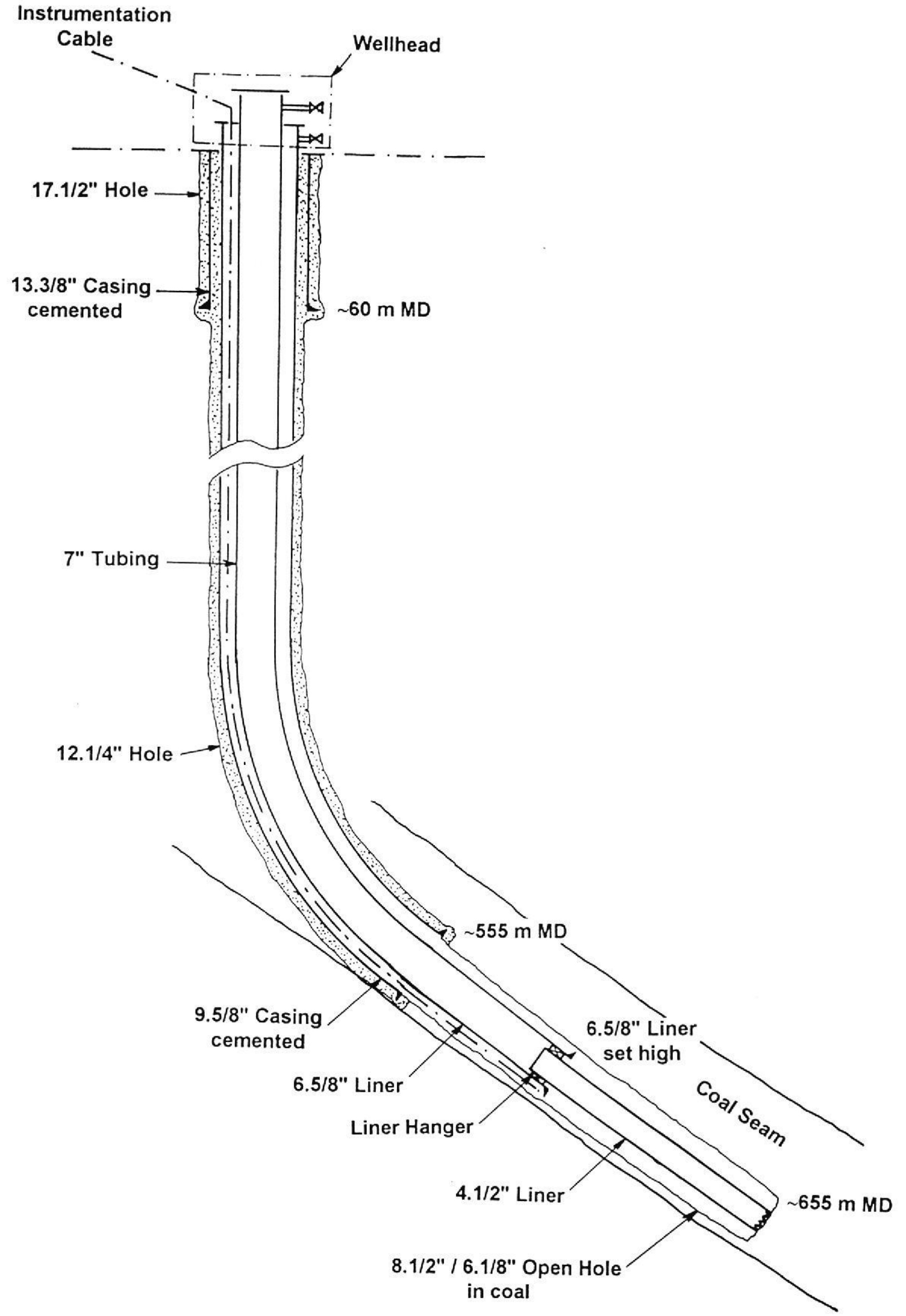


Figure 3c . ET4 Planned Completion(Second Contingency Programme)

