# FIELD TRIALS AND DEMONSTRATION OF THE GAG-3A INERT GAS GENERATOR

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## *ABSTRACT*

On 11, 16, 17 and 18 April 1997 tests of the Polish developed GAG-3A inert gas generator were carried out at the Collinsville No 2 Coal Mine. These demonstrations indicated that the GAG-3A device was applicable in underground coal mines and that with respect to inertisation rate the device outperformed all other currently available techniques. The unit was assembled rapidly and operated safely during surface and underground trials and no mechanical problems were encountered with the device.
The GAG-3A is not suitable for every fire scenario particularly if large volumes of fresh air are being drawn into the mine, but with respect to the selection criteria developed by the Moura related Task Group 5 criteria, the unit performed up to the specifications required.

## *INTRODUCTION*

Any coal mine can be beset by problems associated with fires and explosions. Many techniques have been used to control these events with varying degrees of success. Inertisation in various forms has been used for many years and was last used in Queensland to some effect in 1986 when the NSW based Mineshield device vaporised 600 tonnes of liquid nitrogen which was then injected into the post explosion atmospheres of the Moura No 4 coal mine.
This project was designed to test a device which produces large volumes of (low $O_2$ concentration) inert gas from a commonly available fuel (Avtur). At the outset, it should be understood that inertisation can be divided into two Categories.

**CATEGORY 1** - Low flow devices, typically ½$m^3$/sec. This equipment includes:

- Pressure Swing Absorption (PSA) - Which uses chromatographic techniques to separate nitrogen and oxygen from normal air.
- Distillation - In this case the air is liquidified and then fractionally distilled to produce oxygen and nitrogen.
- Tomlinson Boiler - Boiler flue gas is produced by burning diesel fuel in a modified hot water boiler.
- Mineshield - Where liquid nitrogen is vaporised and injected into the mine (there are significant problems with respect to liquid nitrogen in Queensland because of the comparatively low production capacity of the current nitrogen generating units and the logistics associated with transportation).

**CATEGORY 2** - High flow devices, typically 20 - 30$m^3$/sec.

The GAG-3A is currently the only operational device on the market, which will produce inert gas at higher flow rates. Further research on very high flow devices (80 - 100$m^3$/sec) using a Pratt-Whitney TF30 jet is yet to be carried out and the significant size of this type of device would make its applicability in coal mines difficult. Figure 1 shows the assembled GAG-3A located in one of the portals of the trial mine and Figure 2 shows a schematic illustrating the main features of the unit.
The Collinsville project was jointly funded by ACARP, the Queensland Government, BHP, and Shell. MIM made their recently closed Collinsville No 2 mine available for use by the research team.
The project was organised to provide four demonstration days for Industry members to witness the use of the GAG-3A device. One day was assigned for the underground demonstration where the jet was located underground and operated to show the inertisation of a panel or small localised area. The other three days where allocated to surface demonstrations where the jet was connected to a portal seal and a large area of the mine was inerted.

## *MINE LAYOUT*

The mine was reopened and was extensively instrumented to enable real time remote determination of gas concentrations, air velocity, air temperature and relative humidity. Fibre optically linked television cameras were used to provide real time pictures of the movement of inert gas through the mine and also to view the fire sled during the coal burning phase of the tests.
Gas analysis data was provided by SIMTARS Mobile Gas Analysis Facility and the MIM Maihak

tube bundle monitoring system. A high speed MTI gas chromatograph was available for more detailed analysis. Data loggers were installed underground to collect information from the sensor arrays and this data was displayed real-time on surface computers.
Figures 3 and 4 show the location of the monitoring systems used during the tests.
The CSIRO mine exploration device, Numbat, was also used during the whole mine inertisation phase and useful corroborative visual data was obtained from this device.

## MINE VENTILATION SYSTEM

To facilitate the conduct of the trial plan at Collinsville No 2 mine, certain aspects of the mine ventilation system had to be altered for each phase of the trials.
Originally the mine had been ventilated by two axial flow fans located on the eastern and western sides of the main development headings. At closure, the mine was temporarily sealed by constructing Tecrete stoppings in 3 & 5 Headings (see Figure 3), by infilling 4 Heading portal, and Tecreting over the louvres on the two fans. When the mine was re-opened only 5 Heading was fully opened, although an access door was constructed in the stopping in 3 Heading portal and No 3 Fan on the eastern side of the mine was restarted. This provided sufficient ventilation to clear the mine of the predominantly carbon dioxide seam gas and later for the purposes of re-entering and working within the mine.
This however was not a satisfactory arrangement for the inertisation trials with the GAG-3A operating on the surface. For these trials it was intended to locate the GAG-3A in 3 Heading portal and to inert a large part of the mine between 2 and 5 Headings and down to 18 Level. To be able to do this it was necessary to seal 5 Heading at the surface and provide an alternative surface intake if the fan was to be kept running. This was achieved by opening the control louvres on No 1 fan (western side of the mine) without starting the fan. This allowed fresh air into the western returns which travelled to the mine fan across the inertisation zone via the overcasts at 6 & 7 Levels (see Figure 3).
For the first set of surface trials on 7th & 8th April 1997, No 3 Fan was run on its electric drive and measurements were taken underground to ensure the air quantity was sufficient to avoid stalling the fan. Generally the fan flows were about 90 $m^3/s$.
A regulator in 3 Heading was used to admit a controlled quantity of fresh air past the GAG-3A as part of these trials.

