UNIVERSITY OF BRADFORD

DISASTER RESEARCH UNIT

Occasional paper No. 7

Flixborough - The Human Response

Kenneth Westgate B.Sc. (Hons)

January 1975
(Reprinted September 1976)

298

UNIVERSITY OF BRADFORD

DISASTER RESEARCH UNIT

Flixborough - an Analysis of the Human Response.

Kenneth Westgate B.Sc.(Hons)

OCCASIONAL PAPERS: NUMBER SEVEN

DECEMBER 1974

PREFACE

The Disaster Research Unit was formed in December 1973 and is a research group within the Project Planning Centre for Developing Countries at the University of Bradford. Unit members are:

James Lewis ARIBA, Senior Research Fellow and Unit Leader,

Philip O'Keefe, B.A. (Hons), Research Fellow,

Kenneth Westgate, B.Sc.(Hons), is attached to the Unit as a Research Student.

This series of Occasional Papers will contain the results of the Unit's work. An Index of the Occasional Papers is included on the inside back cover.

Disaster Research Unit, University of Bradford, Bradford, Yorkshire, BD7 1DP, England.

Bradford (0274) 33466.

ACKNOWLEDGEMENT

The author wishes to extend his thanks to Vic Marshall, Senior Lecturer in Chemical Engineering at the University of Bradford who initiated the idea, to Arthur Blyton and the Transport and General Workers' Union for their generous help and assistance, and to the employees of the Nypro plant at Flixborough whose patient and enlightening evidence has made this report possible. Thanks must also be extended to Jim Lewis and Phil O'Keefe of the Disaster Research Unit and Dr. Michael Gane of the Project Planning Centre for Developing Countries at the University of Bradford for their helpful advice and suggestions, and to Alec Baird of the Project Planning Centre for Developing Countries for his help with the diagram.

CONTENTS

Chapter		Page
1	Introduction	1
2	Historical Background	2
3	Response to the Explosion	6
4	The Warning System and Safety - Malfunction and Response	16
5	Summary and Conclusions	22
	Reference	26

CHAPTER 1

INTRODUCTION

On the afternoon of Saturday 1st June, 1974, an explosion rocked the chemical plant of Nypro (UK) Limited at Flixborough, near Scunthorpe, in Lincolnshire. The plant was left utterly devastated, twentyeight lives were lost and the villages surrounding the plant were severely damaged.

The magnitude of the explosion and the fact that surrounding villagers were greatly affected prompted discussion and debate as to why such an event was allowed to happen. Safety in plants of this size was questioned and the whole spectrum of rapid technological development and economies of scale was placed under the microscope.

This report, while appreciating the value of such analysis, does not attempt to cover it. The report is concerned with the responses of survivors from the plant to the explosion, to the extreme and stressful situation in which they found themselves and to the warning system and safety regulations operating at the plant. The report does not seek to lay down definitive regulations for the safety of chemical plants. Rather it seeks to examine, through the responses of personnel on site at the time of the explosion, the necessity of basing all such warning systems and safety regulations on these responses. Only by a comprehension of people's action and, to some extent, the reasons behind the responses in a disaster situation can one possibly write in safety regulations which not only work, but also reflect disaster activity.

The report is based on the statements of twenty respondents given about a month after the event. They were all survivors of the explosion and they gave their evidence freely and were not restricted by a specific questionnaire. They were asked to describe the events involving themselves on the afternoon of the explosion. No restriction was placed on them to refer to specific episodes.

CHAPTER 2

HISTORICAL BACKGROUND

> '... the increased scale of operations demands the integration of safety planning into the overall design - and at the design and not production stage. Some risks are now so great that a major failure is unacceptable and the possibility must be eliminated at the very outset ...
>
> We may well see a continuing fall in the fatal accident rate while, at the same time, we are faced increasingly with the risk of failures which could result in multiple deaths and injuries of near-disaster proportions'. (HM Chief Inspector of Factories, 1972).

In the light of these remarks, the growth of the Nypro plant at Flixborough gives an indication of the type of condensed growth brought about by an increased scale of operations on the one site. This growth took place over a very short historical period indicative of the speedy rate of post-war technological development.

The present Nypro plant began life in 1964 when the Dutch State Mines (DSM), who at that time were running down coal-mining activities and moving into the chemical industry, devised a new process for producing nylon which would directly compete with the process currently in use with ICI and Dupont, who held the monopoly. ICI and Dupont held the patent for the product Nylon-66. DSM were able to produce nylon by a different method, calling their final product Nylon-6. Their basic product, caprolactam, allowed Courtaulds to enter the nylon field by using the DSM process which was so unlike the Nylon-66 process as to not infringe the patent.

Thus, in 1964, DSM, in partnership with the British fertilizer producer Fisons, set up Nypro (UK) Limited for two reasons. Firstly, because DSM had no experience of operations in the UK and therefore required a British partner, and secondly because the major and quite substantial by-product of the then DSM process was ammonium sulphate, the important fertiliser base. The plant was producing, by 1967, twenty thousand tons of

caprolactam per year, all of which was sold to Courtaulds.

After some time the DSM process was refined and the by-product, ammonium sulphate, was gradually eliminated. This by-product was an expensive luxury in the actual nylon-making process and through its elimination, Fisons found it necessary to break partnership with DSM as there was now no longer any need for them to continue with a lack of their basic ingredient. DSM, still with little experience of English operating conditions, then looked around for a new partner and turned, naturally, to its British counterpart, the National Coal Board (NCB). The latter, after a series of discussions, entered partnership with DSM in May 1969, owning fortyfive percent of Nypro (UK) Limited, while DSM held the other fiftyfive percent.