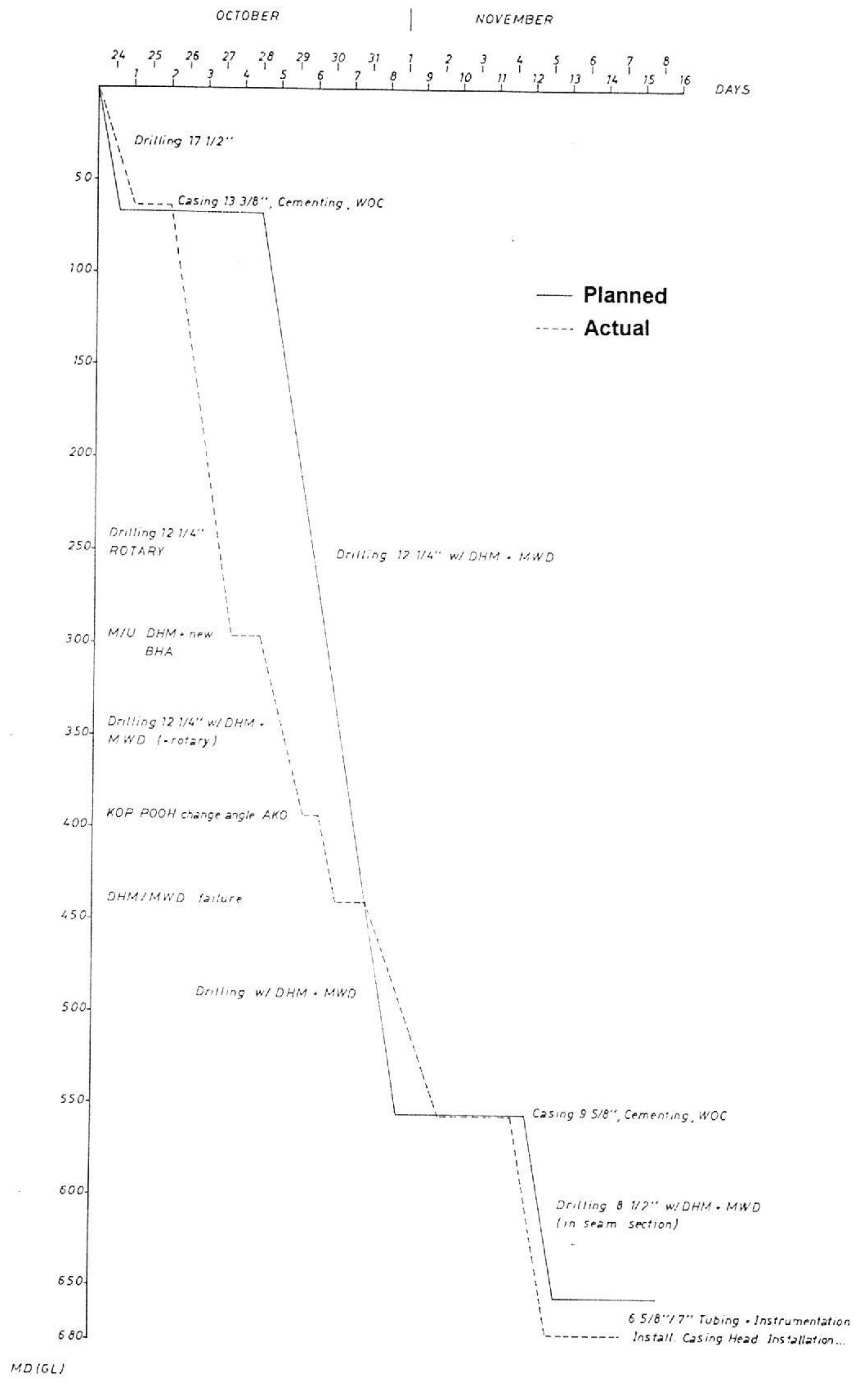


Figure 4 . ET4 Depth/Time Progress compared to Pre-spud Estimate

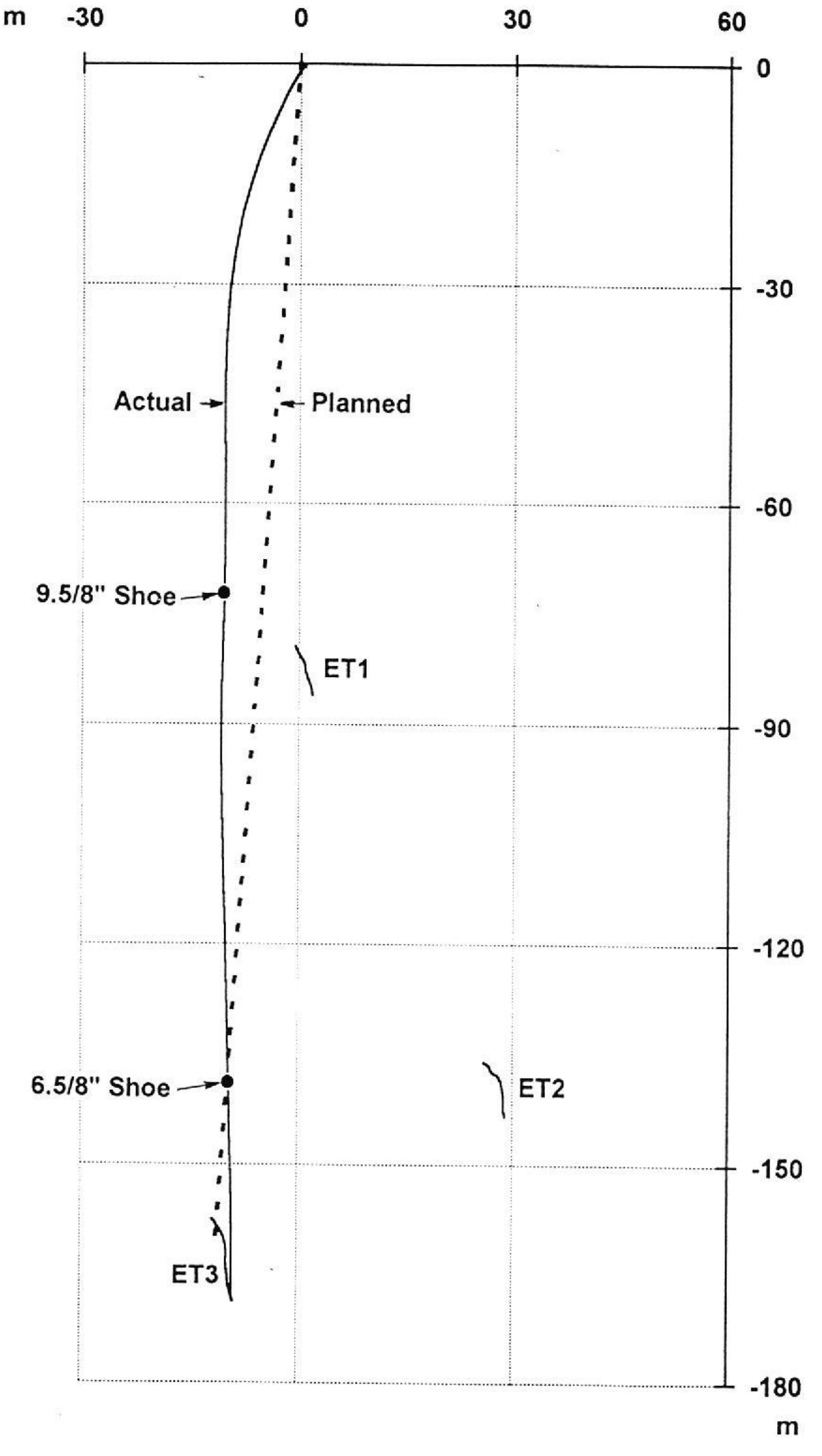


Figure 5a . Comparison of ET4 Planned and Actual Trajectories (Horizontal Section)

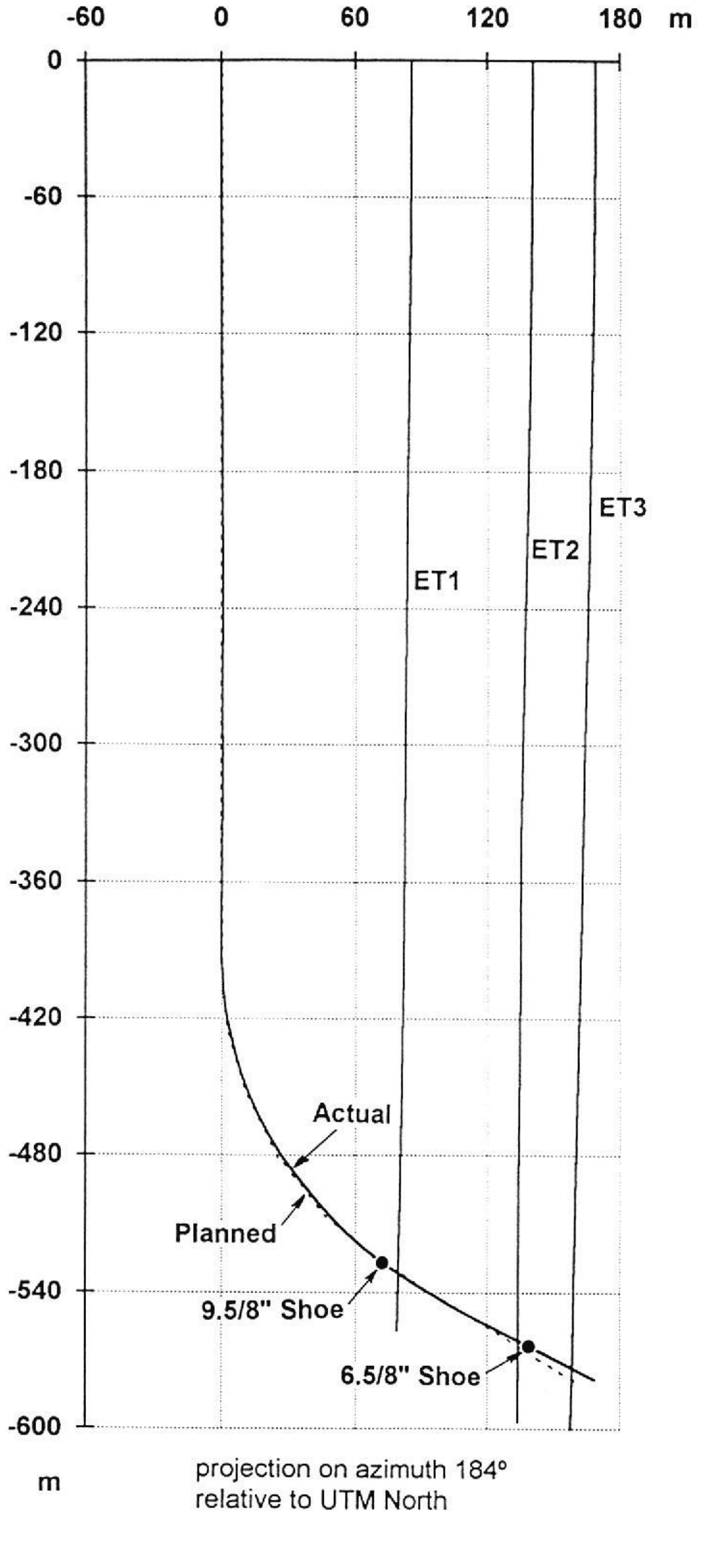


Figure 5b . Comparison of ET4 Planned and Actual Trajectories (Vertical section - Complete Trajectory)

