A MODERN APPROACH TO METHANE DRAINAGE CONTROL AND UTILISATION

By

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ABSTRACT

Approval to operate Longwall No. 7 at Appin Colliery in 1979 was granted pursuant not only to the usual statutory provisions, but also that an adequate means of drainage of methane gas be incorporated. A methane drainage plant was subsequently designed and constructed some two km from the pit top at the site of the Colliery main upcast and downcast shafts.

Modern plants of this nature are completely automated using programmable controllers and computers to provide control and management reporting functions. Complex mechanical systems are installed to extract the gas and in handling and storage processes.

Gas utilisation plants exist which can generate power from methane. These plants are further enhanced by harnessing waste heat produced in the generation process.

The installation, automation control and monitoring of these plants incorporates many facets of engineering from high voltage power supply and computer technology to complex gas handling procedures used in gas compression storage and generation of electric power.

INTRODUCTION

The extraction and utilisation of methane for safety or economic reasons requires diligent application of proven safety methods and inovation in the process planning and development of equipment designed to modern technical standards.

Appin Colliery's methane extraction plant is an example designed around proven practice and current technology.

Gas utilisation plants require adequate consideration to buffer storage mediums. Size, type, protection and control are only some of the aspects to be considered. These plants incorporate compressors, de-humidifiers and waste heat recovery units, with electric power generation being one likely end use. Selection of this equipment must be made with end use and economic constraints borne in mind.

The Appin extraction plant is located at a remote site introducing requirements for remote control and monitoring computer systems. Because of this plant's importance to mine safety and production many aspects relating to plant integrity are incorporated. Micro processors are used in automation and monitoring hardware and in management reporting systems.

MECHANICAL ASPECTS OF CONTROL OF METHANE GAS EXTRACTION AND UTILISATION PLANTS

Hawker Siddeley Engineering Pty. Limited submitted a tender for the surface works associated with the methane drainage project at Appin Colliery as described in a paper by S. Battino and R. Regan (1982). In the event the company was awarded two contracts, namely

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one for the supply, installation and commissioning of the mechanical surface equipment and the second for the supply, installation and commissioning of the control equipment associated with the mechanical plant. The design parameters were the subject of discussion with the Collieries Division of A.I.S. and the final plant layout reflected features peculiar to the site. Basic design philosophy will be dealt with in later sections, therefore remarks in this section of the paper will be limited to the following.

1. Revised P and I diagram for the surface equipment insofar as it reflects the requirements peculiar to the clients' requirements and the specification stipulation that this is an unmanned and "remote" site.
2. The suggested equipment necessary to convert this gaseous release of potential energy into a reliable and beneficial energy source. In particular this would deal with electrical power generation from gaseous fuel detailing a plant which is already in operation.
3. The various alternative means of compressing, storing, and modifying crude methane collection systems to provide a stable energy source for conversion into electrical or thermal energy.

THE APPIN METHANE DRAINAGE SURFACE INSTALLATION

As originally envisaged the Appin installation followed along the lines recommended by the Consultants, and as shown by Morris (1982) Fig. 4. The final installation was as shown on the attached P and I Drawing, Fig. 1, which incorporated the following alterations which were pertinent to the peculiar circumstances at Appin.

1. The suction hand opening magnetic valve was deleted and replaced by a motorised open/shut valve. This decision was prompted by the realisation under some fail/safe circumstances it was more realistic to allow this to remain in the open position. In fact closure was only required in the event of fire or gas release to atmosphere within the building. In all other emergency and alarm modes the valve would remain open.
2. An automatic by-pass system was installed which would release the methane to atmosphere in the event of total failure of the gas exhausting system. Please note that the use of a negatively biased non return valve in this by-pass line ensures that decay of suction vacuum will release methane to atmosphere and that the valve will re-seal on establishment of inlet vacuum.
3. Differential pressure valves were deleted for installation at a later date if gas was to be utilised for energy production.
4. Methane could be released to atmosphere at the ventilation fan outlets or by means of a separate chimney and transfer from one discharge point to the other was automated so that release via the chimney would occur if the ventilation fans stopped.
5. Critical valves such as those on compressor outlets were provided with position indicators. Any malfunction could thus be alarmed and action taken.
6. Compressors, together with their water cooling and pumping circuits were treated as unit items so that in the event of malfunction on any unit critical component the compressor would shut down.
7. Only two controls (compressor hand stop and compressor motor thermister) were

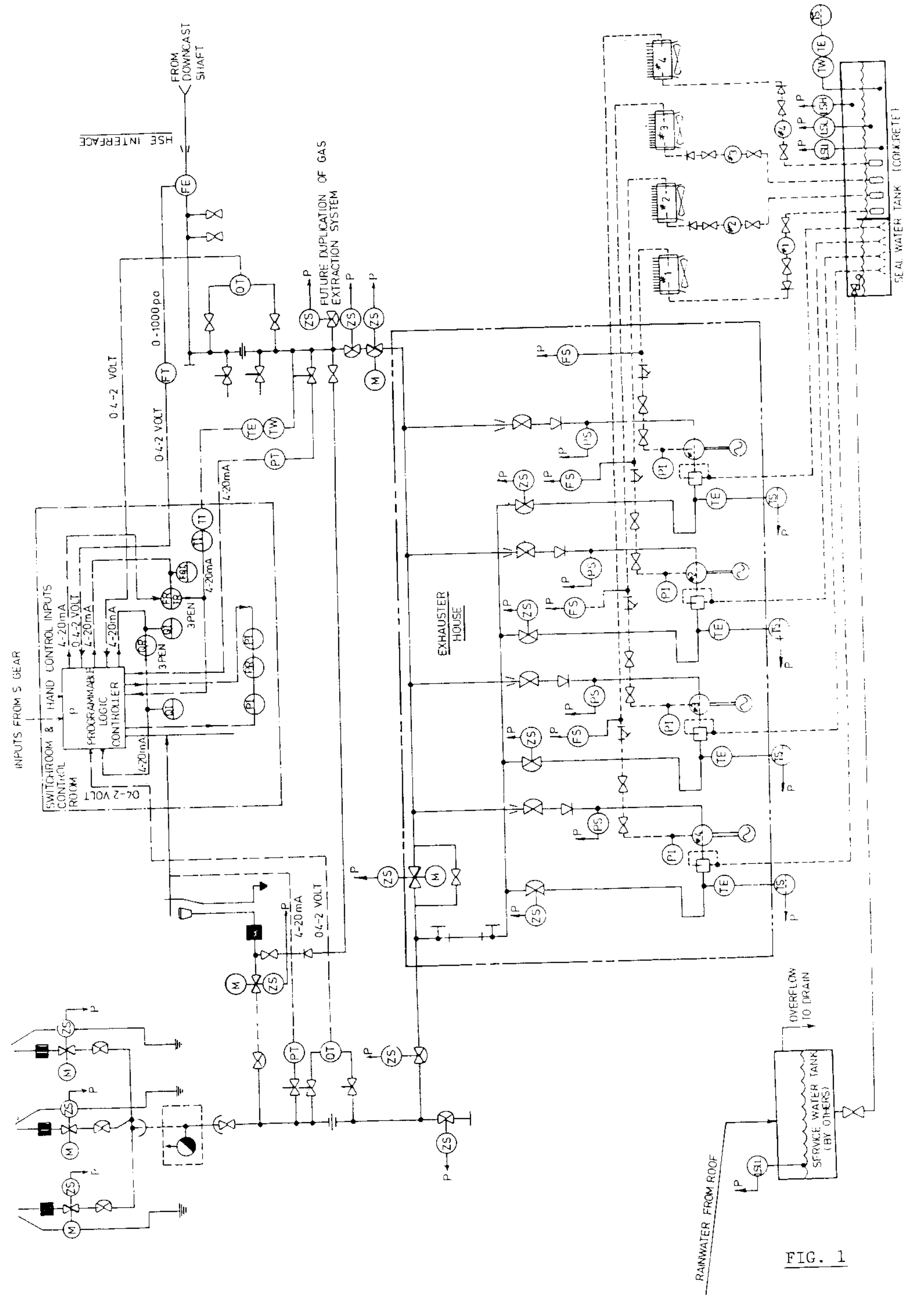
FROM DOWNCAST SHAFT
HSE INTERFACE
FUTURE EXPLOITATION OF GAS EXTRACTION SYSTEM
0-1000 pa
0.4-2 VOLT
4-20mA
INPUTS FROM S GEAR
SWITCHROOM & CONTROL ROOM
HAND CONTROL INPUTS
PROGRAMMABLE LOGIC CONTROLLER
3 PEN
EXHAUSTER HOUSE
SEAL WATER TANK (CONCRETE)
OVERFLOW TO DRAIN
SERVICE WATER TANK (BY OTHERS)
RAINWATER FROM ROOF

FIG. 1

hard wired into the compressor control. All other stop/start transfer, shutdown, control and alarm functions were incorporated into the P.L.C. The station was therefore designed for unattended operation.

