DEMONSTRATING THE ADEQUACY OF PROTECTION AFFORDED BY OCCUPIED BUILDINGS ON CHEMICAL SITES

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Following publication of the Chemical Industries Association's guidance on occupied buildings in February 1998, the UK Health & Safety Executive (HSE) has encouraged its implementation. Both the guide and HSE's response has resulted in some confusion as to how the guidance should be followed and the depth of analysis required to demonstrate, or otherwise, that onsite buildings afford adequate protection. Two approaches to 'comply' with the guidance and 'satisfy' HSE's expectations of it have been developed. One approach is a qualitative assessment, reflecting the resources, experience and expertise typically available within chemical companies. The other approach is qualitative for the assessment of 'toxic only' hazards and quantitative for the assessment of fire and explosion hazards. It is hoped that by discussing both methods, companies will be able to form a view on approaches best suited to their own site and circumstances.

Keywords: occupied buildings, CIA, protection

INTRODUCTION

Guidance for occupied buildings on chemical sites has been available for some time. In the UK, following the major accident at Flixborough in which the control building was destroyed, the Chemical Industries Association (UK CIA) published guidance on the construction of control buildings[1] in 1979 and more recently, in America, the API[2] published RP752: "The management of hazards associated with the location of process buildings", in 1995. However, the fire at Hickson & Welch[3,4] in September 1992 led the UK CIA to set up a Building Standards Task Force (BSTF) in 1993 to revise the existing guidance. Membership of the BSTF was largely drawn from the 'larger' chemical companies: Exxon; BP; Monsanto; BG; ICI and Mobil were all represented, with only Hickson & Welch representing 'small to medium' sized companies.

The BSTF accepted that there was a need for new guidance and that it needed to cover all occupied buildings on chemical sites. Some research work on vulnerability was undertaken on behalf on the Health & Safety Executive (HSE), with the results considered by the task force[5]. During the work of the BSTF, discussions were held with HSE to ascertain their views on the emerging document. The discussions led to some modifications and the guidance was finally published[6] in February 1998. In parallel, work on occupied buildings was undertaken elsewhere in the EU and both France and Holland have published codes of good practice.

Following publication of the guidance, a number of chemical companies have begun to address the implications of the guide. This is especially true of those companies so far 'targeted' by HSE as part of their plans to encourage implementation of the guidance. With this in mind, the following discussions outline the approach taken by Hickson & Welch (Part 1) and the approach adopted by Four Elements (Part 2) for a similarly 'sized' chemical company. Our hope is that by discussing both methods companies will be able to form a view on sensible approaches for their own site.

PART 1: THE APPROACH ADOPTED BY HICKSON & WELCH

Given the genesis of the new guidance and the part Hickson & Welch had played in its production, the company was not surprised to be 'targeted' in the first round of HSE's initiative. Well before the guidance was published, the company had reviewed it's buildings and the fire precautions on site. However the buildings review had not been performed in a structured way and the company realised that a more formal approach was required to meet HSE's requests for information. This section of the paper describes how the company approached the issue.

THE HICKSON & WELCH FIRE

Since the Fire at Hickson & Welch is often quoted as the initiating event for the revision of the UK CIA guidance, it is worth briefly reviewing that incident and the company's response to it.

Abnormal material had collected in a still base which proved difficult to remove. The decision was made to remove the material mechanically, by scraping it out through the manway, which had been opened. To assist the removal, the material was warmed using steam. Under the conditions inside the still base, the material was unstable at the temperature of the steam used. The contents of the still have been estimated at about 7 tonnes. The material decomposed very rapidly and spontaneously ignited. This resulted a jet flame emerging from the open manway.

The jet flame lasted for about one minute, but in this time it cut through a wooden framed control building about 25m from the still base. The flame then went on to strike the main office block, of traditional brick and glass construction, some 58m away. The control building was destroyed and the office block set on fire. Tragically, four employees in the control building and one in the office block lost their lives.

The low level of protection offered by the wooden framed building was immediately apparent, although the building had a valid HSE fire certificate. The damage to the office block, though severe, was of the kind which might be expected when exposed to such a fire, however started. In their report on the fire[3] HSE drew a number of lessons of which number 7 was: "The design and location of control and other buildings near chemical plants which process significant quantities of flammable and/or toxic substances should be based on assessment of the potential for fire, explosion and/or toxic releases at those plants. Companies should assess the suitability of existing control room buildings and if they are found to be vulnerable, reasonably practicable mitigating measures should be taken".

In response to the fire and the HSE findings, Hickson & Welch rebuilt the control building to withstand a calculated maximum credible accident: a vapour cloud explosion with an overpressure of 0.3 bar. The new building, of reinforced concrete construction, cost over £500,000, has no external windows and was built to give high protection against toxic gas release. The office block has also been modified to remove all the windows on the side facing the plant. This side has been rebuilt as a reinforced, plain brick wall, again designed to withstand 0.3 bar overpressure. The cost of this wall was £290,000.

Following the incident, HSE reviewed the Hickson & Welch fire certificate. Hickson & Welch also carried out their own review. These reviews and other associated work (including the control building and office block rebuild/refurbishment) led to a total spend of approximately £2,000,000 in the five years 1993 to 1998.

HSE'S RESPONSE TO THE PUBLICATION OF THE UK CIA GUIDANCE

HSE responded rapidly to the publication of the new UK CIA guidance. An inspector from the Major Hazards Assessment Unit (now the Methodology and Standards Development Unit) presented a paper immediately before publication[7] and, whilst the views in the paper were presented as "not necessarily those of HSE" (despite the paper's title), they have clearly been followed through into HSE thinking.

Following this, in mid 1998, HSE inspectors from the Chemical and Hazardous Installations Division (CHID) used their regular attendance at meetings of 'Responsible Care Cells' (organised regionally by CIA member companies) to make clear that "although this is industry guidance, HSE will treat this as if it were HSE guidance"[8]. They also made it clear that CHID expected companies to produce 'action plans' in response to the guidance and that CHID was prepared to take enforcement action if companies did not produce action plans of their own.

This firm stance was underlined in a letter sent to selected companies operating CIMAH sites[9], towards the end of 1998. This letter was prepared centrally by CHID Headquarters and asked companies to state which buildings were "already located in accordance with the [CIA] guidance, and for those which are not, the margin by which they fail to meet it, and the action you plan to take." This information – and more – was requested within one month.

WEST YORKSHIRE RESPONSIBLE CARE CELL RESPONSE TO HSE'S LETTER

Four companies in the West Yorkshire area received the HSE letter, with other companies realising that they could expect similar letters in the following year. This led the CIMAH sites in West Yorkshire to meet, to discuss the issue and to see if a common approach could be adopted by the companies affected. This discussion showed that sites varied in both the quantity of information already available and the ability to respond to the questions asked in the HSE letter. However, it was also plain to the companies present that the work asked for by HSE was considerable and could not be reasonably achieved in the timescale HSE had requested. The companies agreed on the matters which were of common interest and asked for a meeting with HSE. In the meeting HSE accepted some of the companies concerns and a modified strategy was suggested. This strategy was formalised in a further letter to the companies involved[10].

