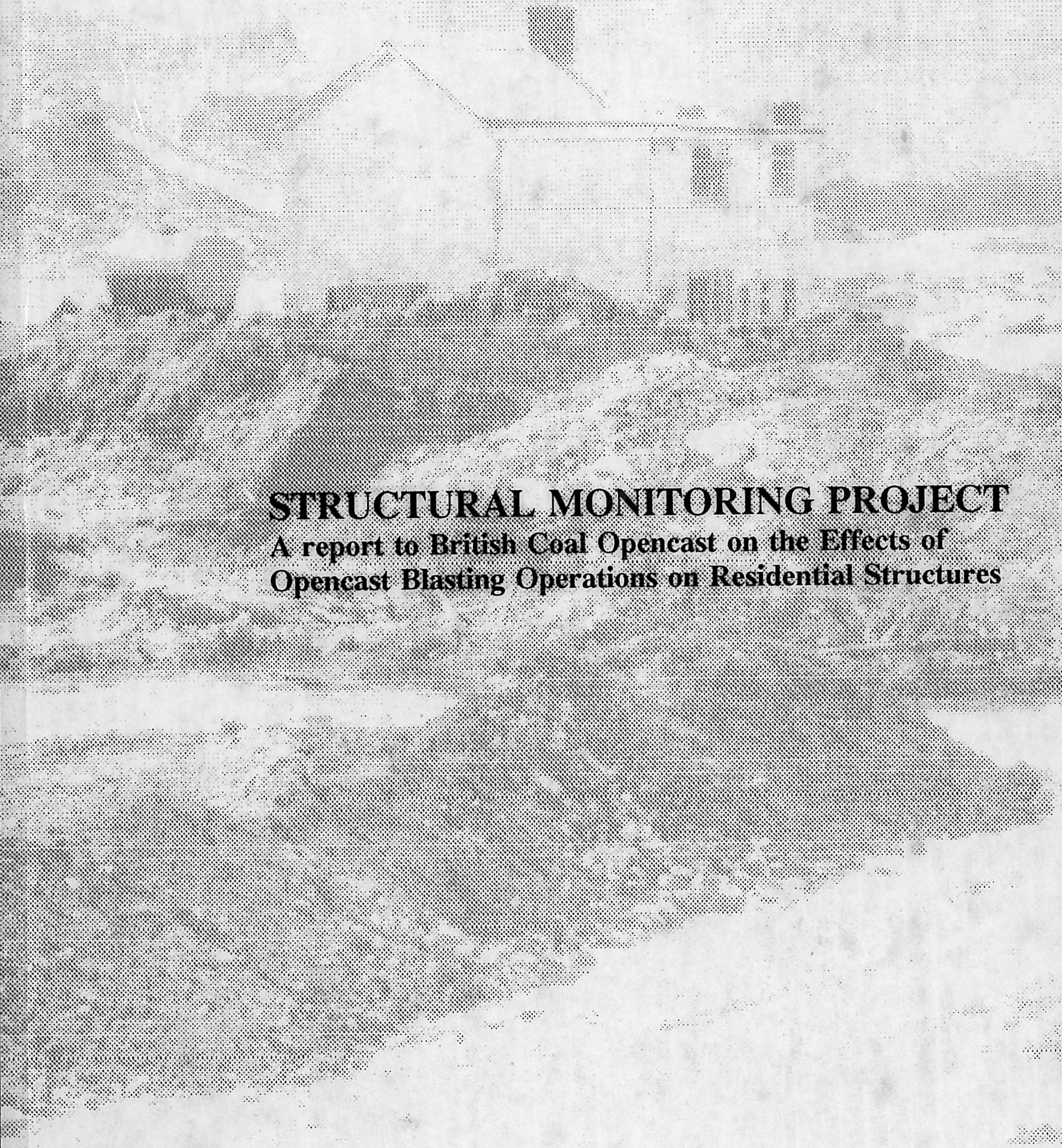
Department of Mining and Mineral Engineering



STRUCTURAL MONITORING PROJECT

A report to British Coal Opencast on the Effects of Opencast Blasting Operations on Residential Structures

Blasting Research Group

September 1993

Structural Monitoring Project. A report to British Coal Opencast on the effects of opencast blasting operations on residential structures.

The final report on research carried out between 1990 and 1993 on a joint project, between The University of Leeds and British Coal Opencast.

Blasting Research Group
The Department of Mining and Mineral Engineering

Robert A. Farnfield
Toby J. White
Michael P. Kelly

September 1993

CONTENTS

PART I: PROJECT DESCRIPTION AND DATA COLLECTION

I.1. INTRODUCTION 6
I.1.1 BLASTING RESEARCH GROUP 6
I.1.2 PROBLEM 6
I.1.3 POSSIBLE CAUSES OF DAMAGE 6
I.1.3.1 Causes associated with structure 6
I.1.3.2 Causes associated with ground 6
I.1.3.3 External causes 7
I.1.4 PREVIOUS RESEARCH 7
I.1.5 AIMS AND OBJECTIVES 7
I.1.6 METHOD 7

I.2. TEST SITE DESCRIPTIONS 8
I.2.1 GILFACH IAGO OPENCAST COAL SITE 8
I.2.2 "GLYNCOED" - THE HOUSE 8
I.2.3 WALL CONSTRUCTION 11
I.2.4 SKELTON OPENCAST COAL SITE 11
I.2.5 DIFFERENT RESEARCH METHODS 14

I.3. RESEARCH PHASES 16

I.4. VIBRATION MONITORING 17
I.4.1 GROUND VIBRATION 17
I.4.2 STRUCTURAL VIBRATION 17
I.4.3 AIR-OVERPRESSURE 17

I.5. ENVIRONMENTAL MONITORING 18
I.5.1 WIND SPEED AND DIRECTION 18
I.5.2 RAINFALL 18
I.5.3 EXTERNAL TEMPERATURE 18
I.5.4 INTERNAL TEMPERATURE 18
I.5.5 PLASTER TEMPERATURE 19
I.5.6 WATER TABLE 19

I.6. STRUCTURAL MONITORING 20
I.6.1 PRECISION LEVEL SURVEY 20
I.6.2 CRACK WIDTH MONITORING 20
I.6.3 STRUCTURAL INCLINATION 22

I.7. CRACK SURVEYS 23
I.7.1 INITIAL SURVEY 23
I.7.2 CRACK PROCESSING 24
I.7.3 PHASE 1 SURVEYS 24
I.7.4 PHASE 2 SURVEYS 25

I.8. EQUIPMENT 26
I.8.1 VELOCITY TRANSDUCERS 26
I.8.2 ACCELEROMETERS 26
I.8.3 AIR OVERPRESSURE 26
I.8.4 ANEMOMETER AND WINDVANE 27
I.8.5 ASPIRATED PSYCHROMETERS 27
I.8.6 PIEZOMETRIC WATER LEVEL 27
I.8.7 PRECISION LEVELLING EQUIPMENT 27
I.8.8 LINEAR VARIABLE DISPLACEMENT TRANSDUCERS 28
I.8.9 PRECISION INCLINOMETERS 28
I.8.10 SKELTON OCCS 28

PART II: DATA ANALYSIS

II.1. INTRODUCTION 30

II.2. ENVIRONMENTAL PARAMETERS 31
II.2.1 WIND 31
II.2.1.1 Wind Speed 31
II.2.1.2 Wind Direction 31
II.2.2. TEMPERATURE 31
II.2.2.1 External Temperature 32
II.2.2.2 Room B Temperature 32
II.2.2.3 Room A Temperature 33
II.2.3. RAIN 33
II.2.4. WATER TABLE LEVEL 33

II.3. STRUCTURAL PARAMETERS 34
II.3.1 INCLINOMETERS 34
II.3.2 PRECISION LEVELS 34
II.3.2.1 Ground Levels 34
II.3.2.2 House Levels 35
II.3.3 CRACK WIDTHS 35
II.3.3.1 LVDT 1 (Reference) - Wall B2 35
II.3.3.2 LVDT 2 - External 35
II.3.3.3 LVDT 2 - Wall B2 35
II.3.3.4 LVDT 3 - Wall A2 36
II.3.3.5 LVDT 4 - Wall B4 36
II.3.3.6 LVDT 5 - Wall B2/B3 36
II.3.3.7 LVDT 6 - Wall B2/B3 37
II.3.3.8 LVDT 7 - Wall B1 37
II.3.3.9 LVDT 8 - Wall B1 37
II.3.3.10 LVDT 9 - Wall B1 37
II.3.3.11 LVDT 10 - Wall B1 37
II.3.3.12 LVDT 11 - Wall A3 38
II.3.3.13 LVDT 12 - External 38
II.3.3.14 LVDT 12 - Wall B2 38

II.4. VIBRATION DATA 39
II.4.1 SOURCES OF VIBRATION 39
II.4.2 BLAST VIBRATIONS 39
II.4.2.1 Buried Transducer Data 39
II.4.2.2 Other Monitoring Locations 43

II.5. CRACK GROWTH 44
II.5.1 FOUR-WEEKLY SURVEYS (PHASE 1) 44
II.5.1.1 Room A 44
II.5.1.2 Room B 44
II.5.1.3 Phase 2 Crack Growth 45
II.5.2 PHASE 1 CRACK GROWTH AND WALL TYPE 46
II.5.2.1 External Walls 46
II.5.2.2 Old Cottage Walls 47
II.5.2.3 Single Skin Internal Wall 47
II.5.2.4 Plasterboard Walls 47
II.5.2.5 Door and Window Edges 47
II.5.3 PRE- AND POST-BLAST SURVEY RESULTS (PHASE 2) 47
II.5.4 PHASE 2 CRACK GROWTH AND WALL TYPE 49
II.5.5 CRACK WIDTHS 49

II.6. INITIAL CORRELATIONS 50
II.6.1 WIND & EXTERNAL TEMPERATURE 50
II.6.2 EXTERNAL & INTERNAL TEMPERATURES 50
II.6.2.1 Room A and External Temperature 50
II.6.2.2 Room B and External Temperature 50
II.6.3 RAIN & WATER TABLE 51
II.6.4 PRECISION LEVELS & INCLINOMETERS 51
II.6.5 INCLINOMETERS & EXTERNAL TEMPERATURE 51
II.6.6 CRACK WIDTH & TEMPERATURE 52
II.6.6.1 Heaters Off 52
II.6.6.1.1 External Temperature and Crack 52
II.6.6.1.2 Internal Temperature and Crack 52
II.6.6.2 Heaters On 55
II.6.6.3 Non-linear Relationship 55
II.6.7 EXTERNAL FACTORS AFFECTING CRACK WIDTH 56
II.6.7.1 Subsidence Effects 59
II.6.7.2 Vibration Effects 59

II.7. CRACK GENERATION IN PHASE 1 60
II.7.1 GENERAL OBSERVATIONS 61
II.7.2 CRACK GROWTH CORRELATIONS 61
II.7.3 CRACK GROWTH AND VIBRATION 62

II.8. CRACK GENERATION IN PHASE 2 63
II.8.1 PHASE 2 DESCRIPTION 63
II.8.2 TEMPERATURE CRACKING 65
II.8.3 GROUND HEAVE CRACKING 65
II.8.4 VIBRATION CRACKING 66

II.9. ADDITIONAL EXPERIMENTS 69
II.9.1 COMPARISON OF HYDROPHONES 69
II.9.1.1 Bruel & Kjaer 69
II.9.1.2 Birchalls 69
II.9.1.3 Comparison of Units 70
II.9.2 PPV TRANSFER FUNCTIONS 72
II.9.2.1 Buried to Foundation 72
II.9.2.2 Buried to Upstairs Window 72
II.9.2.3 Buried to Upstairs Walls 82
II.9.3 USING PPV TRANSFER FUNCTIONS 82

II.10. CONCLUSION 83

PART III: APPENDICES

PART I: PROJECT DESCRIPTION AND DATA COLLECTION

I.1. INTRODUCTION

I.1.1 BLASTING RESEARCH GROUP

The Blasting Research Group (BRG), at the Department of Mining and Mineral Engineering, The University of Leeds, has been involved in looking at all aspects of blasting and its effect on the environment since the late 1970's. This work is summarised in Ref 1. Work has included monitoring and predicting vibration levels and gaining a better understanding of the processes involved. This means dealing with the large number of variables of the blast itself, considering the way seismic energy is transmitted away from the blast, and determining the effect of vibrations on structures and people. All these factors have financial, legal and environmental consequences and it is the aim of British Coal Opencast who fund the work, to reduce costs, safeguard the future development of sites and reduce environmental disturbance.

I.1.2 PROBLEM

One of the areas of most concern is the effect of blast induced ground vibrations on a residential properties. Often, the onset of even low levels of intermittent, impulsive vibrations will cause a home owner to examine the structure of their house, with the resulting identification of cracks and damage which had not previously been observed. The conclusion the resident often incorrectly reaches is that the blast is the cause of such damage. Other possible causes such as temperature changes are overlooked and it then becomes very difficult to persuade owners otherwise. This can have a significant effect on the operation of that site and may also influence the outcome of any future public inquiries.

I.1.3 POSSIBLE CAUSES OF DAMAGE

The causes of cracking are generally due to differential movement and can be divided into those associated with the structure itself, those associated with the ground beneath and those caused by some external factor operating on it.

I.1.3.1 Causes associated with structure

These include items such as material shrinkage and creep, corrosion or decay, differential thermal movements in dissimilar materials and poor design.

I.1.3.2 Causes associated with ground

These include ground subsidence and heave due to volume changes in clay soils, settlement and heave of floor slabs on unsuitable in-fill, instability of sloping ground, movement due to consolidation, mining subsidence, and differential settlement.

I.1.3.3 External causes

Apart from the obvious damaging incidents, such as being struck by a falling tree or a vehicle the external causes are many. They include ground vibration effects, which are usually low frequency signals from a variety of sources, for example, earthquakes, traffic, roadworks or mine blasting. The varying levels of damage will depend on both the magnitude and the frequency of the vibration. Large air overpressure events such as those connected with bomb explosions will also have a very significant effect.

I.1.4 PREVIOUS RESEARCH

The structural effects of blast vibrations have been the subject of extensive research over many years and there is a considerable body of knowledge. Much of this work has been carried out by the United States Bureau of Mines (USBM) and this has recently been summarised by Siskind (Ref 2). However, the application of such work to the U.K. coal mining industry can be difficult because of the predominantly different house construction and scale of blasting found in the U.S.A.. There has been no long-term study in the U.K. of the effect of blasting on buildings and so it was agreed with British Coal Opencast that this would be a valuable area of research for the Research Group.

I.1.5 AIMS AND OBJECTIVES

The specific aim of the project was to investigate all causes of cracking in buildings with the idea of isolating any damage which can be attributed specifically to blasting. In this manner it was hoped that it would be possible to identify some of the factors involved when cracking takes place, and to observe the threshold level of vibration damage. Information will also be produced on the level of cracking which can be expected from factors other than blasting. This would allow for opinions to be derived as to other probable causes for cracking where the vibrations level has been too low to have been a contributing factor.

It was also the intention of the project to gather a large amount of blast damage data so that parameters could be analysed to see if any would give a better correlation with damage than the generally accepted Peak Particle Velocity.

I.1.6 METHOD

The proposed method for the research was to find a building or buildings in the middle of an opencast coal site which could be surveyed and monitored as the workings approached it. The site needed to have regular blasting as part of the operations. The house, which would obviously be unoccupied, needed to be in a reasonable state of repair and be in a position where it could be left until blasting was very close to it. All this had to be available with minimal interruption to the site contractor and coal production.

I.2. TEST SITE DESCRIPTIONS

Eventually two buildings were found which met the criteria, although both of them had drawbacks. The first was a house in the middle of Gilfach Iago OCCS near Ammanford in South Wales. The second was a disused canteen situated in the middle of Skelton OCCS near Leeds in Yorkshire.

I.2.1 GILFACH IAGO OPENCAST COAL SITE

Gilfach Iago shown in Figure I.2.1 had a site area of 129 hectares and a total tonnage of anthracitic coal of 925,000 tonnes. Production was at the rate of 2,500 tonnes per week and having started coaling in June 1988 it was anticipated to finish coaling in mid 1995. The geology is highly disturbed and features steeply dipping coal seams.

Blasting took place at various horizons and initially used electric detonators with detonating cord but then gradually switched to using non-electric detonators. Because of the complex geology, the nature of the blasting varied enormously, but in general the blasts were quite small. An example of a small blast is a 4 x 4 grid of 4m holes on 4m centres with 8kg of ANFO in each. This sometimes increased to 70 holes, 8m deep with 32kg of ANFO in each. Usually there was just one hole per delay, but with non-electric detonators this occasionally rose to three which could result in a maximum instantaneous charge weight of over 90kg.

I.2.2 "GLYNCOED" - THE HOUSE

The property used for the test work was an isolated stone built cottage (Fig. I.2.2) with a two storey extension to the rear situated in the middle of the site. When the house was first identified it was in a reasonable condition, but before the research could begin it was vandalised and fell into a poor state of repair. This included the roof tiles being removed and left bare for several months, so considerable work was required before the work could begin. Due to the condition of the building it was decided to limit research to the two rooms in best condition. These were both in the extension, but on separate floors. Including all the rooms would have resulted in more data, but it was felt that the basic requirement of the project was quality not quantity. In other words, the collected data needed to be as accurate and reliable as possible. To try to monitor too many rooms could have resulted in significant features being missed.

The walls of the old cottage were stone with rubble fill so they were not typical modern UK house construction. Every so often these rooms and the external walls were scanned to see if any major new cracks had developed, but the research was concentrated in the extension.

The foundation under the concrete floor of the original cottage was rubble. The extension had a strip type foundation with concrete beams under the main walls and gravel fill under the concrete floor. There were a wide variety of wall types in the two rooms which are described in the next section.

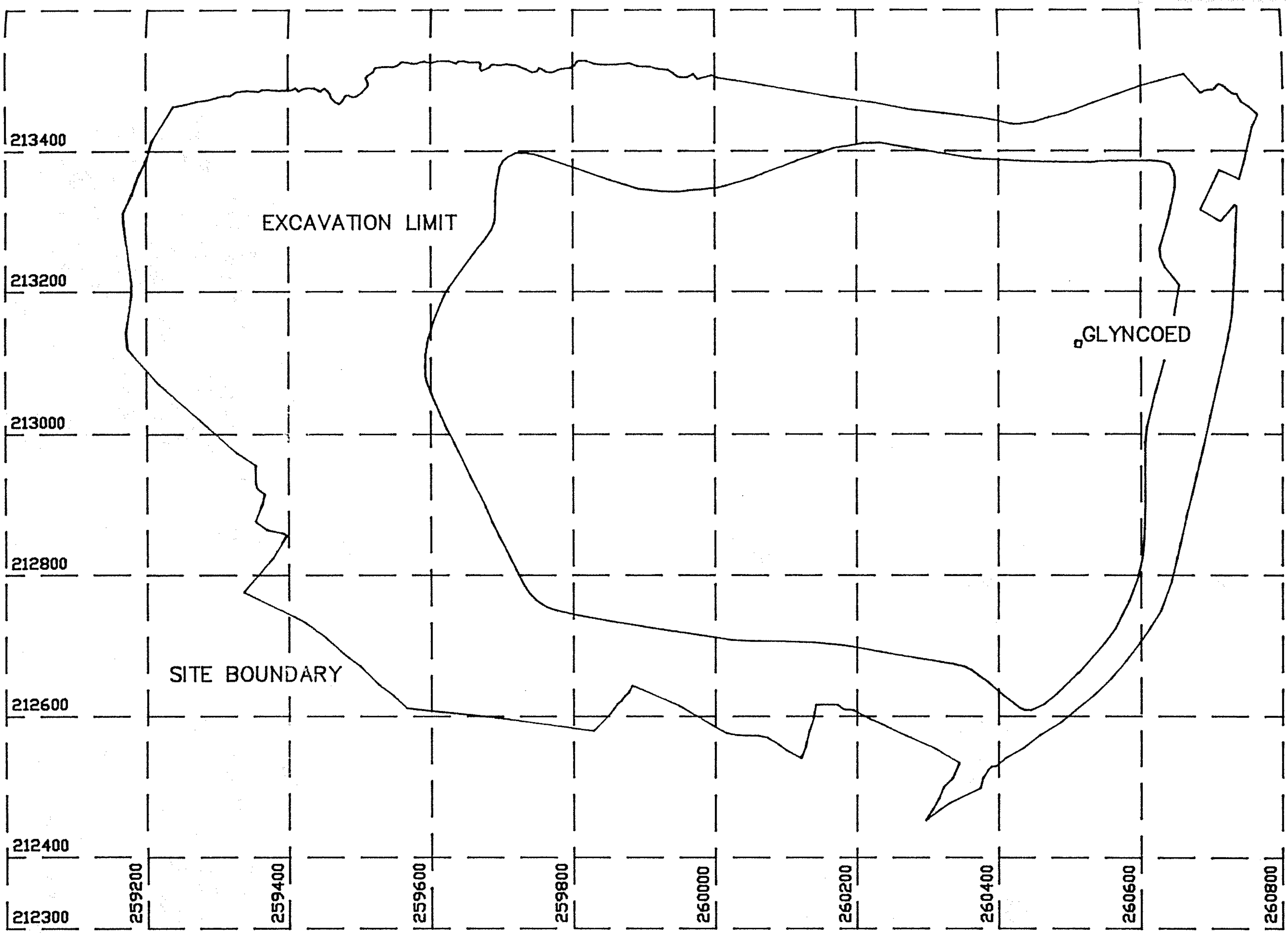
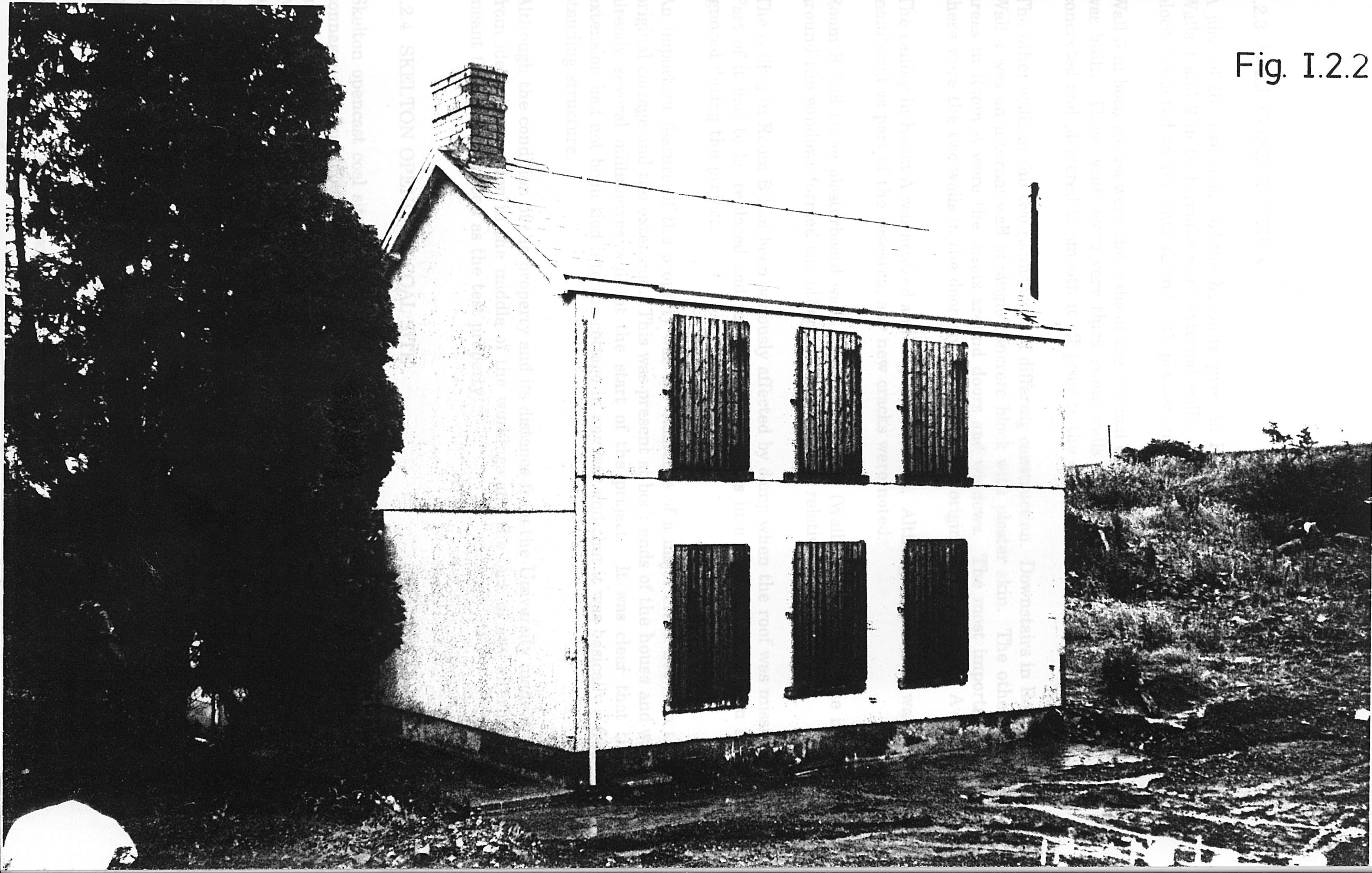


Fig. I.2.1 GILFACH IAGO SITE PLAN

Fig. I.2.2



I.2.3 WALL CONSTRUCTION

A plan of the two floors of the house is given in Figure I.2.3 with the walls labelled. Walls 1 and 2 in both rooms were external walls. These were of double-skin concrete block, rendered on the outside and with plaster on the inside.

Wall 3 in both rooms were the walls of the original cottage against which the extension was built. These walls were very thick stone walls with rubble fill. They had been concreted and plastered to smooth it off prior to the extension being built.

The other walls in the two rooms were of differing construction. Downstairs in Room A, Wall 4 was an internal wall of single concrete block with plaster skin. The other wall areas in Room A were the insets around doors and windows. The most important of these were the two walls in the doorway through to the original cottage (Walls A & B).

The ceiling in Room A was artexed and in good condition. Although the ceiling was not monitored as part of the research, any new cracks were noted.

Room B had three plasterboard walls with plaster skim (Walls 4, 5 and 6). The inset around the windows formed the other 3 walls, and were relatively unimportant.

The ceiling in Room B had been seriously affected by damp when the roof was missing. Part of it had to be replaced and replastered, so it was in a very poor condition and ignored during the project.

An important feature of the property was the existence of a major crack between the original cottage and the extension. This was present at both ends of the house and was already several millimetres wide at the start of the project. It was clear that the extension had not been tied into the cottage in any way and that it was basically a free standing structure.

Although the condition of the property and its distance from the University made it far from ideal, its position in the middle of the workings and the lack of any alternative meant that it was chosen as the test property.

I.2.4 SKELTON OPENCAST COAL SITE

Skelton opencast coal site covered an area of 214 hectares (Fig. I.2.4) and had a total tonnage of bituminous coal of 1,200,000 tonnes. Production was at the rate of approximately 4,000 tonnes per week and was expected to end in mid 1994. The geology was varied with horizontal beds in parts and steeply dipping and faulted seams in other areas.

Blasting initially took place on most horizons using a variety of blast designs and detonation systems. The blasting operations gradually moved closer to the test area. However, blasting took place very erratically and as the site progressed there was an increase in the use of hydraulic prime movers which further reduced the need for blasting. In the end very few ground vibrations of any significant magnitude were recorded at the canteen so the project here was of limited use.

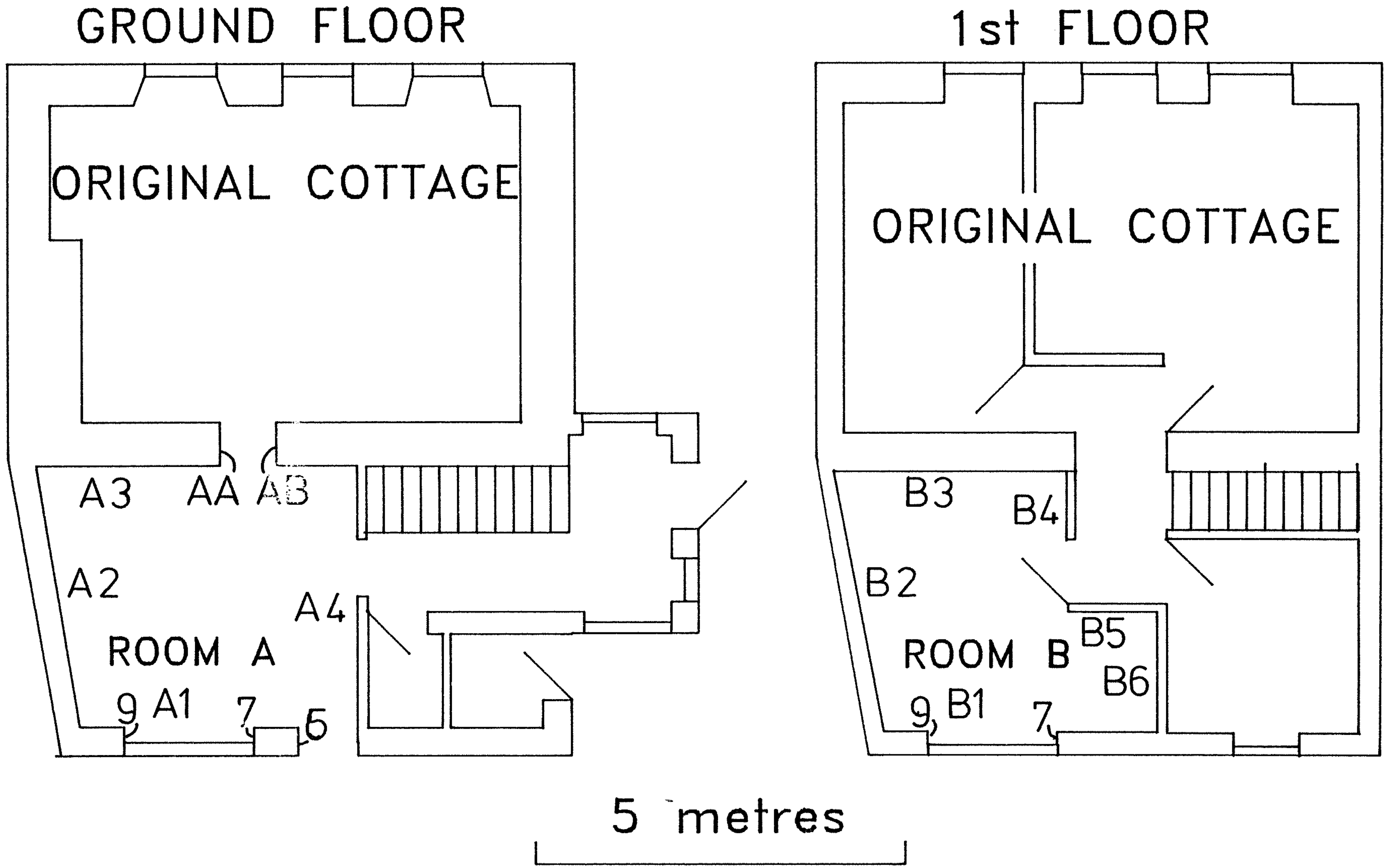


Fig. I.2.3 GILFACH IAGO TEST HOUSE

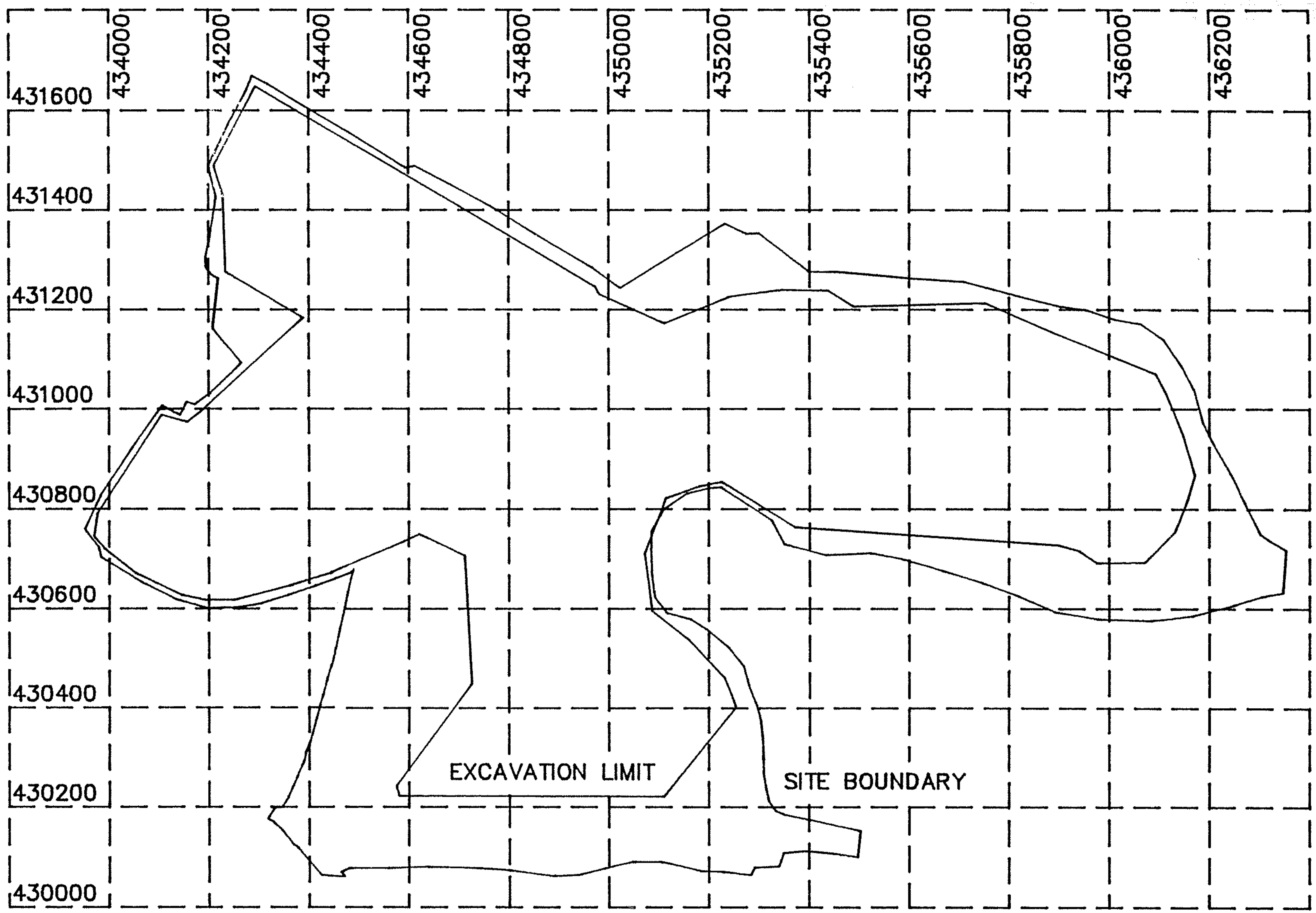


Fig. I.2.4 SKELTON OCCS SITE PLAN

The structure in use for the research was brick built and formerly the staff canteen and kitchen for the contractors plant yard. The former kitchen in the building was the only room to have had plaster on the walls but it was found that the plaster was already so badly cracked (Fig. I.2.5) that it was unsuitable for the research work. Consequently, one end wall of the kitchen area was completely stripped and re-plastered. The wall was approximately 5.5m wide by 4.5m high and had openings in it for a door and a window. It was an internal wall which allowed the environment on both sides of the wall to be controlled as explained in the next section.

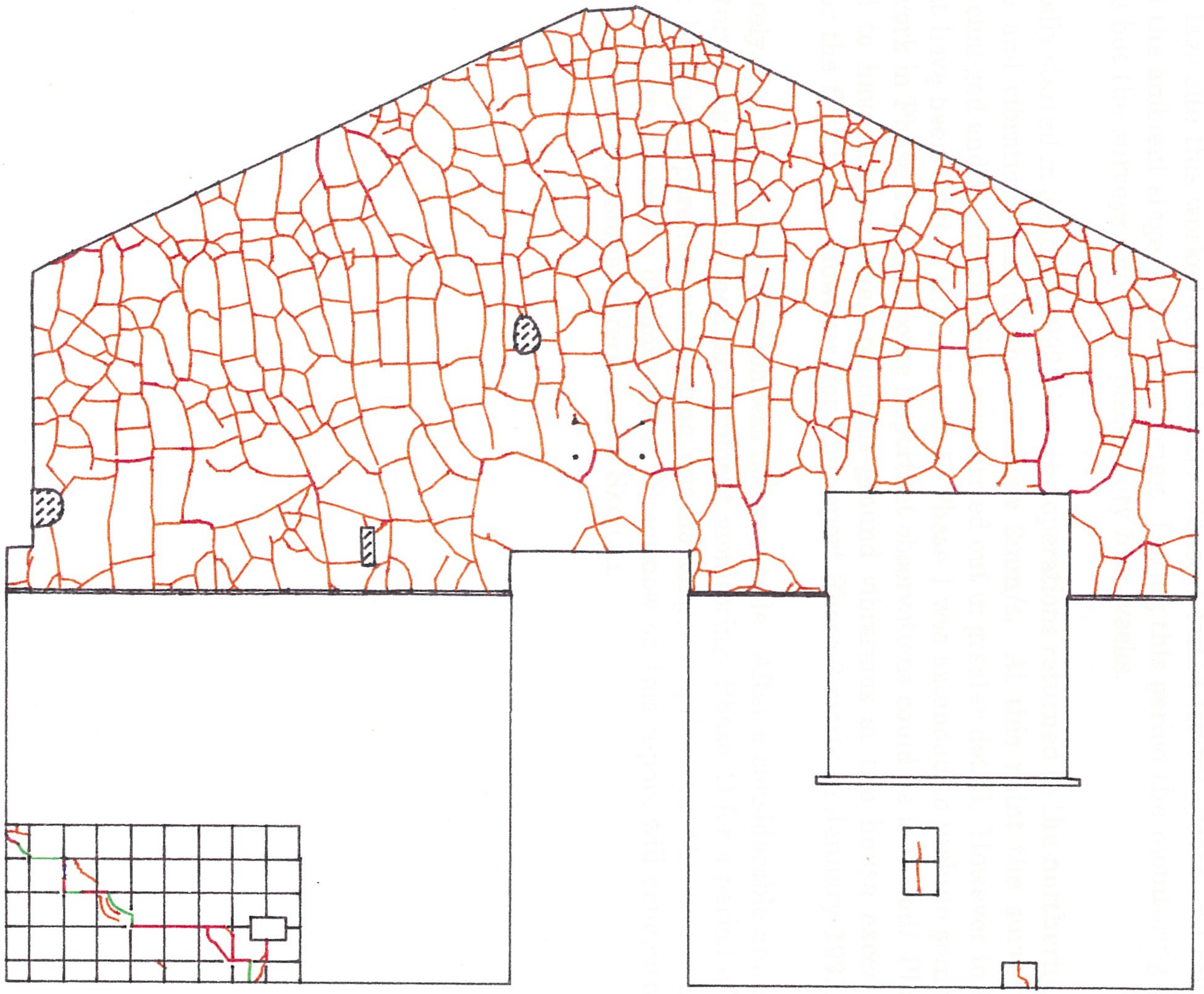
I.2.5 DIFFERENT RESEARCH METHODS

While the overall aims at the two test sites were similar, the emphasis was different. The project at Gilfach Iago was looking at all possible causes of cracking to determine the relative importance of each. Within a few months it became obvious that temperature was a key factor in the development of cracks. When the project started on Skelton, it was decided that the environment around the wall should be controlled and kept as constant as possible to minimise the temperature effects. This would reduce the number of parameters, and hopefully make it easier to identify the specific effects of the ground vibrations.

To accomplish this a partition was constructed which separated the wall from the rest of the canteen. A ventilation system was designed to maintain an even temperature by producing an airflow across the wall and on both sides.

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. I.2.5



LEGEND

LEEDS UNIVERSITY CRACK INDEX (LUCI)

LUCI	WIDTH (mm)	COLOUR
0	0 – 0.1	orange
1	0.1 – 1	red
2	1 – 2	green
3	2 – 5	blue
4	5+	magenta

DETAIL

AREAS NOT SURVEYED

DERIVED DATA

Wall Area: – 18.241m²

Crack Length: – 127.9m

SCALE

500 mm

SKELTON ROOM A, WALL 2. INITIAL SURVEY

I.3. RESEARCH PHASES

The research was split into two phases for each of the test structures. The first phase was when opencast operations were distant and had little or no effect on the structure. This produced a considerable amount of data on the effect of various parameters on the wall.

The second phase involved monitoring as the operations moved progressively nearer the property. The buildings were left in place for as long as possible so that the effect of blasting could be measured and damage observed.

At Gilfach Iago site this worked satisfactorily. Phase 1 lasted for two years and can be considered the ambient stage of the monitoring. During this period the monitoring was continuous but the surveys only took place every four weeks.

Phase 2 really started in January 1992 when the operations returned to the northern end of the site and vibrations started to rise above 2mm/s. At this point the surveying procedure changed and the monitoring was carried out in greater detail. However in the papers that have been written (Refs. 3, 4 & 5) Phase 1 was extended to include some of the early work in Phase 2 so that some important observations could be included. Phase 2 was said to have started when resultant ground vibrations at the house exceeded 10mm/s for the first time. However, for this report Phase 2 starts in January 1992.

Unfortunately, the situation at Skelton was not so simple. After a considerable amount of preparatory work in the canteen, and ambient monitoring (Phase 1) for a period of 18 months, it became apparent that blasting was no longer required on the site. The Skelton project was therefore of limited use. From now on this report will concentrate on Gilfach Iago with occasional references to Skelton.

I.4. VIBRATION MONITORING

With the objective of the project being to determine the effect of blast induced vibrations it was essential to ensure that all signals were monitored and recorded accurately. In order to establish the vibration levels around the house several sets of monitoring equipment were used. Four sets of triaxial transducers continuously monitored the house (i.e. sampling 500 times a second) along with 2 air overpressure transducers. When the vibration level exceeded a predefined trigger level, data was recorded for further analysis.

I.4.1 GROUND VIBRATION

The vibrations being transmitted into the house were monitored using a triaxial velocity transducer (geophone) array which was buried in the ground next to the foundations of the structure. The array was linked to a Leeds University/British Coal Continuous Blast Monitoring System (CBMS) station which is an advanced data capture unit (Ref 6). This was left in position throughout the project and was used to record the ground vibrations reaching the house. In a sense, what had happened to the seismic signals before they reached the house were of no concern in this current project. The aim here was to look at how a structure responds to a given vibration which is applied to it. The transmission effects can be considered separately.

I.4.2 STRUCTURAL VIBRATION

A further CBMS station connected to another triaxial array of velocity transducers was located inside the house. This was positioned in a variety of locations during the project so that the transfer functions could be examined.

Because the accurate measurement of vibration was critical to this project it was decided to also install two sets of very high quality accelerometers. Each set of three transducers was linked to a CBMS station but the accelerometers could be arranged as desired. One set was attached in a triaxial arrangement to the wall and ground just above foundation level, close to the location of the external velocity transducers. These remained here for the duration of the project and acted as a check and comparison for the input signals. Initially, the other set was located in a triaxial array at the lower left corner of the upstairs window (Wall B1). This array was then split up and one accelerometer positioned in the midpoint of each of three upstairs walls (B2, B3 & B6). They ended the project in the middle of three downstairs walls (A2, A3 & A4).

I.4.3 AIR-OVERPRESSURE

Two different hydrophones were installed on the roof of the house to measure the air-overpressure associated with blasting. The shock wave from the blasting was not anticipated to cause any damage, but there had previously been some problems on the site with excessive air-overpressure and it was hoped that the recordings would help to resolve any difficulties. Two different models of hydrophone were used so that a comparison could be made between them.

I.5. ENVIRONMENTAL MONITORING

The blast ground vibrations were not the only external variables to affect the house. The environmental conditions, particularly the weather and the ground water level, are parameters which affect the house and may have an influence on cracking. They therefore needed careful monitoring. A weather station was designed and built as part of the central monitoring computer and this recorded data (either sampled or averaged) every 20 minutes.

I.5.1 WIND SPEED AND DIRECTION

Wind speed and direction were monitored every second using a mast mounted anemometer and windvane. A running mean and standard deviation was kept for the wind speed and these were recorded and re-initialized at the end of each 20 minute period. The maximum and minimum wind speed in each period was also recorded, although the minimum was not very useful as it was almost always zero.

For the wind direction a count was kept of the percentage of each 20 minute period that the wind was blowing in each of 8 sectors of the compass. A ninth alternative of wind idle was used if the wind speed was less than 0.3 mm/s

I.5.2 RAINFALL

A tipping bucket rain gauge situated on the flat roof of the extension was used to record the rainfall around the house. The amount of rain in each 20 minute period was recorded in the computer.

I.5.3 EXTERNAL TEMPERATURE

An aspirated psychrometer was fixed on the outside north facing wall of the house. The wet and dry bulb thermometers allowed the external temperature to be recorded every 20 minutes so diurnal as well as seasonal variations were recorded. It also meant that a measure of humidity could be obtained. Because it is mounted on the wall of the house it may have been slightly affected by heat radiating from the house.

I.5.4 INTERNAL TEMPERATURE

Two aspirated psychrometers were also placed in the rooms under investigation and read every 20 minutes. These were very important as they showed how the rooms responded to changes in external temperature as well as highlighting the effects of the heaters when they were on.

I.5.5 PLASTER TEMPERATURE

An attempt was made to measure the temperature of the plaster on the wall using platinum resistance thermometers which were buried in the plaster. These were not successful as there were problems with calibration.

I.5.6 WATER TABLE

Piezometric ground water levels were monitored in four boreholes around the house using pressure transducers. Three boreholes had two transducers each which were monitoring water level in different horizons, and recording onto loggers every hour. This information was downloaded and incorporated into the database at regular intervals. Unfortunately there were severe problems with the loggers and much of the data was lost or corrupted.

However, the fourth borehole adjacent to the house had just one transducer and was linked directly to the main monitoring computer. The water level here was recorded every 20 minutes along with all the other parameters and showed how the water table responded to rainfall. Significant changes in the water table may have an effect on the stability of the ground surrounding and under the house which may result in subsidence.

I.6. STRUCTURAL MONITORING

The structural monitoring which took place concerned the creation or extension of cracks, and the behaviour of the house and surrounding ground which may be responsible. The monitoring comprised regular wall and level surveys as well as continuous monitoring of parameters such as crack widths and floor tilting. The procedure changed between Phase 1 and Phase 2 as the blasting got closer. The crack surveys are such an important part of the project that they are described in detail in the next chapter.

I.6.1 PRECISION LEVEL SURVEY

A total of 16 permanent level stations were installed on the Gilfach Iago house and surrounding ground (Fig. I.6.1). Eleven of these were attached to the external walls of the house and five were in the ground up to 10m away. The furthest ground station (GL1) was taken as the reference. Although the initial level of the reference station was obtained, it was not possible to subsequently tie it into the site datum because of its distance from any other site stations. During the project it became apparent that GL1 had moved (possibly due to vehicles running nearby, or on it!). The resulting change in reference level had to be approximated and accounted for in all the other levels. In other words, the levels given may not be absolute, but relative to GL1 they are correct.

Throughout Phase 1 these surveys took place every four weeks. During Phase 2 a survey was attempted every week so that the affects of the approaching excavation and blasting could be more closely observed.

I.6.2 CRACK WIDTH MONITORING

Crack widths were measured using Linear Variable Displacement Transducers (LVDTs) which were positioned over cracks and fixed to the walls by means of perspex blocks and epoxy adhesive. Eleven LVDTs were used and they were put across a variety of cracks during the project. In addition to these, one LVDT was located in an area of plaster with no cracks which was used as a reference. The 12 LVDTs were sampled every 20 minutes and the data recorded on the central computer. A table of the positions of the LVDTs is shown in Table 6.1.

As well as being measured every 20 minutes, changes in crack width were recorded in association with blast vibrations. Immediately after a seismic event had triggered the vibration recorders, the crack widths were measured and the difference between that and the pre-event width was calculated and recorded. In this way it was possible to determine whether the wall response to vibration produced stresses around the crack, which may have resulted in crack growth.

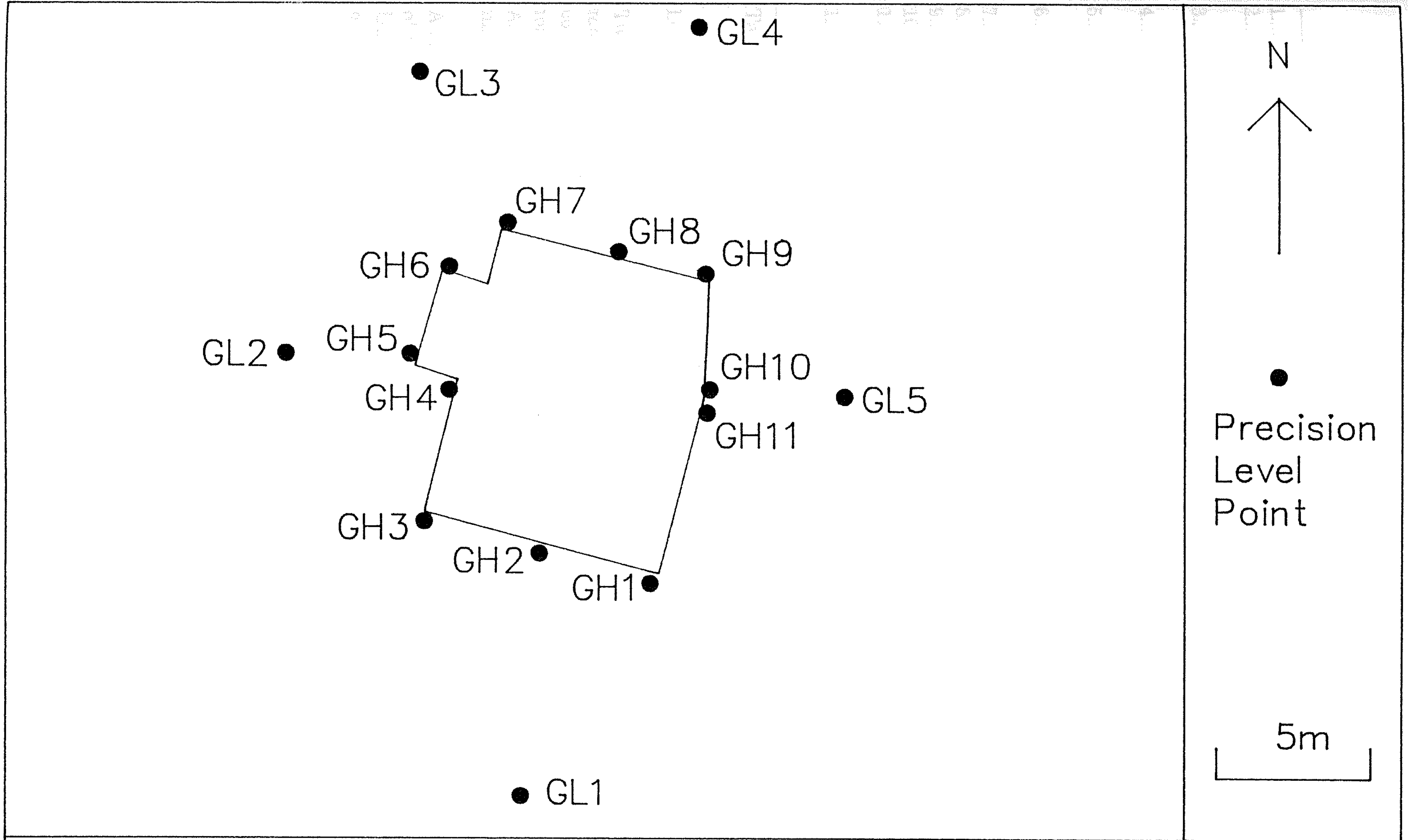


Fig. I.6.1 LOCATION OF PRECISION LEVEL SURVEY POINTS

1......		Wall B2
2......		External, West Side
	21/12/90	Wall B2
3......		External, West Side
	13/3/90	Wall A2
4......		External, East Side
	21/2/90	Wall B4
5......		External, East Side
	21/2/90	Corner of Walls B2 & B3
6......		External, East Side
	21/2/90	Corner of Walls B2 & B3
7......		Wall B1
8......		Wall B1
9......		Wall B1
10......		Wall B1
11......		Wall A3
	20/10/90	Wall A2
12......		External, West Side
	30/4/90	Wall B2

Table 6.1 Locations of LVDTs

I.6.3 STRUCTURAL INCLINATION

Two precision inclinometers were installed, mounted horizontally and perpendicularly, to monitor any subsidence which may have taken place. They were positioned on the concrete floor in Room A in the NE corner and lined up with the walls. Once again, the instruments were read every 20 minutes to obtained the angle of dip of the floor. Although they would only pick up tilting movement, it was important additional information to the precision level survey data.

A second unit was installed in the NW corner of the downstairs room with the objective of monitoring any differential tilting which might lead to racking stresses in the house. Unfortunately, this second unit did not function properly and no useful information was obtained from it.

I.7. CRACK SURVEYS

This was arguably the most important aspect of the project, so the procedure will be explained in considerable detail. An initial crack survey of Rooms A and B at Gilfach Iago was carried out in January 1990 using the following methods.

I.7.1 INITIAL SURVEY

The poor condition of some of the walls would have made the survey very difficult, so all the wallpaper was removed and the walls in Room A were whitewashed. This significantly improved the observing and marking of cracks, as well as making it easier to photograph. Many of the observed cosmetic cracks would probably not have been visible if the original wall coverings had been left on and so would not have been considered as damage in a normal residential property.

A horizontal line was drawn at the same level on each wall using a precision level instrument and this line was used as the datum. A grid of 0.5 m squares was then marked on each wall. The insides of windows and door openings were included as separate walls and each square was uniquely coded to identify which room and wall the square was on.

Having prepared the walls, each square underwent a detailed examination for cracks. A crack had to be visible to the naked eye in order to be noticed, but the full extension of cracks was sometimes determined using a magnifying glass or hand-held microscope. The location of each crack was marked in pen on the wall at each change of direction or approximately every 10 cm. A different symbol was then used to mark the ends of the cracks.

When the square had been surveyed and marked it was then photographed in black and white using a 35 mm compact zoom camera with date function. A series of tests were carried out to determine the optimum zoom and exposure settings. A lighting rig was built to avoid having to use the flash which tended to be too bright. The zoom setting (from 38 to 90mm) was not found to be critical but wherever possible the focal length was set to 50mm. The distortion around the edges of the print was never found to exceed 5mm which was considered acceptable, so image processing was not required.

Initially the crack widths were measured during the survey, but this was difficult to do accurately and they showed very little change anyway. The procedure was therefore changed to a simple classification according to the index given in Table 7.1.

LUCI	WIDTH (mm)	B.R.E.DEGREE (Ref 7)
0	0.0 - 0.1	Negligible
1	0.1 - 1.0	Very Slight
2	1.0 - 2.0	Slight
3	2.0 - 5.0	Slight
4	5.0 +	Moderate
		Severe
		Very Severe

Table 7.1 Leeds University Crack Index

I.7.2 CRACK PROCESSING

At the University the photographs were developed and printed onto A4 prints. Initially, all the details of the wall, e.g. wall edges, windows, doors, screw holes were digitised into the AUTOCAD drawing package on an IBM PS2 computer using a TDS A3 digitising tablet. One CAD drawing was used for each wall and the coordinate system of the drawing adjusted to match that of the wall in the following manner.

Each square on a wall was given a unique number based on rows and columns. If a square in Gilfach Iago, Room A, Wall 2 was the 4th square along and the 3rd square up it would be given the code GA243. The advantage of this system was that it could also be used in terms of x,y coordinates. The top-left corner of the square in the very bottom left of each wall was given the coordinate 500,500. Because each square is 500mm by 500mm it is then very easy to work out the x,y coordinates of the corners of each square.

The process of digitising the cracks involved calibrating the photograph and using the square coding system to make sure the cracks were positioned in the right place on the wall. The calibration was standardised to use the bottom left and top right of each square wherever possible. Where a partial square was being digitised a mark was made at a known position on one of the square edges and used in the calibration. This produced a drawing of each wall showing the location of all cracks and other relevant features. The lines in the form of polylines were then edited so they reflected the width classification of the crack.

A programme was written for AUTOCAD's programming language, AUTOLISP, which automatically produced a diagram on which cracks with different indices were shown in different colours. Another AUTOLISP programme was used to calculate the total crack length on a particular wall. These plots were then archived for reference.

I.7.3 PHASE 1 SURVEYS

During the two years of Phase 1 the surveys took place every 4 weeks. The walls were observed to see if new cracks had appeared or if old cracks had lengthened or widened. Any changes were marked on the wall and then a photograph was taken. The A4 print was then digitised onto the existing drawing of the wall. Only the new cracks needed to be digitised. The AUTOLISP programme was used again to calculate the total crack length and the increase was then noted. The updated plot was stored for use in the next digitising process. The newly recorded cracks were stored separately so that each survey on each wall could be recalled if necessary.

In this way a picture of the seasonal changes in crack development was constructed. At this stage the surveys were not regular enough to allow crack generation to be correlated with specific events.

I.7.4 PHASE 2 SURVEYS

The survey procedure used in Phase 1 was quite adequate while blasting was a long way off and vibration damage was extremely unlikely. However, when the excavation started to approach the house and resultant ground vibration levels started to rise above 2mm/s the effect of each vibration event had to be assessed. Therefore surveys were carried out on a much more regular basis.

An attempt was made to obtain a full survey before and after each blast (pre- and post-blast). The pre-blast survey was necessary so that cracks which may have appeared after the last post-blast survey were not considered the effect of the next blast. The time lag could be anything from 1 hour to several days, depending on how frequently blasting took place. If the blasts were very close together then it was not always possible to do a post-blast and a pre-blast survey. This did not matter too much because if the time lag was a matter of 1 or 2 hours then the post-blast survey for one blast can quite legitimately be considered the pre-blast survey for the next.

If the time between blasts was much less than an hour, then a full post-blast survey was not possible. In this situation, certain walls were designated as priority walls and as many of these as possible were surveyed before the next blast occurred. If walls were not surveyed between blasts then obviously any cracks which were detected on the post-blast survey could have arisen from either of the blasts or during the time between them. On the two occasions when this did happen the cracks were not considered examples of vibration damage.

Because a full survey could take from 1 to 2 hours there was a degree of uncertainty involved. Because it was not possible to carry out pre- and post-blast surveys of all the walls within 10 minutes either side of the blast a compromise had to be reached.

I.8. EQUIPMENT

This chapter contains details and simple specifications of all the equipment which was used in the project. High quality equipment was used wherever possible although some cheaper alternatives were used in parallel so that comparisons could be made. A small aspect of the project was to determine whether more expensive equipment was any more useful.

The equipment described here is that used on Gilfach Iago OCCS. The instrumentation for Skelton OCCS was very similar.

I.8.1 VELOCITY TRANSDUCERS

These were used in a fixed triaxial array for monitoring the ground vibration outside, and a moveable triaxial array inside.

Type: Geospace HS1, Geospace Corporation

The output from these geophones was monitored by a Continuous Blast Monitoring System designed by Leeds University. The CBMS unit had a maximum range of ±50 mm/sec (close to the limit of the transducers) and a digital resolution of 0.024 mm/sec. The frequency response was ±3 dB between 4 and 125 Hz. The sampling frequency was 500 Hz and each record contained 4.1 seconds of data.

I.8.2 ACCELEROMETERS

Six accelerometers with associated line drivers were installed in different positions in the house.

Type: Accelerometer type 8318, Bruel and Kjaer
Type: Line driver type 2813, Bruel and Kjaer

The range and accuracy of these depends largely on the amplifiers they are connected to. Each set of three accelerometers was connected to another CBMS station. The system gave a full scale of 15.8 m/s^2 and a digital resolution of 0.0077 m/s^2. Taking a sinusoidal frequency of 10 Hz this gives a maximum velocity of 250 mm/s. During most of the project there was a x10 amplifier which gave a full scale of only 25 mm/s but with enhanced resolution. This was removed as the vibration levels rose.

I.8.3 AIR OVERPRESSURE

Two hydrophones of different types were installed. Both were very high quality and with the amplifiers in the CBMS stations could record a maximum of 140 dB (200 Pascals). The digital resolution was 0.098Pa and the system was linear from 2Hz upwards.

Type: Hydrophone type 8101, Bruel and Kjaer
Type: Hydrophone type M/01/TA, D.J.Birchalls

I.8.4 ANEMOMETER AND WINDVANE

A mast mounted anemometer and windvane was used to record wind parameters with a dedicated control unit. This unit gave a wind speed range of 0 to 25 m/s with accuracy of ±2.5%. The wind direction measures from 240 deg through W,N,E,S,W,N,E to 120 deg on 10 deg divisions. The average accuracy in normal turbulent conditions is ±3 degrees.

Type: Porton Anemometer & Windvane type D600, Vector Instruments

The control unit was sampled every second by the central monitoring computer and the required data recorded and stored (see Chapter I.5.1)

I.8.5 ASPIRATED PSYCHROMETERS

These were used for monitoring wet and dry bulb temperatures externally and in both rooms. The platinum resistance thermometers had a range of -20 to +65 Celsius and an accuracy of 0.2 Celsius. These were connected to digital meters which had a range well in excess of the thermometers but an accuracy of just ±1 Celsius. Readings of the wet and dry bulb temperature were taken at 20 minute intervals with the fan being run for one minute prior to that.

Type: Psychrometer type H301, Vector Instruments

I.8.6 PIEZOMETRIC WATER LEVEL

A total of seven piezometric pressure transducers were used to monitor water level in 4 boreholes. Six of these were connected to surface loggers which recorded data every hour. The data recorded was in terms of pressure and this was converted to head of water, and then to water table level above site datum. One of the transducers was connected to the central monitoring computer which recorded the pressure (converted to water level) every 20 minutes. This transducer was located at a depth of 6 m and measured height of water above it to 0.002 m.

Type: Pressure Transducer type PDCR/35D, Druck Limited

I.8.7 PRECISION LEVELLING EQUIPMENT

The equipment used initially was a CTS S400 level with an invar staff. Levels could be read to 0.001 feet (0.3 mm) and estimated to 0.001 feet. A survey was considered to be acceptable if the misclosure was less than .0017 feet (0.5 mm). Towards the end of the project this was replaced by a Wild electronic level which was metric and was accurate to 0.1mm. This was a far more reliable machine than the old manual CTS level.

I.8.8 LINEAR VARIABLE DISPLACEMENT TRANSDUCERS

These were used for measuring variations in crack width. The transducers used had a full range of ±2.5mm and are accurate to 0.002 mm (2 microns). The LVDT used as a reference showed that they were not susceptible to temperature variations and gave a true indication of movement between the two perspex blocks used in the mounting.

Type: LVDT Type DG2.5, Schlumberger Industries

They were all connected to the central monitoring computer and readings taken every 20 minutes as well as after each recorded vibration event.

I.8.9 PRECISION INCLINOMETERS

Four of these were used in two sets of two, each set mounted perpendicularly on a base plate and cemented to the floor. They had a range of ±6 degrees with an error band ±0.25% full scale.

Type: Precision Inclinometer type 685B, RDP Electronics

Unfortunately one of the sets was damaged and severely affected by temperature variations, so the data recorded was invalid. The other set appeared to give good data throughout the project.

I.8.10 SKELTON OCCS

The range of equipment installed on Skelton was not as great as on Gilfach Iago. This was partly because only one wall was being monitored and partly because the blasting never got close enough to the structure to necessitate the installation of items such as accelerometers. However, the following was installed in the canteen.

6 Internal Platinum Resistance Thermometers
1 Anemometer and Windvane
1 Tipping Rain Gauge
4 LVDTs
1 Triaxial Geophone Unit

PART II: DATA ANALYSIS

II.1. INTRODUCTION

With such a large amount of data it is vital that an ordered approach be taken in the analysis of the data. For this reason each of the parameters which have been monitored will be first looked at individually. This will allow features and trends to be identified before any correlation is carried out between parameters. Two types of plot have been used for the data which is recorded every 20 minutes. The weekly plots which contain every data point have been included in the monthly reports but have not been reproduced here. Because the data is frequently referred to in different parts of the text the data plots have been placed in Appendices at the rear of the report.

The daily summaries contained in Appendix A take one parameter for each day (e.g. maximum, mean, etc.) and plot them for the whole project. This results in approximately 800 data points for each parameter as the monitoring lasted for this number of days.

Appendix B contains information relating to the blasts which were recorded at the property. This includes all the raw data as well as some summary diagrams.

Appendix C concerns the crack growth data and shows when and where cracks were observed. Once again, summary diagrams are included.

Observation and comments will be made on this data in Chapters 2 to 5, before comparisons and correlations are attempted between parameters in Chapter 6. A discussion of the crack generation which took place in Phases 1 and 2 is given in Chapters 7 and 8. Chapter 9 contains the results of some of the other experiments which were carried out as part of the project.

Chapter 10 outlines the conclusions resulting from the project.

II.2. ENVIRONMENTAL PARAMETERS

II.2.1 WIND

While wind was not expected to have any structural effects on the building it was felt that it was an important parameter to measure, as the direction and strength of the wind could have a significant affect on the temperature in and around the house.

II.2.1.1 Wind Speed

Mean wind speed and standard deviation were plotted in the monthly reports and it was hoped that together they would give an indication of the strength and gustiness of the wind. The mean showed that wind speed could change very quickly and was never constant for very long. The standard deviation simply showed that the windier it was, the greater the variation and therefore gustiness. On many days there was a diurnal variation with higher wind speeds during the day and lower speeds at night. Periods of calm (wind speed less than 0.3m/s) never seemed to have lasted for more than 3 to 4 hours. This must be due, in part, to the exposed position of the house.

The daily maximum and mean wind speed is plotted in Fig. A.1. This again shows large variation with some very sharp changes in mean and maximum from day to day. There are no obvious seasonal trends, although it appears that most of the strongest gusts occurred in January. May seems to have been a fairly quiet month in all three years while the spring of 1992 shows a slight rise in the mean wind speed.

II.2.1.2 Wind Direction

Wind direction is represented by 9 parameters, (8 points of the compass and wind idle) and so it was not possible to plot it on the weekly plots. However, rose diagrams are given in the appendix (Fig. A.2.). These show that in certain months one or two wind directions may be dominant, but taken over the whole project the wind direction is quite variable. The South and South-West are the prevailing wind directions, but the North and North-East are also significant. The East, South-East and North-West are all very low. During the project the wind was considered idle (less than 0.3m/s) for 7.8% of the time.

II.2.2. TEMPERATURE

Three sets of wet and dry bulb thermometers were used to monitor the temperature outside the house and in the two rooms being investigated. In order to simulate a residential property a heater was placed in each of the rooms. The heater in Room A was an oil-filled electric radiator while Room B had a fan heater. They both had thermostats which controlled the temperature and both were set up with time switches so they could be turned on and off during the day. During the first two winters they were set to come on between 06.00 and 09.00, and then again between 18.00 and 22.00. During the summer months and in the latter stages of the project the heaters were left off.

II.2.2.1 External Temperature

A plot of the mean daily temperatures in Figure A.3 shows how variable the temperature was outside the house. The normal seasonal variations are apparent, with highs in the months of July and August and lows from December to February. The highest mean temperature was 26C which is very warm for a 24 hour period, while the lowest was -6C. Changes in mean temperature of between 5C and 10C from day to day were not uncommon and periods of stable temperature lasting more than 3 days were rare. The mean temperature over the whole project was 9.6C and the daily temperature range averaged 6.8C. The daily ranges were slightly higher in the summer than in the winter but the highest (20C+) was in May when the nights were still cold and the days were hot. Nevertheless, the range was remarkably consistent throughout the project.

Figure A.4 shows the absolute maximum at 33C in July 1990 and the absolute minimum reaching -12C in February 1991. It again shows that the daily range was fairly constant throughout the project.

II.2.2.2 Room B Temperature

Room B will be considered first because there is a complete data set, whereas Room A was only recorded for half of the project. The weekly plots given in the monthly reports show how quickly the fan heater affected the air temperature. When it came on the temperature rose very quickly to a point where the thermostat cut in. When the heater switched off the temperature fell very quickly, partly because the heater gave no further heat and partly because the window in Room B was partially open.

The seasonal variations are again apparent in the daily mean temperature (Fig. A.5) which is a combination of the external temperature and the internal heater. The changes from day to day are again quite large. The influence of the heater can be seen in both the mean temperatures and the daily ranges. The heater was on for the first two winters but off for the third and the lower mean temperatures reflect this. The effect is most noticeable in the daily range. The heater was switched on for two periods; from the start of the project until May 1990 and then from November 1990 to May 1991. During these periods the daily ranges averaged 11.0C because of the warmth during the day when they were on and the cold winter nights when they were off. During the period when the heaters were permanently off the average was only 2.9C. This is much less than the average for the external temperature because of the filtering effect of the house on the internal temperatures.

The mean temperature in Room B over the whole project was 13.8C with a mean of 15.4C when the heating was on and 12.6C when the heating was off.

Two points need to be noted. First, while the heating was on, Room B was probably heated more than a typical residential property. Mean temperatures in excess of 20C are higher than would normally be expected. Second, there is one particular day in February 1991 when the heating did not come on. The mean temperature and the temperature range dropped very dramatically. This unusual feature may have been a significant factor in the cracking which will be considered later.

The highest recorded temperatures in Room B (Fig. A.6) occurred when the heating was still on during the spring and summer of 1990 when it reached 28C on several occasions. The lowest temperature was -4C and on that day even the maximum was less than 0C.

II.2.2.3 Room A Temperature

The thermometer in Room A was only installed in December 1990, so there is only 18 months of data. The different type of heater in Room A resulted in much more even temperatures, without the extremes of Room B. Figure A.7 shows the daily mean temperatures and the daily ranges while Figure A.8 gives the absolute maximums and minimums on each day. The mean temperature for the monitoring period in Room A is 12C and this is the same for when the heater is both on and off. The average range varies from 1.9C when the heater is off to 4.7C when the heater is on which is considerably less than the 11C average range observed in Room B. This reflects the different type of heater and the improved insulation of Room A which gives a maximum temperature of 20C and a minimum of 2C.

The variation in range observed at the end of the project (January - June 1992) is probably the effect of the adjacent room (in the old cottage) being heated, while a member of the research team was stationed at the house permanently. Heat will have passed through the connecting doorway and slightly raised the temperature of Room A.

II.2.3. RAIN

The total amount of rain recorded at the property during the project was 3.24 metres. This fell during 484 days of the 868 days recorded and there was over 1cm of rain on a total of 110 days. The largest amount of rain during one day was 70mm and this fell in January 1990 which was also the wettest month with over 340mm from 22/1 to 18/2/90. January 1991 was also very wet (240mm), but January 1992 was relatively dry. No dominant trends can be identified from either the monthly (Fig. A.9) or the daily (Fig. A.10) plots. It cannot even be stated that there is more rain in the winter than in the summer.

II.2.4. WATER TABLE LEVEL

The average daily water level is given in metres above the base of the piezometer pressure transducer in Figure A.10, along with the daily rainfall. It rises and falls between 3 and 4.2 metres throughout the project, until May 1992. At that point it drops to 1.2m over a period of four days and then continues to fall to 0.6m over the next 2 weeks. It then drops to zero as the borehole is completely de-watered.

II.3. STRUCTURAL PARAMETERS

II.3.1 INCLINOMETERS

Two sets of two inclinometers were used to monitor floor movement in Room A, but only one set gave reliable data (Fig. A.11). The E-W inclinometer shows very little variation until the last four weeks and even this is a change of only 0.05 degrees. The N-S inclinometer shows more movement with a gradual tilting and then levelling of around 0.15 degrees. As with the E-W readings there are some more sharp changes near the end of the project when the excavations were getting progressively closer to the property.

A change of 0.15 degrees represents differential movement of approximately 10mm from one side of the room to the other. Some of this variation may be due to temperature dependency of the inclinometers but checks indicated that this had a negligible effect. The negative correlation which exists between the temperature and the N-S inclinometer is probably a function of movement of the house foundation caused by thermal expansion and contraction of the building materials.

A positive change in tilt angle in the N-S inclinometer (IN1) represents a dip to the north, while a negative change is a tilting to the south.

The amount of tilting up until March 1992 is unlikely to have caused any damage, but the large and sudden tilting in the last few months may correspond to house movement which could be linked to increases in crack length.

II.3.2 PRECISION LEVELS

After the initial settling down period the ground station levels around the house varied by no more than 2mm until towards the end of the project. These slight variations show no relationship with rainfall or water table so they are probably the result of experimental inaccuracies. During the final three months, while excavation was taking place all around the property, the ground and house levels started to move around quite significantly. Unfortunately it was not possible to determine the absolute movement because the reference station (GL1) was affected by ground movement. However, it was possible calculate the approximate movement of the reference and account for it.

II.3.2.1 Ground Levels

In the last two months of the project when the property was perched on the top of a pillar, there was a significant drop in three out of the four stations (Fig A.12). GL2 and GL4 both finished with falls of about 5mm, although GL2 initially seemed to rise by a couple of millimetres. The station with the biggest drop was GL5 to the east of the house which fell nearly 12mm. This was on the site of some made up ground and was very close to an observed shaft. This large fall may have been due in part to the collapse of some old workings.

II.3.2.2 House Levels

The precision level stations attached to the outside of the house are very revealing. The monthly survey points are shown in Figures A.13 and A.14, and the final changes in level are shown on the plan in Figure A.15. These figures show clearly that there was a considerable amount of movement in the south wall of the original cottage while almost no movement in the northern wall. The levels in the side walls suggest that the whole structure has tilted south-east, but that the tilt has been greater in the old cottage than in the extension. There is no obvious relationship with ground level.

II.3.3 CRACK WIDTHS

In order to develop an understanding of the way cracks are created and developed, it was important to monitor some existing cracks and determine the key factors which affect them. Twelve LVDTs were used, with one set up as a reference and others being positioned in various parts of the house. Some of them were relocated during the project and plots of the daily mean crack width for each position, together with the relevant temperature plots, are given in Figures A.16 to A.30. These are not all plotted on the same scale as some cracks have shown considerable variation, while the changes in others are very small. An exception will be made in this section because comparisons will be drawn between the crack widths and temperature as this is a very important and obvious feature of the crack width changes.

