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Petroleum Products Sector
Refining

Facility Siting Screening Workbook

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Amoco PPS - Refining

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I. INTRODUCTION

A. Scope of Workbook

The OSHA Process Safety Management Regulation (29 CFR 1910.119) requires that a process hazard analysis (PHA) address facility siting. The American Petroleum Institute (API) believes that OSHA is interpreting facility siting as the hazards associated with locating occupied buildings in or near process facilities. The Process Hazards Analysis section of the "AOC Refining Department Implementation Guidelines for OSHA 1910.119" provides a framework for local Process Hazards Management (PHM) personnel to address the facility siting requirements during the unit PHAs. This Workbook presents an enhanced facility siting methodology.

Occupants of refinery buildings can potentially be exposed to three types of process hazards: (1) vapor cloud explosions (VCEs) resulting from release and ignition of flammable materials, (2) fires resulting from the release and ignition of flammable materials, and (3) intrusion of toxic materials into buildings.

The primary focus of the siting analysis outlined in this document is to determine the effects of potential vapor cloud explosions (VCEs) on refinery buildings. Depending upon unit-specific conditions, VCEs have the potential to seriously damage building structure, posing a risk to building occupants. The potential hazards associated with VCEs are covered in sections II through V of this Workbook.

In most cases the impact of fires or toxic gas releases on a building's structural integrity is minimal, and generally occurs over a period of time. This normally allows for initiation of an emergency response plan. The potential hazards associated with fires and toxic releases are addressed in sections VI and VII of this Workbook.

B. Format of Workbook

This Workbook is organized so that small tables, figures, and examples are imbedded in the text close to where they are discussed. Full-page material -- the Checklist, Screening questionnaire, Worksheets, and graphs -- are placed at the end of the section in which each was first cited.

C. General Methodology Overview

Each building within the refinery that is intended to shelter personnel or contains critical equipment (e. g., Firehouse) which is expected to be accessed and operated during an emergency should be evaluated. Since unexpected events initiated from adjacent process units or other nearby operations (i.e., storage facility) may impact a building's integrity, each building ~~must be~~ evaluated ~~from a~~ "building perspective" rather than from a "unit perspective."

Buildings that are occupied on a part-time basis and/or temporary buildings, such as turnaround trailers, should also be evaluated using this siting methodology. Buildings that are of similar construction which are located in the same area of the plant (e.g., a cluster of turnaround or office trailers), should be treated as one building for the purposes of the siting evaluation, even if these buildings are not physically connected.

The screening process for facility siting as outlined in this Workbook consists of four steps: (1) building identification and initial screening, (2) consequence screening, (3) risk screening and assessment, and (4) risk reduction. The purpose of this tiered approach is to provide a methodology that minimizes the depth of analysis of buildings that pose low risk to occupants. The analysis becomes more complex as the process continues through the various levels.

D. Building Analysis Checklist

As a final step in these facility siting studies, a checklist review using the Building Analysis Checklist (Table 1) should be performed on all buildings that are occupied or contain critical equipment which is expected to be accessed and operated during an emergency. The Checklist will ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity (such as a small explosion, a fire, or a toxic gas release) are properly addressed in the design and use of the building. Completed checklists and any recommendations resulting from the checklist review should be forwarded to the appropriate management personnel for consideration/resolution.

E. Facility Siting Reference Document

Since this Workbook is intended to be used as a screening tool by refinery personnel, extensive technical background data and lengthy justification discussions are not included. A Facility Siting Reference Manual contains this information and can be consulted if further insight is required on a particular subject. The General Office Process Safety group can be contacted to obtain a copy of this reference book.

F. Facility Siting Spreadsheet

The methodology for the facility siting analysis can be completed by hand, using the formulas and graphs supplied in this Workbook. Alternately, a PC-based siting analysis spreadsheet is available (contact the General Office Process Safety group) to eliminate the need for the user to extract values from graphs and tables, or perform calculations. This should be particularly useful when evaluating several different risk reduction options.

G. Documentation

Copies of all facility siting Tables, calculations, and other pertinent data, should be forwarded to the Refinery Process Hazards Management group for long-term retention with the unit PHA files.

Table 1
Amoco PPS - Refining
FACILITY SITING
BUILDING ANALYSIS CHECKLIST

Building identification: ____________________ Date: __________
Team members: ____________________

This checklist should be applied to all refinery buildings and will help to identify potential hazards to building occupants. The completed checklist should be forwarded to the appropriate management personnel for review. The checklist is formulated so that all "No" answers require evaluation. Some questions may not be applicable to a particular building.

BUILDING NAME:		
ISSUE	Yes/No/NA	RESPONSE
1. Have the following concerns been evaluated for personal work areas within the building: a. Those located along walls facing potential blast sources?		
b. Those adjacent to exterior windows?		
c. Those within proximity to tall unanchored equipment, storage racks, or wall-mounted equipment?		
2. Is the building covered by an emergency response/evacuation plan? (Amoco PSG #24)		
3. Are the building occupants trained in the building emergency response/evacuation plan?		
4. Does the building have doors on the opposite side of the building from likely sources of fires or blasts? (Amoco Spec 12C-4)		
5. Is there a way for occupants to determine wind direction from all building egress routes?		
6. a. If the building is constructed of concrete block, is it located more than 100 feet away from a hydrocarbon source? Alternately, is the building separated from ignition and process areas with minimum distances between boundaries of 50 feet and 25 feet, respectively? (Amoco Spec 12C-4)		

BUILDING NAME:

ISSUE	Yes/No/NA	RESPONSE
b. If the answer to all questions in 6a was "no", has the potential for fire to impact the building integrity been studied?		
7. Are the interior or exterior building fire protection systems adequate?		
8. Is the building pressurization system properly designed for the building area classification?		
9. Is there a detection system within the building or in the fresh-air intake to detect hydrocarbons or toxic materials that could be present during a release? (Spec 12C-4)		
10. Can the building circulation systems and ventilation hoods be stopped quickly to prevent toxic gas ingress within the building? (Amoco PSG #24)		
11. Is a policy in place for each secured building to ensure that: a. An adequate supply of Drager tubes, or other suitable detectors, is available to test the building air for the most likely contaminant(s)?		
b. There is sufficient bottled or fresh supply air available for the occupancy load? (Amoco PSG #24)		
12. If the building contains critical equipment which is expected to be accessed and operated during an emergency: a. Has consideration been given to strengthening the building or relocating the equipment?		
b. Has the safety of personnel required to access the equipment been considered?		

II. BUILDING IDENTIFICATION AND INITIAL SCREENING

A. Overview

The basic premise of the Building Identification and Initial Screening step is that it is reasonable to apply coarse, simple, and conservative screening techniques to identify buildings that pose little or no potential hazard to occupants. Every plant building should be identified and the screens described in this section applied. Guidance is provided later in this section to help the user determine if a building requires further study. The following are the six screens:

1. Study applicability - This Workbook can only be applied to buildings having three stories or less. Buildings that have two or three stories must have substantial floor systems at each story level. Buildings with more than three stories will require a special study to assess the building response to a VCE.

2. Functionality - Only buildings that have a routine presence of personnel, or that contain critical equipment which is expected to be accessed and operated during an emergency, will require further siting evaluation.

3. Location - Buildings located far enough away from potential hazards will not require further siting evaluation.

4. Site-specific conditions - If the site-specific conditions for all facilities that can potentially affect a building clearly preclude a significant degree of vapor confinement, or clearly indicate that there is no source of materials that can potentially form a vapor cloud upon release, no further siting evaluation will be required.

5. Construction type - Blast-resistant buildings will not require further siting evaluation.

6. Occupancy - Buildings that have "low" occupancy will not require further siting evaluation.

B. Building Identification and Initial Screening Table

Building Identification and Initial Screening is intended to be performed by refinery or other personnel familiar with the refinery buildings (i.e., function, occupancy, construction type, potential hazards, etc.). The study can be performed as part of a PHA or may be coordinated by a separate team. Unit and refinery plot plans will be required to identify the location of potential hazards relative to each building. Building Identification and Initial Screening is required for every refinery building, and should be documented. A "Building Identification and Initial Screening Table" (Table 2) can be used to facilitate this documentation. This table will either indicate why the building was removed from further consideration or will provide information for a team to conduct additional siting evaluation. Copies of the Building Identification and Initial Screening Tables should be forwarded to the next study team so that the data gathered during this step can be utilized.