EQUIPMENT SELECTION

The type of equipment that is needed to convert the methane air mixture into a usable fuel depends on the proposed eventual use to which the gases are put. The remarks in this section are confined to the treatment and handling of gases that are to be used for electrical power generation. The process is essentially the same irrespective of which type of prime mover is used (gas turbine, dual fuel or spark ignition engine). Gas is required at pressures of approximately 540 kPa for turbines and 340 kPa for reciprocating engines. A typical gas handling scheme is as shown in Fig. 2. The equipment is installed on a sludge gas utilisation scheme at a major sewage works in Australia. The installed capacity of the generating plant is 4.0MW and the sludge gas has the same calorific value as a mixture of 60% methane and 40% air.

Gas Holder

A conventional water sealed gas holder is used of $4500m^3$ capacity which allows variations in gas production rates to be catered for. It also caters for variations in gas usage when the generators are running in "island mode". The gas holder is column guided and fully automated. Position switches on the holder perform the following functions.

1. Shut the inlet valve when the gas holder is full and ignite the waste gas burner.
2. Open the gas inlet valve and extinguish the burner when the holder moves from the full.
3. Shut off gas compressors when the gas holder is empty.
4. Allow re-start of compressors when partially full.
5. Vent gas to atmosphere if holder travel is impeded.
6. Give remote level and alarm indication.

The gas holder is designed with a specially reinforced bell to withstand slight vacuum conditions and external reinforcing to permit stable operation in the event of a cyclone (50m/sec wind velocity).

Compressors

Horizontally opposed reciprocating compressors are used on the gas holder outlet to compress the gas to 340 kPa. Each compressor will deliver sufficient gas for one dual fuel engine of 2.0MW giving two working compressors and one in reserve. The compressors have the following safety and control features.

1. Low inlet pressure shutdown.
2. Automatic outlet pressure regulation by step control (25% - 50% - 75% - 100% flow).
3. Automatic shut down for lub oil failure, cooling water failure, high outlet gas temperature.
4. Automatic overspill in the event of excess gas compression (normal operating mode is volume modulation with no power wasted by overspill).
5. Automatic transfer of duty between compressors on failure to start or loss of outlet pressure.
6. Automatic stop/start of compressors according to gas demand.
7. Control by local P.L.C. or remote computer as selected.

Gas De-Humidifier

After compression gas becomes saturated and a small de-humidifying plant is installed to reduce the gas dew point to 15^oC thus protecting the extensive downstream pipework

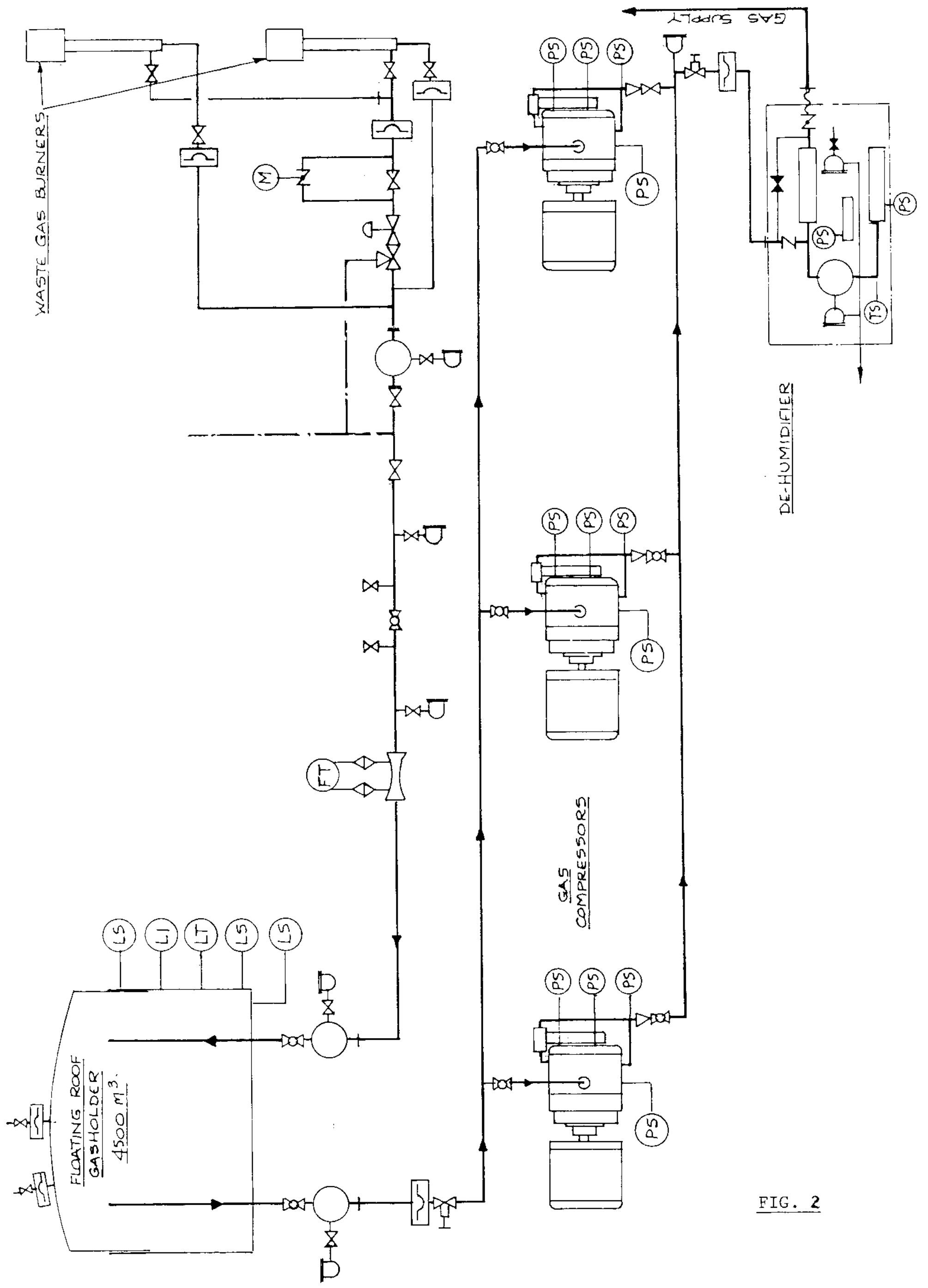
WASTE GAS BURNERS
GAS SUPPLY
DE-HUMIDIFIER
GAS COMPRESSORS
FLOATING ROOF
GASHOLDER
4500 m3.
PS
TS
M
FT
LS
LI
LT

FIG. 2

and gas receivers. The gas is cooled in a shell and tube heat exchanger. The cooled outlet gases pass through a condensate filter and then through a second heat exchanger where they serve to cool the incoming gases. In this way maximum use is made of the conventional refrigeration unit which will deal with $1500m^3$/hr using a small 5kW electric motor.

Waste Heat Recovery

The plant under discussion utilises dual fuel (methane/diesel) engines to drive the generators. Waste heat recovery is installed as a use can be found on the site, for low grade heat in the form of hot water. Heat is recovered from both the engine jacket water and exhaust gases and the pipework follows the layout as shown in Fig. 3. Such a system is applicable to gas turbines. Where higher grade heat is required exhaust steam boilers, forced hot water or heating oil boilers can be fitted to exhaust systems. Jacket water heat recovery is limited to low grade temperatures.

Electrical Generation

The electrical generators and associated controls allow for the following options.

- Peak lopping for peak tariff consumers.
- Load shedding for power outages.
- Fuel economies - match sets to load for different sizes.
- Ramp up/down for auto start up/shut down.
- Manual override capability.
- Auto reclosure for non critical faults.
- Data logging or interface with existing data loggers.
- Utilisation of waste heat for steam or hot water production.

At this Wastewater Treatment Plant methane (waste sewerage gas) is used as the fuel source for an automatic power station comprising two 3.3kV 2.0kW generators. It should be noted that the entire plant including wastewater processing is run by two shift operatives through a central control facility utilising a Honeywell TDC 2000 computer.

The automatically controlled station can be run in parallel with the local supply authority or in "island mode".

The power station facilities include:

1. Automatic synchronisation with the supply authorities system.
2. Soft loading of incoming generator.
3. Importing or exporting of fixed quantities of kW power.
4. Auto selection of any required in house plant power factor.
5. Auto kW/KVA sharing between gen sets.

Due to the requirement that the station be run unattended or with limited attendance complex protection monitoring equipment was employed.

Fig. 4 shows the type of interconnection of protection supplied on this station, and gives a brief of its functions.