II.3.3.1 LVDT 1 (Reference) - Wall B2

The reference LVDT was placed over a piece of plaster with no cracking in it on Wall B2. It shows some minor daily changes, but remains almost constant throughout the project and certainly shows no correlation with temperature (Fig. A.16).

II.3.3.2 LVDT 2 - External

This was initially positioned outside at the top of the major crack between the cottage and the extension on the western side of the house. The inverse correlation with temperature which is obvious in the week plots of the monthly reports is hidden in Figure A.17 by several sharp changes. One of these changes (20/2/90) was caused by resetting the amplifier but the others are due to changes in the relationship between crack width and temperature. In a detailed study in the Second Biannual Progress Report these changes were shown to be caused by rapid temperature changes with no accompanying crack movement, rather than by a specific event causing a sudden crack width change. In other words, the underlying linear inverse relationship still exists with a reasonably constant gradient, but the intercept does change from time to time.

II.3.3.3 LVDT 2 - Wall B2

In November 1990 this LVDT was repositioned over a crack on Wall B2. The crack must have been an old inactive crack, as the LVDT showed only very slight movement of less than 20 microns (Fig. A.18) but did appear to have a linear inverse relationship with temperature.

II.3.3.4 LVDT 3 - Wall A2

Apart from the first few weeks when this unit was outside, it was positioned on the downstairs wall A2. It covered a vertical crack which appeared to be following plaster which covered some conduiting and was therefore a line of weakness. During the project the width varied by 0.15mm and showed a good correlation with Room A temperature (Fig. A.19) which was recorded from December 1990.

II.3.3.5 LVDT 4 - Wall B4

As with LVDT 3, this unit was initially outside on a major external crack, but was then brought inside and placed over a crack in the upstairs plasterboard wall, B4. The crack ran from the top of the door frame up to the ceiling. This was the only unit which was not placed on a concrete block wall and shows some very interesting and unique features.

Up until May 1990 there were some sharp, sudden changes in crack width which coincided with sudden changes in temperature (Fig. A.20), but which did not show the same good linear relationship. Then from May to September 1990 there were almost no changes in crack width at all. During the winter of 90/91 there were again some significant changes in crack width with a reasonable inverse relationship. The following summer showed another stable period with very little change. In the winter of 91/92 when there was no internal heating there were some vary large variations in mean daily crack width (almost 0.2mm) with a good inverse relationship with temperature.

It seems as though the linear inverse relationship was only true below a certain temperature. Above it the wall was stable with virtually no movement. This was probably a function of the different materials used in the construction of wallboard, and the way they responded to temperature changes.

The final feature to note is the very sharp rise in crack width on 8th May 1992 which is obviously not connected with temperature. It will be shown later that this is connected to a vibration event.

II.3.3.6 LVDT 5 - Wall B2/B3

This unit and LVDT 6 were both positioned over a major crack in the corner between Walls B2 and B3, with LVDT 5 near the top. This crack ran right through to the outside of the house and formed a complete break between the old cottage and new extension. The amount of movement in LVDT 5 was very large with a complex relationship with temperature. Figure A.21 shows that although the LVDT was inside, the crack width plot has a very good inverse relationship with external temperature. This is because the crack was basically an external crack which goes right through the wall and so is therefore related to external temperature. The weekly plots reveal that the effects of internal temperature are superimposed on this, particularly when heaters are switched on, and this causes a drop in crack width. This information is lost in the daily means shown in Figure A.21 where external temperature is seen to be the dominant influence.

In the last two weeks of monitoring the crack width increases dramatically by over 1mm. As it is definitely not a function of temperature, it must be due to movement in the building and this will be investigated later.

II.3.3.7 LVDT 6 - Wall B2/B3

LVDT 6 was positioned near the bottom of the same crack as LVDT 5 and shows very similar characteristics (Fig. A.22). A plot of the difference between the two LVDTs in Figure A.23 shows that the two do not move by the same amount but that the movement in LVDT 6 is proportional but smaller. This indicates that the extension and the original cottage are rotating away from each other, with a hinge point at the base of the wall. This is confirmed by examining the same corner downstairs where the cracking has not yet appeared internally, which suggests there is less movement lower down.

The LVDTs on the major crack on this side of the house do not show the same sudden jumps in crack width as LVDT 2 which is on the major crack on the other side of the house. This suggests the extension is behaving differently on either side.

II.3.3.8 LVDT 7 - Wall B1

The next four LVDTs were all positioned on the same upstairs wall (Wall B1). Three of them (7, 8 & 9) were actually on the same crack which ran diagonally down from the bottom left corner of the window. Figure A.24 shows that LVDT 7 which was nearest the window actually has only a small amount of movement. The weekly plots show a good correlation with temperature and this can just be seen in the day to day changes. However, the seasonal variations are absent so there are no long term changes here.

II.3.3.9 LVDT 8 - Wall B1

This unit was in the middle of the crack and shows a greater amount of movement and some seasonal variation (Fig. A.25). It also shows a sharp increase in crack width at the end of the project which is not related to temperature.

II.3.3.10 LVDT 9 - Wall B1

This unit is at the lower end of the same crack, near Wall B2. In Figure A.26 it shows less variation than LVDT 8 but slightly more seasonal variation than LVDT 7. On the whole there is a good inverse linear relationship with temperature for all these LVDTs but the differences between them highlight the fact that a crack behaves differently along it's length. This will be due to the differences in stress in the wall itself as well as local differences in temperature.

II.3.3.11 LVDT 10 - Wall B1

LVDT 10 was also on B1, but on a separate crack, under the window (Fig. A.27). It has similar features to the other three on this wall, with the addition of a sharp increase in crack width during the period of large temperature fluctuations in February 1991. This has resulted in a slight but permanent rise in crack width which did not occur on the other crack at this time.

II.3.3.12 LVDT 11 - Wall A3

This unit was placed on the wall of the old cottage over what appeared to be an old crack which had been filled in. This experienced only very slight movement and showed no correlation with the changing temperature (Fig. A.28).

II.3.3.13 LVDT 12 - External

For a short period this unit was placed outside over the major crack separating the cottage from the extension. The limited amount of data shown in Figure A.29 seems to indicate that this crack was growing quite rapidly, but in fact this was due to the LVDT unit slipping and is not a true reflection of any structural movement.

II.3.3.14 LVDT 12 - Wall B2

During most of the project LVDT 12 was situated over an old crack on Wall B2. This crack was very stable and although it showed a slight correlation with temperature towards the end (Fig. A.30), the amount of movement from day to day was less than 10 microns.

II.4. VIBRATION DATA

II.4.1 SOURCES OF VIBRATION

Vibration monitoring was carried out in the house throughout the project. The type and location of the transducers have already been described and these were used to record all vibration events occurring above a threshold level. In this way, not only were the blast events recorded but vibration from other sources as well. These included sources inside the house such as running upstairs, shutting a door or moving a ladder, as well as those from outside such as heavy plant and machinery moving close to the house and people walking over the buried transducer. Some of these sources (e.g. shutting a door) resulted in significant PPV values, but they were mainly of a much higher frequency and shorter duration than the blasts. Of the several thousand non-blast events recorded only a few were found to have had any effect on crack widths and these will be discussed later. All the others have been disregarded in the analysis which has concentrated on the blast events.

II.4.2 BLAST VIBRATIONS

During the research project there were a total of 1640 blasts on the site. Chapter 2.1 in Part I has described how variable the blasts were and many of them were too far away or too small to produce seismic signals measurable at the house. A total of 850 were measured at one or more locations within the property and the peak particle velocities of all these have been listed in Appendix B. The first part lists the buried and foundation triaxial transducers which remained in the same place throughout the project, along with the roving unit which moved about but stayed as a triaxial set (Table B.1). The second part in Table B.2 gives the set of three accelerometers which were moved around and did not always have a triaxial configuration. Where the three units have been separated, there is of course no resultant.

II.4.2.1 Buried Transducer Data

Most of the analysis has been carried out on the buried transducers because these were the most abundantly recorded and represented the point of input of the vibration into the house.

The frequency distribution of the PPVs is much more easily described using the two research phases because the range increases dramatically in Phase 2. Figure II.4.1 shows the bulk of all resultant PPVs lie between 0.3mm/s (the trigger level) and 1.4 mm/s. In Phase 2 (Fig. II.4.2) there are only 12 blasts with PPVs above 10mm/s but there are a significant number between 2mm/s and 10mm/s.

Figure II.4.3 shows how the number of blasts were distributed through the research project. Apart from the Christmas periods, when the site shuts down for two weeks, the number of blasts per month has remained fairly constant. However, the proportion of blasts with no vibrations reaching the house does change. During the first year this increases as the workings start 200m from the house and move away. The number of blasts over 0.5mm/s remains very small until January 1992, when Phase II sees most

Fig. II.4.1 PHASE 1 BURIED RESULTANT PPVs

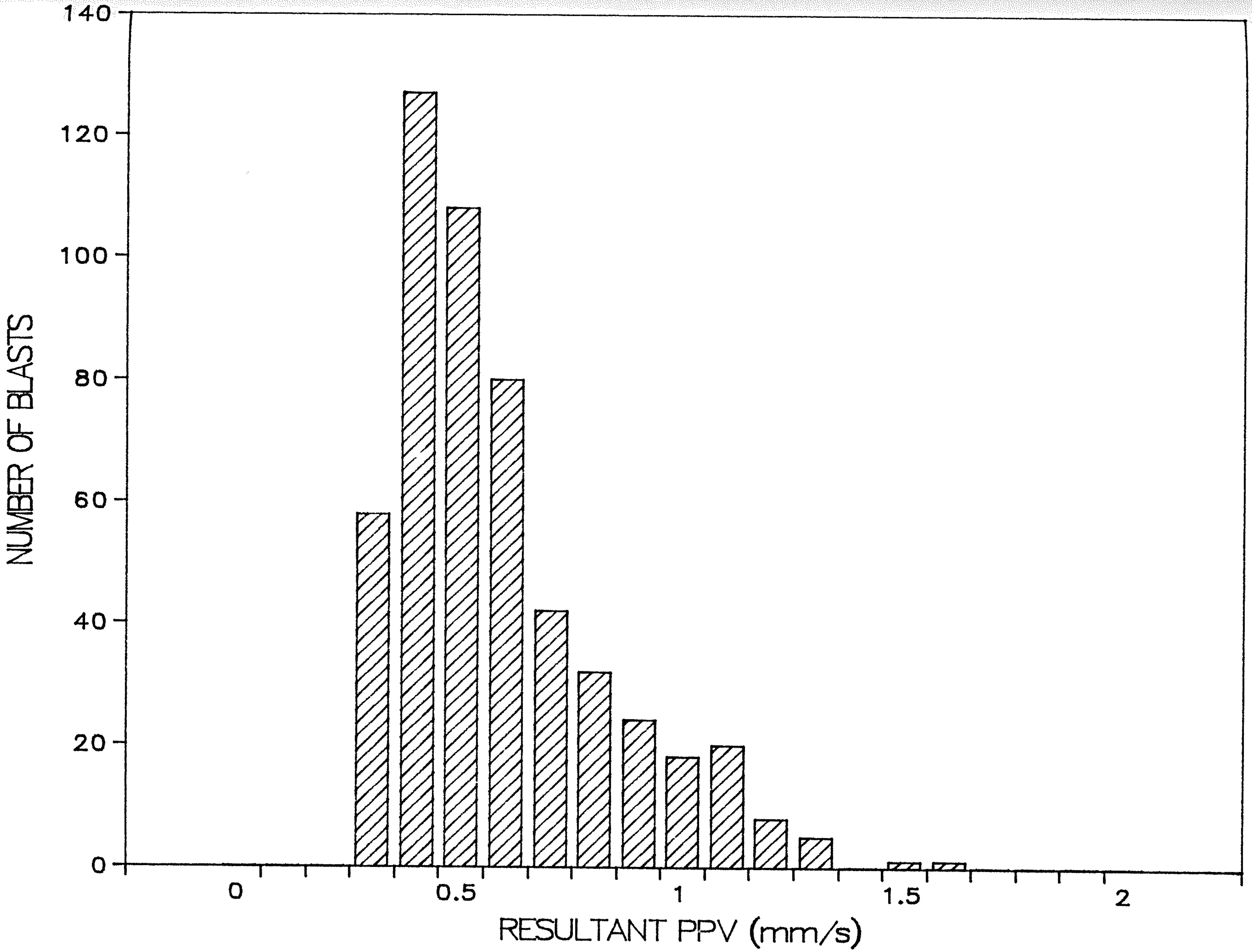


Fig. II.4.2 PHASE 2 BURIED RESULTANT PPVs

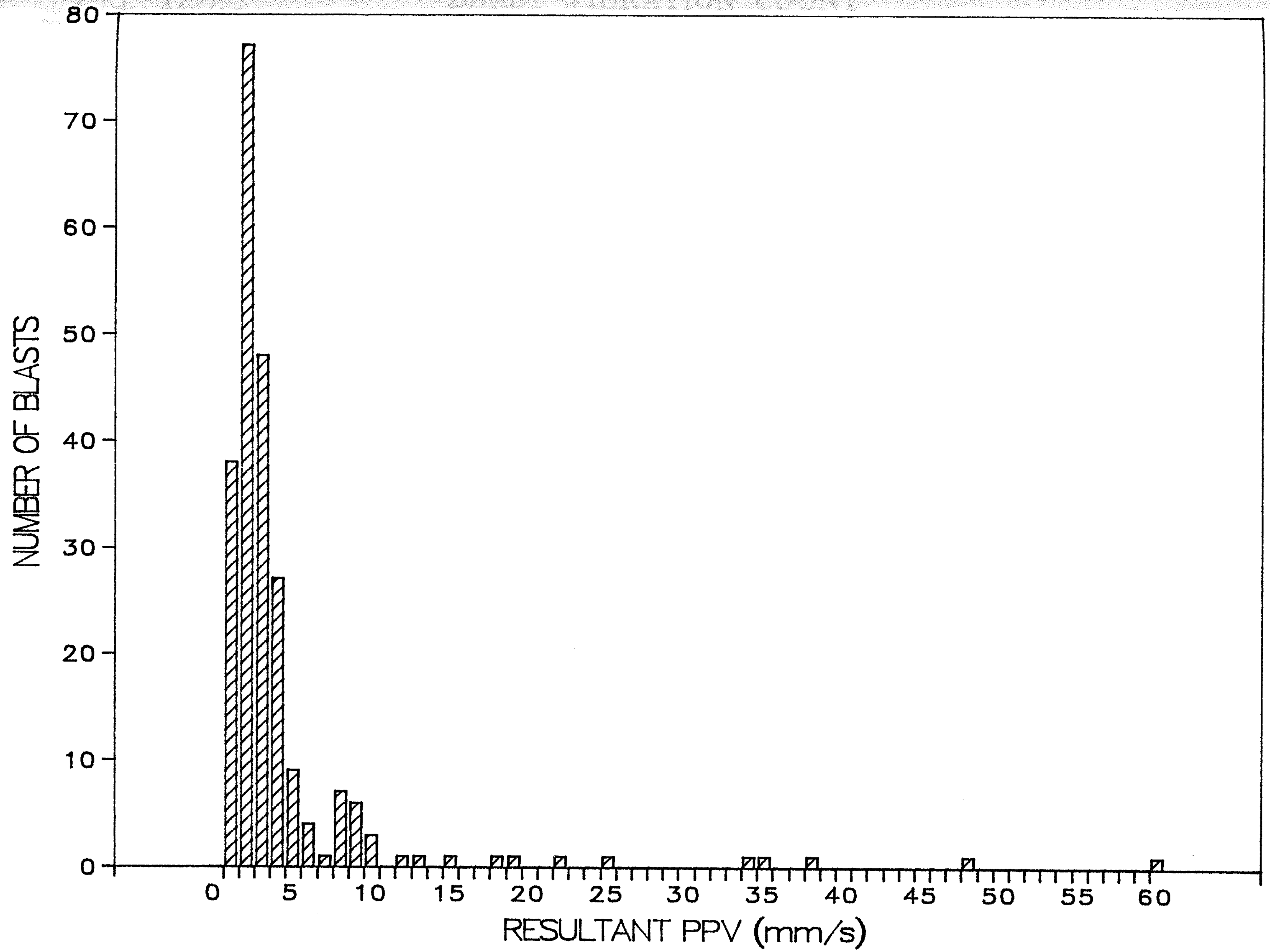
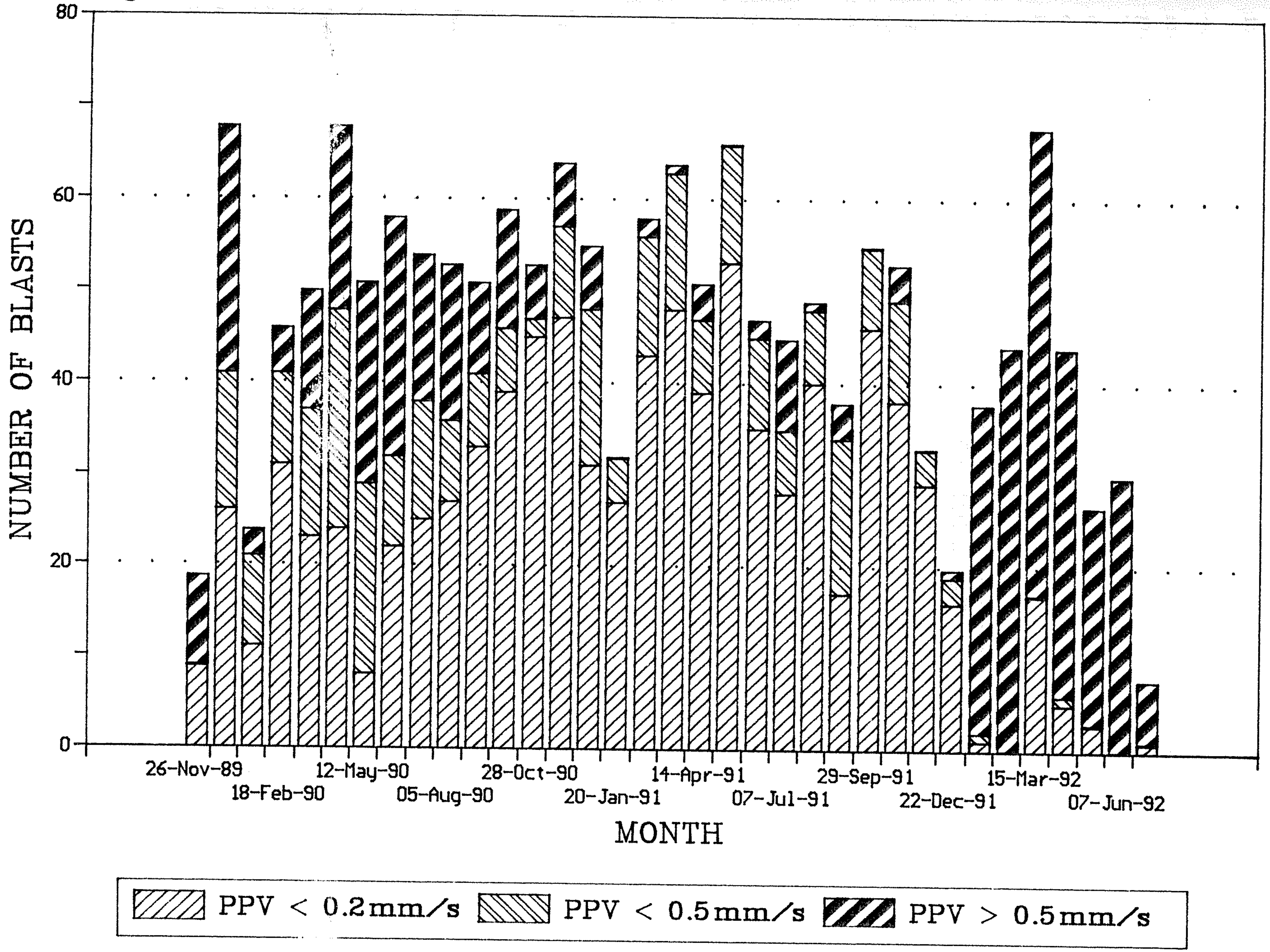


Fig. II.4.3 BLAST VIBRATION COUNT



blasts close to the property and most PPVs in excess of 0.5mm/s.

There is a considerable amount which could be done with the information collected, but for now there will simply be a short description of the main features of the signals.

The 12 blasts with resultant PPVs greater than 10mm/s in the ground outside the house are shown in Figures B.3 to B.14 and listed in Table II.4.1. They show that there is a great deal of variation in the signals, even though most of the blasts were within 100m. The maximum amplitude lies in a different orientation from blast to blast. Although the dominant frequency generally lies between 8 and 25Hz, it does vary from channel to channel and blast to blast. These variations are likely to be the result of differing blast locations and blast designs.

BLAST	DATE	TIME	DIST	HOLE	MICW	TOTAL	PPV
1570	2/4/92	12:13	57.0	39	32.2	772.5	24.1
1571	2/4/92	15:39	58.5	24	32.3	615.3	59.9
1594	25/4/92	10:00	102.5	32	32.3	725.9	11.7
1595	27/4/92	12:01	84.7	40	32.3	995.3	17.3
1596	28/4/92	15:02	107.8	39	32.3	978.9	21.7
1597	29/4/92	11:59	85.0	40	32.3	995.3	18.7
1601	1/5/92	10:00	66.6	13	32.3	337.7	12.5
1604	5/5/92	15:42	25.0	30	32.3	763.5	34.7
1607	7/5/92	11:57	41.0	23	32.3	490.1	33.5
1609	8/5/92	11:02	9.4	28	32.3	821.4	47.8
1621	19/5/92	10:00	96.9	33	32.3	991.7	14.3
1646	9/6/92	12:43	38.5	20	32.3	645.0	37.4

Table II.4.1 Blasts with resultant PPV greater than 10mm/s

Unfortunately, not all the blast coordinates were correct so some of the distances in the table may be misleading.

II.4.2.2 Other Monitoring Locations

Vibration data was also being recorded on the other monitoring units. Unfortunately by the end of the project the monitoring system recording the accelerometers (both the foundation and structural set) had become unreliable and only a small amount of data was recorded. The roving triaxial transducer set was upstairs on the floor in Room B between Walls 2 and 3 until 27/4/92, and then it was repositioned outside at the South-West corner of the house. Again, the monitoring system recording this data did not function fully all the time, and some data was lost.

II.5. CRACK GROWTH

The monitoring of crack growth was the most important part of the project and the results of every survey have been plotted in the 4-weekly reports. All this data has been summarised in Appendix C. Figures C.1 to C28 show the crack development on each wall throughout the project. The first series of diagrams (Figs. C1 to C 14) show the initial cracking in the house and the growth in each of the four 6-month periods in Phase 1. The second set give the crack growth in Phase 2 (Figs. C15 to C28). Tables C.29 and C.30 summarise all this information and the data from the 4-weekly surveys will be discussed first.

II.5.1 FOUR-WEEKLY SURVEYS (PHASE 1)

The surveys which were carried out at 4-weekly intervals give a good overview of the development of the cracks in the two rooms being monitored. Seasonal trends can be identified, as well as effects caused by the approach of the workings. What it does not allow is the relating of specific crack developments to specific events. To facilitate this, pre- and post-blast surveys were carried out during Phase 2 and the results are discussed separately in Chapter II.5.2.

II.5.1.1 Room A

Every wall in Room A with the exception of Wall A5 (a wall around a window) has at least doubled the amount of cracking during the project (Table C.29). Walls A1, A2 and A3 showed some crack increase during each month. The other walls tended to have short periods of crack growth followed by several months of stability.

The total increase was 41.19m, from 26.54m to 67.73m. There were several months where cracking increased by more than 3 metres. These were May 1990, Dec 1990, and May 1992 with the largest increase at 4.61m during Jan 1991. The only pattern of crack development is that more cracks appear during winter and spring than during summer and autumn.

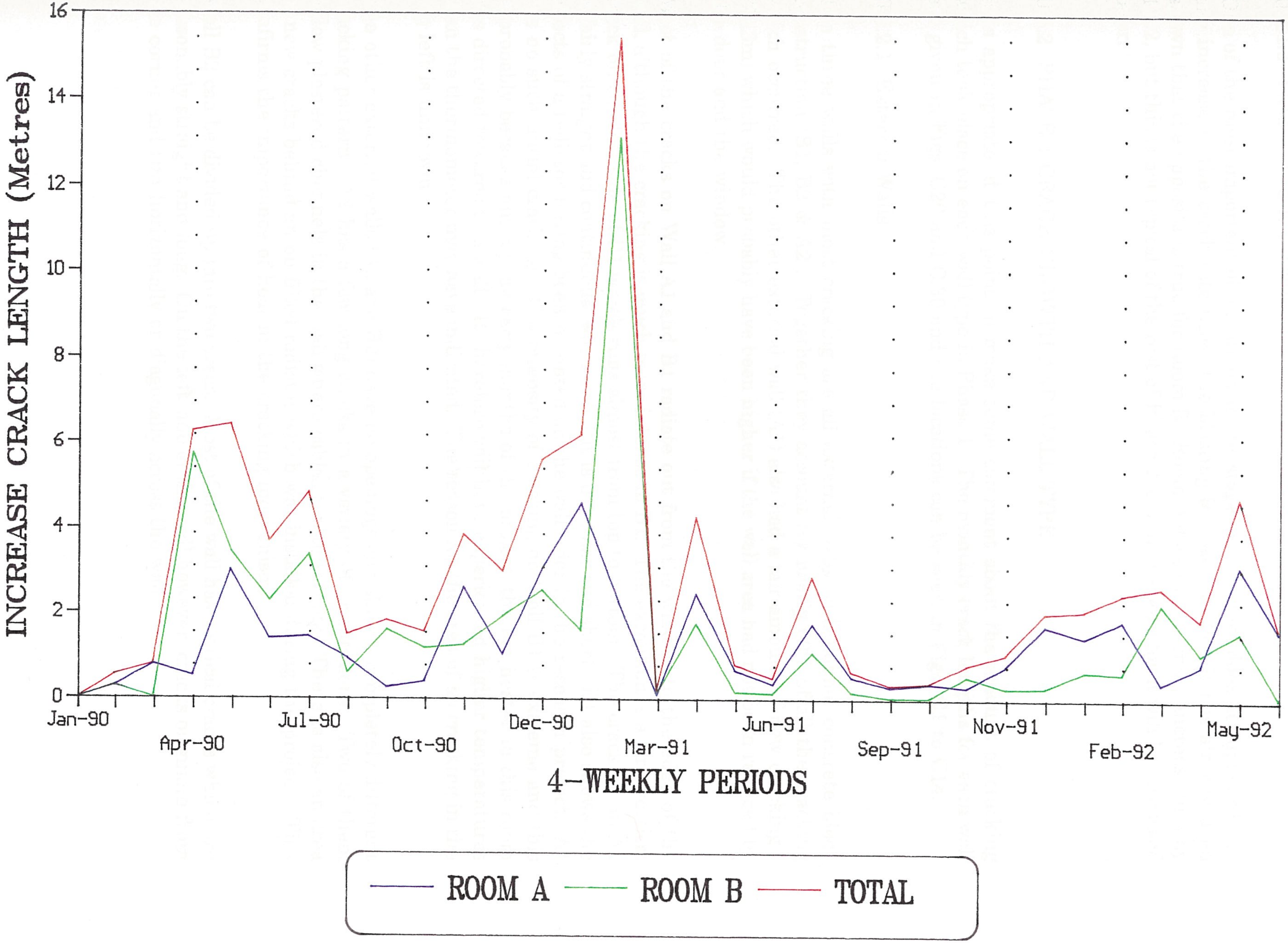
A plot of monthly crack increase is given in Figure II.5.1 which also includes the data for Room B which is considered next.

II.5.1.2 Room B

The total amount of cracking in Room B was greater at 49.58m (Table C.30), with an increase from 34.74m to 84.32m. Most of this took place on the two concrete block walls (B1 and B2) but there was also a significant amount on the old cottage wall (B3). Of the three plasterboard walls, two showed crack increases of 0.73 m and 1.13 m respectively which is considerably less than the concrete block walls but is still significant.

The most important feature of Room B is the amount of cracking which took place in the first 13 months of the project. Nearly 39m (78% of the total) of crack growth took place before March 1991 and after that the crack rate declined dramatically. A similar trend can be observed on Room A, but it is not as pronounced. As with Room A there are four

Fig. II.5.1 MONTHLY CRACK INCREASE



months where the crack increase exceeds 3m but the highest in Feb 1991 of 13.137m is over twice as much cracking as the next highest (5.739m) in Apr 1990.

II.5.1.3 Phase 2 Crack Growth

One of the most important observations at this stage is that there does not appear to be any increase in the crack rate when the blasting is close. In fact it has already been shown that the opposite is true for Room B. Room A does have a sharp increase in May 1992, but this is not typical of the rest of Phase 2 and the reasons for it will be discussed later.

II.5.2 PHASE 1 CRACK GROWTH AND WALL TYPE

It is appropriate at this point to make some comment about the amount of cracking which took place on each wall type in Phase 1. The monthly crack lengths for each wall are given in Figs. C29 and C.30 and the locations can be seen in Figs. C1 to C14.

II.5.2.1 External Walls

The three walls with most cracking are all external walls with double concrete block construction (B1, B2 & A2). Together they account for nearly 60% of all the cracking which occurred. The other external wall (A1) also had a fair amount of new cracking (7.13m) which would probably have been higher if the wall area had not been reduced by the door and the window.

Most of the cracks on Wall A1 and B1 radiate out from the window to the edge of the wall, although the cracking is much more intense in B1. The exception is a long vertical crack on the left side of B1 which runs almost from top to bottom. The cracking on A1 is fairly straight and continuous, while on B1 it is irregular and short. B1 also shows the effects of a radiator having been mounted on the wall prior to the research project. A1 has no such initial cracking. The intensity of cracking on Wall B1 is extreme and this is probably because during the early months of the project, the fan heater in this room was directed towards this wall. It therefore will have experienced higher temperatures than the thermometer may have indicated. The reason for the area of no cracking in the top left is unknown.

The other external walls (A2 and B2) have no openings and show a completely different cracking pattern. A2 has a few long cracks in a variety of orientations. Two of them follow plastered channels in the wall where cables run to sockets. There is also an area of new cracks behind an oil filled radiator which was installed during the project. This confirms the importance of heat in the cracking mechanism.

Wall B2 can be divided up into two areas. Most of the wall has vertical cracks which are reasonably straight and long. On the left side of the wall however, cracks originate from the corner and run horizontally or diagonally across the wall.

II.5.2.2 Old Cottage Walls

The old cottage walls (A3 & B3) also had quite a lot of cracking (total - 16.94m) although it appears to have occurred more intermittently than the external walls. The cracking on Wall A3 is very irregular with many small cracks occurring across the wall. Wall B3 is unusual in that half the plaster has come away from the wall to reveal a concrete layer covering the stone wall. One vertical and one horizontal crack account for most of the cracking, the rest being irregularly placed on the wall.

II.5.2.3 Single Skin Internal Wall

Wall A4 is the only wall of this type in the project and was simply a single concrete block wall with plaster covering. In comparison with the other walls discussed so far this shows very little cracking. There is no spatial pattern, although the cracking does increase towards the end of the project.

II.5.2.4 Plasterboard Walls

All three plasterboard walls are in Room B (B4, B5 & B6) and none of them show very much cracking. Wall B4 had two cracks at the start of the project which extended from the top corners of the door to the edge of the wall and new cracks only occurred around the edge of the wall. B5 had almost no new cracking, but B6 did have some extending in from the left hand wall.

These walls appear to have been most resistant to cracking during Phase 1 which suggests that the stresses in these walls were less than in others and that the materials in them are more able to cope with the stresses involved.

II.5.2.5 Door and Window Edges

All the other walls are simply the inside edges around doors and windows. Most of these have had cracks in them which run across the edge. They are normally straight and run from one side to the other.

II.5.3 PRE- AND POST-BLAST SURVEY RESULTS (PHASE 2)

The Phase 2 results outlined above are given in much greater detail in Table II.5.2 which shows the pre- and post-blast survey information. The pre-blast survey data represents cracks which developed between blasts. They are therefore very unlikely to have been caused by blast vibrations and are the result of some other external factor.

Every post-blast survey in which damage was observed has been included in the Table on the basis that the damage could have been caused by the blast vibration. It is possible that because of the time lag between the blast going off and the post-blast survey being carried out, the damage could have been due to something else. In other words it may have occurred anyway, even without the blast. These new cracks cannot therefore be referred to as blast damage, but post-blast damage which may have been caused by the blast vibrations.

Date	Blast Ref.	Pre-Blast A	Pre-Blast B	Post-Blast A	Post-Blast B	Buried PPV
11/1		0.811	0.593			
15/1		0.502	0.06			
20/1		0.172				
27/1			0.038			
29/1		0.28	0.219			
30/1	1448	0.421	0.054	0.111	0.068	8.68
3/2		0.179	0.007			
4/2		0.051				
5/2			0.018			
8/2		0.053				
10/2		0.023	0.07			
15/2		0.127	0.088			
18/2		0.605	0.049			
21/2		0.066				
24/2		0.044				
28/2		0.123				
29/2			0.18			
8/3			0.534			
9/3			1.201			
10/3			0.304			
14/3			0.043			
18/3		0.141				
25/3		0.079	0.657			
28/3		0.35	0.343			
2/4	1570			0.062		24.1
2/4	1571			0.25	0.018	59.9
8/4		0.056				
13/4		0.042	0.024			
15/4			0.664			
16/4		0.479	0.039			
27/4	1595	0.367	0.043	0.314		17.28
28/4	1596	0.946		0.719	0.058	21.74
5/5	1604	EXTERNAL DAMAGE				34.7
7/5	1607	EXTERNAL DAMAGE				33.5
8/5	1609			0.347	0.79	47.84
15/5		1.017				
19/5	1621			0.435	0.051	14.34
20/5		0.013				
29/5		0.051				
30/5		0.091				
3/6		0.013				
9/6	1646	EXTERNAL DAMAGE				34.4

Table II.5.2 Damage Analysis

It can be seen that there have only been 7 blasts where damage was found in the post-blast surveys. Damage was found elsewhere in the house after three further blasts, but not in the two rooms being monitored. The total amount of damage measured in the two rooms in post-blast surveys is 3.223m. This is therefore the maximum amount of damage which could possibly have been due to blasting. This is out of a total of 13.527m of cracking which was found in Phase 2. The post-blast damage is therefore only a small percentage of the total in Phase 2 (23.6%) and a tiny percentage of the total amount of cracking in the project (3.3%). As will be seen later, even this small amount of post-blast cracking is probably an over estimate of the amount of damage caused by blast vibrations.

A wall by wall breakdown of cracking is given later in Figure II.8.1.

II.5.4 PHASE 2 CRACK GROWTH AND WALL TYPE

The cracks which occurred in Phase 2 (Figs. C.15 to C.28) all follow the same trends as those in Phase 1. Most of the new cracking is in the form of extensions, but even the new cracks fit the general pattern of existing cracks. The main difference between Phase 1 and Phase 2 cracking is that the majority of new cracking has shifted from Room B to Room A. This may be the result of the intensity of cracking already in existence in Room B not allowing any new cracks to develop, plus the fact that there is no longer any heating in the house and so Room B is not getting as warm.

II.5.5 CRACK WIDTHS

In the early stages of the project, crack widths were also being monitored for changes. The cracks were classified using crack indexes and checked in each survey. The time involved in doing this, coupled with the fact that the cracks showed very little measurable change, meant that this part of the survey was abandoned. Instead a quick visual examination was carried out and where a crack had obviously moved from one of the crack indices to another, this was noted and put on the wall plot.

During Phase 1 there were some cracks in the corners of walls and ceilings which did show signs of widening, but non were found in the main body of the walls.

At the end of Phase 2 when the blasting had got very close, there were several instances of cracks opening up quite dramatically, but once again, these were restricted to the corners and ceiling.

II.6. INITIAL CORRELATIONS

Having discussed the data from all the monitored parameters separately, it is now possible to start looking at some of the correlations which exist. The objective all the time is to build an understanding of the various forces acting upon the house and to attempt to isolate those which influence the cracking rate.

Data used here is taken from both Phases. Some correlations are made using the 20 minute data while others use data which has been reduced in some way, e.g. daily average, daily minimum, monthly maximum, etc..

II.6.1 WIND & EXTERNAL TEMPERATURE

It has been noted (Chapter II.2.1) that the wind speed was often higher during the day than it was in the evening. Of course this is the same trend as is found in the external temperature and so on many days there is a positive relationship between wind speed and external temperature. This relationship may be important in regard to minimum temperatures as these only occur when there is calm.

II.6.2 EXTERNAL & INTERNAL TEMPERATURES

Internal temperature was measured in both rooms, although monitoring in Room A did not begin until December 1990. The most obvious point to make is that while the heaters were on in the two rooms the internal temperatures bore absolutely no relation to the external temperatures. It was only while the heaters were off that there was any sort of correlation. The relationship between each room and the external temperature will be considered separately.

II.6.2.1 Room A and External Temperature

When the heaters were off the air temperature in the middle of Room A was reasonably stable. While it did respond to changes in the outside temperature, there was often a lag and a decrement. During the winter months when the external variations in temperature were quite small, the Room A temperature remained fairly constant at about 8 to 10C, showing that it was quite well insulated. In the summer months the Room A temperature showed a stronger positive correlation with external temperature, mainly because the temperature ranges were greater and because of the radiation effects of the sunlight on the external walls.

II.6.2.2 Room B and External Temperature

This relationship is really in two parts. In Phase 1 a small window was left open which meant that the air temperature in Room B responded very quickly to changes in the external temperature. The range in Room B was much greater than in Room A as the maxima were higher and the minima were lower.

During Phase 2 the window was closed and the ventilation was reduced. While the temperatures were lower and not as stable as Room A the 20 minute plots are quite similar. The daily plots (Figs. A.5 and A.7) actually show that for the last three months of the project the daily range in Room B is less than that in Room A.

II.6.3 RAIN & WATER TABLE

The plot of daily rainfall and water level in the borehole adjacent to the house (Fig. A.10) gives a clear indication of the relationship between the two. When it rains the water level rises sharply and then drops slowly during dry periods. The sharp drop at the end of Phase 2 is obviously not related to the rainfall and will be explained in Chapter II.8.3.

II.6.4 PRECISION LEVELS & INCLINOMETERS

There was no obvious relationship between the precision level survey data and the daily inclinometer data. This is probably because the resolution (or frequency) of the survey data is much lower than the inclinometers and the changes throughout Phase 1 appear almost random.

II.6.5 INCLINOMETERS & EXTERNAL TEMPERATURE

The daily means for these variables are plotted in Figure A.11. The external temperature has been chosen because it is felt that if the stability of the house is affected by temperature, it is likely to be a whole house effect rather than localised to one particular room.

The E-W inclinometer remains fairly constant throughout the project and shows no correlation with temperature. The inclinometer aligned N-S does indicate some correlation, but it varies from place to place. There is no doubt that the N-S maxima in January and December 1991 correspond to the temperature minima. Indeed, there is a strong inverse correlation right through from December 1990 to March 1992. Outside this period, however, the relationship appears to be a positive one. If it is assumed that the inclinometer data is correct then the only possible explanation is that the effects of temperature made the house tilt very slightly in different ways during the project. This may have been caused by changes in the underlying stability which influenced the house movement during periods of expansion and contraction. The fact that no correlation is found in the E-W data suggests that either that the inclinometer was malfunctioning or that all the tilting took place in the N-S plane alone. In either case the amount of variation is so small (fractions of degrees) that the movement is unlikely to have had any effect on cracking, until perhaps the last month. As with the water table, it shows a sharp change and this will also be considered Chapter II.8.3.

II.6.6 CRACK WIDTH & TEMPERATURE

The crack response to temperature is considered separately for the period when the internal heating is on and when it is off.

II.6.6.1 Heaters Off

The most obvious observation from both the 20 minute and the daily average data is the strong inverse relationship between temperature and crack width. This is shown particularly well in the external temperature and crack data in Figure II.6.1 and agrees with previous work (Ref 8).

II.6.6.1.1 External Temperature and Crack

The inverse correlation is due to the thermal expansion and contraction of the building materials as the temperature falls and rises. The crack being considered is the major structural crack where the extension joins the original house. The temperature being measured is external air temperature so there is a lag between that and the wall temperature which is the parameter the crack will actually be responding to. The lag on the west wall crack was found by cross-correlation techniques to be 1 hour (to the nearest 20 minutes). This may be greater than on the east wall which has more sun on it so the wall temperature will change more rapidly.

Various types of regression were used to look at the correlations. It was found that a second order polynomial regression showed only a slight improvement on a standard linear regression. However a larger improvement was made when the time lag was accounted for by shifting the time data 3 units (1 hour) forward.

II.6.6.1.2 Internal Temperature and Crack

The internal temperature and B4 crack width in Figure II.6.1 also shows a good inverse relationship. The heater is on between 6.00 and 9.00 and again between 18.00 and 22.00 and the effects are clearly visible. Again, it is the air temperature which is shown here, but now the cracks are responding very quickly to the changes in temperature. This suggests the plaster temperature follows the air temperature very closely. This is because the heater being used is a fan heater and will cause the hot air to circulate over the walls and transfer heat rapidly.

The relationship between internal temperature and the crack width on Wall B1 is more complex. The crack looks like a structural crack associated with stresses around the window and the wall is an external wall. The plot gives the impression that there is a positive relationship between crack width and temperature but this can be explained by considering how the internal temperature varies.

With no internal heating the temperature in Room B must be a function of the external temperature and heat transfer from outside to in. This heat transfer by conduction through the wall and ventilation through the window means that the internal temperature lags behind the external and has a decrement factor which will be reflected in the crack widths (Ref 8). The lag and decrement due to conduction, of a building similar to the one here, has been calculated (Ref 9) to be approximately a 10 hour lag and

Fig. II.6.1

WEEKLY CRACK WIDTHS AND TEMPERATURES

- NO HEATING -

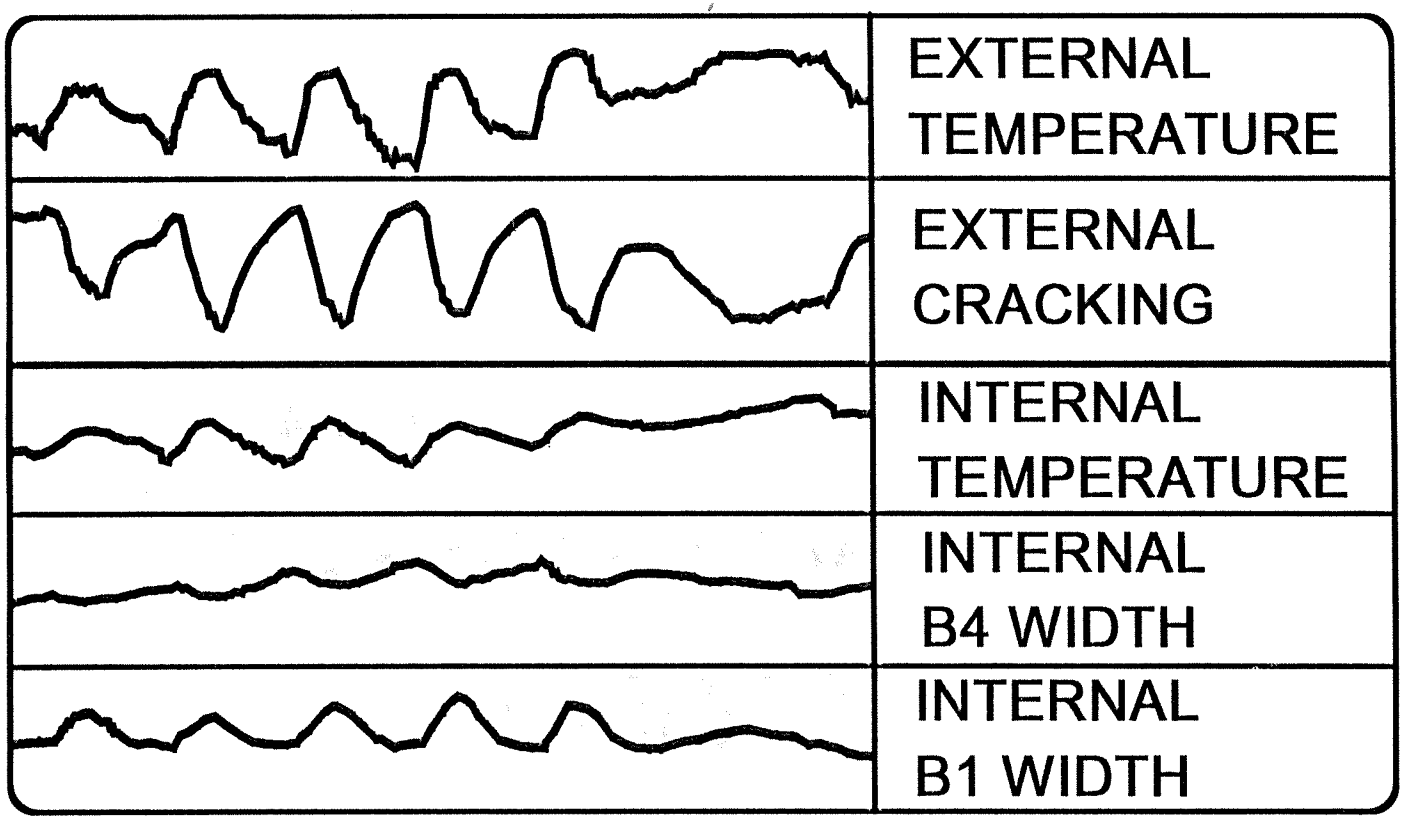
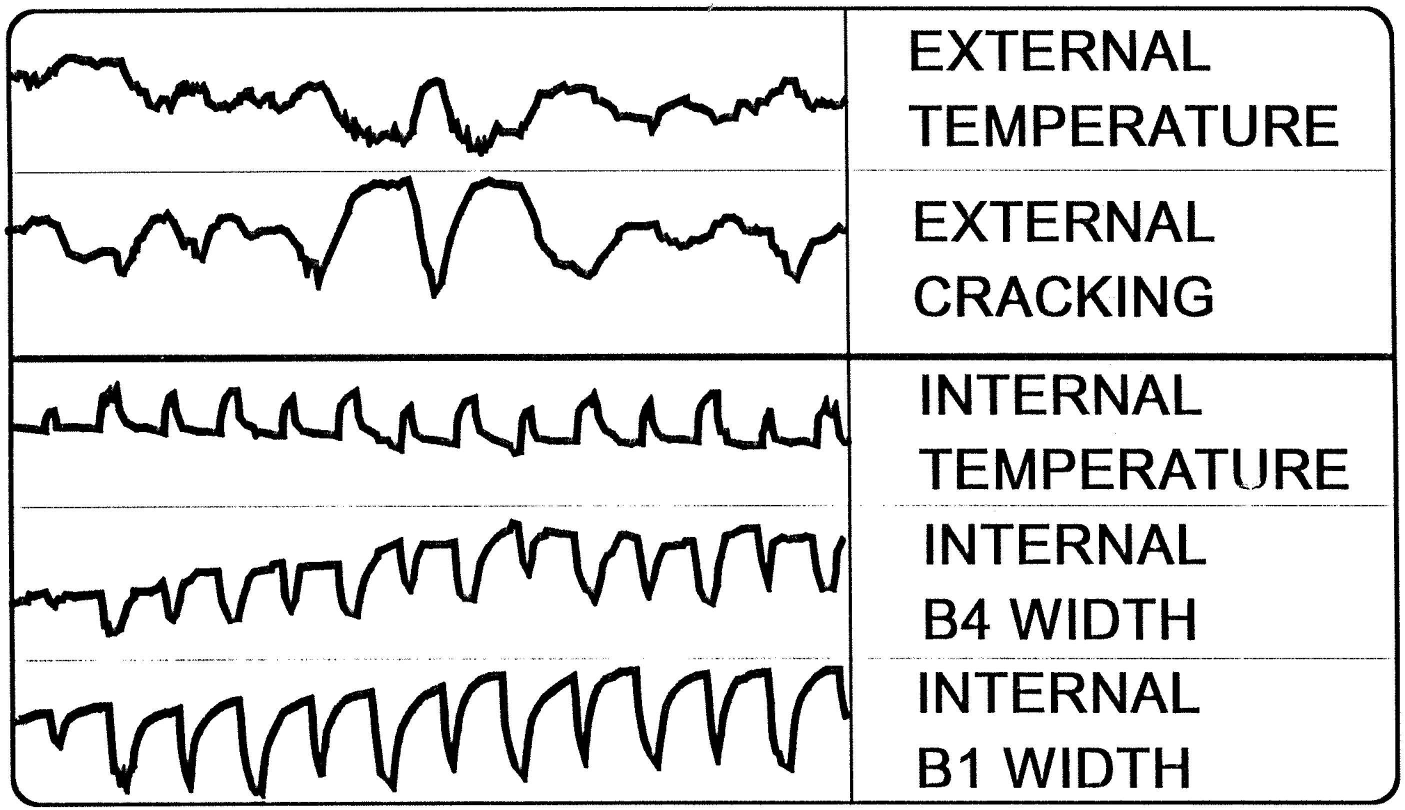


Fig. II.6.2

WEEKLY CRACK WIDTHS AND TEMPERATURES

- HEATING ON TWICE DAILY -



a 0.1 decrement factor. Ventilation will affect this and in fact the internal air temperature follows the external temperature quite closely. However the plaster temperature will be some function of the internal and external temperatures and is likely to lag behind both of these. When there is no heating the B1 crack width therefore reflects the lag in plaster temperature. This apparent positive correlation between temperature and crack width arises because the lag is of the same order as the diurnal variation.

II.6.6.2 Heaters On

A plot of one weeks data where the heaters were switched on is shown in Figure II.6.2. Of course the heating has made no difference to the inverse correlation between external temperature and crack width, but the character of the internal crack widths and temperatures are totally different to when the heater was off. Both walls (B4 and B1) show a very strong inverse correlation with temperature because the heater in room B is now the dominant source of heat. The fan heater in Room B distributes the heat around the room very rapidly and so heat transfer to the wall takes place quickly. This means the lag between crack width and temperature is only 20 minutes as opposed to the hour when the heaters were off.

Some multilinear regression analysis was carried out to see if the internal temperature/crack correlation could be improved by adding the external temperature component. One weeks data was selected from Crack 8 LVDT and the regression correlated with internal and external temperature. This did give a slight improvement in the correlation coefficient ($r^2=0.91$ cf $r^2=0.88$) but highlighted the fact that the external component was much less significant than the internal temperature.

II.6.6.3 Non-linear Relationship

Occasionally there are examples of a non-linear relationship between crack width and temperature. In other words the crack widens or narrows in a manner which is not related to the temperature but to some other factor. These may include adjustment in the way cracks respond due to material fatigue, or the cracks reaching the limit of expansion or contraction while the temperature is still changing.

This feature can be observed in different ways and at different times. An example has been mentioned in Chapter II.3.3.2 and is shown here in Figure II.6.3, where four different data sets are defined for the external crack width versus temperature plot. These data sets represent several days of stability followed by a change in temperature with no accompanying change in crack width over a period of a few hours (usually at night).

Elsewhere the changes can be seen to take place on a daily basis. Figure II.6.4 shows six consecutive days where the crack width changes daily in its relationship with temperature. What causes these adjustments is not clear, but it is felt that it is probably an internal function of the way the building materials respond thermodynamically.

Some non-linear crack width affects however are related to external dynamic forces acting upon the house and these are considered in the next chapter.

Fig. II.6.3 EXTERNAL DATA FOR 3/9/90 TO 30/9/90

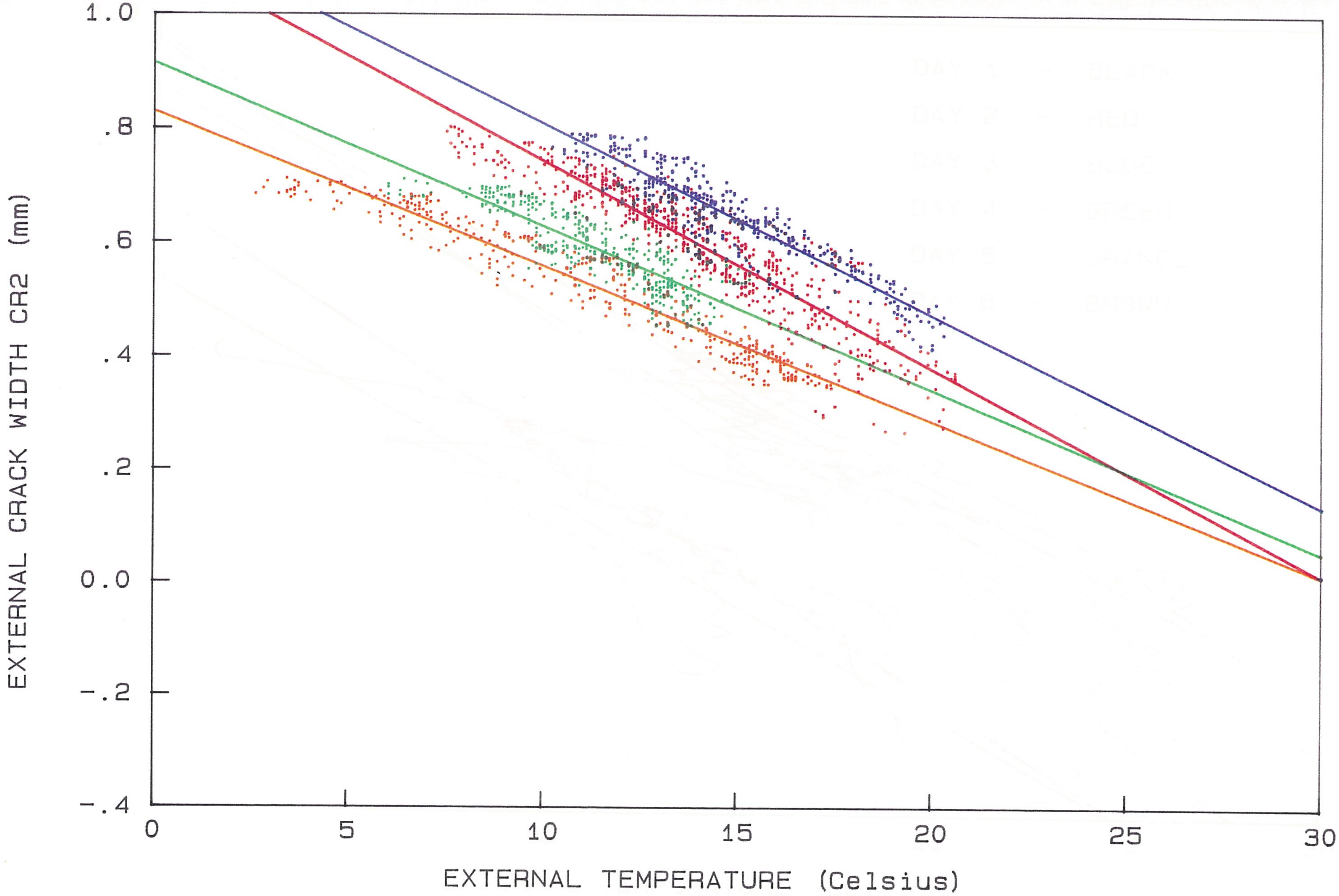
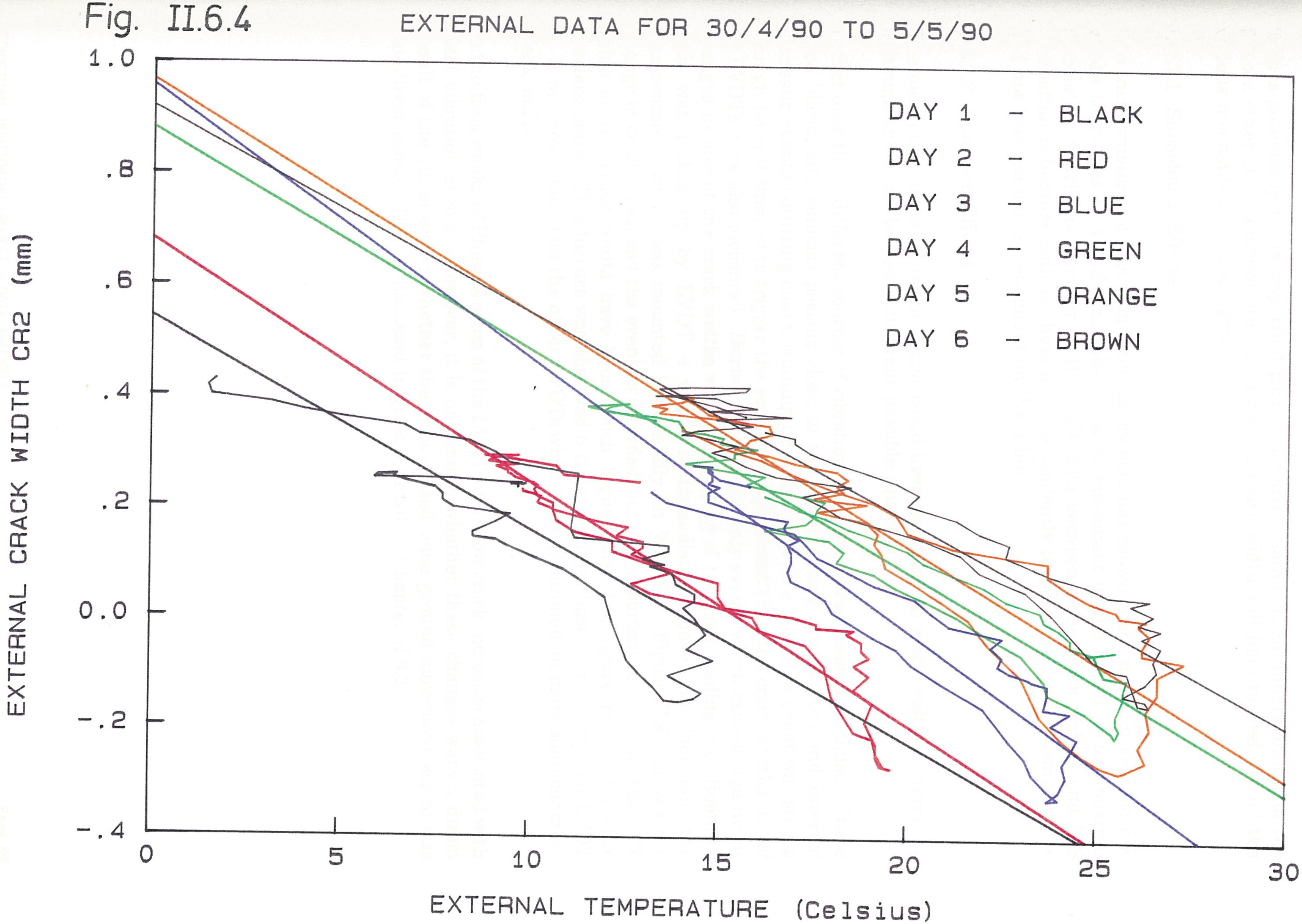


Fig. II.6.4


EXTERNAL DATA FOR 30/4/90 TO 5/5/90
1.0
.8
.6
.4
.2
0.0
-.2
-.4
EXTERNAL CRACK WIDTH CR2 (mm)
0
5
10
15
20
25
30
EXTERNAL TEMPERATURE (Celsius)
DAY 1 - BLACK
DAY 2 - RED
DAY 3 - BLUE
DAY 4 - GREEN
DAY 5 - ORANGE
DAY 6 - BROWN

II.6.7 EXTERNAL FACTORS AFFECTING CRACK WIDTH

This is potentially a very important part of the investigation as an understanding of the factors other than temperature which control crack width will help to understand the various mechanisms of crack growth.

II.6.7.1 Subsidence Effects

The inclinometer and precision level survey data has shown that except for the last few weeks there was no significant subsidence or movement in the house. The apparent correlation which does appear in the daily data between some crack widths and N-S inclination is because both of these are independently inversely related to temperature and not because one is dependent on the other.

II.6.7.2 Vibration Effects

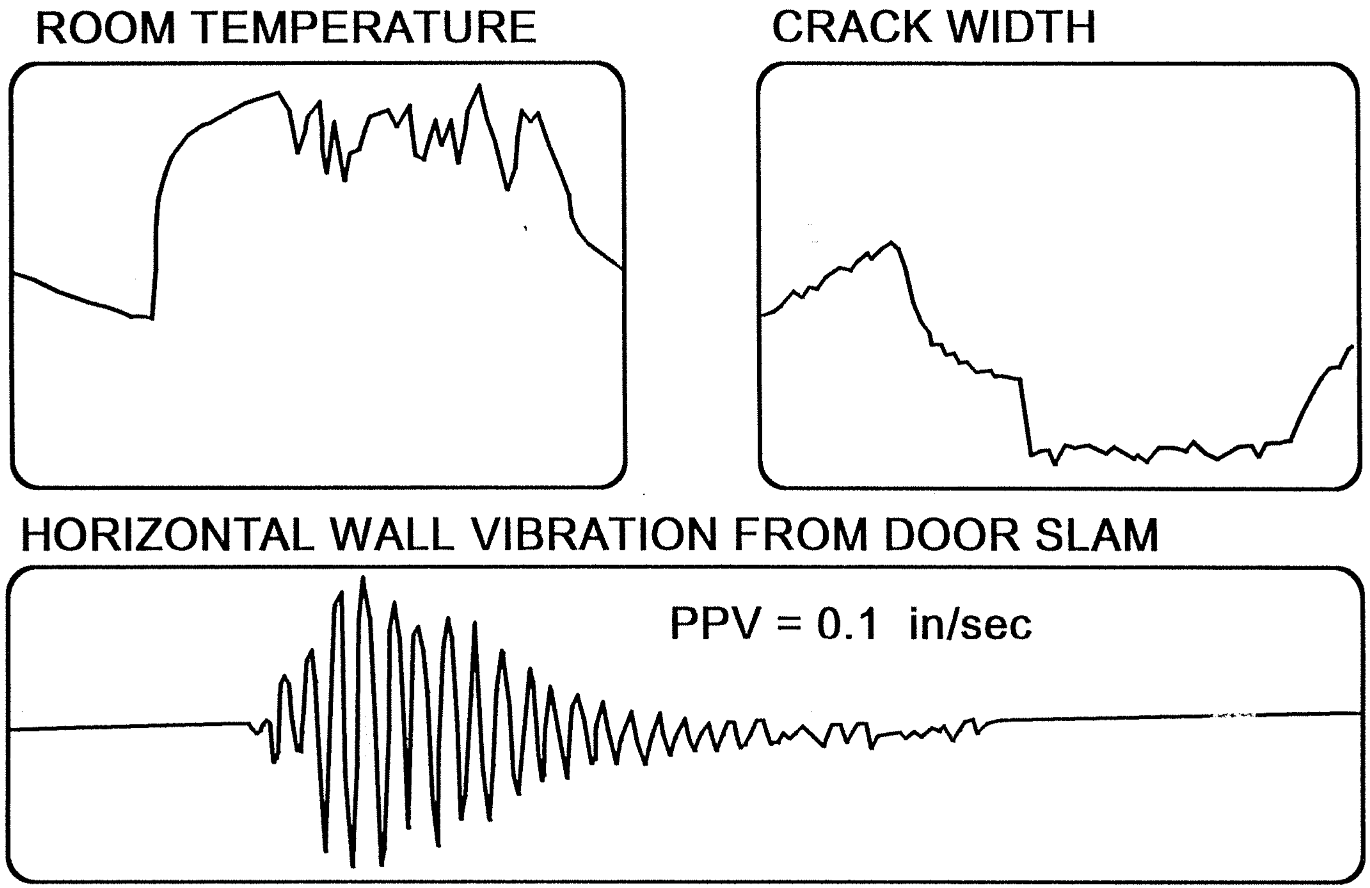
The only other external factor which could have an effect on crack width is vibration, although there can be many different possible sources.

In fact only three different sources of vibration were monitored inside the house. These were blasts, site vehicles passing close to the house (dump trucks etc.) and internal domestic events (shutting doors, running up stairs etc.). If a vibration event was strong enough (over 0.3mm/s) to trigger the recording equipment then the crack widths for all 12 LVDTs were also measured. During Phase 1 the only events which caused significant changes in any of the crack widths were the closing of the door leading into Room B. This was picked up by LVDT 4 which is immediately above the door and the accelerometer which was mounted horizontally on Wall B6. Figure II.6.5 shows the change in crack width and the event as recorded, but it is important to note that the PPV value at the crack would have been much higher than the figure recorded at the accelerometer. This feature was observed 6 times during Phase 1 and always on LVDT 4. It was never found on the other LVDTs which were positioned on more solid concrete block walls.

In the final weeks of Phase 2 some of the LVDTs did show crack increases associated with blast vibration events. However, it is not known whether these changes were a direct result of the vibrations or whether the blast caused some ground movement which was the direct cause. This is discussed in greater detail in Chapter II.8.3.

Fig. II.6.5

NON BLAST VIBRATION



II.7. CRACK GENERATION IN PHASE 1

The fact that crack surveys were carried out every 4 weeks means that it is not possible to correlate the crack growths to any other parameters without significantly reducing the data set first. This has been carried out for blast and temperature data, but care must be taken in the interpretation. Before undertaking any quantitative analysis some observations will be made on a qualitative basis.

II.7.1 GENERAL OBSERVATIONS

It is important to note that there was over 60 metres of cracking in the two rooms at the beginning of the project. Much of this was in corners or was old cracking which had been partially infilled. The intense cracking already present under the window in Room B (Figure C.8), where a radiator had been mounted, suggests that heat is a significant factor. The installation of a fan heater pointing towards this wall was responsible for many of the new cracks which appeared during the period the heater was on.

The effect of heating was later confirmed when an oil-filled radiator was placed against a portion of Wall B2 which had no cracks visible. Cracks started appearing once the plaster had become more brittle and susceptible to cracking after two months of drying out. This two month lag for Wall B2 is a reflection of the lag for the whole house at the very start of the project when there was very little cracking during the first two months (Fig II.5.1). Unfortunately there is currently no accurate, reliable method of measuring the moisture content of a wall, so although it is thought to be important in crack generation, this has not yet been proven.

II.7.2 CRACK GROWTH CORRELATIONS

Although plaster seems more susceptible to cracking when it is dry, Figure II.5.1 shows that after the first two months of drying out, most cracking occurs during the winter. The reason for this is that although the heaters were on for the first two winters, the daily minimum temperatures in each room are still much lower than in the summer. It has already been shown with regard to the crack widths that the plaster contracts with decreasing temperature, so the resulting stresses are likely to cause the plaster to fail under tension. After the heaters were switched off in July 1990 the rate of cracking was significantly reduced in both rooms. When the heating was switched back on, the amount of cracking gradually increased through the winter, until in February there was an astonishing 13m of new cracking in Room B. It was during this period that the lowest external temperatures were experienced and therefore the room was experiencing very large and rapid temperature variations. Room A had a more stable temperature because of the different type of heater (radiator instead of fan heater) and because there was not the same amount of ventilation. This suggests that cracking may be related to lowest temperature, the temperature range, or a combination.

The almost total lack of any cracking in March '91 was due to the higher temperatures and the fact that the large amount of cracking in February had probably released all the stresses in the walls. In April the cracking went up again as the heating was still on, but then dropped when the heating was off. The heating remained off for the rest of the project and the cracking rate never reached the levels it had previously because the plaster could absorb more moisture. The cracking remained very low throughout the summer and then gradually rose through the winter. The profile for this winter is very different to the previous two when the heaters were on and this again suggests the cracking is a function of how dry the plaster is and the temperature changes.

II.7.3 CRACK GROWTH AND VIBRATION

The distribution of resultant blast vibrations recorded in the ground next to the property in Phase 1 is given in Figure II.4.1. Of the 1,384 blasts on the site, 524 were recorded. Only 35 have been greater than 1 mm/s and the maximum is 1.51mm/s.

Although there are a large number of blast recordings they are all at a very low level. There is no evidence that vibrations have caused the cracks to grow, either in width or in length.

II.8. CRACK GENERATION IN PHASE 2

II.8.1 PHASE 2 DESCRIPTION

Phase 2 of the project commenced in January 1992 as the blasting started to approach the property. The PPV distribution in this phase is shown in Figure II.4.2 and the large vibration events are given in Table II.8.1.

Date	PPV mm/s	Wall	Pre-Blast Damage mm	Post-Blast Damage mm	Extension or New Cracking
30/01	8.7	A1	---	58	
	"	A2	---	32	
	"	A4	421	21	
	"	B1	---	49	
	"	B2	55	---	
	"	B3	---	19	
02/04	24.1	A1	---	62	Ext
02/04	59.9	A3	---	250	New
	"	B2	---	18	Ext
25/04	11.7	No damage			
27/04	17.3	A1	131	229	New
	"	A2	213	---	
	"	A3	23	---	
	"	A4	---	85	New
	"	B1	43	---	
28/04	21.7	A1	77	21	New
	"	A2	108	8	Ext
	"	A3	686	---	
	"	A4	75	690	New
	"	B1	---	19	Ext
	"	B3	---	39	Ext
29/04	18.7	No damage			
01/05	12.5	No damage			
05/05	34.7	External damage			
07/05	33.5	External damage			
08/05	26.1	AB	---	347	New
	"	B2	---	790	New
19/05	14.3	A3	---	435	New
	"	B1	---	10	Ext
	"	B3	---	41	Ext
09/06	37.4	External damage			

Table II.8.1 Large vibration events

Pre-and post-blast surveys commenced as vibrations gradually increased to exceed 2mm/s, reaching 8.7mm/s at the end of January. The survey for this blast revealed a slight crack increase of 18cm, but there was also a large amount of cracking in the pre-blast survey and so it may have occurred even if there had been no blasting. A further 18cm of cracking was picked up in a post-blast survey on 3/2 but the wall it was found on had not been surveyed before the blast so it is not known if it was induced by the blast.

Vibration levels did not get much higher until 2/4 when a blast took place very close to the property and resulted in a resultant PPV of 24.1mm/s (Fig. B.3). This was the first blast over 10mm/s and another one later that day was the largest the house ever experienced at 59.9mm/s (Fig. B.4).

From then until the house was demolished on 10/6 there were a total of 78 blasts, 12 of which were over 10mm/s. These, along with one other which may have caused damage, are shown in Table 2 with the results of the surveys.

It is apparent that there is no simple relationship between resultant PPV values and damage as there is cracking found on the studied walls after blasts of 14.3 and 17.3mm/s but not after 33.5 or 34.7mm/s, although these did cause damage elsewhere in the house (see Chapter II.8.3).

The cracking was a mixture of new cracks and extensions to existing ones with no apparent link between crack type and mode of formation. Table II.8.2 shows how much of the increase was due to non-blasting factors (found in a pre-blast survey) and how much of it could possibly have been caused by blasting (post-blast).

Room A		
	Total amount of cracking (m)	9.34
	Cracking found in post-blast (m)	2.24
	Cracking found in pre-blast (m)	7.10
Room B		
	Total amount of cracking (m)	6.21
	Cracking found in post-blast (m)	0.99
	Cracking found in pre-blast (m)	5.22
Total		
	Days on which cracking occurred	38
	Total amount of cracking (m)	15.55
	Cracking found in post-blast (m)	3.23
	Cracking found in pre-blast (m)	12.32

Table II.8.2 Phase 2 cracking

The amount of cracking by other factors is nearly four times as high as the amount which might have been the result of the vibrations. However, one of the difficulties is that not all cracking found in a post-blast survey is the direct result of the vibrations.

II.8.2 TEMPERATURE CRACKING

It has been shown in Phase 1 that low temperatures have a significant effect on the rate of crack growth. It was suggested that the cracking which occurred after a blast on 30/1/92 of only 8.7mm/s may have been caused by low temperatures rather than the vibration.

The relationship between crack growth and low temperatures is highlighted by Figures II.8.1 and II.8.2 which show the daily crack and temperature data for Phase 2. The days when cracking was observed nearly always coincide with days when the temperature fell sharply. While some cracking was found after the blasts on 30/1, 27/4 and 28/4, there was considerable new cracking found in the pre-blast surveys. It is possible that the cracking found after the blast was caused by low or dropping temperatures and appeared in the two to three hour period between pre- and post-blast surveys. This could account for up to 1.27m of post-blast cracking.

The fact that most of the new cracks found in Phase 2 have identical trends to the Phase 1 cracks suggests they may have the same cause, i.e. temperature.

