TEST PLAN

Methane capture from the Żory Mine borehole
Methane to LNG Żory Coal Mine Project
Assistance Agreement: XA-83396101-0

Submitted by the Institute for Ecology of Industrial Areas, Katowice, Poland

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Introduction

The Test Plan serves as a basic guidance document for performing methane capture at the experimental borehole drilled in the framework of the Methane to LNG Żory Coal Mine Project. The project is performed under the Methane to Market Partnership Assistance Agreement XA-83396101-0. The primary goal of the Żory Project is to promote cost effective, near-term methane recovery and end-use opportunities in Poland with the aim to provide Poland with a clean-burning alternative fuel resource – LNG and thus contribute to a significant reduction of methane emission.

Background

One of the main tasks of the project has been focused on investigating the capture alternatives of the recoverable methane resources from the Żory coal mine. Three methane capture alternatives have been analyzed:

1. use some of the existing 43 wells
2. drill a new research borehole
3. use of the existing underground infrastructure (e.g. headings and galleries) of the other coal mines operating in areas adjacent to the Żory coal mine area.

A detailed analysis of the methane capture alternatives indicated that from the viewpoint of project objectives drilling of a new research borehole turned out to be the most promising and burdened with the lowest risk of failure.

Project site

The project focuses on the abandoned KWK "Żory" coal mine. The Żory mine is located in the southwestern portion of the Polish part of the Upper Silesian Basin, approximately 10 km southeast of the city of Rybnik. Coal production began in 1979 and was discontinued in 1996, with formal abandonment occurring in September, 1997. The abandonment of this mine consisted of filling the two working shafts and embanking the main heading at the active levels of the mine. According to reports prepared prior to the mine abandonment, Żory mine methane resources are located between the depths of 100 and 1,225 meters and amount to 7,777,750,000 m^3.

Photo1. Location of the project site

Research borehole location

The analysis of the methane bearing tests made in the years 1985 - 1996 in underground excavations of the abandoned coal mine „Żory" lead to the conclusion that the best conditions for methane accumulation in the coal beds are in the Section „PZ" where high values of methane capacity have been identified at the levels of 400 m and 705 m, as well as high average values of methane bearing between the carboniferous roof and the depth of 705 m.

The most convenient access to the deposit is in its highest possible point. The abandoned workings of the 327/1-2 level in the Section „PZ" are located in the highest point of the bed located 215 m below the ground level at the depth of the carboniferous roof on the level of 140 m.

Therefore the research borehole is located in Section „PZ", above the interpenetrating abandoned workings of levels 327/1-2 and 327/4, in the highest possible point of the workings. This location of the designed borehole in Section ”PZ" is also advantageous due to a very easy methane migration to the perforated section of the borehole through the pores and cracks in the sandstone overlaying the first mined level 327/1-2, facilitated by the impact of the mining operations.