For the underground demonstrations on 11 April 1997, care had to be taken in establishing a ventilation system that was safe and would prevent the potentially lethal GAG-3A exhaust gases from contaminating outbye occupied areas of the mine.
For these trials the GAG-3A was located in 5 Heading, and the exhaust was ducted through a stopping between 14 & 15 Levels (see Figure 4).
To provide airflow over the 2000 litre underground fuel pod in 13 Level, the stopping between 5 & 6 Headings was breached and airflow was controlled by a brattice regulator. Airflow over the GAG-3A engine unit was controlled by a sliding door at 14 Level, 5 - 6 Headings. To prevent the possibility of GAG-3A exhaust gas moving above 15 Level, brattice stoppings were constructed in 3 & 4 Headings, and the GAG-3A exhaust directed into the eastern returns by breaching the seal at 16 Level, 5 - 6 Headings. For these trials, No 3 Fan was operating on electrical drive, 5 Heading was fully open and the regulator in 3 Heading was fully open. As a further precaution, sentries provided by Mines Rescue and equipped with gas monitoring equipment and self contained breathing apparatus, maintained a watch on the brattice stoppings in 3 & 4 Headings to ensure no exhaust gas moved up dip against the ventilation. At no stage during the trials was there any indication of this occurring.
For the second set of surface trials conducted between 14 & 18 April 1997, the same basic configuration was used as in the first set of surface trials (see Figure 5). However, to reduce undesirable leakage of fresh air into the inertisation zone, it was decided to run No 3 Fan on its diesel emergency drive and to short-circuit the fan at the surface by opening the airlock doors. The regulator in 3 Heading was also sealed up with boarding and cement to reduce leakage. The combined effect of these measures was to reduce the airflow underground to about 30 $m^3/s$ and to greatly reduce the potential for leakage into the inertisation zone.
As part of these trials a controlled underground coal fire in a steel firesled was to be established. The inertisation trials would involve attempting to extinguish this contained coal fire. The location of the fire was in 5 Heading between 14 & 15 Levels, the same as the GAG-3A location for the underground trials (see Figure 5). The Tecrete stoppings built around the GAG-3A site at 5 Heading, 14-15 Level, and at 14 Level, 4 - 5 Heading, were both demolished so that the inert gasses were directed over the fire site. The brattice stoppings in 3 & 4 Headings, 14 - 15 Level were left in place, and the breached stoppings at 13 Level and 16 Level were closed off.
For the surface trial of 15 April 1997, it was decided to attempt to run the GAG-3A with the fan

switched off. The ventilation configuration was otherwise identical to the other surface trials of that week.

After each of the surface trials, the inertisation zone was cleared by opening the 5 Heading stopping, the access door and regulator in 3 Heading, and closing the louvres on No 1 Fan. This caused the maximum volume of fresh air to enter the mine and effectively cleared the inertisation zone in time for the next trial. The mine was extensively monitored using the original fixed Maihak system and SIMTARS Mobile Minewatch to ensure that all areas of the mine were safe for personnel entry. No personnel were allowed underground after a trial until the area was inspected by a deputy beforehand.

## EXPERIMENTAL RESULTS

Figures 6a - 6c depict the spread of inert gas with the fan operating through the sections of the mine covered by the demonstration. In a period of 360 minutes the bulk of the area of interest had the oxygen level reduced to below 12%. A similar exercise in 1986 at Moura No 4, in a smaller area, took 600 tonnes of vaporised liquid nitrogen and five days to achieve a similar result.

Figures 7a - 7b depict a similar though slower outcome with the mine fan off. There were some problems with seal leakage and loss of inert gas at the surface, but the jet was still effective.

## DEMONSTRATION OUTCOMES

The selection criteria for the trial developed by the Moura related Task Group 5 Committee were met with the exception that output flow rates were slightly below the levels predicted (19 $m^3/s$ against an expected 20-25 $m^3/s$). This diminution in flow rates was attributed to higher ambient air and water temperatures.

The Task Group 5 Criteria for the Demonstration were as follows:

1 Unit can continuously deliver 20 $m^3/s$ of oxygen deficient atmosphere.

2 When operating normally the unit is to operate without any evidence of external flame.

3 The unit is to deliver oxygen deficient atmospheres containing less than 5% oxygen.

4 Automatic shutdown of equipment following failure of the water supply system.

5 This unit is to demonstrate the ability to extinguish flames from an underground coal fire within specific operating conditions as determined from the trial.

The unit was assembled rapidly and operated safely during all aspects of the trial and no mechanical problems were encountered.

Over 100 industry stakeholders visited the demonstration and feedback questionnaires were generally positive. The demonstration supported the view that the device was suitable for coal mine use.

No external flame was visible on the device.

The unit produced noise levels in excess of 124 dB(A) (when measured 1 m from the jet) in both surface and underground operations.

Environmental noise levels measured 2.3 km from the GAG-3A were not impacted by the operation of the unit.

The simulated fire in the mine was extinguished by the inert gas from the GAG-3A. This was evidenced by temperature profiles and actual video footage.

The limited gas stratification experiment conducted indicated that the gas produced by the GAG-3A tended to move closer to the roof than the floor.

The trial demonstrated that the GAG-3A device has applications in underground coal mines and that it outperformed all other available technologies with respect to volume of inert gas produced.

It is clear that the GAG-3A produces lower oxygen levels over a wider range of excess air conditions and therefore has a much wider range of applicability then other available technology.

## CONCLUSION

The GAG-3A jet inertisation device demonstrated its capability with respect to the inertion of relatively large underground volumes in a short time span. No other available inertisation technology has flow rates comparable to the GAG-3A unit. The unit operated without problems and the underground demonstration particularly showed the non-intimidatory nature of the device.

The GAG-3A does not have universal applicability and high fresh air fan intakes would tend to swamp the inert gas output of the jet. However innovative ventilation solutions are needed to get around this problem because in the final analysis the GAG-3A is simply a tool to produce large volumes of inert gas. This tool must be utilised by competent ventilation engineers to maximise the benefit from the device. Furthermore this device has been used successfully for decades in coal mines in Eastern Europe where the use of the jet has been professionally supported by ventilation engineers working in mines with complicated ventilation layouts.