II.8.3 GROUND HEAVE CRACKING

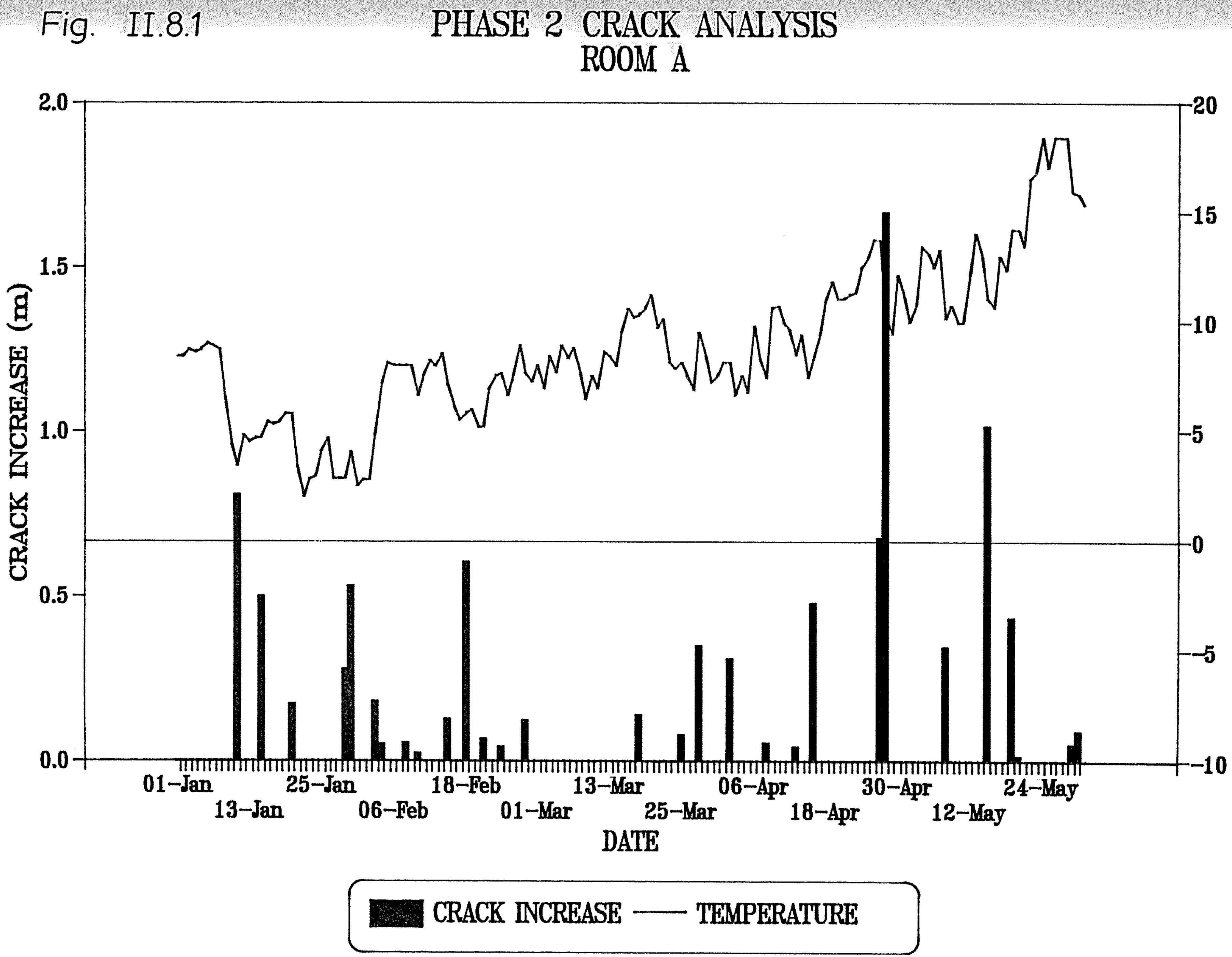
During the final months of the project the ground around the house was being excavated in the advance reduction, leaving it on an isolated pillar. The approach of the advance reduction is marked by the sharp drop in water table as the water escapes from the borehole through the highwall. The building was then susceptible to settling and slippage. The blasts on 5/5, 7/5 and 8/5 were close to the property and resulted in considerable movement. The crack between the cottage and extension widened by 1.5mm and 2mm after the first two and on the 8/5 the crack widened so much that the LVDT reached its stop point. The inclinometers on the extension floor only show a slight change after the blast on 8/5, which suggests it was the cottage rather than the extension which was experiencing the subsidence.

Although only the blast on 8/5 gave rise to damage within the two survey rooms, all three caused damage elsewhere. One of the large downstairs windows facing the blast was cracked. There was definitely no flyrock, but whether it cracked because of structural vibration or because of air overpressure is not clear. Large cracks appeared in the rendering of the older cottage and in the concrete path surrounding the house. A crack also opened up in the floor of Room A in the doorway between the extension and the cottage.

Whether the damage associated with these blasts are the direct result of the vibrations is debateable. The cracks would not have appeared if the blast had not taken place, but the current condition and position of the house must also have had a big influence. It is therefore possible that the damage was not due to the vibrations themselves but to the permanent displacement which took place.

The only occurrence of damage after these blasts (Fig. B.13) must also be viewed with caution as the property was in a very bad state of repair. If the damage caused after 5/5 is due mainly to ground movement rather than shaking then this would account for 1.623m of cracking.

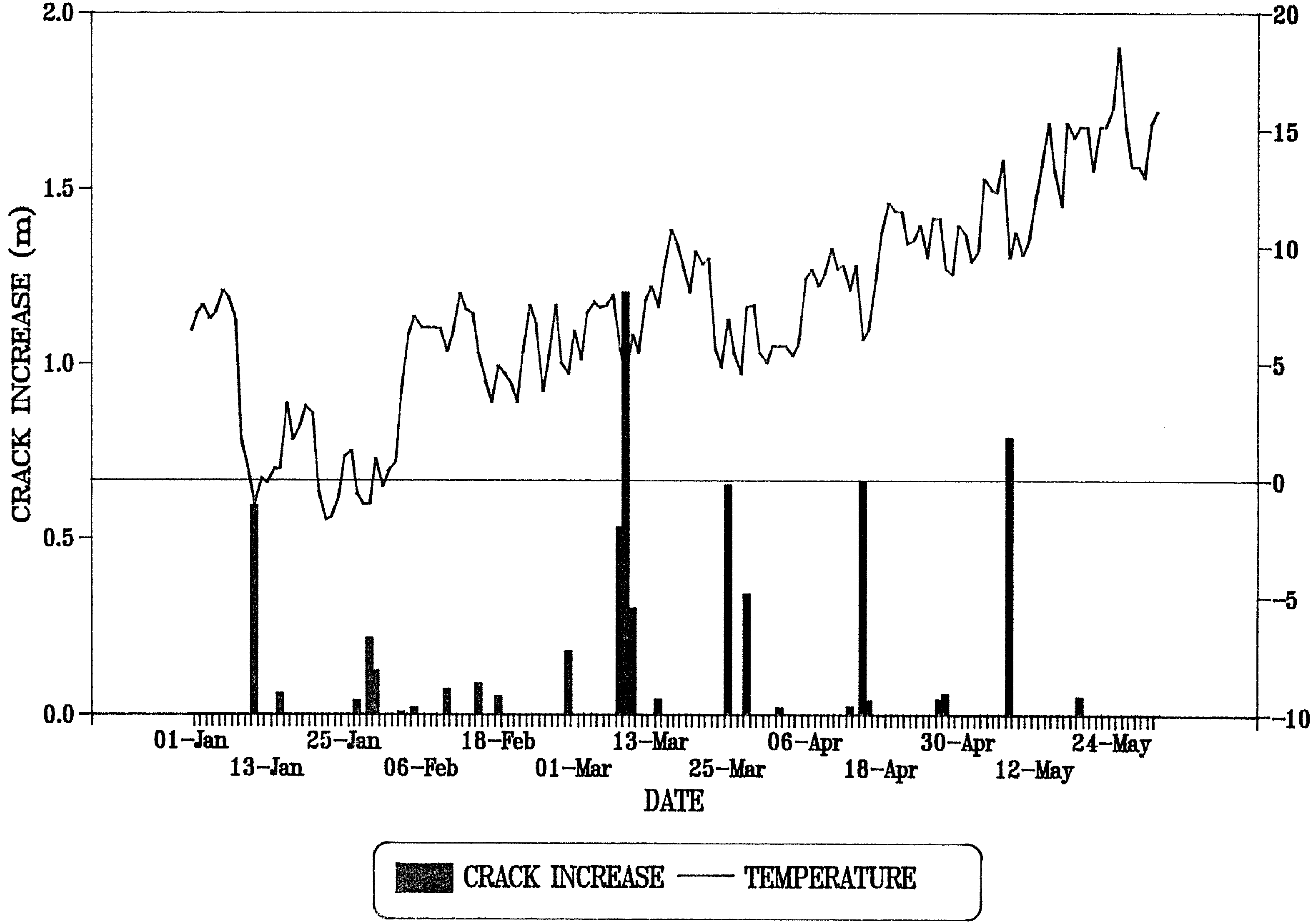
Fig. II.8.1



PHASE 2 CRACK ANALYSIS
ROOM A
2.0
1.5
1.0
0.5
0.0
CRACK INCREASE (m)
20
15
10
5
0
-5
-10
DAILY MIN TEMP (C)
01-Jan
13-Jan
25-Jan
06-Feb
18-Feb
01-Mar
13-Mar
25-Mar
06-Apr
18-Apr
30-Apr
12-May
24-May
DATE
CRACK INCREASE
TEMPERATURE

Fig. II.8.2

PHASE 2 CRACK ANALYSIS
ROOM B



II.8.4 VIBRATION CRACKING

If the alternative causes are responsible for some of the cracking it leaves just 0.33m found in the post-blast surveys which can only be explained by vibration damage. All of this was found after two blasts on 2/4. The first of these was the first large vibration the house experienced (24.1mm/s) and gave rise to 0.062m of crack extensions which could be viewed as less important than new cracks. The second was the largest (59.9mm/s) and gave rise to 0.268m of predominantly new cracking of which 0.25m occurred on one wall. It is possible that more of the 3.23m of cracking found in the post-blast surveys was caused by vibration, but it has been shown that there are other explanations for these cracks.

Table II.8.1 also shows whether the post-blast cracks which were found were extensions or new cracks. Some of the new cracks were branches from existing cracks but run in a completely different direction to the original. It is interesting to note that the extensions are all quite limited in length (up to 62mm), whereas the newly formed cracks are mostly well over 100mm. This suggests that whatever the cause, high stresses in an area of little or no cracking give rise to large failures which can be quite extensive. If the stresses occur around existing cracks, then much of the strain is absorbed by the cracks itself although small extensions are possible.

This implies that the more cracking there is, the less new cracks will appear, as more of the stresses will go into the existing cracks with perhaps some extensions.

II.9. ADDITIONAL EXPERIMENTS

Although this project was primarily concerned with monitoring the development of damage in a domestic building, the large amount of instrumentation which was used also enabled other experiments to be carried out. The two which will be described here concern the comparison of two different makes of hydrophone which were used for monitoring air overpressure, and the use of PPV based transfer functions to predict levels of vibration.

II.9.1 COMPARISON OF HYDROPHONES

Two high quality hydrophones were used to monitor the air overpressure associated with blasting events. Although they were actually monitoring all the time they only recorded when the ground vibration exceeded a preset threshold. The two types were a B&K Type 8101 and a Birchalls Type M/01/TA. Further specifications are given in Chapter I.8.3. Both units were mounted on the flat roof of the extension and pointed vertically upwards. First of all, the data from each unit will be described and then the two will be compared.

II.9.1.1 Bruel & Kjaer

This unit operated for most of the project although there were some problems with the data recorder so only 443 blasts had their overpressure recorded. One of the major problems with air pressure recordings is the effect that wind has on the signal. Even with high quality wind shields, the signal from the blast can very easily be totally obscured by pressure changes due to the wind. It was therefore necessary to visually inspect the signals and determine which were good records of blast induced air overpressure and which were not.

Figure II.9.1 gives the distribution of maximum amplitudes in dB for both the good and the bad signals. The number of signals for each is almost the same (225/218) but the distributions are very different. The mean for the bad signals is much higher than the good (118.1dB cf. 114.2dB) because the wind and blast pressure levels are acting together to produce higher amplitudes than would be produced with blast alone.

There are a significant number of good events with the pressure exceeding 130dB. At this level, even with some wind, the signal from the blast is going to be recognisable, even if it is distorted slightly. The highest reading of 135.9dB was on one of the close in blasts.

II.9.1.2 Birchalls

This unit was only in operation during Phase 2 and captured just 106 events (Fig. II.9.2). Because most of the blasts were fairly close, the majority (79) of the signals were good and the average for these was 120dB (cf. 114.2 for B&K unit). The maximum level on this unit was 136.3dB which was for the closest and highest PPV blast which gave 135.6dB on the B&K unit.

Fig. II.9.1 UNIT 1 AOP

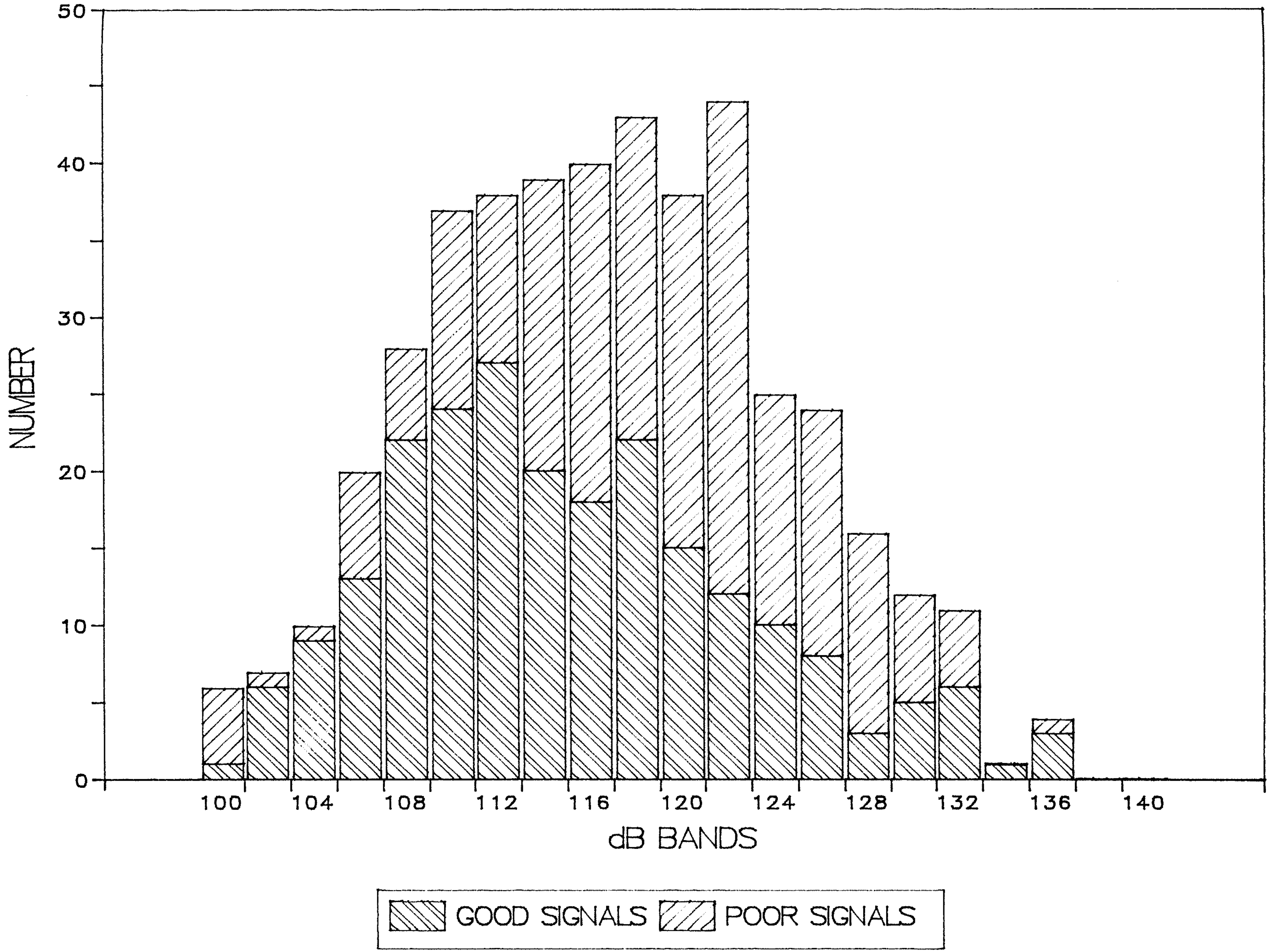
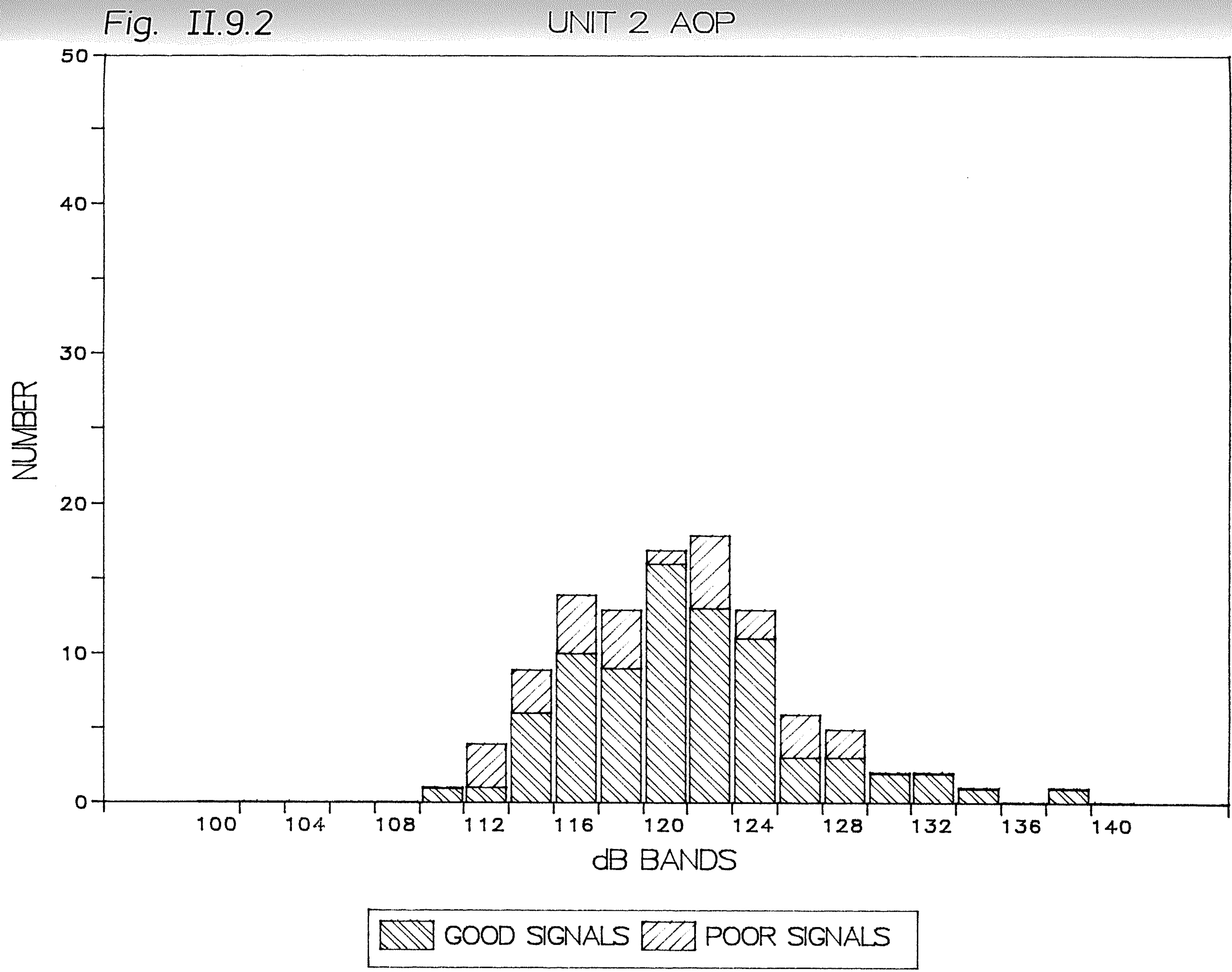


Fig. II.9.2


UNIT 2 AOP
NUMBER
0
10
20
30
40
50
100
104
108
112
116
120
124
128
132
136
140
dB BANDS
GOOD SIGNALS
POOR SIGNALS

II.9.1.3 Comparison of Units

Because the Birchalls unit was only used in Phase 2 there are not a large number of blasts which have had readings recorded at both units. Figure II.9.3 contains all the data and shows that there is a high degree of scatter. If only the pairs of good records from the two units are plotted (Fig. II.9.4), the correlation improves dramatically. This indicates that the two units were giving very similar amplitudes and suggests that either of the units is satisfactory for monitoring air overpressure.

II.9.2 PPV TRANSFER FUNCTIONS

With twelve vibration transducers being used to monitor the movement of the house, there is an ideal opportunity to look at how signals change from one place to another. The ideal method is to look at the frequency spectra and calculate a difference ratio for each frequency. This approach is currently being taken by R. Farnfield and will be the subject of a future paper. For the time being, this report will consider just the peak amplitudes for each signal, and see whether it is possible to reasonably predict from one position to another.

II.9.2.1 Buried to Foundation

These two monitoring locations were very close together. The buried set were three velocity transducers arranged triaxially and buried about two feet down outside the back door. The foundation set were three accelerometers which were mounted to the floor and the sides of the wall corner just above the floor. The accelerometer signals were integrated to find the peak particle velocity.

Figure II.9.5 shows the resultant PPVs for 273 blasts. The reasonable correlation coefficient disguises the fact that there are two subsets within this data. The first is given in Figure II.9.6 where just the blasts with PPVs up to 4mm/s are plotted. The regression line is a very good fit and shows that there is a negative amplification from buried to foundation. This can be explained by the foundation being more rigid than the softer ground outside.

Figure II.9.7 shows the other subset of resultants greater than 4mm/s. Even though there are fewer points and a greater scatter, the regression line is clearly greater than one which indicates an amplification from buried to foundation. It is not known why the transfer function changes at the 4mm/s level, but it may be related to the higher level PPVs being closer blasts and therefore having higher frequency components.

II.9.2.2 Buried to Upstairs Window

Three accelerometers were mounted on the window ledge and the two sides of the wall at the bottom left of the window in Room B. The signals were again integrated and compared with the PPVs compared with those from the buried geophones.

The resultant plot (Fig. II.9.8) shows a high degree of scatter over the fairly short range of PPVs. The individual orientation plots (Figs. II.9.9 to II.9.11) show that most of this is due to the longitudinal vibrations, which also show the greatest amplifications. This

Fig. II.9.3 COMPARISON OF AOP UNITS (ALL)

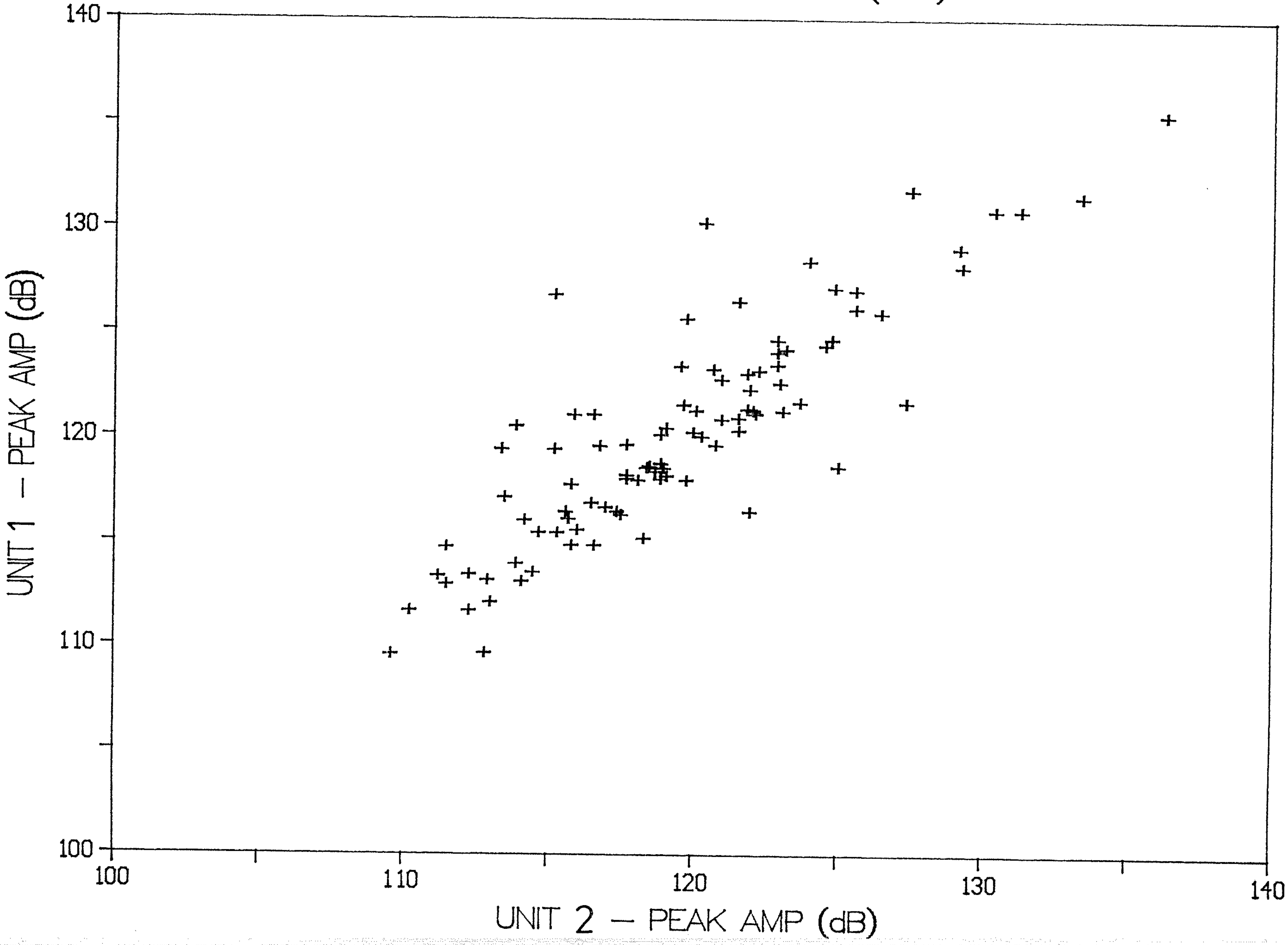


Fig. II.9.4 COMPARISON OF AOP UNITS

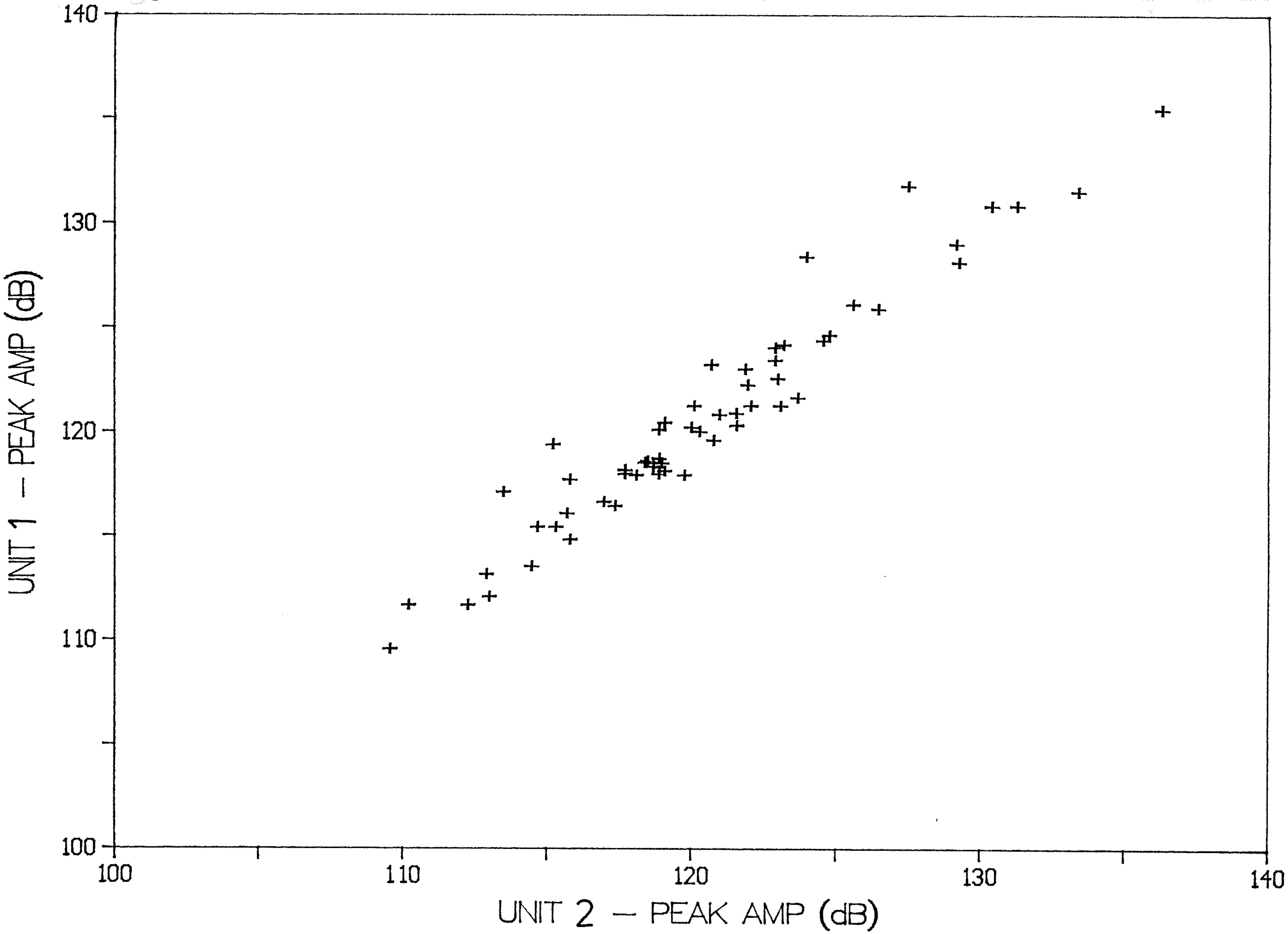


Fig. II.9.5

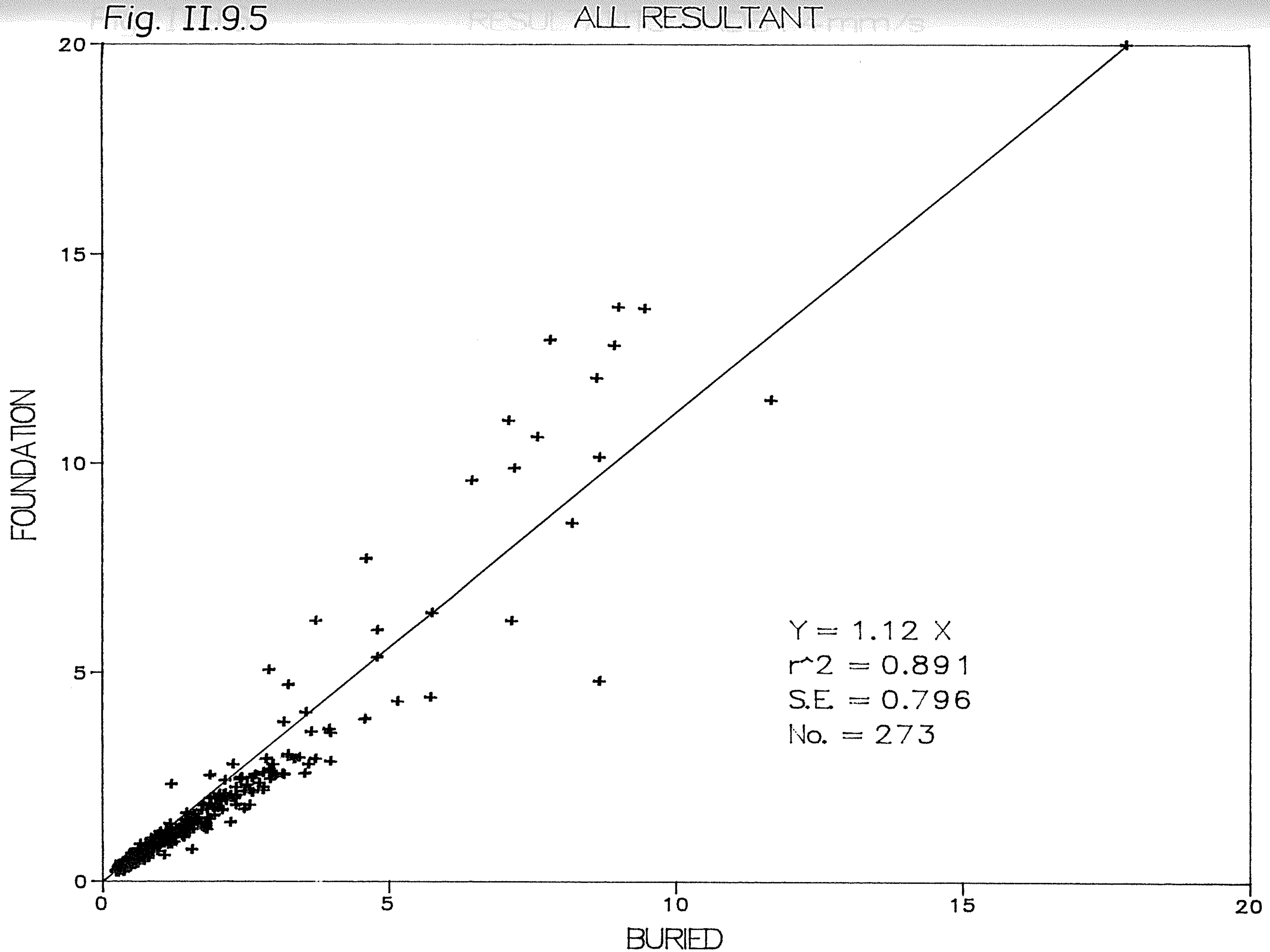

ALL RESULTANT
20
15
10
5
0
FOUNDATION
0
5
10
15
20
BURIED
Y = 1.12 X
r^2 = 0.891
S.E. = 0.796
No. = 273

Fig. II.9.6

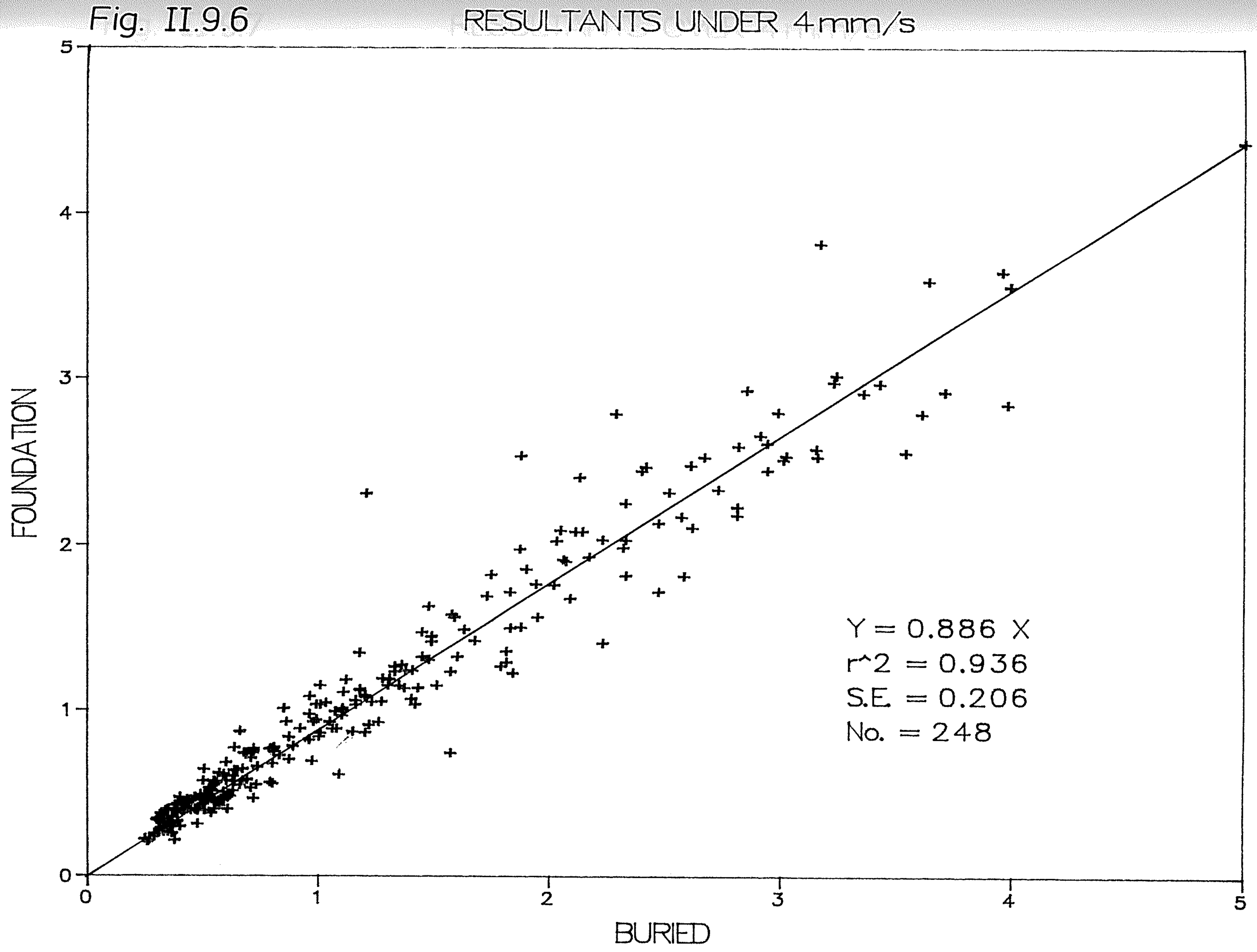

RESULTANTS UNDER 4mm/s
FOUNDATION
BURIED
0
1
2
3
4
5
Y = 0.886 X
r^2 = 0.936
S.E. = 0.206
No. = 248

Fig. II.9.7

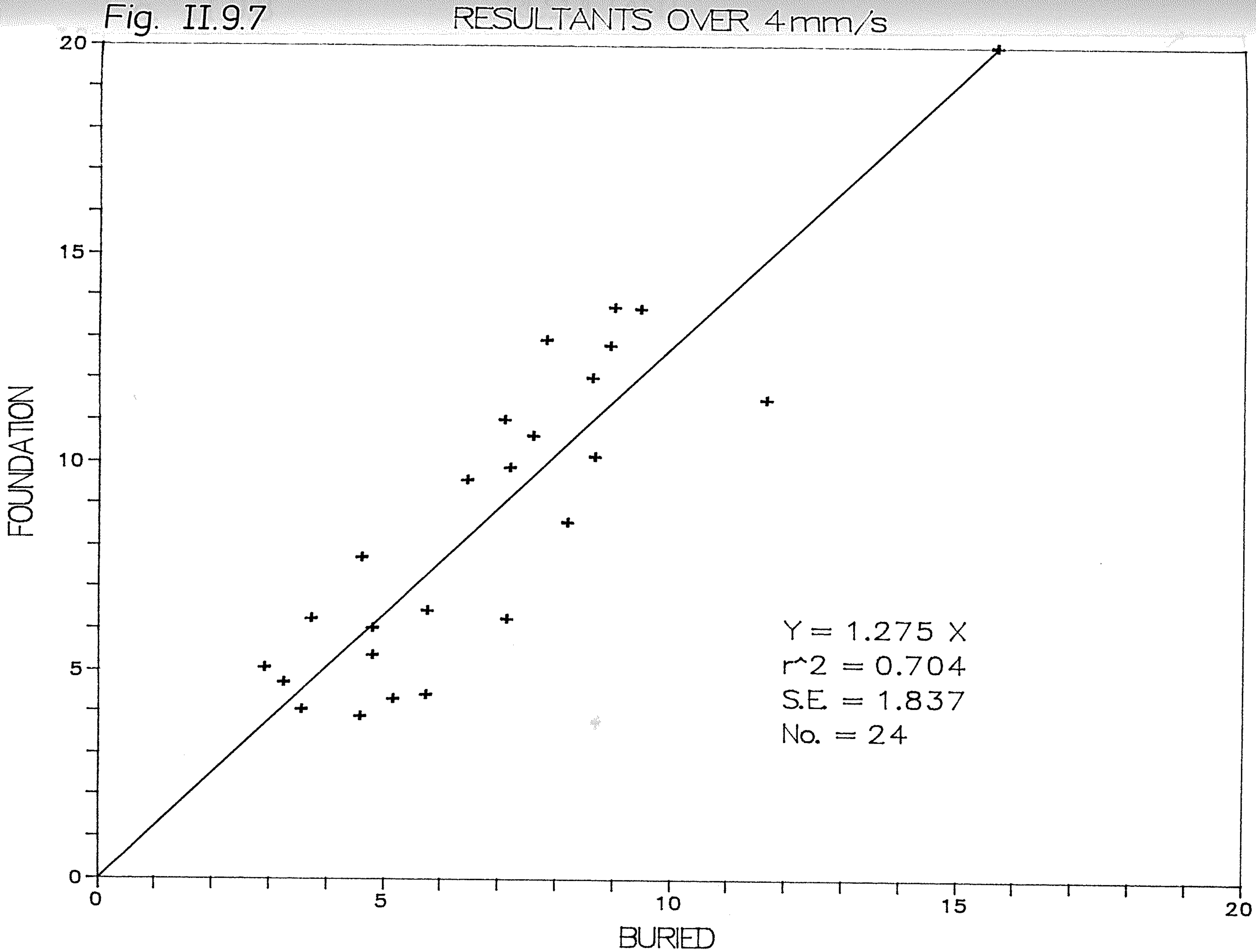

RESULTANTS OVER 4mm/s
FOUNDATION
BURIED
0
5
10
15
20
Y = 1.275 X
r^2 = 0.704
S.E. = 1.837
No. = 24

Fig. II.9.8

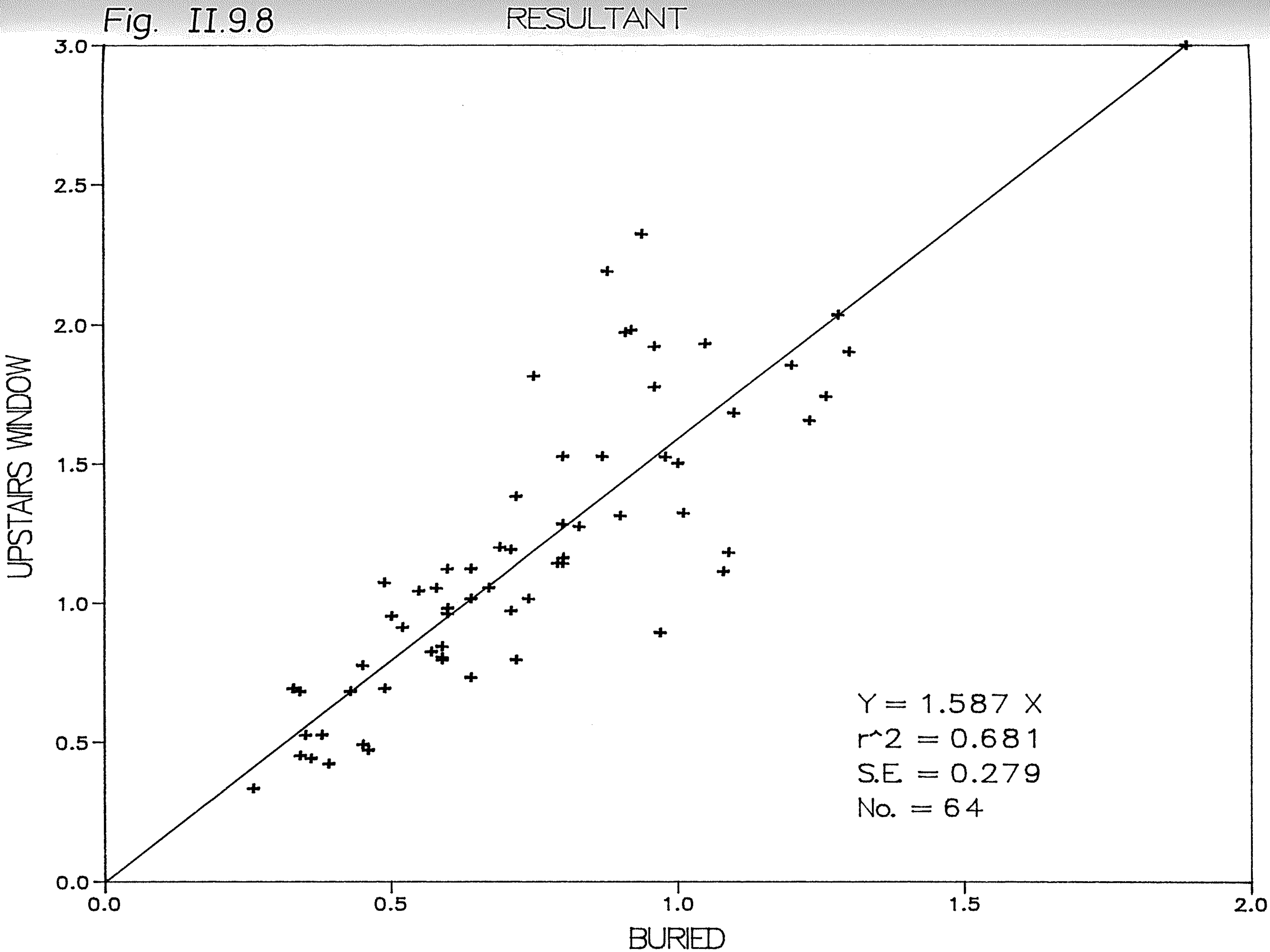
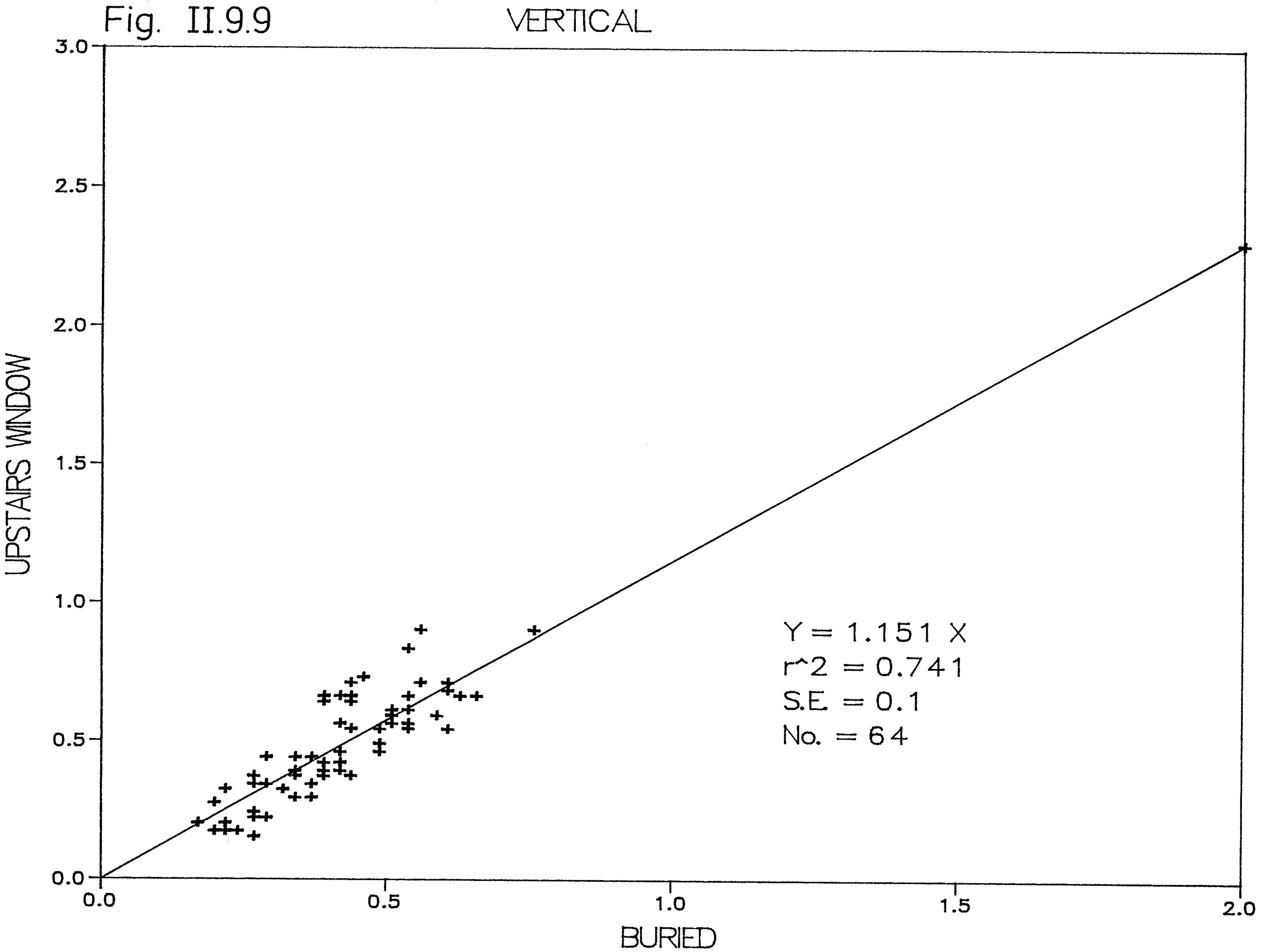

RESULTANT
UPSTAIRS WINDOW
BURIED
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Y = 1.587 X
r^2 = 0.681
S.E = 0.279
No. = 64

Fig. II.9.9



VERTICAL
UPSTAIRS WINDOW
BURIED
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
Y = 1.151 X
r^2 = 0.741
S.E. = 0.1
No. = 64

Fig. II.9.10

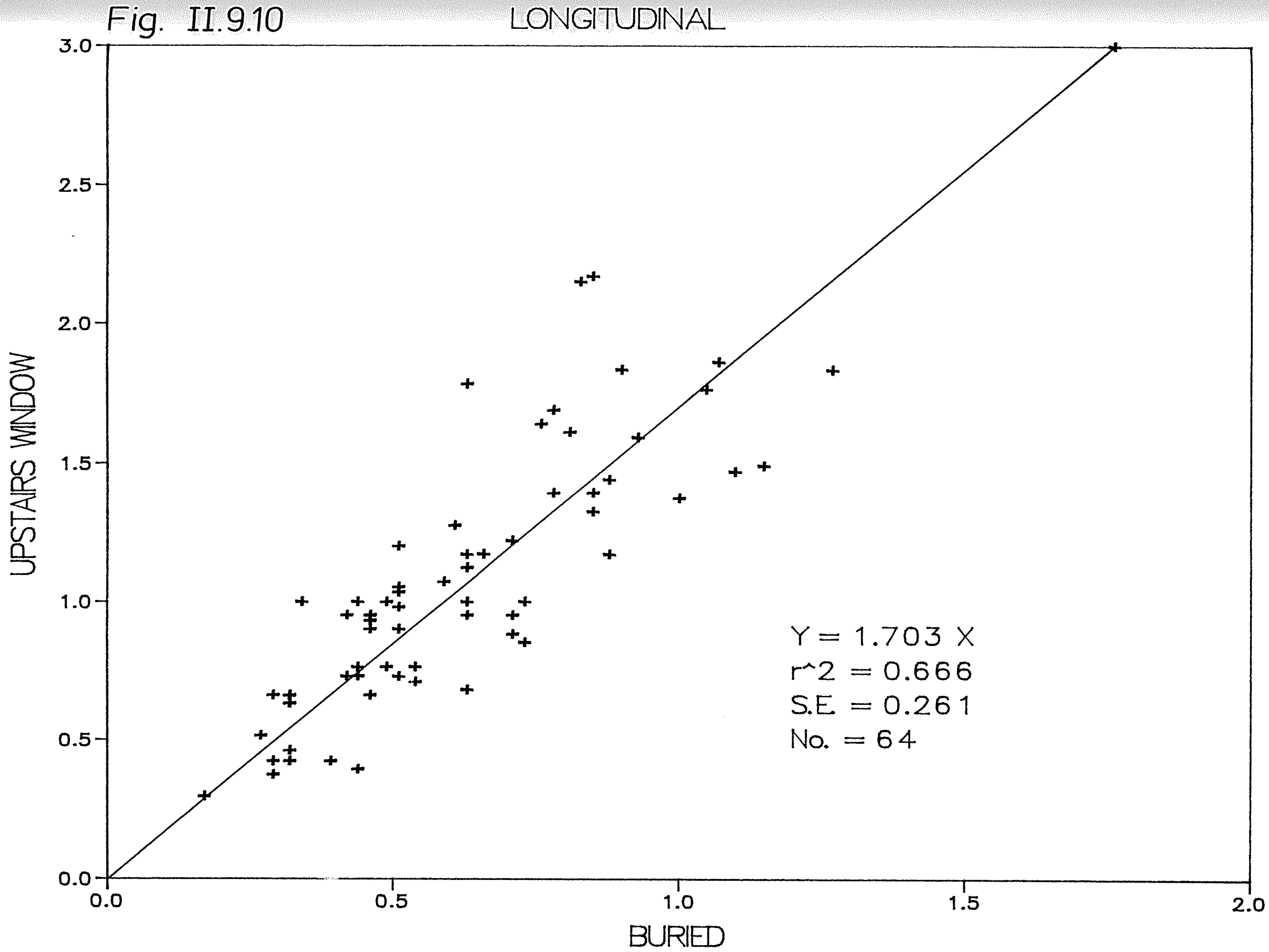
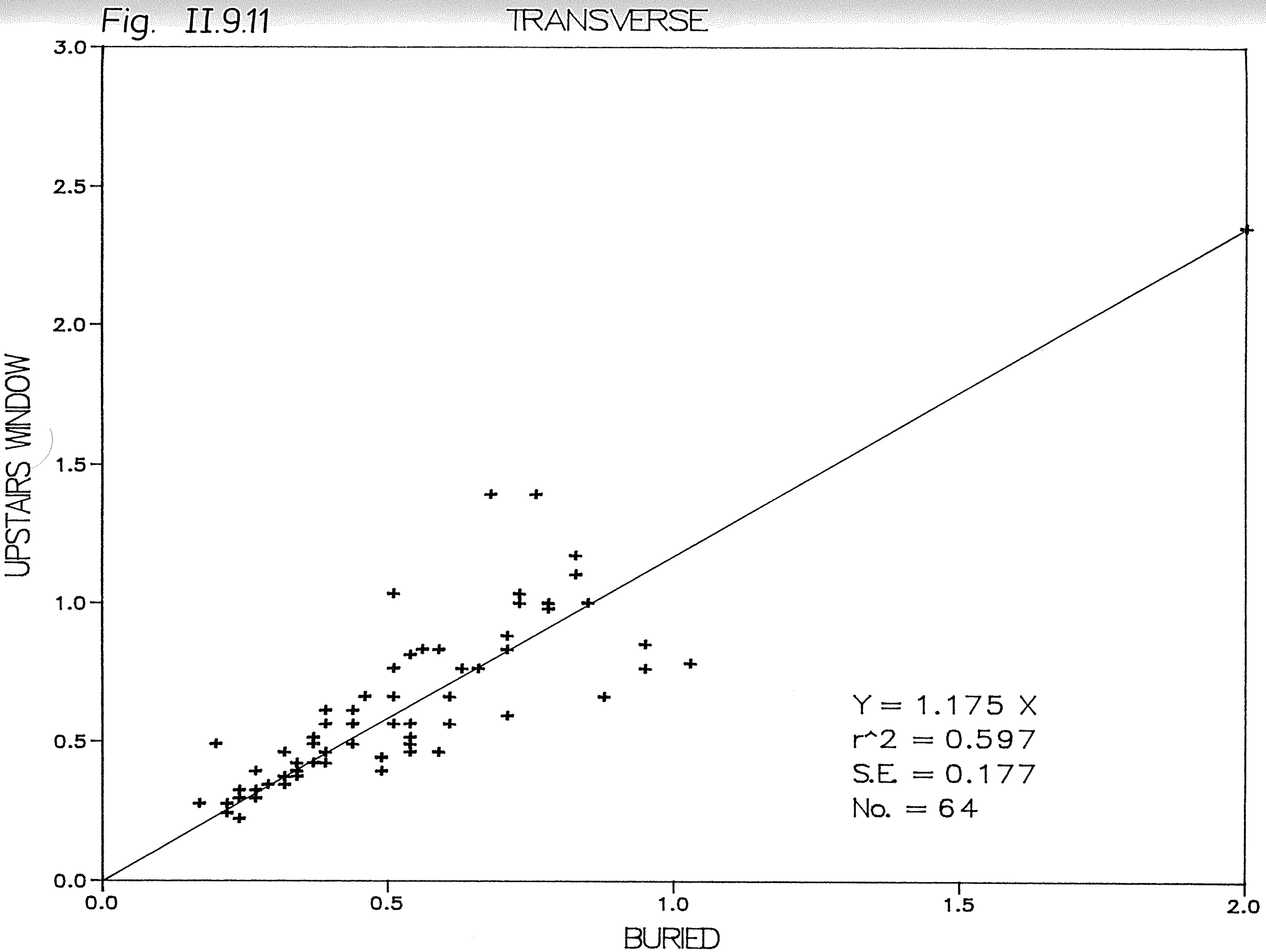

LONGITUDINAL
UPSTAIRS WINDOW
BURIED
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
Y = 1.703 X
r^2 = 0.666
S.E = 0.261
No. = 64

Fig. II.9.11


TRANSVERSE
UPSTAIRS WINDOW
BURIED
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
Y = 1.175 X
r^2 = 0.597
S.E. = 0.177
No. = 64

is not surprising as it is the longitudinal transducers which are monitoring the vibrations perpendicular to the wall and it is this direction which has the greatest freedom of movement. The other two directions (vertical and transverse) are both in the same plane as the wall and so are restrained and show only a slight amplification.

II.9.2.3 Buried to Upstairs Walls

Three upstairs walls were monitored in their mid-spans using accelerometers and compared with the same orientation from the buried.

The PPV transfer function from buried to Wall B2 is shown in Figure II.9.12. The wall is an external concrete block wall. An amplification factor of 2.5 exists and correlation coefficient and standard error are good, indicating high confidence in predictions. The regression is expected to go through the origin as if the there is no signal in the ground outside there will be no related signal in the wall. This is confirmed when the intercept is calculated to be only 0.281 and the regression line for this shows very little change in gradient or correlation to the regression calculated for zero intercept.

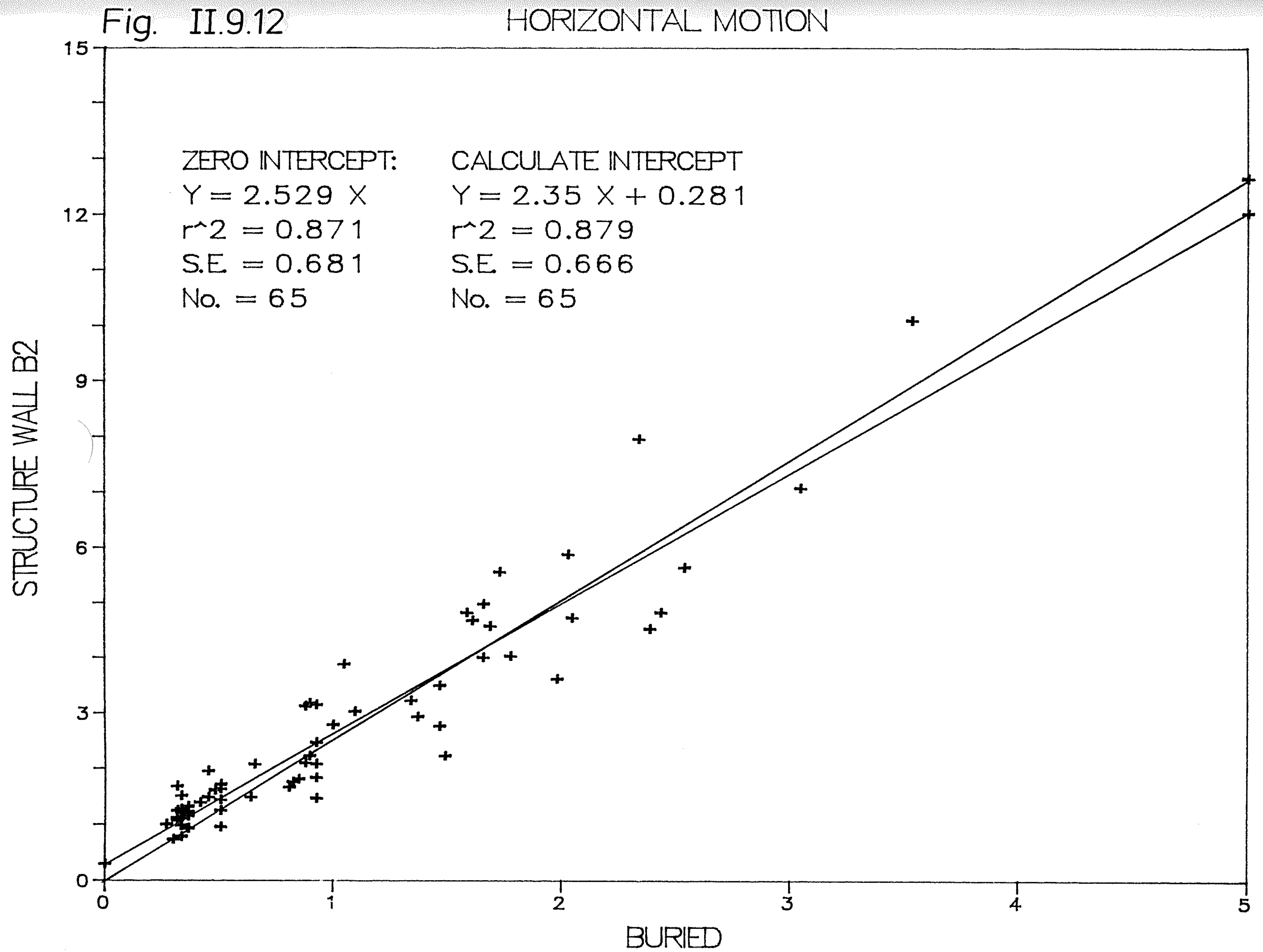
The transfer function for Wall B6 which is in the same orientation as B2 is given in Figure II.9.13. The plasterboard gives a much higher amplification, but there is also much more scatter. The regression lines calculated for zero and computed intercepts are very different which is probably a function of the scatter. It would be much harder to accurately predict values for this wall although it would be possible to state that they would be high than for Wall B2. The variation could be a function of the frequency of the input signal and this is currently being investigated by R. Farnfield and will be reported in a future paper.

Finally, Figure II.9.14 shows the PPV data from the longitudinal buried transducer and the accelerometer on Wall B3. This is an internal wall which is part of the old cottage. There is a 2.4 amplification factor which is similar to Wall B2 in the other orientation, although the scatter seems to increase with larger PPV values.

II.9.3 USING PPV TRANSFER FUNCTIONS

In certain circumstances it is quite valid to use simple regression analysis to predict the peak levels of vibration in one part of a house, using those monitored in the ground outside. High confidence levels could be expected if the structure being monitored is reasonably rigid. Obviously the amplification factor (positive or negative) will vary from location to location and the correct factor will have to be determined empirically. With some structures such as the plasterboard wall, the scatter is too great and spectral transfer functions are probably required.

Fig. II.9.12



HORIZONTAL MOTION
ZERO INTERCEPT:
Y = 2.529 X
r^2 = 0.871
S.E. = 0.681
No. = 65
CALCULATE INTERCEPT
Y = 2.35 X + 0.281
r^2 = 0.879
S.E. = 0.666
No. = 65
STRUCTURE WALL B2
BURIED
0
3
6
9
12
15
0
1
2
3
4
5

Fig. II.9.13

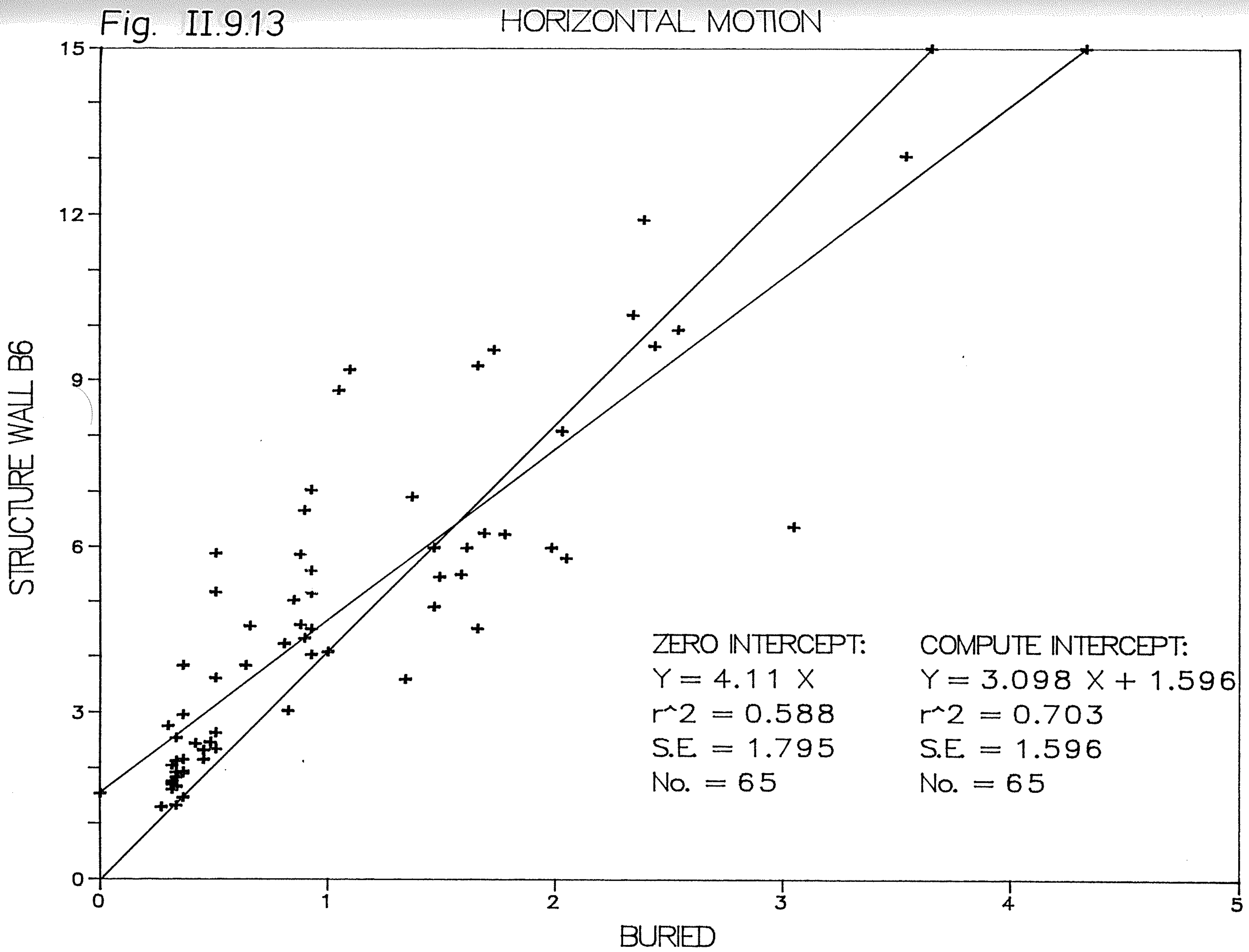
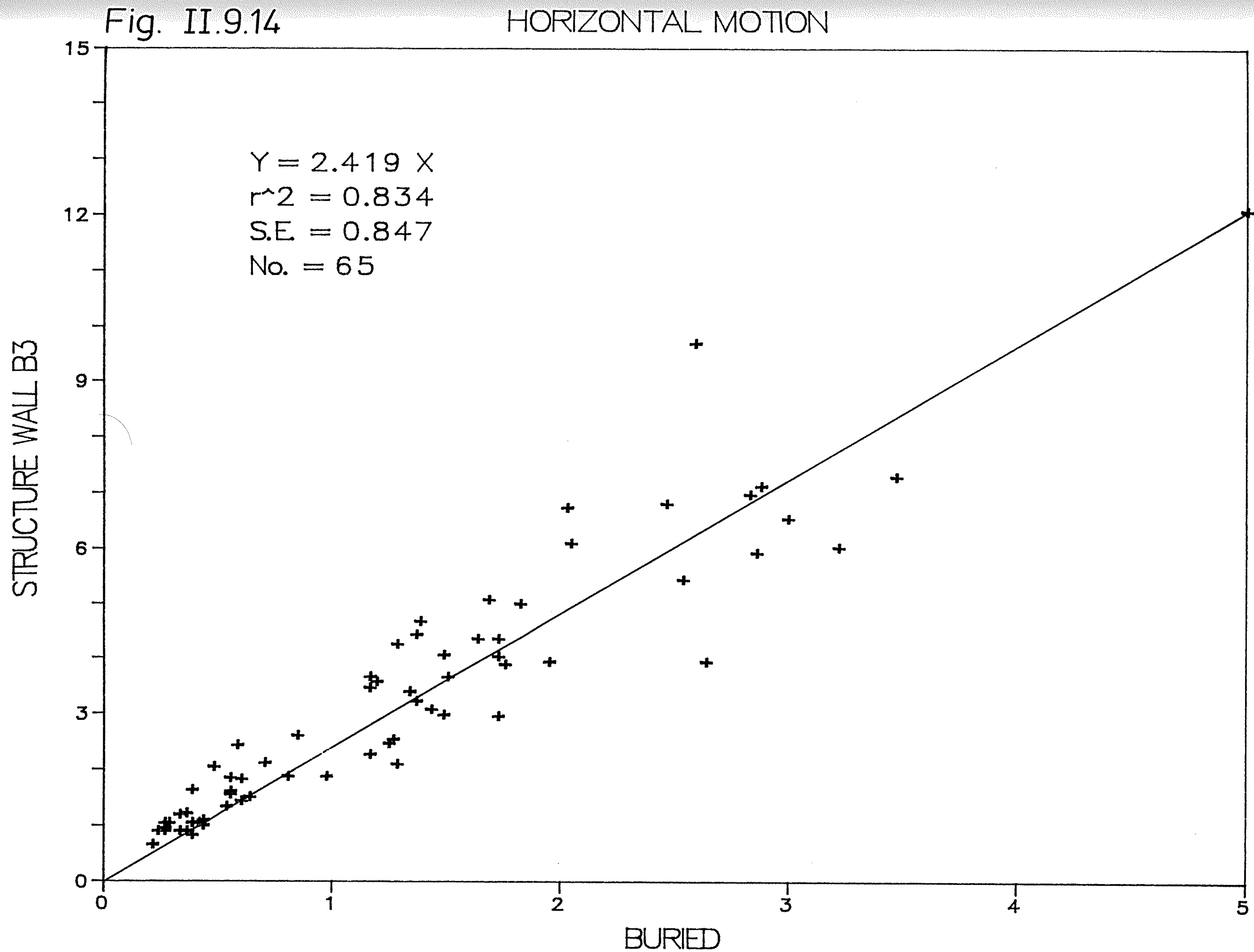

HORIZONTAL MOTION
STRUCTURE WALL B6
BURIED
15
12
9
6
3
0
0
1
2
3
4
5
ZERO INTERCEPT:
Y = 4.11 X
r^2 = 0.588
S.E = 1.795
No. = 65
COMPUTE INTERCEPT:
Y = 3.098 X + 1.596
r^2 = 0.703
S.E = 1.596
No. = 65

Fig. II.9.14



HORIZONTAL MOTION
Y = 2.419 X
r^2 = 0.834
S.E. = 0.847
No. = 65
STRUCTURE WALL B3
BURIED
0
3
6
9
12
15
1
2
4
5

II.10. CONCLUSION

The house has been monitored during two years of low level vibrations during which there was a very significant increase in cosmetic cracking in the two rooms being studied. There was no indication that vibration caused any damage at all.

As the blasting approached the house, the vibration levels rose to a maximum of 59.9mm/s. Out of a total of 250 blasts in Phase 2 only two have definitely resulted in damage although there are another six where blast vibrations could have been a contributing factor. The amount of vibration cracking is very small compared to the amount of ambient cracking and it is still of a cosmetic nature.

During the surveys it was not possible to distinguish between cracks formed by different methods. Therefore, the assumption is made that cracks found in post-blast surveys are a result of the blast vibrations. It has been shown that this assumption is not always valid. For example, if there is a large time lag between pre- and post-blast surveys, then other factors may have influenced the generation of new cracks. This is particularly true when the rate of ambient cracking is high due to the plaster being dry and cold.

The lowest PPV blast which almost certainly gave rise to damage was 24.1mm/s despite the fact that the house was in a poor condition. Of the other lower PPV blasts which may have caused cracking, only one (8.7mm/s) is below the level permitted in opencast coal operations in the U.K. and the low temperatures at that time are likely to have been a factor in the small amount of crack growth. This study therefore supports the proposition that with current practices, opencast mine blasting does not give rise to damage in residential properties.

REFERENCES

1. Kelly, M.P., White, T.J. and Farnfield, R.A. (1993). Environmental effects of blasting : ten years of British Coal research at The University of Leeds. Leeds University Mining Association Journal 1993. pp139-148.
2. Siskind, D.E. (1991). Criteria for Safe Mine Blasting in the USA. Explosives Engineering, September 1991.
3. Farnfield, R.A. and White, T.J. (1993). Research into the Effect of Surface Mine Blasting on Buildings: Long Term Monitoring Projects. The Mining Engineer, **152**, No. 380, May 1993. pp319-324.
4. White, T.J., Farnfield, R.A. and Kelly, M.P. (1993). The Effect of Low Level Blast Vibrations and the Environment on a Domestic Building. Proceedings 9th Annual Symposium on Explosives and Blasting Research, San Diego, February 1993. pp71-81.
5. White, T.J., Farnfield, R.A. and Kelly, M.P. (1993). The Effects of Surface Mine Blasting on Buildings. In Rock Fragmentation by Blasting, Rossmanith (Ed), the Proceedings of the 4th International Symposium on Rock Fragmentation by Blasting, Vienna, July 1993. pp105-111.
6. White, T.J. and Farnfield, R.A. (1993). Computers and Blasting. Trans. Instn Min. Metall. (Sect.A: Min. industry), **102**, 1993. ppA19-A24.
7. Building Research Establishment (1981). Assessment of Damage in Low-Rise buildings. Building Research Establishment Digest No. 251. July 1981.
8. Wall, J.F. (1967). Seismic-induced Architectural Damage to Masonry Structures at Mercury, Nevada. Bull. Seis. Soc. Am., **57**, No 5, pp991-1007.
9. Koenigsberger, O.H., Inger-soll, T.G., Mayhew, A. and Szokolay, S.V. (1974). Manual of Tropical Housing and Building, Part one: Climatic Design. (page 290). Longman Group Limited. 320pp.