During this time the plant had been growing, new processes and thus new machinery was installed at Flixborough, and the use of cyclohexane was introduced as the initial chemical in the manufacture of caprolactam. Not only was the plant added to, but also the actual Nylon-6 process itself was subtracted from because of the inclusion of refinements. These additional refinements led to the elimination of stages of the process leading from cyclohexane to caprolactam.

By 1973 the plant had nearly doubled in size compared with the original, and more refinements to the process meant the elimination of yet another stage. Also, because cyclohexane was expensive to purchase, a process was developed to obtain cyclohexane from benzene.

Thus the Nypro plant became a refined, and reasonably efficient economic unit, but at the same time it carried some of the most dangerous chemicals known to the chemical industry - benzene, ammonia, and the colourless liquid with the consistency of petroleum spirit, cyclohexane. The problem with regard to the latter is in its high inflammability. It has a flash-point of minus eighteen degrees centigrade and thus has always to

be stored in sealed tanks. Also, the initial stage in the process of obtaining caprolactam, that of oxydising the cyclohexane, was regarded, in the words of an NCB spokesman, 'as a particularly hazardous process'.

This initial stage involves the feeding of cyclohexane into a plant with ammonia through which oxygen is subsequently passed to produce the substance cyclohexone oxime. The mixture at this stage is highly explosive. They key to the safety of the operation lies in the regulation of the amount of oxygen fed in. If too much oxygen is mixed with the cyclohexane and ammonia, then the whole mixture becomes unstable. The second stage, though less dangerous, still involves the use of potentially risky substances. It involves the treatment of cyclohexone oxime with sulphuric or phosphoric acid to produce caprolactam by an alteration of the substances internal structure in what is known as an isomerising plant. From here on, the caprolactam is transported to Courtaulds or British Enkalon plants where it is fed into a polymerising plant which causes the substance to react with itself and stretch out in a series of threads which are then spun together into the fibre, Nylon-6.

The June 1st explosion occurred at a section of the plant where the cyclohexane was being heated under pressure in a series of six reactors. One of these reactors had been taken away for cleaning at the time of the explosion and the gap was filled by a temporary pipe especially constructed for the purpose. The pipe had been fitted by outside contractors and it is not clear whether the normal safety checks, such as X-raying, had been carried out. What can be determined is that the pipe was not in its normal position after the explosion, but whether this was a result of the explosion itself is a matter of conjecture. But it is certainly considered likely that the pipe was not equal to the job it was created for. The evidence indicates that it was not properly supported and that it imposed upon the bellows, which were situated at one end of it, a shear

force. Initially the pipe had scaffolding screw-jacks underneath it as well as being held by flanges at each end, but it is understood that the screw-jacks were removed once the pipe was in place and had set.

The consequence of this was that the pipe failed and allowed cyclohexane vapour, produced because the cyclohexane was being heated under pressure, to leak into the atmosphere. Initially, this cyclohexane vapour is merely inflammable and if the leak had been noticed immediately and a means of ignition applied to it, it would have produced a sheet of flame. However, the cloud of vapour was able to grow in size until it achieved the appropriate mix of cyclohexane and air to render it an explosive mixture. This meant that the first source of ignition that the vapour met would have caused an explosion. To this end, the explosion was bound to occur, and it is a salient point to remember that if the entire fire brigades of Lincolnshire had been waiting outside the plant, it is doubtful whether they could have done anything to offset the holocaust.

CHAPTER 3

RESPONSE TO THE EXPLOSION

The major explosion at the Nypro Plant took place at approximately 16:50 on the afternoon of Saturday June 1st, 1974. Of the permanent staff of 550 employed by the company, some seventy of these were on site at the time of the explosion, of whom twentyeight died.

The explosion was ascertained to have occurred adjacent to the six reactors which constituted Section 25A of the plant (see map, Appendix I). The prevailing wind blew across the plant from the south-west to the north-east. It would appear that, though heavier than air, the cloud of vapour released from the pipe did indeed drift in the direction of the prevailing wind as it was released. This conclusion is drawn from the fact that the twentyeight Nypro employees who died were located in the control room in the south-central part of the site, immediately to the north-east of Section 25A.

The response of the survivors of the explosion was governed by their position within the plant at the time. Common factors can be detected although details individual-for-individual varied according to their proximity to the location of the explosion. Responses can be categorised into,

1. awareness of the sequence of events constituting the explosion;
2. response to the actual noise-impact of the explosion;
3. flight response immediately after the explosion depicting snap-decisions with regard to personal safety priorities;
4. responses to selected individuals injured or trapped who lay within the escape route from the devastated area;
5. minor responses with regard to hospitalisation after being located by the public services;
6. perception of the time period between the two distinct explosions which constituted the main event;

7. other responses less common among the majority of respondents but discernible among selected individuals.

1. Awareness of the Sequence of Events Constituting the Explosion.

In general, responses indicate a common pattern which emerges concerning the actual explosion. One factor is abundantly clear - the leaking cyclohexane vapour did not just explode. There was a series of events leading up to and following from the devastation, of which the actual explosion was only a part. The evidence, summarised, gives a sequence as follows:

RUMBLE → VAPOUR → EXPLOSION → FIRE

These four quite separate episodes combined to create the total event although the time period involved was obviously small (see below, section 6). Detailed description of these four episodes varied although the distinction between the four was clear in most cases. This varied response indicates a differing descriptive emphasis between the intital noise, the cloudiness that followed, the main explosion and the fire which enveloped the plant after it.