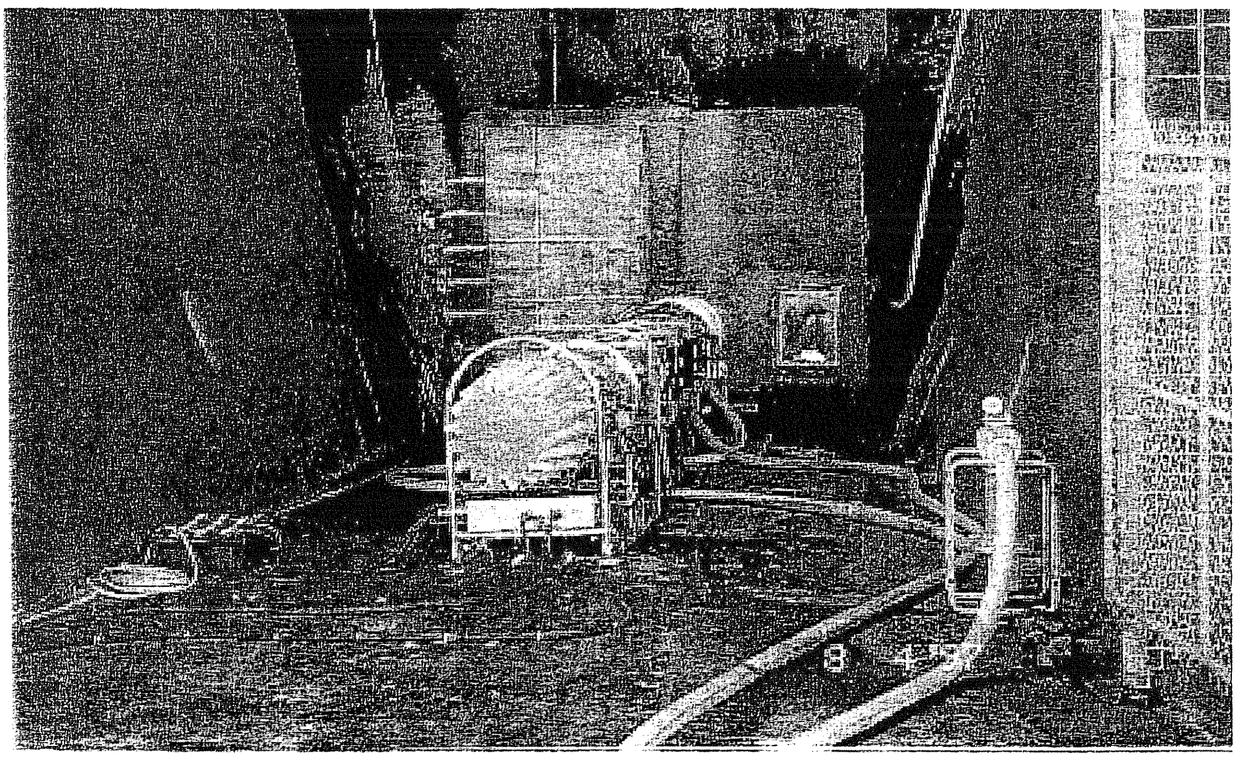


**FIGURE 1 - ASSEMBLED GAG-3A ON SURFACE**

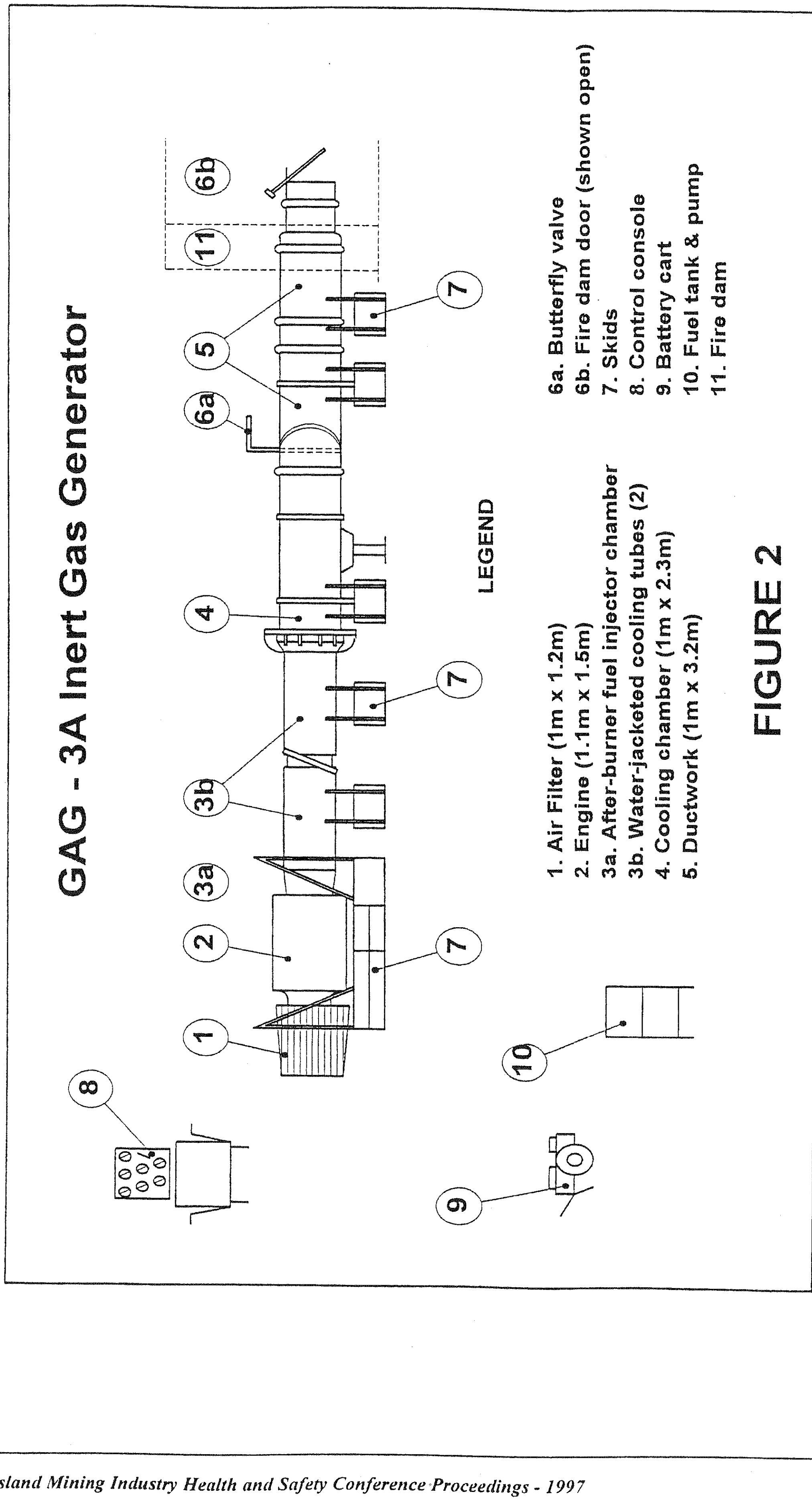

GAG - 3A Inert Gas Generator
1
2
3a
3b
4
5
6a
6b
11
7
8
9
10
LEGEND
1. Air Filter (1m x 1.2m)
2. Engine (1.1m x 1.5m)
3a. After-burner fuel injector chamber
3b. Water-jacketed cooling tubes (2)
4. Cooling chamber (1m x 2.3m)
5. Ductwork (1m x 3.2m)
6a. Butterfly valve
6b. Fire dam door (shown open)
7. Skids
8. Control console
9. Battery cart
10. Fuel tank & pump
11. Fire dam