C. Study Applicability Screen

Any building that has more than three stories should not be subjected to the rest of the Facility Siting Screening exercise; such a building will require a special study to assess its response to a potential VCE. All of the data pertaining to building strength and response to a VCE that was used to develop this Workbook applies only to buildings of three stories or less.

Buildings that have two or three stories can be included in the Facility Siting Screening exercise only if there are substantial floor systems at each story level. This has been defined as a floor system consisting of any of the following floor constructions: 1) metal decking supported by metal joists, 2) metal decking with concrete topping, 3) decking with a metal horizontal truss system, or 4) cast-in-place or precast reinforced concrete floor slab. If the floor construction does not meet any of these criteria, a special study to assess the building response to a VCE, performed by an expert in building design and VCE response, is required.

The potential hazards to occupants of any building containing a significant amount of light hydrocarbons within the building walls should be evaluated as part of the facility PHA. The facility siting methodology presented in this Workbook is concerned with the effect on the building from an external event; internal sources of hydrocarbon are not within the scope of this document.

D. Functionality Screen

Buildings that do not have a routine presence of refinery personnel will not require further siting analysis unless the building contains critical equipment which is expected to be accessed and operated during an emergency. A building that has a "routine presence of personnel" is defined as any building in which any single individual spends more than 5 hours per week inside, OR any building for which the sum total of hours that all refinery personnel spend inside exceeds 25 hours per week on an annualized basis.

Some examples of buildings containing critical equipment that might require further study are those which house refinery fire pumps, the refinery fire station, or those that contain activation switches (deluge, shutdowns, etc.) for emergency devices.

E. Location Screen

All buildings of interest (those that have a routine personnel presence, or which contain critical equipment which is expected to be accessed and operated during an emergency) will require further siting evaluation. Various studies have shown that minimal damage to a building will result if it is located far enough away from a vapor cloud explosion. The definition of "far enough" varies depending on the particular building construction and the size of the blast.

Most of the buildings within our facilities can be sorted into three categories: (1) wood frame, (2) steel frame, and (3) concrete, masonry, brick, and/or cinder block. Each building under study should be sorted into one of these categories. Once the general building type has been determined, Table 3 should be used to determine if the building is "far enough" away from a potential vapor cloud explosion. If the building is located more than the minimum safe distance from an operating unit or an other hazard (as measured from the center of the nearest concentration of congested equipment within a unit battery limits) a checklist review using the Building Analysis Checklist (Table 1) should be performed to complete the facility siting analysis. This review will help ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

Occasionally a building is constructed of two different structural types. In these cases, the area of the building that is typically occupied should be determined and the construction type of the occupied area identified. If this determination cannot be made, then the most limiting building construction should be used for the location screen.

Table 3
SAFE DISTANCE CRITERIA

Building Type	Minimum Safe Distance
Wood frame and siding (trailer)	350 feet
Steel frame and siding (sheet metal)	450 feet
Concrete, masonry, brick, or cinder block	700 feet

Since general construction standards apply to wood or steel frame and siding buildings, good estimates of the minimum safe distance standards have been established for these categories. Note that the minimum distance standard for wood buildings (trailers) is somewhat less than the standards for other types of buildings. Data from actual events indicate that trailers tend to roll in response to a VCE, and walls and roofs do not collapse on occupants, resulting in fewer serious injuries/fatalities.

The minimum safe distance shown in Table 3 for concrete, masonry, brick, and/or cinder block buildings is conservative since the strength of these buildings varies considerably depending on the wall thickness, height, and reinforcement. These factors will be taken into account when evaluating the building strength during the Consequence Screening portion of the facility siting analysis.

F. Site-Specific Conditions Screen

If the site-specific conditions for all facilities that can potentially affect a particular building clearly preclude a significant degree of vapor confinement, or clearly indicate that there is no source of materials that can potentially form a vapor cloud upon release, further detailed analysis of the building will not be required.

It is unlikely that significant blast pressures will be developed if light hydrocarbons are released in an open plant environment, since there is little of the vapor confinement required to create dangerous overpressure. If the unit layout and spacing between equipment clearly preclude a significant degree of vapor confinement, the building should be removed from further consideration. Guidance to help determine this is provided in section III.C. The facility siting study team must conduct a site tour of the area around the building in order to reach this conclusion.

If there is no source of materials that can potentially form a vapor cloud upon release, the building should be removed from further consideration. Generally, light hydrocarbons up to and including butane, and heavier hydrocarbons processed at elevated temperatures and pressures, have the potential for a VCE upon release. Note that this evaluation must consider the potential for these materials to be released from equipment at an adjacent facility and drift into a congested area of equipment that does not contain materials that can form a VCE upon release.

If it is determined that no further detailed facility siting analysis is required for a particular building due the site-specific conditions, a review using the Building Analysis Checklist (Table 1) should be performed to complete the facility siting analysis. This review will help ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

G. Construction Screen

Blast-resistant buildings will not require further detailed facility siting analysis. For the purposes of this screen, a building is blast-resistant if it has been specifically designed for an overpressure load of at least 3 psi static pressure acting on all external surfaces. Section 7.0 of Amoco Specification 12C-4 discusses this requirement. A review using the Building Analysis Checklist (Table 1) should be performed to complete the facility siting analysis of these buildings. This review will help ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

H. Occupancy Screen

The occupancy screen has two independent levels of concern: individual occupancy and total occupancy. Buildings that are occupied less than 20 hours per week by any single individual and less than 200 hours per week by all occupants should be removed from further consideration. Occupancy levels should be developed on an annualized basis with consideration for overtime, job rotation, vacation, holidays, sick time, as well as temporary building utilization.

Some other factors to consider when determining the building occupancy levels include (1) the presence of supervisory and office personnel, (2) routine equipment maintenance requirements, (3) lunch or break gatherings, (4) training or safety meetings, (5) visitors, and (6) maintenance planning activities (to obtain permits, for example). The total population occupancy should be multiplied by 1.05 to account for miscellaneous short-term visitors (i.e., janitors, delivery personnel, etc.).

Buildings that are not occupied (on both an individual and population basis) according to the requirements prescribed above should be subjected to a checklist review using the Building Analysis Checklist (Table 1) to complete the facility siting evaluation. This review will help ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

I. Path Forward

Any building that has not been removed from further consideration during the Building Identification and Initial Screening step will require additional facility siting evaluation. If the Building Identification and Initial Screening step was performed by a PHA team, an action item should be taken at this point indicating which buildings require additional siting evaluation. It is recommended, however, that the PHA team not perform this analysis.

Table 2

Amoco PPS - Refining Facility Siting Analysis
BUILDING IDENTIFICATION AND INITIAL SCREENING

Building name : ____________________
Screening team members : ____________________
Date : ____________

STUDY APPLICABILITY SCREEN	Yes/ No	If yes, stop analysis. This building requires special study.	If no, document this and proceed to next question.
Is this building more than three stories?			
	Yes/ No	If yes, document this and proceed to the next question.	If no, stop analysis. This building requires special study.
Are there substantial floor systems at each story level, defined as (a) metal decking supported by metal joists, (b) metal decking with concrete topping, (c) decking with a metal horizontal truss system, or (d) cast-in-place or precast reinforced concrete floor slab?			
FUNCTIONALITY SCREEN	Yes/ No	If any answer is yes, document this, and proceed to the Location Screen.	If all answers are no, stop. Analysis is complete for building.
Does any one single occupant spend more than 5 hours/week in this building?			
Do all occupants spend more than 25 hours/week in this building?			
Does the building contain any equipment that must be accessed and operated during an emergency such as fire trucks, shutdown switches, etc.?			