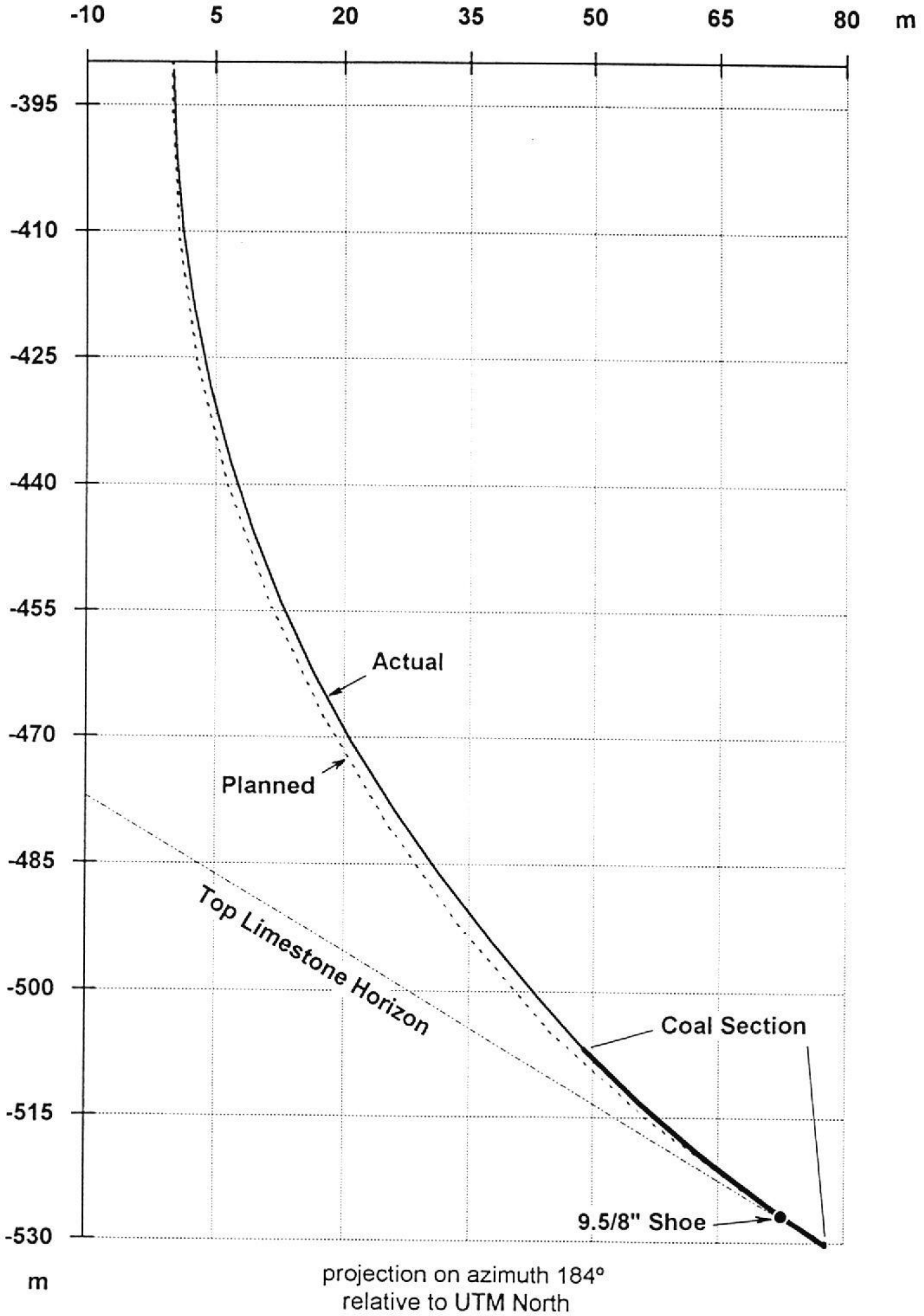


Figure 5c . Comparison of ET4 Planned and Actual Trajectories (Vertical Section - Build Interval)