FIGURE 2

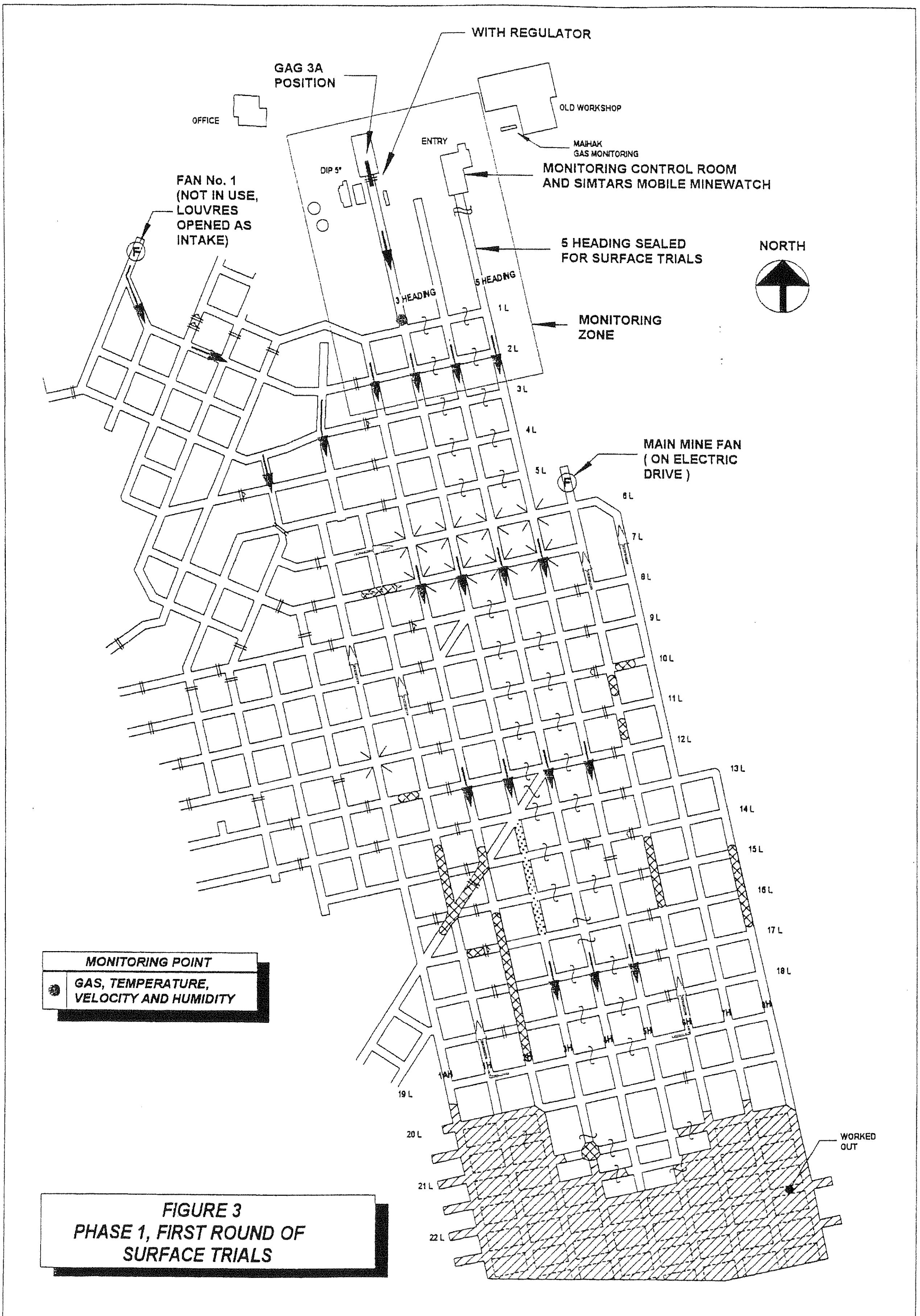



FIGURE 3
PHASE 1, FIRST ROUND OF SURFACE TRIALS