PART III: APPENDICES

Fig. A.1

DAILY WIND SPEED

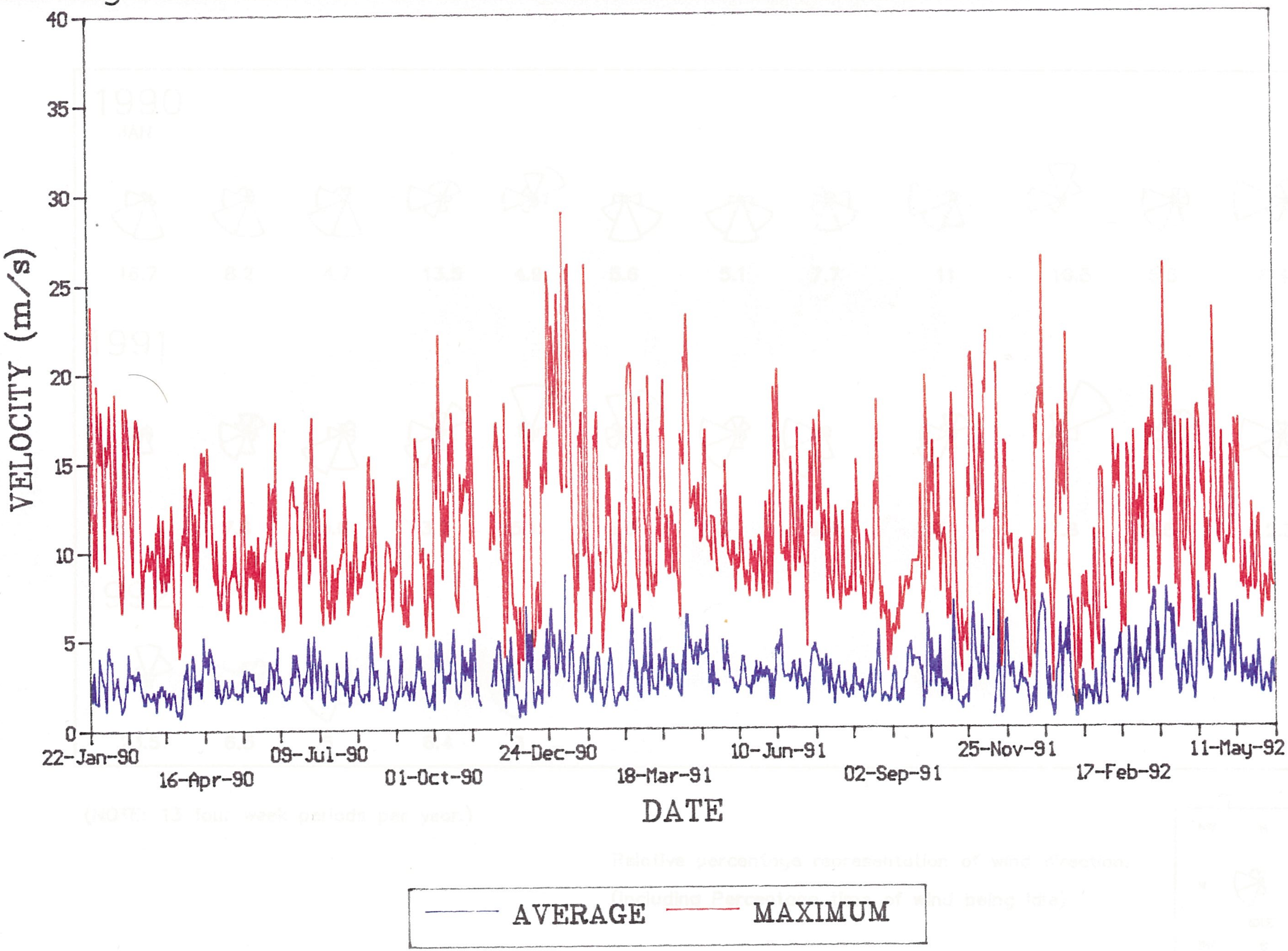
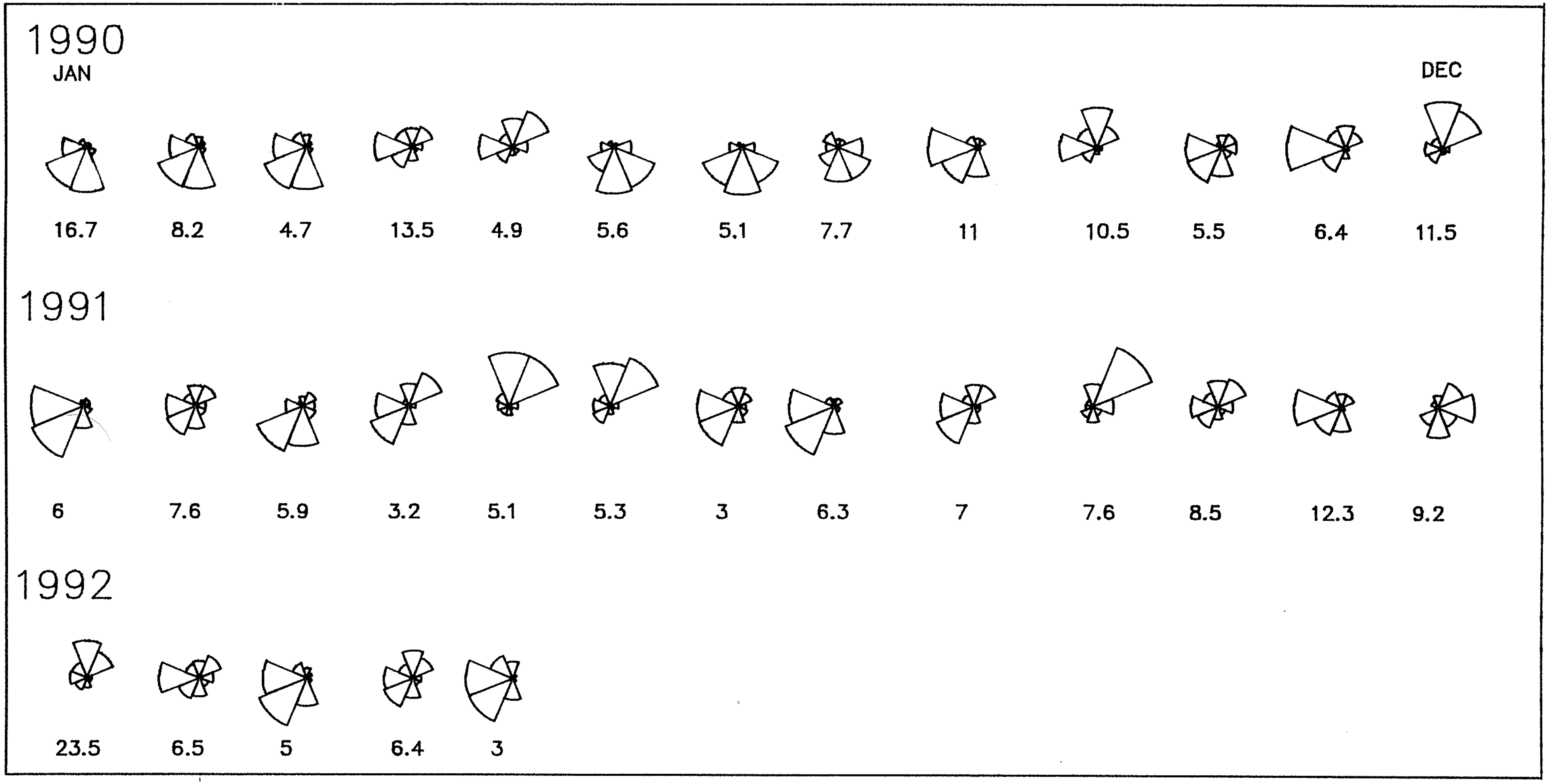


Fig. A.2 MONTHLY WIND DIRECTION ANALYSIS



(NOTE: 13 four week periods per year.)

Relative percentage representation of wind direction.

(Including Percentage time of wind being idle)

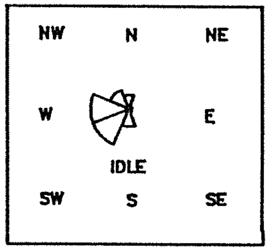


Fig. A.3 DAILY EXTERNAL TEMPERATURE

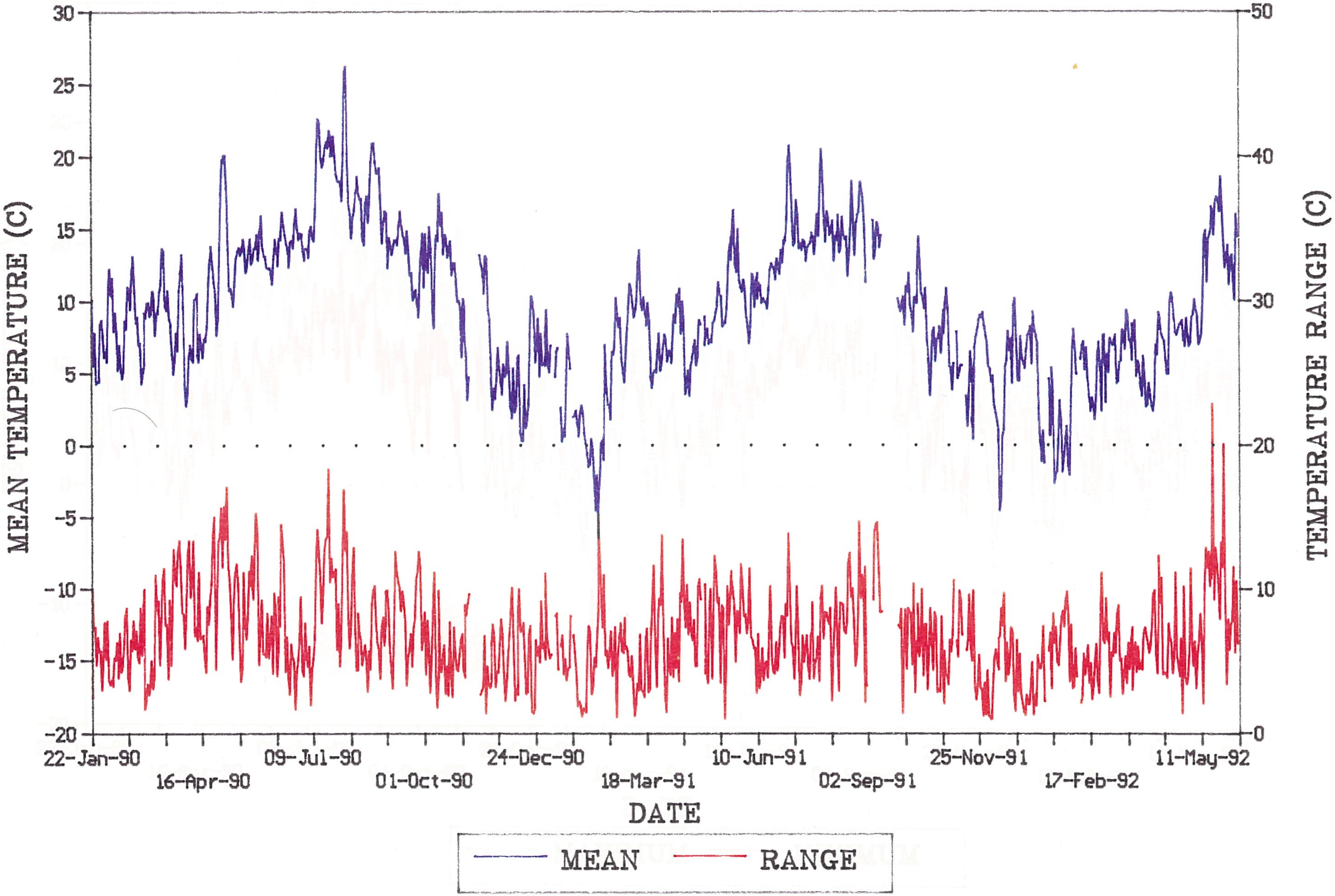


Fig. A.4 DAILY EXTERNAL TEMPERATURE

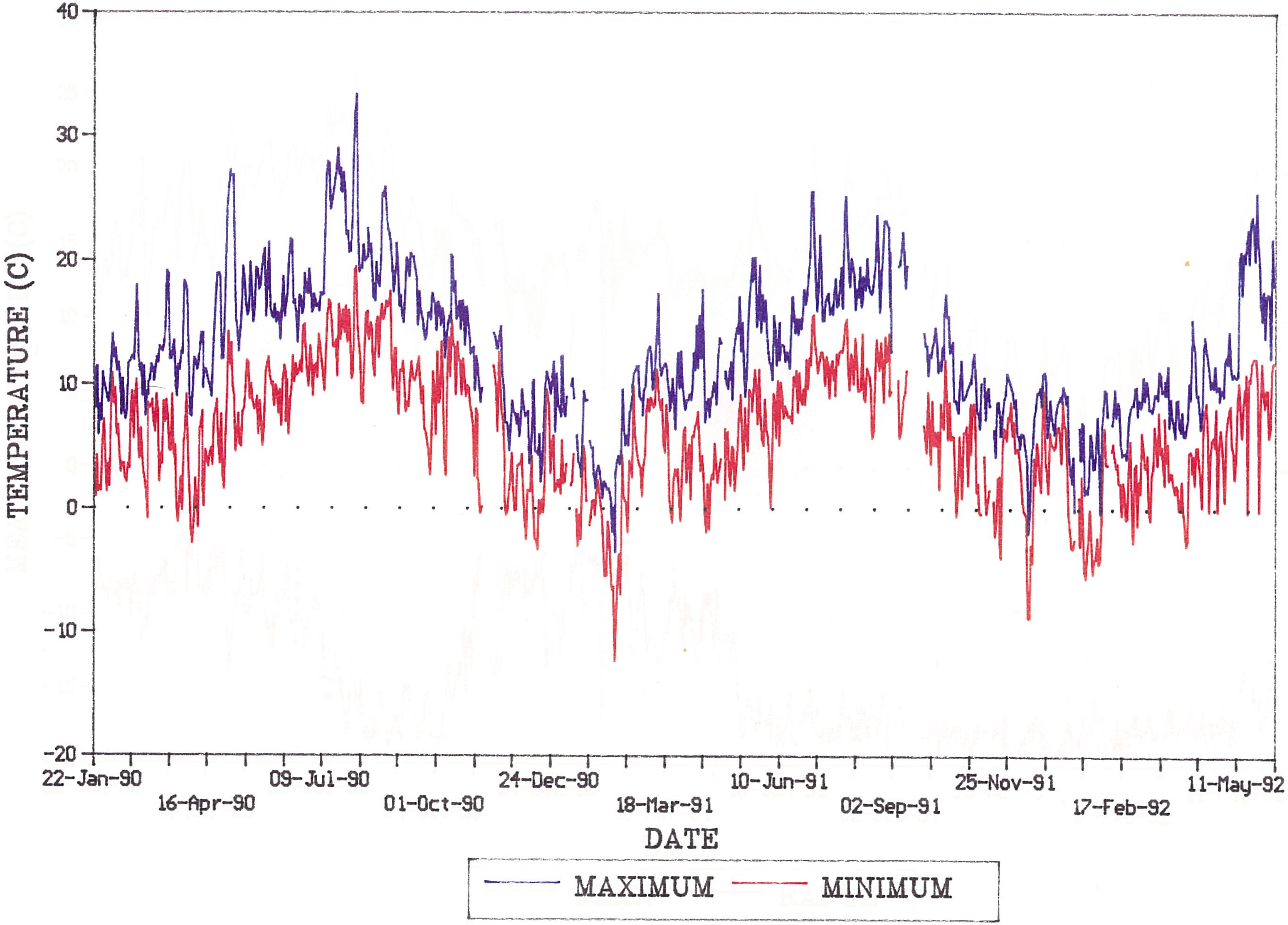
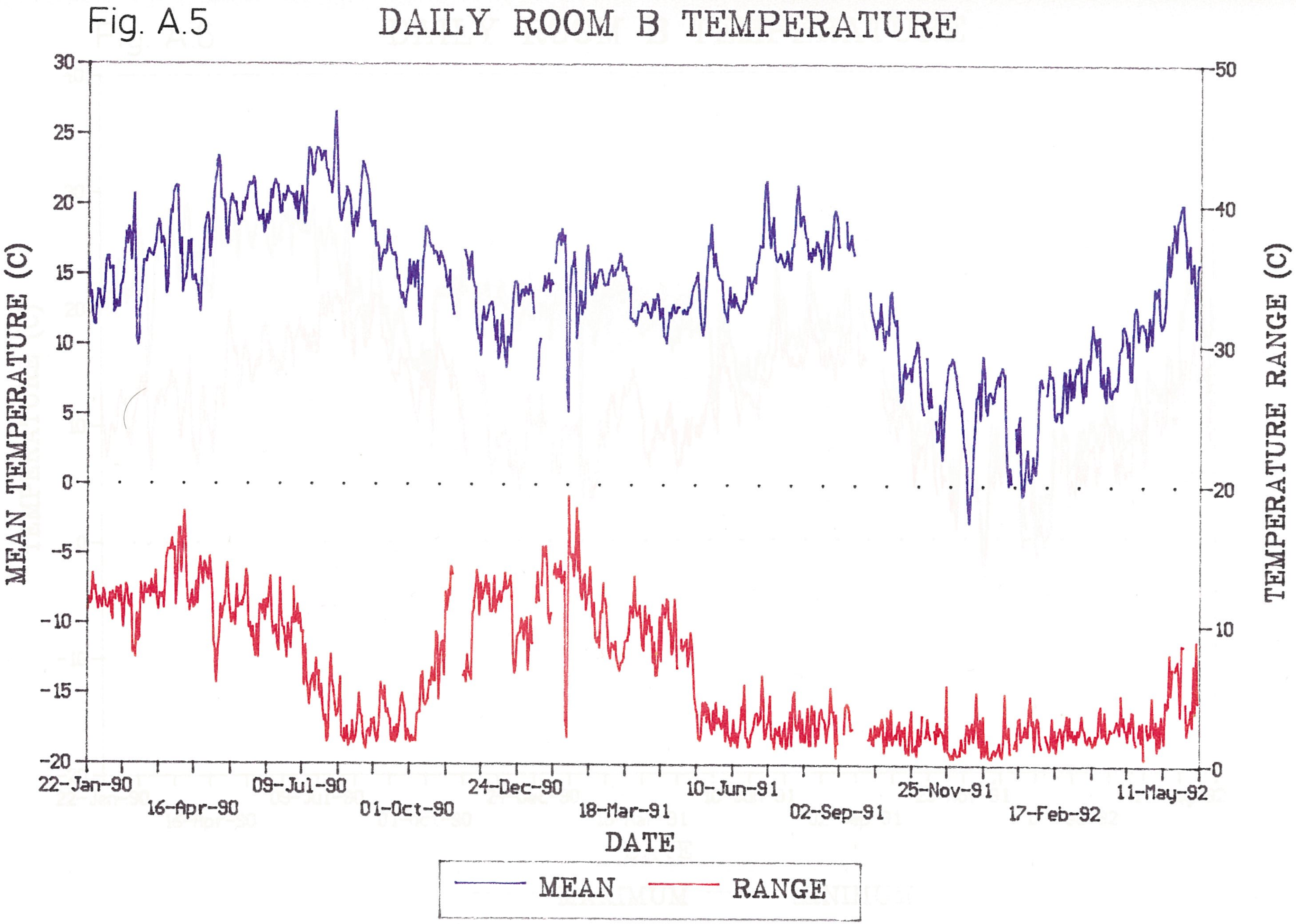


Fig. A.5



DAILY ROOM B TEMPERATURE
MEAN TEMPERATURE (C)
TEMPERATURE RANGE (C)
30
25
20
15
10
5
0
-5
-10
-15
-20
50
40
30
20
10
0
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92
DATE
MEAN
RANGE

Fig. A.6

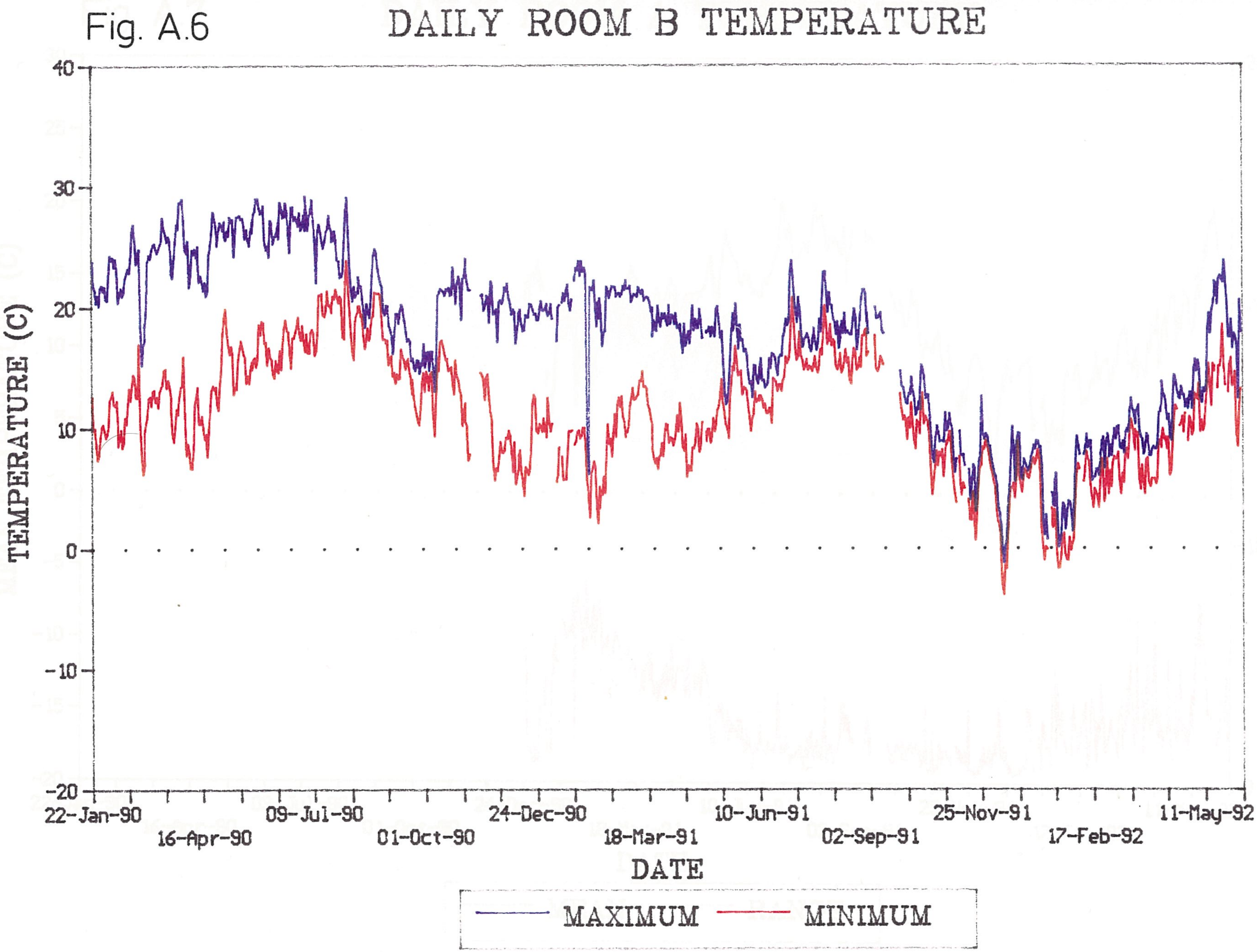

DAILY ROOM B TEMPERATURE
40
30
20
10
0
-10
-20
TEMPERATURE (C)
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92
DATE
MAXIMUM
MINIMUM

Fig. A.7 DAILY ROOM A TEMPERATURE

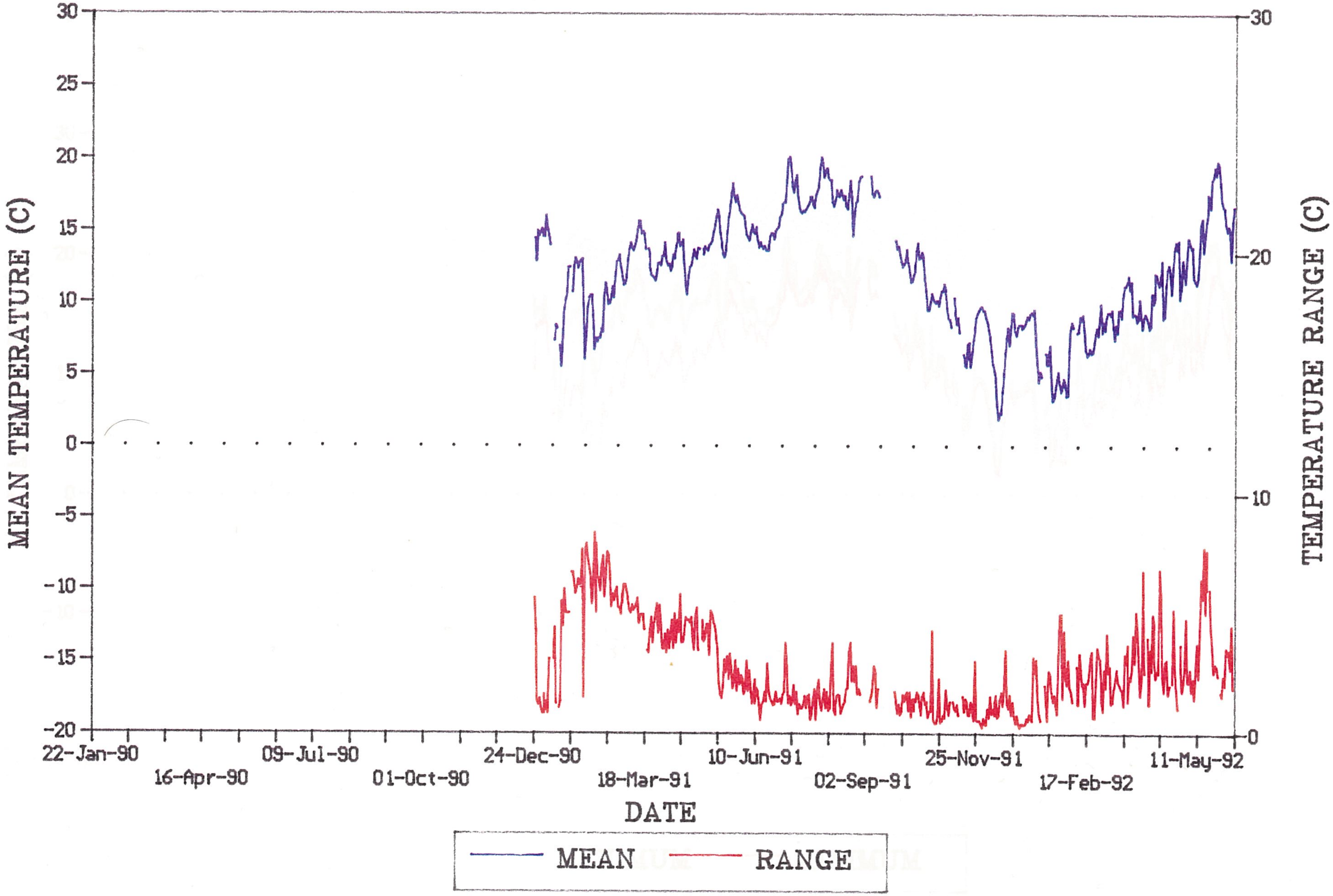


Fig. A.8 DAILY ROOM A TEMPERATURE

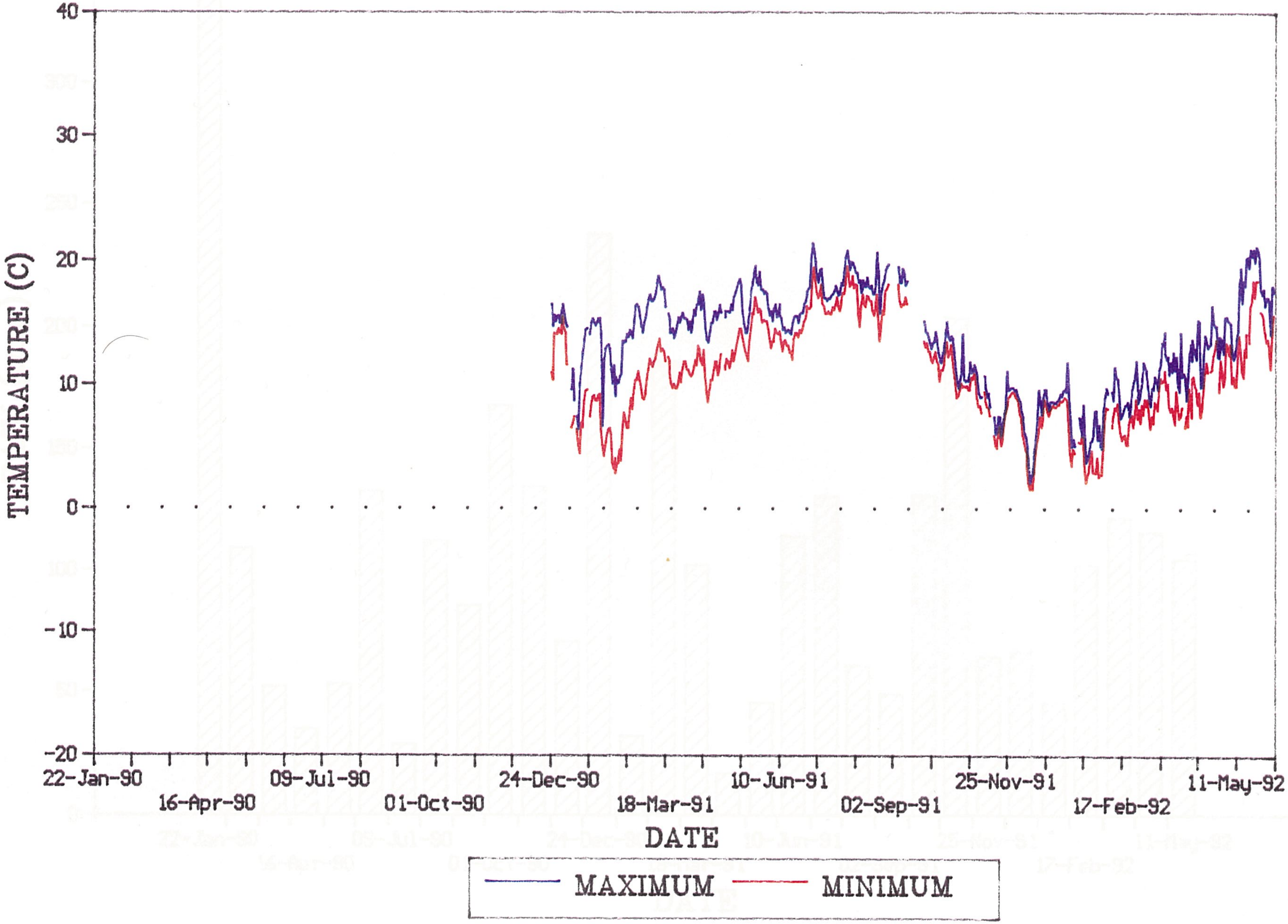
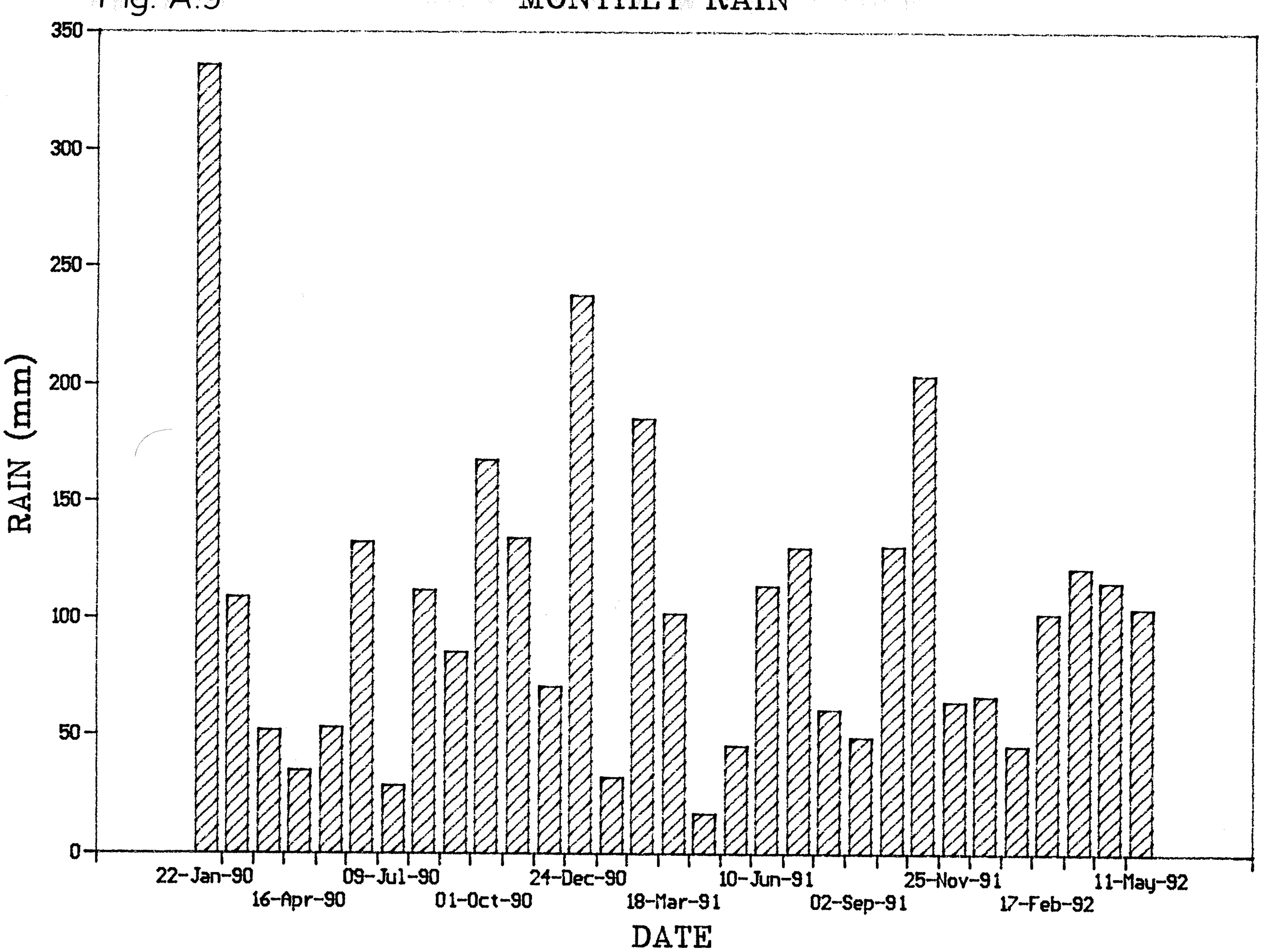


Fig. A.9



MONTHLY RAIN
RAIN (mm)
350
300
250
200
150
100
50
0
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92
DATE

Fig. A.10

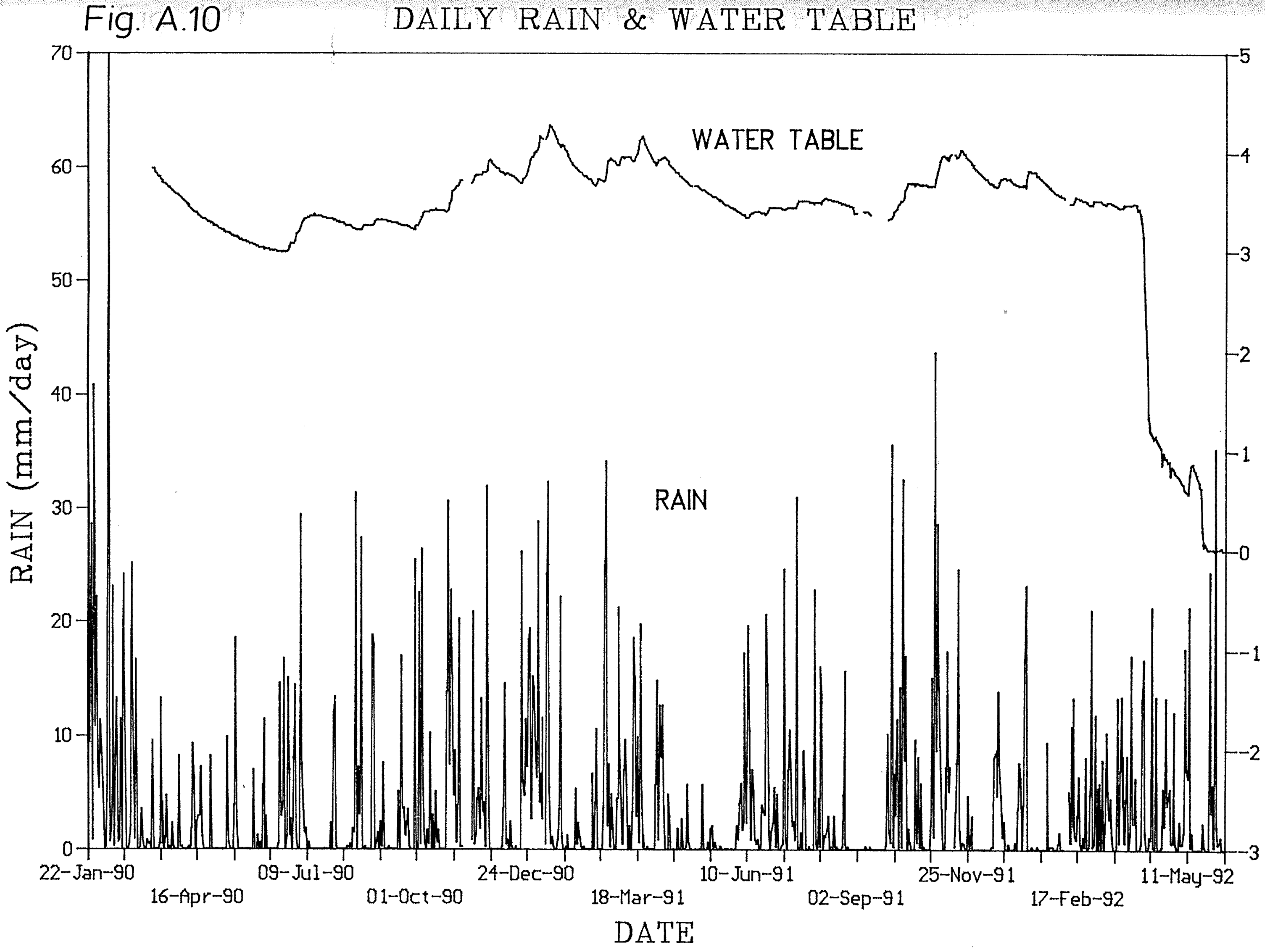

DAILY RAIN & WATER TABLE
WATER TABLE
RAIN
RAIN (mm/day)
WATER LEVEL (m)
DATE
0
10
20
30
40
50
60
70
-3
-2
-1
0
1
2
3
4
5
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92

Fig. A.11 INCLINOMETERS & TEMPERATURE

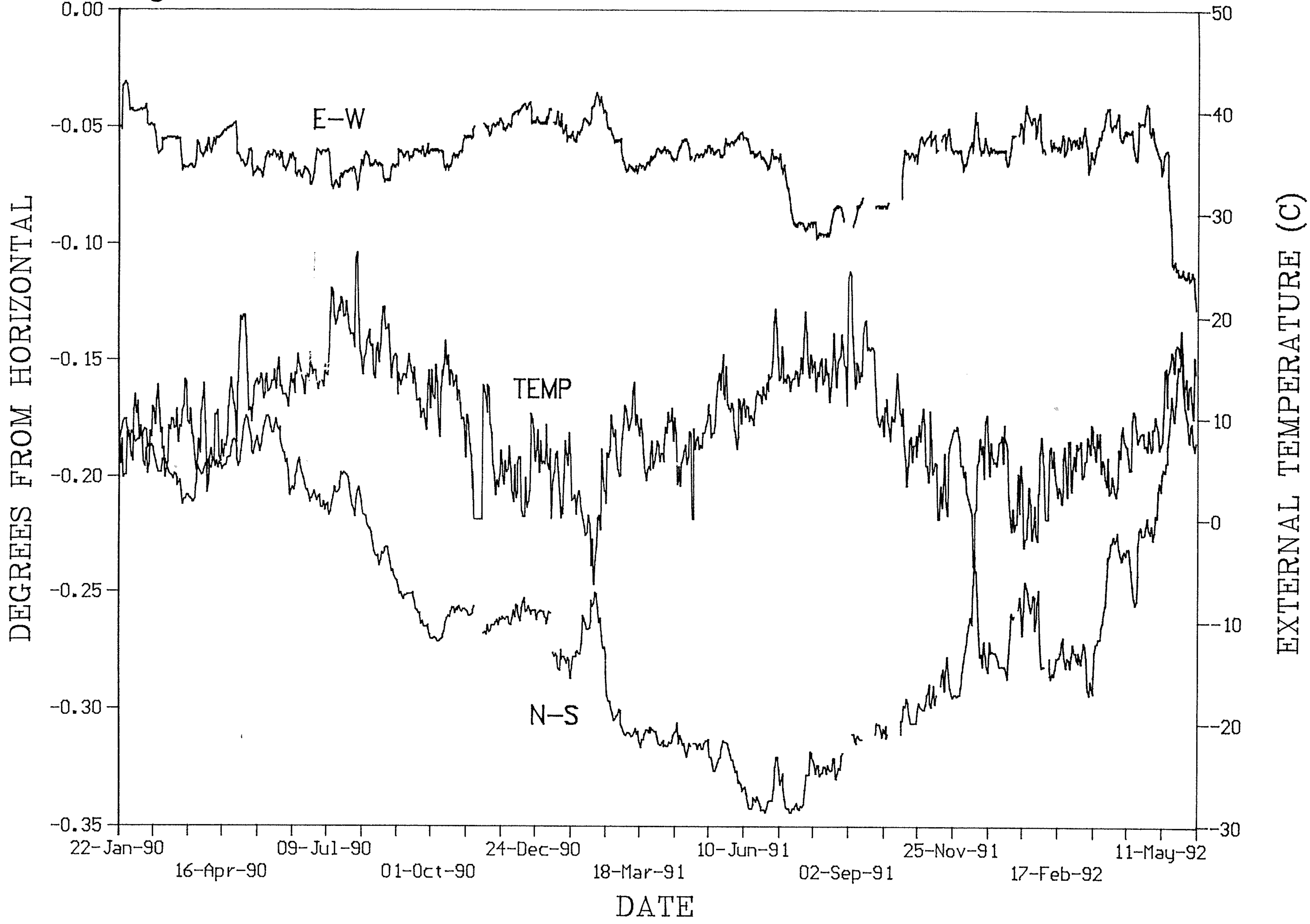


Fig. A.12 GROUND STATION LEVELS GL2 TO GL5

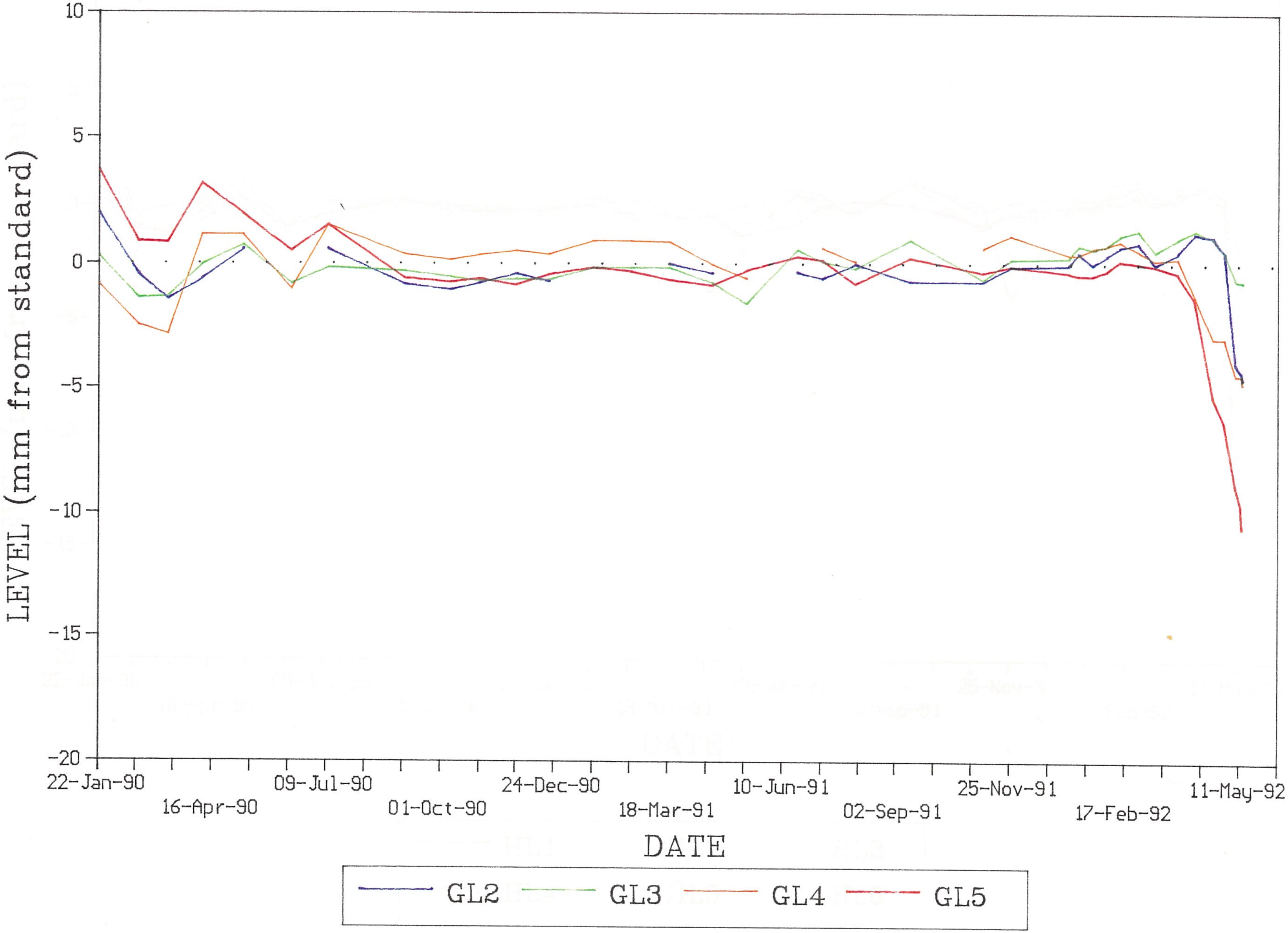


Fig. A.13 HOUSE STATION LEVELS HL1 TO HL6

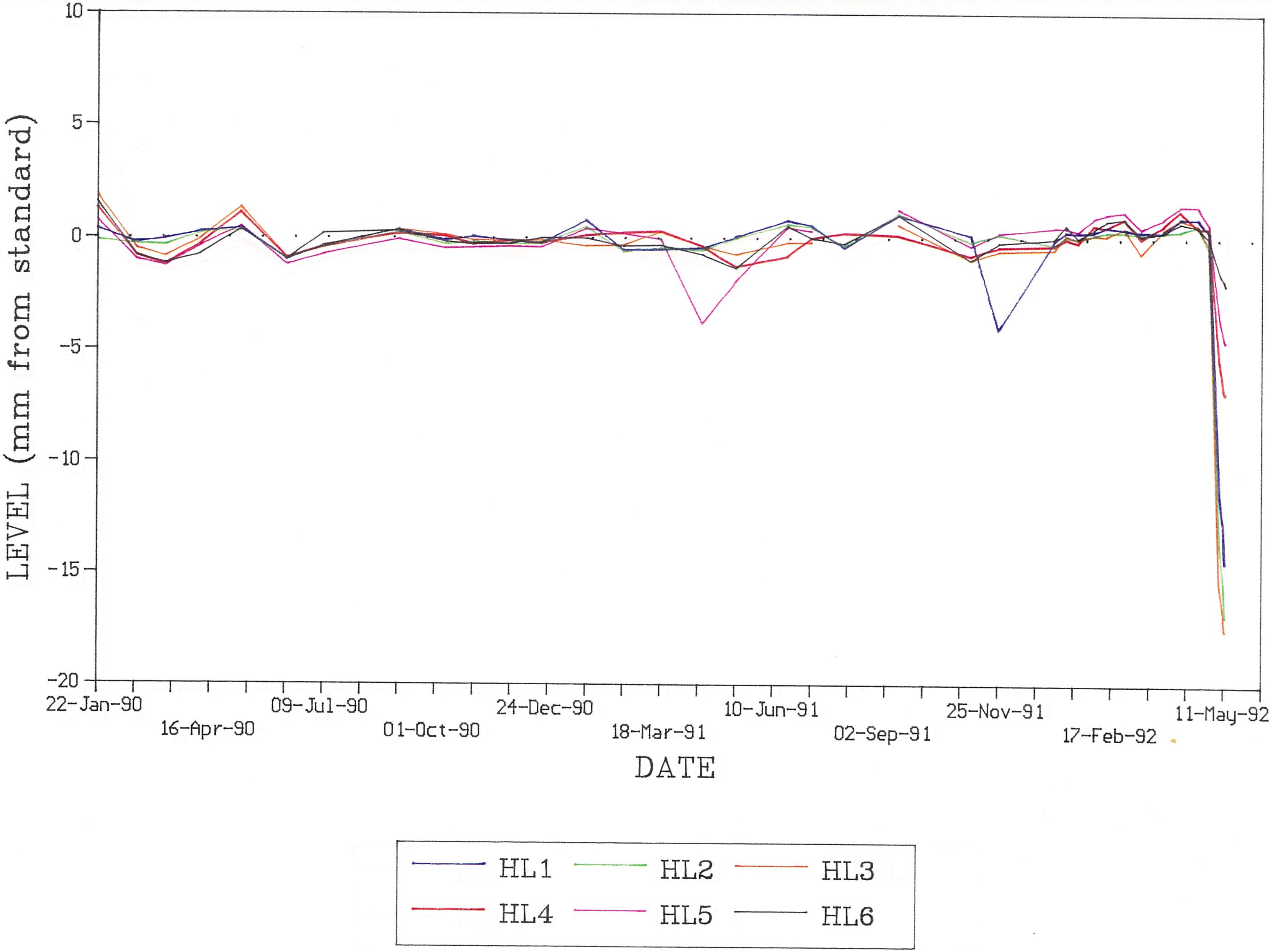
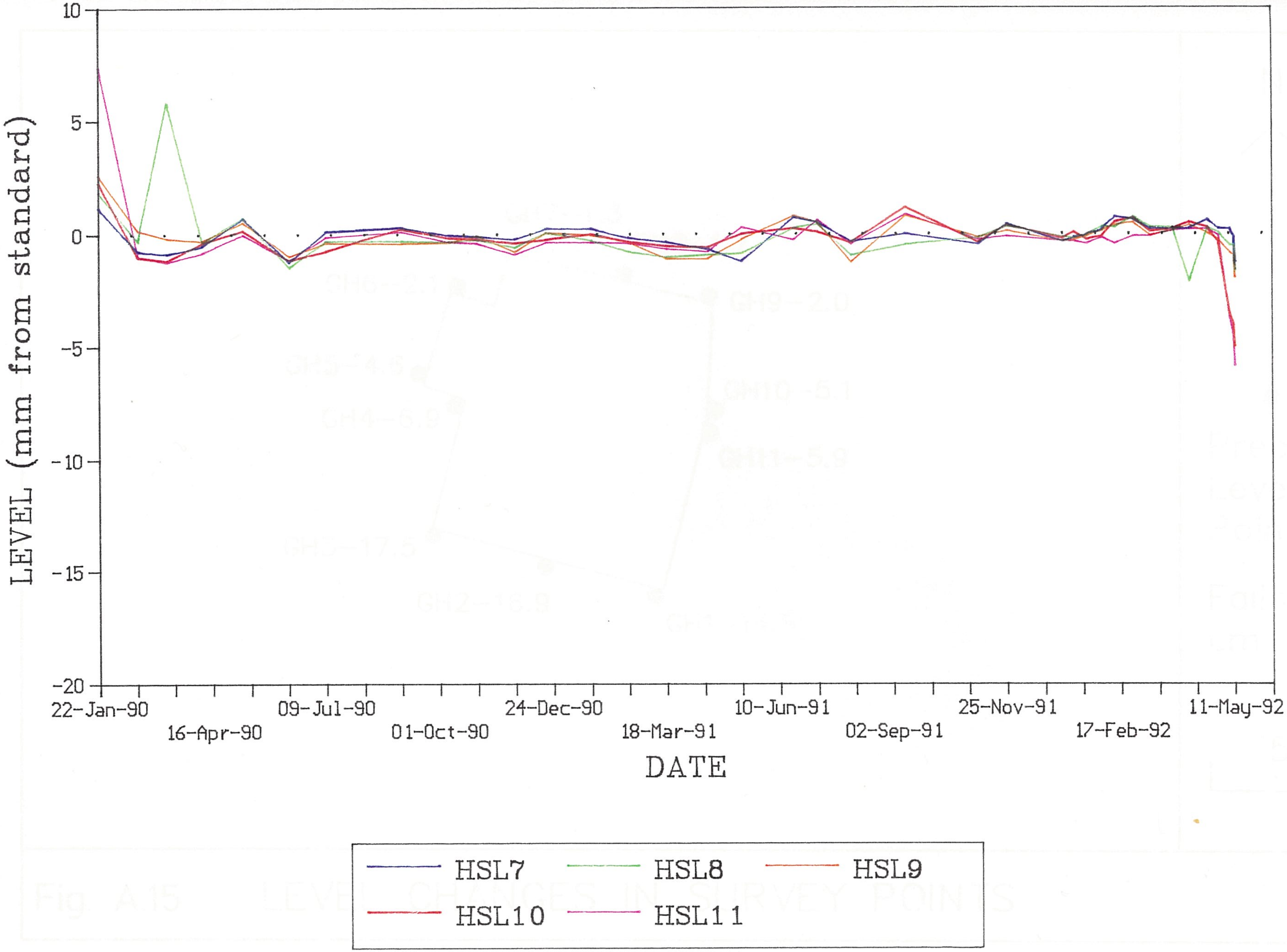


Fig. A.14 HOUSE STATION LEVELS HL7 TO HL11



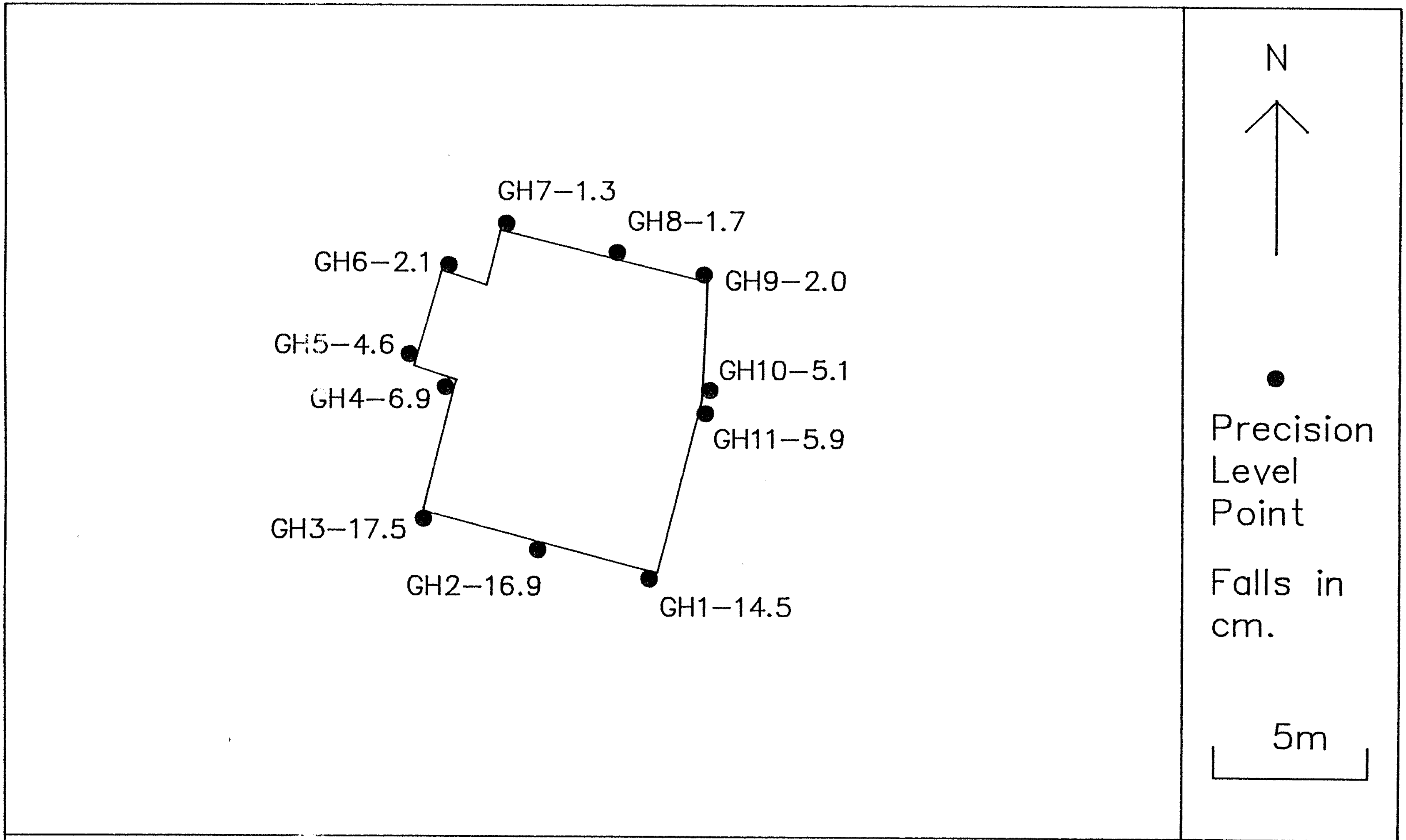


Fig. A.15 LEVEL CHANGES IN SURVEY POINTS

Fig. A.16 REFERENCE LVDT 1

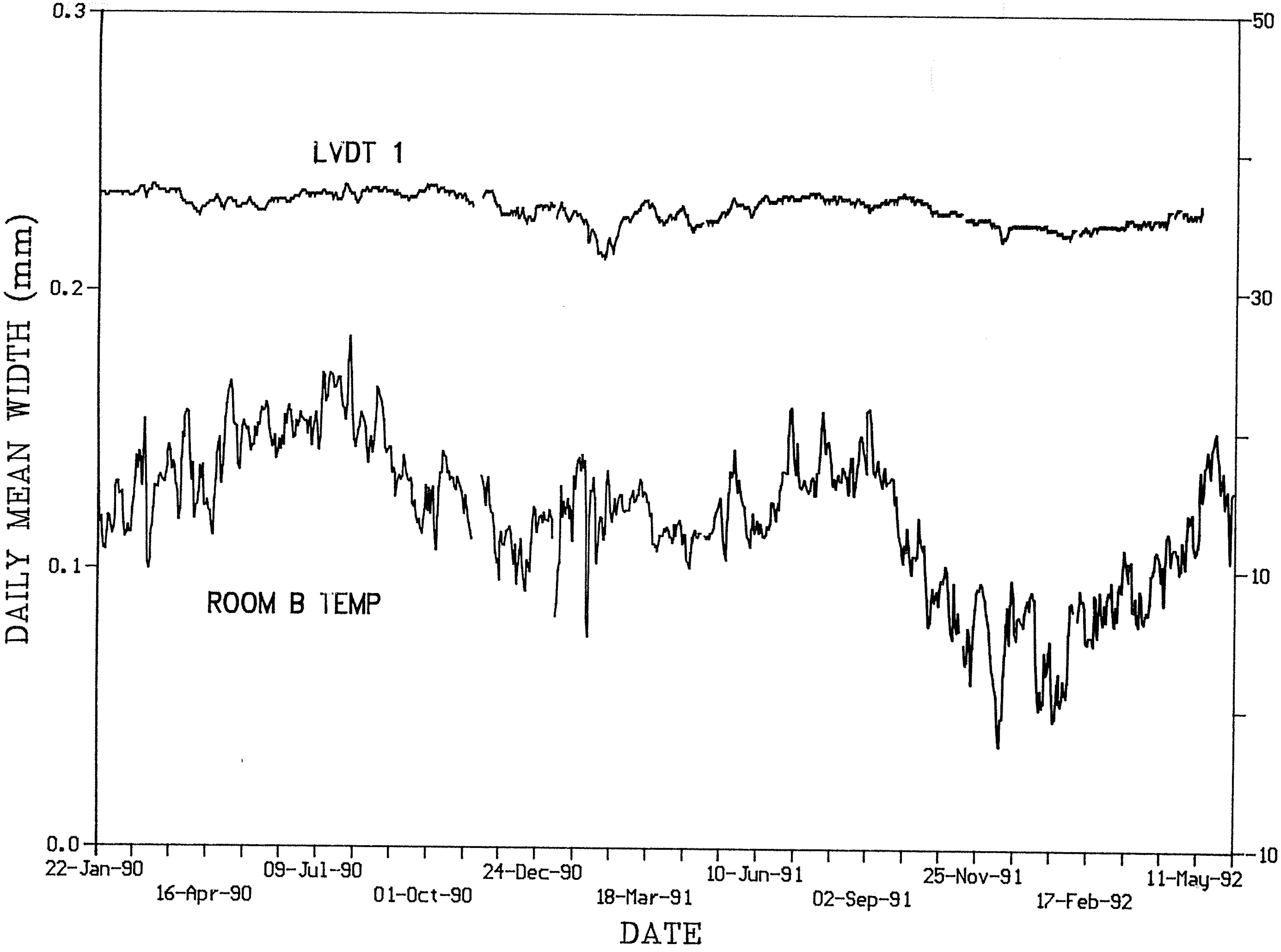


Fig. A.17 CRACK 2 – EXTERNAL

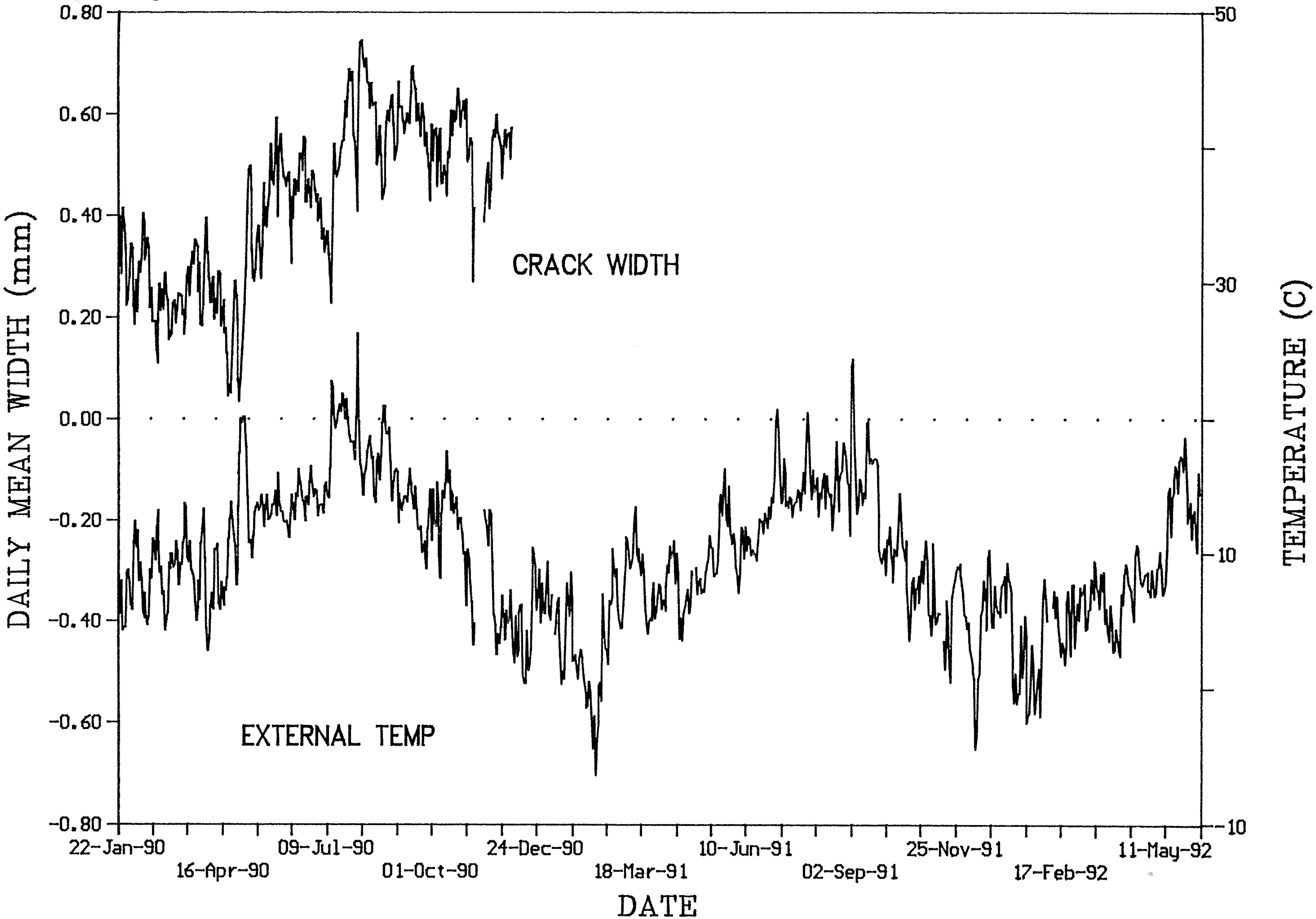
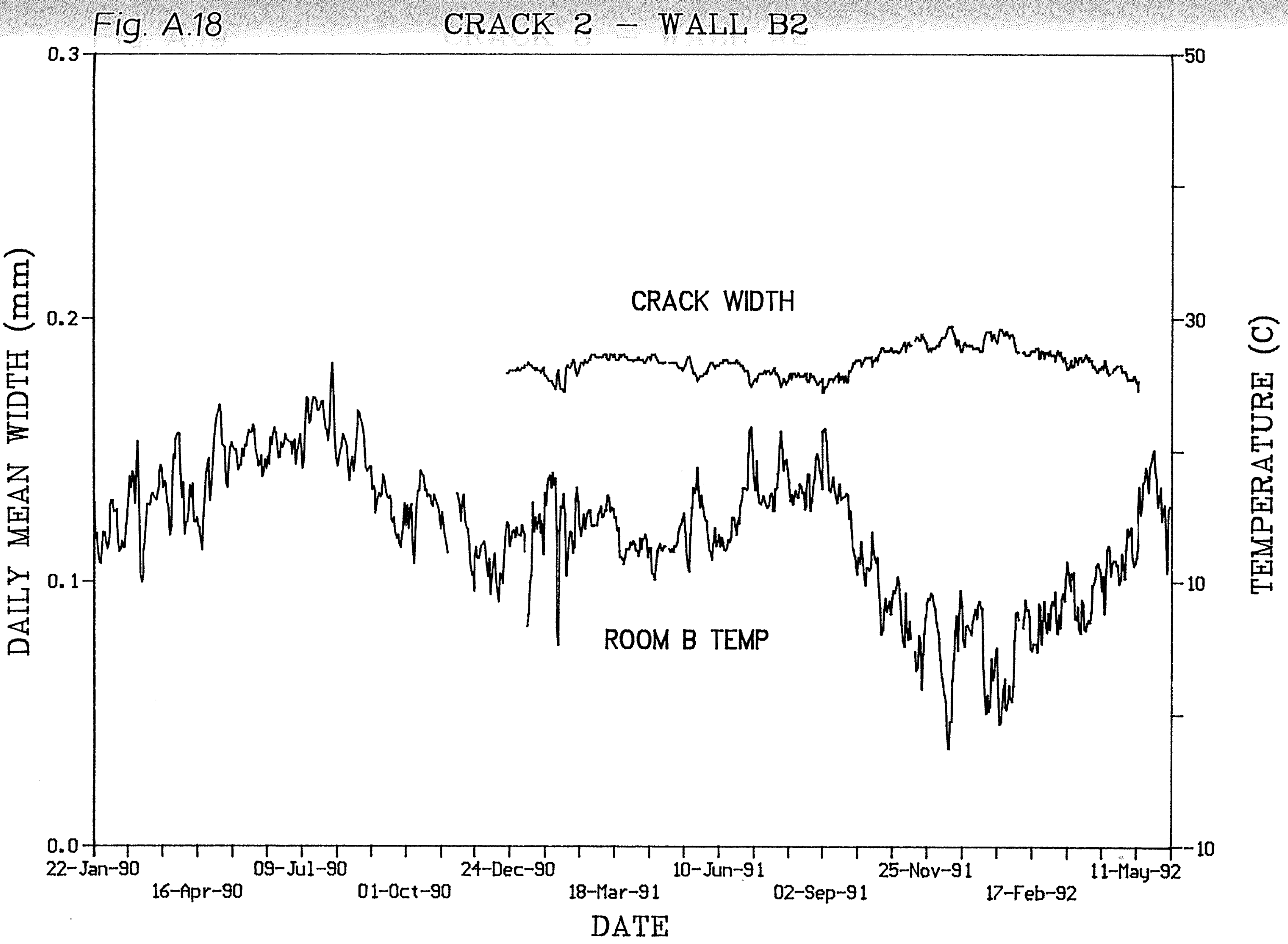


Fig. A.18



CRACK 2 — WALL B2
DAILY MEAN WIDTH (mm)
0.3
0.2
0.1
0.0
TEMPERATURE (C)
50
30
10
-10
CRACK WIDTH
ROOM B TEMP
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92
DATE

Fig. A.19

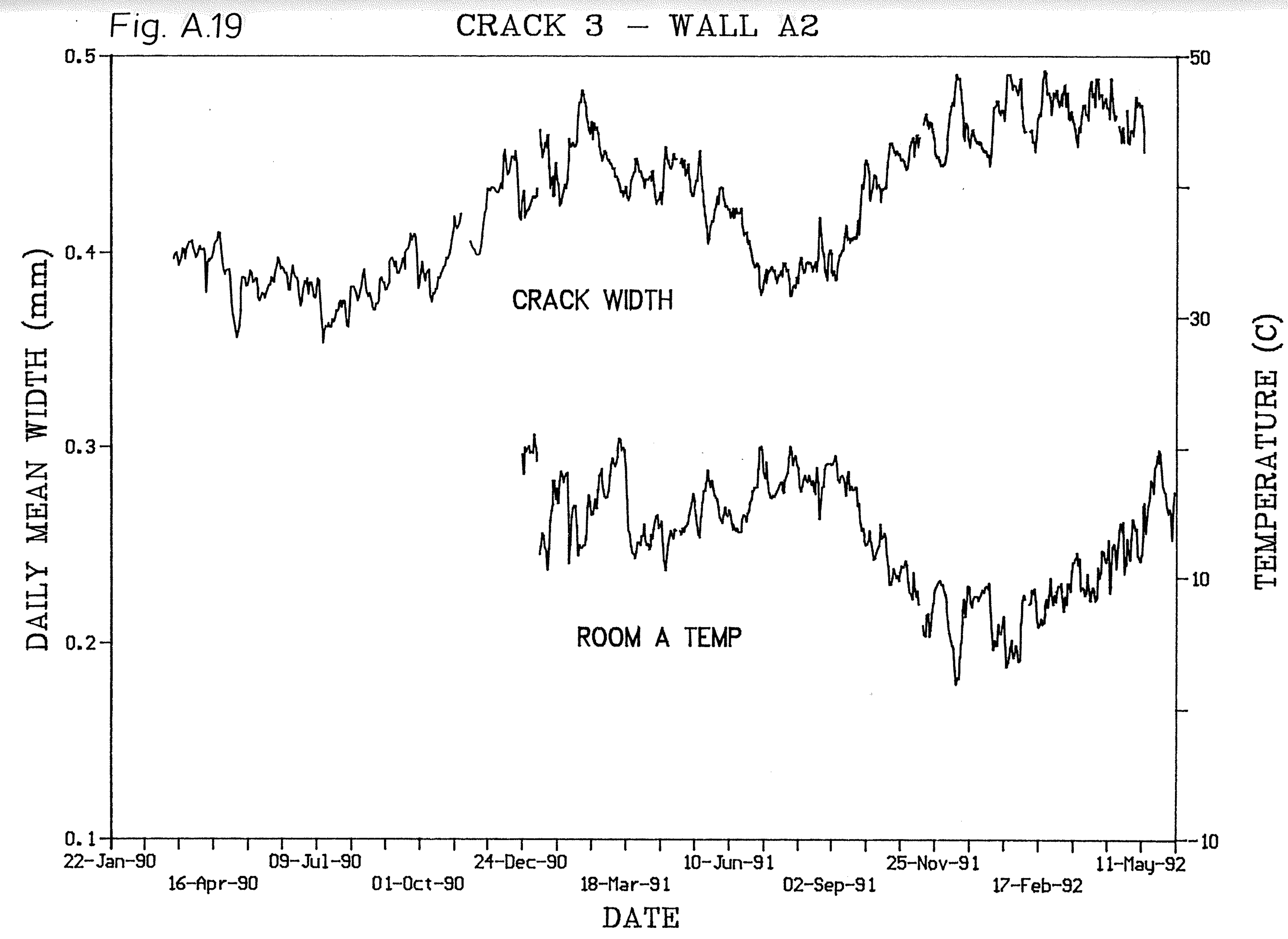

CRACK 3 — WALL A2
DAILY MEAN WIDTH (mm)
0.5
0.4
0.3
0.2
0.1
TEMPERATURE (C)
50
30
10
-10
CRACK WIDTH
ROOM A TEMP
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92
DATE