Electrical Equipment List - Function

1. Differential protection for generator: Detects fault in generator cables or internals, which normal overcurrent protection could not detect, and trips breaker.
2. Isolation switch: Used for safety/ maintenance isolation of dangerous voltages.
3. Earthing switches: Used for safety/ maintenance.
4. Circuit breaker sized to suit generator: Used to connect the generator to grid.
5. Metering: Amps, Volts, KW, KVARS, P. Factor.
6. Overcurrent/earth fault protection: Trips breaker if currents exceed machine

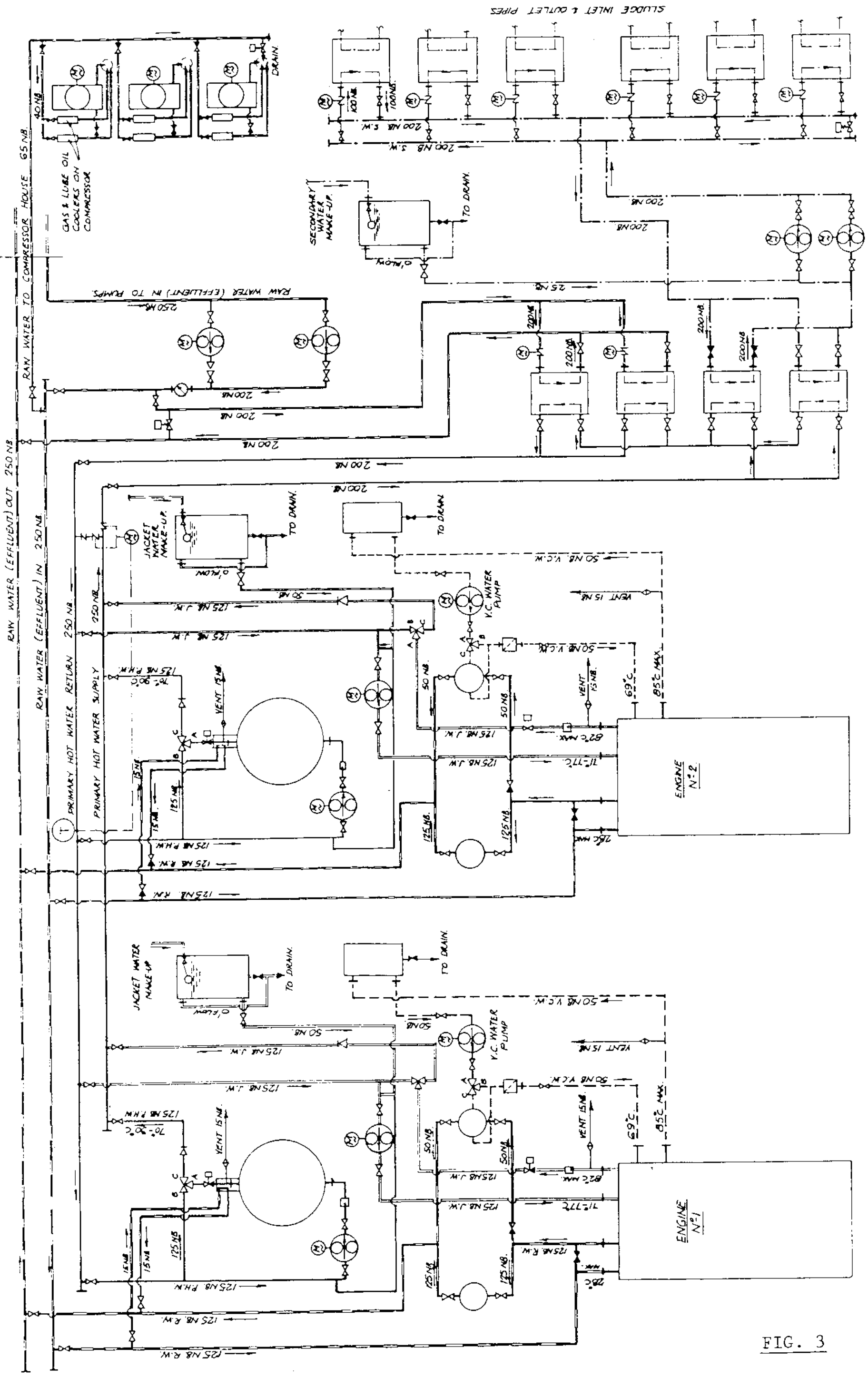
SLUDGE INLET & OUTLET PIPES
RAW WATER TO COMPRESSOR HOUSE 65 NB
RAW WATER (EFFLUENT) OUT 250 NB
RAW WATER (EFFLUENT) IN 250 NB
RAW WATER RETURN 250 NB
PRIMARY HOT WATER RETURN
PRIMARY HOT WATER SUPPLY
ENGINE No 2
ENGINE No 1

FIG. 3

ratings.

7. Excitation voltage transformer: Provides power to excite generator field.
8. Automatic Voltage Regulator (AVR): Automatically maintains generator voltage level or quadrature current droop characteristics.
9. Field failure relay: Detects loss of generator field - trips breaker - prevents generator absorbing large over currents.
10. Reverse Power Relay: Detects loss of prime mover torque (e.g. loss of fuel) and trips breaker.
11. Bias Unit: Controls Gen real or reactive power constant for parallel operation with grid.
12. Winding Temperature Relay: Monitor winding temp and trips breaker if temperature becomes dangerous.
13. Excitation C.T.'s: Current transformers to provide energy to excitation circuit in event of short circuit dropping terminal volts below level capable of sustaining short circuit currents. This is necessary to ensure current operated protection has operated.
14. Star Point: Point at which generator neutral is established.
15. Standby Earth Fault: Backup earth fault protection, voltage operated.
16. Neutral Contactor: Contactor can be opened when generator is run in parallel with another generator whose neutral is bonded to earth, or in parallel with grid. Opening can limit harmonic curculating currents if set waveform differs significantly from the line voltage waveform.
17. Neutral Earth Cubicle: Earthing Resistor or Reactor to limit fault current that can flow from phase to earth, limiting fault MVA/damage it could cause.
18. Automatic Synchronizer: Controls voltage and speed of incoming set to match line volts and frequency, and enables closure of breaker when phase angles are within certain tolerances for sufficient length of time.
19. Manual Synchronising: Enables operator to manually accomplish matching line volts, frequency and phase to generator volts, frequency and phase.
20. Import/Export Unit: Enables operator to control import or export of MW and/or MVAR to a grid in conjunction with own in house load demands.

Choice of Equipment

Gas Storage. The three types of storage available are detailed below, together with comments on their respective features.

1. Low pressure storage in conventional water sealed gas holders. Capital cost is high but running and maintenance costs are negligable. In particular small storage volumes are expensive and economy of scale is apparent over $3000 m^3$.
2. Low pressure storage in piston type holders with mechanical or diaphragm type seals. Capital costs are slightly less than a water sealed holder but maintenance and running costs are increased.
3. High pressure storage in cylindrical bullets or spherical vessels. Capital cost is approximately half that of low pressure storage but running costs are high, being mainly the energy costs associated with compression. To achieve reasonable storage volumes it is necessary to compress to much higher pressures than those required for combustion. A commonly accepted limit is the top pressure achievable by single

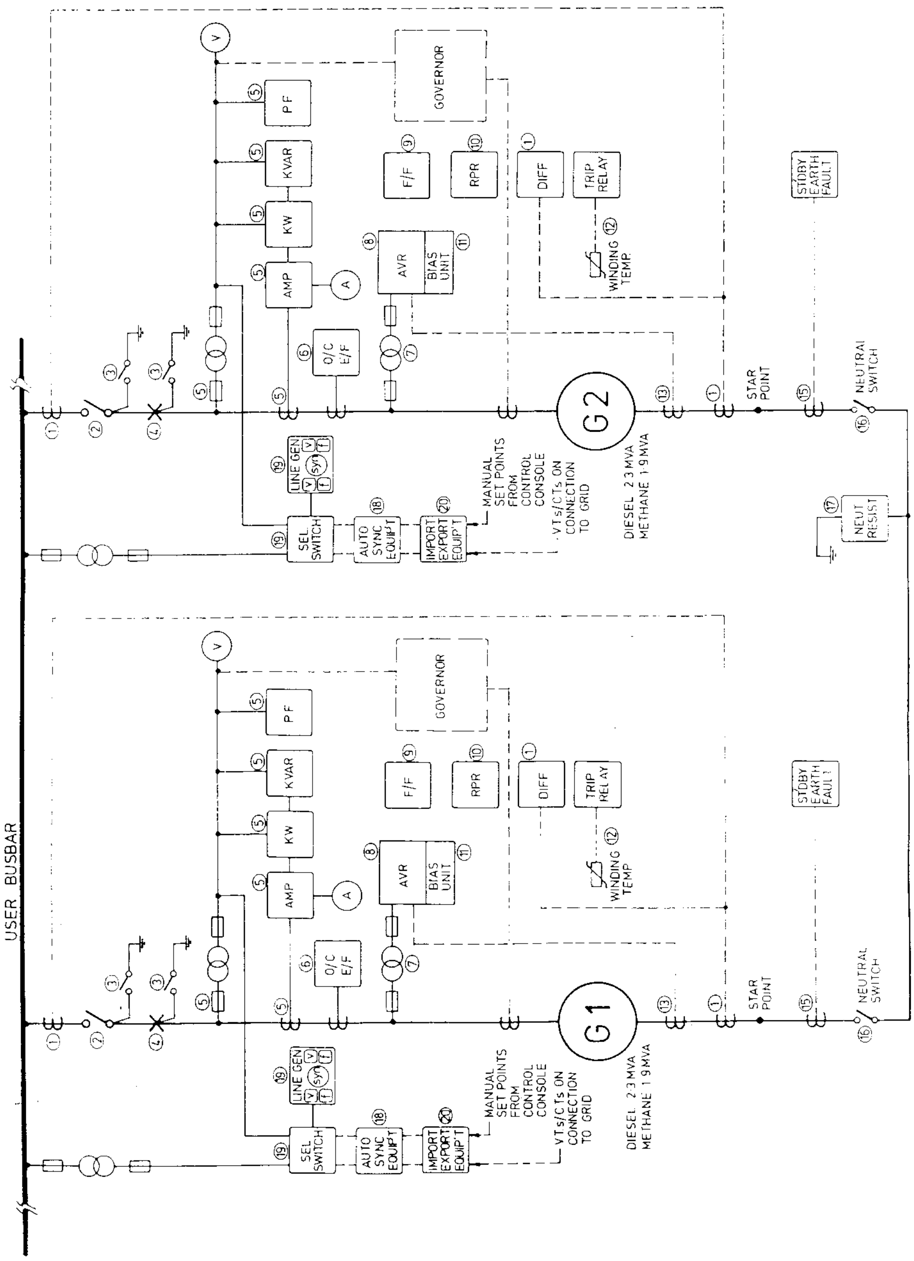
USER BUSBAR
GOVERNOR
PF
KVAR
KW
AMP
F/F
RPR
DIFF
TRIP RELAY
AVR
BIAS UNIT
O/C E/F
WINDING TEMP
STDBY EARTH FAULT
G1
G2
STAR POINT
NEUTRAL SWITCH
NEUT RESIST
LINE GEN
SEL SWITCH
AUTO SYNC EQUIPT
IMPORT EXPORT EQUIPT
MANUAL SET POINTS FROM CONTROL CONSOLE
VTs/CTs ON CONNECTION TO GRID
DIESEL 2.3 MVA
METHANE 1.9 MVA

FIG. 4

stage compressors being approximately 600 kPa.