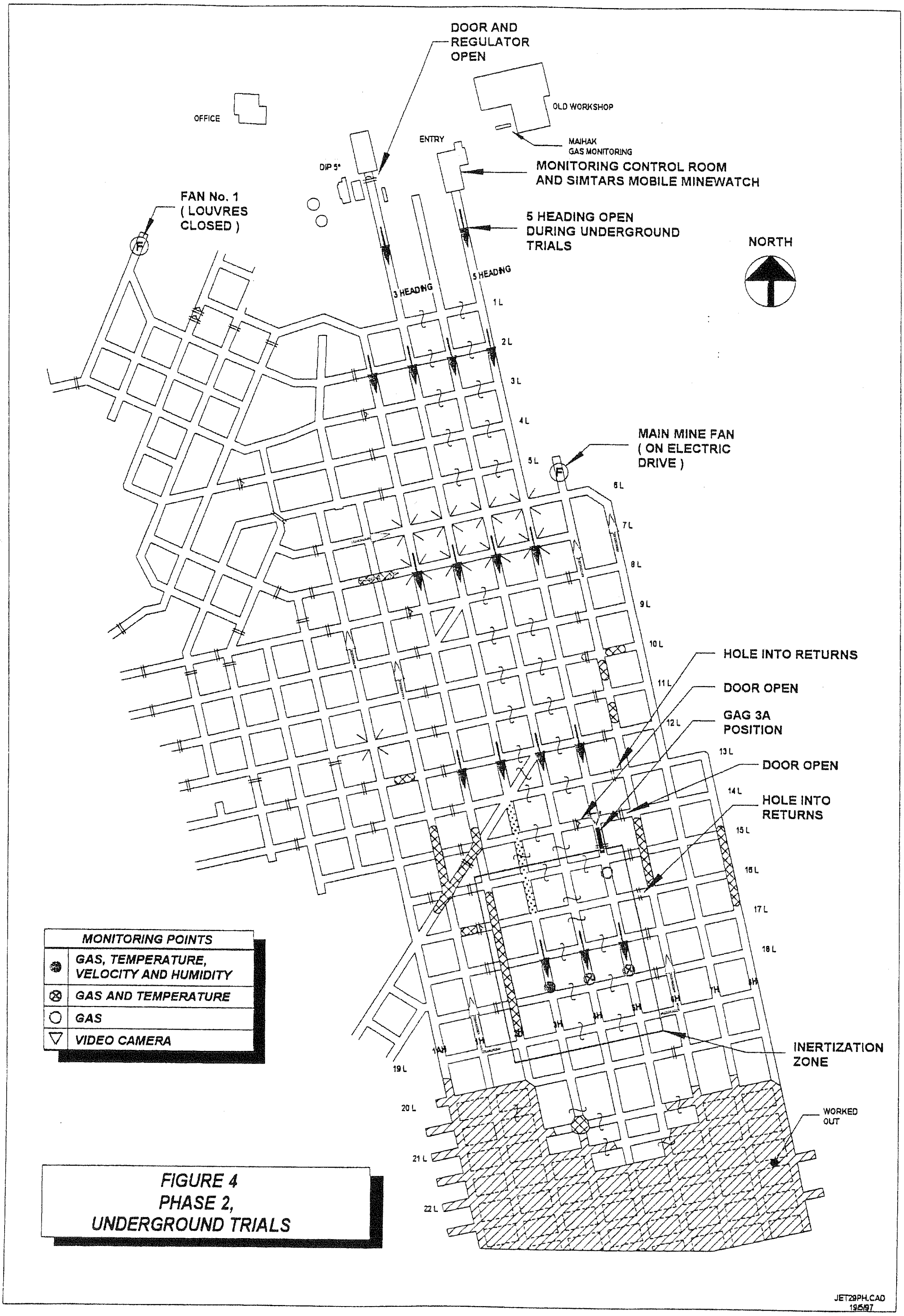



FIGURE 4
PHASE 2,
UNDERGROUND TRIALS

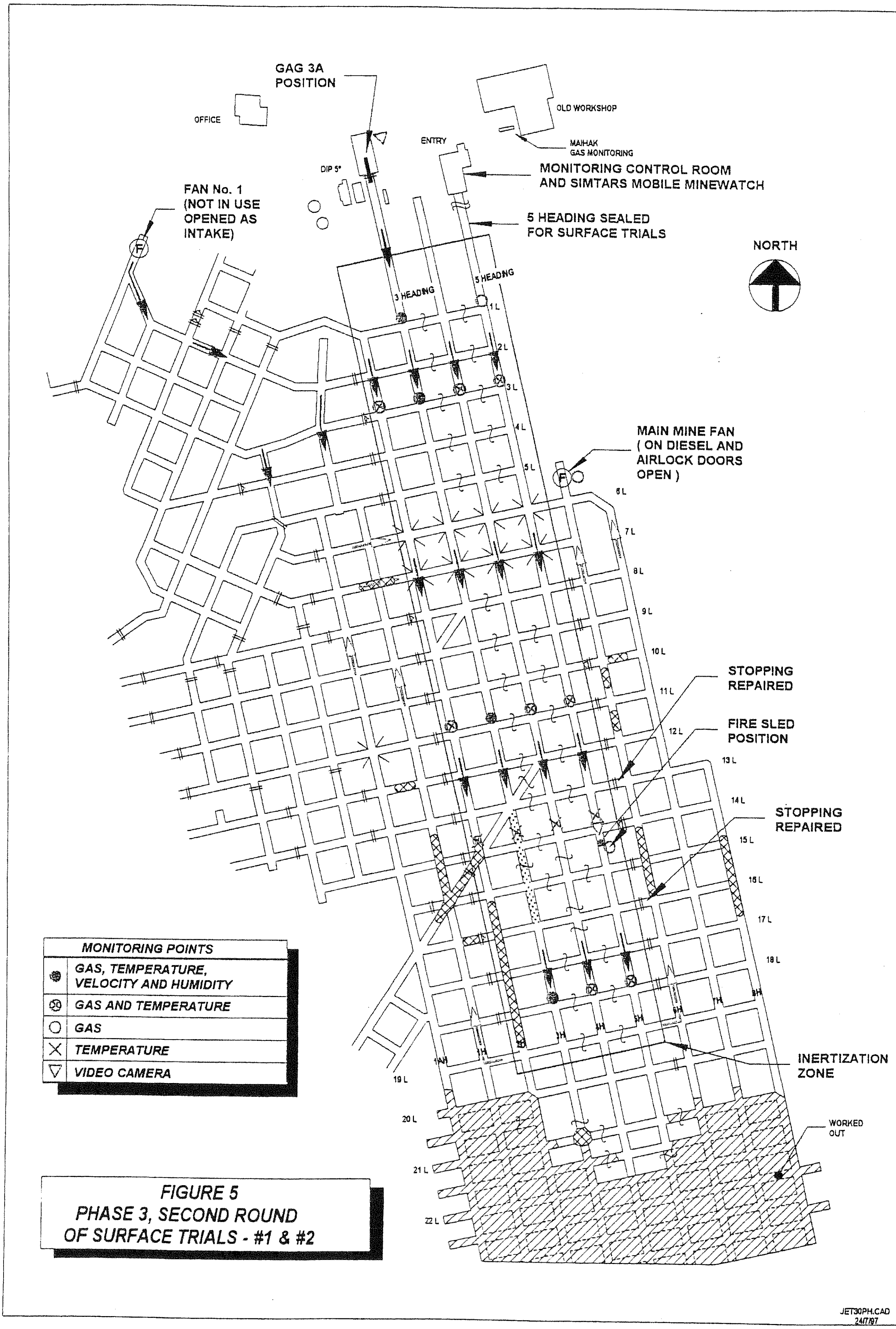



FIGURE 5