Table 2 (continued)

LOCATION SCREEN - choose correct question based on building construction material	Yes/ No	If yes, list units and proceed to next Site-Specific Conditions Screen.	If no, document this and proceed to Checklist.
Wood - are there any units within 350 ft of the building?			
Steel - are there any units within 450 ft of the building?			
Concrete/brick - are there any units within 700 ft of the building?			
SITE-SPECIFIC CONDITIONS SCREEN	Yes/ No	If yes, list units/materials, and proceed to next question.	If no, document this and proceed to Checklist.
Do any of the units listed above process material that can form a vapor cloud?			
	Yes/ No	If yes, document this and proceed to Checklist.	If no, proceed to the next screen.
Does the unit layout clearly preclude a significant degree of vapor confinement?			
CONSTRUCTION TYPE SCREEN	Yes/ No	If yes, document this and proceed to the Checklist.	If no, proceed to the Occupancy Screen.
Is the building designed to withstand an overpressure load of 3 psi static pressure on all external surfaces?			
OCCUPANCY SCREEN	Yes/ No	If yes, document this, and proceed to the consequence screen in Workbook.	If no, proceed to next question.
Does any one single occupant spend more than 20 hours/week in this building? (Indicate hours/week of most exposed individual)			
	Yes/ No	If yes, document this, and proceed to the Consequence Screen in Workbook.	If no, document this and proceed to the Checklist.
Is the total time that all building occupants spend in this building more than 200 hours/week? (List hours/week for all personnel)			

III. CONSEQUENCE SCREENING

A. Overview

All buildings that were not removed from further consideration during the Building Identification and Initial Screening step of this Workbook should be subjected to Consequence Screening. This step consists of the following three tasks: (1) building construction categorization, (2) congested area definition and blast source volume calculation, and (3) incident overpressure and vulnerability calculations. If a building can withstand the anticipated blast overpressure generated by all of the facilities that can affect it, a review using the Building Analysis Checklist (Table 1) should be performed to complete the facility siting analysis for the building.

Consequence Screening is intended to be performed by refinery personnel familiar with the information presented in this Workbook and with building construction details. The Consequence Screening should be performed from a "building perspective," taking into account all areas of congested equipment without regard for process-unit boundaries. Personnel familiar with the various facilities and events that may affect a building will need to be consulted to help identify where applicable congested areas exist. These factors suggest that the Consequence Screening should be performed outside of the unit PHAs.

Detailed building construction drawings are required in order to assess the building design characteristics and strength under blast load. Unit and refinery plot plans will also be needed to identify the location of congested areas relative to the building. Information collected during the Building Identification and Initial Screening step will also be required in order to perform this step.

A Building Consequence Screening Worksheet (Table 5) is provided to summarize the results and findings of this analysis.

B. Building Construction Categorization

The first task of the evaluation team is to review the building construction drawings and determine which of the five wall categories (W1 - W5) and which of the four roof categories (R1 - R4) (both specified in Table 4) best describe the building being analyzed. This information should be entered on the appropriate lines of the Building Consequence Screening Worksheet (Table 5). The wall height, wall thickness, and details of any vertical reinforcement should also be recorded. Use the average building story height as the wall height for multi-story buildings. This information will be used later in this analysis. If any of this information is unavailable or uncertain, then a conservative assumption should be made and the analysis should be continued. For example, assume that the walls are unreinforced (W3) if the drawings do not clearly indicate reinforcement type.

Table 4
GENERAL BUILDING WALL/ROOF CATEGORIES

Wall Category		Roof Category	
W1	Wood frame and siding	R1	Wood decking
W2	Metal frame and siding	R2	Metal decking
W3	Unreinforced masonry bearing wall	R3	Metal decking with concrete topping
W4	Steel or concrete frame with unreinforced masonry infill walls	R4	Reinforced concrete slab
W5	Reinforced concrete or masonry shear walls		

As before, if a building is constructed of two different structural types, the study team should determine which area of the building is occupied, and identify the construction type of the occupied area. If this determination cannot be made, then the most limiting building construction should be used for the consequence screen.

If the building wall height or thickness varies, then the tallest wall height (single story) and the thinnest wall thickness should be recorded.

C. Congested Area Definition and Blast Source Volume Calculation

This facility siting methodology recognizes that significant blast overpressure can only be developed when substantial quantities of an explosive mixture are concentrated in a congested area. At this stage of the analysis no attempt will be made to determine the release point that generates the explosive mixture. Congested areas will be identified, and it will be assumed that their volume will be filled. The facilities that can potentially impact each building should have been identified in the Building Identification and Initial Screening step. At least one congested area must be identified at each of the facilities on this list.

1. Congested Area Definition

The analysis team should tour all units to identify congested areas that can potentially affect the building under study. These are large rectangular areas where equipment, buildings, piping, etc., are closely packed. Boundaries of congested areas should be taken at open areas such as roadways or unit center access aisles, but these open areas must be free of confinement in the vertical direction as well as in the horizontal direction. An overhead pipe rack may force a congested area definition to be extended across a unit center aisle, for example, if the piping in the rack is nearly continuous. The length and width of the congested areas should be measured either by pacing off the distances or by lifting the distances off a scaled drawing. It is suggested that no more than three congested areas be identified per operating unit to help ensure that the effect of a congested area close to the building is not masked. It is helpful to mark these congested areas on a unit plot plan. All congested area dimensions should be recorded in the appropriate columns of the Building Consequence Screening Worksheet (Table 5: column 1 for length and column 2 for width).

2. Aspect Ratio Adjustment

The congested area definition should be adjusted if the length (the longer of the two dimensions) is more than 1.6 times the width (the smaller of the dimensions). This "aspect ratio" adjustment is based on the observation that vapors clouds generally tend to disperse somewhat evenly and do not form long, cylindrical shapes. The adjusted congested area length (the actual length or the width multiplied by 1.6, whichever is less) should be recorded in column 3 of the Building Consequence Screening Worksheet. One exception to this rule is if the congested area identified is a building with continuous walls. Under this scenario, the congested area dimensions should not be adjusted, since the vapor cloud will take the shape of the enclosure.

3. Congested Volume Calculation

The volume of the congested area should now be calculated. The width of the congested area (column 2) is multiplied by the adjusted length (column 4) to yield the confined area. The confined area is multiplied by 20 to produce the congested volume. The height of the congested area is assumed to be 20 feet based on the results of gas dispersion modeling conducted over many release scenarios. The congested volume (in MFt^3) is entered into column 5 of the Worksheet.

4. Blast Source Volume Calculation

The blast source volume is calculated by adjusting the congested volume for spacial probability by dividing the volume by 2. This adjustment is based on the assumption that whatever wind exists will concentrate the explosive mixture on one side or the other of the congested area. No attempt will be made at this time to estimate which sections of the congested area are more likely to contain the explosive mixture due to prevailing wind direction. The blast source volume is entered into column 6 of the Worksheet. Note that if the congested volume defined is a building with enclosed walls, no spacial adjustment should be applied since wind will not be a factor. If it is determined that the building is vented, or partially vented, the spacial probability adjustment may be applied.

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5. Distance of Incident to Building

The distance from the center of each of the originally defined (before adjustments) congested areas to the nearest wall of the building being studied should be determined by using a scaled drawing. Do not attempt to adjust these distances to reflect any aspect ratio or spacial probability adjustments. This distance (in feet) should be entered into column 7 of the Worksheet.

The following example should illustrate the congested area data gathering and blast source volume calculations performed during the initial stage of a building facility siting evaluation.

Example: Building Data Gathering & Congested Volume Calculation

A facility siting evaluation is to be performed for an operating unit control room. The walls of the building are non-reinforced concrete blocks (W3) and support the roof, which is metal decking with concrete topping (R3). Three units can potentially affect the building. During the field survey, congested areas are identified as follows: Unit A has one congested area (A1); Unit B has two congested areas (B1 and B2); and Unit C has three congested areas (C1, C2, and C3). The table below presents the data collected and shows the initial calculations performed for this evaluation.

Congested Area	Length (ft)	Width (ft)	Adj. Length (ft)	Congested Volume (Mft^3)	Blast Source Volume (Mft^3)	Dist. to Building (ft)
A1	257	92	147	270	135	215
B1	257	74	118	175	87	110
B2	257	74	118	175	87	202
C1	404	129	206	531	265	680
C2	239	55	88	97	48	827
C3	128	92	128	236	118	551

The length, width, and distance to the building are all measurements taken in the field. The adjusted length is either the actual length or the width multiplied by 1.6, whichever is less. The congested volume is the width times the adjusted length times 20. The blast source volume is the congested volume divided by 2.