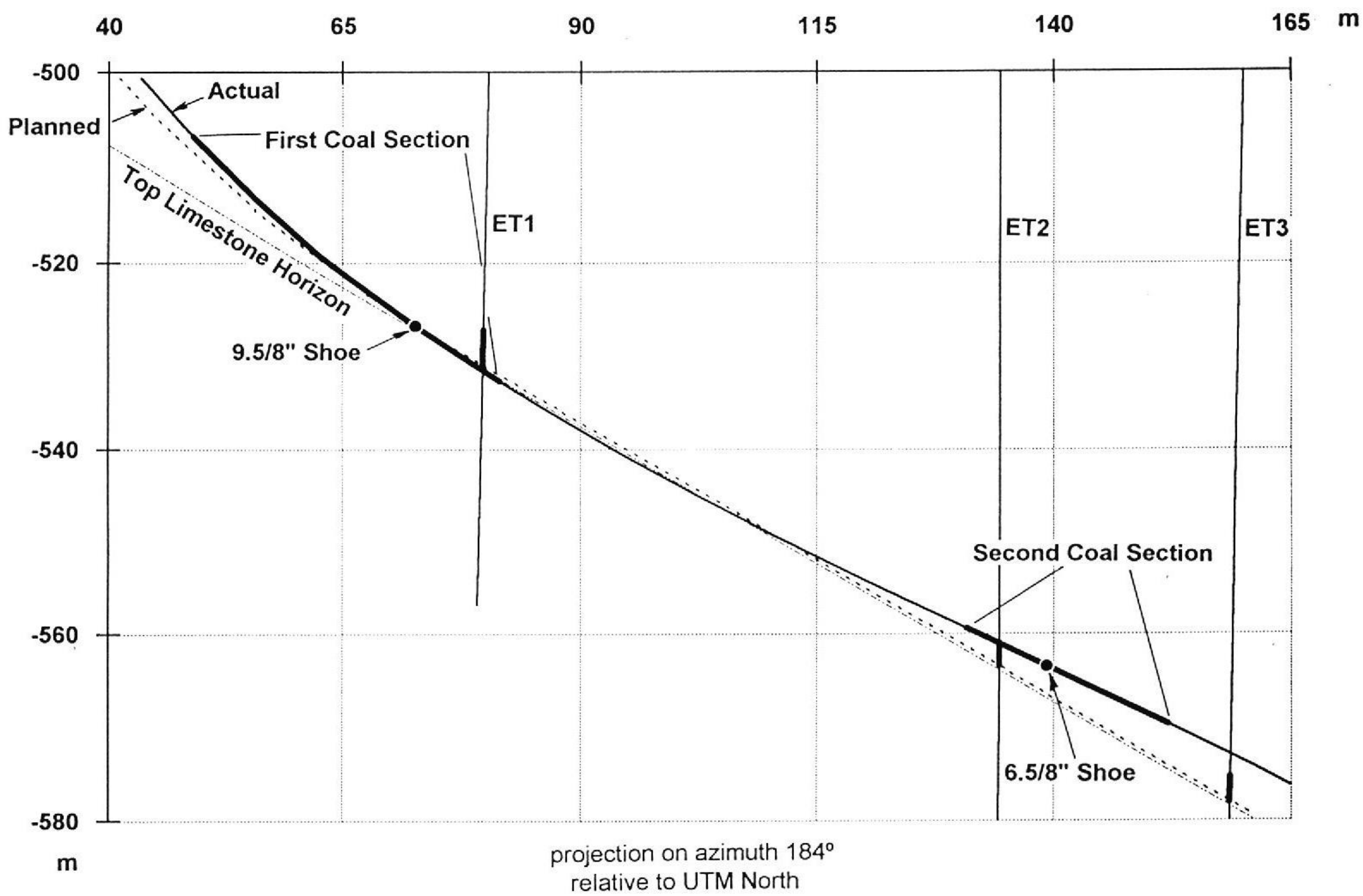
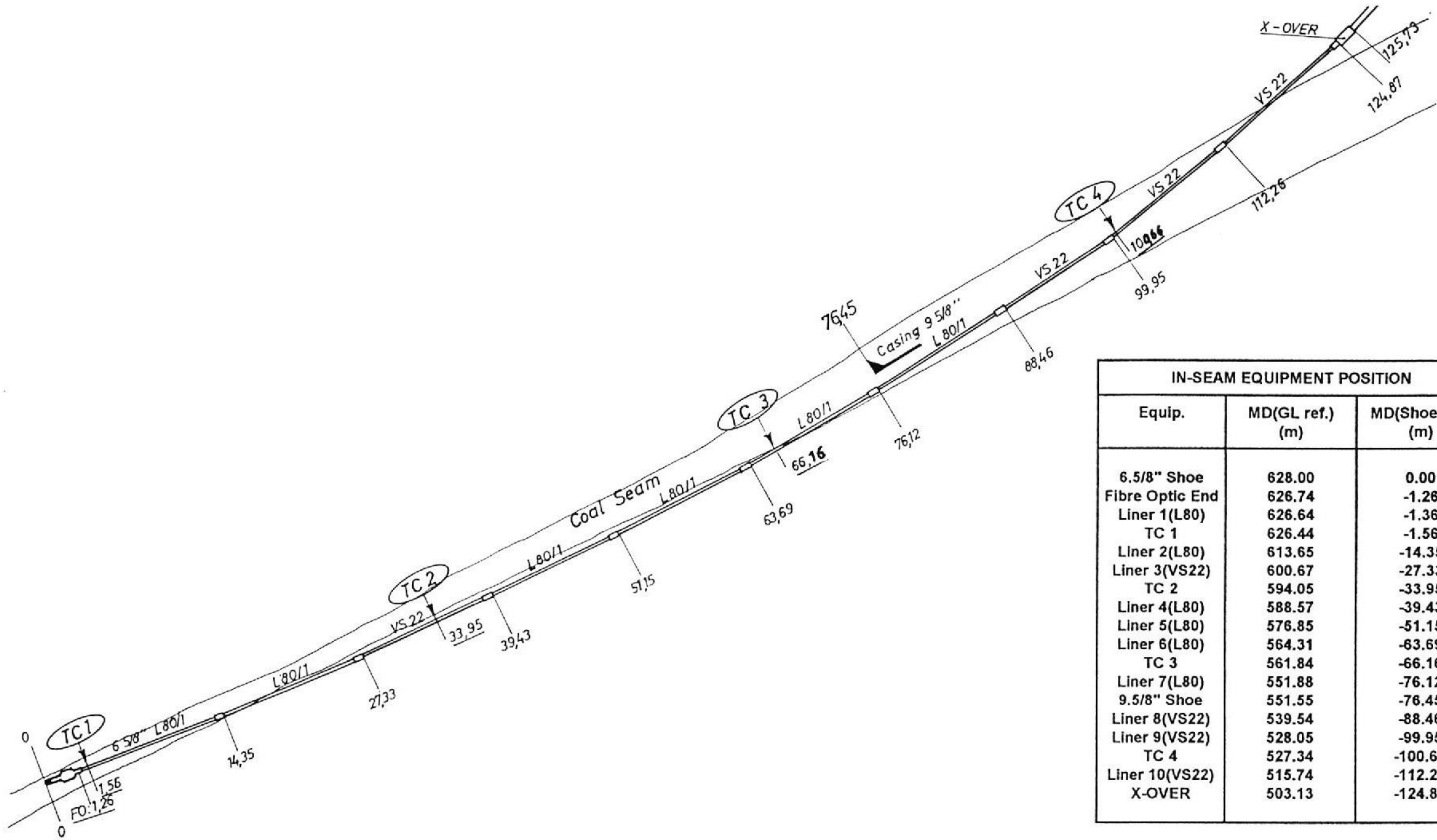


Figure 5d . Comparison of ET4 Planned and Actual Trajectories
(Vertical Section - In-seam Interval)



IN-SEAM EQUIPMENT POSITION		
Equip.	MD(GL ref.) (m)	MD(Shoe ref.) (m)
6.5/8" Shoe	628.00	0.00
Fibre Optic End	626.74	-1.26
Liner 1(L80)	626.64	-1.36
TC 1	626.44	-1.56
Liner 2(L80)	613.65	-14.35
Liner 3(VS22)	600.67	-27.33
TC 2	594.05	-33.95
Liner 4(L80)	588.57	-39.43
Liner 5(L80)	576.85	-51.15
Liner 6(L80)	564.31	-63.69
TC 3	561.84	-66.16
Liner 7(L80)	551.88	-76.12
9.5/8" Shoe	551.55	-76.45
Liner 8(VS22)	539.54	-88.46
Liner 9(VS22)	528.05	-99.95
TC 4	527.34	-100.66
Liner 10(VS22)	515.74	-112.26
X-OVER	503.13	-124.87