PHASE 3, SECOND ROUND
OF SURFACE TRIALS - #1 & #2

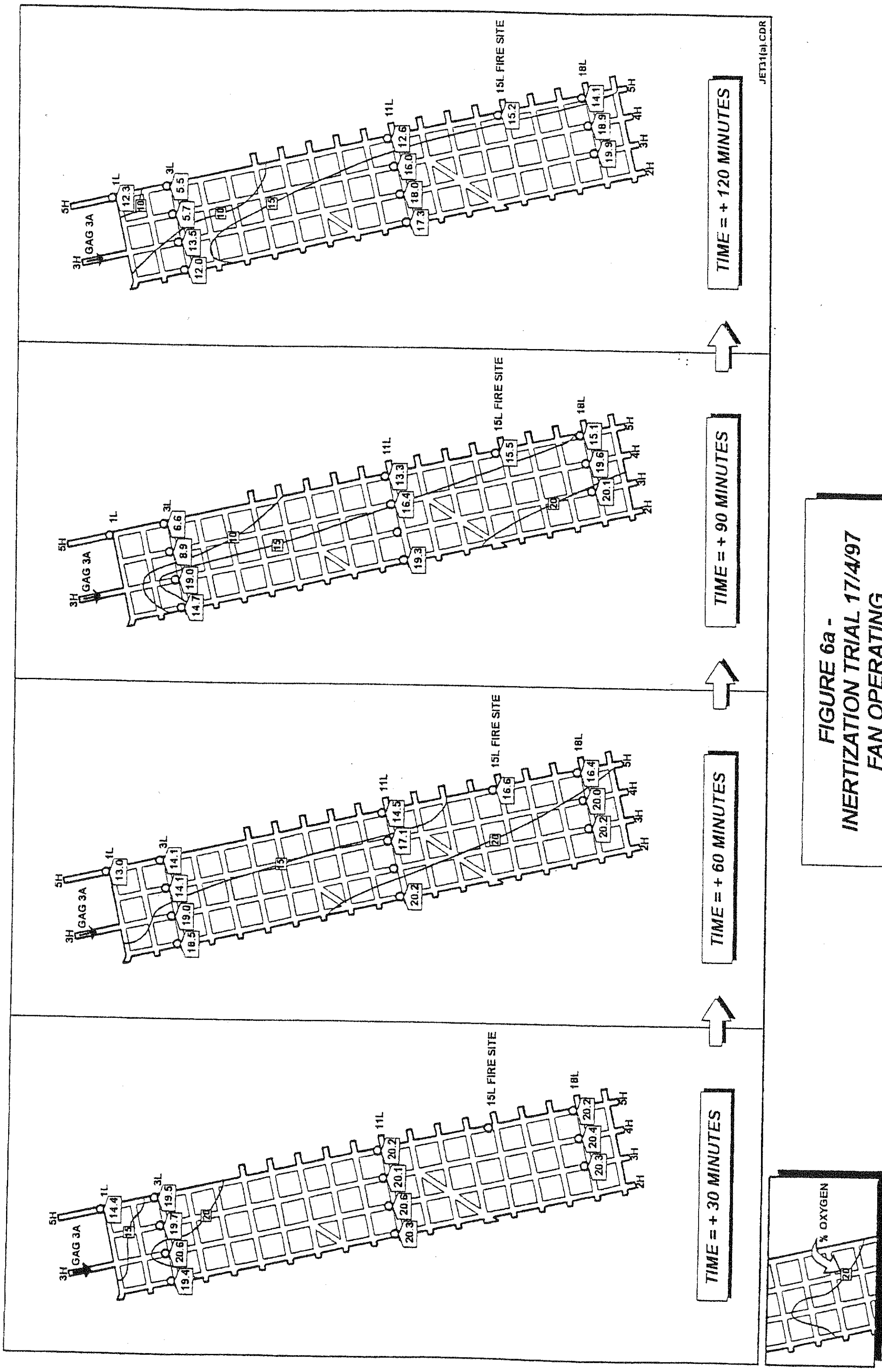



FIGURE 6a -