D. Incident Overpressure and Vulnerability Calculations

The incident overpressures will be estimated for each of the blast source volumes and distance-to-building data sets defined in sections III.C.4 and III.C.5. Vulnerability of building occupants to injury will be estimated from the calculated incident overpressures, the reflected pressure loads on the building, and the building construction information. The incident overpressure and occupant vulnerability will be estimated using correlations created by a consultant, EQE International, Inc. Background information on these correlations is available in the Facility Siting Reference Manual.

1. Incident Overpressure Estimation

For each blast source volume (column 6) and distance (column 7) information sets specified on the Building Consequence Screening Worksheet, the incident overpressure (Ps) should be estimated from the graphs in Figures 6A, 6B or 6C. The incident overpressure (Ps) should be recorded in column 8 of the Worksheet.

2. Reflected Pressure Calculation

The reflected overpressure load on the building walls (Pr') should be calculated using the following formula:

$$Pr' = 2\,(Ps) + 0.05\,(Ps)^2$$

This represents the increased pressure that the building is subjected to as the initial pressure waves hit the building walls and reflect back towards the incident. Incoming pressure waves add energy to the reflected waves and increase the effect on the building. The reflected overpressure (Pr') should be recorded in column 9 of the Worksheet.

3. Reflected Pressure Adjustments for Wall Thickness and Height

Any building that was identified in section III.B as having a W3, W4 or W5 wall type should be studied to determine a reflected pressure modification factor (MF). This modification factor is necessary since baseline parameters for wall height and thickness were established to develop the graphs included in this Workbook. Any significant deviation from these baseline parameters will require an adjustment to Pr'.

Table 7 provides wall-thickness modification factors (MFt) and wall-height modification factors (MFh). Buildings with wall thicknesses more than the baseline parameter (10-13 inches) result in a modification factor (MFt) of less than one, resulting in a decrease in the reflected pressure effect. This makes sense, since buildings with thicker walls would logically be stronger than the baseline building. Buildings that have shorter walls than the baseline parameter (16-19 feet) also result in a modification factor (MFh) of less than one, resulting in a decrease in the reflected pressure effect. This makes sense, since buildings with shorter walls should logically be less susceptible to a pressure wave. Any wall thickness modification factors (MFt) or wall height modification factors (MFh) should be recorded on lines F and G, respectively, of the Worksheet.

Table 7
BUILDING WALL THICKNESS AND HEIGHT MODIFICATION FACTORS

Wall Thickness (inches)	Modification Factor (MFt)	Wall Height (feet)	Modification Factor (MFh)
4	2.1	8	0.4
5	1.8	9	0.4
6	1.6	10	0.5
7	1.4	11	0.6
8	1.3	12	0.6
9	1.2	13	0.7
10	1.0	14	0.8
11	1.0	15	0.8
12	1.0	16	1.0
13	1.0	17	1.0
14	0.9	18	1.0
15	0.9	19	1.0
16	0.8	20	1.2
18	0.8	21	1.3
		22	1.4
		23	1.5
		24	1.5
		25	1.6

4. Reflected Pressure Adjustments for Wall Reinforcement

Any building that was identified in section III.B as having a W5 wall type should be studied to determine if an additional adjustment to the reflected pressure is warranted. This modification factor is necessary since baseline parameters for wall reinforcement were established to develop the graphs included in this Workbook. Any significant deviation from these baseline parameters will require an adjustment to Pr'.

Table 8 provides wall reinforcement modification factors (MFr). Buildings with wall reinforcements better than the baseline parameter (one row of #6 @ 16", #8 @ 24", #10 @ 40"; or two rows of #4 @ 22", #5 @ 32", #6 @ 48") result in a modification factor (MFr) of less than one, resulting in a decrease in the reflected pressure effect. This makes sense, since buildings with better reinforcement would logically be stronger than the baseline building. Any wall reinforcement modification factor (MFr) should be recorded on line H of the Worksheet.

Table 8
BUILDING WALL REINFORCEMENT MODIFICATION FACTORS

Reinforcement ONE ROW	Modification Factor MFr	Reinforcement TWO ROWS	Modification Factor MFr
#8 @8"; #10 @ 8"	0.4	#5 @ 8"; #6 @ 12"; #8 @ 20"; #10 @32"	0.4
#6 @ 8"; #8 @ 12"; #10 @ 16"	0.6	#4 @ 10"; #6 @ 24"; #8 @ 38"	0.6
#6 @ 12"; #8 @ 16"; #10 @ 28"	0.8	#4 @ 16"; #6 @ 32"	0.8
#6 @ 16"; #8 @ 24"; #10 @ 40"	1.0	#4 @ 22"; #5 @ 32"; #6 @ 48"	1.0
#4 @8"; #6 @ 20"; #8 @ 32"; #10 @ 48"	1.2	#4 @ 28"; #5 @ 40"	1.2
#4 @ 10"; #6 @ 24"; #8 @ 40"	1.4	#4 @ 32"; #5 @ 48"	1.4
#4 @ 12"; #6 @ 28"; #8 @ 48"	1.6	#4 @ 40"	1.6
#5 @ 24"; #6 @ 32"	1.8	#4 @ 48"	1.8
#4 @ 16"; #6 @ 38"	2.0		
#5 @ 32"; #6 @ 44"	2.2		
#4 @ 22"; #5 @ 36"	2.4		
#4 @ 26"; #5 @ 40"	2.6		
#4 @ 28"; #5 @ 44"	2.8		
#4 @ 32"; #5 @ 48"	3.0		

5. Calculation of Reflected Pressure Modification Factor (MF)

The three wall modification factors (MFt, MFh, MFr) should be multiplied together to calculate the overall reflected pressure modification factor (MF). (Note that the wall reinforcement modification factor (MFr) will be equal to 1.0 for buildings with wall types of W3 and W4).

$$MF = MFt \times MFh \times MFr$$

The overall reflected pressure modification factor (MF) should be entered onto line I and in column 10 of the Building Consequence Screening Worksheet.

6. Building Reflected Load Calculation

The building reflected load (Pr) is calculated by multiplying the reflected pressure (Pr' - column 9) by the wall modification factor (MF - column 10). Note that MF = 1 for buildings with wall types W1 and W2. The building reflected load (Pr) should be entered in column 11 of the Worksheet.

$$Pr = Pr' \times MF$$

7. Vulnerability Estimation

The vulnerability (V) of occupants within a building depends on the degree of building damage resulting from a VCE at a nearby process facility, and this is a function of the building's reflected pressure load and the type of building construction. These variables are correlated in Figure 9, and the occupant vulnerability can then be estimated. In this context, vulnerability is expressed as the fraction of building occupants that receive serious injuries given the level of building damage. All vulnerability estimates should be recorded in column 12 of the Worksheet. The following example is provided to illustrate how to use the graphs in Figures 6A, 6B, 6C, and 9 to obtain the incident overpressure and the occupant vulnerability.

<u>Example: Incident Overpressure & Occupant Vulnerability Estimation</u>

The facility siting evaluation example introduced in section III.C.5 of this Workbook will be used as a basis for this example. Additional facts pertaining to this building were obtained as follows: the building walls are 15 feet tall (MFh = 0.8) and are 8 inches thick (MFt = 1.3). Wall reinforcement does not exist for this building since the walls were classified as W3, and MFr is, by definition, set equal to 1.0. Therefore, the overall modification factor (MF) is (0.8)(1.3)(1.0) = 1.04. The table below shows the information calculated or taken from the graphs, to estimate the vulnerability of building occupants.

Congested Area	Blast Source Volume (Mft³)	Dist. to Building (ft)	Incident Overpressure. Ps (psi)	Reflected Pressure Pr' (psi)	Reflected Load Pr (psi)	Vulnerability
A1	135	215	4.2	9.3	9.7	1.00
B1	87	110	9.7	24.1	25.1	1.00
B2	87	202	3.9	8.6	8.9	1.00
C1	265	680	1.1	2.3	2.4	0.25
C2	48	827	0.6	1.2	1.3	0.00
C3	118	551	1.1	2.2	2.3	0.19

The blast source volumes and distances to the building are repeated from the previous example. The incident overpressure (Ps) is obtained from Figures 6A, B or C. The reflected pressure (Pr') is calculated according to the equation $Pr' = 2(Ps) + 0.05(Ps)^2$. The reflected load (Pr) is the reflected pressure times MF (1.04 for this example). The occupant vulnerability is obtained from Figure 9.