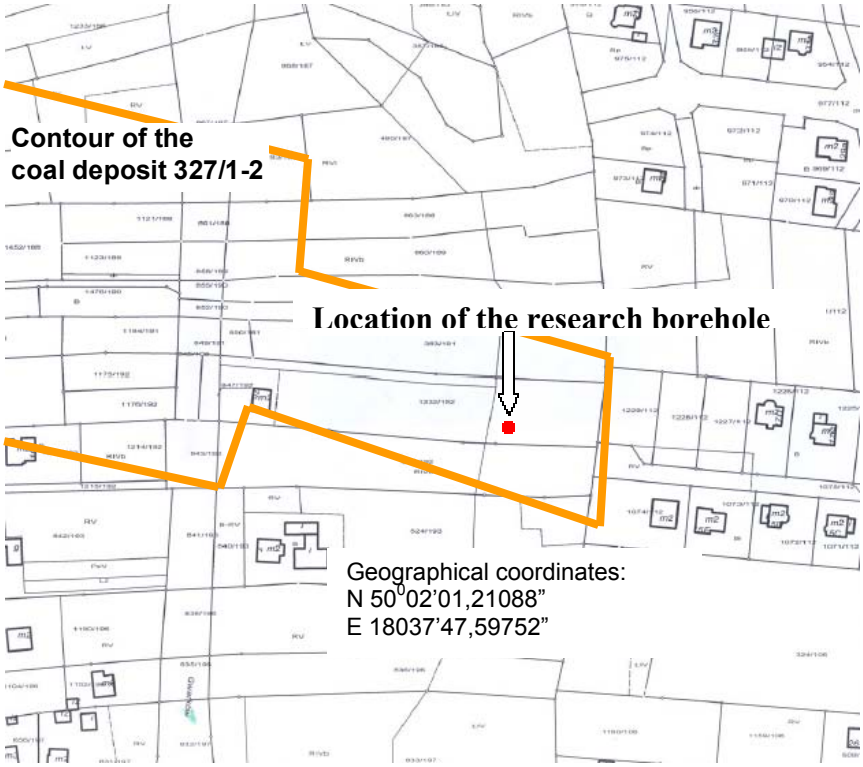

Figure 1. Location of the Żory Mine research borehole

The impacts of the mining activities from the excavating coal beds sum up enlarging the cracks zone and the rock mass slackening area. The presence of the abandoned workings in several beds extracted one after another is an additional advantage for the location.

The exact location of the borehole is within the lot number 1232/192. CETUS – Energetyka Gazowa, a subcontractor in that project and the owner of the concession for „Żory” mining area has the right to use the property for the purpose of geological research, on the basis of the agreement concluded with the owners of the property. A leased lot has the surface of 1591 m^2. CETUS has also the right to buy the property after a leasing period expires i.e. after

June 30th 2009. The bore hole is to be located on the lot not destined for farming or building the house, and the nearest inhabited buildings are located in the distance of over 100m, which has an essential meaning as drilling works can be very strenuous for the surroundings (mostly noise and heavy equipment used). It is optimal as for the surface location within section „PZ"; within the rest of the area drilling to the shallowest located gobs is impossible due to very compact settlement.

The site has been properly prepared for the drilling, access road has been hardened to enable transport of the drilling equipment. Power and water supply have been provided to ensure proper operation of the drilling works. The site has been also fenced to avoid trespassing and for safety reasons.

Borehole construction

The contractor performing the drilling is Śląskie Towarzystwo Wiertnicze DALBIS Sp. z o.o. with its legal seat in Radzionków . The construction of the research bore hole made from the surface shall secure the stability of the hole, safety of the works, enable carrying the geophysical researches, and isolate, after examining, the drilled water-bearing and gas-bearing layers. Provided that the methane flow is obtained – the construction should enable its exploitation. The proposed construction of the bore hole:

a) Holocene formation ≈ 10m ppt (underground) protected with casing pipes cemented to the surface (initial leading column),

b) Holocene formation ≈50 m ppt protected with casing pipes cemented to the surface,

c) Neogen formation ≈150 m ppt which is ≈10 m in carboniferous formation protected with casing pipes cemented to the surface,

d) Carboniferous formation a 140→215÷240 m ppt protected with casing pipes (liner) perforated between 155-215 m.

Heel of a shot during drilling the overlay from the depth of about 50 m and carboniferous formation shall be armed with piping framing and blow-out preventer.

Due to the purpose of drilling and the construction of the borehole coreless drilling is used. It is made using mechanical equipment for usual diameters, with flushing. The depth, borehole construction and the drilling technology are determined in details in technical and geological design of the bore hole. The following construction is planned

- depth 0,0 ÷ 10,0 m – Ø 457 mm pipes cemented to the surface,

- depth 0,0 ÷ 50,0 m - Ø 339,7 mm pipes cemented to the surface,

- depth 0,0 ÷ 140,0 m - Ø 244,5 mm pipes cemented to the surface,

- depth 130,0 ÷ 215,0 m - strainers Ø 168,7 mm (liner).

The precise depth of the foundation shall be determined by the geologist supervising the drilling works, after boring planned geological layers.