However the second letter still required the companies to undertake a significant amount of work, without suggesting in detail how the assessment part of the work should be undertaken. The rest of this paper discusses one possible, relatively simple approach and then goes on to suggest how it can be extended into a more formal risk assessment. The virtue of this approach is that it deals with significant hazards fairly quickly, without detailed analysis. Then, once the 'obvious' problems have been dealt with and the amount of work consequently reduced, the more formal risk assessment referred to in the CIA guidance and asked for by HSE in their letter, can be undertaken to see what further actions are justified.

THE HICKSON & WELCH APPROACH TO THE HSE LETTER – AVAILABILITY OF INFORMATION

Soon after receiving the HSE letter, Hickson & Welch realised that the information requested was not readily available. It is possible that CHID considered the information requested would be available from CIMAH Safety Reports and associated documentation. This is certainly not the case for Hickson & Welch and, both from reading a number of Safety Reports and from discussions with the operators of CIMAH sites, it is unlikely that this is generally the case. Most CIMAH Safety Reports only discuss a small number of the most significant events in any detail. These are usually the events which are judged to have off-site consequences and are often toxic gas or toxic fume releases.

On-site, the 'threats' to any building may well be dominated by the events which could occur close to that building (i.e. within a few tens of metres). Furthermore, with regard to major hazard accidents, the risks to a building or person on a chemical site will tend to be associated with the – relatively - much more frequent incidents involving 'small' amounts of material resulting in little or no off-site impact.

These 'more frequent but smaller events' - as examples: flammable liquid fires where the material has been spilled, is drummed or is in a storage; releases from reaction vessels, of either toxic or flammable material; vessel or pipework failure leading to the ejection of material under pressure and possible subsequent jet fire; etc. - need to be assessed individually and then summated to provide a 'proper' assessment of the risks to each individual building. Aware of this fact, Hickson & Welch concluded that it could not devote the resources required to attain this level of detail, especially not in the time-scale originally requested. Indeed, since the company did not have the capability in-house to make the detailed calculations required, referring to consultants would have been very hard to justify at a time of financial difficulties. Therefore, whilst risk assessment is quite rightly at the heart of modern health and safety management, any assessment must be commensurate with the effort it requires. In this case, Hickson & Welch decided that detailed assessment could be kept to an amount required to deal with the residual problems, after treating the 'obvious' problems first.

THE COMPANY'S APPROACH

Hickson & Welch concluded that what was required was – initially at least – a simple tool which would enable some rapid assessment to be done. The aim of this assessment would be to allow future actions to be put into an approximate priority order and allow resource allocation against this action list. The company did not feel that the detailed information requested by HSE would help with this process and that it was considerably in excess of that suggested in the CIA guidance, especially as there is little or no 'information requirement' in the guidance. The guidance is primarily to help ensure that normally occupied buildings adequately protect their occupants with risk assessment as one stage in the process of achieving this. Therefore, Hickson & Welch took the view that the safety needs of the site could best be met by the production of an 'approximately right' – but defensible – list of buildings for action and an associated programme of work.

The method chosen by Hickson & Welch was very simple, though it has since had some refinement. It is worth noting that the refinement has not significantly changed the output. The method relies on judgement by the individuals performing the assessment; however all methods rely on this, be they qualitative or quantitative. Each judgement was codified and recorded to enable re-assessment in future.

INITIAL ASSESSMENT

The initial assessment had only five steps:

(1) a site plan was obtained showing all the buildings on site together with the location of all storage areas, tanks and operational plant;

(2) a printout from the site's access control system was taken at 11:00 on a weekday. This gave both the number on-site and the areas to which they were allocated;

(3) the plan was marked with the main hazards. The hazards were in broad categories, e.g. flammable, toxic gas, LPG, reaction hazard. The hazards were coloured (in red);

(4) the occupied buildings were marked (in green) and the number of people in each building noted down;

(5) the plan was examined and 'conflicts', that is buildings with a number of people in them and hazards nearby, were noted. Judgement was then used to assign a 1 to 3 priority to these buildings.

Some notes to these assessment steps and the assessment steps of the second stage assessment are given in Appendix 1.

These steps produced the plan shown in Figure 1. The process took no more than a couple of hours, once the initial information had been assembled. This simple process very quickly showed the areas of major concern - the major potential problems stood out quite clearly to the two assessors. Interestingly, they were not those which the assessors had been considering before the process began.

Prior to the assessment the focus had been on control rooms in chemical plant. These usually only contain one or two people. Once the plan had been drawn up it was clear that the focus of attention should be on buildings with far more people in them: the Engineering/Engineering Workshops block; the Analytical Department block; and the Process Development Laboratories. All of these are close to chemical plants which have the potential for toxic gas release and/or contained flammable reaction hazards.

In parallel with this assessment a policy on occupied buildings was drawn up and approved by the Board and by the site Safety, Health, Environment and Quality committee. This dual approval ensures that the policy has support and that progress is monitored both by management and by the workforce. The policy is reproduced as Appendix 2.

REFINEMENTS TO THE INITIAL ASSESSMENT

The initial assessment was used to determine a priority list of buildings to be considered in the current year. The buildings which were judged to have high priority were considered in turn to determine what could be done to reduce the risks to their occupants. The actions ranged from demolition to improving protection in case of toxic gas release. A programme of work to address these problems was put in place, following up the significant work already done on site.

However the initial process, whilst very useful in focusing attention on the most significant potential problems, was recognised to be very dependent on the judgement of the two assessors involved. Particularly once the initial conflicts had been addressed, it was recognised that a slightly less subjective assessment would be useful. This would have the advantage of being more transparent, both to the regulators and to those responsible for assessing site buildings in the future. Therefore, a second round of assessments was performed, on a slightly less subjective basis, to determine the priority list for future years.

SECOND ROUND OF ASSESSMENT

The second assessment used the same base information as the first but the information was supplemented as follows:

(6) each occupied building was listed in a spreadsheet with a brief description of its construction (e.g. brick/glass; timber/glass; concrete – blast proof etc.);

(7) the number of people likely to be in each building was entered together with an estimate of the percentage of time people would be present. These were then multiplied together to give an ‘occupancy index’ figure;

(8) the closest hazards were then listed for each building. The same broad groups were used as in the initial assessment but this time the distance from each hazard to the building was estimated and entered into the spreadsheet. Where a building was close to a number of hazards of the same type the most significant was listed;

(9) finally any protection which the building had was noted, for example a fire wall between the building and fire hazards.