8. Consequence Screening

If all vulnerability estimates are less than 0.10, a review using the Building Analysis Checklist (Table 1) should then be performed to complete the facility siting analysis for the building. If any of the vulnerability estimates exceed 0.10, then a Risk Screening step should be performed for the building.

Table 5
Amoco PPS - Refining Facility Siting
BUILDING CONSEQUENCE SCREENING WORKSHEET

Building name: ____________________

Analysis team: __________ __________ __________

Building Construction Information:

A. Wall Type: ________ (from Table 5)
B. Roof Type: ________ (from Table 5)
C. Wall Thickness: ________ inches
D. Wall Height: ________ feet
E. Reinforcement: ________________

F. MFt: ________ (from Table 7)
G. MFh: ________ (from Table 7)
H. MFr: ________ (from Table 8)

I. Modification Factor ---> MF = MFt x MFh x MFr = ________

Congested Volume Calculation and Vulnerability Estimation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Unit/ Congested Area #	Length (L) (feet)	Width (W) (feet)	Max Length (2) x 1.6	Adj. L smaller of (1) or (3)	Congested Vol (MFt³) (2)(4) x 20/1000	Blast Source Vol (MFt³) (5) x 0.5	Distance to Building (ft)	Ps (psi) Figure 6A/B/C	Pr' (psi) 2(8) + 0.05 (8)²	MF (I)	Pr (psi) (9)(10)	Vuln Fig. 9