Test Plan

Success Criteria

The overall objective for coal mine methane (CMM) capturing form the Żory research borehole is to determine the composition of the gas, especially methane and oxygen content from the viewpoint of its future use for LNG production as the key criterion determining the potential successful conversion to LNG. CMM conversion to LNG is economically and technically viable only if the methane content exceeds a certain value. Below this value, scenarios other than conversion to LNG should be considered mainly due to economic reasons. An additional factor determining an efficient liquefaction process is the content of oxygen.

Below five CMM use scenarios are proposed from the viewpoint of methane and oxygen contents indicated as success criteria for each scenario.

Scenario 1	**Methane content below 40%**	The use of gas is rather limited. Installation for is purification and liquefaction will be extremely complicated and energy-consuming and will require high investment outlays and operational costs. The only economically justified way of utilizing the gas of such composition will be combustion for heating purposes
Scenario 2	**Methane content 40-50%.**	Similarly as in scenario 1, conversion to LNG cannot be economically justified. An increased methane content compared to scenario 1 enables a viable utilization of the gas for combined heat and electric power production.
Scenario 3	**Methane content 50-70%,** **Oxygen content below 8%.**	Such a composition of CMM already enables its conversion to LNG. However due to low content of methane and a high content of content of oxygen, economic and technical analyses need to be performed in order to justify the economic viability of the process. High oxygen content requires application of a catalytic reactor in which methane is combusted at the presence of oxygen and as a result carbon dioxide and water are produced. They must be removed from the process. In consequence the system is characterized by high methane losses. Despite the fact that the waste gas can be further utilized for electric energy production to satisfy the needs of the installation, a large volume of it is burnt in the flare. Such a situation has a negative impact on the system performance and its economic effectiveness.

Scenario 4	**Methane content 70-80%, oxygen content below 5%.**	Relatively high methane content in the inlet gas requires a much simpler and thus less energy consuming purification and liquefaction system. Depending on the installation performance, reduced oxygen content can be removed either in a catalytic reactor or by cryogenic separation. Both methods result in a significantly smaller methane losses then in Scenario 3 , improving the performance and efficiency of the entire
Scenario 5	**Methane content above 80%, oxygen content below 3%.**	The most favorable scenario from the viewpoint of LNG production. Low oxygen concentration at high methane content has a positive impact on the economic factors of the investment. Such gas composition requires relatively low investment and operational costs to ensure an economically viable LNG production even in a small scale installation i.e. 5000 gpd LNG.

As indicated above, the minimum requirements for considering CMM conversion to LNG include minimum methane content in CMM in the range of 50-70%, maximum oxygen content below 8%. These values can be considered as criteria of success for this Test Plan.

Protocol for gas sampling from the Żory Mine borehole

Once the construction of the borehole is completed the sampling of the gas will be initiated. Gas sampling will be carried out in accordance with ISO regulations (ISO 10715:1997 – Natural gas – Sampling guidelines). In general two phases of gas sampling are planned:

Phase 1 – consisting in an initial trial capture of the gas combined with testing of the equipment for:

a/monitoring the capture process

b/ measuring the gas parameters

Phase 2 – proper gas capture and monitoring of its parameters to determine:

a/ chemical composition

b/ physical parameters of the gas stream at the outlet

c/ volume of the available gas resource

Figure 2 presents the gas flow diagram i.e. from the borehole outlet to the combustion in the flare. Location of the control and some monitoring equipment is also indicated