(10) the construction, any protection, and the proximity of any hazards, were used to give a rank, on a 1 to 5 scale, for the likelihood of harm to an occupant of the building. A score of 5 represents a low chance of harm, because of a very high protection factor and/or hazards being distant from the building. It follows that 1 represent a higher chance of harm (if a threat were to be realised) because of ‘closer’ hazards and poorer levels of protection.

(11) using this ranking scheme and the occupancy index, together with knowledge of the future of the building (i.e. was the building likely to be taken out of use within a short space of time), the buildings were grouped – by professional judgement – into 6 groups, where group 1 represented buildings needing action in the short term, and group 6 represented buildings judged unlikely to need modification, having been built recently to the standards in the guidance.

(12) finally, a sort was done by the spreadsheet, into priority order. The sort was firstly by the group determined in step 11, and then a secondary sort for each group by occupancy index.

Part of the initial spreadsheet is reproduced as Figure 2 and the sorted spreadsheet is reproduced as Figure 3.

This second assessment, which was not done by the same assessors as the first, confirmed the buildings selected as the highest priority in the first assessment. Again this second assessment for the site was completed in about 3 hours, once the plan was available and the data assembled.

USE OF THE ASSESSMENT

The assessment described is non-quantified and subjective, its ‘accuracy’ relies on the experience and expertise of the assessors. It does not provide a method for comparing risks between sites. Nor does it provide a formal method for comparing the risks to people against established risk criteria or with the risks they face from, for example, manual handling injuries or long term health effects from chronic exposure to toxic substances.

Given what we know of these and similar risks there is a need – for both operators of sites and the regulators – to form some judgement about the resources which companies should devote to occupied buildings compared to the resources devoted to other health and safety priorities. It could surely be argued that the provision of secure occupied buildings is like the provision of PPE under the COSHH regulations, undoubtedly required in many cases but the least favoured way of protecting people.

However, what this assessment technique does provide is a very simple and rapid means of harnessing the expertise of the assessors to prioritise actions and so help to allocate resources. By focusing attention on the buildings with the lowest standards of protection and the greatest number of occupants, it helps show where money can be spent on occupied buildings to greatest effect. The assessment also enables these projects to be judged – subjectively - against other health, safety and environmental projects and the available resources.

Once the most pressing problems have been dealt with, more detailed assessments may be required. These should ensure that resources are still being used on the 'correct' projects and should enable spending to be justified against other demands. More immediately, more detailed risk assessment may be required either to assess new buildings or to provide support for implementation (or otherwise) of risk reduction measures.

PART 2: THE APPROACH ADOPTED BY FOUR ELEMENTS-ERM

Following publication of the CIA guidance in February 1998, by mid-March Four Elements had been invited to a meeting to discuss how one chemical company was intending to address the guidance and HSE's expectations of it. The meeting was attended by both a 'field' and 'HQ' Inspector and three personnel representing the plant's management. At this meeting, and over subsequent discussions, a plan to assess occupied buildings in accordance with the guidance and to the 'satisfaction' of HSE was proposed and work begun.

This work and similar activities to date has resulted in a simple assessment procedure to help satisfy the guidance and HSE's expectations.

FIRE AND EXPLOSION HAZARDS

Excluding the assessment of 'toxic only' hazards, it was concluded that to propose an approach absent of numeric criteria would go against HSE's own approach and expectations, and would ignore the guidance provided by the CIA. Therefore, to avoid the Company formally setting any numeric criteria, it was decided that those referred to in the CIA document (and any subsequent revisions) would be used. This avoided the Company setting any precedents for risk criteria, which they might later wish to withdraw, and ensured that any assessment followed that within the guidance.

The agreed criteria was thus:

(a) for the so called 'hazard-based' approach (HBA), a building should not incur the agreed hazard level (e.g. harm) with an annual frequency greater than 10^{-4};

(b) for the 'risk-based approach' (RBA), the target level of annual individual risk (from events impacting a specified building) should be targeted below 10^{-5}, with a maximum of 10^{-4}. Between 10^{-4} and 10^{-6} further mitigation must be considered to demonstrate that all reasonably practicable measures to reduce risk have been taken (i.e. the ALARP principle) - and - below 10^{-6} no further risk reduction is required.

During discussions with HSE, a preference for HBA was apparent. It is surmised that one reason for this, is that HBA may be more readily comprehended than RBA. For example, HBA only relates the cumulative frequency of a hazard level (e.g. harm) to a single numeric criterion (see point 'a' above). By comparison, RBA relates the product of occurrence frequency of a hazard level (e.g. harm or fatality) and the likelihood of persons being exposed, to individual risk criteria which is related to a tiered framework incorporating the concept of As Low As Reasonably Practicable (ALARP) (see 'b' above and the figure given on page 16 of the CIA guidance). In addition, in certain cases HBA will clearly demonstrate adequate protection and hence, limit the need for additional assessment (i.e. the need for RBA). However, it soon became apparent that at sites with limited opportunity for extensive 'spacing' between processes, storage and buildings, the RBA would prove useful in demonstrating adequate protection and the effectiveness of risk mitigation measures in the context of reasonable practicability (including cost) - in some cases no action is necessary.

Therefore, to satisfy both the CIA guidance, HSE, and the needs of the Company a transparent and substantive assessment framework was devised. The framework is illustrated in Figures 4 and 5. It can be noted that the concepts of 'Time to Cause Harm' (TCH) and 'Required Protection Time' (RPT) were introduced to: reflect the fact that all events have a discrete duration; and that the protection offered by buildings need only remain until the event has passed or escape to a 'safe' area has been affected. In fact, TCH and RPT helps demonstrate that a building may not need to protect occupants against all events.

'TOXIC ONLY' HAZARDS

For 'toxic only' hazards (i.e. those with no appreciable thermal or explosive hazard), Appendix 4 of the CIA guidance details a purely qualitative approach. Although qualitative, to satisfy the purpose of the guide and HSE, substantive evidence is required to demonstrate that buildings afford adequate protection (or that no reasonably practicable measure can be taken to reduce the risk to persons). Hence, for 'toxic only' hazards a 'review form' was devised to address the information required to demonstrate buildings' 'adequacy'. In essence the form is a series of questions that require a simple *Yes* or *No* answer. This is then supplemented by a short explanation to substantiate the case.

An example of the review form is given in Figure 6. For the sake of brevity, only a selection of entries has been completed. It can be noted that, where appropriate, each information requirement is referenced to the specific CIA guidance. However, as the review form illustrates, a number of additional information requirements may be required to help demonstrate adequacy. Once the form is completed, any deficiencies in buildings' protection are immediately apparent. It is then a matter of judgement to decide whether, on balance, the 'positive' safety measures outweigh any 'negatives' and so provide an adequate level of protection.

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APPENDIX 1

The numbering refers to the steps in the Hickson &Welch assessment and is, therefore, not sequential.