Fig. A.20 CRACK 4 – WALL B4

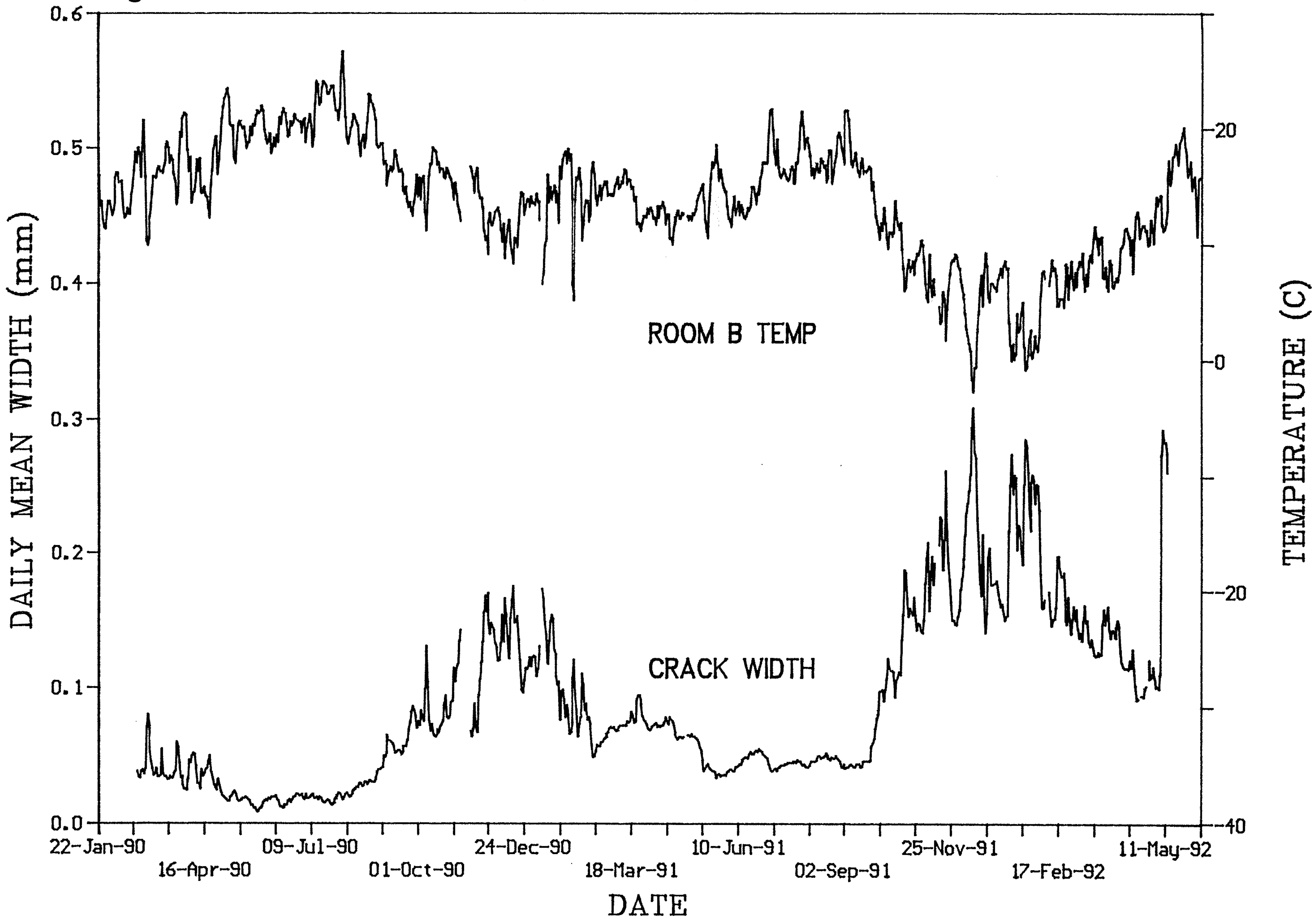


Fig. A.21

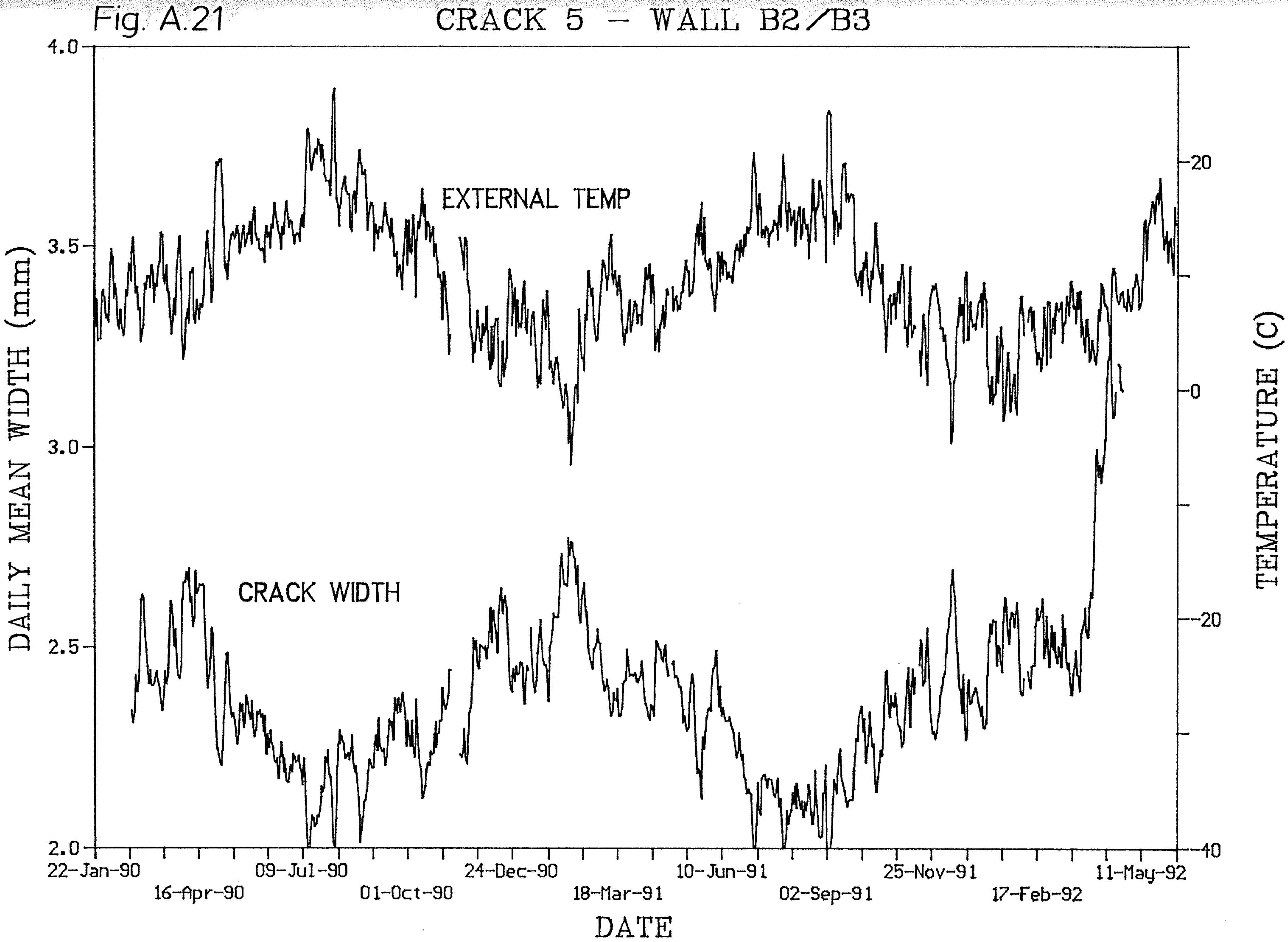

CRACK 5 – WALL B2/B3
EXTERNAL TEMP
CRACK WIDTH
DAILY MEAN WIDTH (mm)
TEMPERATURE (C)
DATE
4.0
3.5
3.0
2.5
2.0
20
0
-20
-40
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92

Fig. A.22 CRACK 6 — WALL B2/B3

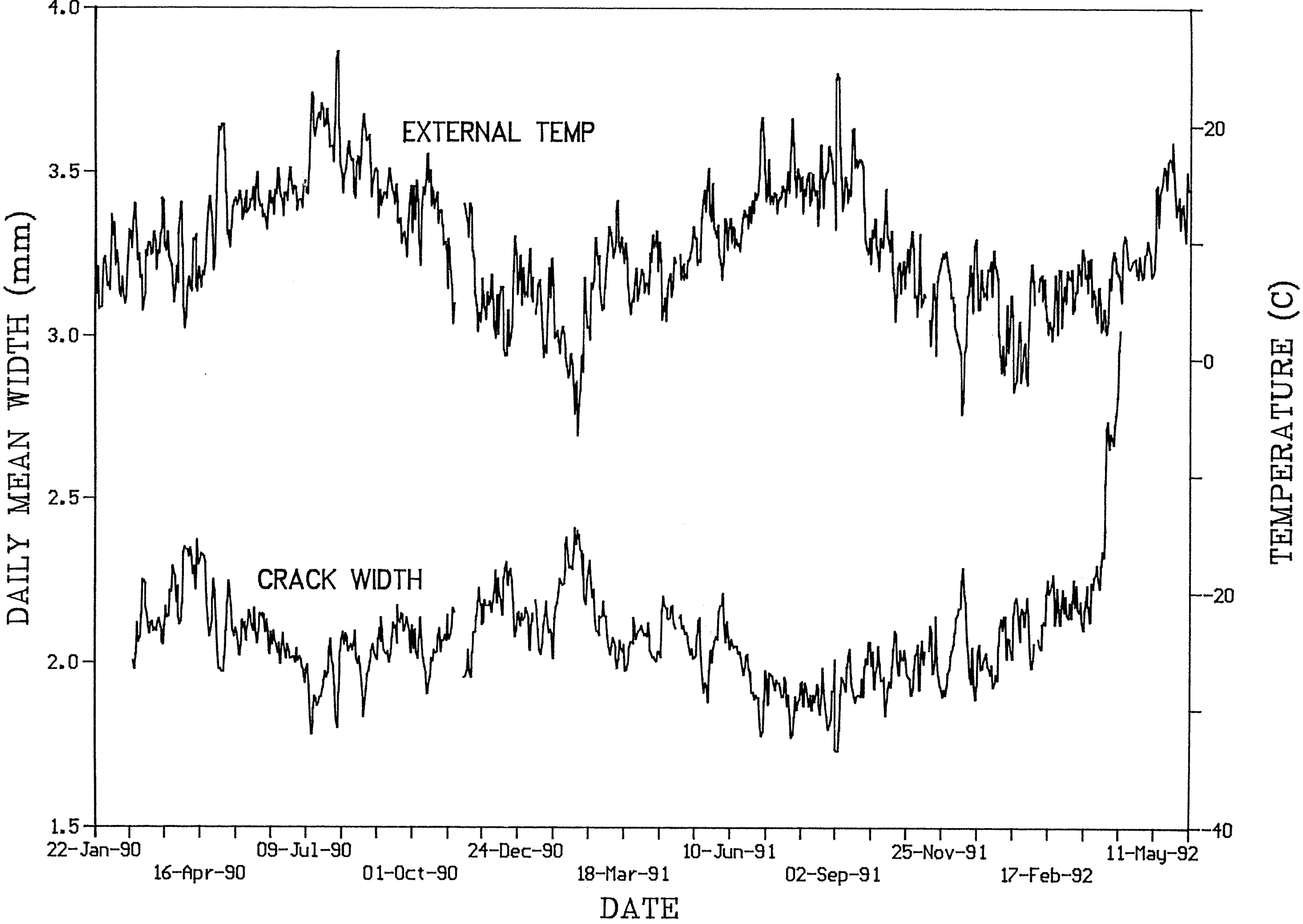


Fig. A.23 CRACK 5 & CRACK 6 DIFFERENCE

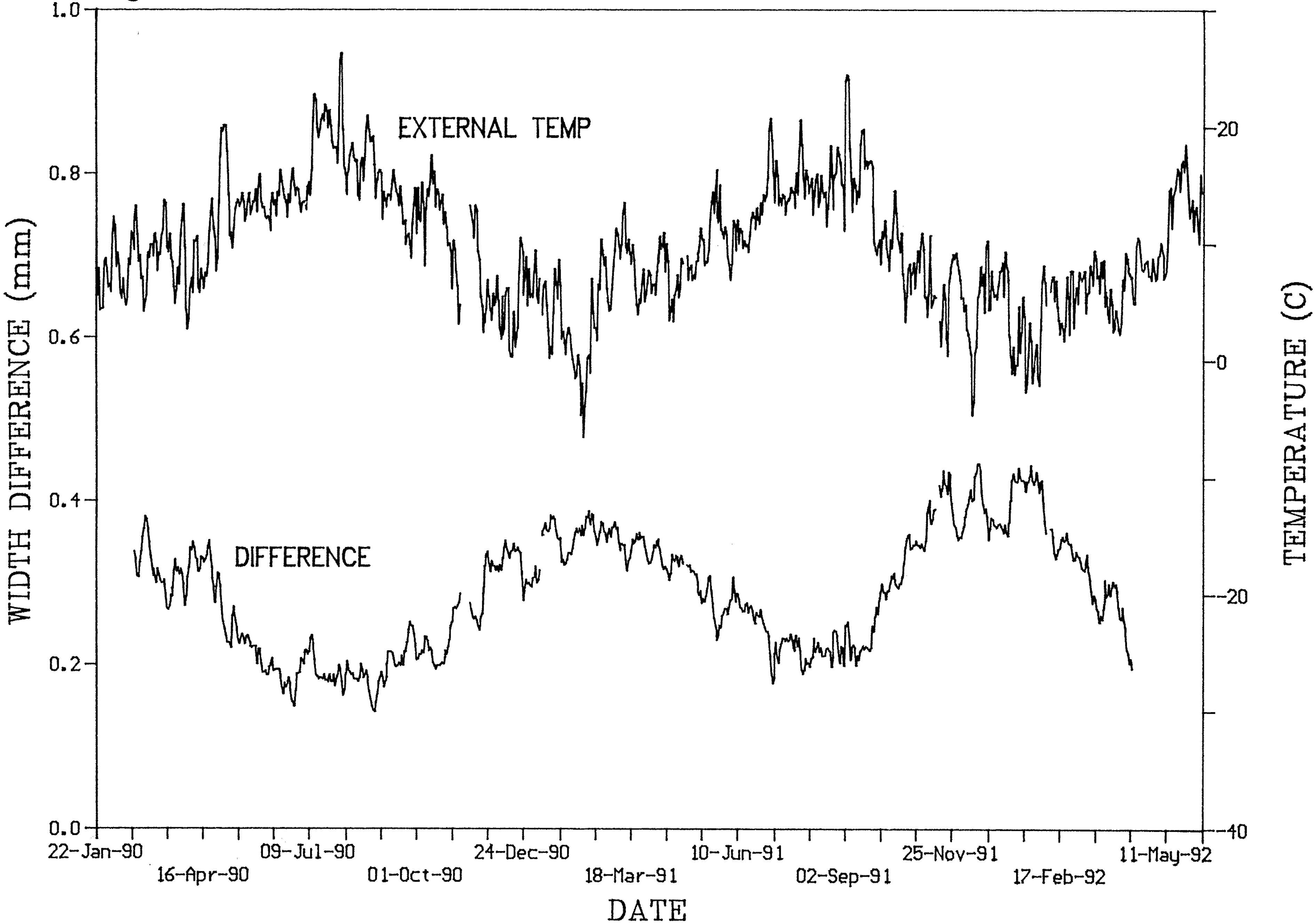


Fig. A.24

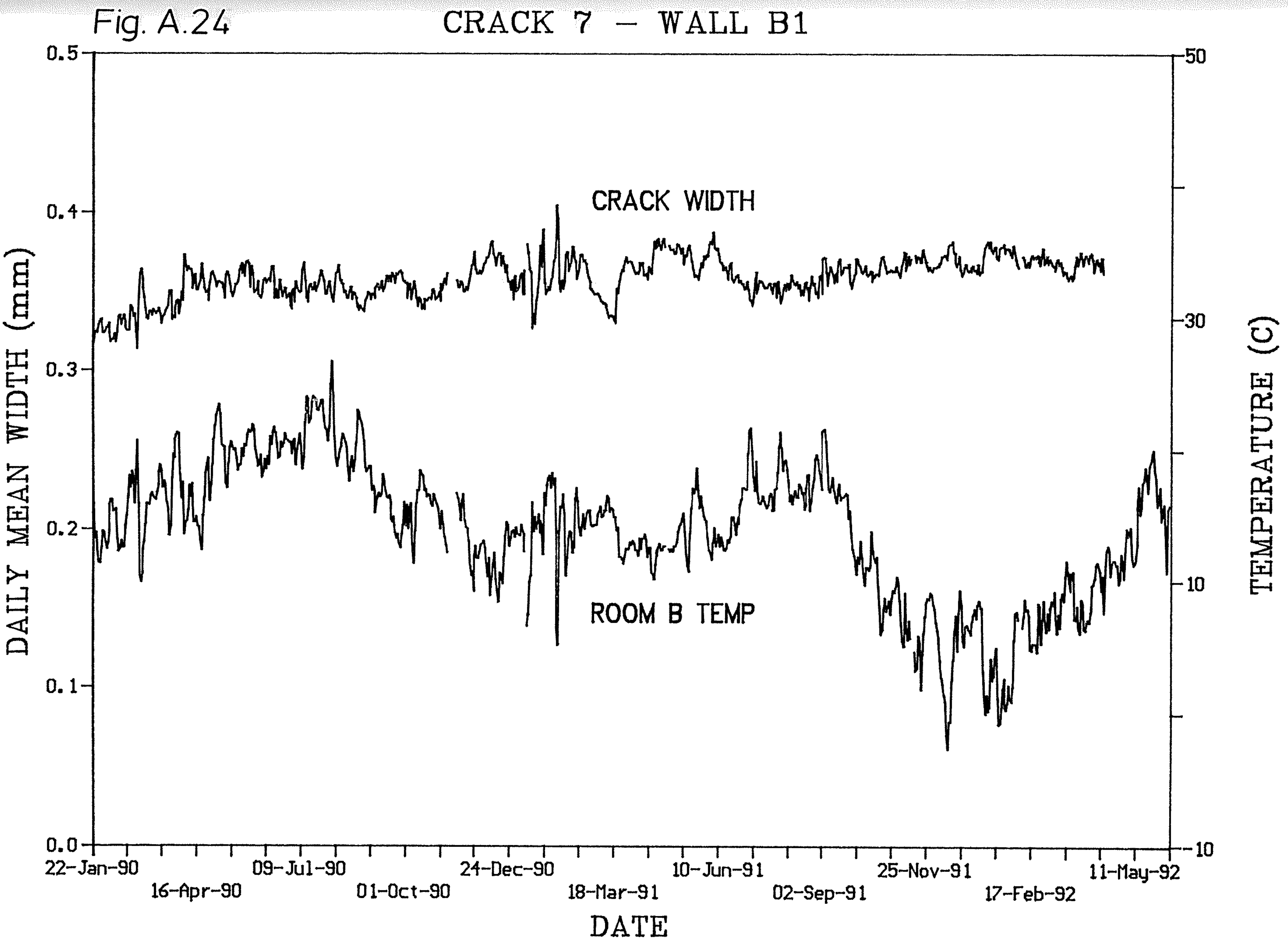

CRACK 7 - WALL B1
CRACK WIDTH
ROOM B TEMP
DAILY MEAN WIDTH (mm)
TEMPERATURE (C)
DATE
0.5
0.4
0.3
0.2
0.1
0.0
50
30
10
-10
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92

Fig. A.25 CRACK 8 – WALL B1

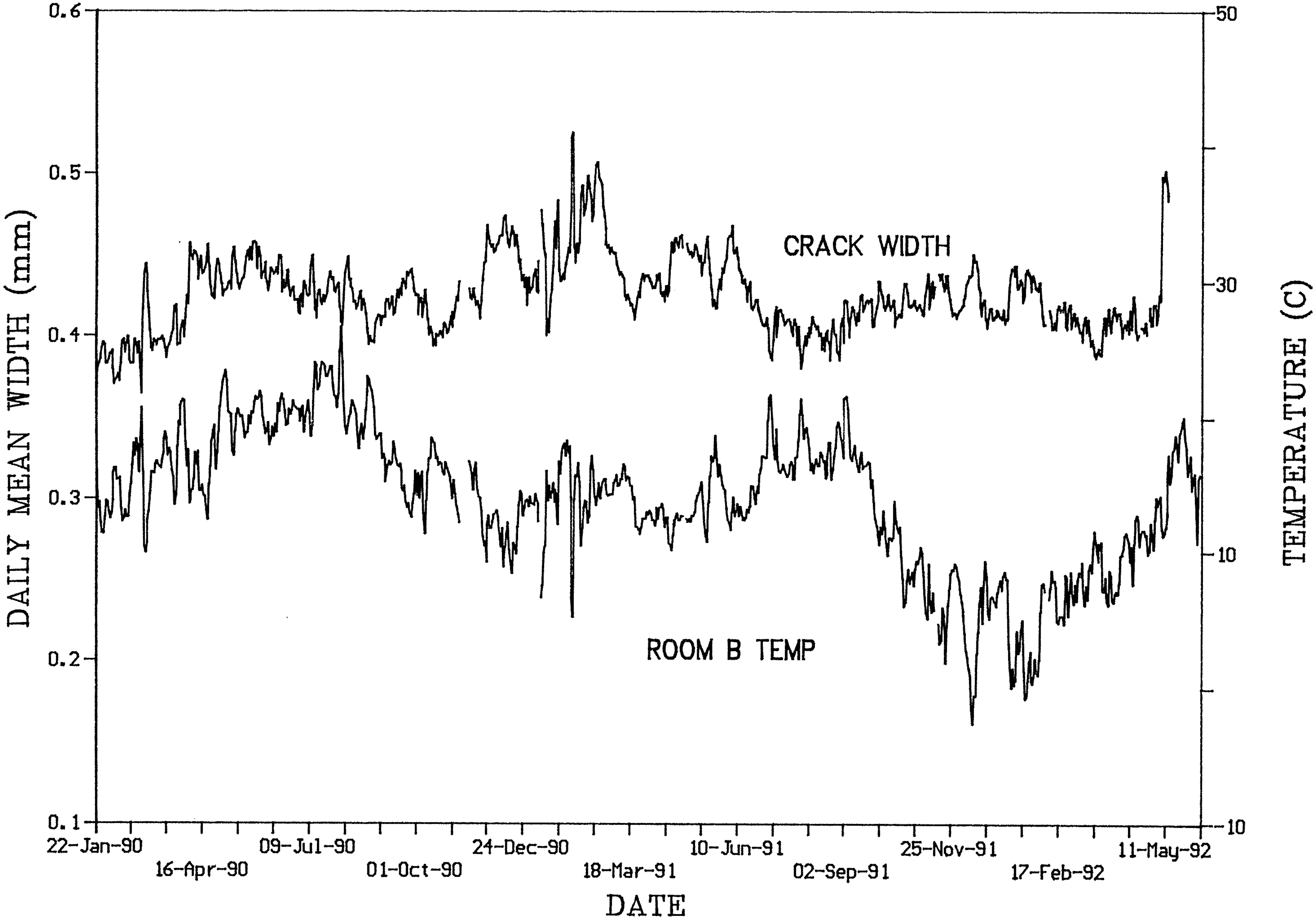
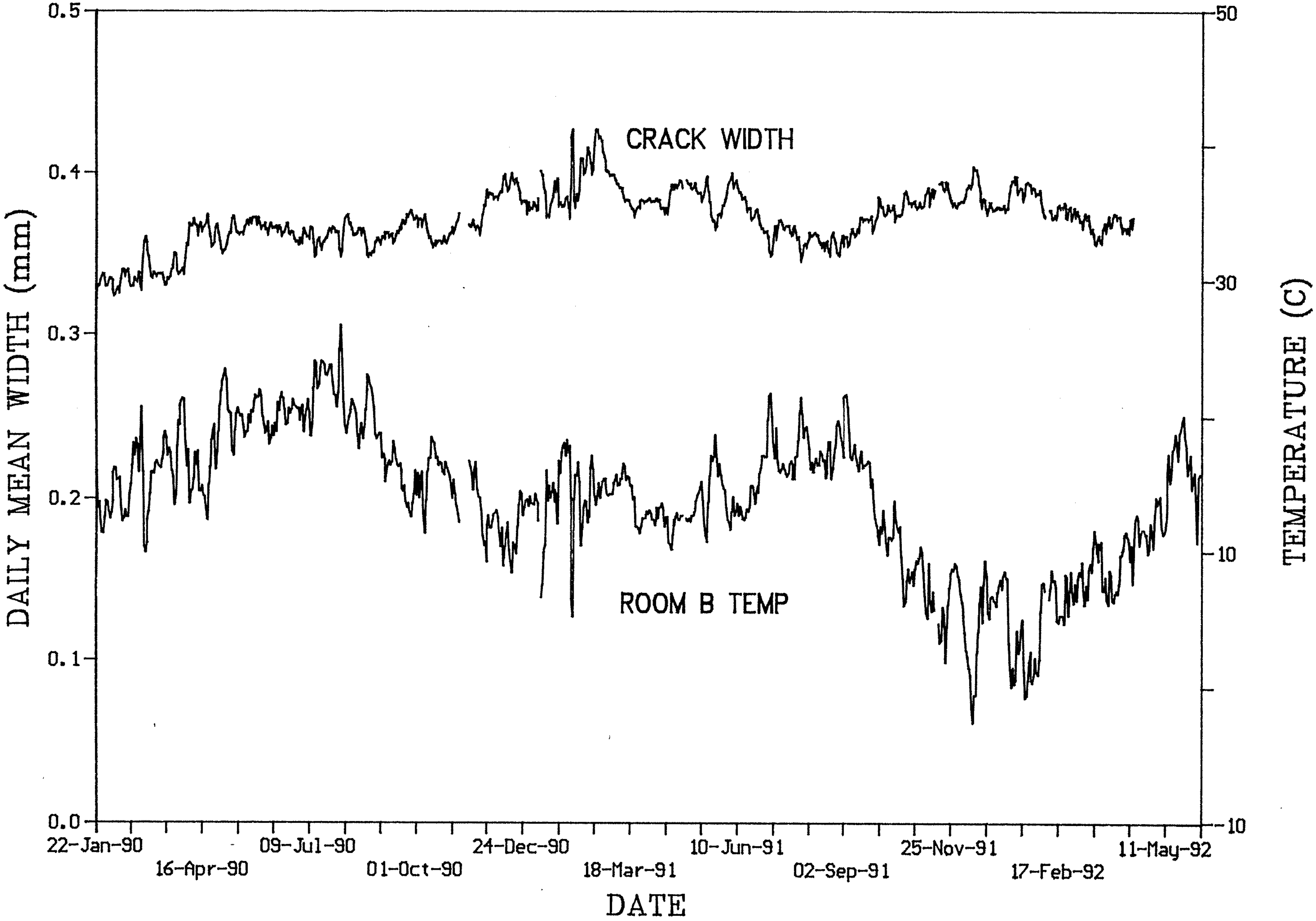


Fig. A.26 CRACK 9 – WALL B1



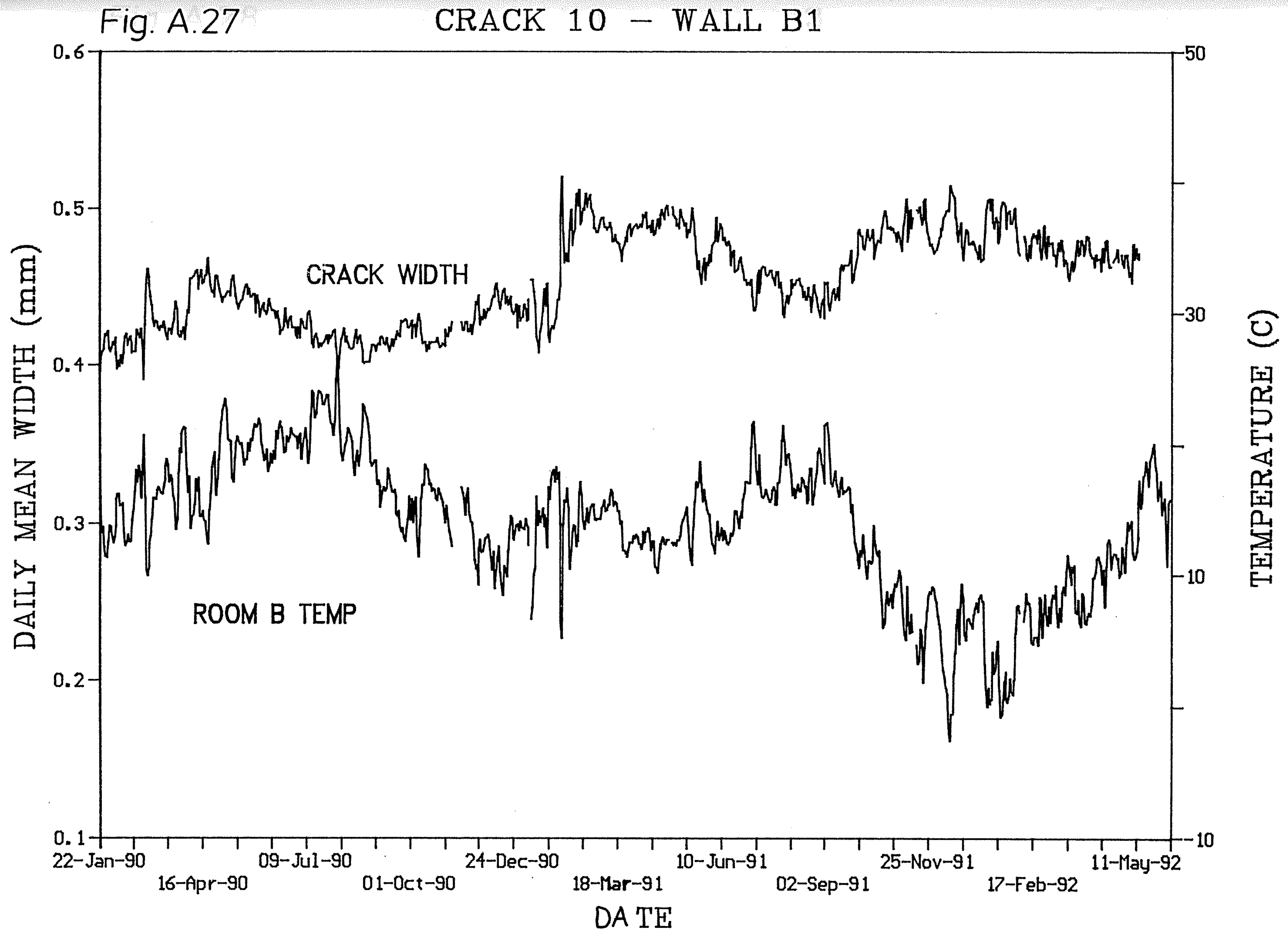
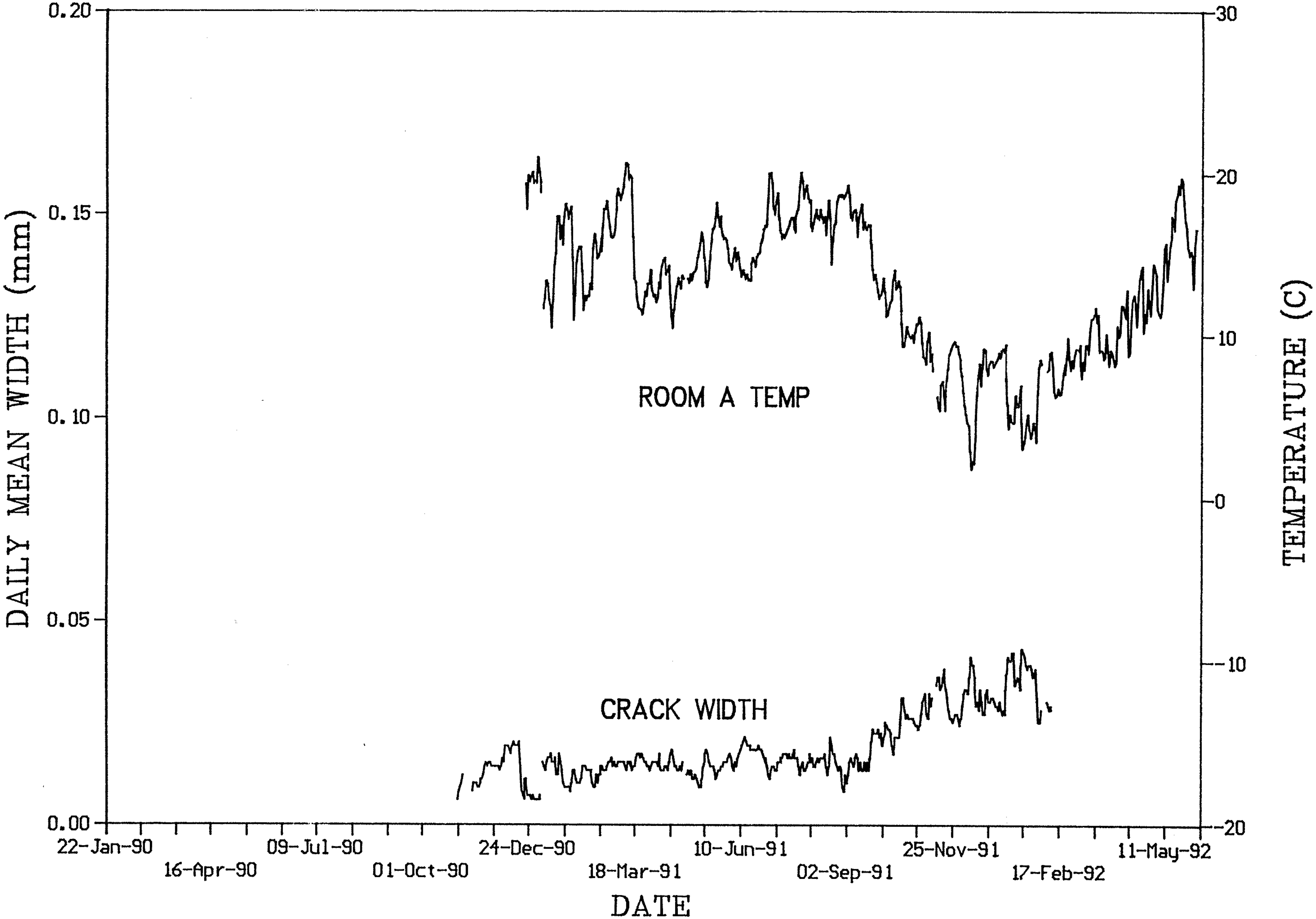


Fig. A.27
CRACK 10 — WALL B1
CRACK WIDTH
ROOM B TEMP
DAILY MEAN WIDTH (mm)
TEMPERATURE (C)
DATE
0.6
0.5
0.4
0.3
0.2
0.1
50
30
10
-10
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92

Fig. A.28 CRACK 11 — WALL A3



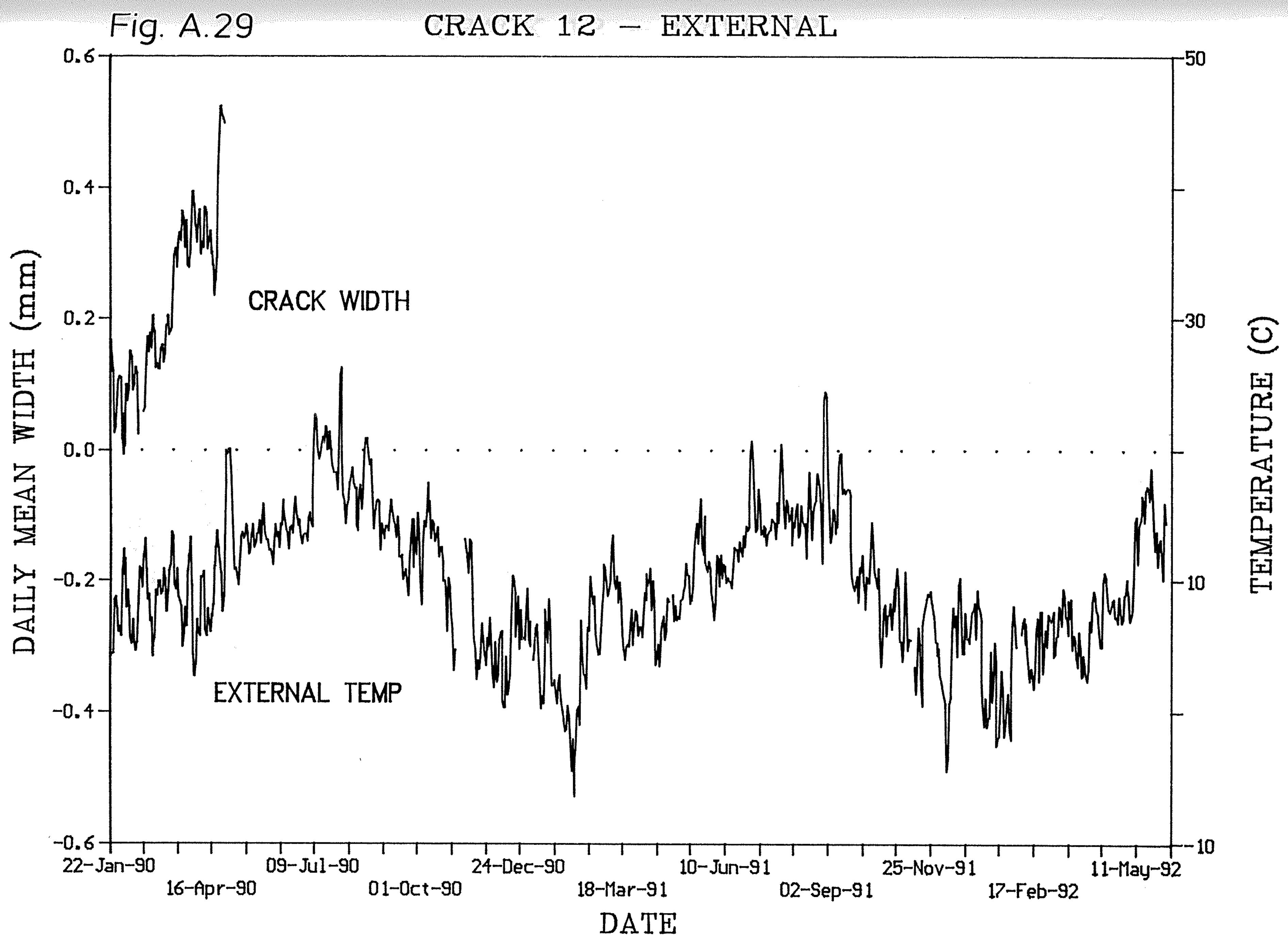


Fig. A.29
CRACK 12 — EXTERNAL
CRACK WIDTH
EXTERNAL TEMP
DAILY MEAN WIDTH (mm)
TEMPERATURE (C)
DATE
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
50
30
10
-10
22-Jan-90
16-Apr-90
09-Jul-90
01-Oct-90
24-Dec-90
18-Mar-91
10-Jun-91
02-Sep-91
25-Nov-91
17-Feb-92
11-May-92

Fig. A.30 CRACK 12 – WALL B2

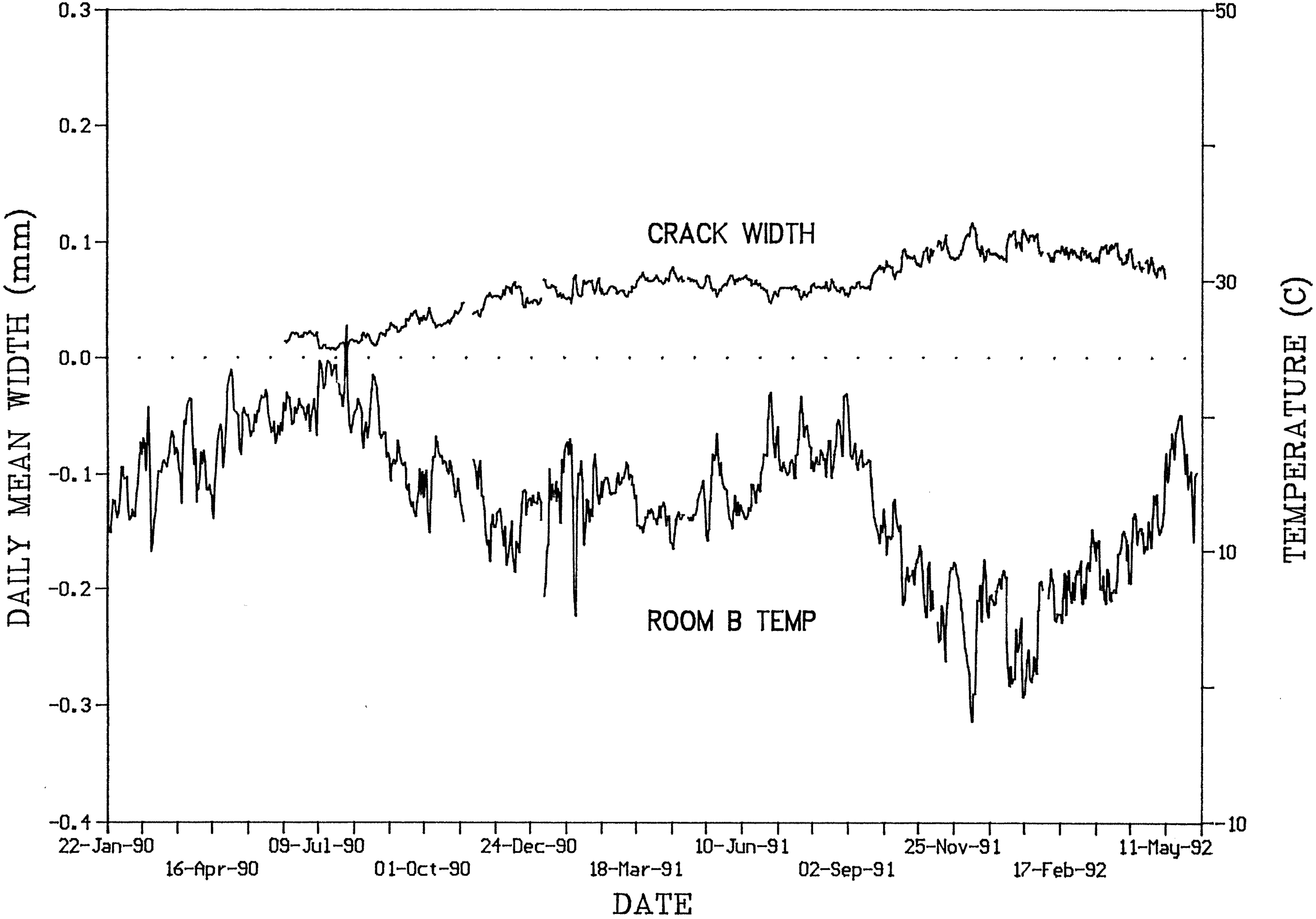


Table B.1.a

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
0006	0.59	0.88	0.73	1.02													
0009	0.56	0.63	0.78	0.82													
0010	0.44	0.83	0.78	1													
0011	0.44	0.27	0.59	0.78													
0012	0.57	0.85	0.71	1.01													
0013	0.37	0.56	0.73	0.81													
0014	0.37	0.42	0.59	0.65													
0015	0.76	0.93	0.88	1													
0018	0.34	1.12	0.63	1.13													
0019	0.34	0.44	0.54	0.59													
0020	0.37	0.42	0.29	0.58													
0021	0.17	0.27	0.2	0.28													
0024	0.29	0.29	0.29	0.35													
0025	0.44	0.56	0.42	0.57													
0026	0.34	0.51	0.27	0.58													
0027	0.17	0.34	0.17	0.4													
0029	0.37	0.37	0.54	0.61													
0030	0.49	0.49	0.54	0.58													
0031	0.39	0.44	0.34	0.45													
0032	0.27	0.42	0.24	0.44													
0034	0.63	1.25	1.1	1.5													
0037	0.37	0.85	0.29	0.87													
0038	0.44	0.59	0.49	0.63													
0039	0.29	0.54	0.54	0.59													
0040	0.46	1.1	0.61	1.22													
0041	0.37	0.68	0.44	0.73													
0042	0.63	0.49	0.61	0.74													
0043	0.51	0.98	0.61	1.12													
0044	0.51	0.78	0.42	0.8													
0045	0.51	1.03	0.61	1.11													
0046	0.32	0.61	0.56	0.67													
0047	0.17	0.42	0.27	0.48													
0048	0.42	0.9	0.56	1.04													
0049	0.42	0.32	0.46	0.54													
0050	0.39	0.68	0.76	0.77													
0057	0.32	0.85	0.51	0.95													
0058	0.24	0.61	0.39	0.65													
0060	0.2	0.27	0.32	0.39													
0061	0.2	0.29	0.32	0.36													
0062	0.49	0.93	0.78	1													
0063	0.39	0.63	0.56	0.73													
0065	0.29	0.59	0.68	0.92										121.4	no		
0066	0.37	0.51	0.61	0.77										109.5	yes		
0067	0.39	0.73	0.73	0.77										110.9	no		
0068	0.44	0.93	0.54	0.98										106.8	yes		
0070	0.22	0.32	0.34	0.37										105.4	yes		
0071	0.22	0.27	0.24	0.33													
0073	0.22	0.29	0.29	0.4										107.6	yes		
0076	0.24	0.44	0.27	0.49										101.7	yes		
0078	0.17	0.2	0.22	0.26										106.2	no		

Table B.1.b

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
0082	0.22	0.29	0.29	0.35										109.3	yes		
0084	0.17	0.29	0.22	0.38										111.8	yes		
0088	0.22	0.32	0.32	0.34	0.17	0.27	0.22	0.31						107.6	yes		
0089	0.2	0.32	0.17	0.34	0.22	0.34	0.15	0.39						100.6	yes		
0090	0.27	0.44	0.39	0.59	0.29	0.44	0.29	0.5						101.4	yes		
0091	0.2	0.29	0.27	0.39	0.17	0.22	0.29	0.32						111	yes		
0092	0.34	0.34	0.32	0.49	0.24	0.39	0.22	0.45						104.4	yes		
0093	0.34	0.63	0.44	0.64	0.34	0.56	0.34	0.57						114.7	yes		
0094	0.39	0.54	0.39	0.59	0.37	0.49	0.29	0.6						111	yes		
0099	0.22	0.46	0.42	0.47										110.9	yes		
0101	0.2	0.39	0.42	0.5										107.6	yes		
0104	0.22	0.44	0.27	0.45										105.6	yes		
0106	0.17	0.24	0.27	0.29										112.6	yes		
0110	0.2	0.24	0.24	0.35										103.3	yes		
0111	0.17	0.24	0.15	0.27										105.1	yes		
0112	0.17	0.42	0.22	0.43										106.8	yes		
0113	0.17	0.32	0.27	0.35	0.15	0.24	0.17	0.26						106.4	yes		
0116	0.59	0.88	0.95	0.98	0.54	0.85	0.44	0.93						116	no		
0117	0.24	0.29	0.22	0.36										108.6	no		
0118	0.49	0.63	0.51	0.9										114.8	no		
0119	0.42	0.59	0.46	0.79	0.32	0.46	0.39	0.56						111.9	yes		
0121	0.27	0.27	0.24	0.38	0.12	0.2	0.12	0.21						119.2	no		
0133	0.17	0.27	0.24	0.32										105.4	yes		
0134	0.39	0.51	0.39	0.59										110.2	yes		
0135	0.32	0.44	0.37	0.46										113.4	yes		
0139	0.17	0.17	0.24	0.26	0.17	0.12	0.17	0.2						103.3	yes		
0146	0.42	0.54	0.56	0.66	0.44	0.44	0.32	0.54						108.7	no		
0154	0.17	0.42	0.22	0.42										105.8	no		
0157	0.59	0.9	0.54	1.06	0.44	0.85	0.39	0.89						123	no		
0160	0.44	0.83	0.61	0.88										113.8	no		
0163					0.24	0.61	0.78	0.8									
0165	0.32	0.71	0.44	0.71										113.7	yes		
0166	0.17	0.27	0.22	0.31										107.2	yes		
0168	0.27	0.73	0.37	0.74										112.4	yes		
0169	0.42	0.46	0.49	0.5	0.39	0.51	0.29	0.57						109.2	yes		
0170	0.42	0.29	0.46	0.55	0.34	0.34	0.2	0.4						107.8	yes		
0171	0.2	0.39	0.24	0.46										120.6	no		
0172	0.39	0.63	1.03	1.09	0.34	0.44	0.49	0.61						107	yes		
0173	0.37	0.73	0.83	1.08	0.34	0.51	0.78	0.89						115.5	no		
0174	0.42	0.51	0.54	0.69	0.34	0.54	0.37	0.58						104.4	yes		
0175	0.2	0.44	0.24	0.46										107	yes		
0176	0.37	0.44	0.44	0.72	0.17	0.32	0.29	0.46						102.7	yes		
0177	0.29	0.32	0.37	0.43	0.2	0.34	0.34	0.45						101.7	yes		
0181	0.29	0.46	0.44	0.51	0.27	0.37	0.2	0.39						107.8	yes		
0182	0.27	0.44	0.27	0.48	0.17	0.37	0.12	0.39						120.9	no		
0183	0.2	0.22	0.24	0.3										106	yes		
0185	0.29	0.37	0.34	0.43										131.8	no		
0187	0.17	0.39	0.27	0.42										109.6	yes		
0188	0.17	0.27	0.27	0.38										118	no		
0189	0.22	0.49	0.37	0.54										108.7	yes		

Table B.1.c

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
0191	0.42	0.83	0.56	0.91										110.2	yes		
0192	0.17	0.29	0.27	0.34										110.3	yes		
0193	0.27	0.46	0.42	0.49										107.9	no		
0194	0.17	0.24	0.24	0.3										108.7	yes		
0195	0.22	0.39	0.29	0.43										104.1	no		
0197	0.2	0.22	0.24	0.27										107.4	yes		
0198	0.32	0.42	0.46	0.54										102.1	yes		
0199	0.2	0.34	0.34	0.45										116	no		
0200	0.39	0.61	0.46	0.64										128.3	no		
0201	0.24	0.24	0.29	0.32										109.3	no		
0202	0.2	0.54	0.34	0.54										110.9	no		
0203	0.22	0.34	0.24	0.43										110.4	yes		
0205	0.22	0.34	0.2	0.41										121.4	no		
0207	0.24	0.42	0.32	0.43										107	yes		
0208	0.22	0.32	0.29	0.36										106.6	no		
0210	0.29	0.46	0.42	0.54										109.3	yes		
0211	0.27	0.42	0.32	0.55										106.8	yes		
0212	0.17	0.24	0.27	0.35										106.4	yes		
0213	0.39	0.46	0.68	0.71	0.42	0.42	0.51	0.53						112.5	yes		
0214	0.63	1.07	0.88	1.18	0.78	1.12	0.73	1.34						111.8	yes		
0215	0.44	0.98	0.44	1.03	0.51	0.98	0.39	1.04						109	yes		
0216	0.32	0.39	0.37	0.44	0.2	0.44	0.17	0.44						101.4	no		
0217	0.32	0.51	0.34	0.61	0.27	0.39	0.22	0.4						103.3	no		
0218	0.27	0.37	0.42	0.49	0.22	0.46	0.29	0.49						107.2	yes		
0219					0.17	0.2	0.17	0.27									
0220	0.29	0.37	0.29	0.39	0.17	0.39	0.2	0.43						103.9	yes		
0221	0.34	0.49	0.39	0.56	0.27	0.51	0.39	0.56						108.3	yes		
0222	0.2	0.39	0.2	0.4										108.4	yes		
0223	0.17	0.32	0.22	0.36										123.9	no		
0224	0.2	0.29	0.17	0.3	0.17	0.24	0.15	0.25						105.6	yes		
0225	0.42	0.88	0.63	1.07	0.39	0.81	0.54	0.99						101.4	yes		
0226	0.44	0.73	0.46	0.79	0.42	0.68	0.44	0.76						109	yes		
0227	0.22	0.51	0.22	0.54	0.29	0.46	0.2	0.51						103	yes		
0228	0.49	0.9	0.81	0.99	0.51	0.71	0.73	0.94						106	yes		
0229	0.22	0.34	0.29	0.36										109.8	yes		
0237					0.24	0.49	0.32	0.53									
0240	0.24	0.34	0.32	0.37	0.22	0.24	0.27	0.35						124.6	no		
0241	0.17	0.32	0.32	0.36	0.24	0.24	0.29	0.31						114.4	no		
0244	0.24	0.42	0.22	0.46										111.9	no		
0245	0.22	0.37	0.24	0.4	0.37	0.39	0.22	0.47						115.4	no		
0246	0.2	0.32	0.2	0.33										123.8	no		
0247	0.29	0.42	0.27	0.45										122.5	no		
0248	0.51	0.88	0.95	1.01	0.49	0.85	0.61	0.86						107.4	no		
0249	0.22	0.56	0.34	0.57	0.17	0.12	0.12	0.14						127.1	no		
0250	0.24	0.49	0.34	0.51	0.22	0.39	0.22	0.45						129.7	no		
0252	0.51	1.39	0.73	1.51	0.61	1.15	0.76	1.15						115.4	no		
0254	0.17	0.24	0.2	0.27										114	yes		
0257	0.2	0.27	0.27	0.33										113	no		
0258	0.51	0.81	0.68	0.92	0.54	0.85	0.61	0.89						118	no		
0261	0.78	1.05	0.85	1.16	0.71	0.95	0.66	1.06						118.8	no		

Table B.1.d

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0263	0.17	0.29	0.27	0.31										119.1	no		
0264	0.22	0.49	0.34	0.56	0.2	0.39	0.2	0.44						111.3	no		
0266	0.42	0.46	0.54	0.64	0.49	0.59	0.27	0.63						105.8	no		
0267	0.17	0.24	0.27	0.33										120.3	no		
0268	0.32	0.46	0.37	0.49	0.27	0.34	0.27	0.42						112	no		
0269	0.22	0.29	0.32	0.38										120.5	no		
0270	0.44	0.51	0.54	0.6	0.46	0.42	0.22	0.48						113.7	no		
0271	0.46	0.51	0.59	0.63	0.39	0.56	0.34	0.6						128.1	no		
0272	0.29	0.51	0.34	0.6	0.37	0.61	0.24	0.68						120	no		
0273	0.44	0.71	0.51	0.8	0.34	0.61	0.34	0.67						125.6	no		
0274	0.34	0.63	0.59	0.64	0.37	0.76	0.32	0.77						119.2	no		
0275	0.49	0.42	0.29	0.6	0.39	0.56	0.17	0.57						121.6	no		
0276	0.2	0.2	0.24	0.29	0.15	0.22	0.17	0.23						111	yes		
0277	0.22	0.54	0.32	0.57	0.17	0.42	0.24	0.42									
0278	0.27	0.49	0.34	0.55	0.22	0.44	0.22	0.45						104.7	no		
0279	0.17	0.32	0.2	0.33										124.4	no		
0280	0.24	0.32	0.42	0.43													
0281	0.17	0.34	0.2	0.37										117.4	no		
0282	0.2	0.27	0.27	0.32	0.22	0.37	0.15	0.37									
0283	0.24	0.42	0.37	0.45										106.8	no		
0285	0.29	0.56	0.17	0.59										108.3	no		
0286	0.61	0.49	0.61	0.97	0.42	0.51	0.39	0.69						111.7	yes		
0287	0.34	0.46	0.39	0.52	0.27	0.46	0.27	0.49						104.7	yes		
0288	0.34	0.29	0.34	0.4	0.27	0.22	0.2	0.29									
0289	0.24	0.29	0.24	0.29	0.15	0.24	0.15	0.25									
0290	0.32	0.37	0.34	0.48	0.24	0.27	0.2	0.31									
0291	0.15	0.32	0.22	0.39													
0292	0.22	0.27	0.37	0.38	0.2	0.34	0.29	0.39						112.8	no		
0293	0.22	0.46	0.32	0.5										114.8	no		
0294	0.61	0.93	0.73	1.1	0.61	0.95	0.51	0.97						122.9	no		
0295	0.2	0.29	0.27	0.32	0.2	0.34	0.15	0.35						120.8	no		
0296	0.61	0.76	0.78	0.96	0.51	0.95	0.46	0.98						120.7	no		
0298	0.37	0.51	0.49	0.67	0.42	0.61	0.27	0.64						117.7	no		
0299	0.51	0.51	0.71	0.8	0.54	0.46	0.42	0.55						110	yes		
0301	0.39	0.51	0.46	0.55	0.34	0.46	0.29	0.54						112.3	yes		
0303	0.17	0.51	0.27	0.53										114	yes		
0305	0.61	0.73	0.51	0.83										114.4	no		
0306	0.29	0.66	0.49	0.75										124.1	no		
0307	0.17	0.39	0.15	0.43										130.6	no		
0308	0.24	0.37	0.34	0.4										104.9	yes		
0310	0.34	0.54	0.73	0.75										106.8	yes		
0311	0.22	0.32	0.24	0.35										125.3	yes		
0313	0.2	0.42	0.24	0.43										107.9	yes		
0315	0.42	0.37	0.56	0.67										110	yes		
0317	0.27	0.37	0.44	0.56										113.2	no		
0324	0.44	0.61	0.51	0.72										111.7	no		
0325	0.17	0.37	0.17	0.37										115.7	no		
0326	0.54	0.68	0.56	0.81										120.8	no		
0327	0.54	0.85	0.59	0.94										124.7	no		
0328	0.24	0.63	0.32	0.73										108.7	no		

Table B.1.e

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0329	0.29	0.66	0.39	0.68										115.4	no		
0330	0.34	0.56	0.42	0.61													
0331	0.54	0.93	0.63	1.01	0.64	1.03	0.42	1.15						113.9	yes		
0332	0.34	1.03	0.56	1.09										114.8	no		
0333	0.29	0.61	0.49	0.66										113.4	no		
0334	0.46	0.9	0.49	0.91										115.3	no		
0335	0.22	0.29	0.27	0.34										109.2	yes		
0337	0.49	0.63	0.51	0.71										114.9	no		
0338	0.22	0.49	0.27	0.53										109.6	no		
0340	0.17	0.29	0.24	0.37										120.9	no		
0342	0.42	0.81	0.51	0.94										109	no		
0345	0.22	0.56	0.24	0.62										107	no		
0346	0.24	0.29	0.24	0.37										113.9	no		
0347	0.27	0.54	0.34	0.55										110.2	yes		
0348	0.24	0.39	0.34	0.46										116	no		
0349	0.54	0.66	0.71	0.83	0.66	0.71	0.66	0.72						110.4	no		
0351	0.37	0.46	0.42	0.49										127.6	no		
0353	0.34	0.39	0.59	0.66										117.4	no		
0356	0.24	0.39	0.29	0.43										108.3	no		
0357	0.24	0.39	0.29	0.43										108.3	no		
0358	0.29	0.54	0.46	0.57										120.5	no		
0360	0.2	0.37	0.32	0.41										115.1	no		
0361	0.2	0.37	0.32	0.41										115.1	no		
0363	0.2	0.42	0.37	0.52										124.9	no		
0364	0.27	0.63	0.42	0.66										124.4	no		
0368	0.34	0.59	0.46	0.71										127.3	no		
0370	0.51	0.61	0.51	0.71	0.54	0.71	0.29	0.71						114.1	no		
0372	0.37	0.95	0.63	1.02										113.1	yes		
0377					0.44	0.76	0.39	0.84									
0383	0.22	0.34	0.32	0.36	0.22	0.27	0.2	0.29						106.2	yes		
0384	0.17	0.24	0.27	0.33										105.4	yes		
0386	0.22	0.29	0.22	0.33	0.15	0.24	0.15	0.26						108.3	no		
0387																	
0389	0.27	0.44	0.34	0.58													
0393	0.56	1.1	0.83	1.26	0.61	0.88	0.71	0.93						109.9	yes		
0395	0.56	0.78	0.85	0.96	0.54	0.98	0.61	1.08									
0396	0.44	0.61	0.56	0.72	0.42	0.76	0.42	0.76						109.6	yes		
0398	0.29	0.34	0.32	0.4										104.9	no		
0399	0.34	0.59	0.39	0.68										127.8	no		
0400	0.27	0.24	0.2	0.3													
0401	0.56	0.63	0.61	0.68													
0402	0.42	0.68	0.66	0.81	0.39	0.71	0.61	0.75									
0403	0.27	0.54	0.34	0.62													
0404	0.22	0.22	0.24	0.37													
0406	0.34	0.46	0.27	0.54													
0407	0.22	0.39	0.29	0.43													
0408	0.54	1.05	0.54	1.2	0.44	1.05	0.44	1.09									
0410	0.22	0.44	0.46	0.47													
0413	0.42	0.73	0.49	0.87					DOOR	0.42		0.42					
0417	0.22	0.44	0.29	0.48													

Table B.1.f

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
0418	0.56	0.51	0.32	0.67	0.27	0.56	0.2	0.57	DOOR	0.42		0.22					
0420	0.34	0.32	0.22	0.38	0.22	0.42	0.24	0.42	DOOR	0.42		0.49					
0421	0.34	0.49	0.46	0.52													
0422	0.39	1.15	0.51	1.23	0.51	1.05	0.42	1.05	DOOR	0.54		0.51					
0423									DOOR	0.39		0.42					
0424	0.32	1.05	0.34	1.07					DOOR	0.39		0.37					
0425	0.34	0.63	0.39	0.7													
0426	0.27	0.42	0.32	0.53													
0427	0.2	0.32	0.22	0.33													
0433	0.42	0.49	0.54	0.68					DOOR	0.42		0.49					
0434	0.42	0.63	0.44	0.7													
0436	0.54	0.71	0.73	0.8	0.56	0.54	0.64	0.76	DOOR	0.61		0.68					
0445	0.15	0.29	0.39	0.41													
0446	0.17	0.42	0.22	0.43													
0447	0.24	0.81	0.42	0.82													
0449	0.17	0.51	0.24	0.54													
0455	0.17	0.46	0.22	0.47													
0457	0.17	0.24	0.27	0.29													
0461	0.15	0.27	0.24	0.34													
0462	0.27	0.61	0.34	0.63													
0463	0.2	0.51	0.27	0.54													
0464	0.17	0.17	0.27	0.28													
0471	0.15	0.39	0.34	0.51													
0475	0.32	0.73	0.42	0.85													
0476	0.34	0.59	0.51	0.62													
0477	0.17	0.37	0.27	0.38													
0478	0.2	0.44	0.27	0.44													
0481	0.29	0.49	0.42	0.54					DOOR	0.42		0.44					
0484	0.32	0.71	0.49	0.77					DOOR	0.39		0.42					
0487	0.24	0.44	0.27	0.56													
0491	0.34	0.42	0.39	0.5													
0494	0.44	0.71	0.49	0.77													
0495	0.37	0.39	0.39	0.42													
0496	0.17	0.24	0.24	0.36													
0498	0.51	0.88	0.61	0.99													
0500	0.24	0.37	0.39	0.5													
0502	0.15	0.24	0.2	0.31													
0504	0.29	0.37	0.42	0.5													
0505	0.54	0.63	0.54	0.75													
0507	0.37	0.56	0.44	0.58													
0508	0.63	0.85	0.63	0.87	0.54	0.85	0.44	0.87									
0509	0.24	0.49	0.32	0.57													
0510	0.59	0.54	0.63	0.73	0.44	0.46	0.44	0.54									
0511	0.24	0.51	0.39	0.57													
0512	0.29	0.42	0.32	0.47													
0513	0.2	0.32	0.32	0.42													
0514	0.76	1.07	0.66	1.28	0.68	1.03	0.56	1.19									
0515	0.49	0.71	0.54	0.78													
0516	0.27	0.56	0.39	0.66													
0517	0.27	0.39	0.24	0.46													

Table B.1.g

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0519	0.51	0.78	0.59	0.9													
0521	0.24	0.37	0.34	0.38													
0523	0.2	0.34	0.15	0.39													
0525	0.22	0.44	0.39	0.45													
0526	0.22	0.44	0.39	0.45													
0528	0.46	0.44	0.42	0.55													
0529	0.42	0.56	0.59	0.71					DOOR	0.39		0.59					
0532	0.27	0.39	0.27	0.4													
0533	0.27	0.42	0.24	0.46													
0538									DOOR	0.39		0.54					
0539	0.34	0.68	0.59	0.7													
0546	0.44	0.85	0.88	1	0.51	0.71	0.51	0.84	DOOR	0.59		0.56		110.9	yes		
0548	0.66	1.27	0.78	1.3	0.54	1.15	0.73	1.15	DOOR	0.56		0.68		128.4	no		
0550	0.49	0.83	0.78	0.86	0.49	0.88	0.54	0.93	DOOR	0.51		0.56		126.1	no		
0551	0.27	0.42	0.51	0.56										117.5	no		
0560	0.37	0.39	0.71	0.75													
0563	0.42	1	0.76	1.05	0.46	0.9	0.73	0.93	DOOR	0.51		0.68		125.6	no		
0564	0.24	0.63	0.42	0.67										129.3	no		
0566	0.2	0.22	0.27	0.28										126.2	no		
0567	0.27	0.83	0.46	0.84													
0569	0.2	0.32	0.22	0.35													
0575	0.24	0.34	0.29	0.4										118.7	no		
0577	0.2	0.17	0.22	0.29										117.1	no		
0581	0.15	0.42	0.42	0.49										112.3	no		
0584	0.29	0.49	0.39	0.57										126.3	no		
0586	0.2	0.42	0.32	0.45										121.7	no		
0587	0.42	1.03	0.56	1.07										110	yes		
0591	0.37	0.68	0.54	0.76					DOOR	0.42		0.34		134.2	no		
0593	0.39	0.78	0.71	0.8					DOOR	0.51		0.46		130.8	no		
0595	0.44	0.61	0.83	0.91					DOOR	0.49		0.76		119.5	no		
0598	0.17	0.17	0.15	0.19													
0608	0.29	0.66	0.49	0.81													
0612	0.17	0.51	0.32	0.6													
0614	0.34	0.54	0.27	0.57					DOOR	0.39		0.24					
0615	0.17	0.32	0.29	0.38													
0616	0.42	0.93	0.51	1.05					DOOR	0.39		0.32					
0617	0.32	0.83	0.32	0.88					DOOR	0.34	0.85	0.27	0.91				
0647	0.17	0.46	0.22	0.5													
0650	0.2	0.78	0.34	0.81													
0660	0.17	0.15	0.15	0.19													
0661	0.2	0.51	0.17	0.57													
0667	0.17	0.37	0.34	0.49													
0673	0.15	0.32	0.24	0.34													
0677	0.15	0.22	0.22	0.27													
0678					0.22	0.27	0.22	0.28									
0683	0.22	0.49	0.32	0.51	0.24	0.44	0.22	0.46									
0686	0.15	0.29	0.2	0.31													
0687	0.15	0.27	0.27	0.37	0.2	0.2	0.2	0.25									
0688	0.2	0.49	0.27	0.51	0.27	0.59	0.22	0.64									
0689	0.29	0.51	0.29	0.57	0.34	0.56	0.27	0.62									

Table B.1.h

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0691					0.2	0.46	0.15	0.48									
0695					0.22	0.27	0.22	0.3									
0699	0.2	0.2	0.22	0.28													
0700	0.2	0.32	0.24	0.35	0.22	0.32	0.15	0.32									
0701					0.15	0.24	0.17	0.28									
0703					0.27	0.34	0.24	0.38									
0704	0.29	0.56	0.46	0.62	0.37	0.46	0.27	0.48									
0706	0.34	0.51	0.39	0.59	0.44	0.39	0.29	0.47									
0707	0.34	0.39	0.44	0.54	0.34	0.29	0.24	0.37									
0709	0.17	0.17	0.22	0.24													
0717	0.2	0.44	0.24	0.5													
0719	0.17	0.29	0.22	0.33													
0723	0.37	0.34	0.42	0.53	0.39	0.49	0.27	0.53	DOOR	0.42	0.37	0.27	0.43				
0727	0.27	0.44	0.32	0.5	0.32	0.42	0.2	0.43	DOOR	0.29	0.34	0.2	0.39				
0728					0.17	0.17	0.15	0.18									
0729	0.2	0.15	0.17	0.23													
0730	0.2	0.37	0.24	0.44													
0732	0.17	0.39	0.24	0.43													
0733	0.32	0.49	0.46	0.63	0.46	0.39	0.34	0.51	DOOR	0.44	0.37	0.37	0.5				
0735	0.22	0.34	0.51	0.53	0.29	0.44	0.32	0.53	DOOR	0.27	0.39	0.27	0.45				
0736					0.22	0.24	0.1	0.26									
0737	0.17	0.44	0.22	0.46													
0738	0.2	0.46	0.22	0.47													
0741	0.22	0.29	0.34	0.41	0.2	0.27	0.27	0.39									
0742	0.27	0.32	0.22	0.35	0.27	0.24	0.15	0.28	DOOR	0.24	0.24	0.15	0.27				
0743	0.17	0.27	0.27	0.35	0.15	0.29	0.22	0.31									
0746	0.17	0.27	0.15	0.27													
0747	0.24	0.42	0.29	0.53													
0748	0.15	0.24	0.17	0.26													
0750	0.2	0.42	0.27	0.45													
0752	0.2	0.44	0.39	0.5													
0754	0.27	0.42	0.51	0.54	0.24	0.32	0.44	0.46	DOOR	0.27	0.29	0.51	0.54				
0755	0.27	0.24	0.29	0.35	0.37	0.27	0.2	0.4	DOOR	0.29	0.22	0.22	0.33				
0760	0.22	0.63	0.22	0.66					DOOR	0.27	0.68	0.22	0.72				
0766	0.17	0.12	0.2	0.21													
0767	0.34	0.66	0.54	0.8					DOOR	0.37	0.39	0.39	0.54				
0769																	
0770	0.22	0.2	0.37	0.37													
0775					0.2	0.29	0.15	0.31									
0779	0.22	0.37	0.22	0.39													
0781	0.37	0.32	0.27	0.37	0.32	0.32	0.17	0.35	DOOR	0.37	0.24	0.15	0.37				
0782																	
0788	0.22	0.24	0.24	0.3	0.32	0.29	0.12	0.34									
0797																	
0798	0.2	0.29	0.24	0.3	0.2	0.32	0.2	0.33									
0801	0.27	0.32	0.29	0.42	0.34	0.39	0.22	0.4	DOOR	0.34	0.34	0.15	0.37				
0806																	
0808					0.22	0.46	0.15	0.49									
0809																	
0813					0.29	0.46	0.24	0.5	DOOR	0.29	0.39	0.2	0.42				

Table B.1.i

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0817					0.29	0.39	0.17	0.42	DOOR	0.32	0.32	0.17	0.33				
0820					0.2	0.2	0.24	0.28									
0825					0.34	0.42	0.29	0.43	DOOR	0.34	0.37	0.27	0.45				
0835					0.32	0.57	0.29	0.59	DOOR	0.32	0.49	0.32	0.5				
0838									DOOR	0.29	0.32	0.22	0.39				
0839					0.27	0.24	0.2	0.34	DOOR	0.29	0.2	0.17	0.32				
0869	0.17	0.27	0.17	0.33										105.4	yes		
0873	0.17	0.17	0.12	0.22										104.7	no		
0876	0.24	0.32	0.22	0.35	0.2	0.27	0.2	0.35	DOOR	0.24	0.29	0.2	0.34	107.9	yes		
0882	0.17	0.29	0.24	0.34										105.4	no		
0887	0.22	0.27	0.24	0.32	0.24	0.27	0.24	0.28	DOOR	0.24	0.29	0.22	0.33				
0893	0.39	0.49	0.39	0.55	0.49	0.46	0.34	0.57	DOOR	0.46	0.49	0.34	0.56				
0894	0.34	0.32	0.29	0.41					DOOR	0.37	0.34	0.32	0.43				
0895	0.34	0.34	0.32	0.39	0.32	0.39	0.24	0.4	DOOR	0.32	0.32	0.24	0.38				
0903	0.22	0.24	0.27	0.36													
0909	0.22	0.22	0.15	0.27	0.2	0.2	0.12	0.21									
0918	0.2	0.22	0.37	0.4													
0919	0.17	0.37	0.32	0.43													
0923	0.17	0.27	0.44	0.46													
0924	0.2	0.39	0.22	0.47	0.2	0.42	0.2	0.47		0.24	0.44	0.2	0.51				
0926	0.27	0.39	0.32	0.45	0.32	0.37	0.2	0.39	DOOR	0.32	0.27	0.2	0.33				

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
0931	0.27	0.44	0.42	0.51													
0932	0.2	0.2	0.24	0.25	0.17	0.15	0.12	0.22									
0934	0.2	0.42	0.34	0.46													
0936	0.2	0.37	0.27	0.39													
0938	0.17	0.37	0.27	0.41													
0940									DOOR	0.32	0.39	0.32	0.4				
0942	0.17	0.22	0.32	0.35													
0944	0.17	0.42	0.27	0.45	0.2	0.44	0.24	0.45									
0945	0.29	0.32	0.42	0.55	0.37	0.37	0.22	0.46	DOOR	0.34	0.29	0.27	0.39				
0950	0.34	1.1	0.56	1.15	0.42	0.83	0.44	0.87	DOOR	0.29	0.85	0.39	0.9				
0952	0.17	0.29	0.27	0.34													
0961	0.24	0.54	0.29	0.61	0.22	0.44	0.27	0.47	DOOR	0.24	0.34	0.27	0.42				
0967	0.17	0.32	0.24	0.33													
0979	0.2	0.29	0.29	0.4													
0987	0.17	0.37	0.27	0.39	0.27	0.34	0.24	0.38									
0991	0.17	0.17	0.1	0.18													
1009	0.22	0.27	0.27	0.33	0.27	0.24	0.27	0.3	DOOR	0.27	0.22	0.22	0.28				
1011	0.22	0.24	0.39	0.42	0.2	0.27	0.39	0.39									
1012	0.2	0.32	0.37	0.42													
1019	0.15	0.24	0.15	0.26													
1021	0.17	0.34	0.2	0.36													
1023	0.22	0.42	0.22	0.45													
1024	0.17	0.27	0.22	0.39													
1030	0.2	0.37	0.34	0.42													
1033	0.17	0.27	0.27	0.31	0.32	0.29	0.15	0.33	DOOR	0.29	0.27	0.15	0.3				