Table 1

Differing Descriptive Response to Four Distinct Episodes Constituting the Main Explosive Event at Flixborough.

EPISODE			
1	2 +	3	4 +
Rumble:(Pressure release valve, Release of pressure) Minor explosion Bang Two rumbles*	Vapour White vapour White cloud Heat haze Shimmering Glare and pent-up feeling.	Explosion	Fire Orange glow Black smoke

* Two rumbles possibly due to an echo effect.

\+ While most respondents showed an awareness of episodes 1 and 3, not all were aware of episodes 2 and 4. It was dependent on their location in the plant and their proximity to the explosion's focus.

In general terms the initial noise was indicative of something out of the ordinary, a phenomenon which was unlike normal industrial noise and which compelled the respondents to stop and take notice.

The lack of total awareness to the vapour which followed the initial rumble and to the smoke which followed the main explosion (apart from the factor of proximity to the focus) was also present, with regard to the former, primarily because of an obliterated view due to the situation of some respondents indoors at the time - within laboratories or offices, or because structures within the plant may have likewise caused an obstruction, and with the latter because during the period immediately following the main explosion, many respondents were in the process of escaping from the site and had not the time nor the inclination to be aware of what was happening within the plant behind them. Of those who did mention the fire, many did so because they stopped to look back over the site in the process of fleeing or because they were running in a direction which would render an appreciation of the plant being on fire unavoidable. Also, it must not be forgotten that evidence given may have omitted factors which the respondents may have considered to be unimportant. In other words, the prime response at the time the fire was raging was to get away from the scene of the explosion as quickly as possible.

One important point to be noted, in the light of the qualities ascribed to the leaking cyclohexane vapour (see above Chapter 2), is that the four episodes thus described are generalisations of the overall response, without the clear-cut division assigned to them. (This is especially so given the time factor involved.) In the light of this, some respondents, especially those in close proximity to Section 25A at the time, indicated that there was fire before the explosion as well as, if not in place of, the fire following the main explosion. There is absolutely no reason to doubt this given the low flash-point of the cyclohexane

vapour as well as the fact that the percentage of cyclohexane vapour to air at the perimeter of the vapour cloud would be such that it would be ignitable but not explosive. That is, the explosive quality of the cloud would be found nearer the centre than the outside.

2. The response to the actual noise-impact of the explosion.

As would be expected, the major explosion in terms of noise magnitude was probably indescribable and what is significant in terms of the response to the explosion is that an audio-response was more or less absent among the majority of the respondents. Indeed, the majority (some seventy percent) did not even mention an explosion as such, but only indicated the force of the explosion in that statements were concerned with what the explosion did to the respondents in physical terms. Of those who mentioned the explosion, some sixtysix percent attempted to assess the noise-magnitude of the explosion with the insertion of suitable descriptive adjectives while the other thirtyfour percent merely described the explosion as occurring, en passant, as one of a series of events.

The cause of this lack of audio-response must be, in some senses, a matter of conjecture but several factors may impinge on response-attitude to imply such a situation:

1. The noise of the explosion was obviously present but at such a cataclysmic level as to render an audio-response unlikely and possibly non-existent.
2. The explosion occurred simultaneously with or immediately before the effects of the explosion on the respondents which consequently would lead them to give maximum concern and attention to their own safety.
3. The evidence given may have avoided factors which may have been distressful to repeat.

4. At the time of the explosion many respondents had already anticipated - because of the initial rumble and the vapour cloud - the fact that something was about to happen. Thus the explosion caught them not unaware, but preoccupied and thus again, the noise magnitude might not have been able to impinge upon attitude response.

Table 2

Statements Regarding Response to the Noise-Magnitude of the Explosion

Statements alluding to an Audio-response to the noise-magnitude of the explosion	Statements alluding to the mere presence of an explosion	Statements omitting the explosion in any terms except those concerned with personal, physical effect
'..a loud explosion.'	'The explosion then happened'.	'..explosion hurled us over the embankment'.
'There was an almighty explosion'	'..then the explosion happened'.	'Everything was falling on top of us'.
'...heard a terrific explosion'		'I was then thrown to the ground'.
'..there was a second major explosion'.		'I was flung to the ground'.
		'I was thrown to the floor a few yards from where I stood'.
		'H- got across the road but W- was thrown to the ground'.
		'..everything went dead and the roof came in'.*
		'The next thing I knew was that I was lying on my face on the ground..'
		'I was blown off my feet 40-50 yards..'

Table 2/cont..

Statements alluding to an Audio-response to the noise-magnitude of the explosion	Statements alluding to the mere presence of an explosion	Statements omitting the explosion in any terms except those concerned with personal, physical effect.
		'The next thing I knew was that I picked myself up..'

* The respondent was on the telephone at the time.

3. Flight-response immediately following the explosion.

Activity immediately following the main explosion was quite naturally centred on flight from the centre of the plant towards the perimeter and beyond. But although this quite clearly took place, for some respondents, the situation had been assessed before the main explosion occurred and flight to safety had already begun.