INERTIZATION TRIAL 17/4/97
FAN OPERATING

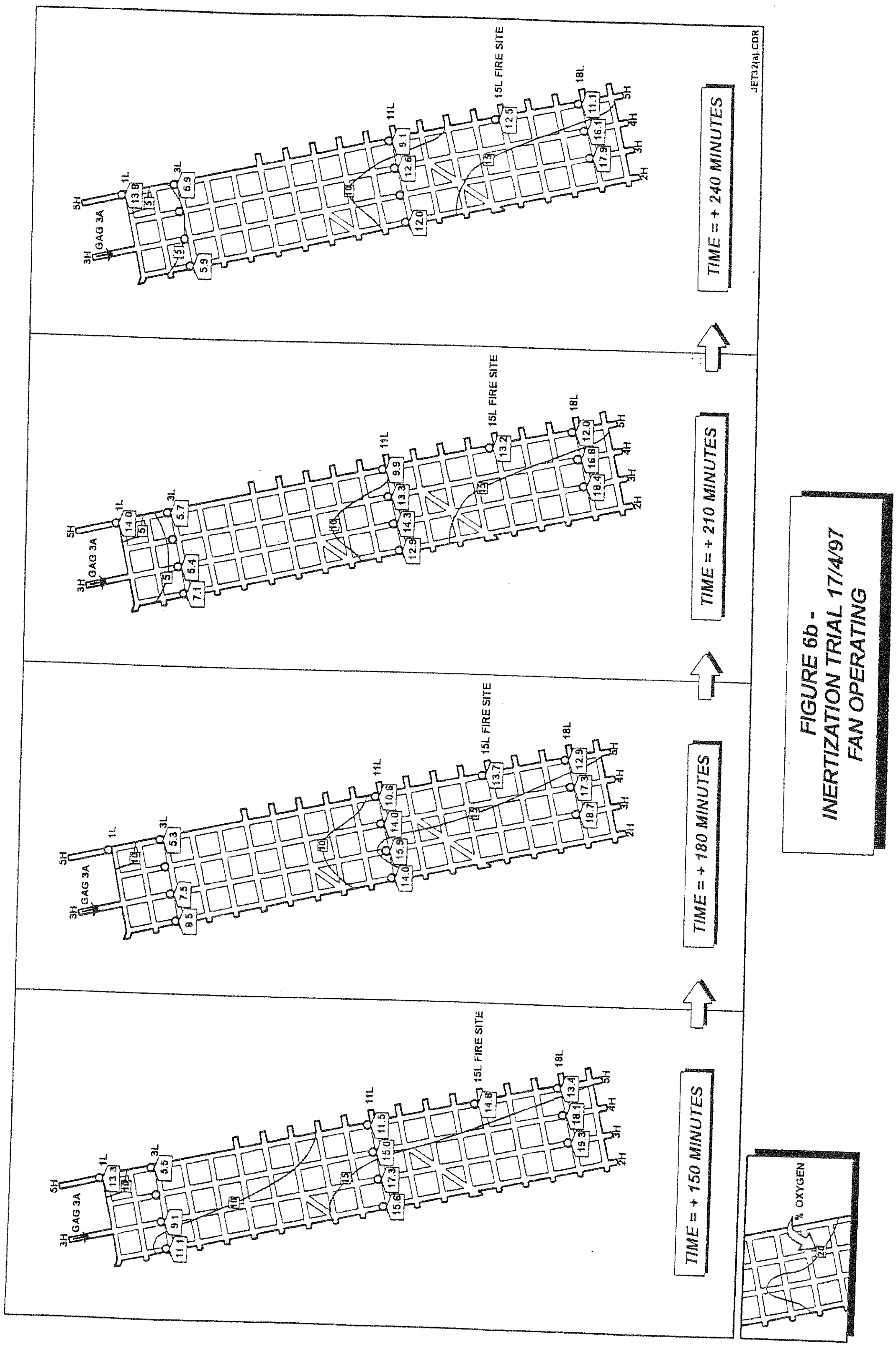
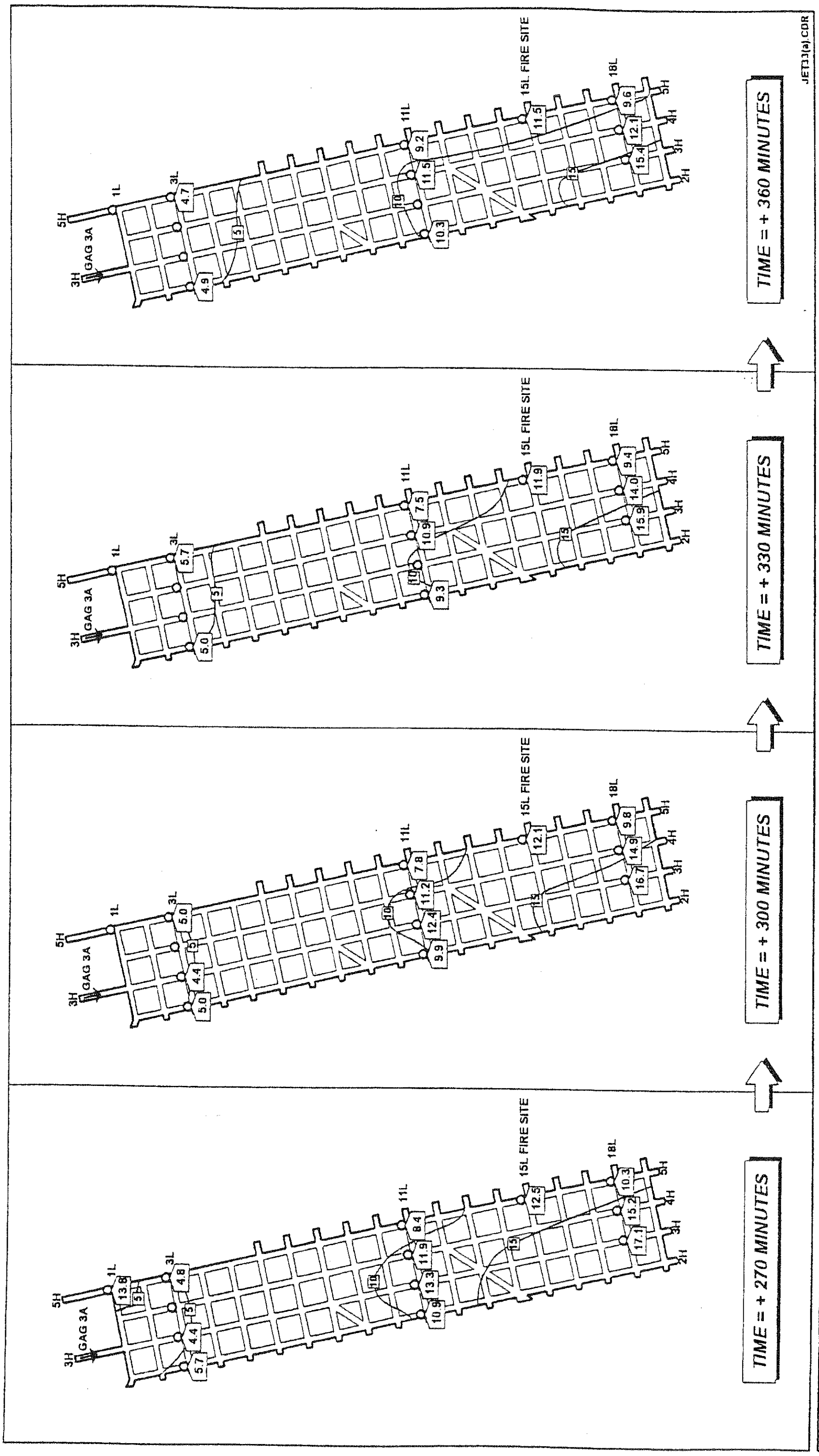