Comments: ____________________

Figure 6A

Pressure vs. Congested Volume & Distance

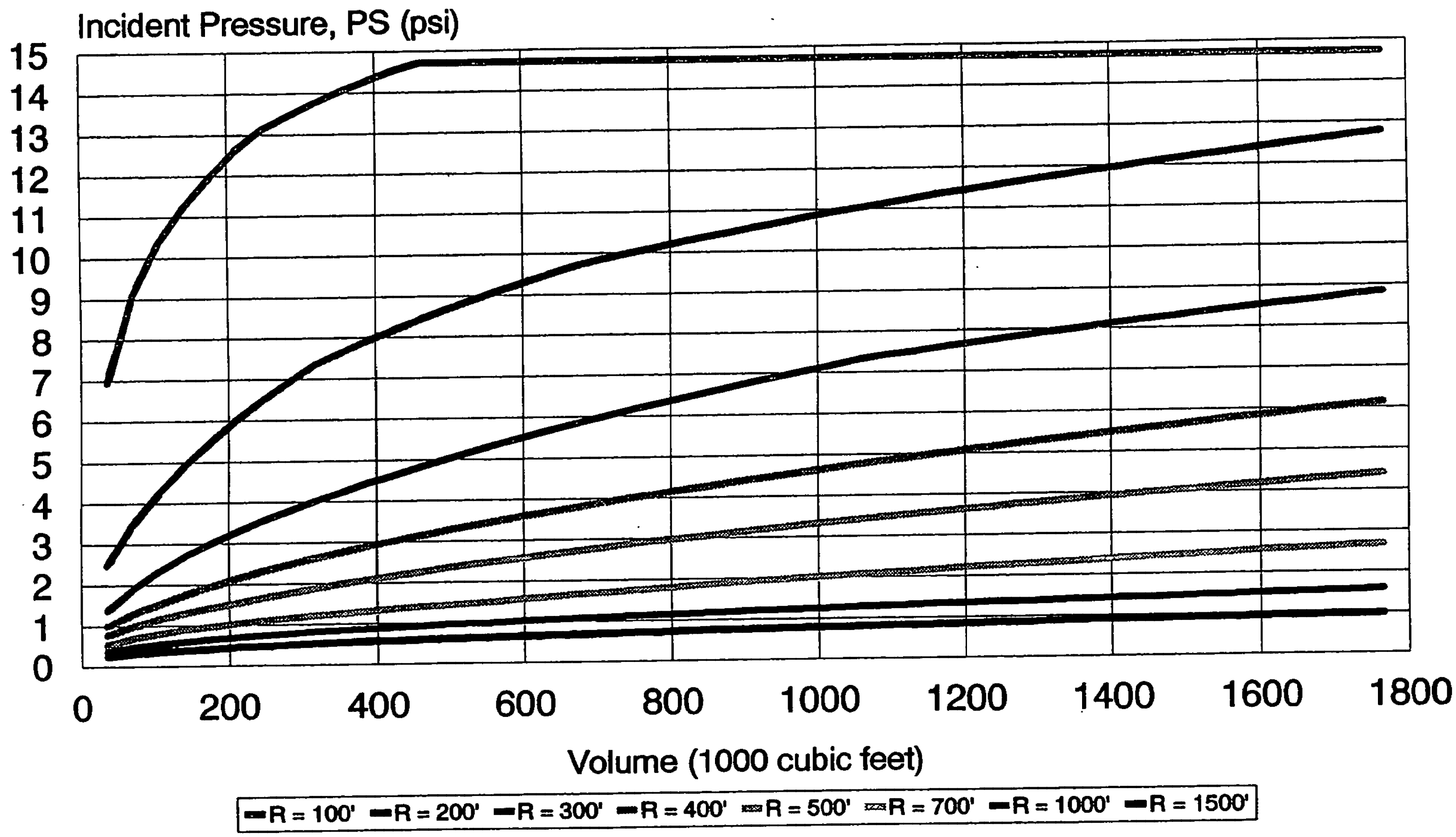


Figure 6B
Pressure vs. Congested Volume & Distance

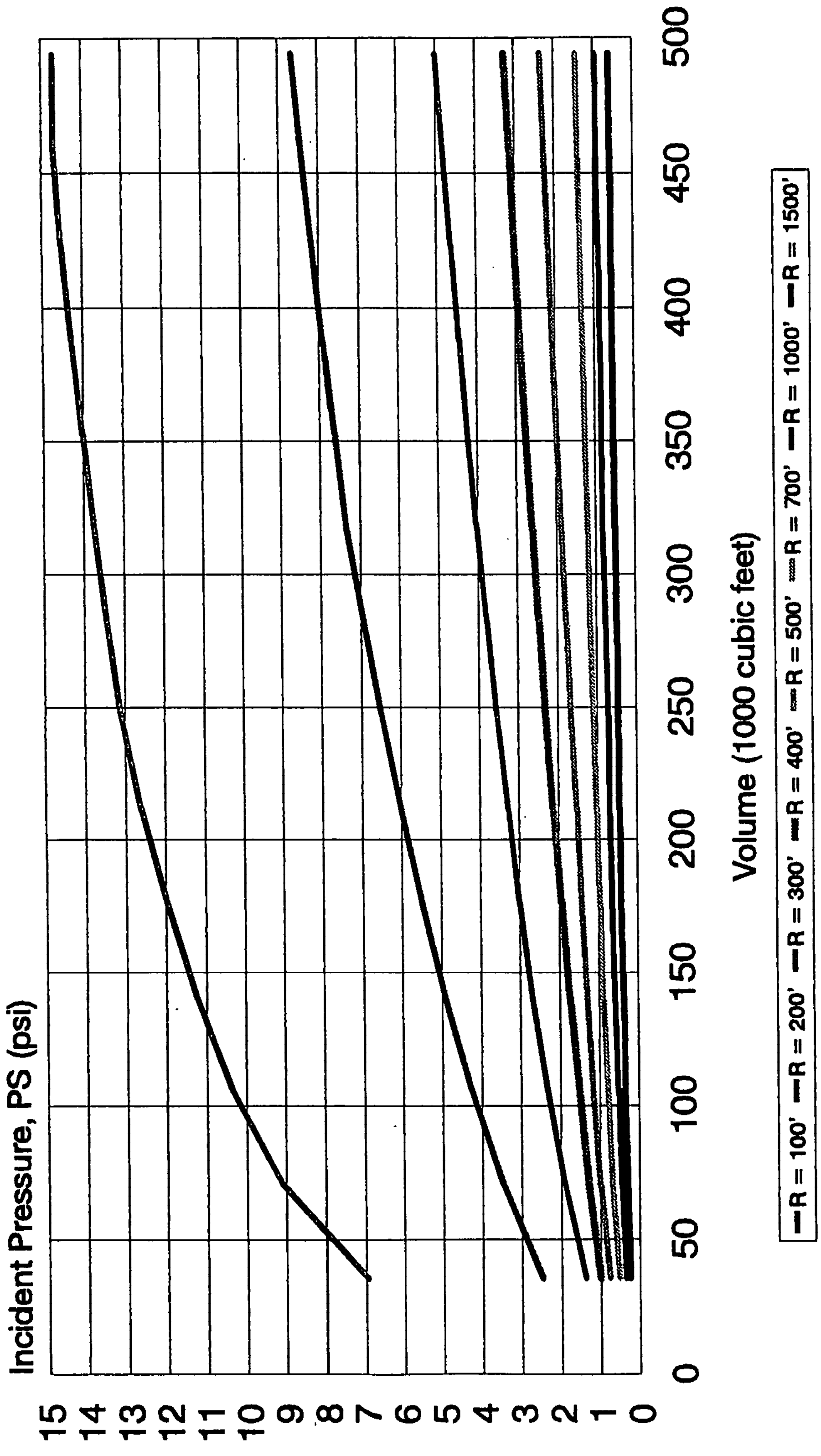


Figure 6C

Pressure vs. Congested Volume & Distance

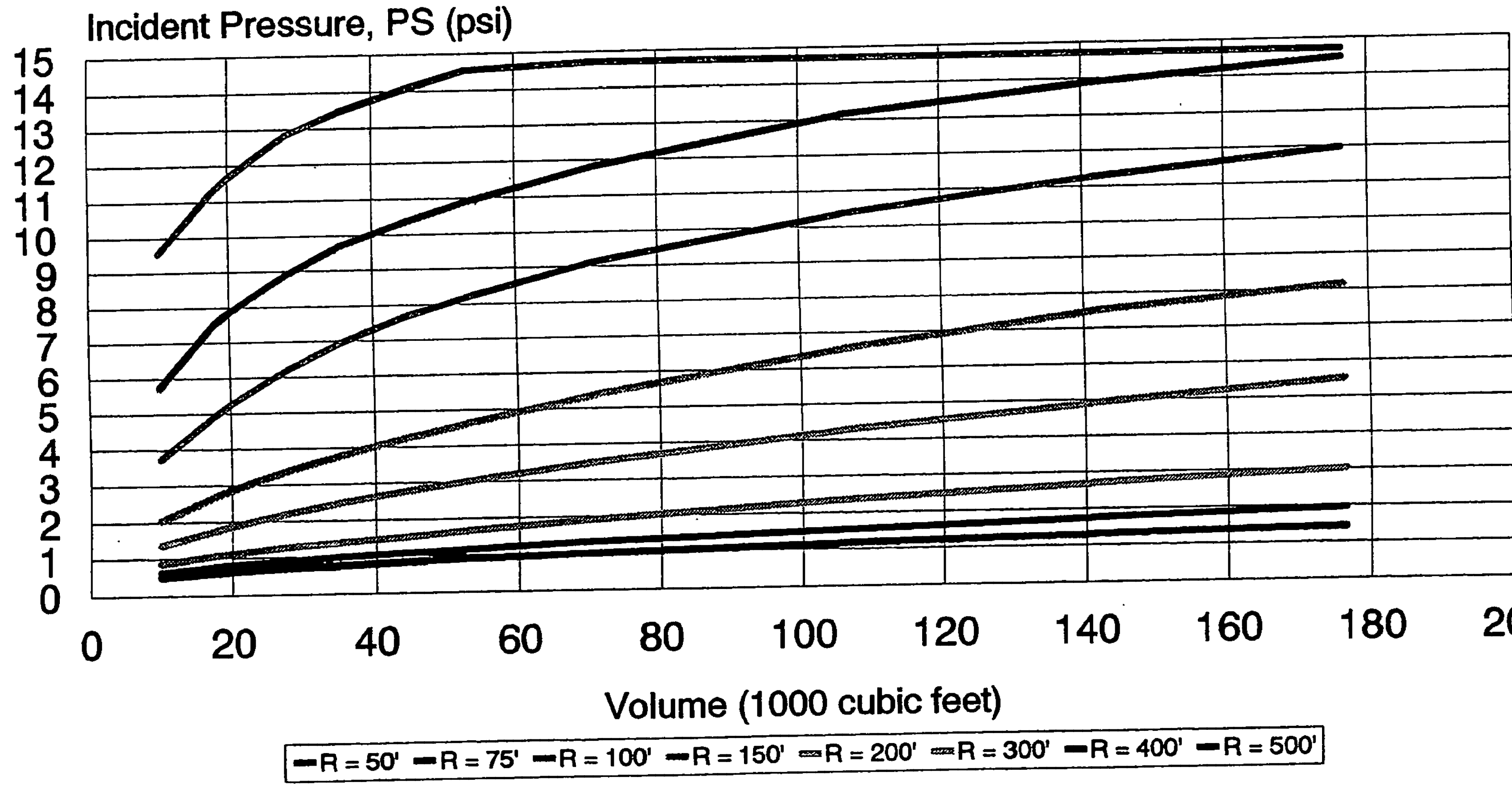
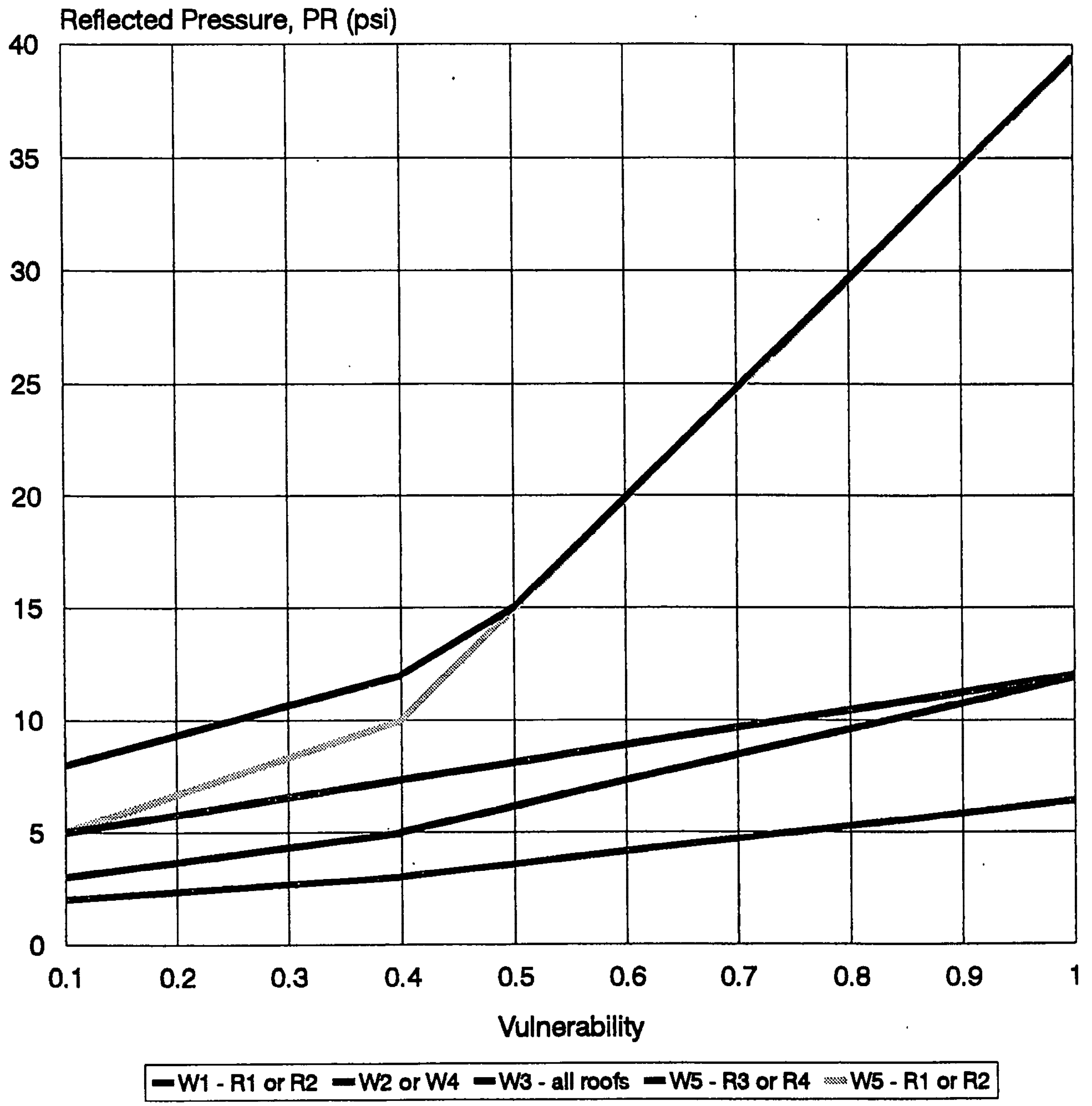