Table B.1.j

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
0931	0.27	0.44	0.42	0.51													
0932	0.2	0.2	0.24	0.25	0.17	0.15	0.12	0.22									
0934	0.2	0.42	0.34	0.46													
0936	0.2	0.37	0.27	0.39													
0938	0.17	0.37	0.27	0.41													
0940									DOOR	0.32	0.39	0.32	0.4				
0942	0.17	0.22	0.32	0.35													
0944	0.17	0.42	0.27	0.45	0.2	0.44	0.24	0.45									
0945	0.29	0.32	0.42	0.55	0.37	0.37	0.22	0.46	DOOR	0.34	0.29	0.27	0.39				
0950	0.34	1.1	0.56	1.15	0.42	0.83	0.44	0.87	DOOR	0.29	0.85	0.39	0.9				
0952	0.17	0.29	0.27	0.34													
0961	0.24	0.54	0.29	0.61	0.22	0.44	0.27	0.47	DOOR	0.24	0.34	0.27	0.42				
0967	0.17	0.32	0.24	0.33													
0979	0.2	0.29	0.29	0.4													
0987	0.17	0.37	0.27	0.39	0.27	0.34	0.24	0.38									
0991	0.17	0.17	0.1	0.18													
1009	0.22	0.27	0.27	0.33	0.27	0.24	0.27	0.3	DOOR	0.27	0.22	0.22	0.28				
1011	0.22	0.24	0.39	0.42	0.2	0.27	0.39	0.39									
1012	0.2	0.32	0.37	0.42													
1019	0.15	0.24	0.15	0.26													
1021	0.17	0.34	0.2	0.36													
1023	0.22	0.42	0.22	0.45													
1024	0.17	0.27	0.22	0.39													
1030	0.2	0.37	0.34	0.42													
1033	0.17	0.27	0.27	0.31	0.32	0.29	0.15	0.33	DOOR	0.29	0.27	0.15	0.3				
1034	0.17	0.24	0.2	0.27													
1050	0.24	0.37	0.29	0.4													
1051	0.22	0.44	0.29	0.49													
1052	0.24	0.61	0.49	0.74	0.29	0.49	0.44	0.66									
1053	0.2	0.17	0.22	0.26													
1054	0.17	0.37	0.29	0.42													
1056	0.29	0.34	0.49	0.51	0.34	0.42	0.37	0.49									
1065	0.2	0.22	0.2	0.33													
1066	0.22	0.29	0.44	0.46													
1067	0.24	0.39	0.37	0.43	0.27	0.39	0.34	0.4									
1079	0.17	0.24	0.32	0.35													
1080	0.22	0.42	0.39	0.48					DOOR	0.29	0.44	0.32	0.46				
1090	0.17	0.17	0.15	0.23													
1094	0.27	0.49	0.42	0.53	0.29	0.46	0.37	0.47									
1095	0.22	0.46	0.24	0.47	0.29	0.37	0.27	0.4	DOOR	0.27	0.49	0.22	0.5				
1096	0.17	0.37	0.39	0.52													
1099	0.2	0.29	0.27	0.32													
1100	0.17	0.24	0.15	0.28													
1104	0.22	0.42	0.27	0.46													
1105	0.29	0.59	0.54	0.83													
1106	0.32	0.44	0.42	0.59					DOOR	0.29	0.39	0.39	0.53				
1108	0.2	0.34	0.39	0.51													
1111	0.2	0.27	0.32	0.38													
1113	0.29	0.56	0.44	0.64					DOOR	0.29	0.51	0.42	0.55				
1114	0.27	0.42	0.29	0.58													

Table B.1.k

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
1115	0.17	0.37	0.42	0.51													
1119	0.17	0.22	0.22	0.24													
1123	0.24	0.68	0.49	0.72													
1124	0.24	0.34	0.49	0.52													
1133	0.2	0.24	0.24	0.32													
1145	0.17	0.22	0.22	0.27													
1148	0.17	0.24	0.15	0.26													
1157									DOOR	0.27	0.56	0.34	0.67				
1162	0.17	0.37	0.34	0.43													
1163	0.29	0.37	0.34	0.41													
1166	0.22	0.37	0.29	0.39													
1168	0.17	0.27	0.32	0.4													
1180	0.24	0.56	0.51	0.62													
1181	0.27	0.34	0.37	0.47					DOOR	0.29	0.36	0.32	0.42				
1183	0.22	0.37	0.32	0.44													
1189	0.17	0.27	0.24	0.3													
1190	0.17	0.42	0.42	0.47													
1197									DOOR	0.29	0.34	0.22	0.39				
1198	0.27	0.42	0.37	0.53													
1199	0.22	0.34	0.32	0.48													
1202	0.17	0.24	0.32	0.32													
1203	0.22	0.39	0.49	0.53													
1206	0.71	0.37	0.2	0.38													
1207	0.2	0.29	0.27	0.35													
1208	0.2	0.22	0.27	0.28													
1209	0.2	0.34	0.32	0.46													
1210	0.2	0.27	0.37	0.38													
1211	0.17	0.17	0.2	0.21													
1212	0.17	0.24	0.27	0.31													
1215	0.24	0.29	0.22	0.31													
1216	0.17	0.22	0.29	0.3													
1217	0.17	0.15	0.27	0.27													
1218	0.2	0.15	0.17	0.24													
1219	0.22	0.64	0.51	0.67					DOOR	0.32	0.49	0.42	0.5				
1220	0.17	0.39	0.37	0.52													
1221	0.17	0.22	0.32	0.36													
1222	0.17	0.27	0.46	0.48													
1244	0.17	0.27	0.17	0.3													
1249	0.22	0.39	0.29	0.42													
1259	0.22	0.29	0.37	0.41					DOOR	0.27	0.34	0.37	0.48				
1261	0.2	0.34	0.34	0.39													
1266	0.17	0.27	0.17	0.34													
1270	0.2	0.27	0.22	0.34													
1271	0.17	0.24	0.27	0.3													
1275	0.2	0.29	0.27	0.31													
1277	0.17	0.15	0.12	0.21													
1289	0.17	0.24	0.22	0.31													
1291	0.17	0.22	0.32	0.37													
1292	0.17	0.32	0.24	0.33													
1301	0.17	0.2	0.32	0.32													

Table B.1.1

BLAST	BURRIED OUTSIDE				FOUNDATION INSIDE				ROVING ANYWHERE					AIR OVERPRESSURE UNITS			
No.	Vert	Long	Tran	Res	Vert	Hor1	Hor2	Res	Position	Vert	Hor1	Hor2	Res	Unit1	Good?	Unit2	Good?
1303	0.32	0.49	0.37	0.54					DOOR	0.32	0.54	0.32	0.58				
1305									DOOR	0.39	0.83	0.54	0.97				
1306	0.34	0.85	0.66	0.96	0.44	0.76	0.54	0.82									
1309	0.22	0.29	0.29	0.35													
1310	0.27	0.42	0.32	0.5													
1315	0.2	0.49	0.24	0.55													
1316	0.17	0.24	0.12	0.25													
1320	0.22	0.37	0.34	0.47													
1321	0.22	0.37	0.34	0.47													
1326	0.37	0.61	0.42	0.66					DOOR	0.34	0.51	0.37	0.55				
1331	0.24	0.37	0.29	0.46													
1333	0.2	0.27	0.27	0.32													
1334	0.17	0.32	0.24	0.4													
1341	0.17	0.17	0.12	0.22													
1344	0.24	0.15	0.17	0.27													
1357	0.27	0.27	0.15	0.29													
1371	0.17	0.44	0.34	0.46										103.6	yes		
1372	0.27	0.44	0.51	0.63					DOOR	0.29	0.44	0.46	0.56	101.4	yes		
1384	0.2	0.22	0.15	0.23										98.4	yes		
1386	0.17	0.34	0.24											102.4			
1387									DOOR	0.27	0.78	0.39	0.82				
1388	0.37	0.56	0.46	0.72	0.24	0.66	0.44	0.75	DOOR	0.27	0.54	0.37	0.57	108.9	yes		
1389	0.37	0.95	0.64	1.17					DOOR	0.34	0.83	0.39	0.94	103.6	yes		
1390	0.42	0.76	0.59	0.87	0.37	0.73	0.39	0.84	DOOR	0.44	0.73	0.34	0.81	130	no		
1391	0.44	0.81	0.51	0.89	0.39	0.73	0.34	0.78	DOOR	0.39	0.66	0.37	0.74	123.8	no		
1392	0.44	0.71	0.64	0.81	0.34	0.76	0.42	0.77	DOOR	0.39	0.64	0.42	0.72	109	no		
1393	0.71	1.29	0.93	1.31	0.51	1.17	0.54	1.19	DOOR	0.59	0.95	0.56	0.97	121	no		
1394	0.22	0.73	0.59	0.88										116.8	no		
1395	0.76	1.64	0.81	1.68	0.32	1.39	0.49	1.42	DOOR	0.44	1.27	0.54	1.29	125	no		
1396	1.12	1.69	1.49	1.9	0.64	1.61	0.95	1.85	DOOR	0.93	1.51	0.88	1.84	121.2	no		
1397	0.42	0.71	0.42	0.87	0.27	0.61	0.32	0.7	DOOR	0.34	0.64	0.34	0.72	110.2	yes		
1398	0.93	1.76	0.93	2.06	0.68	1.69	0.98	1.91	DOOR	0.83	1.25	0.85	1.69	118.5	no		
1399	0.42	1.17	0.51	1.2	0.42	1.05	0.49	1.08	DOOR	0.44	0.73	0.49	0.76	109	yes		
1400	0.56	1.29	0.88	1.41	0.61	1.17	1.05	1.24	DOOR	0.61	1.05	0.95	1.18	116.5	no		
1401	0.29	0.59	0.37	0.66	0.27	0.85	0.34	0.87	DOOR	0.34	0.64	0.34	0.66	124.7	no		
1402	1.54	2.05	1.59	2.11	1.15	1.81	1.25	2.08	DOOR	1.32	1.81	1.39	2.03	120.1	no		
1403	0.68	1.39	0.83	1.49	0.42	1.42	0.76	1.44	DOOR	0.54	1.37	0.68	1.44	118.7	no		
1404	0.88	1.44	0.93	1.45	0.46	1.27	0.51	1.32	DOOR	0.68	1.44	0.56	1.46	112.6	no		
1405	0.29	0.56	0.34	0.59	0.29	0.42	0.27	0.45	DOOR	0.29	0.34	0.27	0.37	112.3	no		
1406	0.39	0.54	0.3	0.65	0.22	0.56	0.2	0.63						110.9	yes		
1407	0.64	1.12	0.68	1.22	0.61	0.81	0.61	0.91	DOOR	0.68	0.68	0.71	0.82	118.3	no		
1408	2.44	2.47	2.44	3.24	1.61	2.64	1.39	3.02	DOOR	1.86	2.22	1.59	2.62	123.5	no		
1409	0.37	0.61	0.37	0.68	0.42	0.68	0.54	0.74	DOOR	0.39	0.71	0.27	0.76	110.2	yes		
1410	0.88	0.64	0.95	0.95					DOOR	0.59	0.66	0.49	0.7	113.1	yes		
1411	0.27	0.39	0.34	0.45										111.8	yes		
1412	0.83	1.17	0.88	1.35	0.56	1.15	0.54	1.15	DOOR	0.78	0.93	0.54	0.95	113.1	yes		
1413	2.91	2.03	3.54	3.96	2.59	1.83	3.17	3.65	DOOR	2.69	1.9	3.27	3.51	116.6	yes		
1414	0.73	1.73	0.85	1.79	0.59	1.25	0.66	1.26	DOOR	0.73	1.27	0.66	1.27	110.8	no		
1415	1.15	1.37	0.93	1.43	0.42	1.05	0.51	1.13	DOOR	0.51	1.03	0.56	1.07	124.6	no		
1416	0.68	1.17	0.93	1.48	0.64	1.22	0.61	1.3	DOOR	0.73	1.22	0.73	1.26	123.6	no		

Table B.1.m

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
1417	1.05	2.83	1.66	3.23	0.88	2.22	2.17	2.98	DOOR	0.98	2.2	1.9	2.8	116.9	yes		
1418	1.34	1.95	1.47	2.33	0.71	1.54	1.05	1.81	DOOR	0.9	1.54	1.1	1.84	117	no		
1419	0.81	1.25	0.9	1.36	0.68	1.17	0.54	1.27	DOOR	0.93	1.03	0.49	1.04	121.8	no		
1420	1.54	2.64	1.66	2.82	1.15	2.34	1.54	2.59	DOOR	1.51	2.05	1.32	2.35	125.6	no		
1421	1	2.59	3.05	3.64	0.88	2.98	2.54	3.59	DOOR	0.93	2.66	2.69	3.38	121.3	no		
1422	1.56	1.37	2.54	2.85	1.42	2.27	1.86	2.93	DOOR	1.59	1.54	1.98	2.33	120.4	yes		
1423	0.68	0.98	0.9	1.1	0.61	1	0.81	1.01	DOOR	0.64	0.93	0.68	1.08	113.4	yes		
1424	0.93	1.27	1.1	1.37	0.81	0.88	0.88	1.13	DOOR	0.93	1.17	0.9	1.26	118.4	no		
1425	1.17	1.73	1.78	1.94	1	1.42	1.29	1.76	DOOR	1.17	1.25	1.32		121.8	no		
1426	1.42	1.73	1.37	1.75	0.95	1.59	0.9	1.82	DOOR	1.03	1.25	0.93	1.47	113.5	no		
1427	1.1	1.51	1.34	1.58	1.05	1.54	1.1	1.57	DOOR	1.05	1.47	1.15		122.6	no		
1428	0.83	1.49	1.05	1.84	0.61	1.05	0.9	1.22	DOOR	0.81	0.88	0.9	1.1	127.1	no		
1429	1.71	3	2.34	3.61	1.59	2.52	2.52	2.79	DOOR	1.66	2.52	2.46	2.89	114.7	yes		
1430	0.85	1.2	1	1.4	0.68	0.98	0.85	1.07	DOOR	0.83	0.9	0.83	1.06	113.9	yes		
1431	1.37	2.54	1.73	2.81	0.93	1.73	1.51	2.18	DOOR	1.17	1.9	1.54	2.23	118.8	yes		
1432	1.64	2.86	2.03	2.99	1.83	2.61	1.34	2.8	DOOR	1.81	2.22	1.46	2.69	119.9	no		
1433	1.05	3.22	1.98	3.43	0.9	2.64	1.37	2.97	DOOR	0.85	2.4	1.42		117.3	yes		
1434	1.63	3.47	2.05	3.71	1.34	2.52	1.69	2.92	DOOR	2.03	2.73	1.61	3.22	114.4	yes		
1435	1.69	2.88	1.61	2.94	1.1	2.54	1.22	2.61	DOOR	1.76	1.9	1.25	2.63	120.7	no		
1436	0.98	1.34	1.47	1.81	1.07	1.1	0.98	1.35	DOOR	1	0.9	0.83	1.22	116.4	yes		
1437	0.81	1.83	1.69	2.05	0.83	1.71	1.15	2.09	DOOR	0.93	1.61	1.17	2.04	116.6	yes		
1438	2.52	1.49	2.39	2.61	2.12	2.1	1.59	2.48	DOOR	2.61	1.37	1.69	2.77	116.1	yes		
1439	0.85	1.83	1.07	1.99										124	no		
1440	0.61	1.51	0.98	1.61										118	no		
1441	1.54	1.9	1.54	2.27										122.2	no		
1442	0.71	1.81	1.12	2.16										116.8	no		
1443	0.78	1.44	1.2	1.84										115.6	yes		
1444	1.15	4.03	1.66	4.33					DOOR	1.32	2.56	1.73	3.05	121.9	no		
1445	1.59	1.95	1.22	1.95					DOOR	1.86	1.64	1.25	1.97	129.2	no		
1446	1.25	1.37	2.88	3.14										125.2	no		
1447	1.49	1.71	1.61	2.35										126.9	no		
1448	5.4	4.54	8.15	8.68	4.91	7.3	4.74	4.8	BF61	9.08	7.15	9.5	10.8	126.4	no	121.6	yes
1449	1.81	2.52	2.49	2.91	1.95	1.81	1.81	2.66						123.3	no	119.6	yes
1450	1.17	1.61	2.42	2.47	0.9	1.05	1.56	1.71						126.8	no	115.2	yes
1451	1.12	1.81	1.03	1.95	0.73	1.25	0.83	1.56						120.5	no	113.9	yes
1452	1.73	1.95	2.93	3.02	1.12	1.66	2	2.54						121	no	115.9	yes
1453	1.61	1.76	2.08	2.47	0.95	1.22	2.08	2.13	BF61	4.02	2.95	3.1	4.13	121	no	116.6	yes
1454	2.49	2.54	3.05	3.17	1.59	3.2	2.52	3.82	BF61	3.1	4.76	4.22	5.06	119.5	no	116.8	yes
1455	2.12	3.69	1.9	3.94										118.4	yes		
1456	4.3	3.71	6.76	7.81										130.8	yes		
1457	2.83	3.32	5.74	5.74	3.56	4.2	4.13	4.4						124.6	no	122.9	yes
1458	3.56	3.05	7.06	7.15	2.88	2.69	6.08	6.23						124.3	yes	124.6	yes
1459	3.86	4.22	3	4.58	2.88	3.37	3.08	3.86						123.1	no	122.3	yes
1460	2.61	4.13	4.83	5.76	2.37	5.44	3.69	6.42						121.3	no	121.9	yes
1461	1.44	3.03	2.78	3.24					BF61	3.47	3.13	2.47	4.01	123.8	yes		
1462	1.71	1.73	1.61	2.24					BF61	2.91	2.05	1.98	3.07	117.3	yes		
1463	3.35	3.15	3.08	4.96										120.1	yes		
1464	2.27	4.13	3.25	4.69					BF61	4.13	3.17	4.4	5.19	121.4	no		
1465	1.34	3.17	1.32	3.54	0.85	2.52	0.9	2.55	BF61	1.56	3.49	1.93	3.96	125.6	no	119.8	yes
1466	1.12	2.83	2.22	2.94	1.12	2.44	1.64	2.45	BF61	1.93	2.78	2.54	2.89	130.2	no	120.4	no

Table B.1.n

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
1467	1.32	3.78	2.76	3.98	0.98	2.76	1.59	2.85	BF61	2	3.64	3.2	5.11	118.5	yes	118.4	yes
1468	0.46	1.1	0.61	1.11	0.49	0.98	0.51	0.99	DOOR	0.46	0.93	0.44		121.7	no		
1469	0.83	2.52	1	2.52	0.98	2.3	0.76	2.32		1.49	2.25	1.47	2.32	122.2	yes	122	yes
1470	0.93	2.66	1.69	2.81	1.07	2.1	1.07	2.23	BF61	1.83	2.66	2.03	3.01	121.2	yes	120.1	yes
1471	1.25	2.42	1.15	2.51					BF61	1.12	2.88	1.47	3.05	115.3	no		
1472	1.12	2.91	1.42	3.05					BF61	1.78	2.59	2.03	3.08	111.3	yes		
1473	0.88	1.93	1.61	2.3					BF61	1.49	2.05	2.93	3.46	118.3	yes		
1474	0.85	1.76	1.54	1.99										114.2	yes		
1475	0.93	2.12	1.25	2.39					BF61	1.61	2.39	1.25	2.58	114	yes		
1476	0.46	0.71	0.88	0.91										115.1	yes		
1477	0.68	1.15	0.76	1.22					BF61	1.1	1.98	1.25	2.18	126.6	no		
1478	0.85	1.25	1.44	1.49	0.83	1.12	1.15	1.41	BF61	1.27	2.37	1.51	2.8	118.5	no		
1480	0.61	1.07	0.59	1.2	0.71	0.81	0.39	0.86						125.2	no		
1481	0.78	0.93	1.15	1.16	0.81	0.68	0.59	1.03	BF61	1.32	1.17	0.95	1.7	118.3	no		
1482	0.51	0.95	0.73	0.99	0.61	0.88	0.71	1.03						122.7	no		
1483	0.76	1.34	0.85	1.38	0.73	1.1	0.64	1.24						113.4	no	112.3	yes
1484	0.51	1	0.81	1.01										117.5	no		
1485	1.1	1.39	1.81	1.88	0.78	1.1	1.47	1.5	BF23	1.15	1.93	2	2.2	119.4	no	113.4	no
1486	1.83	4.27	3	5.15	1.39	4.22	2.91	4.3	BF23	1.9	6.03	4.91	7.47	121.2	yes	123.1	yes
1487	1.95	2.12	2.44	2.62	1.17	1.83	1.73	2.1	BF23	1.9	3.32	4.93	5.45	121.1	no	122.2	yes
1488	1.34	1.86	1.98	2.32	1.12	1.64	1.51	1.98	BF23	2.42	3.59	3.1	4.41	119.6	no	117.7	yes
1489	0.98	1.44	1.39	2.14	0.64	1.76	1.22	2.08						117.9	yes	118.1	yes
1490	1.47	1.98	1.2	2.09	0.76	1.42	0.95	1.67						120	yes	120.3	yes
1491	1.05	1.51	1.32	1.87	0.88	1.88	0.61	1.97	BF23	1.17	1.22	2.73	2.81	114.8	yes	116.6	no
1492	2.05	1.64	1.86	2.33	0.78	1.39	1.32	2.03						115.5	yes	116	no
1493	1.07	1.64	1.29	1.83	0.64	1.27	1.07	1.49						115.4	yes	115.3	yes
1494	0.39	0.9	0.9	1.24										119	no		
1495	0.68	1.07	0.61	1.27	0.71	1	0.59	1.05						111.6	yes	110.2	yes
1496	0.29	0.56	0.56	0.73										112.8	no		
1497	0.37	0.44	0.39	0.51										109.8	yes		
1498	0.39	0.93	0.85	1.01										110.8	yes		
1499	0.44	1.64	0.64	1.64										109.8	yes		
1500	0.42	0.78	0.54	0.89										110	no		
1501					1.32	2.93	2.83	3.91	BF23	1.49	4.3	3.42	5.27			117.6	no
1502					0.83	1.44	1.12	1.59	BF23	1.17	1.73	2.27	2.3			117.2	yes
1503					0.61	1.93	0.83	2.02								119.6	yes
1507									BF23	1.98	2.64	3.56	3.29				
1508									BF23	1.86	3.69	3.17	4.1				
1509									BF23	2.18	4.69	5.66	7.16				
1510									BF23	2.56	3.93	4.74	4.97				
1511									BF23	2.15	2.64	4.69	4.9				
1512	1.78	1.81	1.76	2.23	1.05	1.73	1.2	2.03						118.5	yes	119	yes
1513	1.44	2.08	1.78	2.4	1.15	2.25	1.49	2.45						119.6	yes	120.8	yes
1514	1.56	1.9	1.93	2.17	0.78	1.73	1.44	1.92	BF23	2.17	2.17	2.76	2.98	118	yes	117.7	yes
1515	2.1	2.32	1.93	2.57	1.12	2.05	1.69	2.17	BF23	1.66	2.22	3	3.43	116.6	yes	117	yes
1516	0.95	1.32	0.98	1.6	0.59	1.29	0.71	1.32	BF23	1.17	1.42	2.22	2.24	112	yes	113	yes
1517	0.71	1.59	1.2	1.83	0.73	1.34	1.07	1.71						116.1	yes	115.7	yes
1518	0.73	1.51	1.07	1.59	0.68	1.44	0.59	1.56	BF23	1.22	1.27	1.73	1.87	111.6	yes	112.3	yes
1519	1.27	2.12	1.69	2.33	1.12	2.08	0.76	2.25	BF23	1.76	1.54	4.25	4.45	118.6	yes	118.5	yes
1520	0.9	1.34	0.61	1.63	0.61	1.34	0.61	1.48						115.4	yes	114.7	yes

Table B.1.o

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
1521	0.81	1.39	1.15	1.61										112.3	no		
1522	1.32	2.03	1.78	2.58	1.27	1.59	1.25	1.81	BF23	1.42	2.12	3.15	3.34	116	yes	114.2	no
1523	0.83	2.05	1.03	2.23	1	1.32	0.73	1.4						113.1	yes	112.9	yes
1524	0.56	1.37	0.83	1.45	0.9	1.44	0.54	1.47						116.4	no	115.9	yes
1525	0.76	1.12	0.98	1.18	0.56	1.07	0.61	1.12						112.9	no	111.5	no
1526	0.78	0.88	0.85	1.08										116.1	no		
1527	1.37	1.39	1.9	2.07	0.95	1.51	1.73	1.9	BF23	1.27	2.34	1.98	2.79	116.3	no	117.5	no
1528	0.85	1	1	1.18										110.8	no		
1529	0.32	0.93	0.54	0.95										118.2	no		
1531					0.81	1.22	1.22	1.73								121.7	no
1532					1.71	2.27	1.66	2.68	BF23	1.76	3.22	3.32	3.95			126.3	no
1533					1.25	1.2	0.9	1.28	BF23	1.32	1.71	3.42	3.55			122.7	no
1535					0.73	1.22	0.64	1.28								116	no
1536	0.49	0.73	0.54	0.79	0.44	0.73	0.42	0.76						109.6	no	112.8	no
1538	0.41	0.88	0.68	1.01	0.61	0.88	0.71	1.03						110.7	yes		
1539	0.59	0.95	0.81	1.02										115.1	no		
1540	0.49	0.64	0.56	0.69	0.57	0.61	0.52	0.74						109.5	yes	109.6	yes
1541	0.68	1.22	0.95	1.33	0.57	1.03	0.81	1.26						113.5	yes	114.5	yes
1542	0.68	1.22	0.95	1.33										111.5	yes		
1543	0.66	1.05	0.95	1.12	0.63	1.07	0.73	1.18						113.9	no	113.9	no
1544					2.91	3.25	3	3.72	BF23	3.08	6.03	6.23	6.92			121.7	yes
1545	0.51	0.61	0.59	0.79										113.2	no		
1546	0.51	0.46	0.42	0.66										110.6	no		
1547									BF23	3.47	7.67	4.1	8.15				
1548	0.71	0.64	0.76	0.85	0.59	0.93	0.71	1.01						114.7	yes	111.5	no
1549	1.88	2.17	3.13	3.36	1.95	2	2.22	2.91	BF23	2.83	3.81	3.98	4.4	120.9	yes	121.6	yes
1550	0.46	0.46	0.54	0.59	0.59	0.46	0.46	0.61						113	no	114.1	no
1551	0.66	0.54	0.34	0.84										107	yes		
1552	0.51	0.49	0.49	0.61										111	no		
1553	2.59	1.86	2.76	3.3										120.3	no		
1554	1.56	2.2	2.54	3.01	1.37	1.66	2.45	2.51	BF23	2.2	3.47	3.08	4.2	118.6	no	125	no
1555	1.05	1.9	1.07	2.03	0.88	1.95	1.05	2.02						121.6	no	127.4	no
1556	1.54	1.39	1.73	1.88	1.17	2.08	1.71	2.54						117.9	yes	119.8	yes
1557					2.27	2.61	3.61	4.23								120.1	yes
1558	1.2	2.03	2.27	2.29	1.1	2.73	2.03	2.79	BF23	1.32	4.47	3.39	4.73	122.7	yes	121	no
1559	1.07	1.27	1	1.48	0.68	1.32	1.05	1.62						121.5	no	119.7	yes
1560					0.9	1.95	1.27	2.05	BF23	1.56	1.98	2.64	2.86			122.5	no
1561	0.81	1.12	1.27	1.57	0.54	0.73	0.46	0.74	BF23	3.47	2.08	2.22	3.67	116.4	no	122	no
1563	0.34	0.61	0.46	0.67										110.7	yes		
1564	0.27	0.51	0.46	0.54										109.5	yes		
1565	0.27	0.29	0.37	0.38										106.4	yes		
1566	1.56	2	2.27	2.67	1.47	2.37	1.66	2.53	BF23	2	3.56	4.37	4.61	121.6	yes	123.7	yes
1567	1.71	3.49	1.76	3.56	1.27	3.98	1.86	4.02	BF23	2.15	3.03	6.25	6.28	118.1	yes	119.1	yes
1568	1.56	2.49	2.17	3.16	1.78	2.37	1.61	2.53	BF23	1.93	3.98	4.18	5.36	120.8	yes	121	yes
1569	0.68	1.22	1.2	1.33	0.59	1.05	0.95	1.23						116.4	yes	117.4	yes
1570	22.05	22.22	21.9	24.1			15.36		BF23	50.02	29.66	37.28	51.64	130.8	yes	130.4	yes
1571	50.02	22.56	36.48	59.87					BF23	50.02	45.97	40.21	69.57	135.4	yes	136.3	yes
1572	0.73	1.27	1.03	1.52										117.7	yes		
1573	1.71	3.69	3.08	3.99	2.34	3.42	1.95	3.56						118.3	yes	118.7	yes
1574	1.25	1.73	1.83	2.02	0.88	1.61	1.17	1.75						115.1	yes	118.3	no

Table B.1.p

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
1575	0.37	0.83	0.66	0.83										115.6	yes		
1576	0.49	1.32	0.85	1.56										117.2	no		
1577	0.78	2.08	1.9	2.42	0.81	1.83	1.61	2.47						118.7	yes	118.9	yes
1578	0.88	1.66	1.27	1.75										116.4	no		
1579	0.9	0.93	1.12	1.42	0.68	1	0.9	1.03						119.4	yes	115.2	yes
1580	0.66	0.71	0.76	1.11	0.66	0.9	0.68	1.11						113.3	no	111.2	no
1581	0.78	0.93	0.98	1.09										110.6	yes		
1582	1.32	2.64	2.86	3.15	1.51	2.42	2.25	2.58						120.2	yes	120	yes
1583					2.49	6.2	3.03	6.52								120.7	no
1584					2.73	2.56	2.98	3.64								126.6	yes
1585					1.27	2.56	1.9	3.07								117.6	no
1586	1.17	2	1.42	2.13	0.71	2.12	1.27	2.41						117.1	yes	113.5	yes
1587	0.98	1.2	1.37	1.81	0.81	0.98	1.27	1.29						117.7	yes	115.8	yes
1588	0.57	1.56	1.32	1.57	0.64	1.22	1.12	1.23						118	yes	118.9	yes
1589	0.39	0.76	0.64	0.82					BF23	1.51	1.39	1.32	1.64	114.6	yes		
1590	0.9	1.51	0.95	1.73	0.85	1.56	0.95	1.69	BF23	2.52	2.32	2.95	3.79	114.8	yes	115.8	yes
1592	1.32	2.59	1.44	2.73	1.69	2.27	0.98	2.33	BF23	3.96	2.05	3.49	4.66	118.2	yes	117.7	yes
1593	0.39	1.44	0.95	1.5										119	yes		
1594	8.55	10.99	8.12	11.67	6.84	10.96	5.69	11.49	BF23	23.19	10.21	16.26	25.7	127.1	yes	124.9	no
1595	10.52	16.46	7.42	17.28	9.72		6.98		EXSWC	17.11	8.15	9.62	17.17	127	yes	125.6	no
1596	21.24	21.12	11.11	21.74					EXSWC	29.15	49.76	16.94		130	yes		
1597	12.43	17.16	16.55	18.73					EXSWC	13.53	8.84	23.88	23.94	125.2	yes		
1598	1.71	2.15	3.83	4.05					EXSWC	2.34	1.22	4.27	4.38	118	yes		
1599	0.68	0.73	0.68	0.83										116.1	yes		
1600	0.71	1.51	1.69	2.08					EXSWC	1.32	1.61	1.9	1.92	117.9	yes		
1601	6.08	7.67	11.57	12.5										125.4	yes		
1602	0.57	1.12	0.78	1.33										118.3	no		
1603	1.05	2	1.71	2.23										118.6	no		
1604	31.59	30.81	18.8	34.67										133.7	yes		
1605	0.51	0.73	0.46	0.87										114.4	yes		
1606	0.64	0.78	1.07	1.1										117.7	no		
1607	29.05	30.13	20.02	33.5						40.02				135.9	yes		
1608	0.78	1.81	1.22	1.85					EXSWC	1.22	1.39	0.95	1.51	115.8	no		
1609	31.42	43.43	26.05	47.84					EXSWC		42.16			134.7	yes		
1610	1	1.34	0.95	1.7					EXSWC	1.29	1.88	1.25	2.29	122.4	yes		
1611	2.22	1.88	3.42	3.43					EXSWC	2.88	1.66	2.73	3.44	126.1	no		
1612	3.49	2.56	2.27	3.95					EXSWC	3.54	2.08	2.73	3.77	122.9	yes		
1613	1.78	3.37	2.3	3.59					EXSWC	2.56	3.08	2.2	3.56	123.5	no		
1614	2.95	2.71	2.93	4.03					EXSWC	2.61	3.42	2.66	3.75	121.2	no		
1615	0.64	1.34	1.2	1.74										119	no		
1616	3.42	3.71	4.52	5.11					EXSWC	3.08	2.93	4.25	4.99	131.4	no		
1617	6.08	5.96	7.15	8.14	3.15				EXSWC	8.3	3.2	6.81	9.22	128.4	yes	124	yes
1618	0.46	0.83	0.88	0.91					EXSWC	0.83	0.88	0.85	1.11	116.6	yes		
1619	0.61	0.95	0.76	1.01					EXSWC	0.95	0.98	0.88	1.27	113.9	yes		
1620	3.42	5.66	7.74	7.77					EXSWC	5.05	2.42	6.98	7.68	125.3	yes		
1621	5.4	13.09	10.21	14.34	3.98									131.8	yes	127.5	yes
1622	5.35	9.47	5.32	9.55					EXSWC	4.66	6.2	6.74	7.48	129.5	yes		
1623	1	1.07	0.75	1.21	1.69	2.08	1.97	2.31						121.2	yes	122.1	yes
1624	0.39	0.51	0.44	0.71					EXSWC	0.27	0.39	0.49	0.54	116.6	yes		
1625	0.44	0.76	0.56	0.8					EXSWC	0.37	0.51	0.73	0.78	112.2	yes		

Table B.1.q

BLAST No.	BURRIED OUTSIDE Vert	Long	Tran	Res	FOUNDATION INSIDE Vert	Hor1	Hor2	Res	ROVING ANYWHERE Position	Vert	Hor1	Hor2	Res	AIR OVERPRESSURE UNITS Unit1	Good?	Unit2	Good?
1626	1.1	1.49	1.9	2.12					EXSWC	0.68	1.83	1.39	2.23	118.1	yes		
1627	5.1	6.84	6.13	7.6	6.18	9.94	7.94	10.62	EXSWC	3.98	4.57	4	5.42	129	yes	129.2	yes
1628	3.47	8.42	6.4	8.94	4.66	11.35	7.23	12.79						131.5	yes	133.4	yes
1629	0.56	1.15	1	1.26					EXSWC	0.59	0.73	0.95	0.98	115.2	yes		
1630	0.34	0.9	0.68	0.92					EXSWC	0.32	0.34	0.81	0.84	113.5	yes		
1631	4.05	6.03	5.98	6.45	7.94	9.03	5.69	9.56	EXSWC	4.64	2.86	4.18	4.84	124	yes	122.9	yes
1632	5.32	7.5	5.32	8.63	11.35	9.5	6.54	12	EXSWC	6.84	3.83	4.15	7.55	128.1	yes	129.3	yes
1633	3.69	7.37	4.22	8.68	7.64	9.3	5.57	10.11	EXSWC	3.91	1.63	4.1	5.41	124.6	yes	124.8	yes
1634	2.37	3.17	4.08	4.8	3.49	3.54	5.59	6.01	EXSWC	2.05	2.64	2.2	3	123	yes	121.9	yes
1635	3.03	4.35	2.3	4.8	4.27	4.49	3.88	5.33	EXSWC	2.1	2.34	2.34	3.47	130.8	yes	131.3	yes
1636	1.64	2.93	3.22	3.73	2.95	3.88	5.47	6.23	EXSWC	1.32	2.39	1.81	2.7	120.3	yes	121.6	yes
1637	1.22	3.13	2.17	3.25	2.37	3.35	3.39	4.68	EXSWC	0.73	1.56	1.61	2.18	116.8	no	116.5	yes
1638	0.42	0.73	0.76	0.83					EXSWC	0.32	0.68	0.44	0.74	115.8	no		
1639	1.07	2.78	2.37	2.9	1.47	4.66	3.25	5.06	EXSWC	0.88	1.47	2.12	2.2	120.4	yes	119.1	yes
1640	4.3	7.06	8.28	9.01	6.81	8.32	13.53	13.71	EXSWC	5.13	4.74	3.91	7.02	125.9	yes	126.5	yes
1641	3.2	6.59	2.52	7.2	6.47	7.52	5.76	9.85	EXSWC	2.91	1.61	3.47	4.06	126.1	yes	125.6	yes
1642	4.32	8.47	3.05	9.47	5.74	12.23	5.76	13.68	EXSWC	3.25	2.44	5.74	6.24	124.1	yes	123.2	yes
1643									EXSWC	3.66	6.96	4.08	7.71				
1644	2.95	5.86	7.72	7.81	3.96	7.3	12.38	12.94						123.4	yes	122.9	yes
1645	2.42	6.69	5.4	8.2	3.47	6.37	7.32	8.55	EXSWC	1.69	2.05	3.15	3.87	123.2	yes	120.7	yes
1646	37.31	29.88	10.03	37.35					EXSWC	14.94	7.18	17.21	19.32	131.7	yes		
1647	1.51	2.25	4.35	4.61	2.3	2.52	7.28	7.71	EXSWC	1.27	2.88	1.42	3.26	122.5	yes	123	yes
1648	2.34	6.47	3.83	7.09	4.05	8.57	6.93	11	EXSWC	2.44	2.78	3.54	4.58	120.1	yes	118.9	yes

Table B.2.a

BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1	Unit 2	Unit 3	(Resultant)
0088	BWIND 0.17	0.42	0.34	0.45
0089	BWIND 0.27	0.66	0.27	0.68
0090	BWIND 0.34	0.76	0.46	0.84
0091	BWIND 0.17	0.37	0.32	0.42
0092	BWIND 0.29	1	0.37	1.07
0093	BWIND 0.39	0.68	0.49	0.73
0094	BWIND 0.42	0.71	0.56	0.79
0104	BWIND 0.17	0.39	0.29	0.49
0113	BWIND 0.2	0.46	0.39	0.52
0116	BWIND 0.59	1.44	0.76	1.52
0117	BWIND 0.17	0.42	0.24	0.44
0118	BWIND 0.54	1	1.03	1.31
0119	BWIND 0.42	1.07	0.66	1.14
0121	BWIND 0.15	0.51	0.22	0.52
0134	BWIND 0.37	0.73	0.42	0.8
0139	BWIND 0.2	0.29	0.32	0.33
0160	BWIND 0.71	2.15	0.56	2.19
0165	BWIND 0.32	0.95	0.56	0.97
0168	BWIND 0.22	1	0.51	1.01
0169	BWIND 0.46	0.93	0.44	0.95
0171	BWIND 0.17	0.42	0.29	0.47
0172	BWIND 0.39	1.17	0.78	1.18
0173	BWIND 0.34	0.85	1.1	1.11

Table B.2.b

BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1		Unit 2		Unit 3		(Resultant)
0174	BWIND	0.39		1.2		0.46	1.2
0176	BWIND	0.29		0.73		0.61	0.79
0177	BWIND	0.22		0.63		0.49	0.68
0246	BWIND	0.27		0.66		0.49	0.69
0247	BWIND	0.34		0.73		0.29	0.77
0248	BWIND	0.56		1.17		0.85	1.32
0258	BWIND	0.61		1.61		1.39	1.98
0261	A871	0.85		1.59		1.17	1.74
0266	BWIND	0.56		0.95		0.51	1.12
0268	BWIND	0.32		0.66		0.42	0.69
0270	BWIND	0.64		0.9		0.49	0.96
0272	BWIND	0.44		1.05		0.37	1.12
0273	BWIND	0.37		1.22		0.66	1.28
0274	BWIND	0.44		0.95		0.46	1.01
0275	BWIND	0.46		0.95		0.34	0.98
0277	BWIND	0.32		0.76		0.46	0.82
0278	BWIND	0.24		1		0.39	1.04
0286	BWIND	0.54		0.76		0.66	0.89
0287	BWIND	0.37		0.9		0.61	0.91
0294	BWIND	0.71		1.59		1	1.68
0296	BWIND	0.68		1.64		1	1.77
0298	BWIND	0.44		1.03		0.39	1.05
0299	BWIND	0.59		0.98		0.83	1.14
0327	BWIND	0.83		2.17		0.83	2.32
0334	BWIND	0.73		1.83		0.44	1.97
0337	BWIND	0.49		1.12		0.56	1.19
0349	BWIND	0.61		1.17		0.88	1.27
0377	BWIND	0.64		1.42		0.83	1.53
0386	BWIND	0.2		0.66		0.27	0.69
0387	BWIND	0.15		0.34		0.22	0.36
0389	BWIND	0.37		1		0.42	1.05
0393	BWIND	0.9		1.47		1.17	1.74
0395	BWIND	0.71		1.69		1	1.92
0396	BWIND	0.54		1.27		0.83	1.38
0408	BWIND	0.56		1.76		0.81	1.85
0422	BWIND	0.64		1.49		0.76	1.65
0436	BWIND	0.54		0.88		1.03	1.16
0505	BWIND	0.66		1.78		0.56	1.81
0508	BWIND	0.66		1.32		0.76	1.52
0514	BWIND	0.9		1.86		0.76	2.03
0546	BWIND	0.66		1.39		0.66	1.5
0548	BWIND	0.66		1.83		0.98	1.9
0563	BWIND	0.66		1.37		1.39	1.93
0593	BWIND	0.66		1.39		0.59	1.52
0689	B2C	0.34					
0704	B2C	0.39					
0706	B2C	2.81	B3C	4.71	B6C	2.17	
0707	B2C	0.44					
0742	B2C	0.49	B3C	0.64	B6C	2.66	
0750	B2C	0.81	B3C	0.81	B6C	2.76	

Table B.2.c

BLAST No.	Unit 1		Unit 2		Unit 3 (Resultant)	
	STRUCTURAL MONITORING LOCATIONS					
0752	B2C	0.76	B3C	1.1	B6C	1.61
0754	B2C	1.32	B3C	1.22	B6C	2.95
0755	B2C	1.2	B3C	0.54	B6C	4.3
0769	B2C	0.83	B3C	0.61	B6C	2.15
0770	B2C	0.59	B3C	0.44	B6C	1.9
0781	B2C	1	B3C	0.95	B6C	2.95
0782	B2C	0.68	B3C	0.93	B6C	0.85
0788	B2C	0.39	B3C	0.37		
0797	B2C	0.73	B3C	0.59	B6C	1.25
0798	B2C	0.59	B3C	0.66		
0806	B2C	1.32	B3C	0.73	B6C	2.22
0809	B2C	0.95	B3C	0.54	B6C	1.9
0813	B2C	0.71	B3C	1.81	B6C	3.49
0818	B2C	0.78	B3C	0.68	B6C	0.81
0819	B2C	0.68	B3C	0.54	B6C	0.78
0820	B2C	0.78	B3C	0.46	B6C	1.47
0821	B2C	0.83	B3C	0.49	B6C	1.12
0825	B2C	0.76	B3C	1.05		
0829	B2C	0.81	B3C	0.9	B6C	1.34
0834	B2C	0.83	B3C	1.14	B6C	0.88
0835	B2C	1.2	B3C	0.98	B6C	2.95
0836	B2C	0.59	B3C	0.9	B6C	0.93
0837	B2C	1.15	B3C	0.73	B6C	1.34
0840	B2C	0.66	B3C	0.73	B6C	3.2
0842	B2C	0.9	B3C	0.88	B6C	1.17
0850	B2C	0.85	B3C	0.64	B6C	1.29
0852	B2C	0.64	B3C	0.56	B6C	0.95
0858	B2C	1.47	B3C	1.29	B6C	1.56
0863	B2C	0.85	B3C	1	B6C	1.17
0864	B2C	1	B3C	0.85	B6C	1.44
0869	B2C	0.81	B3C	0.64	B6C	1.07
0872	B2C	0.73	B3C	0.85	B6C	1.1
0875	B2C	0.85	B3C	0.93	B6C	1.47
0876	B2C	0.66	B3C	1.12	B6C	2.34
0878	B2C	0.71	B3C	0.85	B6C	0.68
0881	B2C	0.61	B3C	0.39	B6C	1.47
0882	B2C	0.88	B3C	0.64	B6C	0.88
0887	B2C	0.61	B3C	0.83	B6C	2.56
0893	B2C	1.07	B3C	1.1	B6C	3.44
0894	B2C	0.98	B3C	1	B6C	2.03
0895	B2C	0.76	B3C	0.81	B6C	2.59
0896	B2C	0.83	B3C	0.51	B6C	0.85
0897	B2C	0.78	B3C	0.9	B6C	1.03
0898	B2C	0.88	B3C	0.85	B6C	2.12
0899	B2C	0.9	B3C	0.9	B6C	1.9
0901	B2C	0.66	B3C	1.98	B6C	0.83
0903	B2C	0.61	B3C	0.85	B6C	1.25
0907	B2C	0.85	B3C	0.54	B6C	1.1
0908	B2C	0.78	B3C	0.73	B6C	1.29
0915	B2C	0.68	B3C	1.03	B6C	0.75

Table B.2.d

BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1		Unit 2		Unit 3		(Resultant)
0916	B2C	2.08	B3C	0.71	B6C	2.27	
0918	B2C	1.66	B3C	0.68	B6C	2.1	
0919	B2C	0.71	B3C	0.71	B6C	0.95	
0923	B2C	1.88	B3C	0.66	B6C	2.34	
0924	B2C	1	B3C	1.44	B6C	2.25	
0926	B2C	0.76	B3C	1	B6C	2.25	
0929	B2C	1.05	B3C	1	B6C	1.32	
0931	B2C	1.27	B3C	1.12	B6C	2.86	
0934	B2C	1.37	B3C	0.56	B6C	2	
0936	B2C	1.07	B3C	1.25	B6C	2.76	
0938	B2C	1.12	B3C	0.78	B6C	1.95	
0940	B2C	1.05	B3C	0.88	B6C	4.03	
0950	B2C	2.3	B3C	2.71	B6C	2.95	
0953	B2C	1.12	B3C	0.98	B6C	1.44	
0969	B2C	0.95	B3C	0.46	B6C	1.61	
1009	B2C	1	B3C	0.68	B6C	1.93	
1011	B2C	1.32	B3C	0.78	B6C	1.49	
1012	B2C	1.29	B3C	0.81	B6C	2.22	
1018	B2C	1.15	B3C	1.59	B6C	0.9	
1047	B2C	2.42	B3C	1.17	B6C	2.91	
1051	B2C	1.34	B3C	0.76	B6C	2.17	
1052	B2C	1.51	B3C	1.12	B6C	2.54	
1055	B2C	1.22	B3C	0.81	B6C	1.44	
1056	B2C	1.49	B3C	0.93	B6C	4.13	
1061	B2C	1	B3C	0.39	B6C	1.42	
1066	B2C	1.42	B3C	0.85	B6C	2.12	
1072	B2C	1.32	B3C	0.81	B6C	1.59	
1075	B2C	1.15	B3C	0.64	B6C	1.17	
1079	B2C	1.37	B3C	0.71	B6C	1.07	
1080	B2C	1.05	B3C	1.32	B6C	1.71	
1092	B2C	1.15	B3C	0.37	B6C	1.44	
1093	B2C	1.44	B3C	0.59	B6C	1.39	
1094	B2C	1.44	B3C	1.34	B6C	1.98	
1095	B2C	1.15		0.85	B6C	2.27	
1097	B2C	1.1	B3C	0.81	B6C	1.59	
1105	B2C	2	B3C	1.69	B6C	2.12	
1106	B2C	1.29	B3C	1.34	B6C	1.32	
1113	B2C	1.88	B3C	0.95	B6C	2.17	
1115	B2C	1.78	B3C	0.76	B6C	3	
1120	B2C	1.25	B3C	1.12	B6C	1.71	
1121	B2C	0.85	B3C	0.68	B6C	2.25	
1123	B2C	1.66	B3C	1.12	B6C	2.37	
1160	B2C	0.98	B3C	0.68	B6C	1.95	
1162	B2C	1.27	B3C	1.22	B6C	1.32	
1163	B2C	0.98	B3C	0.9	B6C	1.93	
1168	B2C	1.12	B3C	0.9	B6C	2.05	
1173	B2C	1.2	B3C	0.61	B6C	2.54	
1180	B2C	1.44	B3C	1.56	B6C	2.34	
1199	B2C	1.69	B3C	0.9	B6C	1.61	~~2.29~~
1203	B2C	1.61	B3C	0.81	B6C	2.47	

Table B.2.e

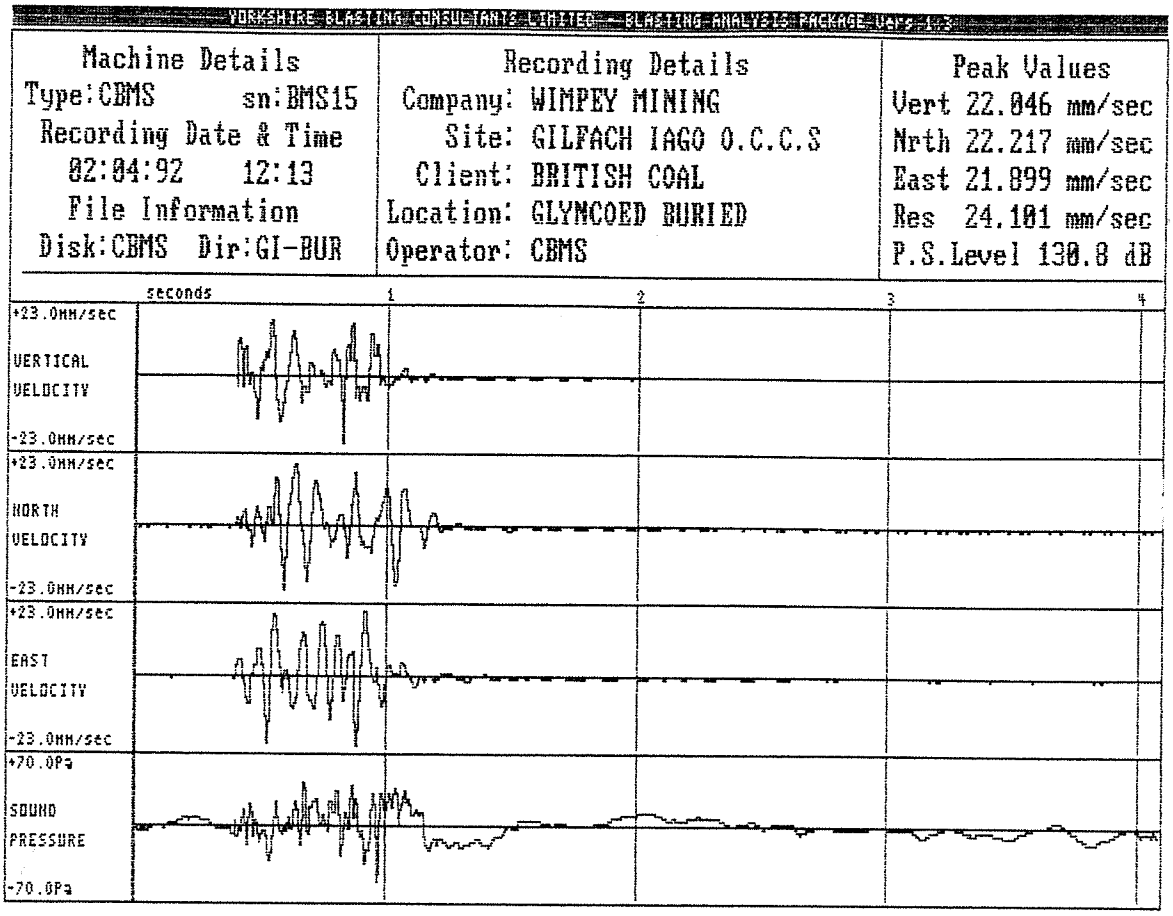
BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1		Unit 2		Unit 3	(Resultant)
1204	B2C	1.22	B3C	0.54	B6C	1.51
1210	B2C	1.22	B3C	1.03	B6C	1.47
1219	B2C	1.25	B3C	1.51	B6C	3.61
1220	B2C	1.15	B3C	1.03	B6C	2.95
1222	B2C	1.49	B3C	0.95	B6C	2.32
1259	B2C	1.32	B3C	1.03	B6C	1.93
1261	B2C	1.51	B3C	1.2	B6C	1.83
1271	B2C	1	B3C	0.9	B6C	1.29
1279	B2C	1.03	B3C	0.88	B6C	1.15
1282	B2C	0.95	B3C	0.34	B6C	1.34
1284	B2C	0.88	B3C	0.42	B6C	1.32
1291	B2C	1.07	B3C	0.66	B6C	1.71
1303	B2C	0.93	B3C	2.05	B6C	1.9
1306	B2C	2.08	B3C	2.61	B6C	4.54
1310	B2C	1.25	B3C	1.05	B6C	1.76
1311	B2C	1.29	B3C	0.88	B6C	1.12
1317	B2C	0.95	B3C	0.59	B6C	0.98
1326	B2C	1.39	B3C	1.44	B6C	2.44
1371	B2C	1.12	B3C	1	B6C	1.66
1372	B2C	1.64	B3C	1.1	B6C	2.64
1387	B2C	1.54	B3C	2.44	B6C	2.93
1388	B2C	1.95	B3C	1.86	B6C	2.15
1391	B2C	0.95	B3C	1.88	B6C	5.15
1392	B2C	1.49	B3C	2.12	B6C	3.83
1393	B2C	2.08	B3C	2.1	B6C	7.03
1395	B2C	1.66	B3C	4.35	B6C	4.22
1396	B2C	2.22	B3C	5.05	B6C	5.42
1398	B2C	2.47	B3C	3.88	B6C	5.13
1399	B2C	1.71	B3C	2.27	B6C	5.86
1400	B2C	3.13	B3C	4.25	B6C	5.84
1401	B2C	0.93	B3C	2.44	B6C	3.83
1402	B2C	4.81	B3C	6.08	B6C	5.47
1403	B2C	1.76	B3C	4.66	B6C	3.03
1404	B2C	1.47	B3C	3.08	B6C	4.49
1405	B2C	1.22	B3C	1.61	B6C	2.54
1406	B2C	0.73	B3C	1.34	B6C	2.76
1407	B2C	0.37	B3C	3.05	B6C	4.57
1408	B2C	4.81	B3C	6.81	B6C	9.62
1409	B2C	1.17	B3C	1.83	B6C	2.15
1411	B2C	0.78	B3C	1.64	B6C	2.12
1412	B2C	2.1	B3C	3.47	B6C	4.57
1413	B2C	10.08	B3C	6.74	B6C	13.06
1414	B2C	1.81	B3C	4.35	B6C	5.01
1415	B2C	1.83	B3C	3.22	B6C	5.54
1416	B2C	3.15	B3C	3.66	B6C	4.03
1417	B2C	4.96	B3C	6.98	B6C	9.25
1418	B2C	2.76	B3C	3.93	B6C	4.88
1419	B2C	2.22	B3C	2.47	B6C	4.32
1420	B2C	4	B3C	3.93	B6C	4.49
1421	B2C	7.06	B3C	9.69	B6C	6.37

Table B.2.f

BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1		Unit 2		Unit 3		(Resultant)	
1422	B2C	5.62	B3C	4.42	B6C	9.91		
1423	B2C	3.17	B3C	1.88	B6C	6.66		
1424	B2C	3.03	B3C	2.54	B6C	9.18		
1425	B2C	4.03	B3C	4.03	B6C	6.22		
1426	B2C	2.93	B3C	2.95	B6C	6.89		
1427	B2C	3.22	B3C	3.66	B6C	3.59		
1428	B2C	3.88	B3C	2.98	B6C	8.81		
1429	B2C	7.96	B3C	6.52	B6C	10.18		
1430	B2C	2.78	B3C	3.56	B6C	4.08		
1431	B2C	5.54	B3C	5.44	B6C	9.55		
1432	B2C	5.88	B3C	5.93	B6C	8.08		
1433	B2C	3.61	B3C	6.01	B6C	5.96		
1434	B2C	4.71	B3C	7.3	B6C	5.76		
1435	B2C	4.66	B3C	7.13	B6C	5.98		
1436	B2C	3.49	B3C	3.39	B6C	5.98		
1437	B2C	4.57	B3C	4.98	B6C	6.23		
1438	B2C	4.52	B3C	4.05	B6C	11.91		
1452	A2C	2.47	A3C	1.56	A4C	4.64		
1453	A2C	2.69	A3C	1.66	A4C	3.05		
1454	A2C	3.83	A3C	3.13	A4C	3.93		
1460	A2C	5.4	A3C	4.2	A4C	6.32		
1483	A162	1.2	AWC	22.05	A384	1.29		
1484	A162	1.17	AWC	11.21				
1486	A162	4.08	AWC	35.62	A384	5.69		
1487	A162	2.49	A175	1.69	A384	2		
1488	A162	1.93	A175	2.59	A384	1.59		
1489	A162	1.81	A175	2.05	A384	2.05		
1490	A162	1.56	A175	1.95	A384	2.3		
1491	A162	2.12	A175	1.73	A384	2.1		
1492	A162	1.69	A175	1.22	A384	1.51		
1493	A162	1.56	A175	1.78	A384	1.66		
1496	A162	0.71	A175	0.46	A384	0.66		
1498	A162	0.9	A175	1.12	A384	0.83		
1499	A162	1.25	A175	1.54	A384	1.1		
1501	A162	3.2	A175	3.44	A384	2.76		
1502	A162	1.66	A175	1.51	A384	1		
1503	A162	2.05	A175	2.39	A384	1.9		
1504	A162	1.56	A175	1.66	A384	1.32		
1505	A162	2.27	A175	2.64	A384	2.47		
1519	A871	1.56	A175	2.54	A915	1.15	AWTR	3.04
1522	A871	1.56	A175	2.42	A915	1.81	AWTR	2.69
1523	A871	1.1	A175	1.81	A915	1.12	AWTR	1.89
1524	A871	1.03	A175	1.56	A915	0.78	AWTR	1.62
1525	A871	0.73	A175	1	A915	0.93	AWTR	1.07
1528	A871	0.81	A175	0.95	A915	1.03	AWTR	1.09
1531	A871	0.85	A175	1.32	A915	1.69	AWTR	2.12
1532	A871	1.98	A175	2.91	A915	2.61	AWTR	3.38
1533	A871	1.51	A175	1.69	A915	1.25	AWTR	1.89
1535	A871	0.9	A175	1.81	A915	0.73	AWTR	2.05
1544	A871	3.47	A175	5.05	A915	4.98	AWTR	6.61

Table B.2.g

BLAST No.	STRUCTURAL MONITORING LOCATIONS Unit 1		Unit 2		Unit 3		(Resultant)	
1549	A871	1.66	A175	3.59	A915	4.22	AWTR	4.61
1553	A871	1.61	A175	2.44	A915	2.59	AWTR	3.22
1554	A871	1.27	A175	2.91	A915	3.32	AWTR	3.74
1555	A871	0.88	A175	2.49	A915	1.78	AWTR	2.62
1556	A871	1.15	A175	2.83	A915	2.54	AWTR	3.76
1557	A871	2	A175	3.17	A915	5.73		
1558	A871	1.03	A175	3.27	A915	3	AWTR	3.77
1559	A871	0.73	A175	1.56	A915	1.47	AWTR	2.03
1560	A871	1.05	A175	2.39	A915	1.64	AWTR	2.52
1561	A871	0.73	A175	1.98	A915	2.12	AWTR	2.38
1566	A2C	2.75	A3C	2.81	A4C	4.17		
1567	A2C	2.22	A3C	5.49	A4C	3.47		
1568	A2C	2	A3C	2.98	A4C	2.95		
1569		1.47		1.76		1.44		
1573	A2C	2.91	A3C	3.39	A4C	5.81		
1574	A2C	1.81	A3C	1.88	A4C	2.17		
1590	A2C	1.61	A3C	2.42	A4C	1.93		
1592	A2C	1.49	A3C	2.34	A4C	2.12		
1593	A2C	0.76	A3C	1	A4C	1.27		
1594			A3C	11.11	A4C	10.33		
1596	A2C	14.31	A3C	46.27				
1597	A2C	23.02	A3C	15.48				
1604	A2C	27.78	A3C	33.02				
1607	A2C	26.95	A3C	58.76				
1609	A2C	46.31	A3C	69.04				
1627	A2C	9.4	A3C	14.97	A4C	8.67		
1628	A2C	8.57	A3C	10.62	A4C	7.45		
1629	A2C	1.78	A3C	2.61	A4C	2.95		
1631	A2C	6.93	A3C	10.86	A4C	6.91		
1632	A2C	7.69	A3C	13.06	A4C	7.1		
1633	A2C	5.91	A3C	7.81	A4C	7.25		
1634	A2C	4.91	A3C	7.46	A4C	3.49		
1635	A2C	4.76	A3C	8.06	A4C	3.93		
1636	A2C	5.96	A3C	6.15	A4C	4.15		
1637	A2C	3.39	A3C	4.47	A4C	2.91		
1639	A2C	3.32	A3C	3.86	A4C	3.42		
1640	A2C	14.01	A3C	12.82	A4C	6.06		
1641	A2C	6.25	A3C	6.37	A4C	4.81		
1642	A2C	5.37	A3C	8.45	A4C	6.06		
1644	A2C	13.75	A3C	12.33	A4C	5.74		
1645	A2C	7.03	A3C	8.86	A4C	6.67		
1647	A2C	7.2	A3C	8.98	A4C	3.05		
1648	A2C	8.74	A3C	5.4	A4C	5.18		


YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
02:04:92 12:13
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 22.046 mm/sec
Nrth 22.217 mm/sec
East 21.899 mm/sec
Res 24.101 mm/sec
P.S.Level 130.8 dB
seconds
1
2
3
4
+23.0MM/sec
VERTICAL VELOCITY
-23.0MM/sec
+23.0MM/sec
NORTH VELOCITY
-23.0MM/sec
+23.0MM/sec
EAST VELOCITY
-23.0MM/sec
+70.0Pa
SOUND PRESSURE
-70.0Pa

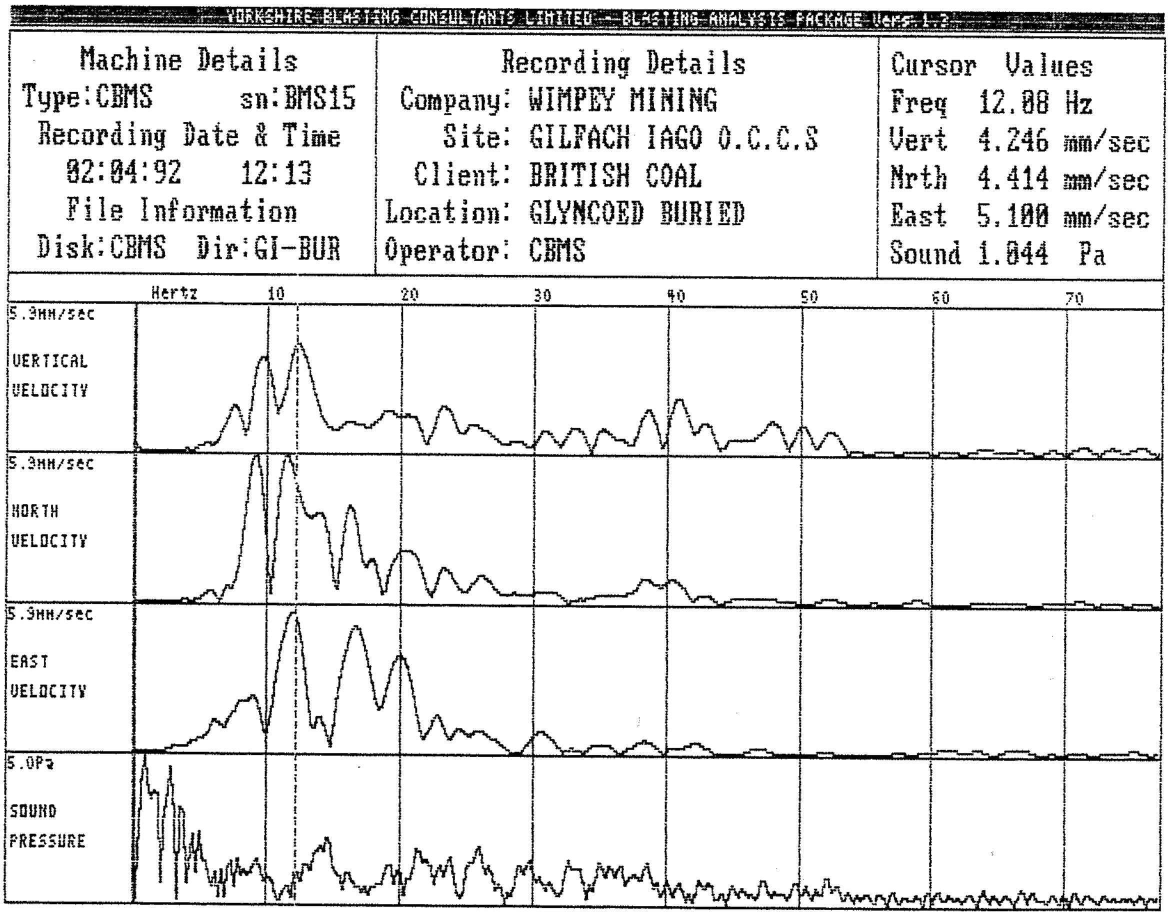
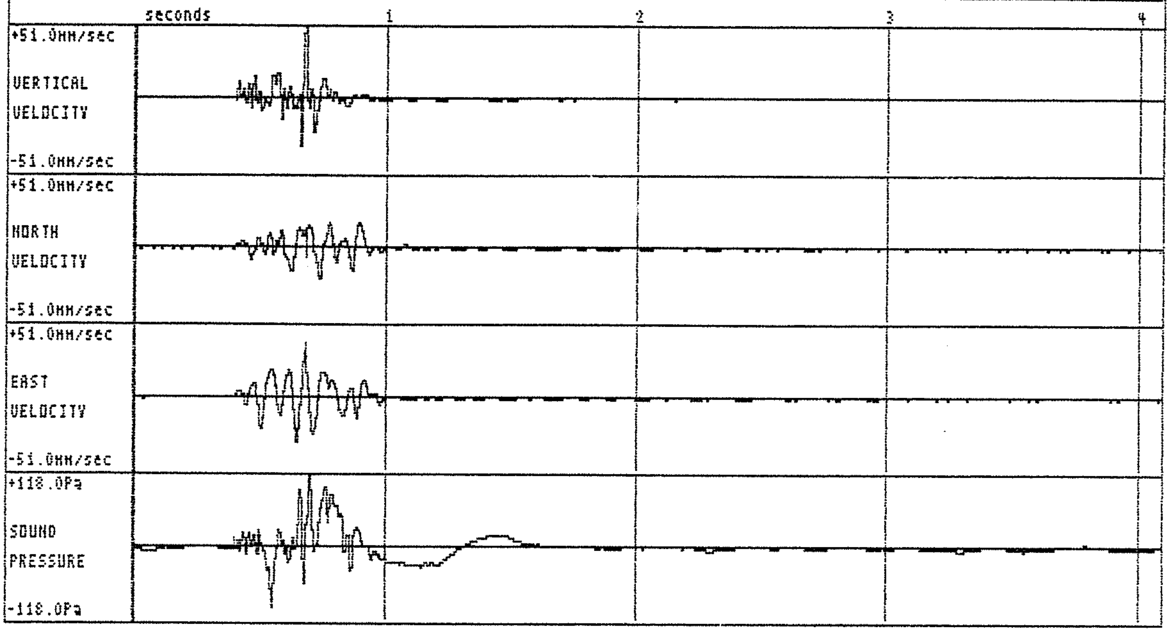

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
02:04:92 12:13
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 12.00 Hz
Vert 4.246 mm/sec
Nrth 4.414 mm/sec
East 5.100 mm/sec
Sound 1.044 Pa
Hertz
10
20
30
40
50
60
70
5.3MM/sec
VERTICAL VELOCITY
5.3MM/sec
NORTH VELOCITY
5.3MM/sec
EAST VELOCITY
5.0Pa
SOUND PRESSURE

Fig. B.3

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers. 1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 50.024 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 22.559 mm/sec
02:04:92 15:39	Client: BRITISH COAL	East 36.475 mm/sec
File Information	Location: GLYNCOED BURIED	Res 59.885 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 135.4 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers. 1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 15.75 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 4.021 mm/sec
02:04:92 15:39	Client: BRITISH COAL	Nrth 4.149 mm/sec
File Information	Location: GLYNCOED BURIED	East 6.969 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 2.483 Pa

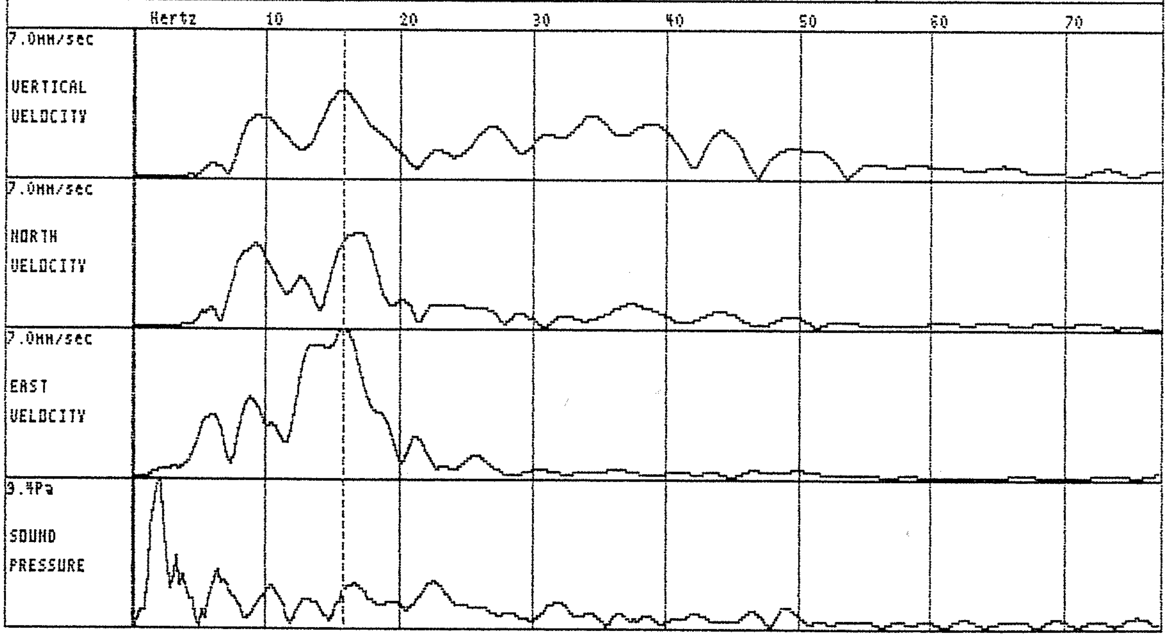
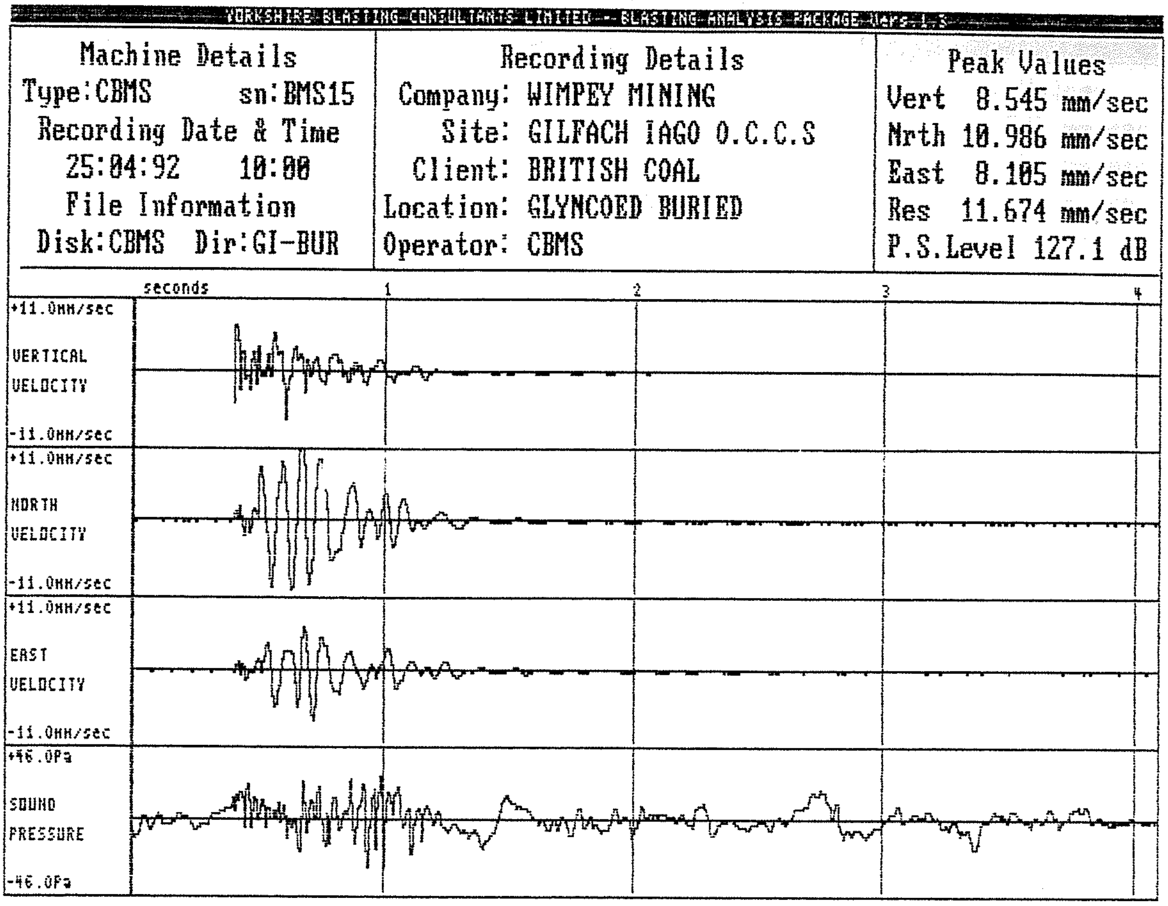


Fig. B.4


YORKSHIRE BLASTING CONSULTANTS LIMITED -- BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
25:04:92 10:00
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 8.545 mm/sec
Nrth 10.986 mm/sec
East 8.105 mm/sec
Res 11.674 mm/sec
P.S.Level 127.1 dB
seconds
1
2
3
4
+11.0MM/sec
VERTICAL VELOCITY
-11.0MM/sec
+11.0MM/sec
NORTH VELOCITY
-11.0MM/sec
+11.0MM/sec
EAST VELOCITY
-11.0MM/sec
+46.0Pa
SOUND PRESSURE
-46.0Pa