Compressing Plant. The choice of liquid ring type compressors for combustible gases & fuel-air mixtures is one of long standing. The advantage of this type of machine is its absolute safety in having no moving metallic parts in contact. However, as means of moving gas along a pipe line it has the disadvantages of high capital cost, heavy weight and dependance on an external water supply. Other types of compressors can be used on the outlet of liquid ring compressors to achieve the high pressures needed for utilisation on the assumption that explosive mixtures will not be handled due to the instrumentation incorporated in the exhausting system. The choice of compression plant has an influence on the plant layout and selection of storage type and volume. The respective features of compressor types are as follows:

1. Liquid Ring
   Suitable for medium flows and limited pressure differentials where safety is prime consideration. Requires water and sealing water with cooling system. Not suited for variable flow rates.
   Efficiency 70/73 per cent up to 70 kPa
   67/70 per cent up to 180 kPa
2. Roots Type
   Suitable for small to medium flows with a maximum of 80 kPa differential available. No cooling water needed. Not suited for varying flow rates. Efficiency 65/70 per cent at 70 kPa.
3. Reciprocating Type
   Suitable for small and large flows. Staged machine capable of very high pressure differentials. Cooling water rates over full range of output with little power loss.
   Efficiency 76 to 78 per cent up to 4:1 pressure ratio (370 kPa).
4. Screw Type
   Suitable for large flows. Staged machine capable of high pressure differentials. Not suited for varying flow rates. Efficiency 70/75 per cent at up to 4:1 pressure ratio (370 kPa).
5. Centrifugal
   Suitable for low or high flows at low pressures or very high pressures capable of varying flow rates over top 40 per cent of flow range. Efficiency 72/76 per cent at up to 2:1 pressure ratio (102 kPa).

Except for specialist use or very large volume flows the choice of compression plant for methane/air usage would be between screw and reciprocating types. A screw compressor, whilst possibly cheaper would be less efficient throughout its volume range and certainly noisy. Means of control would be by inlet throttling, variable speed drive or relief to inlet. Reciprocating compressors, usually of the horizontal opposed type, are efficient throughout the volume range. Control is by means of suction valve unloading which allows the piston to "free wheel" for part of its stroke. There are various means of achieving suction valve unloading which can result in step volume increases in output or infinitely variable output throughout the volume range all at maximum efficiency. In addition, operation is relatively quiet. For continual use at maximum efficiency with precise means of control, and a variable output the reciprocating compressor would appear to be preferable.

Gas Conditioning. For use in dual fuel engines or in turbines a reasonably constant gas quality must be maintained. This means controlling the methane air proportions to a constant calorific value. Dual fuel engines will tolerate a $\pm$5% swing in calorific value from set point though gas turbines are somewhat less flexible. Equipment built into prime movers to compensate for a variable calorific value is not generally available from all manufacturers. An alternative method of stabalising the calorific value is by "ballasting" with additional air. This air can be admitted either before or after the exhausters and can be controled to a set specific gravity of the resultant mixture. It would appear that a set point of 60% methane would be practicable and would lie well outside the explosive limits.

AUTOMATIC OPERATION, CONTROL AND MONITORING OF A METHANE DRAINAGE PLANT - APPIN COLLIERY

Appin Colliery is one of nine operating collieries owned by the Broken Hill Proprietary Company Limited (BHP) Steel Division in the Illawarra Region south of Sydney.

The mining district around the township of Appin has a history of high methane gas in its productive Bulli Seam.

Approval by the then Department of Mineral Resources and Development in 1979 to operate Appin Colliery's new longwall No. 7 was granted pursuant not only to the usual statutory provisions, but also that an adequate means of drainage of methane gas be incorporated.

From this instruction, decisions were made to design and implement not only a system adequate for the drainage of longwall 7 and old goaf areas, but of sufficient capacity, in two stages of construction, to pre-drain future longwall blocks with provision for future colliery expansion.

The site of the extraction plant and the associated surface to underground pipe range at Appin was necessarily remote from the Colliery administration and pit top areas to place the plant as near as practical to working areas.

The location selected was at the site of the existing main ventilation fan complex two km from the pit top. This site was undergoing major changes with the planned installation of a 66/6.6 kV substation to provide power to the new fans, two new mine feeders to be installed in the down cast shaft and for feeding the Colliery pit top area over an existing 6.6 kV transmission line.

The siting of the plant remote from the pit top was the prime reason for the decision to automate the normal operations of the plant. Remote control and monitoring of the plant was required to eliminate full time labour requirements.

POWER SUPPLY SYSTEM

The importance of the methane gas extraction plant to the safety of the Colliery and for the maintenance of continued high production levels is paramount. It is with these aspects in mind that the design of the power supply system developed.

Whilst it is economically not feasible to build in a completely redundant supply of power that would guarantee to maintain permanent operation, the system can be provided with a supply of high reliability. By designing the plant, as far as is practical, in such a way that no one component failure can inhibit either full, part or emergency modes, the ideal of a secure plant from the power supply point of view can be approached.

The supply from the Prospect County Council, the local supply authority is at 66kV and is at present unfortunately on a radial feed. This means that on loss of 66kV the plant must have an alternate power source for plant power down mode for safety reasons.

A 415V, 200 KVA diesel alternator set was provided with the new main ventilation fan complex to drive one fan at half speed by a 75kW pony drive.

This generator set is started automatically on power failure and provides standby power within seconds to the methane extraction plant controls, motorised valves and mine monitoring system.

The 66kV supply is converted to 6.6kV by two 5 MVA ONAN transformers with on load tap changers. The 6.6kV system is high impedance neutral earthed to restrict earth fault currents in accordance with the Coal Mines Regulations Act. Distribution at 6.6kV is by a conventional single bus Reyrolle bulk oil circuit breaker board, run in a split bus configuration with a bus tie run normally open.

Fig. 5 is the line diagram for the distribution system and details the inherent system integrity provided by separating the power supply from 66kV down.

AUTOMATIC CONTROL HARDWARE

The requirement that the plant should be able to operate continuously without the necessity of a full time attendant posed many problems. This aspect was outside the recommendations of the National Coal Board (N.C.B.) Consultants and required appropriate consideration in both mechanical and electrical design.

Automation of the plant can best be described as encompassing automatic control of the methane extraction pumps and ancillaries by selectively determining the number of exhausters required and controlling the inlet vacuum pressure as required by methane gas production and purity.

This type of control necessitates continuous monitoring of process variables, performing calculations utilising the variables and using the result to initiate the required system changes.

Thus the plant required an intelligent control system with the capacity to readily modify control parameters, and the necessary field hardward to be controlled.

Intelligent controllers were investigated with due regard to the above requirements and consideration to the fact that the entire plant control and indication should be handled by the one device. A work load of this magnitude was considered best handled by a micro processor in the form of a programmable logic controller (P.L.C.). After evaluation of a number of different types of P.L.C.'s the Texas Instrument PM550 was considered to provide the most suitable cost effective solution.

The PM550 provides among many of its facilities, the required sophistication in mathematics capability, enhanced operational, monitoring, fault finding capabilities and visual display capabilities with English language type interactive programming.

This P.L.C. is structured utilising modern multi-tasking micro processors providing a flexible system with the capability of performing ladder logic functions and feed back loop control. Fig. 6 illustrates the P.L.C. components mounted in the control cubicle. The PM550 consists of the following major elements:

1. Power supply (P.S.U.)
2. Central Control Unit (C.C.U.)
3. Input/Output Racks (I/O)
4. Input/Output Modules (analogue and digital)
5. Input/Output Bus Expanders
6. Field Power Supplies
7. Video Programming Unit (V.P.U.)

