PROVISION OF A GALLERY FOR INVESTIGATION OF COAL MINE EXPLOSIONS AT LONDONDERRY CENTRE

By

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ABSTRACT

The explosion at Appin Colliery on July 24th, 1979, demonstrated the need for a large scale facility to simulate an underground type explosion and study its effects. The effects of an explosion cannot be established quantitatively using small scale models.

A gallery was constructed for this purpose at Londonderry Centre and commissioned in February, 1980. It is 50 metres long, 2.7 metres in diameter, capable of withstanding an internal pressure of 210 kPa and is the only facility available for this purpose in Australia.

The gallery has provided valuable information on blast effects of explosions in tunnels and is to be used for testing the performance of explosion arresting devices, further investigation of explosion effects, research into basic explosion phenomena and instrumentation development. Additionally, it will provide a demonstration facility for training purposes.

BACKGROUND

As a result of the explosion that occurred at Appin Colliery in July, 1979, it became necessary to examine and test at Londonderry Centre equipment that was involved. The testing programme carried out in the equipment had five main objectives as follows:

1. To determine whether equipment was being used and maintained in accordance with approval conditions.
2. To investigate possible ignition sources.
3. To explain the occurrence of unusual features such as dust patterns on equipment.
4. To explain the movement of heavy pieces of equipment as a result of the explosion.
5. To investigate the development of the explosion which had occurred.

To a substantial extent the above objectives were fulfilled especially with the availability of the Explosions Gallery.

In the early stages of the investigation conventional testing techniques, e.g., the use of the flameproof testing facility, were used extensively. While this approach was satisfactory is supplying answers to a number of the problems encountered it quickly became apparent that testing under simulated large scale conditions was necessary. The provision of the Explosions Gallery allowed a series of tests to be carried out to gauge the effect of an explosion under the conditions thought to exist at the time of the explosion.

It was realised early in October, 1979, that in order to complete the engineering investigation into the Appin explosion it would be necessary to construct an Explosion Gallery to perform testing on full scale items of equipment. The N.S.W. Department of Public Works was commissioned to design the Gallery, place contracts and supervise construction. Despite the intervention of Christmas and New Year periods it was possible to commission the Gallery by late February, 1980, which represents a commendable effort on the part of all concerned. It had been intended to provide an explosion Gallery in 1983-1984

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as part of the Londonderry Centre's development programme but due to the need to investigate aspects of the Appin Explosion the construction date was brought forward.

The main purpose of the Explosion Gallery in respect of the Appin Inquiry was to investigate the effect of explosion pressures on equipment present in the vicinity of the explosion and for this purpose it was necessary to simulate physical conditions. The use of scale models for the purpose of quantative analysis results is fraught with difficulties and should be carried out by scaling in accordance with formulae relating the effect of scaled items on the overall process. This is not possible in the case of gas and dust explosions and exact quantative conclusions can not be derived from small scale models. Their use in connection with explosions should be limited to qualitative purposes, e.g. demonstration.

The use of the Gallery for the Appin Inquiry was to produce the necessary pressures and to observe the effect on full scale items of equipment with regard to movement, dust patterns produced and speed of flame transmission. It needs to be stressed, and I repeat here, that the intention was to construct the Gallery so as to perform testing on full scale items of equipment and not necessarily within a full scale environment. The main conclusions provided by the Explosion Gallery tests were:

1. An ignition of a methane/air mixture would propogate along a steel ventilated duct of 30" diameter to a gas mixture at the end of the duct when the duct itself was in an explosive atmosphere.
2. The speed of this detonation depended on the gas mixture but was typically 20 metres per second.
3. An ignition at the blind end of the 50 metre Gallery with the Gallery almost completely filled with a stoichiometric mixture of methane air could result in detonation or near detonation, that is fast deflagration as a result of which considerable disruption occurred.

Since its construction the Explosion Gallery has been used for a number of functions and it appears that there is a real need for such a facility.