2. In a number of cases, for example engineering workers, the area to which personnel are allocated will be a 'home base' rather than the actual location of work. However, in this case, the work location will usually not be a building but a structure or a piece of equipment in/on a chemical plant. White collar personnel out of their home base are likely to be in meetings. All staff can be away from their home base for training of welfare (see note 3b below).

4a. All buildings which are not plant structures were considered. We chose to consider any buildings occupied for more than 4 hours a week (half a working day) as 'occupied'. This corresponds to a definition HSE have used in the past in considering means of escape in case of fire.

4b. It was important to consider buildings which had no people allocated to them as a home base. From 3a this included (for example) switch-houses. However, further consideration later in the assessment process showed that many of these had a very low priority attached to them.

4c. The numbers from the access control system were used as a guide to the number allocated to each building but were modified by the knowledge of the assessment team. Where a building contained a meeting or training room, for example, the occupancy was increased to allow for this. To err on the side of caution far more increases were made than reductions, with the result that the overall site population apparently increased.

7. Broad assumptions about occupancy were made and only a restricted set of occupancies were used. For example buildings used during day times only were given an occupancy of 25%, control rooms were generally given 100%, engineering workshops – used out of hours and at weekends were given 50%. Also the assumption the "everybody's got to be somewhere" was used, even though technicians, for example, allocated to control rooms in fact spend a significant part of their day working in chemical production buildings.
These assumptions will tend to significantly overstate the actual occupancy but will affect all buildings. The aim is a comparative assessment, to produce a priority for action and it is felt that the assumptions are unlikely to affect the final priority list.

8. Where a number of, for example, toxic hazards existed the closest one was listed unless it was trivial or clearly overshadowed by a greater hazard slightly further away. In these cases the distance to the most significant hazard was used. Where the hazard could occur in a chemical plant building and then affect an occupied building (e.g. a control room), the distance was given as zero, even though the control room might be some tens of metres from the likely hazard.

APPENDIX 2 – OCCUPIED BUILDINGS POLICY

Hickson & Welch, Castleford will ensure that all people within the whole site boundary are exposed to as low a risk as is possible consistent with effective operation of the business. We will use the standards set out in the CIA Occupied Buildings document as providing acceptable risk levels.

1. The number of people at work on the chemical plant will be reduced to the minimum number required for safe and effective operation.

2. People whose work is not required to be done on the chemical plant will be progressively relocated away from operational chemical plant.

3. Where people have to be located close to chemical plant for operations, maintenance or control purposes the buildings in which they work will be assessed against the standards in the CIA document. A programme will be implemented to bring all buildings into compliance with the guidance.

4. The Company will operate a permit system for the site temporary buildings only allowing them to be sited on the chemical works after a risk assessment has been done.