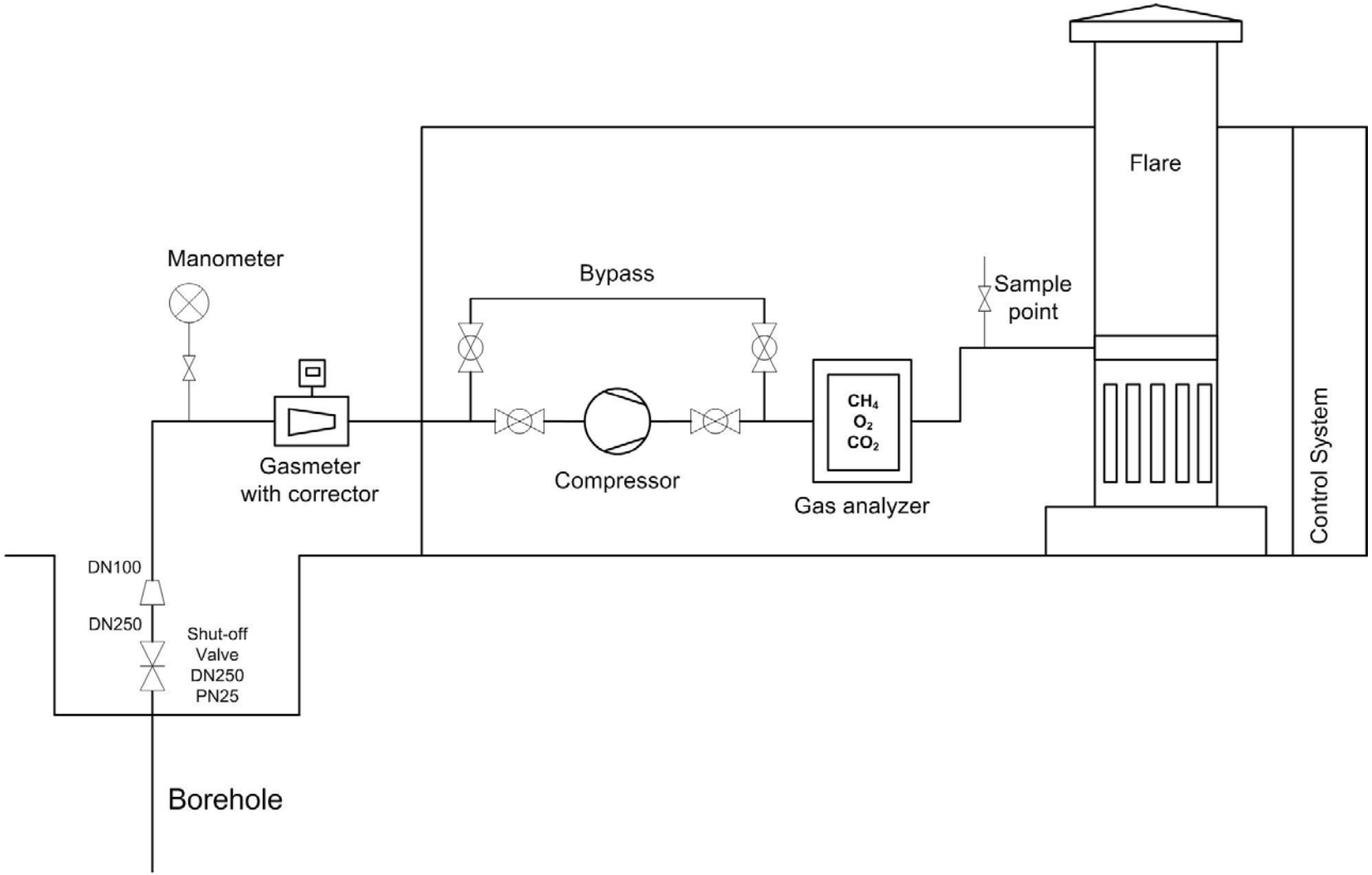

Figure 2. Żory Borehole gas flow diagram and the location of the sampling and monitoring equipment

Description of Phase 1

Duration:

It is planned that this phase will last for about 8 hours and will be considered as preparatory works leading to achieve the proper gas stream that will be subject for further analysis in Phase 2.

Type of analyses

Neither monitoring nor analyses are planned. At the end of the trial capture one gas sample will be collected for chromatographic analysis to determine the parameters of the gas before its flowing into the corrector.

Description of Phase 2

Duration of a single test capture campaign

Gas sampling will be carried out on a continuous basis for the period of 7 days. It is assumed that within a single test capture at least a 72 hour period (3 days) of the gas flow characterized by a stabilized efficiency must occur.