A generalised summary of this movement can be set out as follows:

1. An initial movement from a position in the plant towards the perimeter fence. (As has been stated, this took place for some respondents before the main explosion occurred but it was dependent on the proximity to the focus of activity, that is, Section 25A. Also movement to the perimeter occurred no matter in what part of the plant the respondents were situated.)
2. A secondary movement around the perimeter fence towards a wharf situated on the River Trent adjacent to the plant. (This did not happen in all cases and was dependent again on location within the plant. However, movement was towards the river in general and to the wharf in particular as a place of assembly.) One can only surmise as to whether the attraction of the river was because of the presence of fire. However,

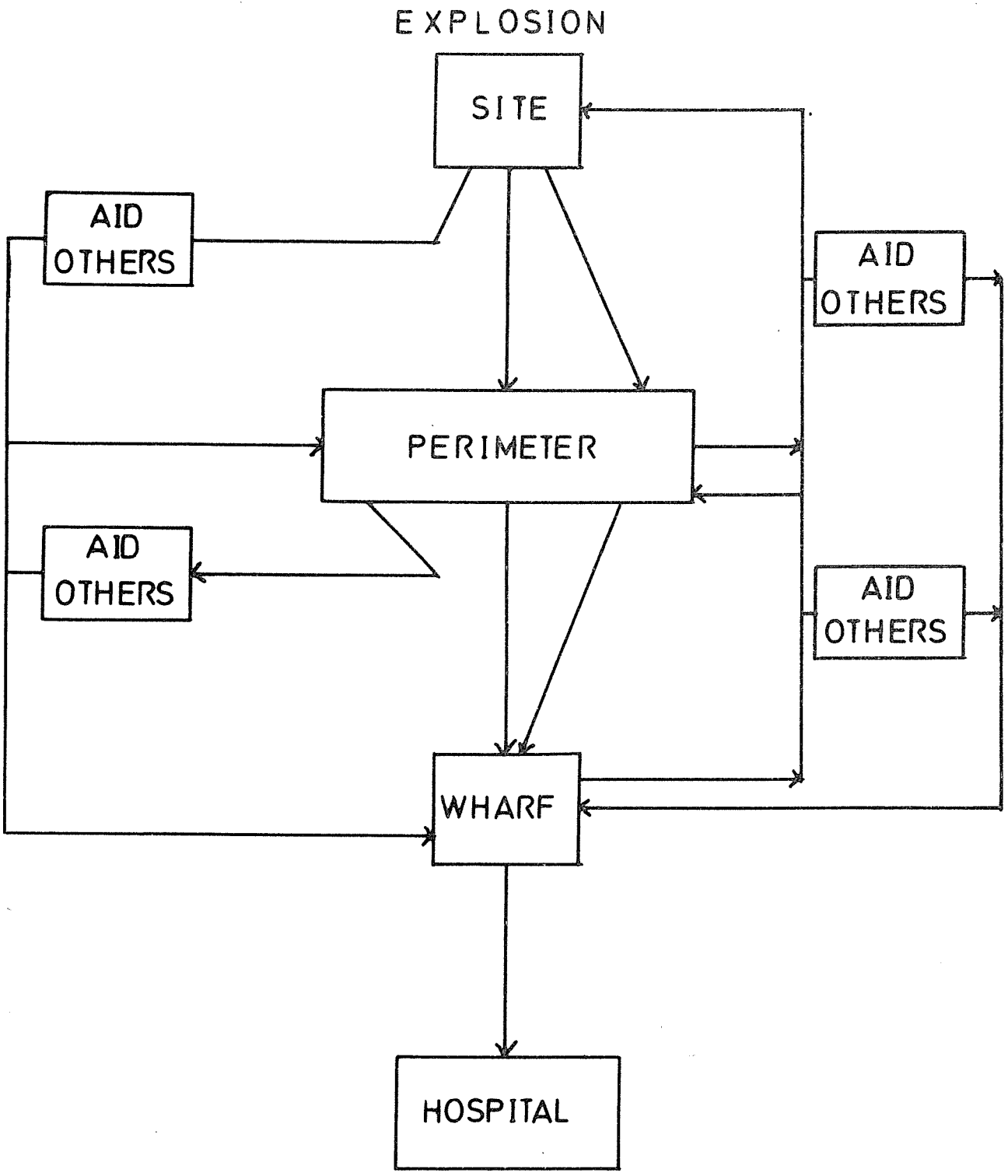


FIGURE 1: Summary of Generalized Flight Response to the Flixborough Explosion Showing Escape Route, Return to the Site and Volunteer Aid to Colleagues.

an interesting point is that for a number of disasters located in a coastal position, the response by many people involved was to run to the water's edge for safety. Also, the river and the wharf were located in an opposite direction from that in which the smoke was drifting and this may have been the reason for the wharf being assessed as a safe assembly point coupled with the fact that the wharf itself is, of course, a large, flat, open area.

3. A movement from the wharf to hospitals in Scunthorpe via the intervention of the public services. (It appears that respondents were either taken by ambulance to a hospital or were picked up by the police.)

These movements away from the centre of activity towards the perimeter, especially with regard to those whose flight-response began prior to the main explosion, can be described as instinctive responses. Safety regulations in case of emergency required Nypro employees to report to the control room or to the gatehouse. But this conditioning obviously failed in the face of instinctive personal safety, and it is important to note that the twentyeight Nypro employees who died were in the control room. Whether they were in the control room because they had reported there in the emergency situation is a matter of conjecture.