CONSTRUCTION AND OPERATING FEATURES

The Gallery dimensions of 50 metre length and 2.7 metre internal diameter were selected to enable development of the required pressure, based on overseas experience, and to provide the capability of housing apparatus in the Gallery for subjecting to explosion effects. Additionally, this size of Gallery could be accommodated comfortably into the layout of the Centre. The pressure withstand capacity of the structure was based on overseas experience for methane/air explosions but does not cater for coal dust explosions.

Standard precast concrete components were used in the construction of the explosion gallery. The gallery is constructed such that its top is approximately at ground level, excavated material was used to cover the gallery, and to form earth mounds at the eastern end. The purpose of burying the gallery and forming earth mounds is to reduce as far as possible the noise and blast effects on nearby residents.

It is designed to withstand internal pressures of +210kPa to -70kPa and is 50 metres long running east/west. At the west end is the plenum chamber and explosion door. The main ventilating fan is mounted on top of the plenum chamber. The east end of the gallery is open and has a roadway running down to it to facilitate placement of testing equipment. This roadway is lined with earth mounds to direct the force of the test explosions upwards.

The plenum chamber is the anchor point

[illegible] gallery. It is constructed of insitu [illegible], of strength 30MPa. Walls are [illegible] thick but the wall facing [illegible] is [illegible] thick fitted with an [illegible]. The door is fabricated from [illegible] plate and 102 x 51 mm channel [illegible]. It is mounted on 'Hebgo' hinges [illegible] to a steel frame case in the concrete [illegible] with a seal to ensure gas [illegible]. At the opposite end of the gallery [illegible] thick insitu wall. Between [illegible] walls are 20 sections of precast [illegible] pipe, which are stressed together [illegible]. The pipes are supported on [illegible] cradle blocks sitting on a base slab, [illegible] wide x 200mm thick, strength 20MPa.

The gallery sections and east wall sit on [illegible] joints and are free to move for [illegible] and thermal movements. The east [illegible] of the gallery is also separated [illegible] east end retaining walls.

The gallery is stressed by No. 6 V.S.L. [illegible] mounted externally on the precast [illegible] sections. The tendons are anchored [illegible] in the 600mm thick insitu walls, and [illegible] in 50mm diameter galvanised pipes [illegible] grouted. Joints between pipe sections were [illegible] grouted. All 'cracks' at joints closed up during stressing when the tunnel shortened by about [illegible]. Provision has been made for a [illegible] increase in tunnel length.

As the gallery sections are relatively light it was decided to strap the sections to the base slab to increase the effective mass and derive benefit from the surrounding earth fill which sits on the base slab.

Two drainage lines bedded in a 300mm layer of gravel fill, run along either side of the gallery and are connected to a sump with automatic pumps.

The gallery floor is concrete placed in the bottom of the pipe sections to provide a flat surface 1.5m wide. The floor is free to move independently of the pipe sections.

This floor has built in inserts designed to enable placing and fixing of components during test. It is also intended to utilise these inserts to install fixtures against the gallery surface to give various degrees of surface "roughness" to correspond to different underground roadway finishes. This "roughness" will affect speed of travel of air pressure.

A cross section of the gallery is shown diagramatically in Figure 1.

The construction sequence was

- Construct west end plenum chamber and anchor walls
- Construct base slab and cradle blocks
- Place pipe section and construct east end walls
- Stress

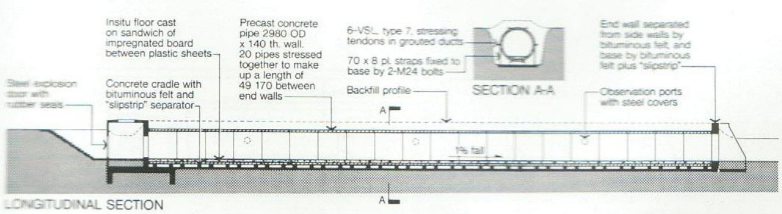

Figure 1

Gas for use in explosions can be introduced either in a controlled way from the plenum chamber via a gas recirculation fan or, if required quickly, directly dumped from cylinders into the main body of the gallery itself.

A main ventilating fan 1.37m in diameter and with a capacity of $510m^3$/min blows air in through the top of the plenum chamber and, with the explosion door open is used to ventilate the whole gallery. When the gallery is being filled with gas and during testing this main fan is used to ventilate the plenum chamber, keeping it free of the gases used in explosions.