Number of campaigns

Not more than 5, the duration of each minimum 3 – maximum 7 days depending on the stability of the gas parameters i.e. fewer campaigns for more stabilized parameters, more campaigns for instable parameters.

Scope and type of analytical procedures

Type of the gas chemical analyses

CH_4, O_2, CO_2 concentration measurements carried out in the captured gas in 15- minute or more frequent intervals. Additionally mercury content in the gas will be measured, the frequency of this measurement will be determined by Hg concentration in the captured gas and will verify from the measurements taken once a minute to once an hour and finally once a day until this parameter will be stabilized.

Analyzed external parameters

Temperature and atmospheric pressure will be measured in situ by a small meteorological station. The data will be colleted simultaneously with the gas sampling for chromatographic analyses. The data from the meteorological station will be transferred to a computer for storage. A comparative analysis to determine potential changes in the atmospheric pressure on the chemical composition of the gas is planned (e.g. diagrams of daily pressure and methane concentration in gas)

Data collection procedure

Data characterizing gas composition and data from the meteorological station will be recorded in special data collection sheets. A template is included in Appendix 1. Data from

the sheets will be transferred to a computer database once a day the. This procedure will be applied both for data collected in-situ and laboratory data from chromatographic analyses.

Characteristics of the analytical methods and equipment

Gas meter and collector – measurement of gas flow in working conditions (m^3/h) and in normal conditions (Nm^3/h) after temperature and pressure correction. The selection of the gas meter will depend on the intensity of the gas stream at the borehole outlet. Setting the corrector with the chemical composition data will take place after the first chromatograph analysis made during the trial capture. Data on the temporary gas flow (efficiency) in normal conditions and their recording in the sheet will be made during sampling for chromatographic analyses. Data will be transferred to a computer database at least once a week.

Chromatograph Unicam 610/50 – samples for chromatographic analyses will be carried out according to the established procedure (ISO 10723:1995 Natural gas – Performance evaluation for online analytical systems). Samples will be collected by qualified personnel. Each sample will be marked in the following way:: M-1 – date –sample no. Sampling will be made at least 6 times a day: every four hours. When the parameters are stabilized, the frequency of sampling may be reduced, however at least one sample per day is assumed. The chromatographic analysis of the collected gas samples will be made during the day i.e. from 7a.m. ÷ 2 p.m. at the laboratory of the CETUS – Energetyka Gazowa by authorized personnel and approved by the Head of the laboratory or Director. Samples collected in the evening or during night will be stored in a closed container located by the borehole and forwarded to the laboratory at 8 a.m. of the following day.

Since 2005 the CETUS Laboratory is a validated analytical lab (Report 220/B/PFC/2004) of the Central Measurement and Research Laboratory of the Polish Oil and Gas Exploration and Mining Company PIGNIG S.A. .

Measurement of the gas overpressure – these measurements are directly linked with the assessment of the exploitable methane resources. It is important to identify if there is overpressure in the borehole which would prove a continuous methane desorption process from the non-exploited coal beds and a simultaneous secondary saturation of the bed with methane migrating from the deeper coal deposits, cracks and faults. The overpressure measurement will be carried out using a manometer installed at the head of the borehole. First measurement will be made before the trial capture. Following measurements will be made each time when the gas flow is stopped (instantly after the stopping and initiation of the capture) without any fixed timeshedule. If the interval between the capture is longer than 3 hours, the overpressure measurement will be made after each 1,5 - 2 hour. The data from the measurement will be recorded in a data sheet. A template is provided in Appendix 2.

Characteristics of the key measurement equipment

Pro2 SAS1 gas analyzer will be used to perform the basic analysis of the captured gas i.e. determination of methane, carbon dioxide and oxygen contents

CH_4 content analyzer

Methane content will be analyzed using NDIR gas analyzer (Non-Dispersive Infrared).The technique relies on the energy absorption characteristics of a particular gas in the infrared region.

Technical parameters

Scope :	0 – 100 Vol%
Precision:	+/- 2%
Time step	5 seconds
Temperature range :	0-45^{0}C
Humidity:	0-100% (non-condensed)
Gas flow	10 – 90 l/h
Power supply:	24 VDC

CO_2 content analyzer

CO_2 content will be analyzed using NDIR gas analyzer (Non-Dispersive Infrared).The technique relies on the energy absorption characteristics of a particular gas in the infrared region.