Associated with this flight to safety is also the response which entailed a return to the site after having left it. The necessity for this was due to:

a) Curiosity, which led respondents to attempt to locate the cause of the explosion and extent of the damage.

b) a desire to aid injured colleagues some who were known to be injured and thus who could be located and others known to be present on the plant but whose location was unknown to the

respondents attempting to aid them. (Only thirty percent of respondents actually returned to the site but the greater part of these returned to aid colleagues than those who returned due to their own curiosity.)

In both these cases, once the motive for returning had been fulfilled, a speedy exit was once again made from the site. In all cases the emphasis was on personal safety. First with the safety of colleagues acting as a secondary emphasis if and when the need arose. Only one respondent voiced feelings of his concern to get home yet part of this instinctive movement must include elements of security which contain the home and family. (See Figure I for a summary of generalised flight response, and Appendix I for a diagram of selected movements in flight response.)

4. Responses to selected individuals, injured or trapped, who lay within an individual's flight path from the devastated area.

This is the element of self-help, help given by those involved in disaster to injured colleagues or kin and not help given by public services and disaster teams especially sent in to alleviate the stricken. Although a minority of respondents indicated making this response, the response is governed by whether,

1. the respondent's flight path led him into contact with injured colleagues,
2. the respondent was with anybody at the time he began his flight, who, if found to be missing later, could perhaps have been injured during his own flight.
3. the respondent knew of the location of any colleagues within certain parts of the plant deemed by him to have experienced damage at the hands of the explosion.

The self-help concept is an intrinsic part of the 'we're all in this together' factor commonly experienced in disaster and, as shown by the Flixborough disaster, respondents were willing to interrupt their own plan for personal safety to aid colleagues off the site. Also there was a willingness to return to the site in the search for and location of missing colleagues which indicates the strength of the particular group-membership with which employees associated themselves within the plant.

Minor responses with regard to hospitalisation after being located by the public services.

Many respondents completed their statements with a reference to the fact that they were picked up and taken to hospital. This highlights the probability that the process of transportation to hospital meant the closing of a frightening chapter and the obtaining of some degree of comfort and security. The essence of the flight response required the need to find its termination in this type of security for its fulfilment.

Perception of the time period between the initial rumble and the main explosion.

The significance of this time period is in its complete unimportance given by the fact that the respondents, when asked for a snap-decision regarding the time period, gave answers which varied from fifteen seconds to one minute from those who wished to put a precise timing on it, while others expressed it only in terms of a few seconds. This emphasises the fact that the events themselves were of far greater importance than the timing of these events. No respondent was adamant concerning the accuracy of his suggested timing. The one respondent whose job it was to check the instrumentation panels in times of emergency gave as his estimation, thirty seconds to one minute. To many others, whose sole object at this time was flight, it was much less. The only estima-

tion that can be made is based on another estimation, that of the ground covered by those who had begun to flee between the initial rumble and the main explosion. But here again the respondents' estimation varied between fifty and eighty yards and it was not clear whether they had in fact begun to flee immediately on hearing the initial rumble or whether there was a time lapse between the rumble and their flight response. The latter appears to be the most likely.

7. Other responses less common among the majority of respondents but discernible among selected individuals.

Whereas many details in the content of the respondents' replies differed, some responses were only discernible among selected individuals which ran against the normal pattern. It is only necessary to cite two examples here because in the main, responses generalised into a set pattern. However, it is interesting to note the response of the respondent whose flight path took him to the perimeter fence as in the other cases but who then took off across the fields to the north-east instead of making his way around the perimeter to the wharf. Likewise, one respondent carried through a thorough checking of the instrumentation panels, which was his job in an emergency, thus showing a greater affinity to conditioned response in the initial stages although he later fell into the normal pattern of flight response, albeit some time after the others.

CHAPTER 4

THE WARNING SYSTEM AND SAFETY - MALFUNCTION AND RESPONSE

1. The warning system

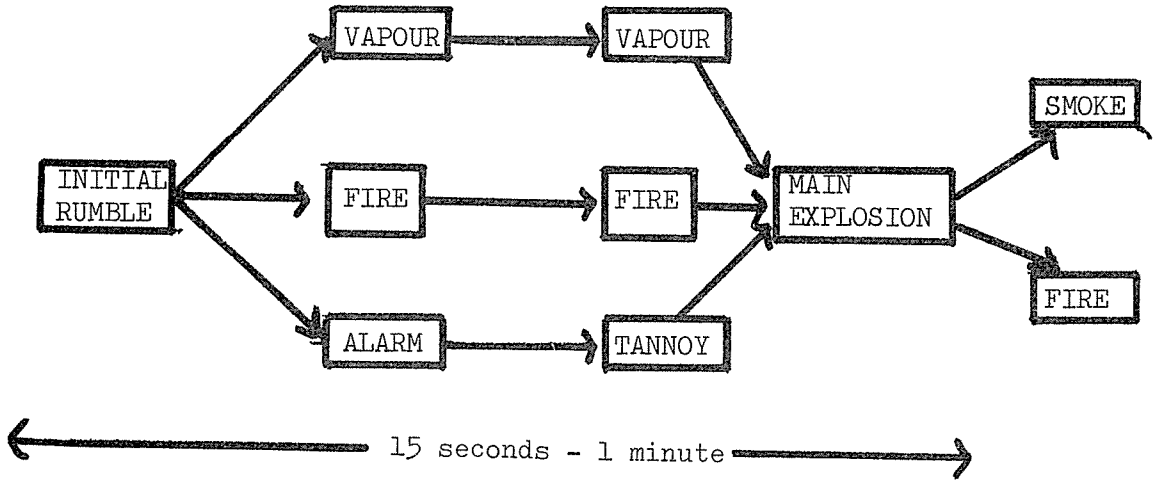
Two parallel systems of warning were operational at the plant in times of emergency - a fire alarm bell followed by a tannoy system which acted as a backup to the alarm bell and provided information regarding the location of trouble. The fire alarm system was operated by the depression of a button through breaking a small pane of glass situated in front of it. These buttons were situated at different points throughout the plant and one of them was adjacent to Section 25A, where the original cyclohexane vapour leak originated. It is thought that personnel from the control room could have depressed their alarm bell but a theory has also been put forward that the explosion may have set off the alarm although this must be doubtful as the alarm bell was heard soon after the initial rumble. The tannoy system was relayed to all parts of the plant via a green button in the control room.