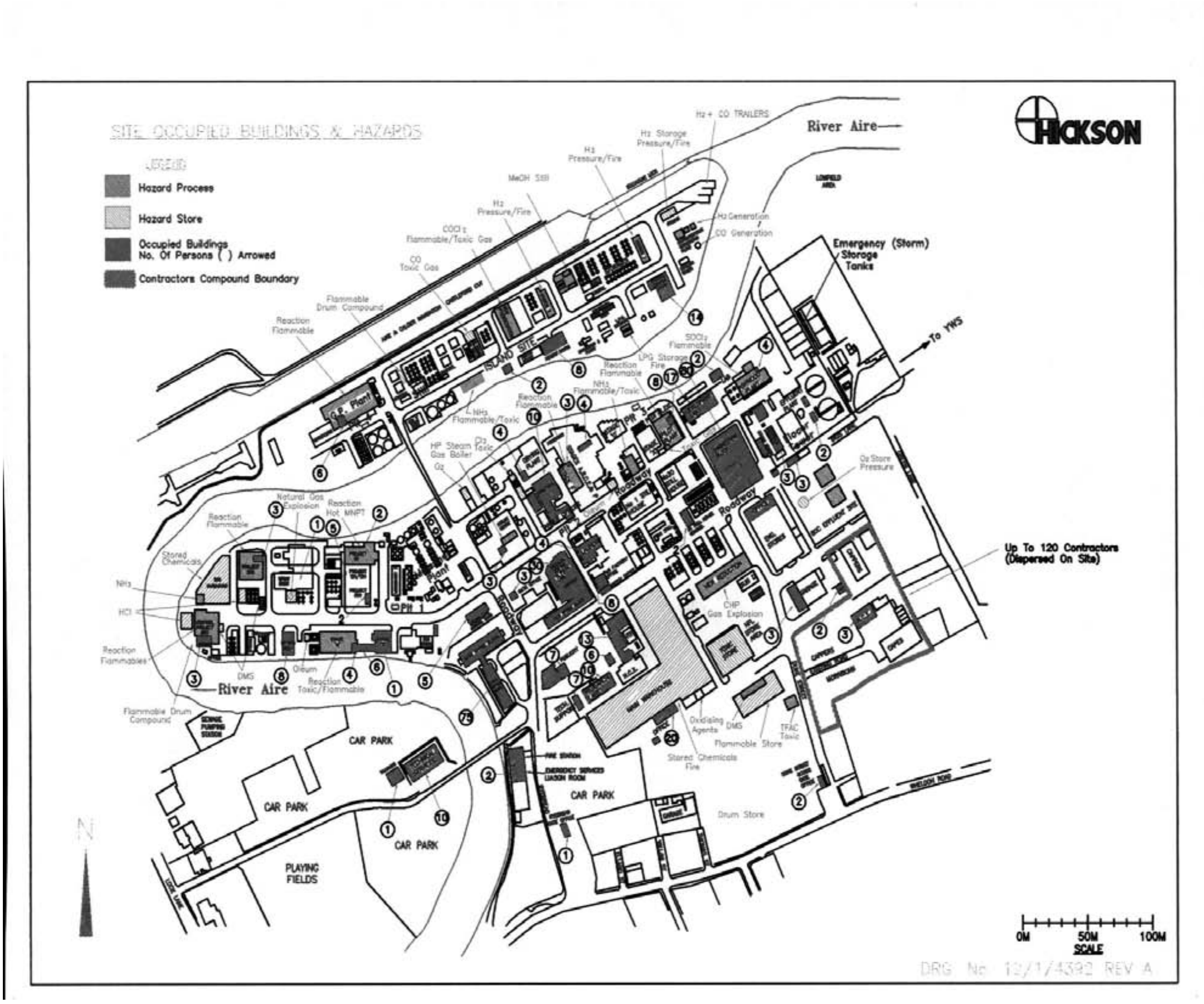


FIGURE 1. Hickson & Welch Site Plan

Risk Assessment for Occupied building on the Castleford Site

Building	Construction	Occupancy			Hazard	Range	Protection		Group
		No	Time	Index			Form/note	Rank	
GP control centre	Concrete blastproof							5	
GP control	Timber/glass	6	100	600	Toxic	0	Glass/wood	1	3
					Flammable	0			
					Reaction	0			
Island site engineers office	Timber/glass	2	25	50	Toxic	25m	fair	2	3
	portable building				Flammable	20m	Bund		
Island site engineering shop	Brick/glass 2 storey,	8	50	400	toxic	30m	internal room	3	3
	big doors				H2 Reaction	20m	?		
Hydrogenation control room	Class 2 brick glass	14	100	1400	H2 Reaction	20m	Small windows	4	2
					LPG	30m			
Ashwood control room	Brick/glass -	2	50	100	Toxic (SOCl2)	0		2	4
	ground floor				Flammable	0			
Hydrogenation lab	Brick/glass	2	25	50	Toxic (SOCl2)	15m	Large windows	2	4
Development Department	Brick/glass - 2 storey	17	75	1275	Toxic (SOCl2)	20m	2 storey	2	1
Pilot plant lab	Brick.glass	8	50	400	Reaction	5m	PP Wall	2	4
					Flammable	5m		2	
					Toxic	5m		2	
Stage B control room	2nd floor - timber/glass	4 (?)	100	200	Toxic (oleum)	0	Many doors	2	4
Stage F control room	Glass/brick	3	75	225	Toxic	0	Large window	2	4
	1st floor - escape route				Flammable	0	Pyran/toughened		
					Reaction	0	glass?		
Analytical main block	Brick/glass - 2 storey	10	100	1000	Toxic	15m		2	1
Analytical - wooden hut	Wood/glass	1	10	10	Toxic	10m	v poor - Threatens CL2	1	1
Tanker office	Brick/glass	2 [+2]	50	100	Toxic	40m	low	2	2
Finishing dept	1 st floor - brick/glass	4	40	160	Toxic	30m	1st floor	3	2
Boiler house	1st floor	3	100	300	Flammable Gas	0	CHP project	2	5
Project 220 control room	Glass - 1st floor	2 [+5]	100	200	Reaction		int. walls	3	4
280 control room	Glass - 1st floor	3	100	300	Toxic	0	Large windows	1	3
					Flammable	0			
					Reaction	0			
250 control room	Glass - 1st floor	3	100	300	Toxic	0	Large windows	1	3
					Flammable	0			
					Reaction	0			
Fitters west	Brick/glass - 2 storey	8	50	400	Toxic (oleum)	10m	1st floor	3	2
Stage M control room	Glass - 1st floor	4	100	400	Toxic	0		1	3
					Flammable	0			
					Reaction	0			
Quadrangle offices	Brick/glass	6	40	240	Toxic	10	St M Wall	3	3
					Flammable	10			
					Reaction	10			
(Meissner smoke room)	Brick/glass	[3]	25	#VALUE!		>50m			6
Meissner Control	Concrete - blast proof	5	50	250	Toxic (Cl2)	100m		5	6
					Reaction	>100m			
					Gas (BH)	50m			
Gate office	Timber/glass - 2 storey	3	100	300	Toxic (Cl2)	75m		2	2
					Gas (BH)	30m			
Canteen	Brick/glass - 2 storey	10	50	500	Toxic (Cl2)	60m	1st Floor	3	2
Canteen (lunchtime)		60	10	600	Reaction	40m			
					Flammable	50m			
Path lab/medical centre	Brick/glass	4	25	100	Toxic (Cl2)	60m	Ablutions	3	5
					Reaction	60m			
					Flammable	60m			
Ablutions	Brick/glass	3	40	120	Toxic (Cl2)	60m	close to	2	5
Ablutions (changeover)		40	10	400	Reaction	60m	canteen		
					Flammable	60m			
Laundry	Brick/glass	4	25	100	Toxic (Oleum)	40m	need to	2	5
					Reaction	40m	review		
					Flammable	40m	proc.		
East managers offices	Brick/glass - 2 storey	8	40	320	Toxic (oleum)	60m		3	4
20 still house control room	Brick/glass - 1st floor	1	25	25	Toxic (oleum)	60m	Future use?		5
Engineering block	Brick/glass - 2 storey	80	50	4000	Toxic (SOCl2)	30m		3	1
					Reaction	30m			
					Flammable	30m			
Capital offices		3	25	75	Toxic (SOCl2)	30m	Access to EB	3	4
Effluent lab	Timber/glass	2	25	50	Toxic (SOCl2)	40m	Future use?	2	6
BOC effluent control	Brick/glass	3	100	300	LOX	20m	New	4	6
					Reaction	15m			
Stores offices	Brisk/glass	3	25	75	Toxic (SOCl2)	80m	Int office	4	5
Garage	Brick/glass	3	25	75	Toxic (SOCl2)	70m		4	5
NCX		3	25	75	Toxic (SOCl2)	70m		3	5
Engineering coordinators		2	25	50	Toxic (SOCl2)	80m		4	5
Warehouse offices	Timber/glass	20	25	500	Toxic (Cl2)	200m		3	4
					Fire (WH)	10m			
HTP labs	Brick/glass - 2 storey	13	25	325	Toxic (Cl2)	130m	Int office - 1st floor	3	5
					Fire (WH)	25m			
HTP offices	Timber/glass	6	25	150	Toxic (Cl2)	130m	Review proc	2	5
					Fire (WH)	30m			

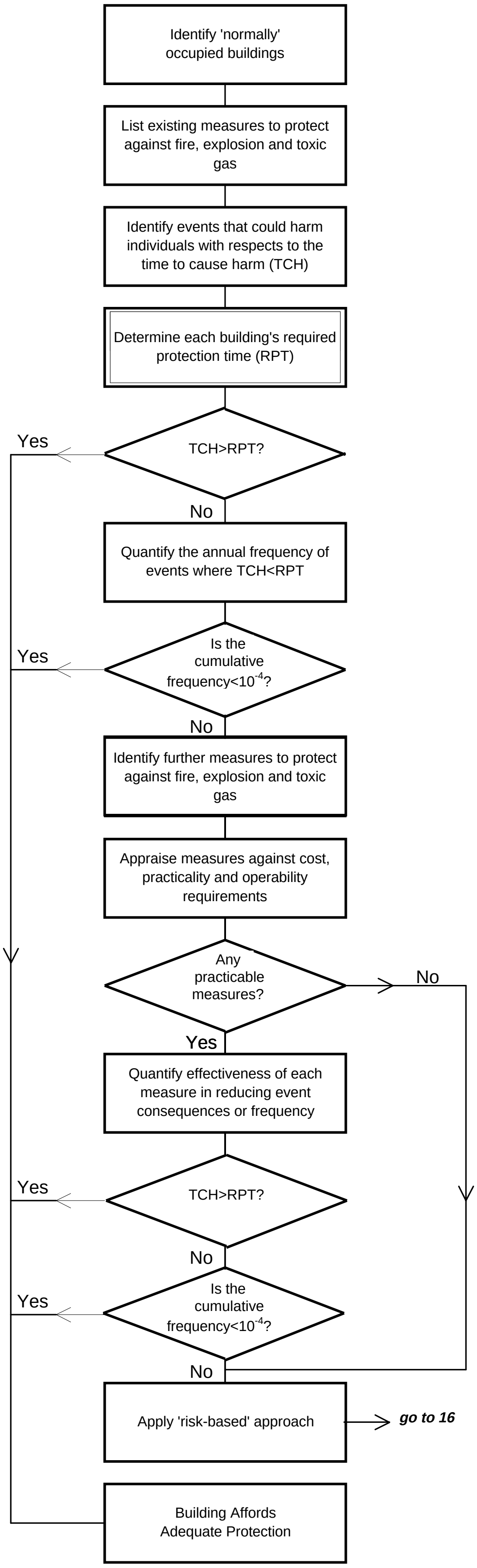
Risk Assessment for Occupied building on the Castleford Site