To keep the gas within the gallery during testing, a steel frame covered with plastic sheeting is erected between the plenum chamber and the open end of the gallery.

This produces a seal forming a gas mixing chamber at the plenum end, the volume of which may be varied to produce differing explosion pressures by alternating the position of the frame along the Gallery. Varying the gas mixture also gives differing explosion pressures. It appears that the practice of allowing the initial explosion to detonate the plastic diaphram may have an effect on test results and accordingly a method of removing the seal just prior to initiation is being investigated.

Gas sampling tubes and sensing devices can be inserted through the gallery walls at 2-3m intervals and are used to determine gas concentrations in the test mixture and ensure a uniform distribution within the mixture.

The gas used for methane/air explosions which is the only type so far conducted is natural gas which contains 92% methane. It is obtained in cylinders from the Australian Gas Light Co. who use compressing plant provided by the Department of Mineral Resources. Mixing of the gas and air mixture is achieved by use of a circulating fan and the layout is shown diagramatically in Figure 2. The igniting method used for tests conducted to date has been either an electric spark or electric detonator.

TYPICAL TEST ARRANGEMENT

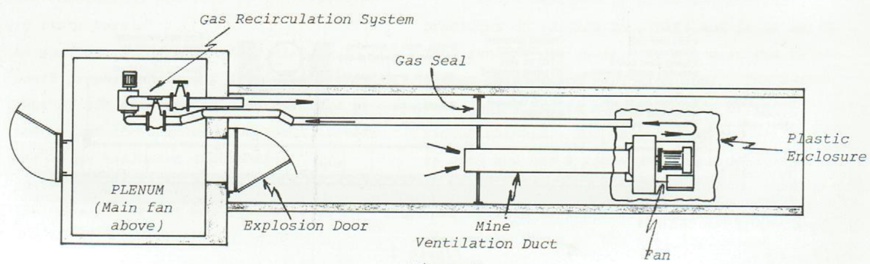

Figure 2

Three observation ports along the length of the tunnel can be used with a closed-circuit television camera and video recorder.

An observation port is also provided in the explosion door at the plenum end of the Gallery.

Figure 3 shows the first concrete pipe section being placed in position on the concrete cradles.

Figure 3

Figure 4 shows the gallery before filling was applied looking towards the open end. It shows the galvanised pipes housing post stressing ropes, strapping of pipe connections, conduits for instrument connections, and provision for the three observation ports.

Figure 5 shows the completed Gallery with the fan evase' circled in the background.

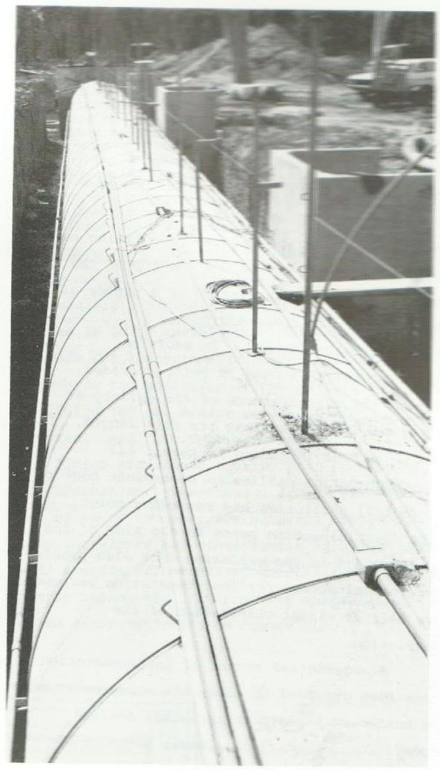

Figure 4

Figure 5

INSTRUMENTATION

It was recognised early in the design of the Gallery that there would be a need to extensively instrument the Gallery. Hence provision was made at the construction stage for both ad hoc and future permanent instrumentation. This provision includes utilising the two holes in the top of each concrete pipe to space 6 instrumentation boxes mounted on water pipe along the top of the gallery and the installation of a number of other water pipes for additional instrumentation access. In addition, instrumentation access is being provided around the circumference of the gallery at 10 metre intervals along its full length. A duct has been installed to permit all instrumentation cabling to be brought back to a central monitoring and recording point. The four inspection ports on the side of the gallery and in the explosion door also provide additional access for instrumentation purposes as well as visual observation of the explosion.