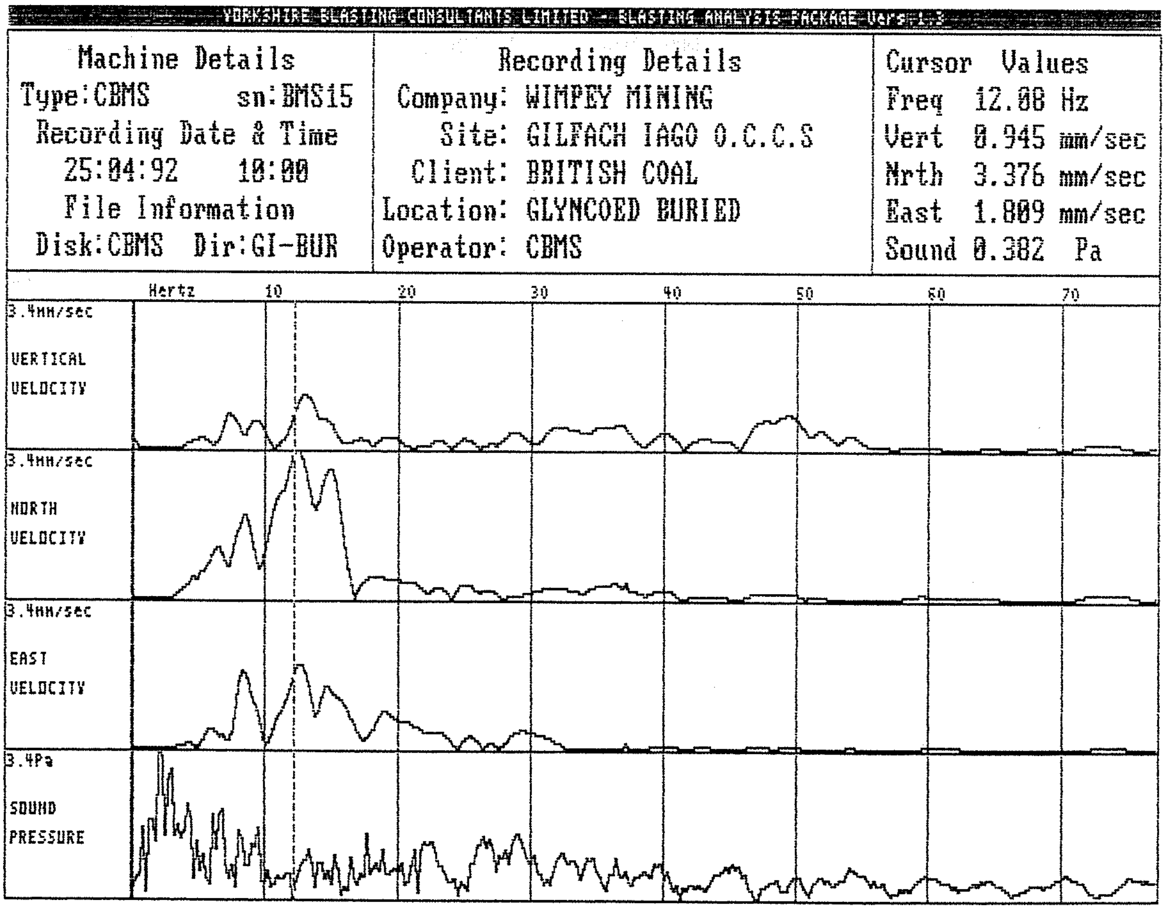
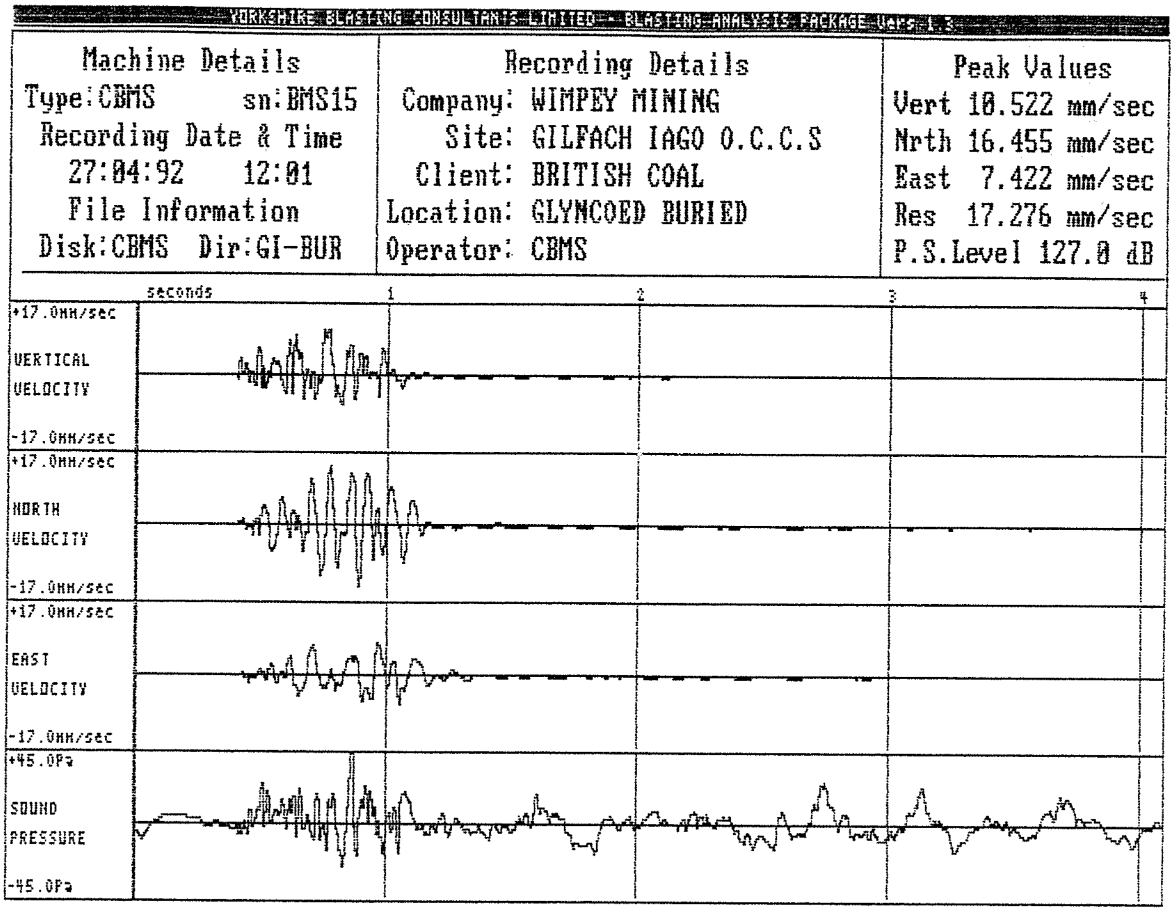

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
25:04:92 10:00
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 12.08 Hz
Vert 0.945 mm/sec
Nrth 3.376 mm/sec
East 1.809 mm/sec
Sound 0.382 Pa
Hertz
10
20
30
40
50
60
70
3.4MM/sec
VERTICAL VELOCITY
3.4MM/sec
NORTH VELOCITY
3.4MM/sec
EAST VELOCITY
3.4Pa
SOUND PRESSURE

Fig. B.5


YORKSHIRE BLASTING CONSULTANTS LIMITED -- BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
27:04:92 12:01
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 10.522 mm/sec
Nrth 16.455 mm/sec
East 7.422 mm/sec
Res 17.276 mm/sec
P.S.Level 127.0 dB
seconds
1
2
3
4
+17.0MM/sec
VERTICAL
VELOCITY
-17.0MM/sec
+17.0MM/sec
NORTH
VELOCITY
-17.0MM/sec
+17.0MM/sec
EAST
VELOCITY
-17.0MM/sec
+45.0Pa
SOUND
PRESSURE
-45.0Pa

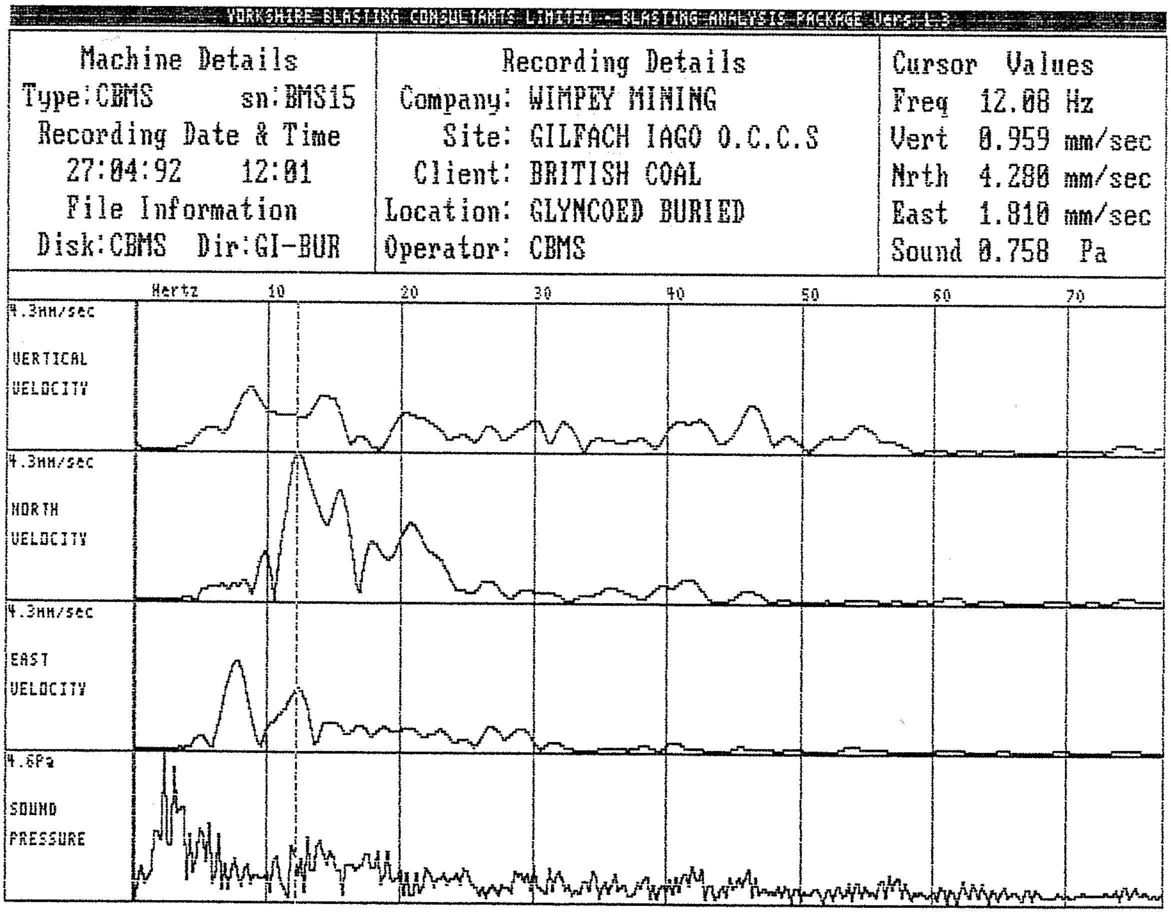
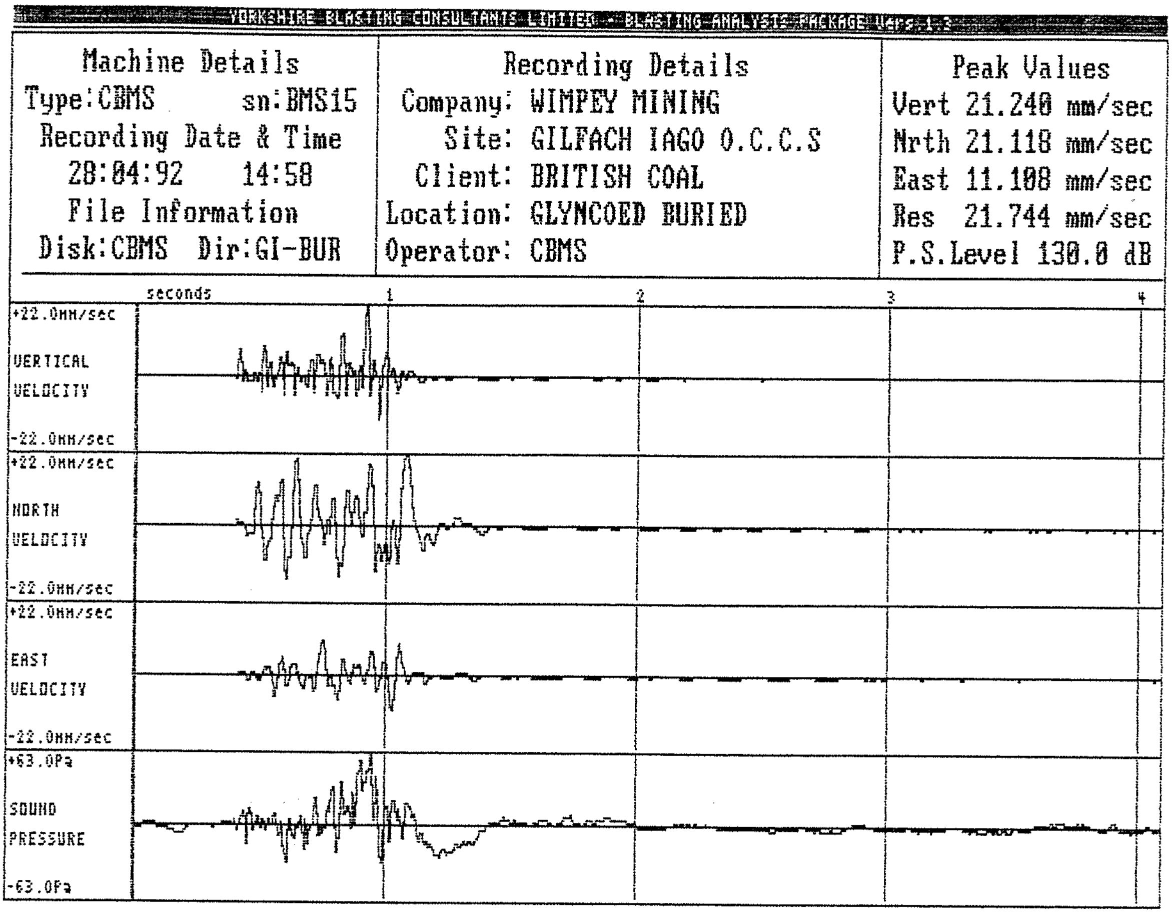

YORKSHIRE BLASTING CONSULTANTS LIMITED -- BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
27:04:92 12:01
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 12.08 Hz
Vert 0.959 mm/sec
Nrth 4.280 mm/sec
East 1.810 mm/sec
Sound 0.758 Pa
Hertz
10
20
30
40
50
60
70
4.3MM/sec
VERTICAL
VELOCITY
4.3MM/sec
NORTH
VELOCITY
4.3MM/sec
EAST
VELOCITY
4.6Pa
SOUND
PRESSURE

Fig. B.6


YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
28:04:92 14:58
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 21.240 mm/sec
Nrth 21.118 mm/sec
East 11.108 mm/sec
Res 21.744 mm/sec
P.S.Level 130.0 dB
seconds
1
2
3
4
+22.0MM/sec
VERTICAL
VELOCITY
-22.0MM/sec
+22.0MM/sec
NORTH
VELOCITY
-22.0MM/sec
+22.0MM/sec
EAST
VELOCITY
-22.0MM/sec
+63.0Pa
SOUND
PRESSURE
-63.0Pa

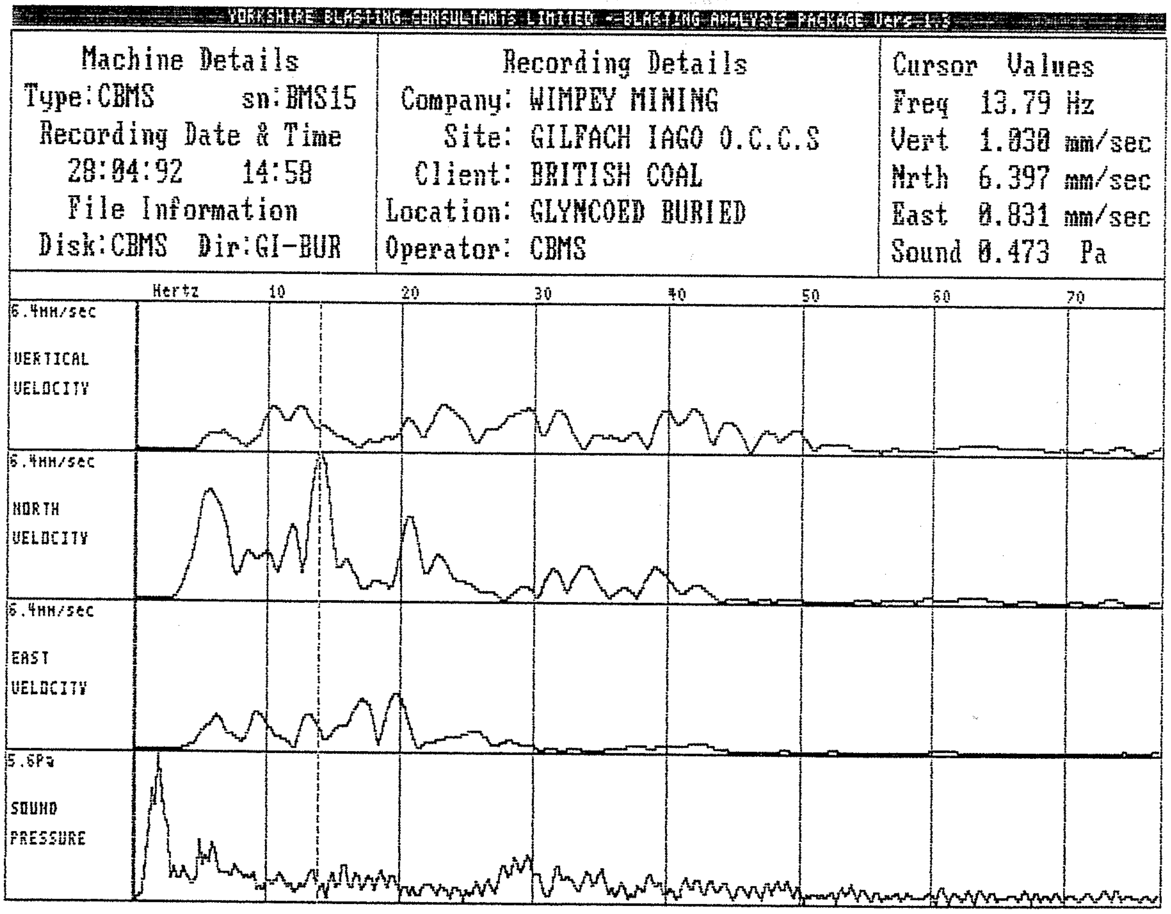
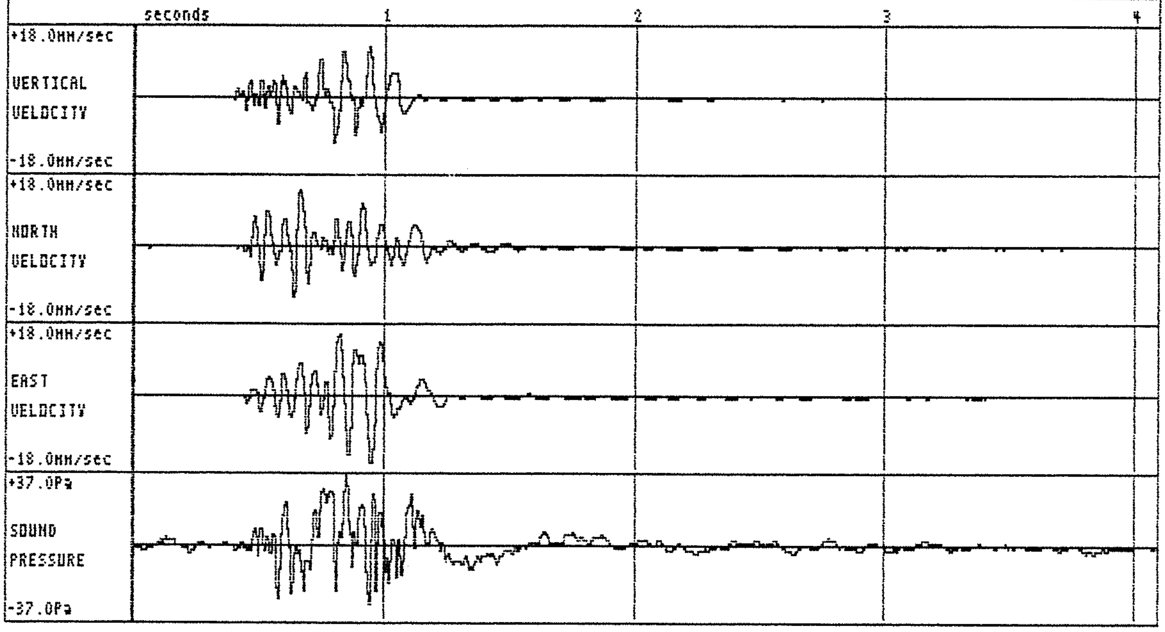

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
28:04:92 14:58
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 13.79 Hz
Vert 1.030 mm/sec
Nrth 6.397 mm/sec
East 0.831 mm/sec
Sound 0.473 Pa
Hertz
10
20
30
40
50
60
70
6.4MM/sec
VERTICAL
VELOCITY
6.4MM/sec
NORTH
VELOCITY
6.4MM/sec
EAST
VELOCITY
5.6Pa
SOUND
PRESSURE

Fig. B.7

YORKSHIRE BLASTING CONSULTANTS LIMITED -- BLASTING ANALYSIS PACKAGE Vers.1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 12.427 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 17.163 mm/sec
29:04:92 11:58	Client: BRITISH COAL	East 16.553 mm/sec
File Information	Location: GLYNCOED BURIED	Res 18.732 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 125.2 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED -- BLASTING ANALYSIS PACKAGE Vers.1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 11.60 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 2.939 mm/sec
29:04:92 11:58	Client: BRITISH COAL	Nrth 0.876 mm/sec
File Information	Location: GLYNCOED BURIED	East 4.341 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 0.395 Pa

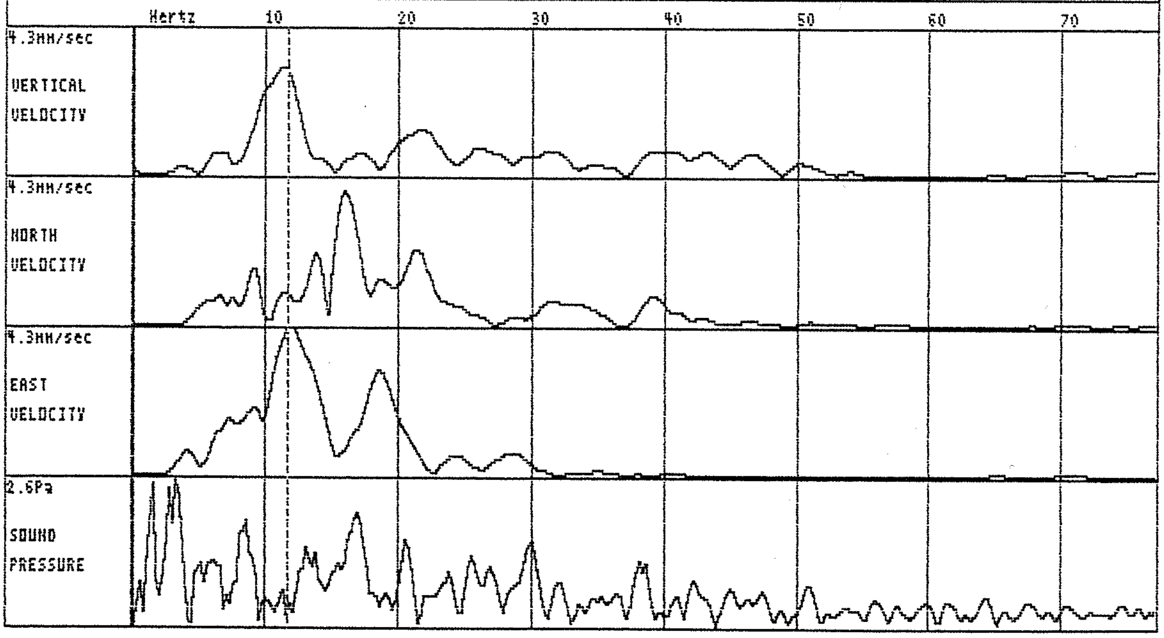
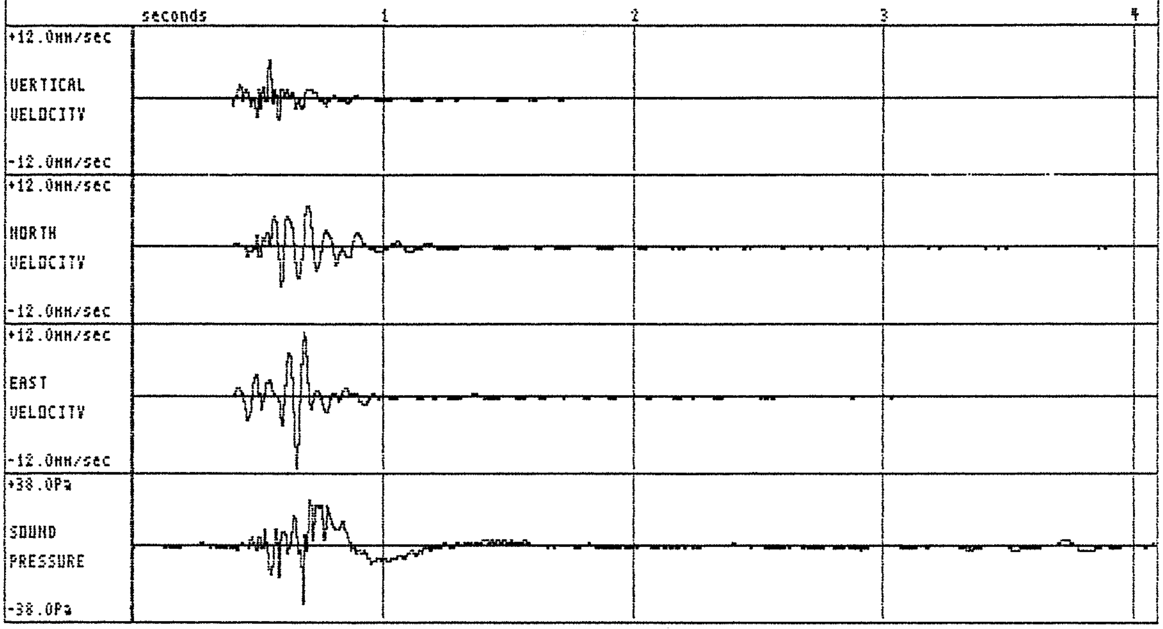


Fig. B.8

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers.1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 6.079 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 7.666 mm/sec
01:05:92 09:59	Client: BRITISH COAL	East 11.572 mm/sec
File Information	Location: GLYNCOED BURIED	Res 12.504 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 125.4 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers.1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 15.50 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 0.224 mm/sec
01:05:92 09:59	Client: BRITISH COAL	Nrth 1.159 mm/sec
File Information	Location: GLYNCOED BURIED	East 1.743 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 0.463 Pa

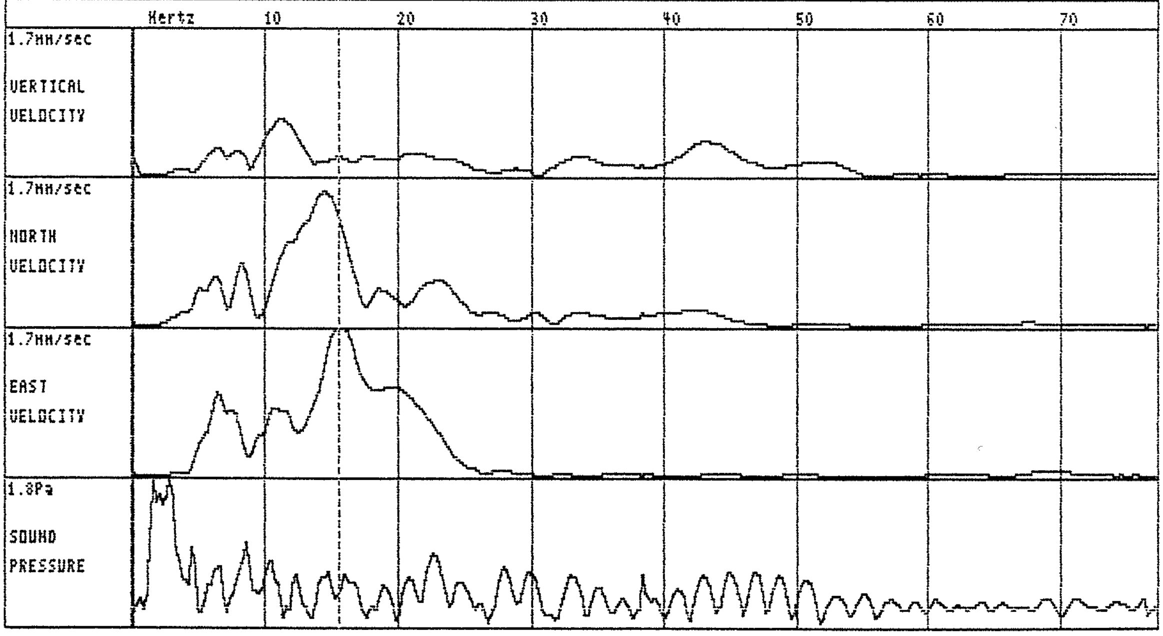
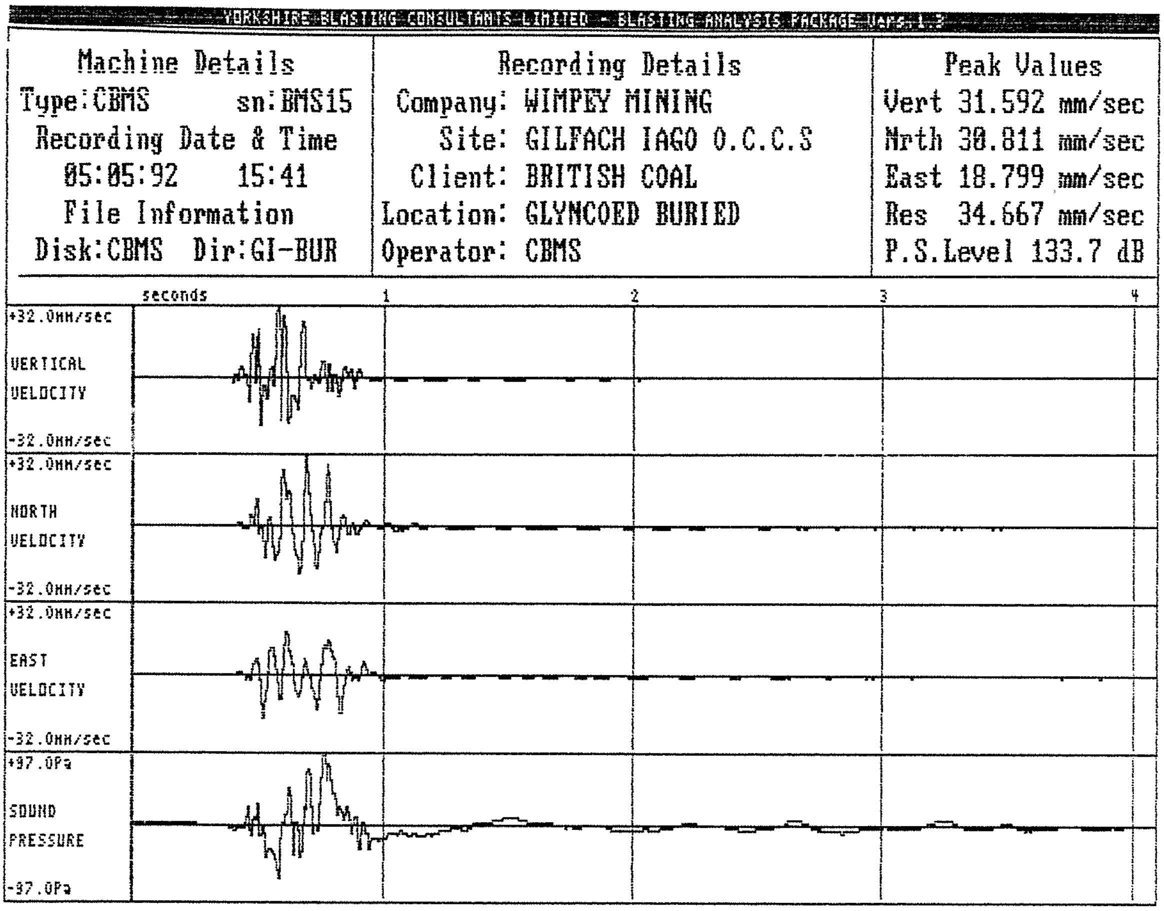


Fig. B.9


YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
05:05:92 15:41
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 31.592 mm/sec
Nrth 30.811 mm/sec
East 18.799 mm/sec
Res 34.667 mm/sec
P.S.Level 133.7 dB
seconds
1
2
3
4
+32.0MM/sec
VERTICAL VELOCITY
-32.0MM/sec
+32.0MM/sec
NORTH VELOCITY
-32.0MM/sec
+32.0MM/sec
EAST VELOCITY
-32.0MM/sec
+97.0Pa
SOUND PRESSURE
-97.0Pa

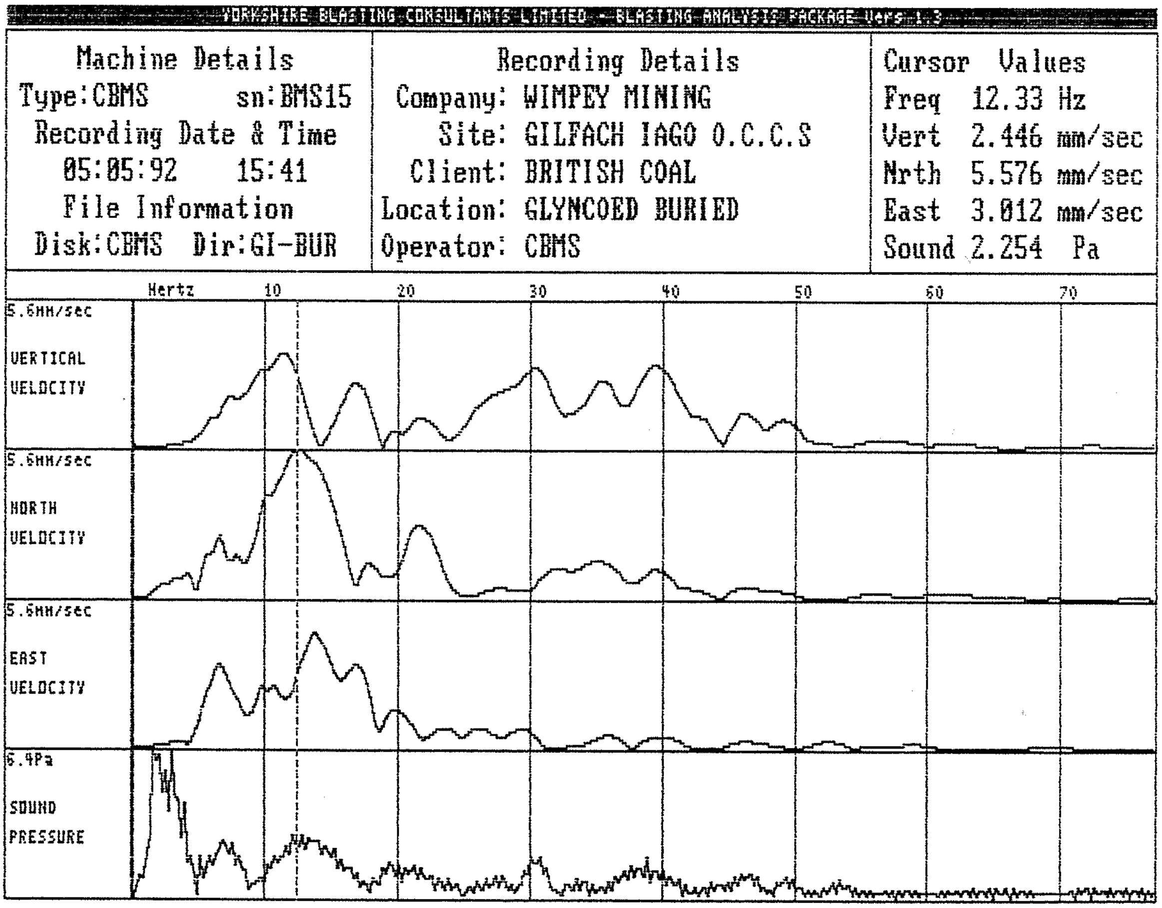
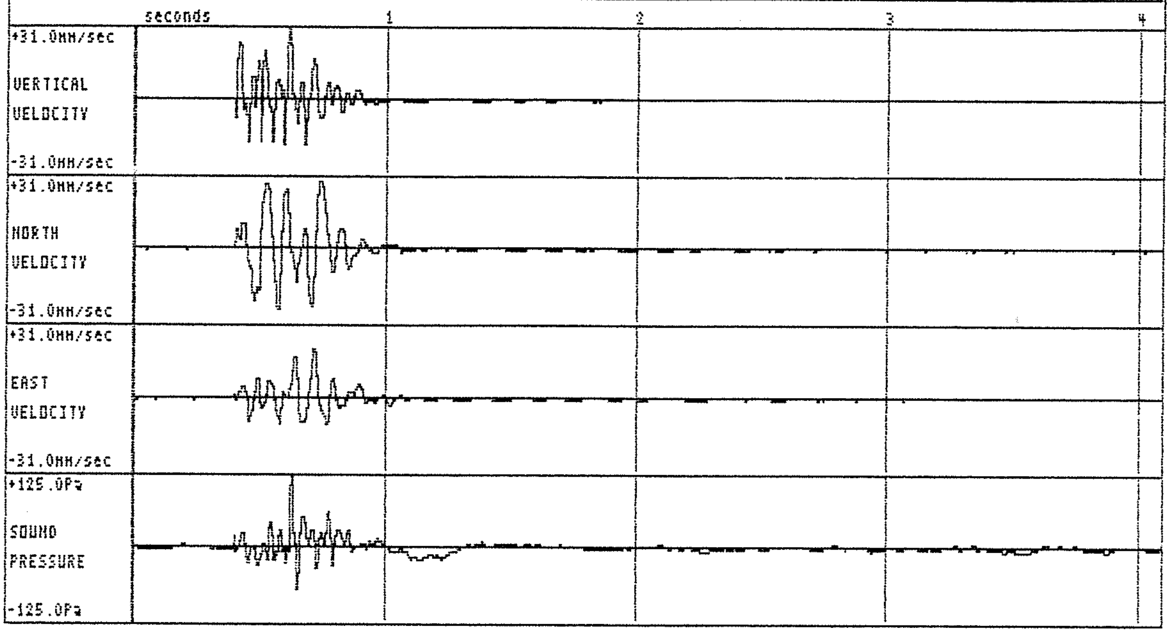

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
05:05:92 15:41
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 12.33 Hz
Vert 2.446 mm/sec
Nrth 5.576 mm/sec
East 3.012 mm/sec
Sound 2.254 Pa
Hertz
10
20
30
40
50
60
70
5.6MM/sec
VERTICAL VELOCITY
5.6MM/sec
NORTH VELOCITY
5.6MM/sec
EAST VELOCITY
6.4Pa
SOUND PRESSURE

Fig. B.10

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 29.053 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 30.127 mm/sec
07:05:92 11:56	Client: BRITISH COAL	East 20.020 mm/sec
File Information	Location: GLYNCOED BURIED	Res 33.499 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 135.9 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 13.55 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 2.022 mm/sec
07:05:92 11:56	Client: BRITISH COAL	Nrth 8.196 mm/sec
File Information	Location: GLYNCOED BURIED	East 2.450 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 1.658 Pa

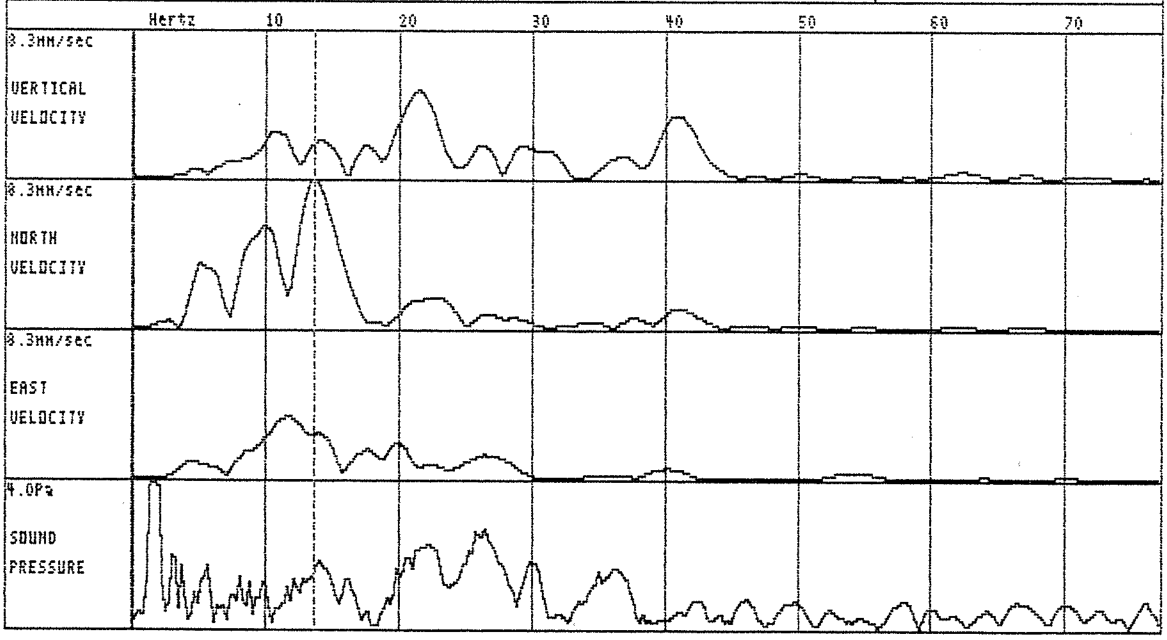
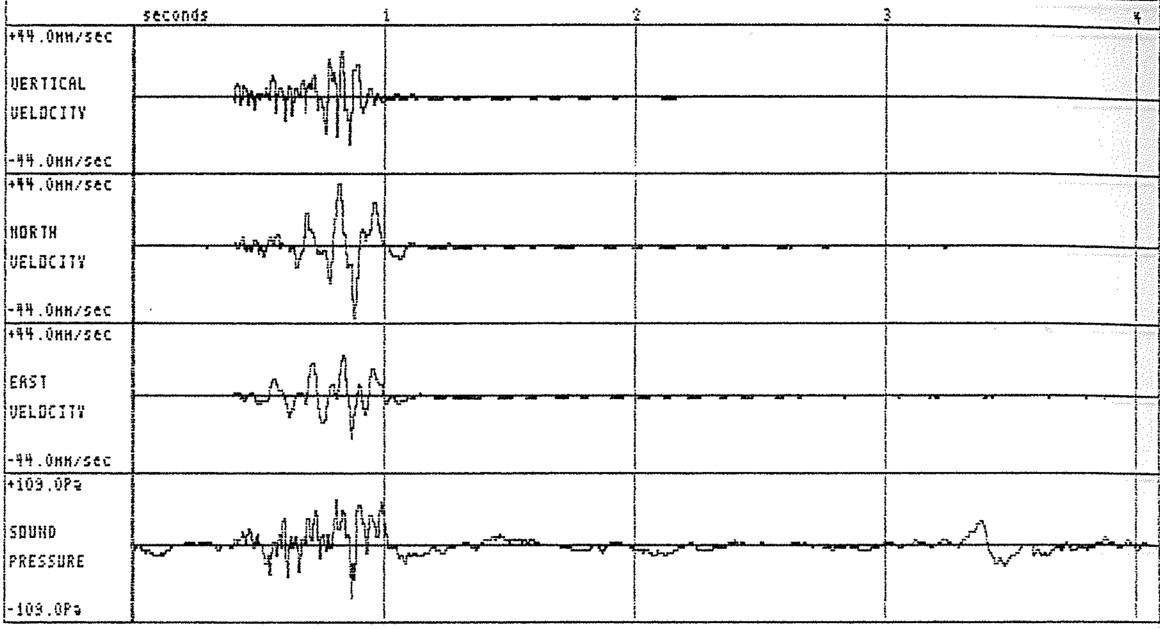


Fig. B.11

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 31.421 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 43.433 mm/sec
08:05:92 11:01	Client: BRITISH COAL	East 26.050 mm/sec
File Information	Location: GLYNCOED BURIED	Res 47.844 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 134.7 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 16.72 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 2.778 mm/sec
08:05:92 11:01	Client: BRITISH COAL	Nrth 1.031 mm/sec
File Information	Location: GLYNCOED BURIED	East 4.486 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 1.100 Pa

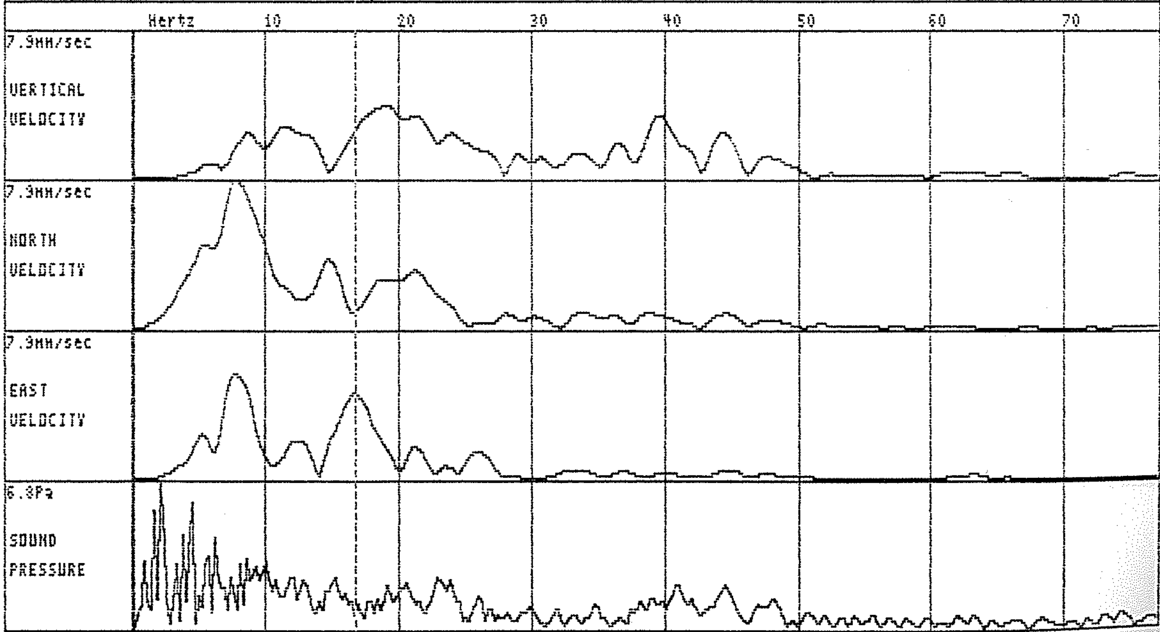
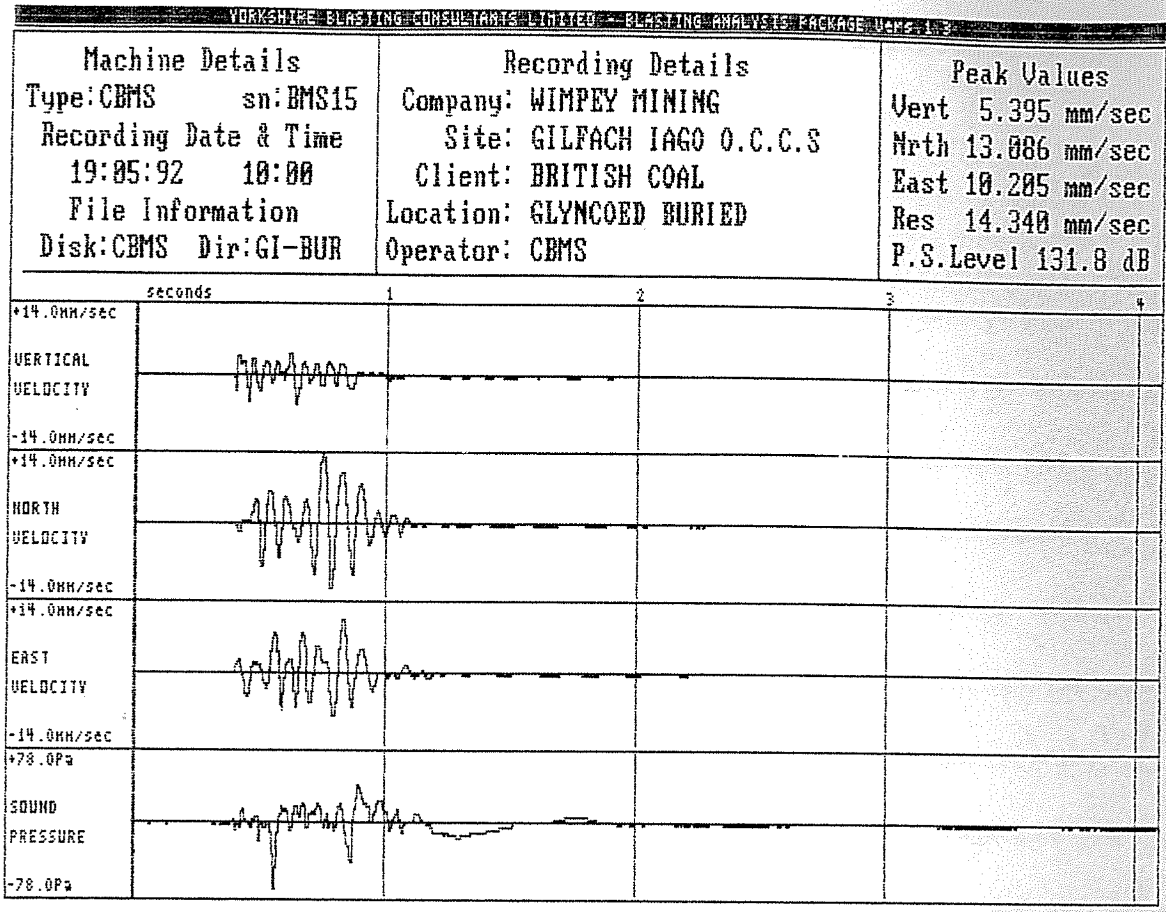


Fig. B.12


YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
19:05:92 10:00
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Peak Values
Vert 5.395 mm/sec
Nrth 13.086 mm/sec
East 10.205 mm/sec
Res 14.340 mm/sec
P.S.Level 131.8 dB
seconds
1
2
3
4
+14.0MM/sec
VERTICAL VELOCITY
-14.0MM/sec
+14.0MM/sec
NORTH VELOCITY
-14.0MM/sec
+14.0MM/sec
EAST VELOCITY
-14.0MM/sec
+78.0Pa
SOUND PRESSURE
-78.0Pa

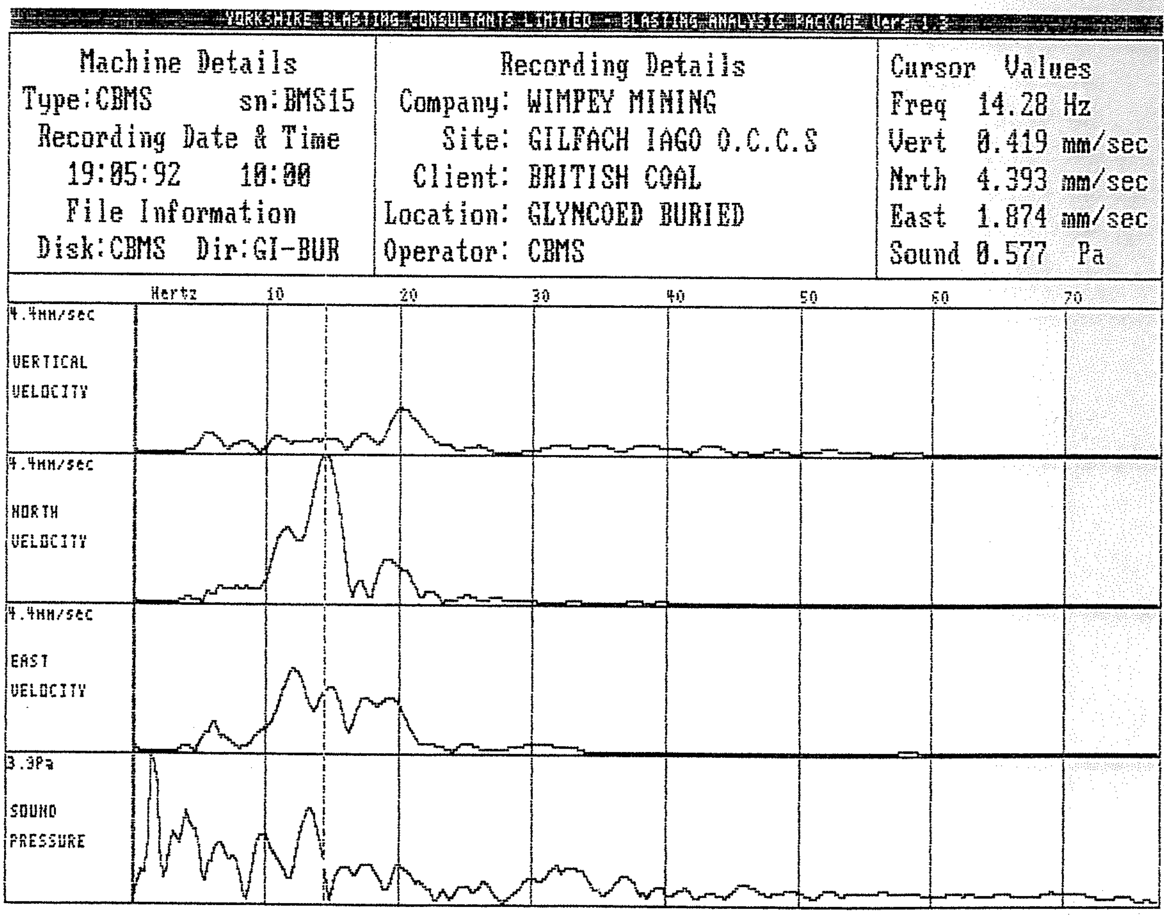
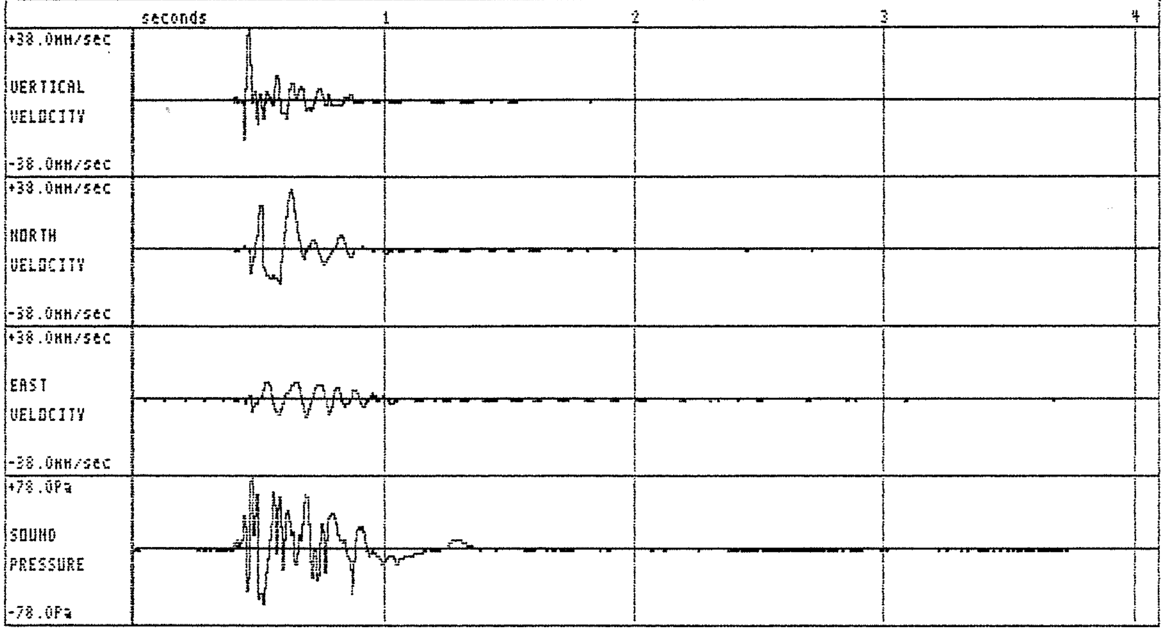

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3
Machine Details
Type:CBMS sn:BMS15
Recording Date & Time
19:05:92 10:00
File Information
Disk:CBMS Dir:GI-BUR
Recording Details
Company: WIMPEY MINING
Site: GILFACH IAGO O.C.C.S
Client: BRITISH COAL
Location: GLYNCOED BURIED
Operator: CBMS
Cursor Values
Freq 14.28 Hz
Vert 0.419 mm/sec
Nrth 4.393 mm/sec
East 1.874 mm/sec
Sound 0.577 Pa
Hertz
10
20
30
40
50
60
70
4.4MM/sec
VERTICAL VELOCITY
4.4MM/sec
NORTH VELOCITY
4.4MM/sec
EAST VELOCITY
3.3Pa
SOUND PRESSURE

Fig. B.13

YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Peak Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Vert 37.305 mm/sec
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Nrth 29.883 mm/sec
09:06:92 12:43	Client: BRITISH COAL	East 10.034 mm/sec
File Information	Location: GLYNCOED BURIED	Res 37.351 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	P.S.Level 131.7 dB



YORKSHIRE BLASTING CONSULTANTS LIMITED - BLASTING ANALYSIS PACKAGE Vers 1.3

Machine Details	Recording Details	Cursor Values
Type:CBMS sn:BMS15	Company: WIMPEY MINING	Freq 9.40 Hz
Recording Date & Time	Site: GILFACH IAGO O.C.C.S	Vert 1.781 mm/sec
09:06:92 12:43	Client: BRITISH COAL	Nrth 4.591 mm/sec
File Information	Location: GLYNCOED BURIED	East 3.012 mm/sec
Disk:CBMS Dir:GI-BUR	Operator: CBMS	Sound 3.430 Pa

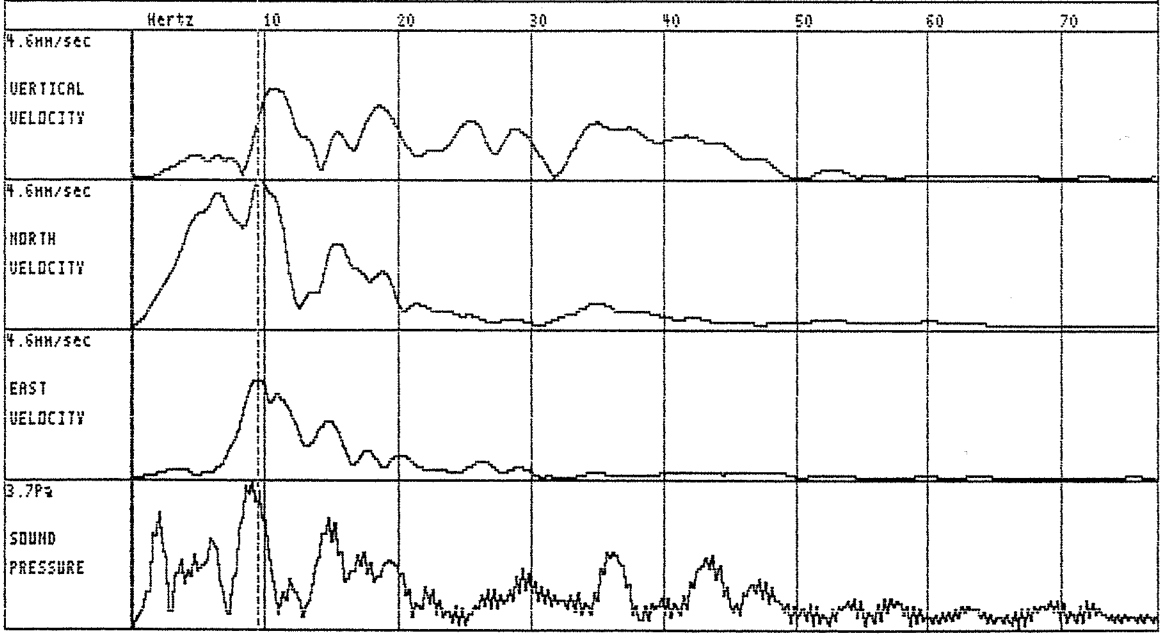
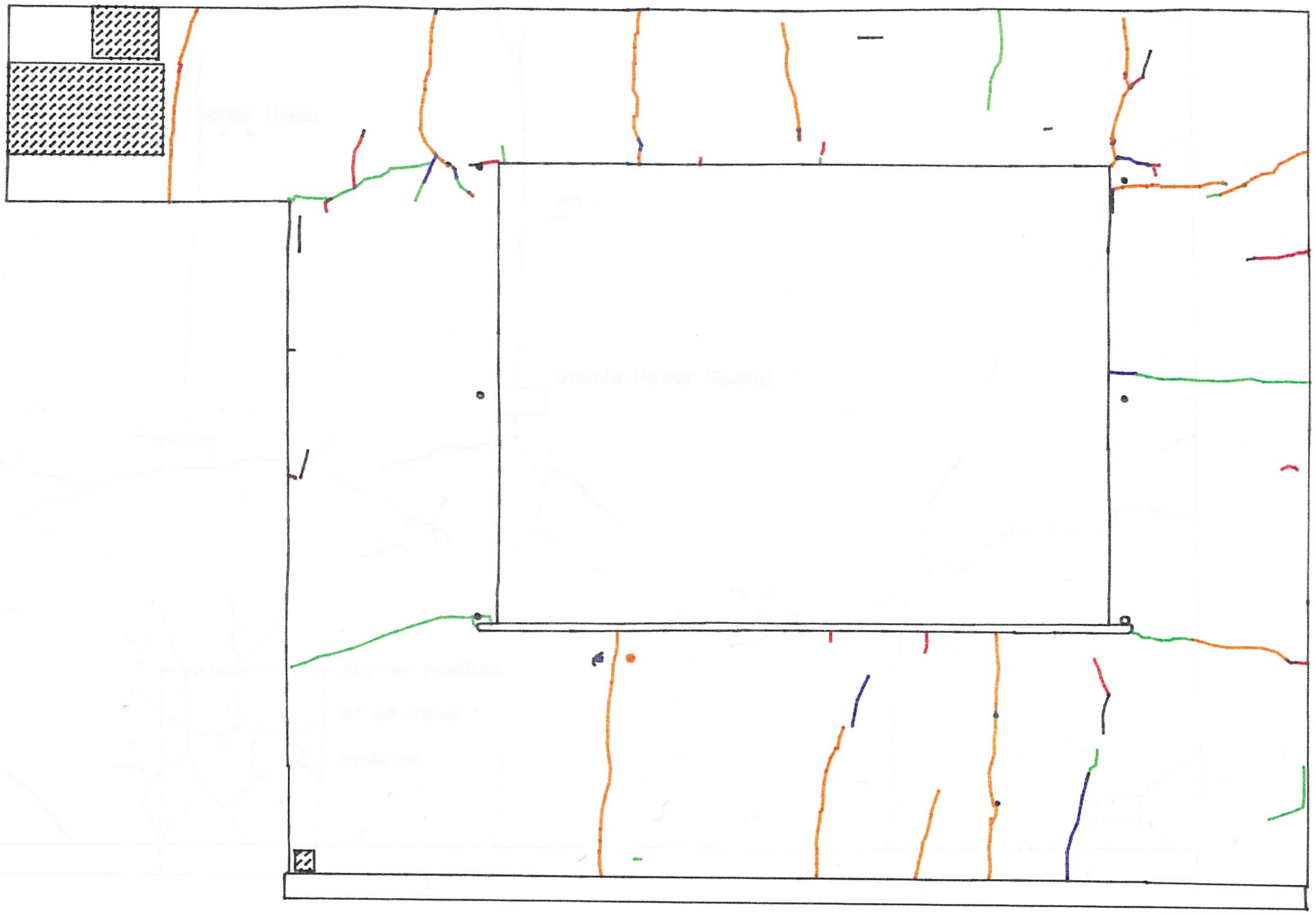


Fig. B.14

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.1



LEGEND

CRACK SURVEY 18/2/90 –
CRACK SURVEY 10/6/90 –
CRACK SURVEY 23/12/90 –
CRACK SURVEY 09/6/91 –
CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 5.40m

Crack Length at 18/02/90 – 5.320m

Crack Length at 10/06/90 – 6.081m^{2}

Crack Length at 23/12/90 – 8.851m

Crack Length at 09/6/91 – 9.894m

Crack Length at 09/6/91 – 10.564m

GILFACH IAGO ROOM A WALL 1

CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.2

LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 – (orange)

CRACK SURVEY 10/6/90 – (blue)

CRACK SURVEY 23/12/90 – (green)

CRACK SURVEY 09/6/91 – (red)

CRACK SURVEY 22/12/91 (black)

SCALE

500 mm

Wall Area :– 9.16m²

Crack Length at 18/02/90 – 9.094m

Crack Length at 10/06/90 – 11.394m

Crack Length at 23/12/90 – 14.134m

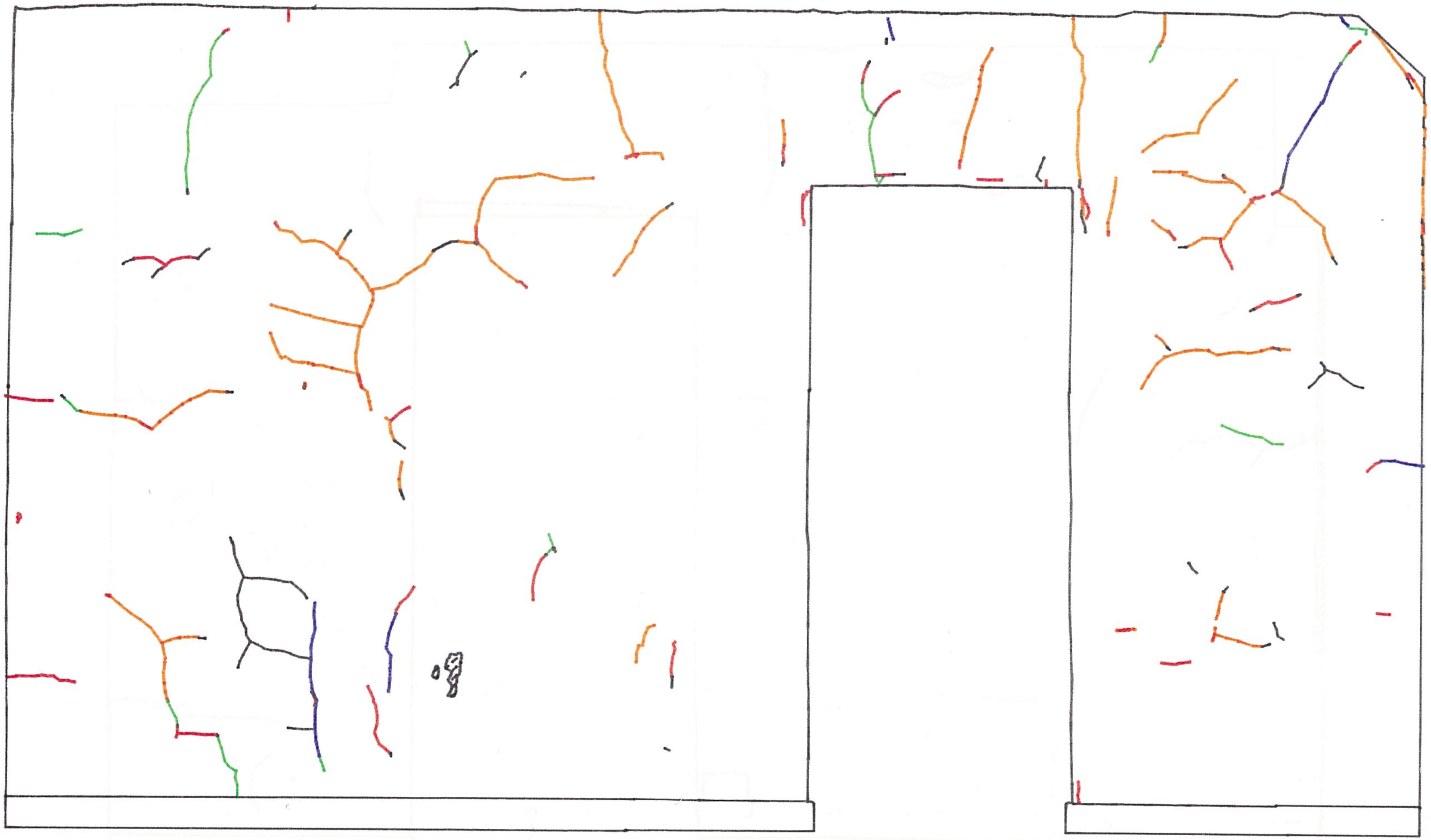
Crack Length at 09/6/91 – 17.91m

Crack Length at 22/12/92 – 19.273m

GILFACH IAGO ROOM A WALL 2 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.3



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –
CRACK SURVEY 10/6/90 –
CRACK SURVEY 23/12/90 –
CRACK SURVEY 09/6/91 –
CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 9.24m

Crack Length at 18/02/90 – 8.997m

Crack Length at 10/06/90 – 10.467m

Crack Length at 23/12/90 – 12.482m

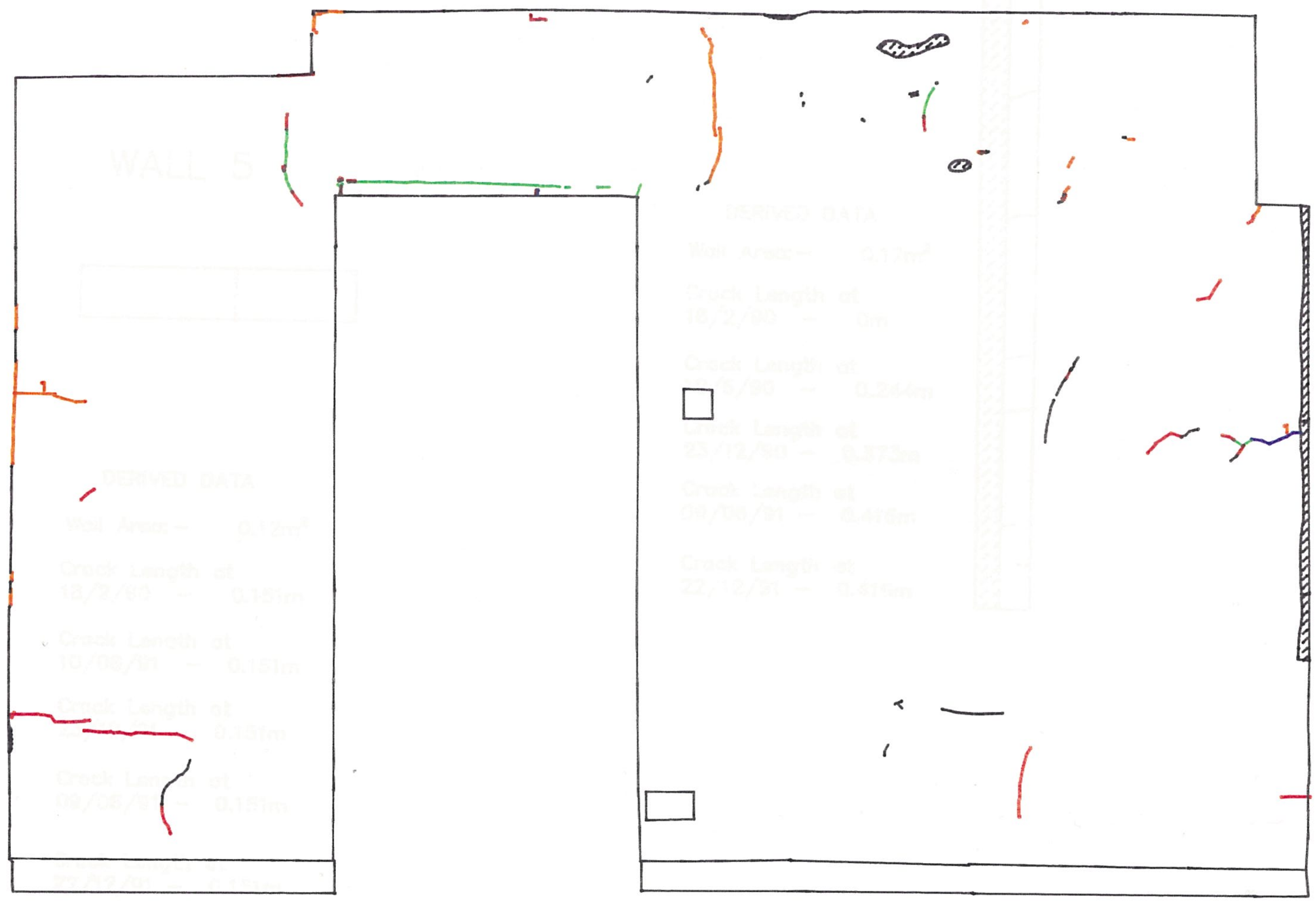
Crack Length at 09/6/91 – 15.36m

Crack Length at 22/12/91 17.662m

GILFACH IAGO ROOM A WALL 3 CRACK GROWTH UPTO 22/12/92

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.4



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –	orange
CRACK SURVEY 10/6/90 –	purple
CRACK SURVEY 23/12/90 –	green
CRACK SURVEY 09/6/91 –	red
CRACK SURVEY 22/12/91	black

SCALE

500 mm

Wall Area :– 7.31m

Crack Length at 18/02/90 – 1.430m

Crack Length at 10/06/90 – 1.599m²

Crack Length at 23/12/90 – 2.674m

Crack Length at 09/6/91 – 4.369m

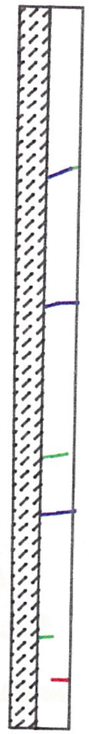
Crack Length at 22/12/91 5.256m

GILFACH IAGO ROOM A WALL 4 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.5