Figure 6 . ET4 In-seam Completion

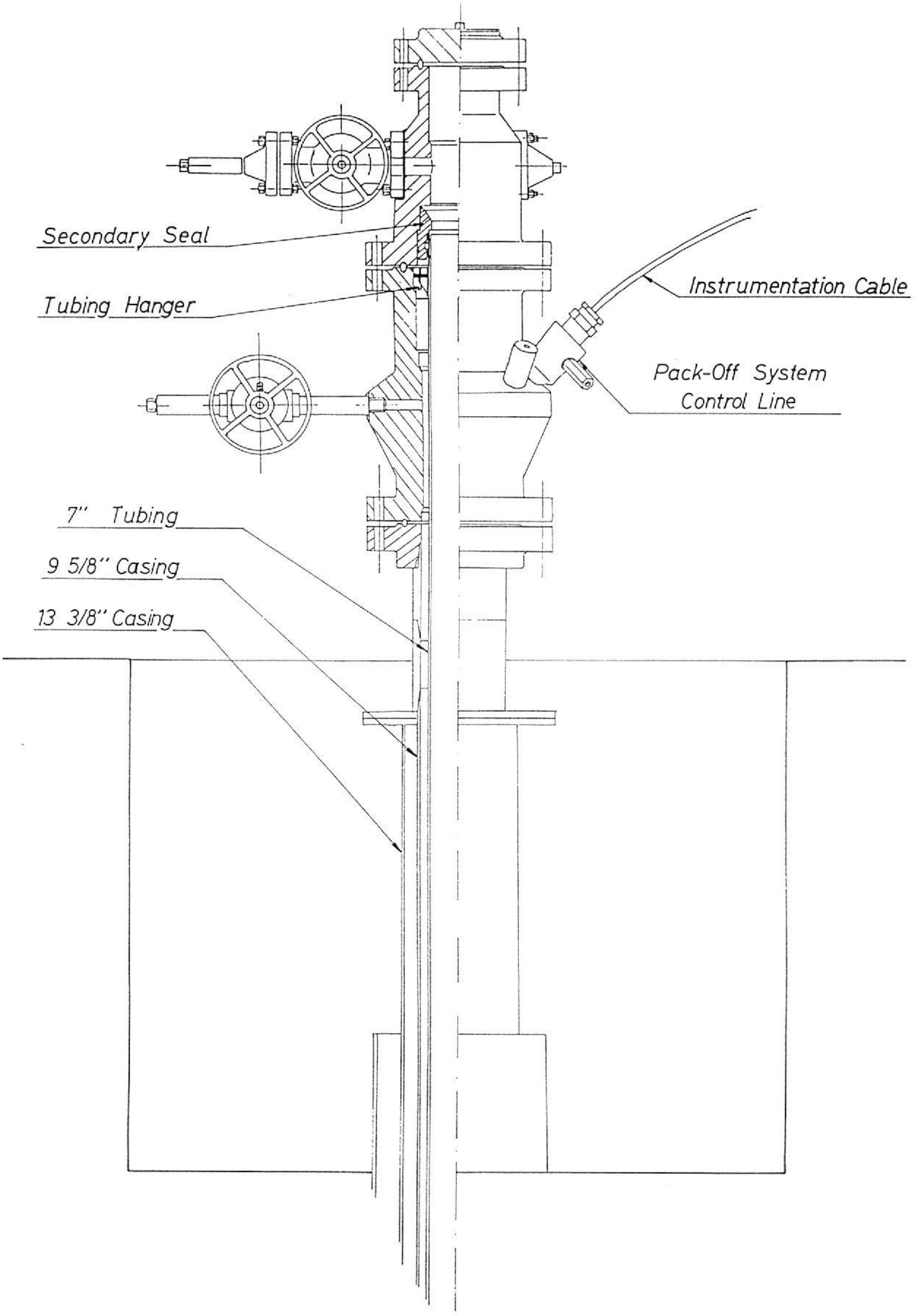


Figure 7 . ET4 Wellhead Assembly

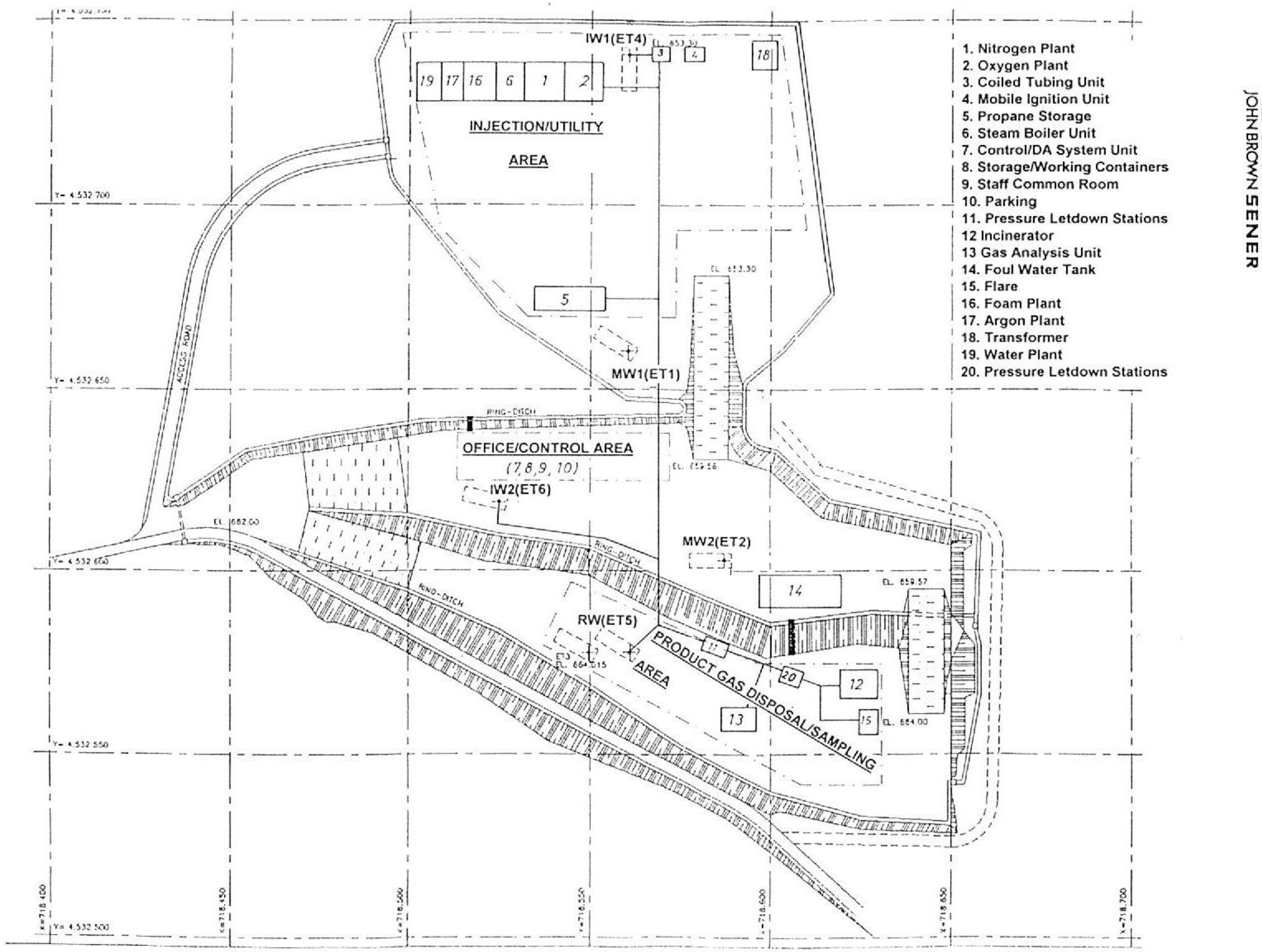


Figure 8 . Surface Plant Areas

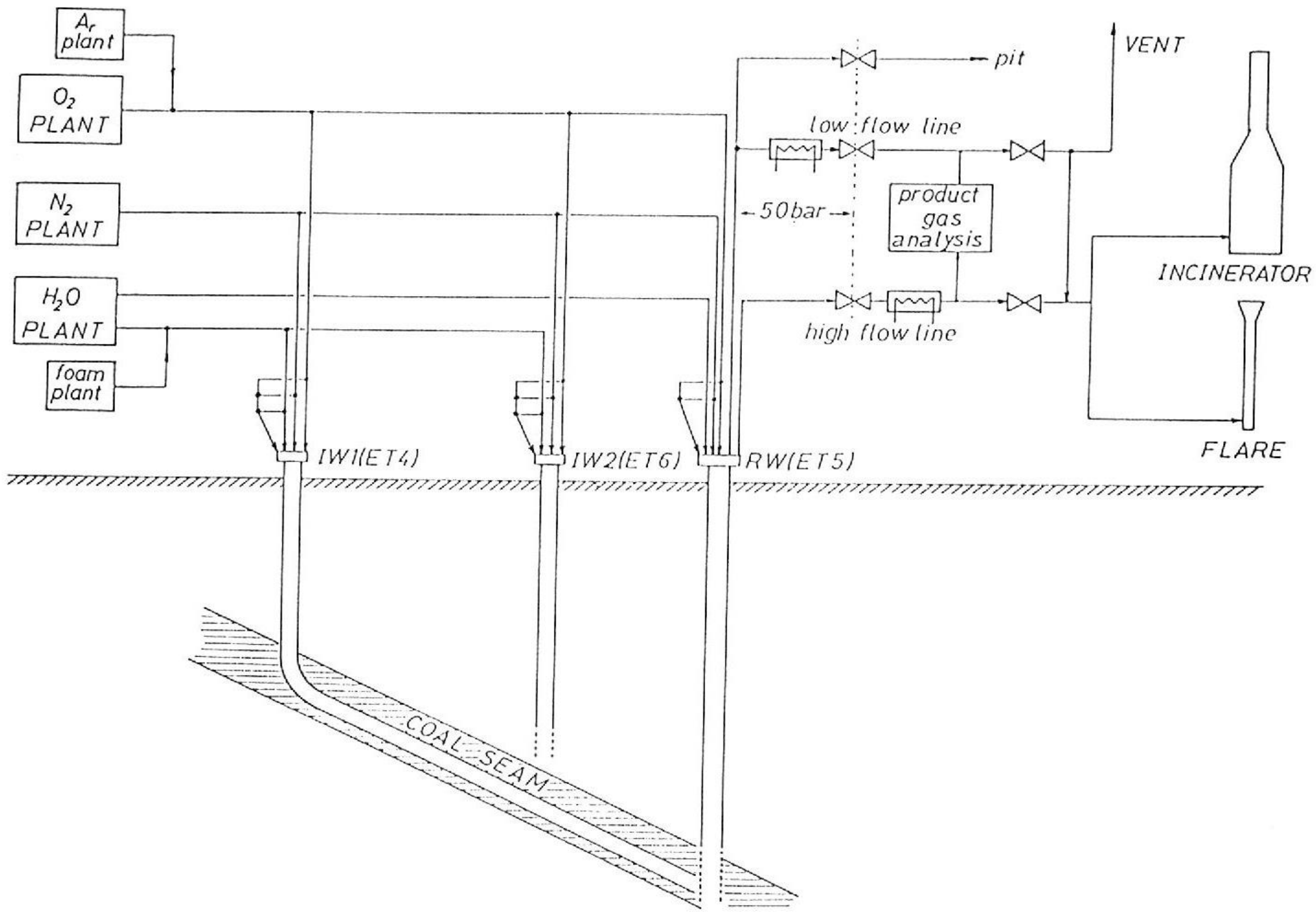


Figure 9 . Process Flow Diagram

Element	ET1	ET2	ET3	Average
Silicon	6.0	8.3	7.6	7.3
Aluminium	4.6	6.8	6.4	5.9
Iron	31.1	31.7	32.5	31.8
Calcium	7.5	7.4	7.0	7.3
Magnesium	1.6	1.4	1.4	1.5
Potassium	0.3	0.3	0.3	0.3
Sodium	0.1	0.1	0.2	0.1
Titanium	0.2	0.3	0.3	0.3

Table I . Upper Coal Seam Ash Composition(wt %)

Lithology	Sample Nº	Vitrinite %	Exinite %	Inertinite %	Reflectance %	Swelling Index	Residual Semi-coke (Gray-King)	Semi-coke Type (Gray-King)
Upper Coal Seam(ET2)	1	68.0	0.0	32.0	0.39	0.0	70.10	Pulverulent
	3	72.6	0.5	26.9	0.38	0.0	68.81	"
	Total	70.3	0.3	29.4	0.39	0.0	69.46	"
Upper Coal Seam(ET3)	1	76.4	0.0	23.6	0.43	0.0	69.75	Pulverulent
	3	76.1	0.0	23.9	0.39	0.0	67.18	"
	Total	76.2	0.0	23.8	0.41	0.0	68.47	"

Table II . Petrographic Analysis at Wells ET2 and ET3

Bit Type	Recommended Drilling Parameter		Observation
	WOB (tonne)	RPM	
SMITH DGJ / 131 17.1/2"	7 - 25	90 - 170	17.1/2" drilling phase