Technical parameters:

Scope:	0 – 100 Vol%
Precision:	+/- 2%
Time step:	10 seconds
Temperature range:	0 – 45oC
Humidity:	0 – 100% (non-condensed)
Gas flow:	10 – 90 l/h
Power supply:	24 VDC

O_2 content analyzer

Technical parameters

Scope:	0 – 25 Vol%
Precision	+/- 10%
Time step:	15 seconds
Temperature range	0 – 45^{o}C
Humidity:	0 -100% (non-condensed)
Gas flow:	10 – 90 l/h
Power supply:	24 VDC

The analyses of the basic parameters of the gas captured from the borehole will be accompanied by the measurement of trace gases including selected hydrocarbons other than methane and mercury compounds. Except mercury, the mentioned compounds will be determined using ATI UNICAM 610/50 gas chromatograph.

UNICAM 610/50 gas chromatography with FID

It is a gas chromatograph with flame-ionization detector (FID), commonly used for analyzing natural gas. Helium and air will be used as a carrier gas.

Technical parameters

Helium is introduced under the pressure of 0,45 MPa from the cylinder in which is stored under the pressure of 16,5 MPa.
Air under the pressure of 0,4 - 0,5 MPa is used for supplying the pneumatic valves which switch the columns.
Oven temperature: 80^{0}C

Detector: FID
Detector temperature 120^{0}C
Injection temperature: 100^{0}C

Hg analyzer

Mercury concentration will be analyzed with the use of RA-915$^+$ ANALYZER (Lumex Ltd).
That is a spectrometer for determination of mercury vapor concentration in ambient air and natural and industrial gases. The mercury analyzer operation is based on differential Zeeman atomic absorption spectrometry using high frequency modulation of light polarization. Mercury lamp is a source of radiation (λ=254 nm), placed in a permanent magnetic field. The mercury resonance line is split into three components (Zeeman mercury triplet: π, σ_-, σ_+). When mercury vapor is absent in the analytical cell, the radiation intensities of both σ_- components are equal but when mercury atoms appear in the analytical cell, the difference between the intensities of the σ components increase as the concentration of mercury vapors grows.

Technical parameters

Detection limit for mercury vapor concentration with the use of:

- Multi – path cell – 0,2 [ng/m^3],
- Single – path cell – 500 [ng/m^3] ,

Maximum mercury vapor concentration with the use of :

- Multi – path cell – 20 000 [ng/m^3],
- Single – path cell – 200 000 [ng/m^3],

Gas or air temperature - +1 – 40 [^{o}C],
Work pressure – 84,0 – 106,7 kPa.

Health and safety measures

Gas sampling on site and further procedures related to samples analysis will be carried out according to respective Polish health and safety regulations and procedures obligatory in the CETUS company.

CETUS – Energetyka gazowa has the following TŰV certificates:

- ISO 9001:2000 – Quality management systems – Requirements,
- ISO 14001:2004 – Environmental management systems – Specification with guidance for use.

Appendix 1

CAPTURED GAS PARAMETERS DATA SHEET

DATE: ……

Sample No	Hour	External parameters		Gas flow Nm^3/h	Gas pressure :		Gas analyzer recordings, % mol		
		Temperature ^0C	Atmospheric pressure hPa		Head kPa	Gas meter kPa	CH_4	O_2	CO_2
1	:								
2	:								
3	:								
4	:								
5	:								
6	:								

TEST CAPTURE NR …….

Annexes :

- 1. Chromatographic analysis data (printouts)
- 2. Diagram and a table of CH_4, O_2, CO_2 content changes (data from the gas analyzer) ,

Appendix 2

BED OVERPRESSURE MEAUREMENT DATA SCHEET

No record	Date	Hour	No of test capturing	Overpressure , kPa
1		:		
2		:		
3		:		
4		:		
5		:		
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