The power supply and central control unit are the basic building blocks of the P.L.C. system, providing the required voltages and currents for the system and containing all the intelligence to perform the controlling tasks required. The C.C.U. interrogates the status of all inputs both digital and analogue and executes resident programmes for sequential logic and provides the necessary

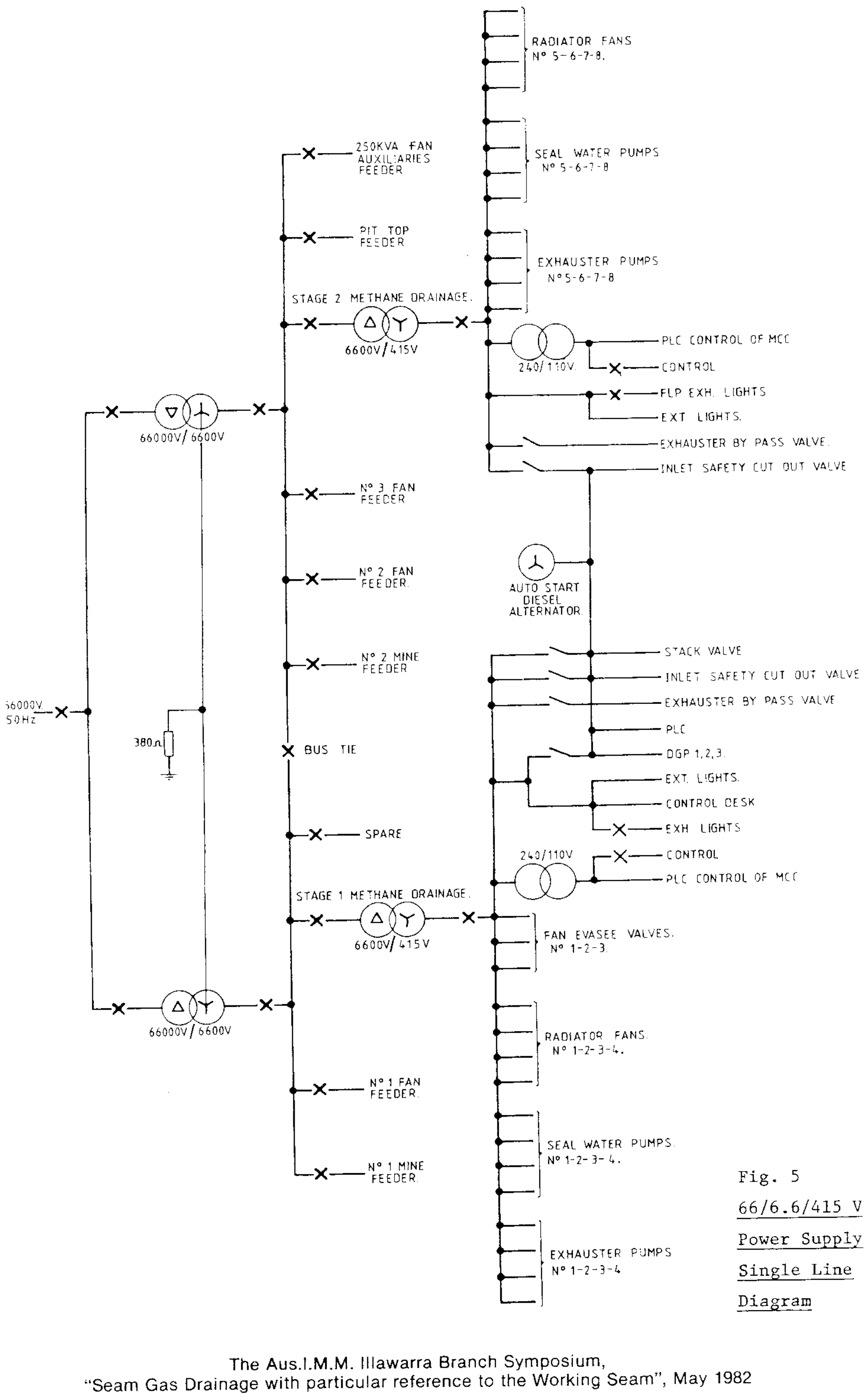

Fig. 5
66/6.6/415 V
Power Supply
Single Line
Diagram

outputs for the process control.

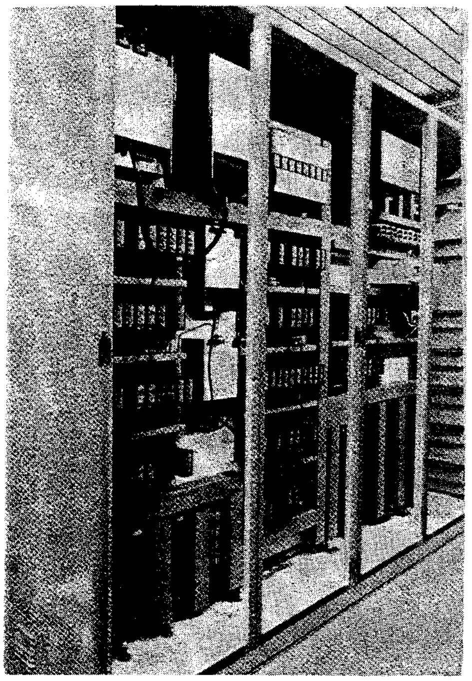

Fig. 6 Appin Colliery Methane Drainage Control Panel Showing P.L.C. Components.

All signals into and out of the P.L.C. are electrically isolated at the I/O modules. These modules also provide the signal conversion necessary to interface field signal levels to C.C.U. compatible logic voltage levels. Specific modules are provided for varying field voltages, discrete inputs (limit switches etc.) and analogue inputs (temperature, current etc.). Interface modules provide the necessary parallel to serial signal conversion for C.C.U. interrogation.

Operator interface is via the video programming unit (VPU) which incorporates a visual display type screen with a keyboard in one portable package. A printer port is also provided for producing paper copies of ladder logic and process loop instructions. On line modifications to programme, process variables and set points can also be accomplished with this unit.

The V.P.U. is permanently located in the control room for use as a maintenance tool and for direct access to process variables.

All programmes are stored in the C.C.U. utilising battery backed up random access memory (RAM) type integrated circuitry with off line storage for housekeeping purposes on magnetic media i.e. floppy disk and paper copy for maintenance purposes.

Programming the unit is made relatively simple by the extensive use of dedicated keys and a question-answer type interactive programming format. The special keys are used to denote the functions normally found in electrical control circuitry i.e. normally open and closed contacts, control relays, timers, counters etc. Descriptive subscripts and control variables such as time in a timing circuit are entered from the alpha numeric keyboard.

TRANSDUCERS

Field data is transmitted to the P.L.C. from various transducers which monitor gas temperature, static pressure, flow etc. Each sensor is designed to conform to intrinsic safety or flameproof standards as required by the Standards Association of Australia.

Field signals from active and passive transducers are conditioned for intrinsic safety by appropriate barriers which limit possible field power levels in these instruments to acceptable limits. Each transducer is treated as a separate exercise with due consideration to cable parameters, instrument burdens source power supplies and installation techniques.

Signal level conditioning is provided for Sieger equipment used for concentration pressure and flow measurements due to non standard output voltages. In addition, the output from the BM2H concentration transducer is also non linear. Therefore, in order to use this instrument in an automatic control system, its output requires linearisation. This is accomplished in both the P.L.C. and monitoring system by utilising a linearisation equation developed to very closely approximate the required linear output.

MECHANICAL SYSTEM

The field components of the automatic control system are controlled via the M.C.C. by the P.L.C. These consist essentially of the exhauster pumps and the various motorised valves used to isolate plant and the motorised by pass valve which is used to regulate gas feedback to control inlet pressure.

The four exhauster pumps in stage 1 (four more are proposed for stage 2) are Nash Hytor CL3002. Each exhauster is driven by a flameproof 185kW 1440 rev./min 415V motor started direct on line and driving its pump at 500 rev./min via a Hansen gearbox. The water sealing for each exhauster is provided by a 2.2 kW mono pump with 5.5 kW fan cooled radiators. Water flow, temperature and gas make in the hot well tanks are monitored and used in the control criteria for the plant.

Manual isolation of gas lines is provided by Saunders diaphragm valves. Keystone butterfly valves driven by 415V 2kW Rotork actuators are used in the plant automation. The actuators electric drive mechanism is completely enclosed in an approved flameproof enclosure.

The Cutler Hammer Unitrol motor control centre (M.C.C.) is designed with phase segregation on busbars and is modular in construction with separate compartments for each drive. This isolation adds to system security and enhances reliability and serviceability.

MONITORING

As BHP Steel Division Collieries Engineering Services Department had recently completed a detailed investigation into computer monitoring systems for coal mine usage, and had concluded that the Honeywell Delta 1000 System most closely met the requirements specified for BHP Collieries, the selection of a monitoring system for the methane drainage plant had been made considerably less difficult.

The control system at the remote site was subsequently designed around this equipment. Since all functions relative to the operation of the plant were to be remotely monitored by the computer, access to the computer at the drainage site was provided for a comprehensive local alarm system.

For stand alone monitoring and cost effective reasons the interface for field signals between the plant process controller (P.L.C.) and the monitoring computer was considered best handled at I/O level in lieu of a software/hardware compromise.

Each field signal therefore is used to energise a P.L.C. input module and is used concurrently as an input to the monitoring system. This type of hardware solution can prove troublesome, particularly where various system power supplies cannot co-exist. Isolation is therefore required and this is generally provided by signal diodes or opto couplers. The latter device also provides a degree of transient voltage protection and is preferred.