Figure 9

Reflected Pressure vs. Occupant Vulnerability



IV. RISK SCREENING

A. Overview

In the Risk Screening step, the individual risk to the most exposed occupant and the population risk to all occupants will be calculated for every building that has not been eliminated from further consideration in the previous screening steps. These risk calculations will require the occupancy information previously developed in Building Identification and Initial Screening (section II), as well as the vulnerability data developed in Consequence Screening (section III). Table 10 is provided to summarize the risk calculations.

Once the individual and the average population risks are calculated, they will be compared to risk criteria that will help determine the next step in the facility siting evaluation. Options are to continue the analysis by performing a Risk Reduction Analysis (section V) or to conclude the analysis by completing a Building Analysis Checklist (Table 1) to ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

B. Risk Definition

One definition of risk is "the possibility of meeting danger or suffering harm or loss." There is risk inherent in everything that we do in life, and working in an oil refinery has some risk associated with it. The risk that we are concerned with for the purpose of this Workbook is the risk of injury to a building occupant from a VCE. This risk is calculated by the following formula:

RISK (R) = (Vulnerability)(Frequency of VCE)(Occupancy)

All risk is additive. The person that flies in a jet airliner once a week is accepting a higher risk than someone who flies once a year. Therefore, to calculate the total risk to building occupants, the effect of all potential VCEs on a particular building must be added together. This leads to the formula:

$R_{total} = R_1 + R_2 + \ldots R_N$; where N = total number of events that can affect a building

C. VCE Frequency

Vapor cloud explosions are rare events. In order to estimate the likelihood of a VCE within an operating facility, historical event history presented in API RP 752, "Management of Hazards Associated with Location of Process Plant Buildings," was studied. In order to simplify the risk screening analysis and to help ensure the statistical validity of the data base, it was decided that an average unit VCE frequency would be used when evaluating the occupant risk for all buildings within Amoco refineries. This frequency is:

4.3×10^{-4} events/unit per year of operation (one event/unit every 2,325 operating years)

It is important to recognize that this average frequency applies for each operating unit that can potentially impact a building. If multiple congested areas are identified within a particular operating unit, the average VCE frequency should be divided by the number of congested areas identified and an equal portion of the frequency should be assigned to each congested area. The following example may be helpful in demonstrating the concept of VCE frequency.

Example: VCE Frequency

The unit control building which was introduced in section III.C.5 of this Workbook will be used for this example. There are three units within the prescribed distance criteria for this building: Unit A has only one congested area (A1); Unit B has two congested areas (B1 and B2); and Unit C has three congested areas (C1, C2, and C3).

VCE frequency for Area A1 is 4.3×10^{-4} events per year;
VCE frequency for Areas B1 and B2 is 2.1×10^{-4} events/year; (4.3×10^{-4} /2)
VCE frequency for Areas C1, C2, and C3 is 1.4×10^{-4} events/year (4.3×10^{-4} /3).

D. Risk Calculation

1. Individual Risk

Individual risk measures the probability of serious injury from a VCE to the most exposed individual in a particular building. A formula to calculate risk was presented earlier as: RISK $(R)_I$ = (Vulnerability)(Frequency of VCE)(Occupancy), where "I" means "individual". A methodology to estimate the vulnerability of building occupants to serious injury due to a VCE has already been discussed (section III.D.7). The frequency of a VCE can be estimated from the discussion in section IV.C. Therefore, only the occupancy is required to calculate the risk.

The building occupancy level of the most exposed individual was calculated as hours per week on an annualized basis (section II.H) with consideration for overtime, job rotation, vacation, holidays, sick time, etc. For the risk calculation, the individual occupancy level should be converted to a fractional occupancy by dividing the person's average total hours worked per week by 168 (24 hours/day x 7 days /week, which represents one full-time equivalent job). For example, it is determined that the most exposed occupant in a particular building is an operator who is controlling a process. The following facts are obtained. This person:

- Works a nominal 40 hour/week shift
- Has three weeks of vacation/year
- Is out of the building being trained for one week every year
- Is cross-trained as an outside operator for two weeks every year
- Has 10 holidays off each year
- Is sick 2 days every year
- Works 208 hours of overtime every year

The average total hours worked by this person is 40(52) - 40(3) - 40(1) - 40(2) - 8(10) - 8(2) + 208 = 1952 hours. This equates to an average of 37.53 hours per week for the year. The fractional occupancy level for this person is 37.53/168 = 0.21.

The overall individual risk to the most exposed building occupant can now be calculated by adding up the individual risk associated with every congested area identified that can affect the building. The following example, which is based on the previous examples, illustrates the correct method to calculate the individual risk to the most exposed building occupant.

Example: Individual Risk Calculation

Congested Area	Vulnerability	VCE Frequency	Occupancy	Individual Risk, R_I
A1	1.00	4.3×10^{-4}	0.21	9.03×10^{-5}
B1	1.00	2.1×10^{-4}	0.21	4.41×10^{-5}
B2	1.00	2.1×10^{-4}	0.21	4.41×10^{-5}
C1	0.25	1.4×10^{-4}	0.21	7.35×10^{-6}
C2	0.00	1.4×10^{-4}	0.21	0.00
C3	0.19	1.4×10^{-4}	0.21	5.59×10^{-6}
TOTAL				1.91×10^{-4}

2. Population Risk

Population (also known as societal or aggregate) risk reflects the likelihood that an accident or event will affect more than one person. The same formula which was used to calculate individual risk applies: RISK $(R)_P$ = (Vulnerability)(Frequency of VCE)(Occupancy), where "P" means "population". The building occupant vulnerability and the VCE frequency terms do not change, but the occupancy term of the equation is different.

In order to calculate population risk, the total average building population must be calculated. This was done previously in section II.H on a hours-per-week basis. For the risk calculation, the total population occupancy level should be converted to a full-time equivalent occupancy by adding up the hours spent by ALL persons in the particular building and then dividing by 168 (24 hours/day x 7 days/week, again one full-time equivalent job). For example, the following information has been supplied relative to a particular building:

- 3 board operators spend 168 hours/week in the building = 504 hours
- 2 shift supervisors spend 135 hours/week in the building = 270 hours
- 3 outside operators spend 72 hours/week in the building = 216 hours
- The operations supt. spends 10 hours/week in the building = 10 hours
- The training coordinator spends 36 hours/week in the building = 36 hours
- The OE and the ME spend 10/hours/week in the building = 20 hours
- The maint. supervisor spends 5 hours/week in the building = 5 hours

The total occupancy for this building is 1061 hours/week. This number is multiplied by 1.05 to account for visitors, janitors, delivery personnel, etc. to yield an occupancy of 1114 hours/week. Dividing by 168 produces an average building occupancy of 6.63 employees.

The population risk can now be calculated by adding up the population risk associated with every congested area identified that can affect the building. The following example, which is based on the previous examples, illustrates the correct method to calculate the population risk for a building.

Example: Population Risk Calculation

Congested Area	Vulnerability	VCE Frequency	Occupancy	Population Risk, R_P
A1	1.00	4.3×10^{-4}	6.63	2.85×10^{-3}
B1	1.00	2.1×10^{-4}	6.63	1.39×10^{-3}
B2	1.00	2.1×10^{-4}	6.63	1.39×10^{-3}
C1	0.25	1.4×10^{-4}	6.63	2.32×10^{-4}
C2	0.00	1.4×10^{-4}	6.63	0.00
C3	0.19	1.4×10^{-4}	6.63	1.76×10^{-4}
TOTAL				6.04×10^{-3}

E. Qualitative Risk Assessment

Once the individual and population risks associated with a particular building have been calculated, they can be compared to other relevant risk level information.