Sorted by priority and occupancy index

Building	Construction	Occupancy No	Occupancy Time	Occupancy Index	Hazard	Range	Protection Form/note	Rank	Group
GP control centre	Concrete blastproof							5	
Engineering block	Brick/glass - 2 storey	80	50	4000	Toxic (SOCl2)	30m		2	1
Development Department	Brick/glass - 2 storey	17	75	1275	Toxic (SOCl2)	20m	2 storey	2	1
Analytical main block	Brick/glass - 2 storey	10	100	1000	Toxic	15m		2	1
Analytical - wooden hut	Wood/glass	1	10	10	Toxic	10m	v poor - Threatens CL2	1	1
Hydrogenation control room	Class 2 brick glass	14	100	1400	H2 Reaction	20m	Small windows	4	2
Canteen	Brick/glass - 2 storey	10	50	500	Toxic (Cl2)	60m	1st Floor	3	2
Fitters west	Brick/glass - 2 storey	8	50	400	Toxic (oleum)	10m	1st floor	3	2
Gate office	Timber/glass - 2 storey	3	100	300	Toxic (Cl2)	75m		2	2
Finishing dept	1 st floor - brick/glass	4	40	160	Toxic	30m	1st floor	3	2
Tanker office	Brick/glass	2 [+2]	50	100	Toxic	40m	low	2	2
GP control	Timber/glass	6	100	600	Toxic	0	Glass/wood	1	3
Island site engineering shop	Brick/glass 2 storey,	8	50	400	toxic	30m	internal room	3	3
Stage M control room	Glass - 1st floor	4	100	400	Toxic	0		1	3
250 control room	Glass - 1st floor	3	100	300	Toxic	0	Large windows	1	3
280 control room	Glass - 1st floor	3	100	300	Toxic	0	Large windows	1	3
Quadrangle offices	Brick/glass	6	40	240	Toxic	10	St M Wall	3	3
Island site engineers office	Timber/glass	2	25	50	Toxic	25m	fair	2	3
Warehouse offices	Timber/glass	20	25	500	Toxic (Cl2)	200m		3	4
Pilot plant lab	Brick.glass	8	50	400	Reaction	5m	PP Wall	2	4
East managers offices	Brick/glass - 2 storey	8	40	320	Toxic (oleum)	60m		3	4
Stage F control room	Glass/brick	3	75	225	Toxic	0	Large window	2	4
Stage B control room	2nd floor - timber/glass	4 (?)	100	200	Toxic (oleum)	0	Many doors	2	4
Project 220 control room	Glass - 1st floor	2 [+5]	100	200	Reaction		int. walls	3	4
Ashwood control room	Brick/glass -	2	50	100	Toxic (SOCl2)	0		2	4
Capital offices		3	25	75	Toxic (SOCl2)	30m	Access to EB	3	4
Duke street gate office	Brick/glass	2	25	50	Toxic (SOCl2)	50m	Brick to rear	3	4
Hydrogenation lab	Brick/glass	2	25	50	Toxic (SOCl2)	15m	Large windows	2	4
Main offices	Brick/glass - 4 storey	75	25	1875	Toxic (Cl2)	100m	Blast wall	4	5
Old offices	Brick/glass - 2 storey	16	25	400	Toxic (Cl2)	90m	Internal wall	3	5
HTP labs	Brick/glass - 2 storey	13	25	325	Toxic (Cl2)	130m	Int office - 1st floor	3	5
Boiler house	1st floor	3	100	300	Flammable Gas	0	CHP project	2	5
Tech services	Brick/glass	10	25	250	Toxic (oleum)	120m	River	3	5
Research	Brick/glass - 2 storey	10	25	250	Fire (WH)	10m	1st floor refuge	4	5
Publicity	Brick/glass	7	25	175	Toxic (Cl2)	120m	Internal walls	3	5
Tech support	Timber/glass	7	25	175	Fire (WH)	10m	Future use?	2	5
HTP offices	Timber/glass	6	25	150	Toxic (Cl2)	130m	Review proc	2	5
Ablutions	Brick/glass	3	40	120	Toxic (Cl2)	60m	close to	2	5
Laundry	Brick/glass	4	25	100	Toxic (Oleum)	40m	need to	2	5
Path lab/medical centre	Brick/glass	4	25	100	Toxic (Cl2)	60m	Ablutions	3	5
Training block/CIRCE	Brick/glass (- 2 storey)	1 [+5]	25	100	Toxic (oleum)	120m	River	3	5
NCX		3	25	75	Toxic (SOCl2)	70m		3	5
Garage	Brick/glass	3	25	75	Toxic (SOCl2)	70m		4	5
Stores offices	Brisk/glass	3	25	75	Toxic (SOCl2)	80m	Int office	4	5
Fire station	Brick/glass	2	25	50	Toxic (Cl2)	180m		4	5
Engineering coordinators		2	25	50	Toxic (SOCl2)	80m		4	5
Ryebread gate office	Brick/glass	1	40	40	Toxic (Cl2)	240m	Modern	4	5
20 still house control room	Brick/glass - 1st floor	1	25	25	Toxic (oleum)	60m	Future use?		5
BOC effluent control	Brick/glass	3	100	300	LOX	20m	New	4	6
Meissner Control	Concrete - blast proof	5	50	250	Toxic (Cl2)	100m		5	6
Effluent lab	Timber/glass	2	25	50	Toxic (SOCl2)	40m	Future use?	2	6

Method for Demonstrating the Adequacy of Protection - Occupied Buildings

Hazard-based Approach



1 *Make a list of all onsite buildings. For those not considered to be 'normally' occupied, record the reasons supporting this decision. Critically appraise the need for persons to be present and list the reasons why.*

2 *Perform this task for each occupied building. Measures might include both physical aspects of the building, personal protective equipment, and procedural actions (e.g. fire resistant walls, respirators, warnings, and escape to a safe location).*

3 *The severity of any injury must not prevent persons taking the emergency actions expected of them such as, shutting down equipment, escaping to a safe location, or 'staying put' until the event has passed.*