SMITH DSJ / 111 12.1/4"	9 - 20	70 - 180	13.3/8" plug/casing shoe drilling
SMITH M1S / 435 12.1/4" Insert bit	7 - 23	90 - 280	12.1/4" drilling phase (vertical/build section) soft/fairly abrasive formation
REED MHP13G / 137 12.1/4" Motor bit with Mudpick	2.5 - 11	150 - 450	12.1/4" drilling phase (vertical/build section) soft/medium formation
REED S13G / 135 8.1/2"	7.7 - 19.6	60 - 250	9.5/8" plug/casing shoe drilling
SMITH MFDGH / 137 8.1/2" Motor bit	7 - 20	100 - 250	8.1/2" drilling Phase (in-seam section) soft/medium formation
REED MHP13G / 137 8.1/2" Motor bit with Mudpick	2.5 - 11	150 - 450	8.1/2" drilling phase (in-seam section) soft/medium formation
SMITH ECONOMILL 5.7/8"	-	-	6.5/8" guide shoe/in-seam drilling phase (basic and contingency 2)
SMITH FDT / 126 6.1/8"	4 - 11	50 - 140	7" plug/casing shoe drilling (contingency 1)
SMITH FDG / 136 6.1/8"	4 - 11	50 - 140	6.1/8" drilling phase (in-seam section - cont. 1) soft/medium formation
REED HPSM / 537 6" Insert bit	8.4 - 16.2	50 - 110	6" drilling phase (in-seam section - cont. 1) soft/medium formation
SMITH ECONOMILL 3.3/4"	-	-	4.1/2" guide shoe drilling (contingency 1 and 2)