A substantial amount of instrumentation has been provided to allow the measurement of a number of parameters including ambient conditions, static and dynamic pressure and flame velocity. The measurement of these parameters involve a complex arrangement of equipment which must be synchronised and controlled. In summary, present instrumentation facilities include the following:

Gas Analysis *The primary system of gas analysis is by use of infrared gas analysers. The sample for the analyser is pumped through a tube from one of the instrumentation accesses provided on top or side of the gallery. When fully commissioned the gas analysis system will have the capability to draw a gas sample from any point within the gallery and provide an analysis for methane, oxygen, carbon monoxide and carbon dioxide concentrations both pre and post explosion. Extensive use is being made of the Chemical Laboratory gas van for verifying gas concentrations and providing post combustion gas analysis.*

Pressure *Provision has been made for the measurement of both static and dynamic pressures. Static pressure measurements are provided by piezoresistive pressure transducers mounted at right angles to the axis of the gallery at strategic locations along the full length of the gallery. Dynamic pressures are measured by the use of strain gauge type transducers with a mechanical arrangement for converting wind velocity to force. The output from each of these transducers is amplified and recorded together with a synchronisation signal on magnetic tape for later analysis to determine the maximum pressures generated and rise time.*

Sound *As part of monitoring the general environmental condition during explosions, microphones are provided at points remote from the gallery itself. The provision of these microphones enable the analysis of airborne noise levels to be made with a view to determining the overall environmental impact.*

Vibration *Two areas have been looked at with respect to vibration produced by explosions. The first involves building up a signature analysis of the vibration characteristics of the gallery. In this respect I must acknowledge the generous assistance given to us by the C.S.I.R.O. National Measurements Laboratory. The technique involves the use of piezo-electric accelerometers attached to selected portions of the outside of the gallery. The results are then recorded on tape and analysed using real time spectrum analysers to determine the frequency of oscillation and amplitudes. The second area involves assessing the vibration transmitted to the surrounding ground. When analysed in* conjunction with airborne noise this provides much valuable information on the effect of an explosion on nearby structures.

Flame Speed The extent of flame travel along the gallery as a result of an explosion is measured using ultraviolet and infrared sensitive photo transistors. The output of these detectors is amplified and recorded on magnetic tape for later analysis to determine flame velocity, extent of travel and duration.

Visual Data All events occurring during the explosions are recorded on colour video tape recorders and high speed movie cameras located about the gallery. Analysis of these can be carried out on a single frame basis and provide much useful data on the exact sequence of events which has occurred. Equipment currently available allows for film speeds of up to 64 frames/second. In the long term this equipment will be supplemented to provide for film speeds of up to 300 frames/second.

Environmental Data To assist in the determination of the factors which affect the development of a gas explosion the general environmental conditions are monitored continuously during explosion. The specific parameters measured include ambient pressure, temperature and humidity, with these parameters being measured both inside and outside the gallery. In addition natural wind velocity outside the gallery is monitored to determine its affect on airborne noise.

Instrumentation Control To facilitate the ready control of all instrumentation fitted to the gallery a microprocessor based control system is being installed. This system will provide for the automatic control of various phases in the operation of the gallery including the gas mixing cycle, start up of external tape recorders and cameras, initiate the firing signal and control post processing of information. The control system will be set up so as to cater for external emergency stop interlocks and other system interlocks and will provide all necessary synchronisation and timing sequences. The proposed installation is shown diagramatically on Figure 6.