2. Warning system and response

Response to the warning system was as much a response to its malfunction as to the warning itself - ambiguity and confusion were two prime constituents of the response. For although the two parallel systems of warning were operational,it is clear from the statements of the respondents that they were not operational in all parts of the plant. While some sections of plant experienced the alarm but not the tannoy system, other sections witnessed neither alarm nor tannoy. But from respondents who heard both systems, a clearer pattern emerges of the sequence of events constituting the main event. Initially the four principal episodes gave a sequence thus:

RUMBLE → VAPOUR → EXPLOSION → SMOKE

Now, with the addition of the warning system and the fire witnessed by some respondents between the initial rumble and the main explosion, a more detailed sequence of events can be drawn up as follows:



Slightly under fifty percent of all respondents reported hearing no fire alarm at all while eighty percent witnessed no tannoy. Of the fifty percent who did not hear the alarm, the great majority did not hear the tannoy either and therefore had no system of warning. Thus it is possible to say that among the respondents, some forty percent had no method of warning, and, consequently, the only evidence this forty percent had of an impending emergency was through their visual and audio responses to the events as they happened. Significantly, thus, the respondents were in a position of having to put their own interpretation on the magnitude of the emergency as it seemed to them. To respondents in the far-flung sections of the plant this was difficult, as although most of them heard the initial rumble and saw the vapour, distance aids curiosity and blurs the perception of the situation. Thus, whereas respondents close to the focus of the explosion who heard both alarm and tannoy were able to assess the situation in less time and begin flight

response almost immediately, this assessment had been made following the operation of the alarm and the tannoy, those with distance between them and the focus of explosion who heard no alarm or tannoy, were not able to assess the situation in as little time and thus began flight response later and even, in one or two cases, attempted to make a more thorough assessment by moving towards the focus before attempting an exit from the site.

3. Attitudes to a faulty and malfunctioning warning system.

Statements from respondents regarding the operation of the warning system reflect a knowledge of its faultiness and point to the fact that its malfunction was only considered to be a serious problem after the explosion. In other words, the statements would appear to indicate that thoughts concerning the efficiency of the warning system were absent until it had been tested in a real situation when its malfunction became a talking point. Respondents gave reasons for this malfunction:

1. The tannoy system was rarely used; it is only operational when the plant is 'upside down'.
2. There were no practice runs at frequent intervals.
3. Many of the leads relaying the tannoy had been corroded thus rendering the system useless in some parts of the plant.
4. It was not easy to pick up the voice on the tannoy. Thus, the location of the emergency and messages concerning appropriate action could not be heard distinctly. This may have been because of the furor caused by the initial rumble but equally it may have been because of poor reception.
5. The fire alarm could not be heard in some sections of the plant because the prevailing wind blew from south-west to north-east and thus carried the sound away from those sections of the plant to the south-west and west.

4. Attitudes to safety precautions and regulations.

Those safety precautions and regulations which the respondents felt directly affected them were outlined in statements regarding the feasibility of these precautions and regulations giving the respondents' experiences during the emergency. Statements were coloured by a natural animosity to those whose responsibility it was to prepare and instigate the regulations. This was only to be expected in the circumstances. Specific facets of safety discussed were as follows:

1. The only safety training given to employees who worked in the laboratories (apart from a knowledge of what to do in the event of fire) was a request to report to the control room in the case of an emergency. This was in spite of the fact that the main laboratory was situated in the centre of the plant and that laboratory workers in the course of their work would be handling chemicals.
2. Nypro employed a safety officer who was resident on the site but he was only appointed in an advisory capacity and had no executive power to enforce safety regulations.
3. First-aid and fire teams had been created from the body of employees at the plant. It was necessary to carry out frequent dummy exercises in order to keep these teams efficient as well as to ensure that the necessary equipment was maintained in good working order. But these teams were lucky to have practice sesssions once a month and when the safety officer was away from the plant for any particular reason when a practice run was scheduled, the latter were often by-passed.
4. Stories sometimes circulated concerning hoses with holes in them and water points too high up on the walls to be of any use. But members of the fire team were able to assert that

this was indeed not the case. (This was an example of the disputation which arose due to the particular circumstances. There was a need for blame to be attached to someone or some body and any person or group of persons in a susceptible position were criticised. Much animosity was directed towards management as expressed by the respondent who said, ' The firm was safety conscious up to a point where it didn't cost them any money'.)

5. Safety lectures were supposed to have been given to personnel yet many had not received them and indeed knew nothing about them. It was indicated that supplementary safety lectures were arranged for those who missed the initial ones but some doubt was expressed as to whether information about these had been issued or not, because some respondents claimed to have had no knowledge either about the initial lectures or the supplementary ones.