FIGURE 6b - INERTIZATION TRIAL 17/4/97 FAN OPERATING



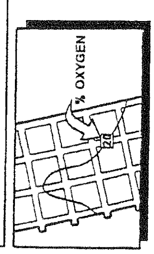




*FIGURE 6c -*
*INERTIZATION TRIAL 17/4/97*
*FAN OPERATING*

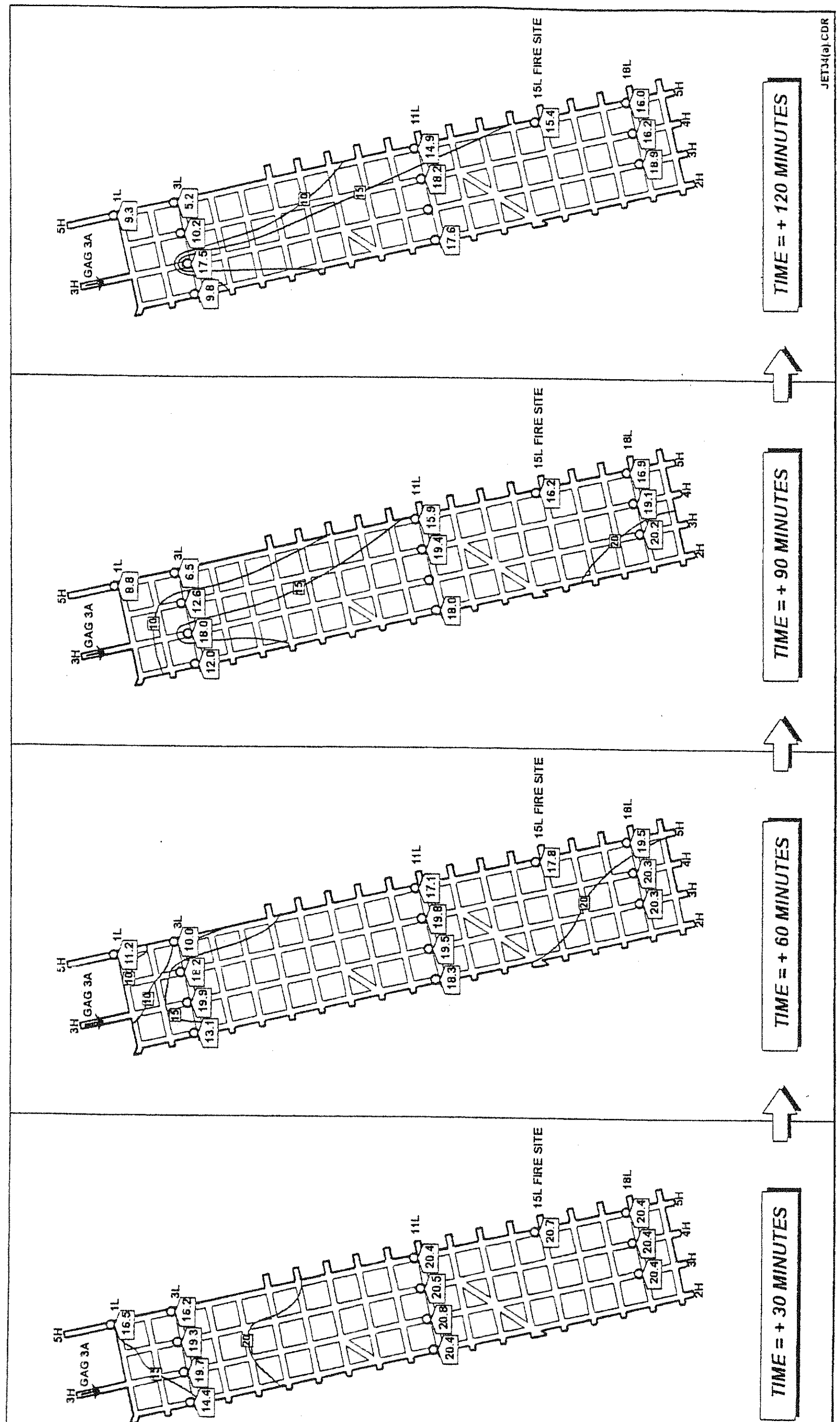
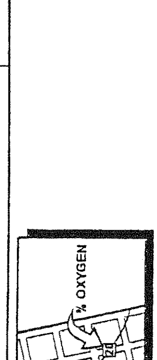



FIGURE 7a -
INERTIZATION TRIAL 15/4/97
FAN OFF



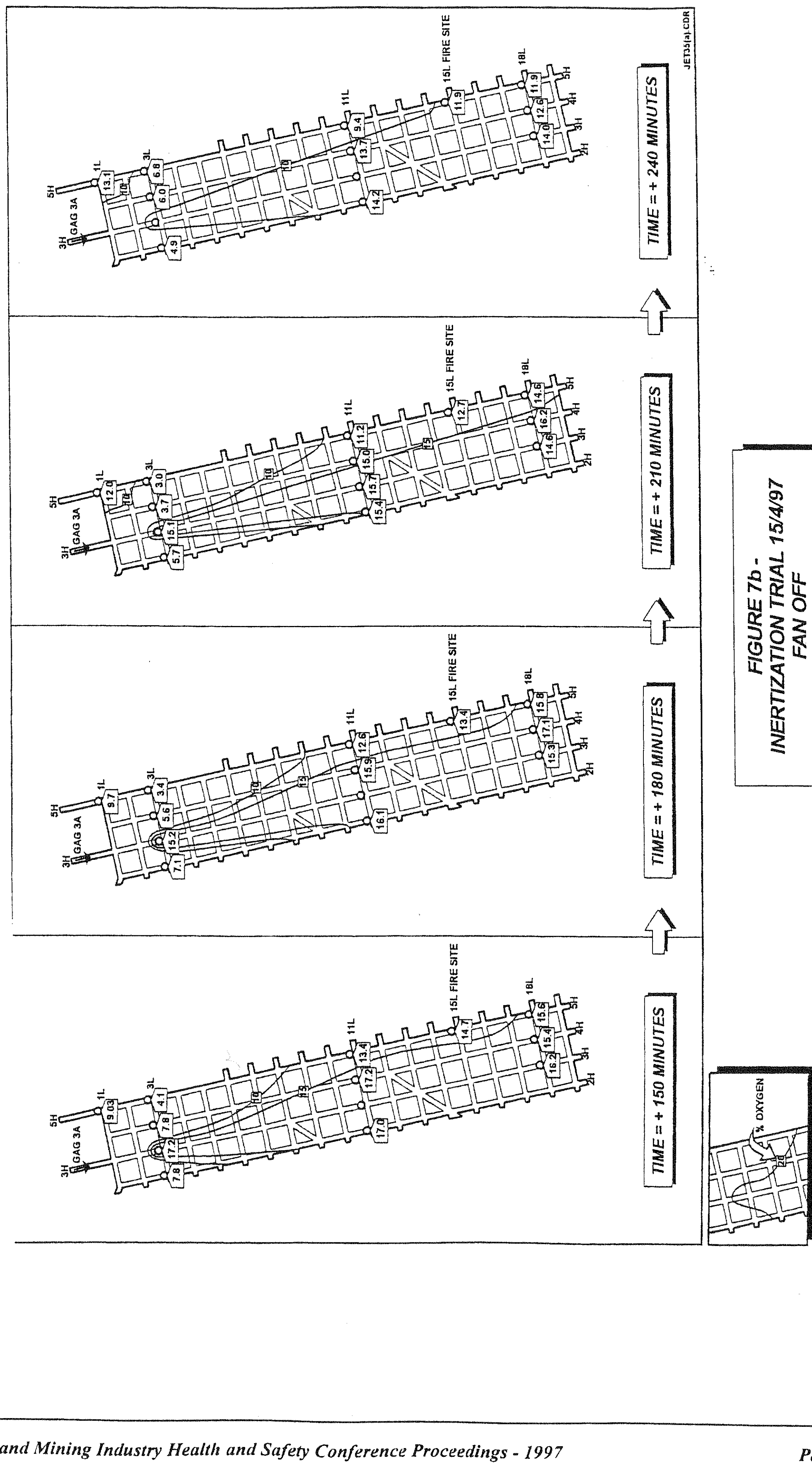



FIGURE 7b - INERTIZATION TRIAL 15/4/97 FAN OFF