4 *For each occupied building determine the Required Protection Time (RPT) (i.e. the period of time for which persons need to be protected so as to take the actions expected).*

5 *For each occupied building, test whether the Time to cause Harm (TCH), for all events, is greater than the Required Protection Time (RPT). If it is, then the building provides adequate protection.*

6 *Appraising each building in turn, summate the frequency of events where the Time to Cause Harm (TCH) is less than the Required Protection Time (RPT).*

7 *For each occupied building in turn, test whether the cumulative frequency of events (TCH<RPT) is less than 1 in 10,000 per year. If it is, then the building provides adequate protection.*

8 *For each building, make a list of additional measures to further protect individuals. Measures might include physical building additions/alterations, mitigation at source and improved emergency procedures.*

9 *For each building, produce a list of mitigation measures and appraise them with respects to costs (e.g. installation and maintenance costs), operability (e.g. processing constraints, increased complexity), and practicality (e.g. physical restraints).*

10 *If no further mitigation measures can be taken, the adequacy of the protection afforded by the building(s) needs to be determined by applying the 'Risk-based' approach (i.e. by Quantified Risk Assessment (QRA)).*

11 *Determine the effective mitigation provided by each measure (e.g. % reduction). Record the evidence supporting the magnitude of reduction.*

12 *Implementing one or more mitigation measures, for each occupied building, test whether the Time to Cause Harm (TCH), for all events, is greater than the Required Protection Time (RPT). If it is, then the building provides adequate protection.*

13 *For each mitigation measures or combination of measures, for each building, test whether the cumulative frequency of events (TCH<RPT) is less than 1 in 10,000 per year. If it is, then the building provides adequate protection.*

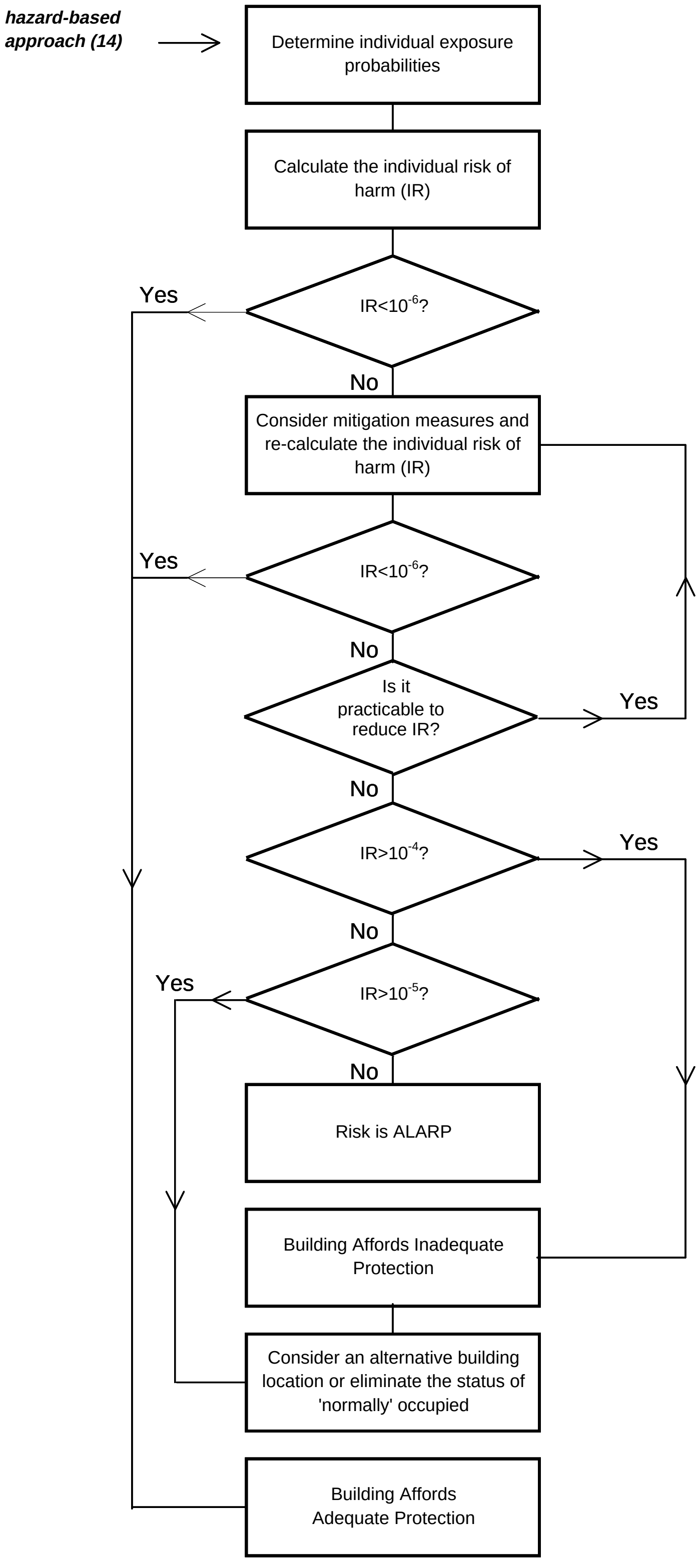
14 *Refer to the Method for Demonstrating the Adequacy of Protection - Occupied Buildings - 'Risk-based' Approach*

15 *Remember to update all procedures, emergency plans and other particulars that may be affected by the implementation of mitigation measures.*

FIGURE 4. Hazard-based Approach: Method for Demonstrating the Adequacy of Protection - Occupied Buildings

Method for Demonstrating the Adequacy of Protection - Occupied Buildings

Risk-based Approach



16 *For each occupied building, determine the probability of exposure to harm for the most exposed individual. Account for shift patterns, weekends and holidays, etc. Record the assumptions used to calculate the probability.*

17 *Use the individual probability of exposure and the cumulative event frequencies determined for the HBA to calculate the maximum Individual Risk (IR) at each building .*

18 *For each occupied building, test whether the Individual Risk (IR) is less than 10^{-6} . If it is, then the IR is broadly acceptable and the building provides adequate protection.*

19 *Implementing one or more mitigation measures identified for the HBA, use the mitigation afforded (i.e. % mitigation) to re-calculate the maximum Individual Risk (IR) at each building.*

20 *For each occupied building, test whether the Individual Risk (IR) is less than 10^{-6} . If it is, then the IR is broadly acceptable and the building provides adequate protection.*

21 *For each occupied building, test whether any other mitigation measures can be taken. If they can, estimate their effectiveness, record supporting evidence, and re-calculate Individual Risk (IR).*

22 *For each occupied building, test whether the Individual Risk (IR) is greater than, or less than, 10^{-4} . If less than 10^{-4} , then the IR may be considered 'tolerable' if it can be demonstrated to be As Low As Reasonably Practicable (ALARP).*