5. Additional safety measures - reactions and suggestions for improvements.

Respondents, in stating their attitudes with regard to safety measures also commented freely on additional measures which they suggested would improve on the existing ones. Of these suggestions two main themes emerged:

a. The case for shatterproof glass. Some buildings had shatterproof glass while others did not. Emphasis was placed on shatterproof glass being placed in laboratories which looked out over the plant. There were windows situated all over the plant, many of which were not reinforced.

b. The 'caged animal' syndrome expressed itself in the form of suggestions for modifying the perimeter fence to make it easier

to penetrate from the inside. The perimeter fence was ten feet tall and characterised by a lack of exits. The suggestion was that exits could be provided which, though locked to aid security, could be opened by keys attached to the perimeter fence in glass cases adjacent to the exits.

It has been stated that the Nypro plant at Flixborough was one of the most safety conscious chemical plants in the country and with the highly dangerous processes with which it was concerned, safety measures presumably should have been stringent. But the evidence from respondents states that although the plant was safety conscious in theory, in practice there were gaps and loopholes in the system which allowed at least for a sense of ambiguity and at most a sense of confusion regarding the actual situation on the ground. Inadequacy or adequacy of the safety regulations can be seen from attitudes and responses of respondents to warning and precautionary malfunction.

CHAPTER 5

SUMMARY AND CONCLUSIONS

1. The responses of groups within a disaster situation such as the one which occurred at Flixborough on 1st June, 1974 must be a major constituent part of any planning of safety regulations and precautions in micro-locations such as the Nypro plant. It is not enough to embrace all that contemporary safety technology has to offer. There is a need to examine response/attitude facets of a disaster alongside safety technology in order to gain as complete a view as is possible. Safety regulations will not work in a satisfactory way if group and individual reaction to them is negative because of consideration of other factors such as those of personal safety.

2. Given the scattered location of the respondents within the plant, awareness of the sequence of events constituting the entire explosion are consistent individual-for-individual. This sequence allows for a breakdown of the event into distinct episodes each of which has a time-period attached to it during which responses take place concerning courses for action to take.

3. Response to noise-impact was such that a majority of the respondents described the impact of the explosion in terms of personal physical impact rather than assessing the noise-impact of the explosion itself. Thus, especially in an event of this nature with a long enough time period between the initial indication of something extraordinary and the main explosion to assess a situation, one can conclude that the personal psychological and physical priorities have already been placed in the forefront of activity during that time period to such a great extent as to render

the actual explosion insignificant in terms of a physical event. Those who recognised an explosion as such probably did not find the necessary response so challenging nor the event so distressful.

4. Flight response entailed movements away from the scene of the explosion towards the perimeter and thence towards a wharf on the River Trent (or to some other point outside the perimeter in a minority of cases). This was followed in some cases by supplementary movement back to the site either because of curiosity, or, in the majority of cases, to aid injured colleagues. This sequence of movements is vital to recognise for the preparation of safety regulations. By all accounts, safety regulations at the Nypro plant entailed the personnel to report to the control room in the case of any emergency. But the control room was situated in the central part of the plant, in proximity to some of the more dangerous processes and whereas this situation is highly suitable for the control of plant machinery and processes, as a place of assembly in times of emergency it proved to be highly unsuitable. This fact emerges not only because twentyeight people died in that control room, (although it can be assumed that not all twentyeight were involved in the controlling process, that some had reported there because of the emergency), but because the respondents showed that their instinctive reaction, warning or no warning and without reference to the conditioning of safety reactions, was to make, on assessing the magnitude and danger of the situation, an instantaneous decision to escape towards the perimeter fence. Thus, it would seem, the necessity of situating collective rooms of assembly for times of emergency on the perimeter of the plant or factory is obvious in cases where the main industrial processes and greatest potential for emergency situations emanate from more central positions. These 'places of collective security' in times of emergency need not be control rooms in the terms of the one in

the centre of the plant where men were told to report, but smaller areas at selected points along the perimeter which contain necessary equipment such as first-aid materials, on-line telephones etc.

5. Self-help, or the aid given by disaster-stricken individuals to injured others in the same circumstances (as distinct from aid given by public services and aid teams from outside), was shown by the Flixborough explosion to be an important element in disaster response-patterns to the extent that even though individuals had gained personal safety, they were willing to return to find missing or injured colleagues, or even stop to aid the injured before they themselves had gained personal safety. Thus, one may conclude that given the right materials and equipment (in terms of first-aid materials, facilities for tea making, on-line telephones etc.), at hand but safe, much of the primary work in elementary disaster relief will be carried out by the disaster-stricken themselves to others in the same situation.

6. Assessment of the time period between the initial rumble and the main explosion lead one to conclude that, because respondents could not clearly delimit this time period but could only hazard a guess (with the result that there was a difference of fortyfive seconds between the more concrete estimates), the passage of time was unimportant compared with the concentration of mental and physical effort on assessing the magnitude of the danger element and, having assessed this, the preoccupation with personal physical safety.

7. Responses to the warning systems operating at the plant were more responses to the malfunction of this system and analysis of the kind of responses made indicated that the importance or significance of the warning system was assessed after the explosion and not before, when it would appear to have been a relatively insignificant element in perception.