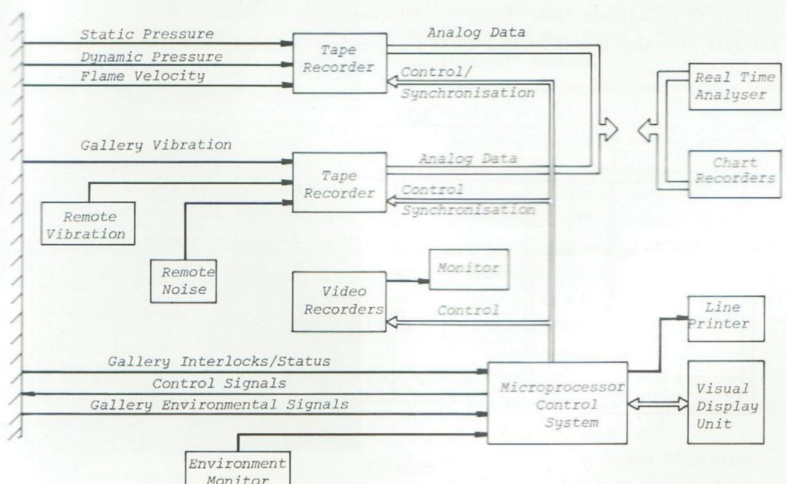

Figure 6

TESTING OF WATER TROUGH BARRIERS

The essential objectives in the prevention of major underground explosion disasters are:

1. To prevent the ignition of an explosive mixture which involves avoiding the accumulation of such a mixture and preventing the occurrence of a source of ignition.
2. To prevent any explosion that occurs from developing into a coal dust explosion, or
3. In the ultimate, to suppress the coal dust explosion.

The last 2 objectives are achieved by general distribution of an inhibitor, usually stone dust, and the provision of passive explosion barriers which almost invariably are either stone dust on platforms or water troughs. Additionally, the practise is sometimes adopted of distributing a consolidating agent such as rock salt to prevent coal dust rising. Regarding explosion barriers, the water trough type is extensively used overseas because of its convenience and the ability to re-erect such a barrier in the minimum time. Water trough barriers have also proved to be popular in Australia for these reasons and an important function of the Explosion Gallery since the investigation into the Appin Explosion was completed has been to test water troughs supplied by local companies. A brief description of this provides a good example of usage of the explosion gallery.

Determining the effectiveness of a complete barrier is normally carried out by testing to ensure that it will prevent passage of any appreciable amount of flame from a coal dust explosion using dust having a specified volatile content. This is possible only in a full scale explosion gallery but individual components of a barrier may be tested under specified conditions at a smaller scale. This is the function of the Londonderry Gallery in testing water troughs.

The testing of individual troughs is performed in accordance with the basic requirements of draft German Standard DIN 21576 which in simple terms requires the trough to operate at a dynamic pressure of 4kPa to give a specific water distribution pattern. The requirement ensures barrier operation with low energy explosions. The

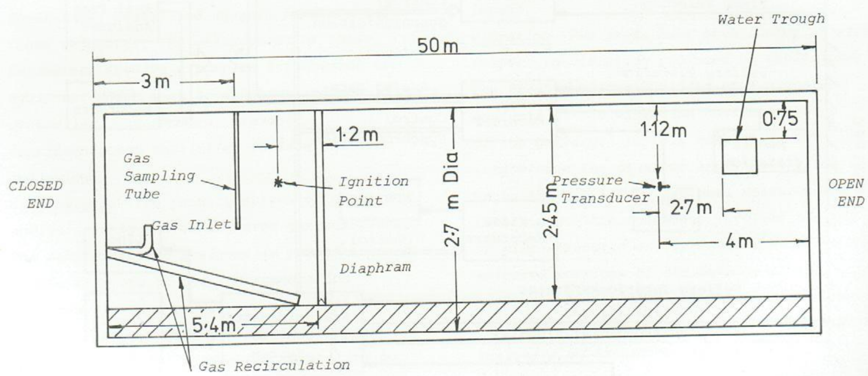

Figure 7

general layout of the test is shown at Figure 7 while Figure 8 shows plan and elevation of the trough support structure. Water distribution from the barrier was assessed using video frames, but this will be done in future by infrared dispersion and high speed cameras. Figure 9 shows a water trough set up for test.