Both discrete and analogue signals generated within the P.L.C. are similarly decoupled for transmission to the monitoring system or the alarm annunciator on the drainage control desk.

The control room at the methane drainage site houses a number of tools for local operational procedures and monitoring purposes. See Fig. 7. These consist essentially of a mimic diagram, alarm annunciator, chart recorders, P.L.C. V.P.U. and an operators terminal for the Delta 1000 monitoring system.

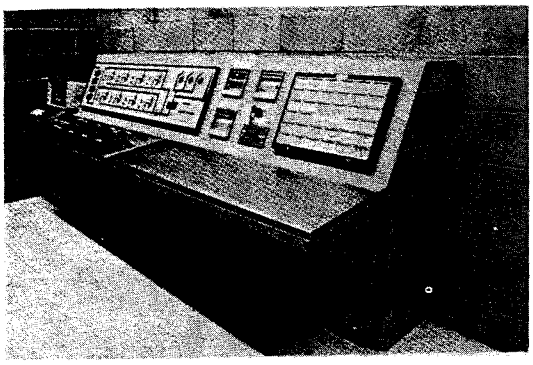

Fig. 7 Appin Colliery Methane Drainage Control Room

The mimic diagram presents at a glance the current operational status of the plant including inlet gas monitoring (temperature, pressure, concentration and flow rate), the position of all motorised valves, the status of machinery (including exhausters, water pumps, radiator fans and main ventilation fans) and outlet gas pressure. Current value of process variables are presented on digital panel meters.

Chart recorders are provided to continuously record plant variables including concentration temperature flow rate and methane flow rate (calculated from total flow and concentration). A mechanical totaliser is used to integrate flow rate signals to record total flow in units of hundreds of cubic metres.

A small alarm annunciator panel is also included which provides a general alarm indication for localising plant abnormal operating conditions.

A bank of selector switches on the desk provide maintenance personnel with an ability to deliberately isolate equipment or to select exhausters in terms of priority under automatic control. This feature permits even utilisation of plant in terms of operation duration.

Access to the P.L.C. software is obtainable via the V.P.U. located in the control room and permanently connected to the P.L.C. This unit allows access to the plant process controller for routine maintenance (diagnostics) as well as plant and breakdown fault finding. The video display can show either which parts of the control system (ladder diagram) are activated and which elements are inhibiting operation if any, or display instantaneous values of analogue input signals.

The monitoring computer is located at the pit top control centre. See Fig. 8. Information is accumulated at the methane drainage site by local stations called Data Gathering Panels (D.G.P.). Each series 1200 D.G.P. (three are used at the drainage site) is capable of monitoring a maximum of 140 digital points or 60 analogue points and is capable of providing control over 35 on/off points or 12 analogue outputs. Combinations of the above are possible with corresponding reductions in other areas.

The information is transmitted to the pit top using frequency shift keying (F.S.K.) type modems over a single telephone pair and uses a redundant path communications link. One path is via intrinsically safe barriers through the normal underground telephone cable system. This permits uninterrupted operation in the event of loss of Colliery ventilation. The second path is via the existing catenary cable underslung on the 6.6kV transmission line to the pit top.

A third pair is provided to drive the

Fig. 8 Appin Colliery Surface Control Room monitoring system V.D.U. at the drainage site. This terminal has full access to the monitoring computer and is activated either under computer control to display current status of points in alarm or can be activated via its keyboard to interrogate plant status. The V.D.U. is located near the P.L.C. V.P.U. to facilitate information access for plant diagnostics.

The computer monitoring installation at the pit top provides the capability necessary for recording and monitoring the operation of the drainage plant. Both discrete (on/off) type information as well as analogue values are recorded and displayed at that location. Alarms are automatically displayed on the V.D.U. and logged on one of the two printers in the surface control room. The second printer is used to produce management information reports which are generated at preset time intervals such as end of shift, day, week etc.

The methane drainage plant operation can be accessed at any time by the V.D.U. in the control room. Daily reports are generated to record process control parameters such as total gas flow and total methane flow etc. Other recorded values include mean values as well as maxima and minima, hours run on major plant and colliery power usage. Energy management is a standard software package and will be used to monitor and control colliery power consumption.

A colourgraphics terminal is also provided for the generation of diagrams to represent the drainage operation and general colliery status. These mimics are provided with up to 26 interactive alarm points being incorporated on up to 80 separate displays.

The monitoring computer is used also to log process variables in the underground section of the methane drainage pipeline. Static pressure, concentration and differential pressure are metered at four points on the underground line. Fig. 9 is a block diagram of the complete monitoring system and figure 10. shows an underground installation with D.G.P. I.S. barriers and transducer power supplies.

PLANT AUTOMATION

At the time of project inception, no surface methane extraction plants were in operation in Australia and to the authors' knowledge, the Appin plant was to be the first fully automated plant to be commissioned.

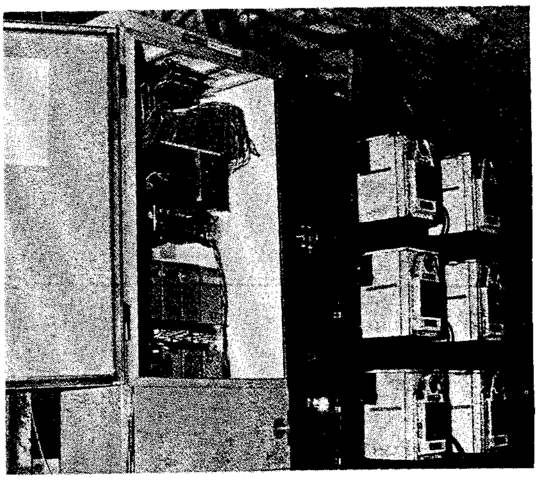

Fig. 10 Appin Colliery Methane Drainage Under-Ground Monitoring Showing D.G.P. I.S. Barriers and I/S Power Supplies.

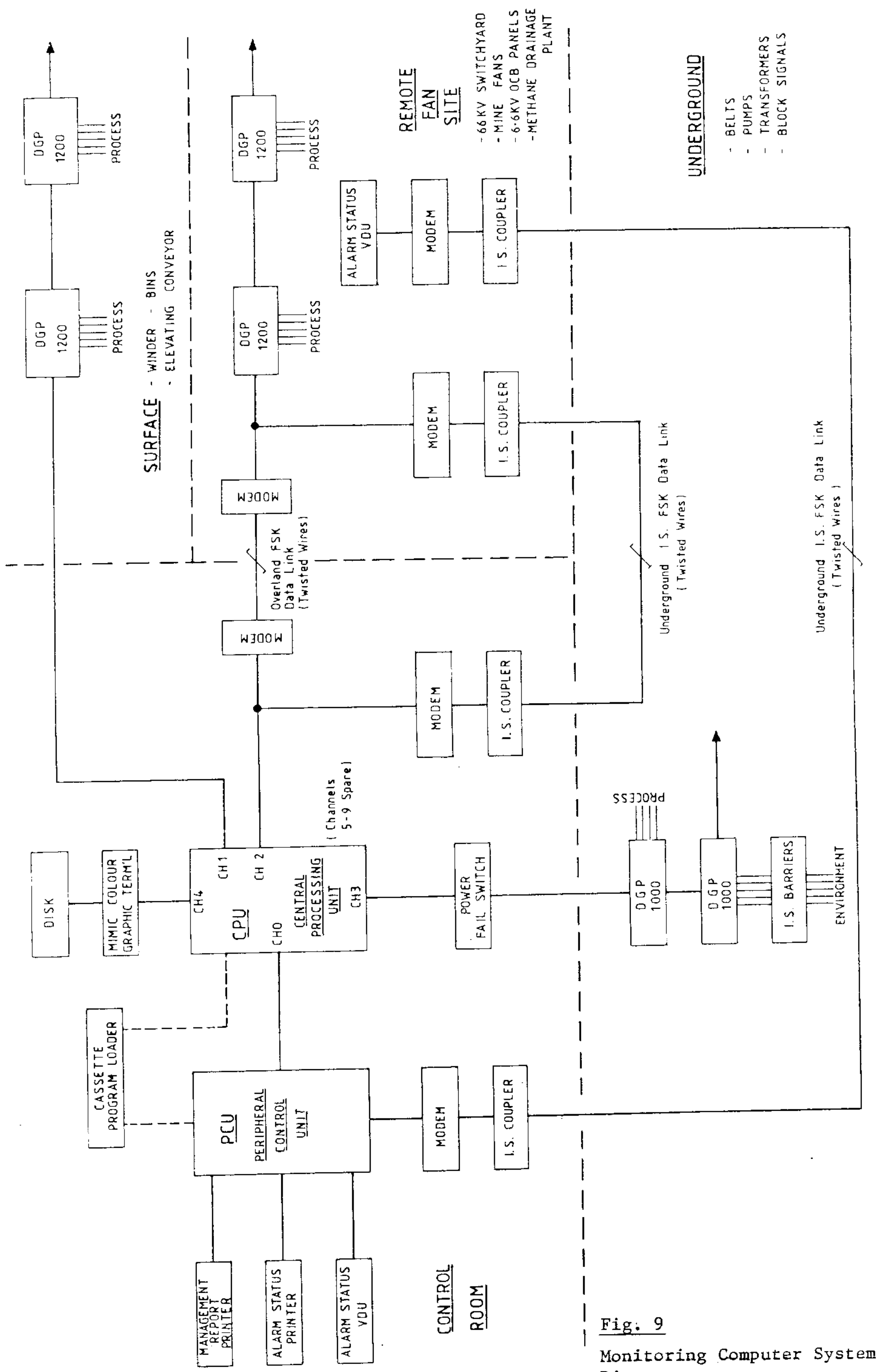

Fig. 9

Monitoring Computer System Block Diagram

N.C.B. Consultants recommendations were limited to the design of a plant with minimal operator intervention yet requiring full time attendance for switching exhausters, adjusting plant pressures and general plant surveillance.