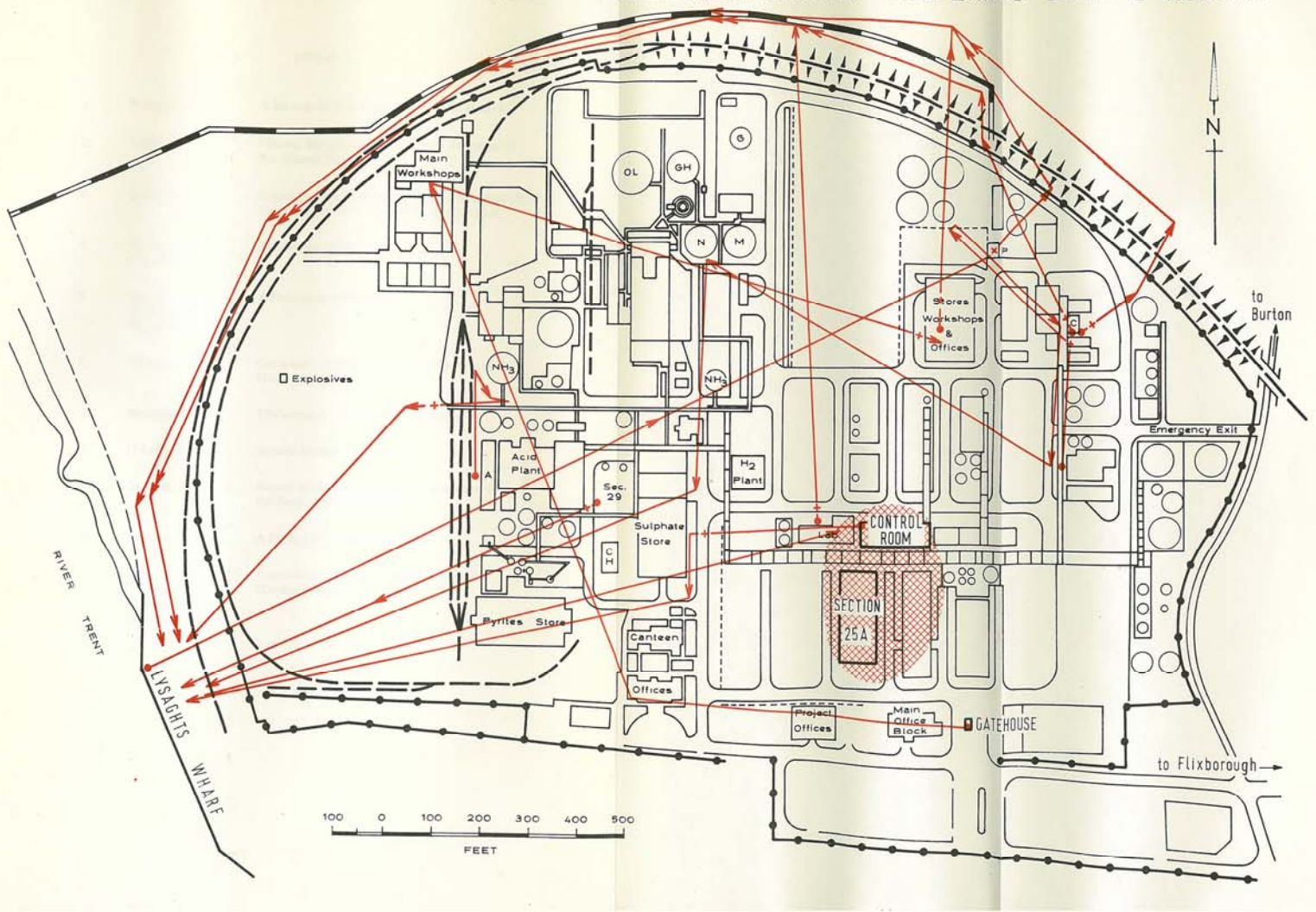
The point here is that a conditioned response by personnel to the warning system was impossible. First, because of the mechanical failure of both the alarm and tannoy systems in parts of the plant, and secondly, because of the lack of awareness of personnel of the warning system due to the inadequacy of reinforcement by those concerned with promoting safety at the plant. In order to operate an efficient warning system (although this may sound elementary). First, there has to be frequent examination of the mechanics of the system not only to make sure that it works but that it reaches all parts of the plant and is then audible, and secondly, practice runs of the warning system coupled with a practice run of emergency regulations are at as frequent an interval as is necessary to create a situation whereby the knowledge of the warning system and emergency regulations provoke responses which indicate a total acceptance of these factors as a way of life within the plant. In other words, warning systems and emergency regulations should be a function of the responses personnel are expected to make or do make in a disastrous situation; warning systems and emergency regulations should not be prepared in ignorance of this human factor and then be expected to function efficiently in an emergency situation. (2)

REFERENCE

Annual Report of HM Chief Inspector of Factories, HMSO, London, 1972.

Appendix I

KEY TO PLAN OF NYPRO PLANT

•	Situation of selected personnel
→	Routes before and after explosion
→→	Escape routes used by several employees
—+—	Interruption of explosion on routes
—●—●—	Perimeter fence
— — —	Railway
	Railway cutting
	Ring road
	Area where actual explosion occurred
A	Acid coolers
CH	Control house
C	Control room
P	Pump house
G	Fuel gas holder
GH	Coke gas holder
N	Nitrogen gas holder
M	Methane gas holder
OL	Oxilene liquor storage tanks

PLAN OF THE NYPRO PLANT AT FLIXBOROUGH SHOWING ESCAPE MOVEMENTS OF SELECTED PERSONNEL BEFORE AND AFTER THE EXPLOSION, INDICATING PREFERRED ESCAPE ROUTES