The instrumentation used for this testing so far has only measured dynamic pressure produced by the explosion blast on a 31.13cm square set at 90° direction to air flow. This is to be supplemented in future by measuring flame speed, static pressure, wind speed and rise time of the blast pressure. This will enable compliance with a full set of conditions as laid down in the proposed German Standard and it will also enable correlation of dynamic pressure which can be calculated in accordance with the formulae $P=\frac{1}{2}pv^{2}$, where p, the unburnt gas density, is proportional to the static pressure, and v is the wind velocity.

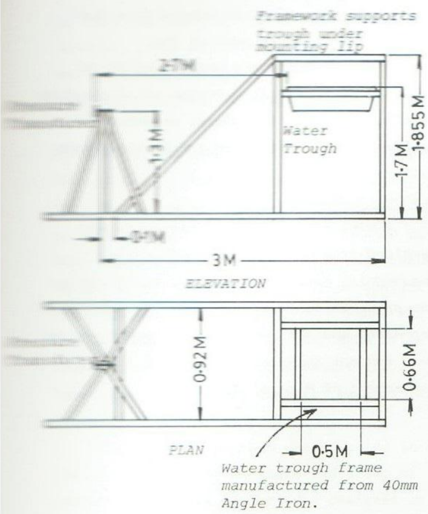

Figure 8

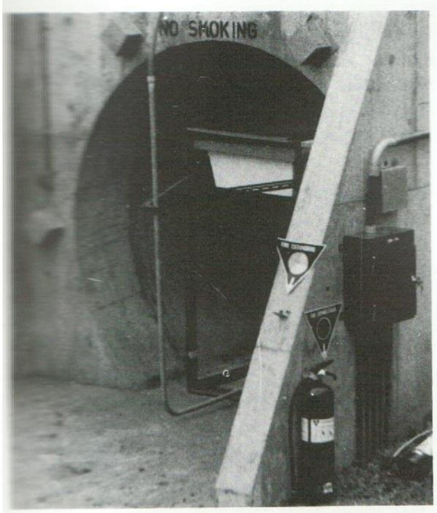

Figure 9

FUTURE USAGE OF THE GALLERY

It is envisaged that the Explosion Gallery will have considerable use for testing and research other than those already mentioned, and this will include:

1. Investigation of basic explosion phenomena.
2. Forming an explosive gas mixture reservoir for investigation of methane layering, and effect of ventilation.
3. General ventilation research.
4. Investigation of performance of explosion barriers in conditions of methane layering.
5. Investigation of incendive sparking between machine picks and rock strata.
6. Tests not involving explosions, but requiring large scale environmental conditions, for example evaluation of instruments under varying conditions; and
7. Demonstration and safety training.

Some of this work will be carried out in conjunction with the Universities. The gallery will be used mainly for mining purposes although its use in connection with non mining explosion problems has been proposed.

Investigation is at present being carried out into the need for additional Gallery facilities, for example to generate coal dust explosions and to investigate the effect of roadways other than single entry type. Overseas testing and research authorities usually have a variety of sizes of explosion gallery of which a 50 metre gallery would probably be the smallest apart from laboratory scale equipment. Most overseas authorities have a full scale mine gallery or galleries that can extend up to 1,800 metres in length which ideally should be placed underground to reproduce exactly the pressure development conditions experienced in practice.

The results obtained in overseas reduced size galleries are correlated with a full scale gallery and as part of the investigation currently proceeding it is proposed to arrive at a method of correlating results from the Londonderry gallery with what would be produced in a full scale mine gallery.

ACKNOWLEDGEMENTS

I wish to acknowledge the assistance received from members of staff at the Londonderry Centre, and Mr. L. Griffiths in the preparation of this paper. The opinions expressed and the conclusions reached are my own, and not necessarily those of the Department of Mineral Resources.

DISCUSSION

[illegible] (Coal Cliff Collieries Pty. Ltd.): Is there any special reason for opting for a circular cross-section for the gallery? Would not a rectangular one (similar to a normal mine roadway) give more relevant results in the tests?

M. LLOYD (Department of Mineral Resources): The section of the Gallery at Londonderry is similar to overseas galleries in as much that it is circular. The distinction should be made here between the Gallery, and an experimental mine. A gallery is primarily a device for producing explosion pressures, dynamic and static, whereas an experimental mine tries to simulate actual underground conditions. Experimental mines are normally made of roadway section.