Table III . ET4 Bit Programme

Day		Drilling	Stop/Main-tenance	Mud Prep./ Circulation	Casing/ Tubing Setting	Cementing / Waiting	Plug/shoe Drilling + Reaming	Totco + Logging (CBL)	Rig Manoeuvre	Others
1	VERTICAL	10.25		3.00					1.00	9.75
2	VERTICAL	9.75		0.75	3.75	2.00		0.25	1.75	5.75
3	VERTICAL	10.50	0.25	1.00		6.50	2.25	0.50	1.50	1.50
4	VERTICAL	22.25		0.75				0.75		0.25
5	VERTICAL	3.25	2.00	0.50				0.25	17.75	0.25
6	VERTICAL	20.00		0.50			1.75	0.50	1.25	
7	VERTICAL	13.00		1.00					8.50	1.50
8	BUILD-UP	2.50	7.00	2.00					12.50	
9	BUILD-UP	14.25							5.75	4.00
10	BUILD-UP	12.25	2.50	0.50						8.75
11	BUILD-UP			1.50	8.50	9.25			4.25	0.50
12	BUILD-UP			0.75		7.25	3.00	4.50	8.25	0.25
13	IN-SEAM	10.75		0.75	4.50		0.75		5.75	1.50
14	IN-SEAM				19.50				2.00	2.50
15	IN-SEAM			1.50					14.75	7.75
Total		128.75	11.75	14.50	36.25	25.00	7.75	6.75	85.00	44.25

Table IV . ET4 Operating Time Distribution(h.min)

Drilling Phase	Bit Type	Drilling Parameter					Formation Crossed	Observation
		WOB (tonne)	RPM	Depth In (m)	Depth Out (m)	Bit Run (h.min)		
Vertical Interval 17.1/2" diam. Rotary assembly	SMITH DGJ / 131 Nozzles: 18/18/18	1 - 7	80 - 90	0.0	62.8	20.00	TERTIARY Conglomerate, marly clay, some sand	Medium to soft formation. T/B/G = 1/1/0
Vertical Interval 12.1/4" diam. Rotary assembly	SMITH DSJ / 111 Nozzles: 14/14/14	5 - 8	100 - 110	62.8	296.3	38.25	TERTIARY Marly clay, clay, sand	Medium to soft formation. Bit used to drill 13.3/8" casing plug/shoe. T/B/G = 3/5/5
Vertical Interval 12.1/4" diam. DHM assembly	REED MHP13G / 137 Nozzles: 18/18/15	6 - 14	215 - 250	296.3	393.0	25.25	TERTIARY + CRETACEOUS Marly clay, marl, clay, some sand	Medium to soft formation. Drilling par. outside recommended range. T/B/G = Worn out
Build-up Interval 12.1/4" diam. DHM assembly	SMITH M1S / 435 Nozzles: 18/18/15	3 - 20	140 - 155	393.0	556.0	36.75	CRETACEOUS (ALBIAN) Sand, clay and coal	Soft formation. T/B/G = 0/2/0
9.5/8" Plug/casing collar and cement drilling	REED S13G / 135 No nozzle	4 - 5	40	479.5	550.3	3.00	Plug, float collar and cement	T/B/G = 0/1/0
In-seam Interval 8.1/2" diam. DHM assembly	SMITH MFDGH / 137 Nozzles: 18/15/15	2 - 14	90 - 210	550.3	675.5	11.50	CRETACEOUS (ALBIAN) Coal, carbonaceous marl/limestone	Soft to medium formation. T/B/G = 0/1/0

Table V . ET4 Bit Report

Item	Estimated Cost (MPTA)	Actual Cost (MPTA)
Drilling		
- Rig and Crew	49.0	43.5
- Directional Drilling	17.0	18.4
- Fluids(Mud)	5.0	6.1
- Bits	5.0	5.4
- Fuel	3.0	2.3
- Water	1.0	0.6
- Engineering	1.0	1.2
- Logging	2.0	1.6
Subtotal Drilling	83.0	79.1
Completion		
- Casing/Tubing	21.0	15.7
- Casing running services	1.5	1.2
- Wellhead assembly	4.0	4.0
- Instrumentation cable	5.5	5.5
- Protectors, flatpack	5.0	5.0
- Cementing and equip.	9.5	7.2
- Civil works	2.0	2.5
- Miscellaneous	3.5	2.4
Subtotal Completion	52.0	43.5
Total Cost	135.0	122.6

Table VI . ET4 Drilling and Completion Costs
(VAT excluded)

Nº	Description	Length(m)	Bottom Measured Depth(m)
45	Pup Joint	2.93	- 2.81
44	Casing Joint + Cement Basket	12.74	- 15.55
43	Casing Joint	13.35	- 28.90
42	Casing Joint	13.34	- 42.24
41	Casing Joint	13.29	- 55.53
40	Casing Joint + Centraliser nº 17	13.27	- 68.80
39	Casing Joint + Centraliser nº 16	12.68	- 81.48
38	Casing Joint	13.34	- 94.82
37	Casing Joint	13.32	- 108.14
36	Casing Joint	13.21	- 121.35
35	Casing Joint	13.34	- 134.69
34	Casing Joint	12.40	- 147.09
33	Casing Joint	13.34	- 160.43
32	Casing Joint + Centraliser nº 15	12.64	- 173.07
31	Casing Joint	13.08	- 186.15
30	Casing Joint	13.34	- 199.49
29	Casing Joint	13.31	- 212.80
28	Casing Joint	13.32	- 226.12
27	Casing Joint	13.07	- 239.19
26	Casing Joint	13.28	- 252.47
25	Casing Joint + Centraliser nº 14	13.05	- 265.52
24	Casing Joint	13.33	- 278.85
23	Casing Joint	12.80	- 291.65
22	Casing Joint	13.00	- 304.65
21	Casing Joint	13.34	- 317.99
20	Casing Joint	13.32	- 331.31
19	Casing Joint	13.35	- 344.66
18	Casing Joint	12.97	- 357.63
17	Casing Joint + Centraliser nº 13	12.81	- 370.44
16	Casing Joint	13.03	- 383.47
15	Casing Joint	12.65	- 396.12
14	Casing Joint + Centraliser nº 12	13.34	- 409.46
13	Casing Joint + Centraliser nº 11	13.04	- 422.50
12	Casing Joint + Centraliser nº 10	12.85	- 435.35
11	Casing Joint + Centraliser nº 9	12.65	- 448.00
10	Casing Joint + Centraliser nº 8	12.39	- 460.39
9	Casing Joint + Centraliser nº 7	12.42	- 472.81
8	Casing Joint + Centraliser nº 6	12.87	- 485.68
7	Casing Joint + Centraliser nº 5	12.59	- 498.27
6	Casing Joint + Centraliser nº 4	13.15	- 511.42
5	Casing Joint + Centraliser nº 3	13.16	- 524.58
4	Float Collar	0.40	- 524.98
3	Casing Joint + Centraliser nº 2	12.77	- 537.75
2	Casing Joint + Centraliser nº 1	13.35	- 551.10
1	Float Shoe	0.45	- 551.55

Table VII . 9.5/8" Casing String Components
(Depth relative to Ground Level)