Having made the major hardware decisions noted in earlier paragraphs and recorded by Bettina & Regan (1982), what remained was the development of the actual control loop. Many alterations to this loop have been made and are yet to be made as more is learned about the equipment and the actual generation of gas from the underground workings.

The initial approach was to set up the plant with the concept that provided enough holes were driven into gas producing areas then the greater the vacuum applied (within equipment and pipe resistance parameters) then the greater the gas flow.

This proved to be a partially incorrect assumption. Whereas the number of holes does have a marked effect on the amount of gas produced and reduced pressure does marginally increase the amount of methane gas extracted, other variables such as the apparent localised effect of longwall mining equipment (working face) to particular holes and apparent seam structure variations have a more significant effect.

As gas is produced under varying pressures, the role of the extraction plant is to provide a reduced pressure on the holes to prevent gas leakage into roadways through rib fractures, overcome the losses in the pipe range, provide a slight negative pressure to the old goaf areas and provide a sufficient positive pressure at the outlet to overcome back pressures. Further back pressures are anticipated with the installation of a future utilisation plant.

The most important aspect is that the exhausters be capable of handling the quantities of gas produced under peak conditions in order to reduce the possibility of excess methane polluting mine roadways resulting in loss of production.

CONTROL LOOP

The following parameters contribute to the process control algorithm.

1. Methane concentration
2. Total gas flow rate
3. Static pressure

Figure 11. is a block diagram of the analogue control loop and figure 12. is a block diagram of the control logic for the drainage plant.

Gas Purity

Gas purity, static pressure and differential pressure (for flow) are monitored at various locations underground on the pipe range and at the inlet to the extraction plant. With the exception of differential pressure, these variables are also monitored at the outlet of the plant. Gas temperature is also monitored at the inlet to the plant.

The Sieger BM2H has been used for continuous monitoring of high level methane. Some difficulties experienced in using this equipment include:

1. Practicality of water drainage on sample lines underground.
2. When used in conjunction with orifice plates or pitot tubes subjected to the variations in flow experienced, regulation of instrumentation gas flows are required so as not to exceed transducer ratings for prescribed instrument accuracies. This necessitated the development of a low pressure gas regulator for this application.

Gas purity is used in the following sub routines of the control system:

1. Differential purity (inlet and outlet gas purity at the extraction plant are compared to provide a zoned protection within the plant for gas leakage. This