WALL 6



DERIVED DATA

Wall Area:– 0.17m^2

Crack Length at 18/2/90 – 0m

Crack Length at 10/6/90 – 0.244m

Crack Length at 23/12/90 – 0.373m

Crack Length at 09/06/91 – 0.416m

Crack Length at 22/12/91 – 0.416m

WALL 5

DERIVED DATA

Wall Area:– 0.12m^2

Crack Length at 18/2/90 – 0.151m

Crack Length at 10/06/91 – 0.151m

Crack Length at 23/12/91 – 0.151m

Crack Length at 09/06/91 – 0.151m

Crack Length at 22/12/91 – 0.151m

LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –

CRACK SURVEY 10/6/90 –

CRACK SURVEY 23/12/90 –

CRACK SURVEY 09/6/91 –

CRACK SURVEY 22/12/91 –

SCALE

500 mm

Wall Area :– 0.29m^2

Crack Length at 18/02/90 – 0.151m

Crack Length at 10/06/90 – 0.405m

Crack Length at 23/12/90 – 0.534m

Crack Length at 09/6/91 – 0.566m

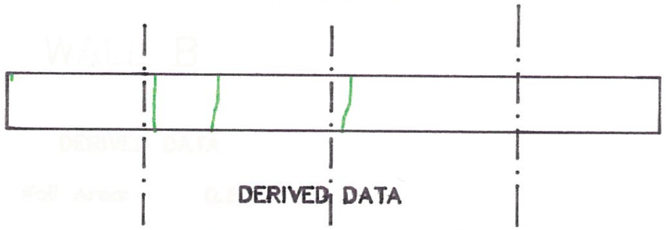
Crack Length at 22/12/91 0.566m

GILFACH IAGO ROOM A WALLS 5 & 6 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.6

WALL 8



DERIVED DATA

Wall Area:– 0.26m²

Crack Length at
18/2/90 – 0.151m

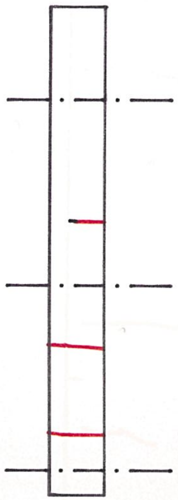
Crack Length at
10/6/90 – 0.151m

Crack Length at
23/12/90 – 0.471m

Crack Length at
09/6/91 – 0.471m

Crack Length at
22/12/91 0.471m

WALL 7



DERIVED DATA

Wall Area:– 0.2m²

Crack Length at
18/2/90 – 0m

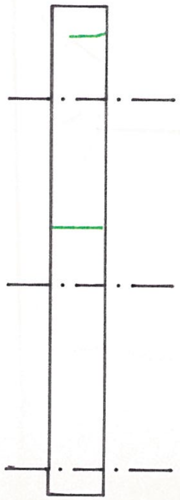
Crack Length at
10/6/90 – 0m

Crack Length at
23/12/90 – 0m

Crack Length at
09/6/91 – 0.378m

Crack Length at
22/12/91 0.395m

WALL 9



DERIVED DATA

Wall Area:– 0.2m²

Crack Length at
18/2/90 – 0.096m

Crack Length at
10/6/90 – 0.235m

Crack Length at
23/12/90 – 0.235m

Crack Length at
09/6/91 – 0.235m

Crack Length at
22/12/91 0.235m

LEGEND

CRACK COLOURS

CRACK SURVEY
18/2/90 – (orange)

CRACK SURVEY
10/6/90 – (purple)

CRACK SURVEY
23/12/90 – (green)

CRACK SURVEY
09/6/91 – (red)

CRACK SURVEY
22/12/92 – (black)

SCALE

500 mm

Wall Area :– 0.66m²

Crack Length at
18/02/90 – 0.247m

Crack Length at
10/06/90 – 0.386m

Crack Length at
23/12/90 – 0.706m

Crack Length at
09/6/91 – 1.084m

Crack Length at
22/12/91 1.101m

GILFACH IAGO ROOM A WALLS 7,8 & 9 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.7

WALL B

DERIVED DATA

Wall Area:– 0.89m²

Crack Length at
18/2/90 – 1.577m

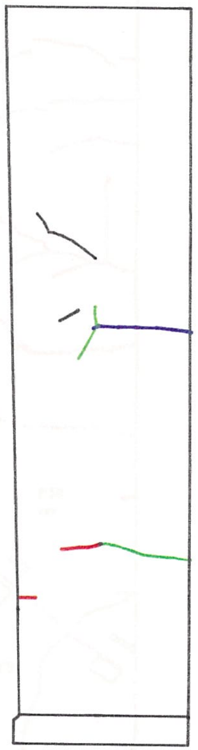
Crack Length at
10/6/90 – 1.903m

Crack Length at
23/12/90 – 2.191m

Crack Length at
09/6/91 – 2.69m

Crack Length at
22/12/91 2.884m

WALL A



DERIVED DATA

Wall Area:– 0.93m²

Crack Length at
18/2/90 – 0m

Crack Length at
10/6/90 – 0.269m

Crack Length at
23/12/90 – 0.663m

Crack Length at
09/6/91 – 0.812m

Crack Length at
22/12/92 1.079m

LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 – (orange)

CRACK SURVEY 10/6/90 – (blue)

CRACK SURVEY 23/12/90 – (green)

CRACK SURVEY 09/6/91 – (red)

CRACK SURVEY 22/12/91 (black)

SCALE

500 mm

Wall Area :– 1.82m²

Crack Length at
18/02/90 – 1.577m

Crack Length at
10/06/90 – 2.172m

Crack Length at
23/12/90 – 2.854m

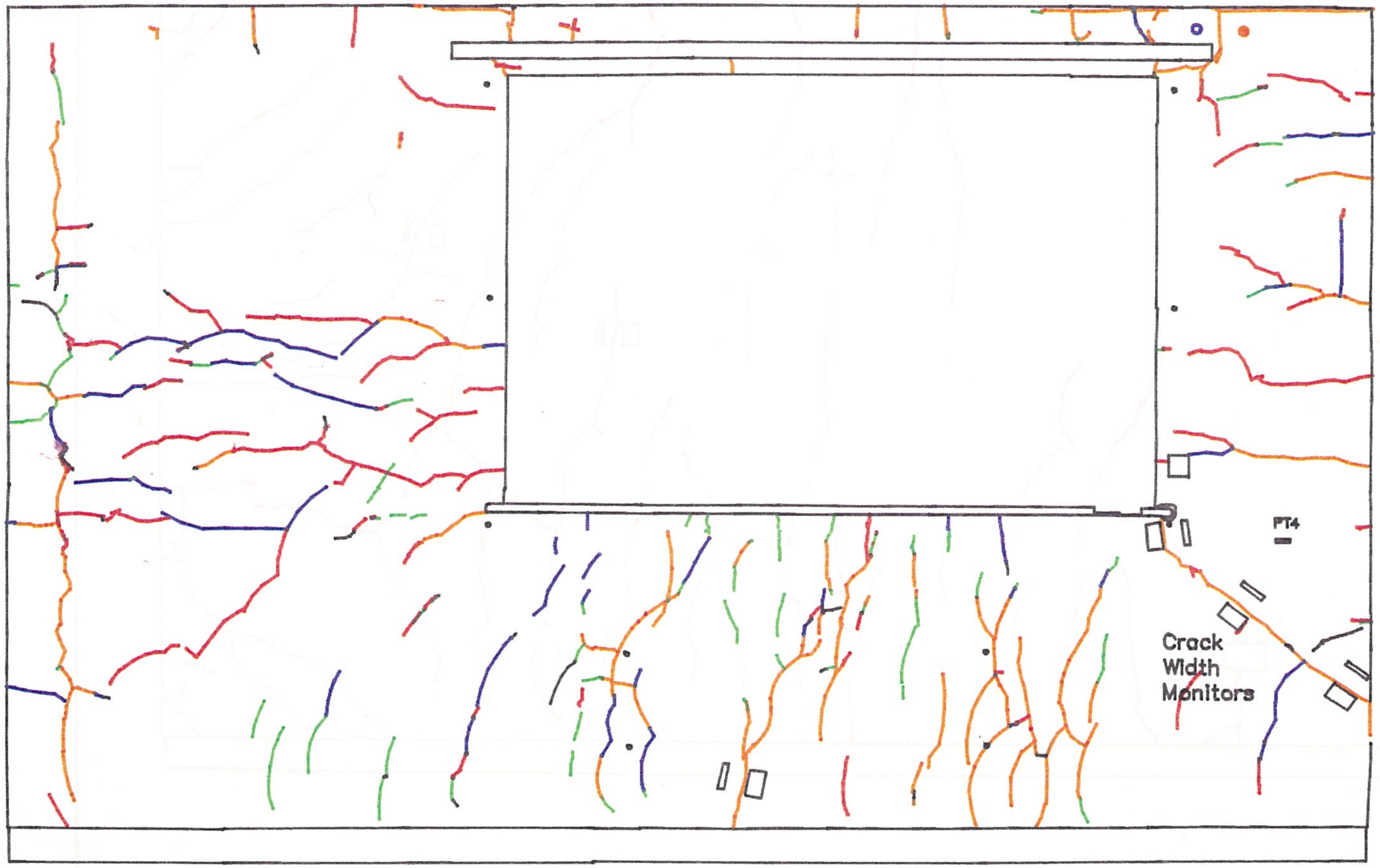
Crack Length at
09/6/91 – 3.502m

Crack Length at
22/12/92 3.963m

GILFACH IAGO ROOM A WALLS A & B CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.8



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 – (orange)

CRACK SURVEY 10/6/90 – (blue)

CRACK SURVEY 23/12/90 – (green)

CRACK SURVEY 09/6/91 – (red)

CRACK SURVEY 22/12/91 (black)

SCALE

500 mm

Wall Area :– 6.13m²

Crack Length at 18/02/90 – 12.759m

Crack Length at 10/06/90 – 17.965m

Crack Length at 23/12/90 – 22.251m

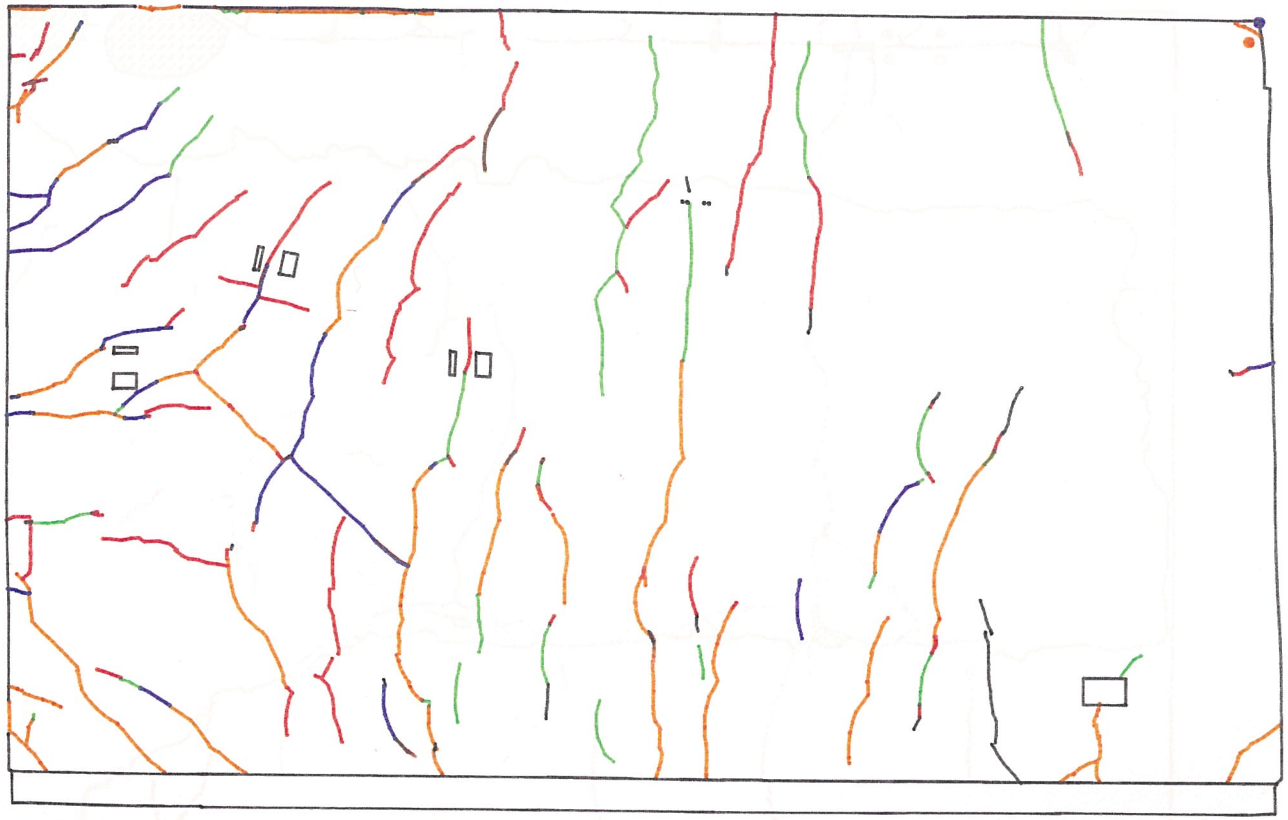
Crack Length at 09/6/91 – 30.31m

Crack Length at 22/12/91 31.116m

GILFACH IAGO ROOM B WALL 1 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.9



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –

CRACK SURVEY 10/6/90 –

CRACK SURVEY 23/12/90 –

CRACK SURVEY 09/6/91 –

CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 8.09m²

Crack Length at 18/02/90 – 10.499m

Crack Length at 10/06/90 – 14.195m

Crack Length at 23/12/90 – 19.371m

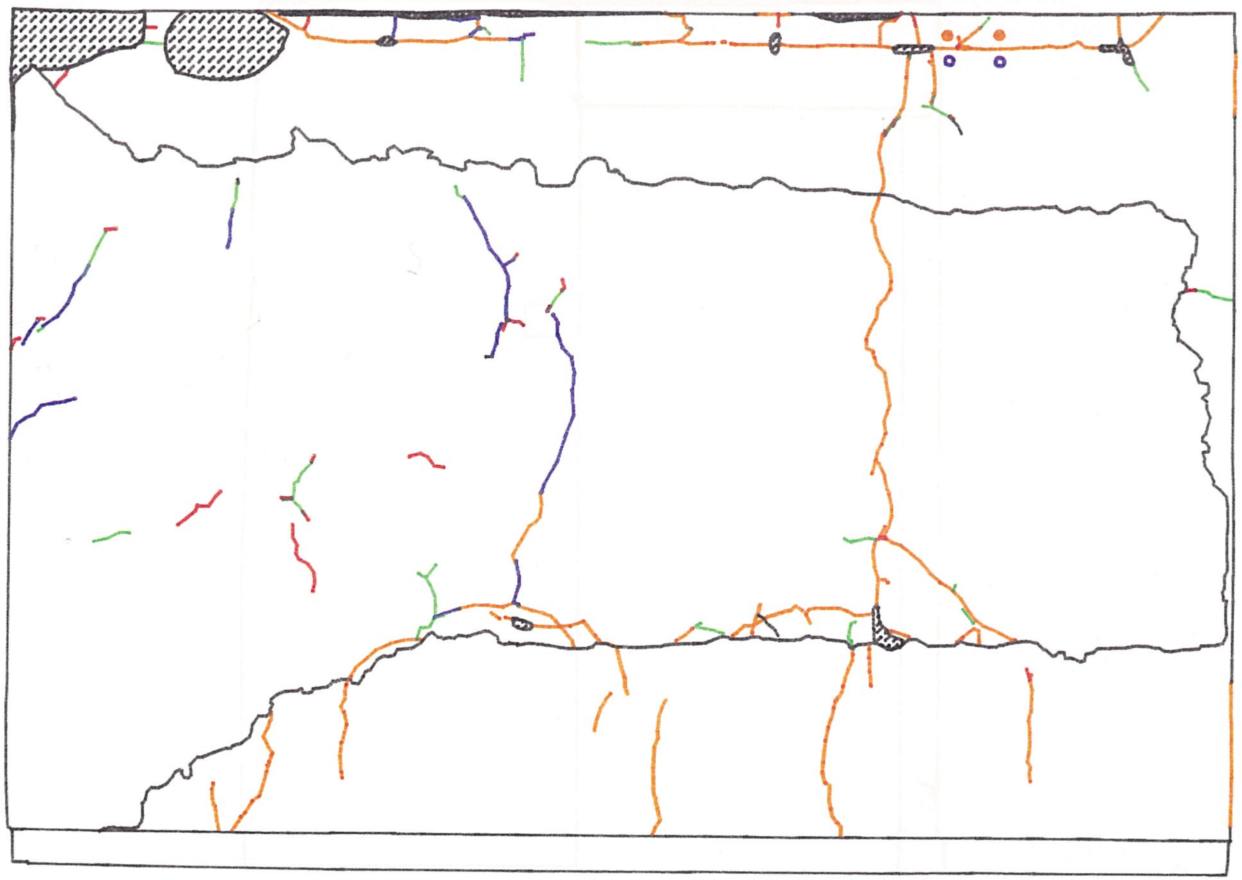
Crack Length at 09/6/91 – 26.41m

Crack Length at 22/12/91 27.635m

GILFACH IAGO ROOM B WALL 2 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.10



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –

CRACK SURVEY 10/6/90 –

CRACK SURVEY 23/12/90 –

CRACK SURVEY 09/6/91 –

CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 7.27m²

Crack Length at 18/02/90 – 9.692m

Crack Length at 10/06/90 – 11.642m

Crack Length at 23/12/90 – 13.656m

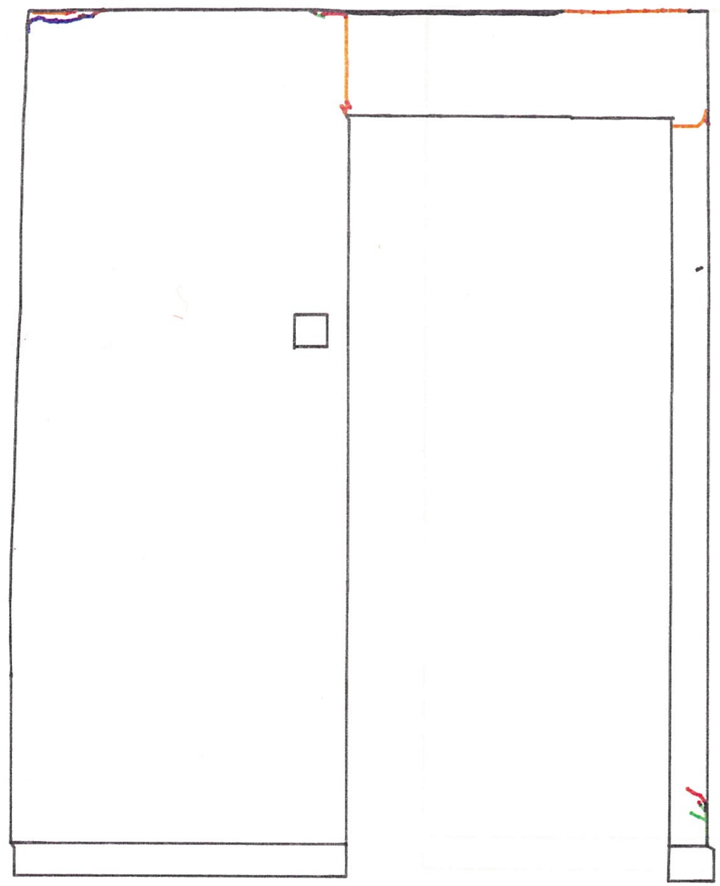
Crack Length at 09/6/91 – 14.61m

Crack Length at 22/12/91 14.754m

GILFACH IAGO ROOM B WALL 3 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.11



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –

CRACK SURVEY 10/6/90 –

CRACK SURVEY 23/12/90 –

CRACK SURVEY 09/6/91 –

CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 2.44m^2

Crack Length at 18/02/90 – 0.826m

Crack Length at 10/06/90 – 1.049m

Crack Length at 23/12/90 – 1.251m

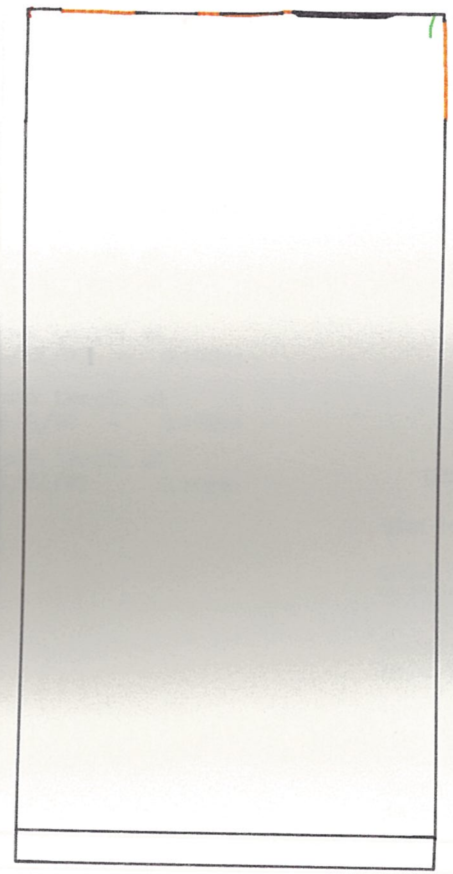
Crack Length at 09/6/91 – 1.506m

Crack Length at 22/12/91 1.540m

GILFACH IAGO ROOM B WALL 4 CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.12



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 – (orange)

CRACK SURVEY 10/6/90 – (purple)

CRACK SURVEY 23/12/90 – (green)

CRACK SURVEY 09/6/91 – (red)

CRACK SURVEY 22/12/91 (black)

SCALE

500 mm

Wall Area :– 2.51m²

Crack Length at 18/02/90 – 0.722m

Crack Length at 10/06/90 – 0.722m

Crack Length at 23/12/90 – 0.789m

Crack Length at 09/6/91 – 0.816m

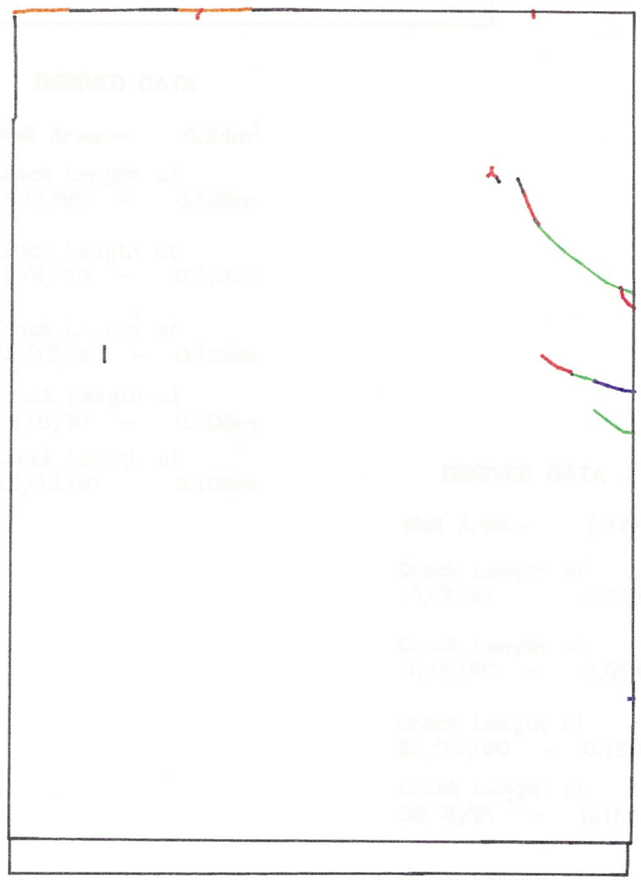
Crack Length at 22/12/91 0.816m

GILFACH IAGO ROOM B WALL 5

CRACK GROWTH UPTO 22/12/91

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.13



LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 –

CRACK SURVEY 10/6/90 –

CRACK SURVEY 23/12/90 –

CRACK SURVEY 09/6/91 –

CRACK SURVEY 22/12/91

SCALE

500 mm

Wall Area :– 3.69m²

Crack Length at 18/02/90 – 0.351m

Crack Length at 10/06/90 – 0.472m

Crack Length at 23/12/90 – 1.002m

Crack Length at 09/6/91 – 1.335m

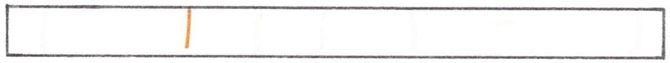
Crack Length at 22/12/92 1.438m

GILFACH IAGO ROOM B WALL 6 CRACK GROWTH UPTO 22/12/92

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.14

WALL 8



DERIVED DATA

Wall Area:– 0.24m²

Crack Length at 18/2/90 – 0.108m

Crack Length at 10/6/90 – 0.108m

Crack Length at 23/12/90 – 0.108m

Crack Length at 09/6/91 – 0.108m

Crack Length at 22/12/91 0.108m

WALL 7

DERIVED DATA

Wall Area:– 0.15m²

Crack Length at 18/2/90 – 0m

Crack Length at 10/6/90 – 0.238m

Crack Length at 23/12/90 – 0.268m

Crack Length at 09/6/91 – 0.466m

Crack Length at 22/12/91 0.466m

WALL 9

DERIVED DATA

Wall Area:– 0.15m²

Crack Length at 18/2/90 – 0.054m

Crack Length at 10/6/90 – 0.054m

Crack Length at 23/12/90 – 0.183m

Crack Length at 09/6/91 – 0.183m

Crack Length at 22/12/91 0.183m

LEGEND

CRACK COLOURS

CRACK SURVEY 18/2/90 – (orange)

CRACK SURVEY 10/6/90 – (purple)

CRACK SURVEY 23/12/90 – (green)

CRACK SURVEY 09/6/91 – (red)

CRACK SURVEY 22/12/91 (black)

SCALE

500 mm

Wall Area :– 0.54m

Crack Length at 18/02/90 – 0.162m

Crack Length at 10/06/90 – 0.400m

Crack Length at 2
23/12/90 – 0.599m

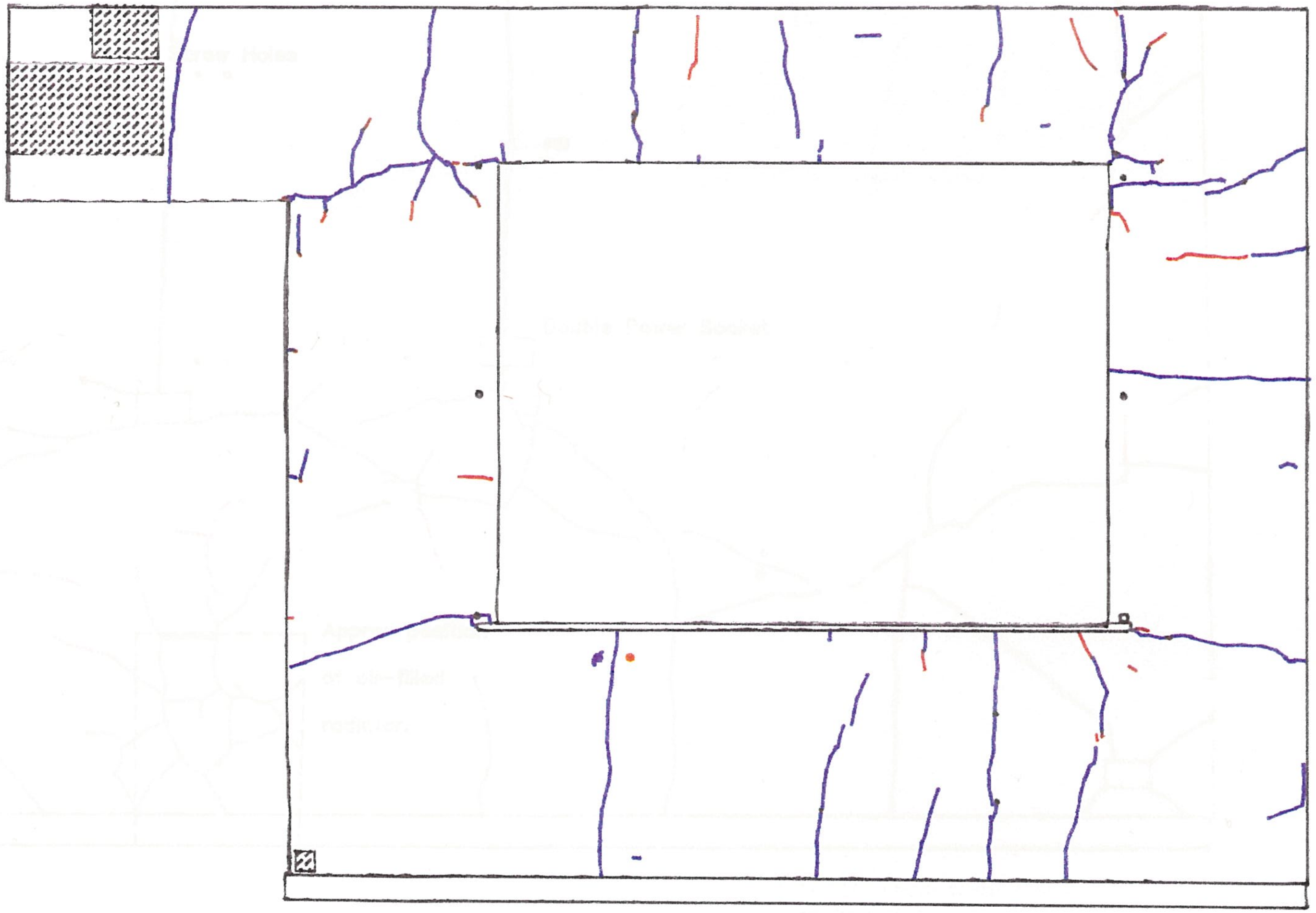
Crack Length at 09/6/91 – 0.757m

Crack Length at 22/12/91 0.757m

GILFACH IAGO ROOM B WALLS 7,8 & 9 CRACK GROWTH UPTO 22/12/92

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.15



LEGEND

CRACK PROFILE PHASE 1 –

CRACK PROFILE PHASE 2 –

SCALE

500 mm

Wall Area :– 5.40m

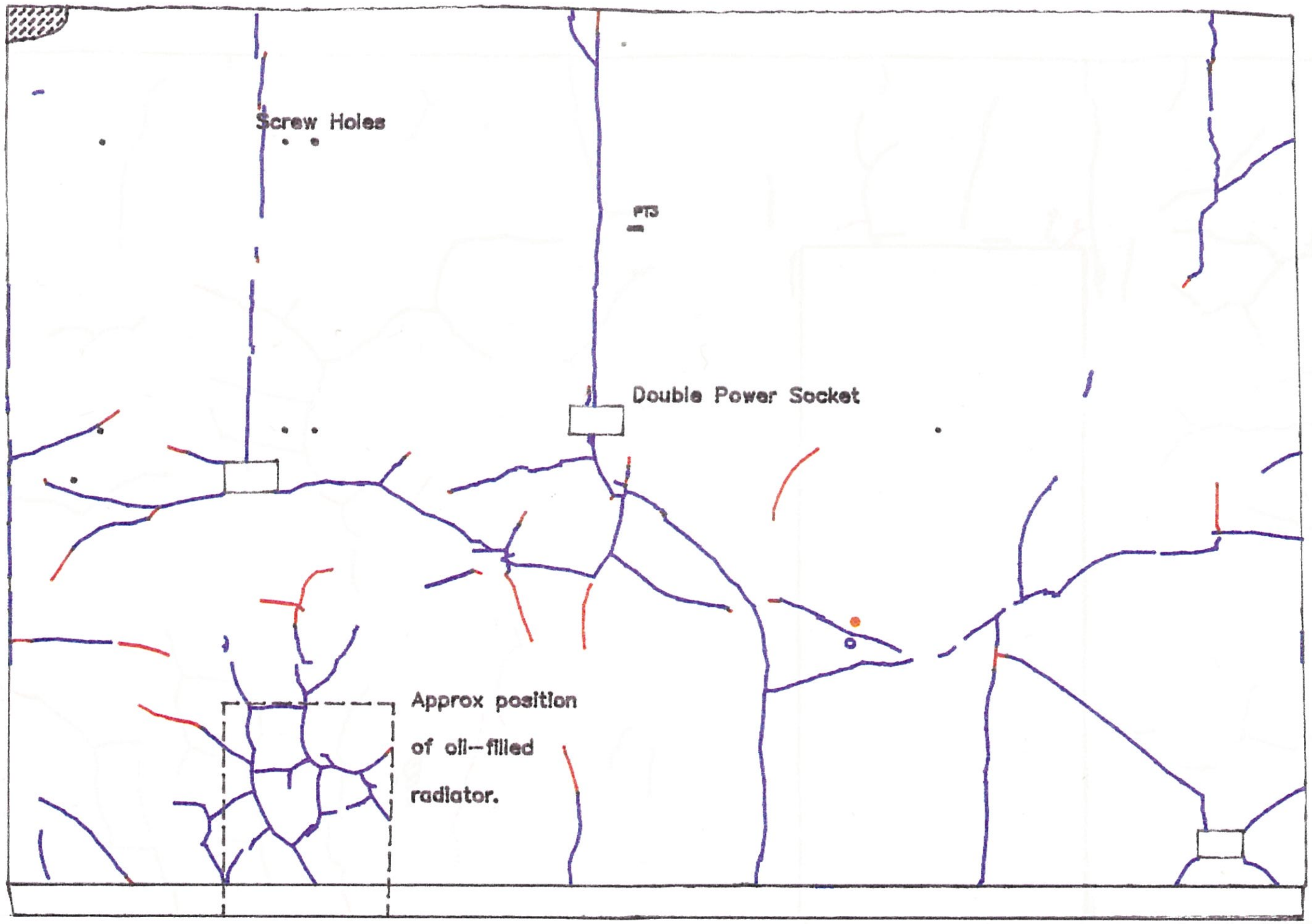
CRACK LENGTH AT PHASE 1 – 10.564m

CRACK LENGTH AT PHASE 2 – 12.165m

GILFACH IAGO   ROOM A   WALL 1   TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.16



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 9.16m²

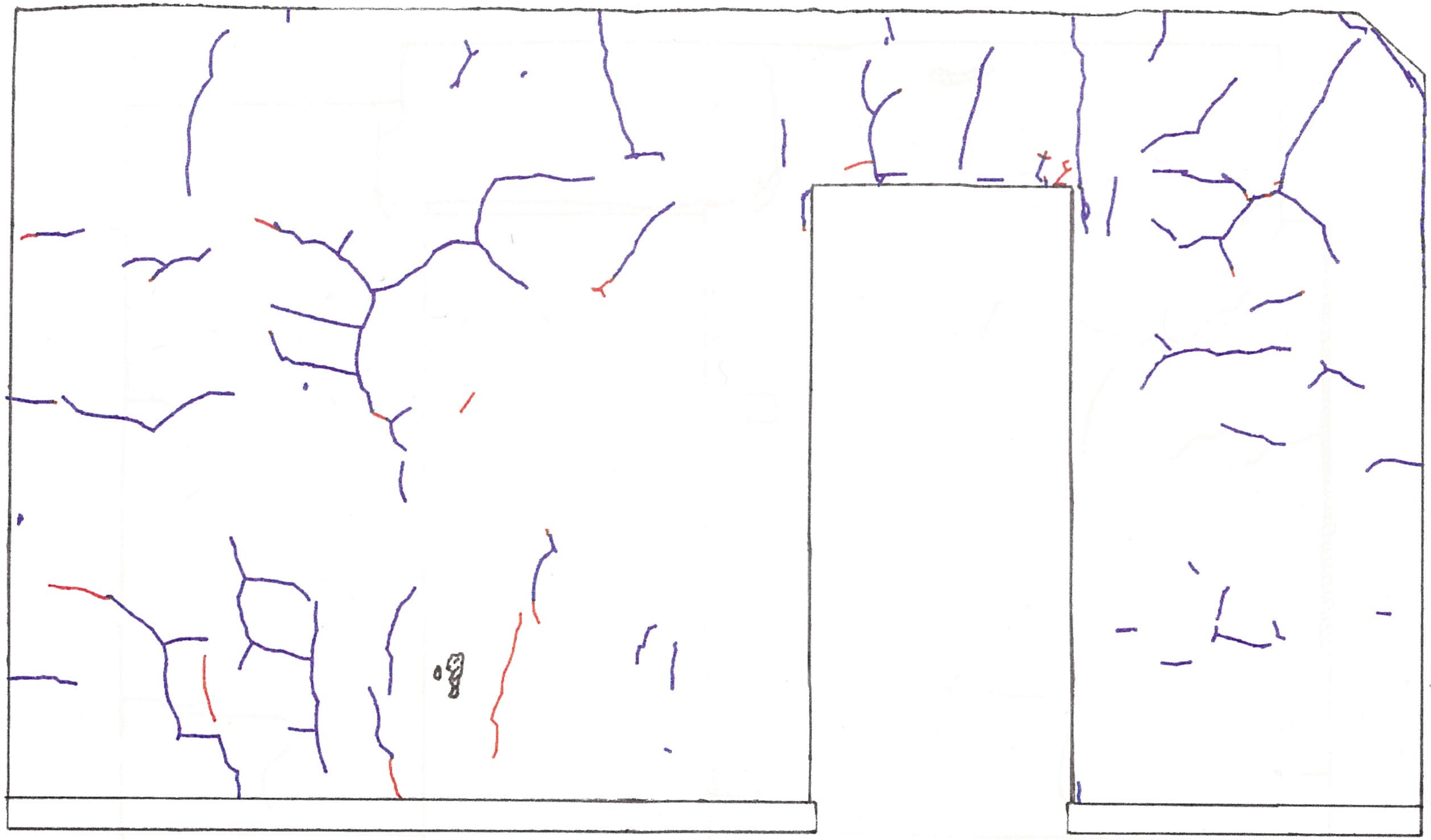
CRACK LENGTH AT PHASE 1 19.273m

CRACK LENGTH AT PHASE 2 21.809m

GILFACH IAGO ROOM A WALL 2 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.17

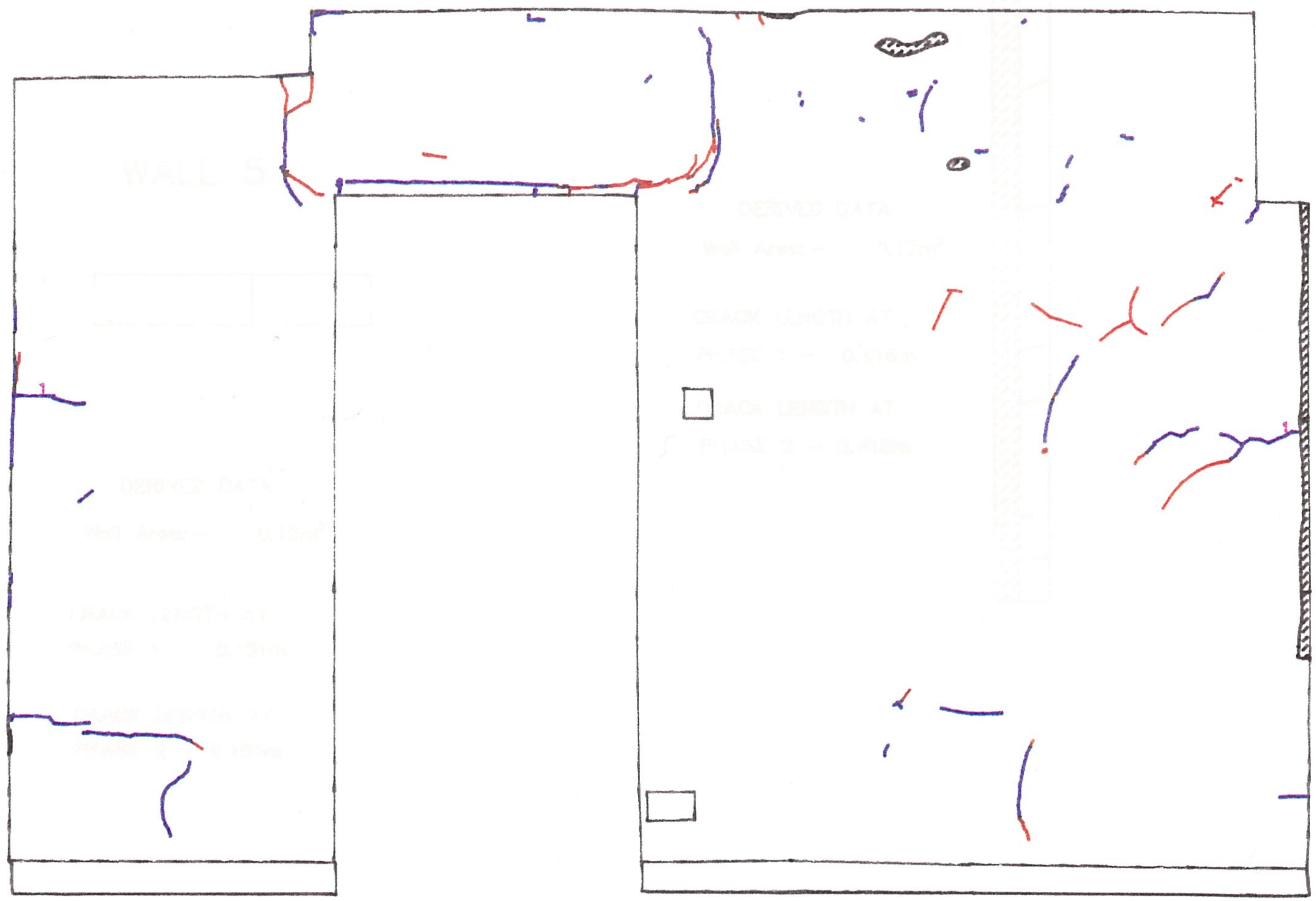


LEGEND	
CRACK COLOURS	
CRACK PROFILE PHASE 1	(blue)
CRACK PROFILE PHASE 2	(red)
SCALE	500 mm
Wall Area :–	9.24m
CRACK LENGTH AT PHASE 1	17.662m
CRACK LENGTH AT PHASE 2	19.611m

GILFACH IAGO ROOM A WALL 3 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.18



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 7.31m

CRACK LENGTH AT PHASE 1 5.256m

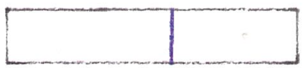
CRACK LENGTH AT PHASE 2 8.010m

GILFACH IAGO ROOM A WALL 4 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.19

WALL 5



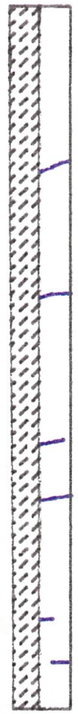
DERIVED DATA

Wall Area:– 0.12m²

CRACK LENGTH AT
PHASE 1 – 0.151m

CRACK LENGTH AT
PHASE 2 – 0.151m

WALL 6



DERIVED DATA

Wall Area:– 0.17m²

CRACK LENGTH AT
PHASE 1 – 0.416m

CRACK LENGTH AT
PHASE 2 – 0.416m

LEGEND

CRACK COLOURS

CRACK PROFILE
PHASE 1

CRACK PROFILE
PHASE 2

SCALE

500 mm

Wall Area :– 0.29m²

CRACK LENGTH AT
PHASE 1 0.566m

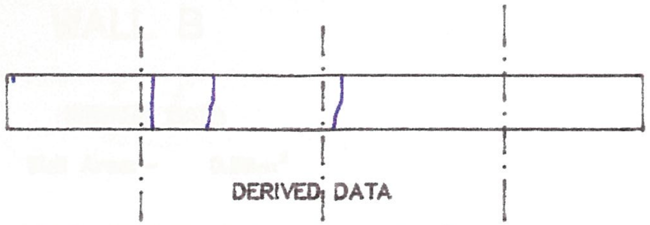
CRACK LENGTH AT
PHASE 2 0.566m

GILFACH IAGO ROOM A WALLS 5 & 6 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.20

WALL 8



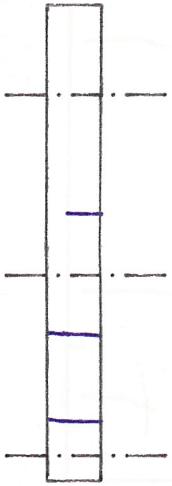
DERIVED DATA

Wall Area:– 0.26m²

CRACK LENGTH AT
PHASE 1 0.471m

CRACK LENGTH AT
PHASE 2 0.471m

WALL 7



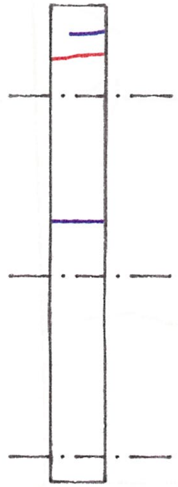
DERIVED DATA

Wall Area:– 0.2m²

CRACK LENGTH AT
PHASE 1 0.395m

CRACK LENGTH AT
PHASE 2 0.395m

WALL 9



DERIVED DATA

Wall Area:– 0.2m²

CRACK LENGTH AT
PHASE 1 0.235m

CRACK LENGTH AT
PHASE 2 0.387m

LEGEND

CRACK COLOURS

CRACK SURVEY
PHASE 1

CRACK SURVEY
PHASE 2

SCALE

500 mm

Wall Area :– 0.66m²

CRACK LENGTH AT
PHASE 1 1.101m

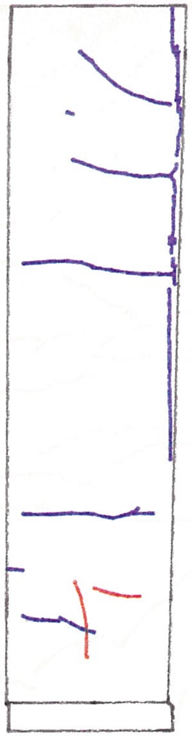
CRACK LENGTH AT
PHASE 2 1.253m

GILFACH IAGO ROOM A WALLS 7,8 & 9 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.21

WALL B



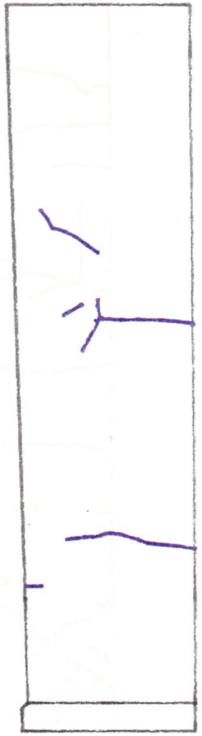
DERIVED DATA

Wall Area:– 0.89m²

CRACK LENGTH AT PHASE 1 2.884m

CRACK LENGTH AT PHASE 2 3.231m

WALL A



DERIVED DATA

Wall Area:– 0.93m²

CRACK LENGTH AT PHASE 1 1.079m

CRACK LENGTH AT PHASE 2 1.079m

LEGEND

CRACK COLOURS

CRACK SURVEY PHASE 1 (blue)

CRACK SURVEY PHASE 2 (red)

SCALE

500 mm

Wall Area :– 1.82m²

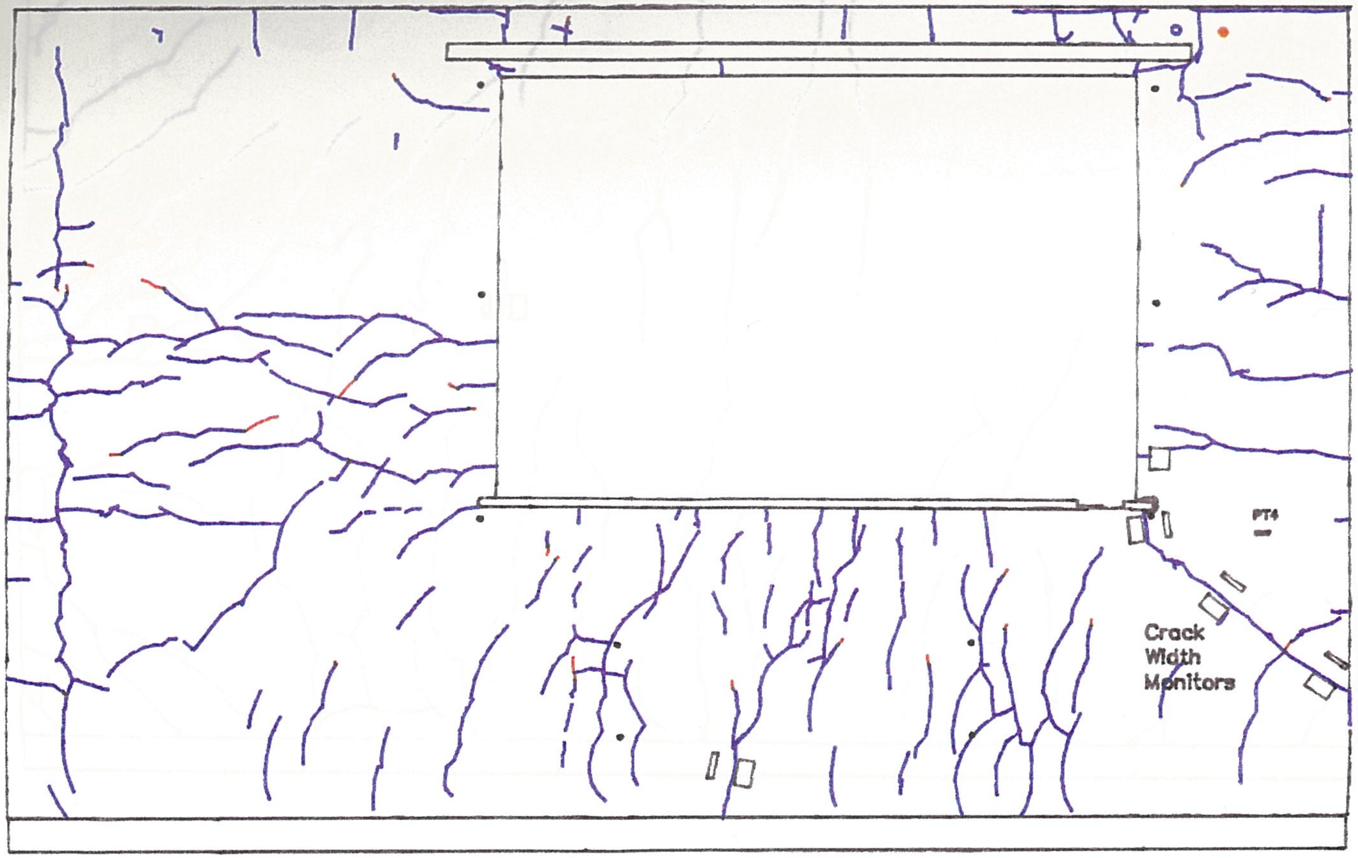
CRACK LENGTH AT PHASE 1 3.963m

CRACK LENGTH AT PHASE 2 4.310m

GILFACH IAGO ROOM A WALLS A & B TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.22



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 6.13m²

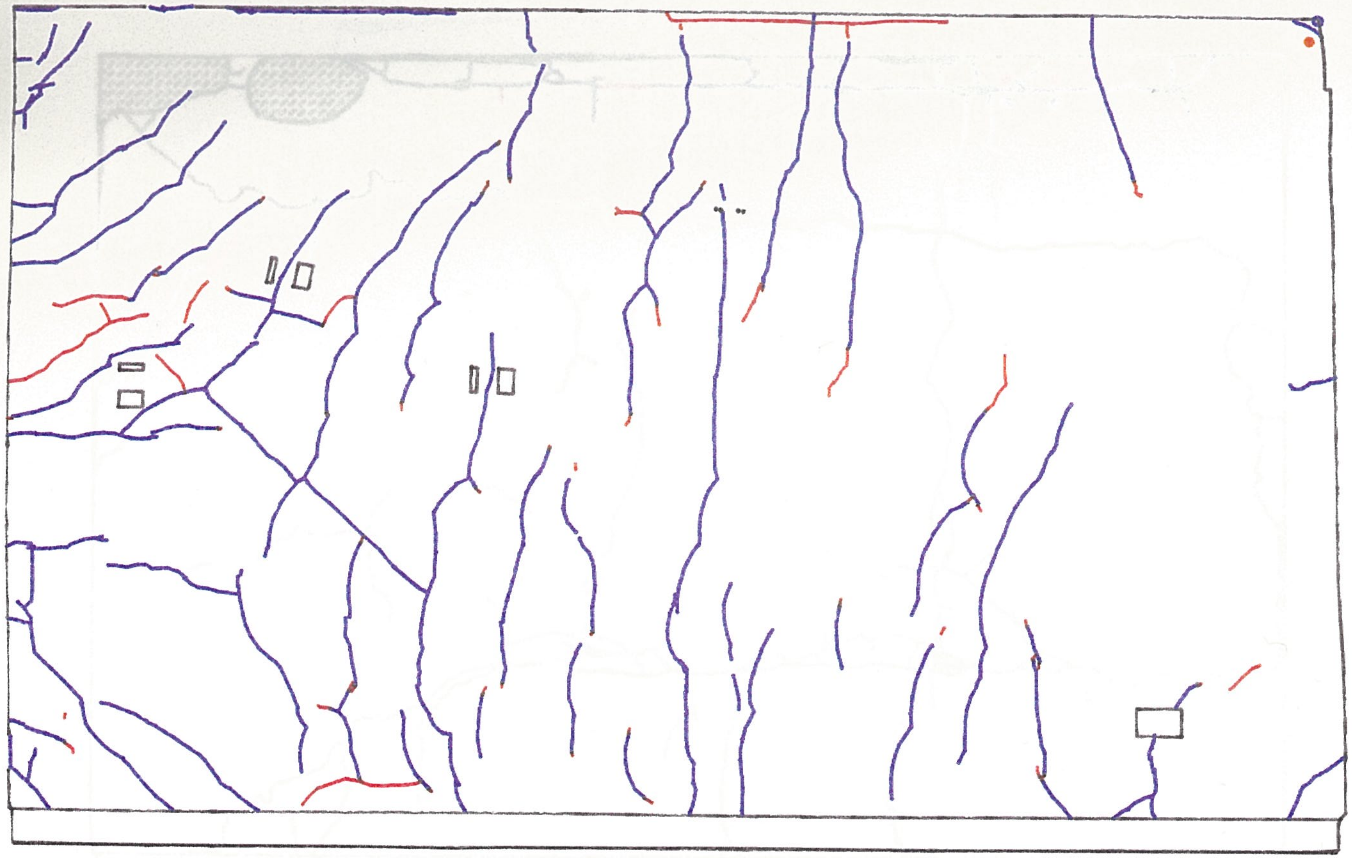
CRACK LENGTH AT PHASE 1 31.166m

CRACK LENGTH AT PHASE 2 32.112m

GILFACH IAGO ROOM B WALL 1 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.23



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 8.09m²

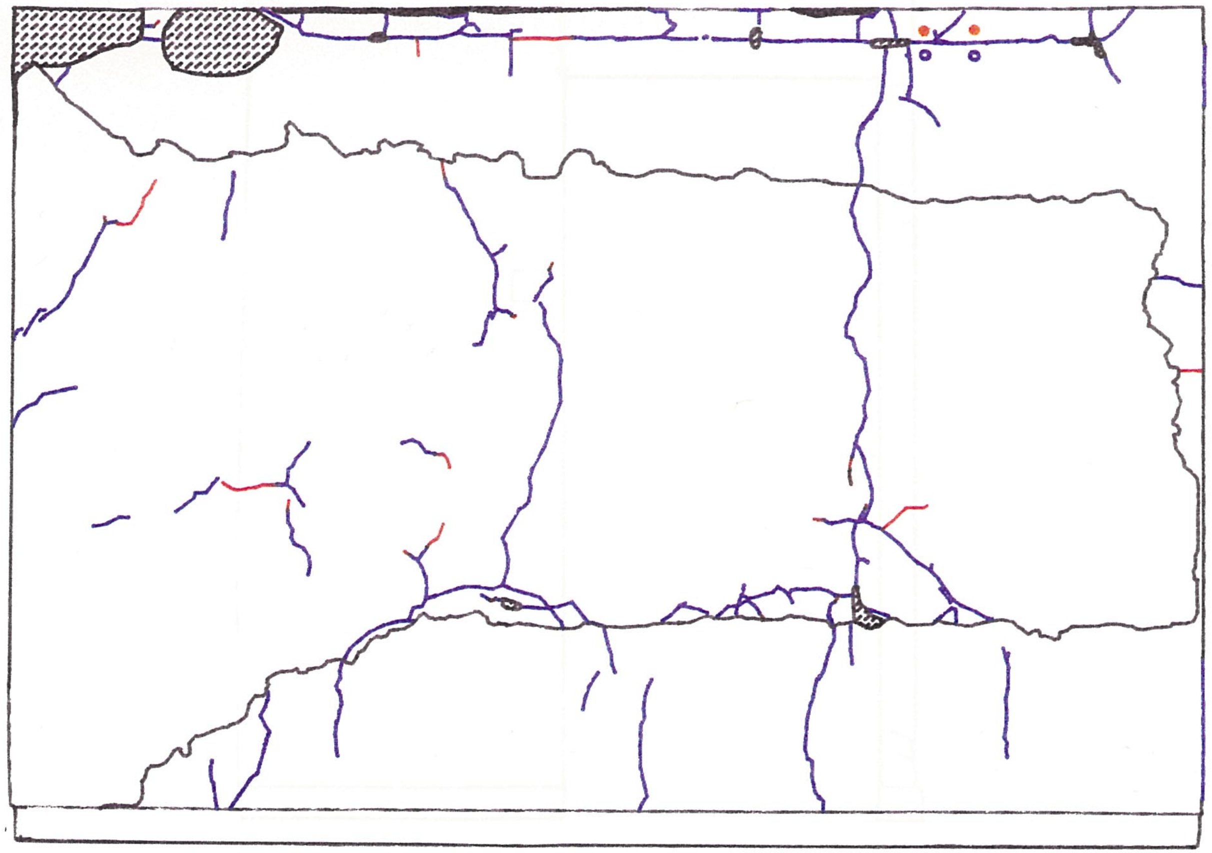
CRACK LENGTH AT PHASE 1 27.635m

CRACK LENGTH AT PHASE 2 31.401m

GILFACH IAGO ROOM B WALL 2 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.24



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 7.27m²

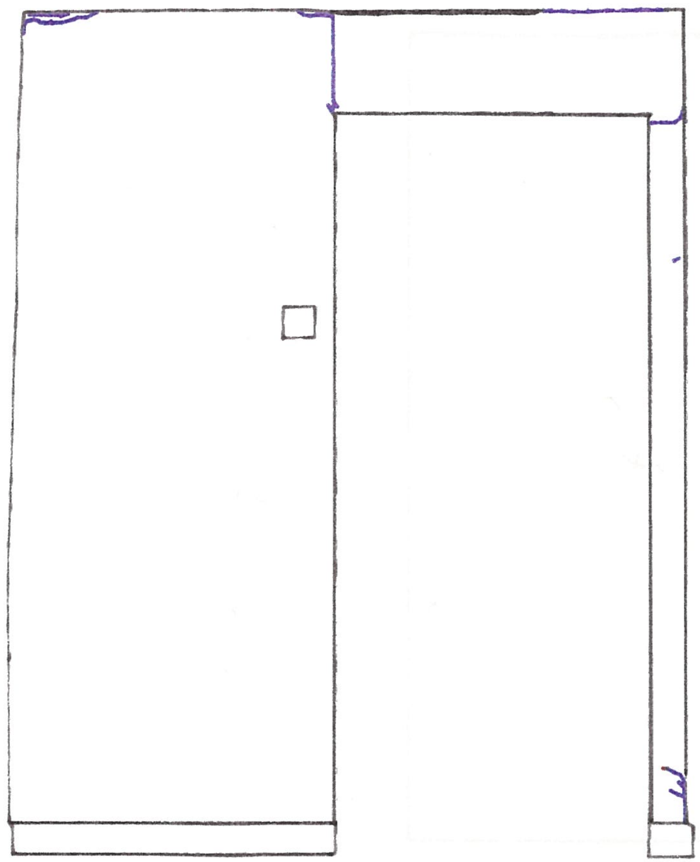
CRACK LENGTH AT PHASE 1 14.754m

CRACK LENGTH AT PHASE 2 16.020m

GILFACH IAGO ROOM B WALL 3 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.25



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 2.44m²

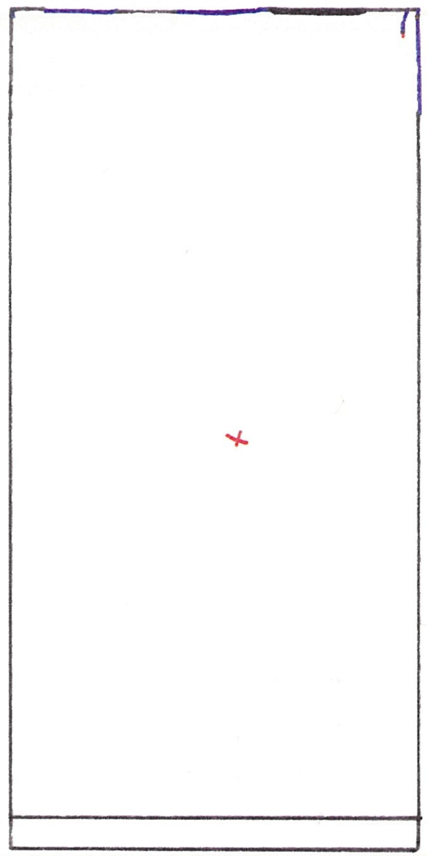
CRACK LENGTH AT PHASE 1 1.540m

CRACK LENGTH AT PHASE 2 1.555m

GILFACH IAGO ROOM B WALL 4 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.26



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 2.51m²

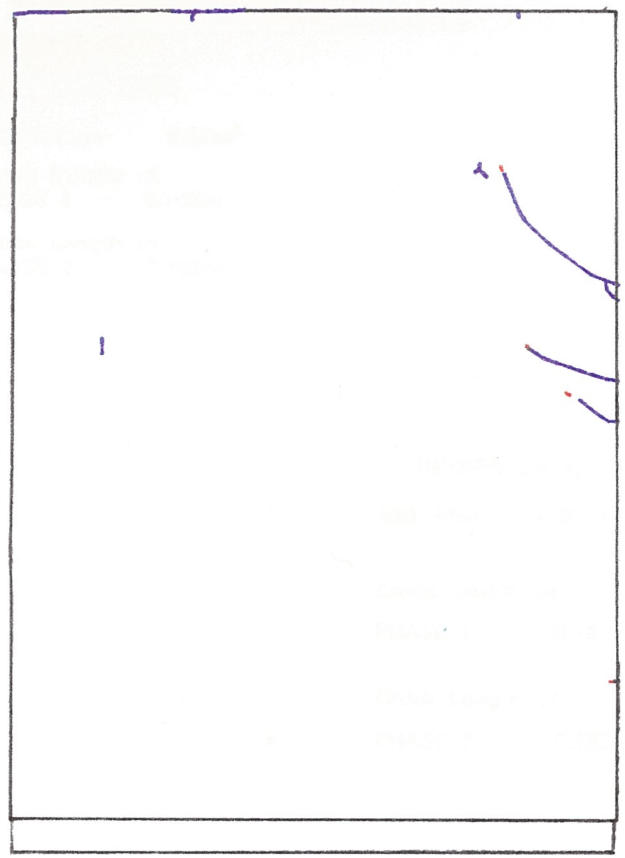
CRACK LENGTH AT PHASE 1 0.816m

CRACK LENGTH AT PHASE 2 0.922m

GILFACH IAGO ROOM B WALL 5 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.27



LEGEND

CRACK COLOURS

CRACK PROFILE PHASE 1

CRACK PROFILE PHASE 2

SCALE

500 mm

Wall Area :– 3.69m²

CRACK LENGTH AT PHASE 1 1.438m

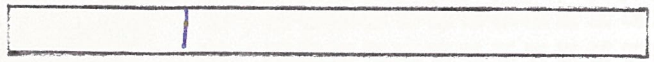
CRACK LENGTH AT PHASE 2 1.480m

GILFACH IAGO ROOM B WALL 6 TOTAL CRACK GROWTH

LEEDS UNIVERSITY: DEPT. OF MINING AND MINERAL ENGINEERING – BLASTING RESEARCH GROUP

Fig. C.28

WALL 8



DERIVED DATA

Wall Area:– 0.24m²

Crack Length at
PHASE 1 – 0.108m

Crack Length at
PHASE 2 – 0.108m

WALL 7

DERIVED DATA

Wall Area:– 0.15m²

Crack Length at

PHASE 1 0.466m

Crack Length at

PHASE 2 0.539m

WALL 9

DERIVED DATA

Wall Area:– 0.15m²

Crack Length at

PHASE 1 0.183m

Crack Length at

PHASE 2 0.183m

LEGEND

CRACK COLOURS

CRACK PROFILE
PHASE 1

CRACK PROFILE
PHASE 2

SCALE

500 mm

Wall Area :– 0.54m

CRACK LENGTH AT
PHASE 1 0.757m

CRACK LENGTH AT
PHASE 2 0.930m

GILFACH IAGO ROOM B WALLS 7,8 & 9 TOTAL CRACK GROWTH

MONTHLY CRACK LENGTH FOR ROOM A

DATE	A1	A2	A3	A4	A5	A6	A7	A8	A9	AA	AB	TOTAL A	MONTHL INCREA
21-Jan-90	5.04	9.09	9.00	1.43	0.15	0.00	0.00	0.15	0.10	0.00	1.58	26.54	
18-Feb-90	5.32	9.09	9.00	1.43	0.15	0.00	0.00	0.15	0.10	0.00	1.58	26.82	0.28
18-Mar-90	5.32	9.09	9.44	1.45	0.15	0.00	0.00	0.15	0.10	0.00	1.90	27.60	0.79
15-Apr-90	5.41	9.09	9.51	1.45	0.15	0.08	0.00	0.15	0.10	0.27	1.90	28.11	0.51
12-May-90	5.59	10.92	10.30	1.52	0.15	0.08	0.00	0.15	0.24	0.27	1.90	31.11	3.00
10-Jun-90	6.08	11.39	10.47	1.60	0.15	0.24	0.00	0.15	0.24	0.27	1.90	32.49	1.39
08-Jul-90	6.98	11.41	10.53	2.09	0.15	0.24	0.00	0.15	0.24	0.27	1.90	33.95	1.46
05-Aug-90	6.98	11.41	11.44	2.09	0.15	0.24	0.00	0.15	0.24	0.27	1.90	34.86	0.91
02-Sep-90	7.03	11.41	11.46	2.09	0.15	0.24	0.00	0.15	0.24	0.43	1.90	35.10	0.23
30-Sep-90	7.32	11.41	11.46	2.19	0.15	0.24	0.00	0.15	0.24	0.43	1.90	35.49	0.40
28-Oct-90	7.99	11.81	12.06	2.30	0.15	0.34	0.00	0.47	0.24	0.66	2.09	38.10	2.60
25-Nov-90	8.31	12.34	12.14	2.32	0.15	0.34	0.00	0.47	0.24	0.66	2.16	39.12	1.03
23-Dec-90	8.85	14.13	12.43	2.67	0.15	0.37	0.00	0.47	0.24	0.66	2.19	42.17	3.05
20-Jan-91	9.26	15.37	13.90	3.49	0.15	0.37	0.30	0.47	0.24	0.66	2.56	46.78	4.61
17-Feb-91	9.58	16.69	14.14	3.88	0.15	0.37	0.34	0.47	0.24	0.66	2.56	49.09	2.31
17-Mar-91	9.58	16.72	14.15	3.88	0.15	0.37	0.34	0.47	0.24	0.66	2.62	49.18	0.09
14-Apr-91	9.81	17.40	15.10	4.25	0.15	0.42	0.38	0.47	0.24	0.77	2.69	51.67	2.49
12-May-91	9.89	17.60	15.32	4.37	0.15	0.42	0.38	0.47	0.24	0.81	2.69	52.34	0.67
09-Jun-91	9.89	17.91	15.36	4.37	0.15	0.42	0.38	0.47	0.24	0.81	2.69	52.69	0.35
07-Jul-91	10.05	18.27	16.39	4.51	0.15	0.42	0.38	0.47	0.24	0.81	2.79	54.47	1.78
04-Aug-91	10.05	18.27	16.65	4.71	0.15	0.42	0.38	0.47	0.24	0.81	2.82	54.96	0.49
01-Sep-91	10.05	18.39	16.67	4.78	0.15	0.42	0.38	0.47	0.24	0.87	2.82	55.23	0.28
29-Sep-91	10.05	18.44	16.96	4.79	0.15	0.42	0.38	0.47	0.24	0.87	2.82	55.60	0.36
27-Oct-91	10.08	18.45	16.96	4.79	0.15	0.42	0.38	0.47	0.24	1.08	2.84	55.86	0.26
24-Nov-91	10.11	18.76	17.12	5.08	0.15	0.42	0.40	0.47	0.24	1.08	2.84	56.66	0.80
22-Dec-91	10.56	19.27	17.66	5.26	0.15	0.42	0.40	0.47	0.24	1.08	2.88	58.39	1.73
19-Jan-92	11.01	20.00	17.75	5.46	0.15	0.42	0.40	0.47	0.24	1.08	2.88	59.85	1.46
16-Feb-92	11.32	20.79	17.80	6.02	0.15	0.42	0.40	0.47	0.39	1.08	2.88	61.72	1.87
15-Mar-92	11.38	20.90	17.86	6.17	0.15	0.42	0.40	0.47	0.39	1.08	2.88	62.09	0.37
12-Apr-92	11.53	21.07	18.34	6.21	0.15	0.42	0.40	0.47	0.39	1.08	2.88	62.93	0.84
10-May-92	12.01	21.81	19.09	7.07	0.15	0.42	0.40	0.47	0.39	1.08	3.23	66.11	3.17
07-Jun-92	12.17	21.81	19.61	8.01	0.15	0.42	0.40	0.47	0.39	1.08	3.23	67.73	1.62
INCREASE	7.13	12.72	10.61	6.58	0.00	0.42	0.40	0.32	0.29	1.08	1.65	41.19	

Table C.29

MONTHLY CRACK LENGTH FOR ROOM B

DATE	B1	B2	B3	B4	B5	B6	B7	B8	B9	TOTAL B	MONTHLY INCREASE
21-Jan-90	12.76	10.23	9.69	0.83	0.72	0.35	0.00	0.11	0.05	34.74	
18-Feb-90	12.76	10.50	9.69	0.83	0.72	0.35	0.00	0.11	0.05	35.01	0.269
18-Mar-90	12.76	10.50	9.69	0.83	0.72	0.35	0.00	0.11	0.05	35.01	0
15-Apr-90	14.93	12.88	10.68	0.93	0.72	0.35	0.10	0.11	0.05	40.75	5.739
12-May-90	17.06	13.83	10.90	1.05	0.72	0.35	0.10	0.11	0.05	44.18	3.427
10-Jun-90	17.97	14.20	11.64	1.05	0.72	0.47	0.24	0.11	0.05	46.45	2.268
08-Jul-90	19.62	15.47	12.02	1.05	0.79	0.47	0.24	0.11	0.05	49.82	3.375
05-Aug-90	19.77	15.89	12.02	1.05	0.79	0.47	0.24	0.11	0.05	50.39	0.573
02-Sep-90	20.00	16.78	12.13	1.05	0.79	0.85	0.24	0.11	0.05	51.99	1.596
30-Sep-90	20.05	17.24	12.59	1.21	0.79	0.85	0.24	0.11	0.05	53.13	1.142
28-Oct-90	20.27	17.64	13.00	1.25	0.79	0.87	0.27	0.11	0.18	54.38	1.248
25-Nov-90	20.96	18.43	13.46	1.25	0.79	0.87	0.27	0.11	0.18	56.32	1.938
23-Dec-90	22.25	19.37	13.66	1.25	0.79	1.00	0.27	0.11	0.18	58.88	2.562
20-Jan-91	23.11	19.73	13.89	1.37	0.79	1.00	0.29	0.11	0.18	60.46	1.584
17-Feb-91	29.64	25.19	14.57	1.37	0.79	1.31	0.45	0.11	0.18	73.60	13.137
17-Mar-91	29.65	25.23	14.58	1.41	0.79	1.31	0.45	0.11	0.18	73.70	0.099
14-Apr-91	30.25	26.38	14.61	1.41	0.79	1.31	0.47	0.11	0.18	75.49	1.788
12-May-91	30.25	26.41	14.61	1.45	0.82	1.34	0.47	0.11	0.18	75.62	0.131
09-Jun-91	30.31	26.41	14.61	1.51	0.82	1.34	0.47	0.11	0.18	75.74	0.125
07-Jul-91	30.59	27.09	14.66	1.54	0.82	1.40	0.47	0.11	0.18	76.85	1.105
04-Aug-91	30.59	27.15	14.74	1.54	0.82	1.40	0.47	0.11	0.18	76.98	0.136
01-Sep-91	30.61	27.15	14.74	1.54	0.82	1.40	0.47	0.11	0.18	77.01	0.021
29-Sep-91	30.61	27.15	14.75	1.54	0.82	1.40	0.47	0.11	0.18	77.02	0.018
27-Oct-91	30.87	27.43	14.75	1.54	0.82	1.40	0.47	0.11	0.18	77.56	0.538
24-Nov-91	30.93	27.62	14.75	1.54	0.82	1.40	0.47	0.11	0.18	77.81	0.253
22-Dec-91	31.17	27.64	14.75	1.54	0.82	1.44	0.47	0.11	0.18	78.11	0.292
19-Jan-92	31.32	28.14	14.75	1.54	0.82	1.44	0.47	0.11	0.18	78.76	0.653
16-Feb-92	31.44	28.55	14.77	1.56	0.82	1.48	0.47	0.11	0.18	79.37	0.612
15-Mar-92	31.71	29.94	15.33	1.56	0.88	1.48	0.47	0.11	0.18	81.63	2.262
12-Apr-92	32.04	30.44	15.45	1.56	0.88	1.48	0.54	0.11	0.18	82.67	1.042
10-May-92	32.10	31.40	15.98	1.56	0.92	1.48	0.54	0.11	0.18	84.27	1.594
07-Jun-92	32.11	31.40	16.02	1.56	0.92	1.48	0.54	0.11	0.18	84.32	0.051
INCREASE	19.35	21.17	6.33	0.73	0.20	1.13	0.54	0.00	0.13	49.58	

Table C.30