Nº	Description	Length(m)	Bottom Measured Depth(m)
52	7" Tubing Joint(N80) nº 39 (cut at the Tubing Hanger Level)	13.33 (8.17)	 - 6.91
51	7" Tubing Joint(N80) nº 38	13.30	- 20.21
50	7" Tubing Joint(N80) nº 37	12.80	- 33.01
49	7" Tubing Joint(N80) nº 36	13.29	- 46.30
48	7" Tubing Joint(N80) nº 35	13.33	- 59.63
47	7" Tubing Joint(N80) nº 34	12.82	- 72.45
46	7" Tubing Joint(N80) nº 33	13.32	- 85.77
45	7" Tubing Joint(N80) nº 32	13.02	- 98.79
44	7" Tubing Joint(N80) nº 31	12.89	- 111.68
43	7" Tubing Joint(N80) nº 30	12.92	- 124.60
42	7" Tubing Joint(N80) nº 29	13.28	- 137.88
41	7" Tubing Joint(N80) nº 28	12.94	- 150.82
40	7" Tubing Joint(N80) nº 27	12.78	- 163.60
39	7" Tubing Joint(N80) nº 26	12.90	- 176.50
38	7" Tubing Joint(N80) nº 25	13.18	- 189.68
37	7" Tubing Joint(N80) nº 24	12.63	- 202.31
36	7" Tubing Joint(N80) nº 23	12.92	- 215.23
35	7" Tubing Joint(N80) nº 22	13.33	- 228.56
34	7" Tubing Joint(N80) nº 21	13.30	- 241.86
33	7" Tubing Joint(N80) nº 20	12.79	- 254.65
32	7" Tubing Joint(N80) nº 19	13.35	- 268.00
31	7" Tubing Joint(N80) nº 18	13.17	- 281.17
30	7" Tubing Joint(N80) nº 17	12.92	- 294.09
29	7" Tubing Joint(N80) nº 16	13.24	- 307.33
28	7" Tubing Joint(N80) nº 15	13.32	- 320.65
27	7" Tubing Joint(N80) nº 14	12.11	- 332.76
26	7" Tubing Joint(N80) nº 13	12.86	- 345.62
25	7" Tubing Joint(N80) nº 12	13.34	- 358.96
24	7" Tubing Joint(N80) nº 11	12.97	- 371.93
23	7" Tubing Joint(N80) nº 10	13.07	- 385.00
22	7" Tubing Joint(N80) nº 9	13.36	- 398.36
21	7" Tubing Joint(N80) nº 8	13.29	- 411.65
20	7" Tubing Joint(N80) nº 7	12.83	- 424.48
19	7" Tubing Joint(N80) nº 6	12.91	- 437.39
18	7" Tubing Joint(N80) nº 5	12.05	- 449.44
17	7" Tubing Joint(N80) nº 4	13.18	- 462.62
16	7" Tubing Joint(N80) nº 3	13.18	- 475.80
15	7" Tubing Joint(N80) nº 2	13.39	- 489.19
14	7" Tubing Joint(N80) nº 1	13.08	- 502.27
13	Cross Over	0.86	- 503.13
12	6.5/8" Liner Joint(VS22)	12.61	- 515.74
11	6.5/8" Liner Joint(VS22)	12.31	- 528.05
10	6.5/8" Liner Joint(VS22)	11.49	- 539.54
9	6.5/8" Liner Joint(L80)	12.34	- 551.88
8	6.5/8" Liner Joint(L80)	12.43	- 564.31
7	6.5/8" Liner Joint(L80)	12.54	- 576.85
6	6.5/8" Liner Joint(L80)	11.72	- 588.57
5	6.5/8" Liner Joint(VS22)	12.10	- 600.67
4	6.5/8" Liner Joint(L80)	12.98	- 613.65
3	6.5/8" Liner Joint(L80)	12.99	- 626.64
2	6.5/8" Liner End Piece	1.07	- 627.71
1	Guiding Shoe	0.29	- 628.00

Table VIII . 7" Tubing / 6.5/8" Liner String Components
(Depth relative to Ground Level)

Item	Flow	Pressure	Temperature	On-site Storage
<u>Process</u>				
O_2 Plant	Up to 1,650 Nm^3 / h	180 bar at delivery	Ambient at delivery	1.5 days
N_2 Plant	Up to 1,200 Nm^3 / h	180 bar at delivery	Ambient at delivery	1.5 days
H_2O(inj.) Pumping Unit	Up to 6,000 l / h	150 / 165 bar	30 / 45 ºC	1.5 days
H_2O(sparge) Pumping Unit	Up to 6,000 l / h	60 / 110 bar	30 / 45 ºC	1.5 days
Foam Pumping Unit	Up to 30 l / h	150 / 165 bar	30 / 45 ºC	5 days
Argon Plant	Up to 1.5 Nm^3 / h	160 bar at delivery	Ambient at delivery	1.5 days
Low Flow Recovery Line	Up to 1,400 kg / h			
- before first decompression		60 / 80 bar	30 / 150 / 350 ºC	
- after heat exchanger		60 / 80 bar	140 / 150 / 350 ºC	
- after decompression		4 / 7 bar	130 / 140 / 350 ºC	
- to vent		atm. / 3 bar	130 / 140 / 350 ºC	
High Flow Recovery Line	1,000 - 15,000 kg / h			
- before first decompression		60 / 80 bar	170 / 300 / 350 ºC	
- after decompression		4 / 7 bar	100 / 270 / 350 ºC	
- after heat exchanger		4 / 7 bar	120 / 270 / 350 ºC	
- to incinerator/flare		atm. / 3 bar	115 / 265 / 350 ºC	
<u>Utility</u>				
Steam Generator Plant	3 t / h	9 / 10 bar	175 / 194 ºC	
Fire Water Plant	90 m^3 / h	9.5 / 15 bar	30 / 45 ºC	2 hours
Utility Water Unit	7 m^3 / h	9.5 / 15 bar	30 / 45 ºC	
Instrument Air Plant	100 Nm^3 / h	8 /9 bar	20 / 45 ºC	
Utility N_2 Unit	100 Nm^3 / h	9 / 13 bar	20 / 45 ºC	
Propane Plant	370 kg / h	2 / 15 bar	Ambient	5 days

Item	Power	Voltage
<u>Electricity</u>		
Main Transformer	400 kW	380 / 220 V
Emergency System	150 kW	380 / 220 V

Table IX . Surface Plant Basic Design Parameters

Description	Cost / Unit(MPTA)	%
Vessels Heat Transfer Equipment Pumps, Comp. & Others Package Units(O_2, N_2, Inc., Flare,...) Electrical Equipment Gas Analysis Unit DAS / Control Unit Spare Parts	5.100 10.000 40.842 106.028 29.559 95.433 81.350 9.208	0.6 1.2 4.8 12.4 3.5 11.2 9.5 1.1
Subtotal Equipment	377.520	44.3
Piping Materials Instrumentation Materials Electrical Materials	45.302 22.651 11.326	5.3 2.7 1.3
Subtotal Materials	79.279	9.3
Mechanical Erection Instrumentation Erection Electrical Erection	74.749 11.326 5.097	8.8 1.3 0.6
Subtotal Erection	91.171	10.7
Civil Works, Foundations and Structural Steel	67.251	7.9
Temporary Facilities	20.000	2.3
Construction Supervision	45.302	5.3
Engineering / Design	94.380	11.1
Contingency	77.490	9.1
Total Cost	852.393	100.0

Table X . Surface Plant Cost Estimate(Phases 2 and 3)