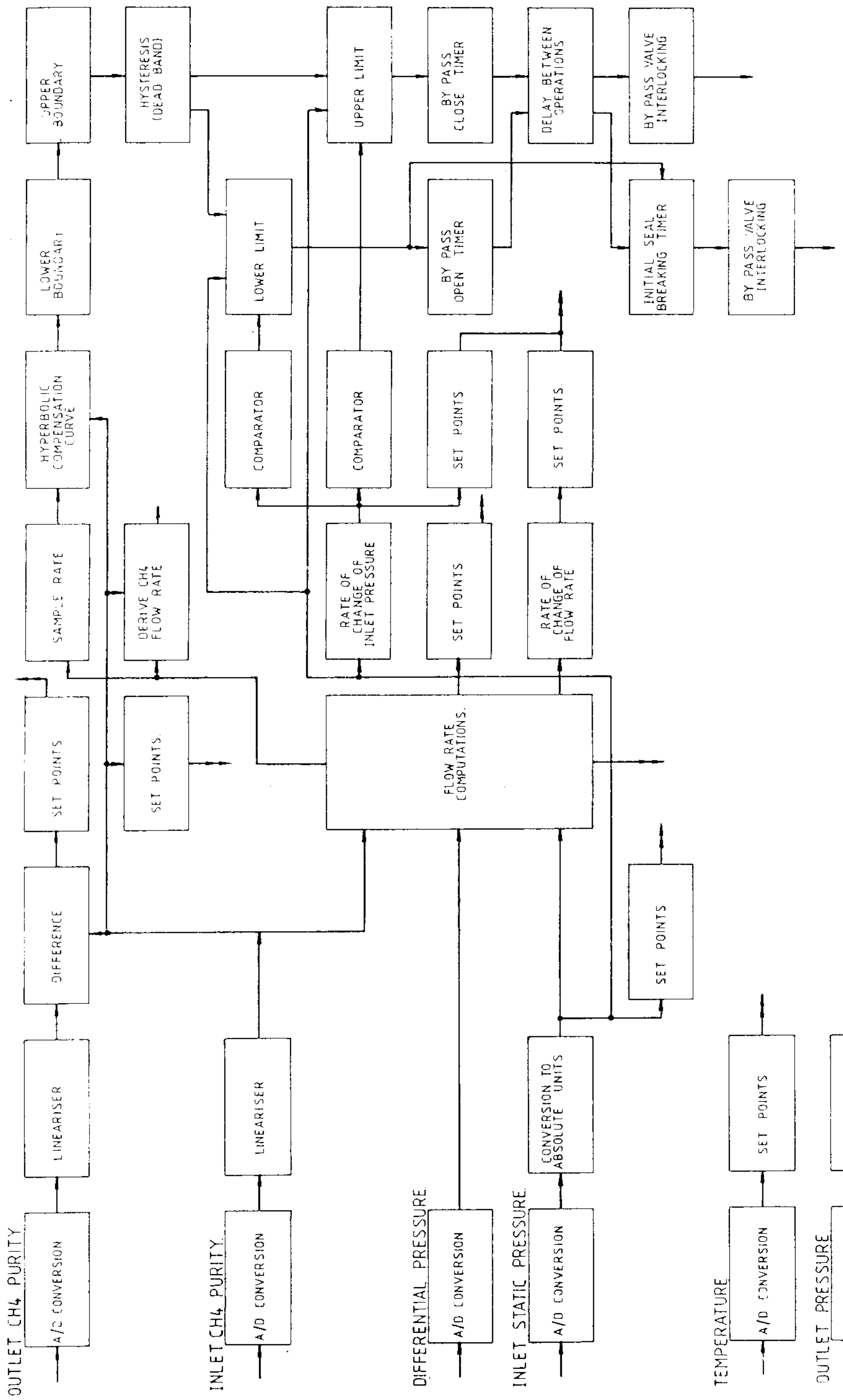

Fig. 11
Analogue Control Block Diagram
Methane Drainage Plant

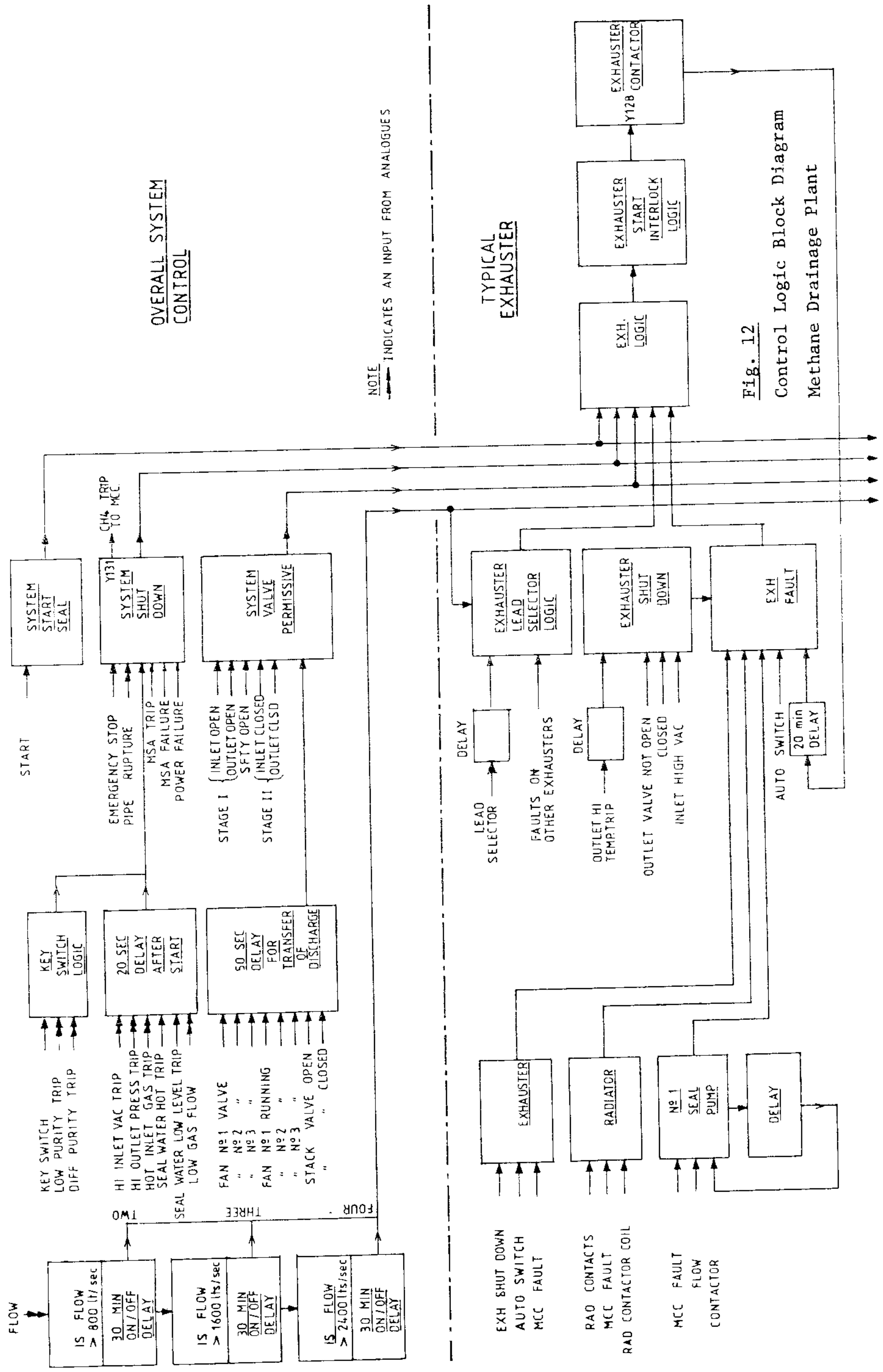

Fig. 12 Control Logic Block Diagram Methane Drainage Plant

is in addition to the M.S.A. A510 low level gas detection system used in the exhauster building and above the hot well tank.)

2. Flow rate calculations
3. Actual methane flow rate
4. Set points for plant shutdown alarm and trip
5. In the pressure control loop

Gas concentration at the inlet to the plant is used to control plant pressures if the measured purity falls below a nominal 50 percent. The degree of control exerted by this function is varied in accordance with its deviation from this value. For values below 50 percent, the plant total pressure is increased (absolutely) in a manner proportional to the purity excursion. This approach has been found to be best in practice to avoid unnecessary plant shut down due to unduly low concentrations of gas. Hysteresis type control is used to permit variations within prescribed limits without system hunting. This output is directed to the by-pass valve control loop for control of inlet pressure. For purity above 50 percent the gas concentration has no bearing on inlet pressure. This pressure is then solely controlled by the by-pass valve control loop.

Gas Flow

Gas flow is related to the differential pressure developed across either an orifice plate or a pitot tube. Each of these devices must be designed for maximum operating pressures with a prescribed gas density at specific flow rates. To use the differential pressure generated across these devices to produce accurate flow rate measurements, transducer signals are conditioned by correcting for relative density at any given methane concentration (relative density = 1 -.004475 x CH_4%) and taking into account the square root relationship and other fixed parameters. This calculation is performed for each orifice plate or pitot tube.

The corrected flow signals are used with comparator type subroutines in the P.L.C. to:

1. Control the number of exhausters (in conjunction with a stimulus period timer of 30 mins).
2. Provide a minimum flow alarm and trip point (consistent with a pipe blockage).
3. Determine a condition called Pipe Rupture (calculated from a time derivative of flow rate and inlet pressure) in which a rapid use of flow indicates a reduction in system resistance consistent with pipe damage, the object being to prevent an explosive mixture of air and methane from entering the system.
4. Sample rate calculations for concentration inner loop.
5. Provides output to composite gas flow totaliser and total methane flow calculation.

Inlet Gas Temperature

Inlet Gas Temperature is monitored and limits set to detect possible abnormal gas temperatures. A current retrofit to the flow subroutine includes temperature compensation. This is necessary due to the fact that ambient air being drawn down the mine downcast shaft (approximately 500m) in which the drainage pipe range is installed has a marked effect on gas temperature.

Variations in temperature in the order of up to $\pm$ 20°C have been recorded. This corresponds to a flow error in the orifice plate or pitot tube calculations of the order of $\pm$ 3 percent.

Inlet Pressure

Inlet pressure is the main controlled variable and limits of 48kPa to 53kPa have been set as the dead band limits for normal operation. This is consistent with manufacturers recommendations on operation of the exhausters. However, experiments the range of pressures consistent with go. pump practice and underground conditions are continuing.

As the pumps are rated at 700 l/sec. at 50 kPa, it appears that at 75 kPa the gas make would be over 1000 l/sec. However, various other quantities must be taken into account.

1. Increased pressures (reduced suction) has led to increased pollution of mine roadways with the occurrence of unpredictably high gas releases.
2. Separators cannot efficiently remove water at 1000 l/sec. causing excessive sealing water losses.

Pressure is used in the control loop in the following manner:

1. Plant shutdown in the event of low pressure (backed up with passive transducers on each exhauster).
2. Control of by-pass valve.
3. Flow rate calculations

Outlet Pressure

Outlet pressure is monitored for overpressure conditions to detect blocked flame traps or closed valves.

SYSTEM INTEGRITY

As noted in the power supply section, many steps have been taken to provide power to the plant under normal and emergency situations. However, many other steps have been taken to increase the reliability of the plant.

Control voltage (110VAC) to the P.L.C., computer monitoring hardware and transducers is supplied by a 3000 VA Gould constant voltage transformer (C.V.T.). The C.V.T. provides power supply conditioning to the loads mentioned for variations in supply voltage and frequency. When under diesel generator set power, the control system is additionally protected by under voltage and under frequency.

Under frequency is of particular importance with transformer fed circuits as there is a likelihood of reduced line frequency causing transient over voltages. Short time battery back up is provided on mine monitoring hardware for uninterrupted monitoring.

The second major aspect is that of detection of major control equipment failure. In the case of the P.L.C. many self testing routines are built in and are continuously monitored. In the event of a catastrophic failure of the P.L.C., all outputs are powered down to a fail safe condition.

The P.L.C. testing routines are supplemented by a watchdog relay circuit which monitors the C.C.U. scan of I/O. The P.L.C. is used to a great extent for plant monitoring. Such intricate yet essential aspects such as maximum valve opening time detected by limits and checked by time, are monitored and alarms given in the event of failure.

Computer equipment at the pit top is housed in an environmentally suitable air conditioned room. This room is fire protected by a smoke detector actuated sprinkler system. Access to this room is prohibited to normal traffic. A small video monitor is provided at the entrance to the control rooms for use by pit personnel. This deters most from entering the control room where dirt carried in on mine clothes could contaminate V.D.U. keyboards or printers.

CONCLUSION

By the use of modern microprocessor based control equipment and sound engineering practice, methane extraction and utilisation plants can be successfully designed and operated.

Concepts of control and protection hitherto rejected due to the complex hardware required can now be handled well within the capacity of equipment with the sophistication of a P.L.C. without detracting from system reliability.

Together with computer equipment the P.L.C. has enabled the methane drainage installation to operate unmanned.

Gas utilisation plants use the same technology together with advanced approaches to storage, compression and generation.

ACKNOWLEDGEMENTS

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REFERENCES

1. Battino, S. and Reagan R., 1982. Methane drainage under the No. 7 longwall block Appin Colliery.
2. Morris, I.H., 1982. Fire damp drainage installations.

DISCUSSION

M. KELLY (Appin Colliery): With regard to utilisation, miners have always held the belief that methane is combustible in air in the range 5-15%. It would seem that from things in the press, or on the radio, installations using for instance 60/40 methane/air mixtures are not as efficient as natural gas installations - with regard to electricity generation, they have got efficiencies of the order of 23%. From memory the stoichiometric mixture of methane/air for the most energy is about 10% methane, 90% air. Is it possible on the basis of the 10/90 mixture to design installations that would for instance use a feed ratio of one part 60/40 methane to six parts air and gain the same energy output as by using 10% natural gas or pure methane with 90% air.

R. STANBURY (Hawker Siddeley Engineering): The first assumption is not accepted. There is no reason why 60/40 methane/air gas can't be combusted or exploded just as efficiently as 100% natural gas supply. After all in the equipment, when the gases go into the cylinder, they are mixed anyway, before ignition, and all it would mean would be a different means of mixing together or of controlling the air/gas ratio. It just means a different setting. There appears no reason that it would mean a less total power output from the machine.

M. KELLY: Even in the paper it is stated that the sludge gas used in the sludge gas plant has the same calorific value as the 60/40 methane air mixture. From simple chemistry, it could be assumed that the highest energy output obtainable would have been at the stoichiometric mixture.

R. STANBURY: Yes, but engines never work at that mixture, always there must be quite a large excess of air to get rid of the combustible whether it is diesel, or whether it is gas. There is always an excess of oxygen in the exhaust gases. Dealing with using a sludge gas in a dual fuel engine 40% of the gases are no use at all. They are neither used as a fuel to burn nor are they providing oxygen to help with the burning.

M. KELLY: But by the same token 80% of the atmosphere is nitrogen, that doesn't do any good for combustion in the normal sense.

R. STANBURY: In that case there is a useless gas going into the cylinder, nothing is known of any de-rate for that lower calorific value. It has a minimal effect if any on the power output. Certainly the same must apply for a turbine.