The circular section was selected in this case for reasons of strength and speed of construction. The Gallery was designed and installed for the purpose of producing a blast. It wasn't so much to simulate an exact underground condition. But the proposal for an experimental mine is rightly based on the need, to try and simulate underground conditions. This would have a rectangular section roadway if our proposals come to fruition.

[illegible] (Anglo American Corporation of South Africa): Is there any idea of the cost of the gallery? Are there any plans at any stage to try to ignite any coal dust in the gallery?

M. LLOYD: The cost of the gallery including the instrumentation was roughly $200,000.

There are not any plans for igniting coal dust in the gallery. At one time it was thought that coal dust would be likely to produce a higher pressure than methane but in fact the reverse is probably true. The dangerous fact about coal dust is of course that in coal dust explosions underground there is so much of the dust and the roadways are so long. No coal dust explosions in the gallery are proposed because really there would be no useful purpose served.

R. WATSON (U.S.Bureau of Mines): Was the day in Pittsburgh really that bad when you took those slides or did you have a defective camera?

M. LLOYD: It was probably a defective camera since you are here.

R. WATSON: Are any noise problems from the gallery being experienced?

M. LLOYD: Yes environmental problems are experienced with residents when the very large scale explosions are conducted, but these are very few and far between. It is expected that the majority of explosions will be conducted in connection with water trough barriers which require a low grade of explosion, and there is not any difficulty there. The instrumentation being installed is of two types. First there is instrumentation for measuring what actually goes on in the gallery and secondly there is also instrumentation for measuring what goes on outside to determine the environmental effect.

Being a low frequency noise the sound of an explosion is difficult to divert. The mounds at the end of the Gallery were seen during the visit to Londonderry and this would be quite effective in diverting high frequency noise upwards. But in this case with a low frequency booming type noise the mounds have little effect, the low frequency wave follows the contours of the surface.

M. VELZEBOER (The Shell Company of Australia): Please comment on the question of water barriers versus stone dust barriers.

M. LLOYD: No tests have been made to compare water trough barriers and stone dust barriers. The information gathered in reports from the U.S.A. and the European Community countries would indicate that first of all water is as efficient a quenching agent as stone dust, and secondly that with present day designs of water barriers, particularly the large capacity water barriers, they are as effective as stone dust barriers - barriers in explosion conditions. According to the information from the European Community this applies even at low wind velocities or low dynamic pressures. In Germany which probably has the highest standard of testing arrangements for explosion barriers in the world, it is claimed that water barriers are more effective than stone dust barriers and are more likely to remain so during the installed life. The British who use stone dust barriers almost exclusively say that water barriers are equally effective and the French seem to be of the same opinion. Explosion barriers are not used in the U.S. but their tests appear to confirm the British and French attitudes.

At Mine Barbara in Poland there is the opinion that water trough barriers are not as efficient as stone dust barriers. However reading reports from the European Community's Committees dealing with explosion barriers, it is believed that water trough barriers are at least as efficient and effective as stone dust barriers.

R. FERGUSON (Department of Mines, W.A.): Why is it not a worthwhile proposal to carry out coal dust explosion testing at the Gallery? Later maybe?

M. LLOYD: Reiterating, the purpose of the Gallery is to produce a pressure to find the effect of a blast pressure on types of equipment. This can be done with a gas explosion and therefore the addition of coal dust is not necessary for this purpose. Full barriers cannot be tested in a coal dust situation. So in that case there is no point in carrying out coal dust tests because the test which would be associated with full barriers cannot be done. The only situation envisaged of wanting to test coal dust in the 50 m gallery is if it was necessary to compare the reactivity of various types of coal and this is done overseas. Some countries use a similar gallery for this purpose but this isn't at the moment done in N.S.W. or Queensland, that is comparing reactivity of various types of coal in a short gallery, and that is why no reason can be seen for doing it. If it will ever become necessary to compare the reactivity of various coals, coal dust would be exploded in the gallery. From present information, it doesn't appear that coal dust will give any higher pressure than is obtained from methane explosions.