23 *For each occupied building, test whether the Individual Risk (IR) is greater than, or less than, 10^{-5} . If less than 10^{-5} , then the IR may be considered As Low As Reasonably Practicable (ALARP).*

24 *Remember to update all procedures, emergency plans and other particulars that may be affected by the implementation of mitigation measures.*

25 *The Individual Risk can only be tolerated in extreme circumstances where there is no reasonable alternative or means to reduce the risk.*

26 *For each building, identify alternative locations and apply the hazard-based approach, or re-appraise the building's function so as to further minimise individual exposure, or eliminate 'normally' occupied status.*

27 *Remember to update all procedures, emergency plans and other particulars that may be affected by the implementation of mitigation measures.*

FIGURE 5. Risk-based Approach: Method for Demonstrating the Adequacy of Protection - Occupied Buildings

OCCUPIED BUILDINGS REVIEW
**** WORKSTATION ****

Typical occupancy: 1 **Review Date:** 4 June-99
Hours typically occupied: 12 hours/day **Plan ref:** Product xyz loading (DRG No. ABC/123)
Maximum occupancy: 1[i]
Categorised as occupied: Yes
Temporary building: No
If categorised as unoccupied give reasons: not applicable

PASSIVE MEASURES		
1	**Located upwind:**	NA CIA Guidance (3.23) Owing to the Workstations intended function, it is located in a sealed room indoors within the Product Loading Area of the Storage Building.
2	**Located maximum distance from hazard sources:**	No x CIA Guidance (3.23) The Workstation is the co-ordinating and monitoring centre for loading operations. Its location, adjacent to the tanker bay has been chosen to facilitate this function and provide added assurance that loading operations are being performed as intended. For example, visual contact with the tankers can be maintained providing additional verification of successful loading and early warning of potential problems. In addition, the location allows rapid access to, and escape from, the bay in the event of a mishap.
5	**Number of windows minimised:**	NA CIA Guidance (A4.2.3 vii.) All windows are non-opening and permanently sealed.
6	**Windows can withstand any pressure preceding or following a hazardous material leak:**	Yes ✓ CIA Guidance (A4.2.3 viii.) No appreciable pressure expected. Reviewed incident records make no mention of pressure accompanying accidental Product xyz releases[ref].
14	**Doors suitable for egress wearing BA:**	Yes ✓ CIA Guidance (A4.2.3 v.) Minimum height/width required for BA [ref] egress is A/B m. All doors will have these dimensions as a minimum opening and this is covered in the sites SMS [ref].
15	**Exits located on more than one side of the building (and two doors as far apart as practicable):**	Yes ✓ CIA Guidance (A4.2.3 v.) Refer to attached site and building plan.
16	**Number of cable and duct penetrations minimised and sealed:**	Yes ✓ CIA Guidance (A4.2.3 ix.) All penetrations are identified in the buildings maintenance programme and checked as part of the annual maintenance check [ref].
22	**Wind direction indicator inside building:**	NA Additional Consideration The Workstation is within the Storage Building and hence, the majority of potential major releases will be visible from the Workstation.
ACTIVE MEASURES		
23	**Detectors alarm (those in the building to) the presence of gas [fume] external to the building:**	Yes ✓ CIA Guidance (A4.2.1) Fume detectors are located at strategic locations throughout the site to warn of major releases of product xyz. Instruments to detect lesser releases have been investigated and found to be impractical [ref].
24	**Gas [fume] detectors initiate automated window closure:**	NA Additional Consideration Windows are non-opening and permanently sealed.
27	**Forced ventilation air intakes sited to minimise risk of contamination:**	Yes ✓ CIA Guidance (A4.2.4 i.) Forced ventilation intakes are sited to the rear of the building and away from hazard sources. Each intake in marked on the attached diagram
29	**Forced ventilation air intakes and exhausts fitted with manually operated closing devices or self-sealing flaps:**	Yes ✓ CIA Guidance (A4.2.4 iii.) The forced ventilation system will have intakes and exhausts fitted with self-sealing flaps. The air intake design is given in document X and can be supplied if necessary.

FIGURE 6. Review Form: Demonstrating the Adequacy of Protection - Occupied Buildings

30	**Forced ventilation can be switched-off manually within the building (or switched to re-circulation):**	Yes ✓ CIA Guidance (A4.2.4 ii.) The forced ventilation system will be manually operable from within the Workstation (i.e. start-up and shutdown)..
33	**Forced ventilation fitted with chemical filtration:**	No x CIA Guidance (A4.2.4 iv.) The forced ventilation system will limit fume entry via this channel by virtue of physical filtration. In addition, as a result of alternative closure measures noted above, it is considered that specific chemical filtration is unnecessary.
34	**In the absence of forced ventilation, the building's volume is sufficient to support activities of personnel:**	Yes ✓ CIA Guidance (A4.2.2) In the absence of fume ingress, the volume of air within the Workstation is sufficient to support the immediate activities of personnel and don BA suits offering 30 minutes protection. The calculation supporting this assertion is attached.
PERSONAL PROTECTIVE EQUIPMENT (PPE)		
35	**PPE supplied:**	Yes ✓ CIA Guidance (A4.2.6) See below.
36	**Hand held self contained respirators available:**	No x Owing to the availability of two 30 minute BA suits, hand held respirators are considered unnecessary.
38	**30 minute BA suits available:**	Yes ✓ Two 30 minute chemical protection BA suits [ref] are permanently located within the Workstation. The duration of protection is considered satisfactory to perform emergency actions and if necessary facilitate escape to a safe location. The duration of protection may well exceed that required.
COMMUNICATIONS		
40	**Means available to communicate with the emergency management centre:**	Yes ✓ CIA Guidance (A4.2.5) Telephones and hand held radios. See below.
41	**Telephone available - land line for offsite communications**	Yes ✓ One telephone permanently installed. Telephone also serves for onsite communications.
44	**Hand held radios available for onsite communications:**	Yes ✓ Workstation personnel are issued with a radio. A back-up radio is also permanently available in the Operator Station.
45	**Site-wide public address system (tannoy) available:**	No x Owing to the relatively confined nature of the site, the limited number of persons on site at any one time, the site-wide alarm and the communication provisions noted above, a public address system is considered unnecessary.
OTHER MEASURES		
51	**Periodic training of personnel in emergency procedures specific to the building:**	Yes ✓ CIA Guidance (A4.2.1) Emergency training is given twice yearly to all personnel. Plant personnel also undertake additional training bi-monthly. The training programme and log is detailed in the site's SMS [ref].
52	**Operation of a 'fit for use' building permit:**	NA CIA Guidance (A5.6) Applicable only to buildings classed as temporary.

FIGURE 6. Continued
Review Form: Demonstrating the Adequacy of Protection - Occupied Buildings

i Text justifying maximum occupancy and reference to Safety Management System preventing more than 1 occupant (i.e. via an entry log and permit system).