If the individual risk associated with a particular building is favorable, the population (or aggregate) risk will be assessed. If either of these evaluations indicates that the risk is not favorable, then further action is required. Section V of this Workbook, Risk Reduction Analysis, discusses some potential options.

1. Individual Risk

Individual risk guidelines for occupied buildings associated with Amoco refineries have been developed by examining criteria that have been proposed, presented, or used by various agencies, other companies, and/or trade association publications when addressing the safety of workers. The Facility Siting Reference Manual should be consulted if specific background information is required. The individual risk guidelines are graphically represented in Figure 11, and are discussed as follows:

Zone 1 - Risk is higher than acceptable limits. Further action is required for buildings in this zone. Any building that has a calculated individual risk above 5×10^{-4} falls into this zone. The risk level adopted by Amoco is half the level typically adopted or proposed by various agencies (1×10^{-3}) as a tolerable risk level for modern industrial societies. Section V of this Workbook, Risk Reduction Analysis, discusses some potential options to reduce the risk.

Zone 2 - Risk is acceptable. Opportunities to reduce risk may be appropriate for buildings in this zone. Buildings that have a calculated individual risk between 5×10^{-5} and 5×10^{-4} fall into this zone. The lower risk level boundary for this zone (which was selected as an order of magnitude below the zone 1 action level) is more than an order of magnitude lower than the maximum "tolerable" risk level defined by various agencies, and is below the average risk for all industry workers. Since there are many assumptions made during a building siting evaluation using this Workbook, it may be appropriate to identify and pursue risk reduction opportunities for buildings with a risk near the upper boundary of this zone.

Zone 3 - Risk is acceptable. No further action required. Any building that has a calculated individual risk below 5×10^{-5} falls into this zone.

Example: Individual Risk Evaluation

For the example building that has been used throughout this Workbook, the individual risk was calculated as 1.91×10^{-4} in Section IV.D.1. This places the building in the center of zone 2, which indicates that the risk is acceptable. Opportunities to reduce the risk may be appropriate, but it is likely that there will be other refinery buildings, which fall in the upper half of zone 2, that warrant risk reduction consideration before this building. Note that in accordance with the facility siting methodology, the population risk must also be evaluated for this building.

2. Population Risk

Since there is little published information on population risk for industrial workers, risk criteria was developed by Amoco. The basic premise is to generate a curve which reflects an aversion to events that result in a multitude of injuries and which also is consistent with the individual risk criteria established for occupied buildings. The base point for the population risk criteria curve (Figure 12) was established by calculating the population risk for an occupancy value of 1 and an individual risk of 5×10^{-4}. The rest of the population risk curve was then established by allowing the population risk to increase with the square root of the average occupancy. Three zones were created by establishing a second risk boundary one order of magnitude below the original. The Facility Siting Reference Manual should be consulted if specific background information is required.

The interpretation of the meaning of the population risk zones parallels the interpretation of the individual risk zones. Action is required for buildings with a population risk that falls into zone 1, and section V of this Workbook discusses some possible options available to management. The risk is acceptable for buildings which have a population risk that falls into zone 2, and risk reduction opportunities may be appropriate. No action is required for buildings with a population risk that falls into zone 3. Once all anticipated individual and population risk concerns have been resolved, the facility siting analysis should be concluded by completing a Building Analysis Checklist (Table 1) to ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

Example: Population Risk Evaluation

For the example building that has been used throughout this Workbook, the population risk was calculated as 6.04×10^{-3}. On Figure 12, the point that represents a risk of 6.04×10^{-3} and a population of 6.63 falls into upper region of zone 2. This indicates that the risk is acceptable, and that opportunities to reduce the risk may be appropriate. (see section V).

Table 10

Amoco PPS Refining Facility Siting

RISK SCREENING WORKSHEET

Building name: ____________________

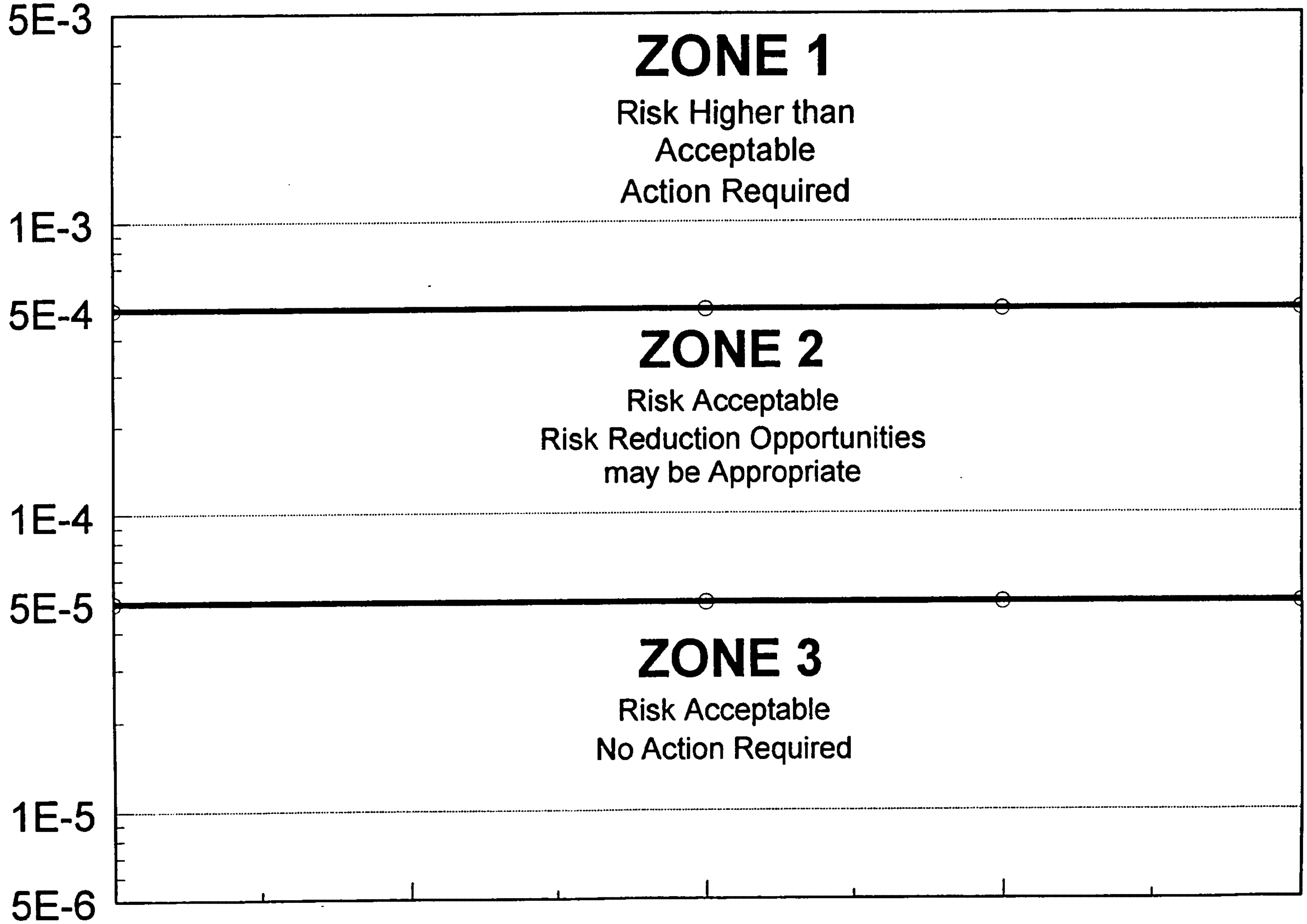
Analysis team: ____________ ____________ ____________

Unit/Congested Area #	Vulnerability (from Table 5, column 12)	VCE Frequency	Occupancy (Individual/Total Population)	Individual Risk	Population Risk
TOTAL RISK					

Figure 11

Amoco PPS Refining - Facility Siting

INDIVIDUAL RISK GUIDELINES

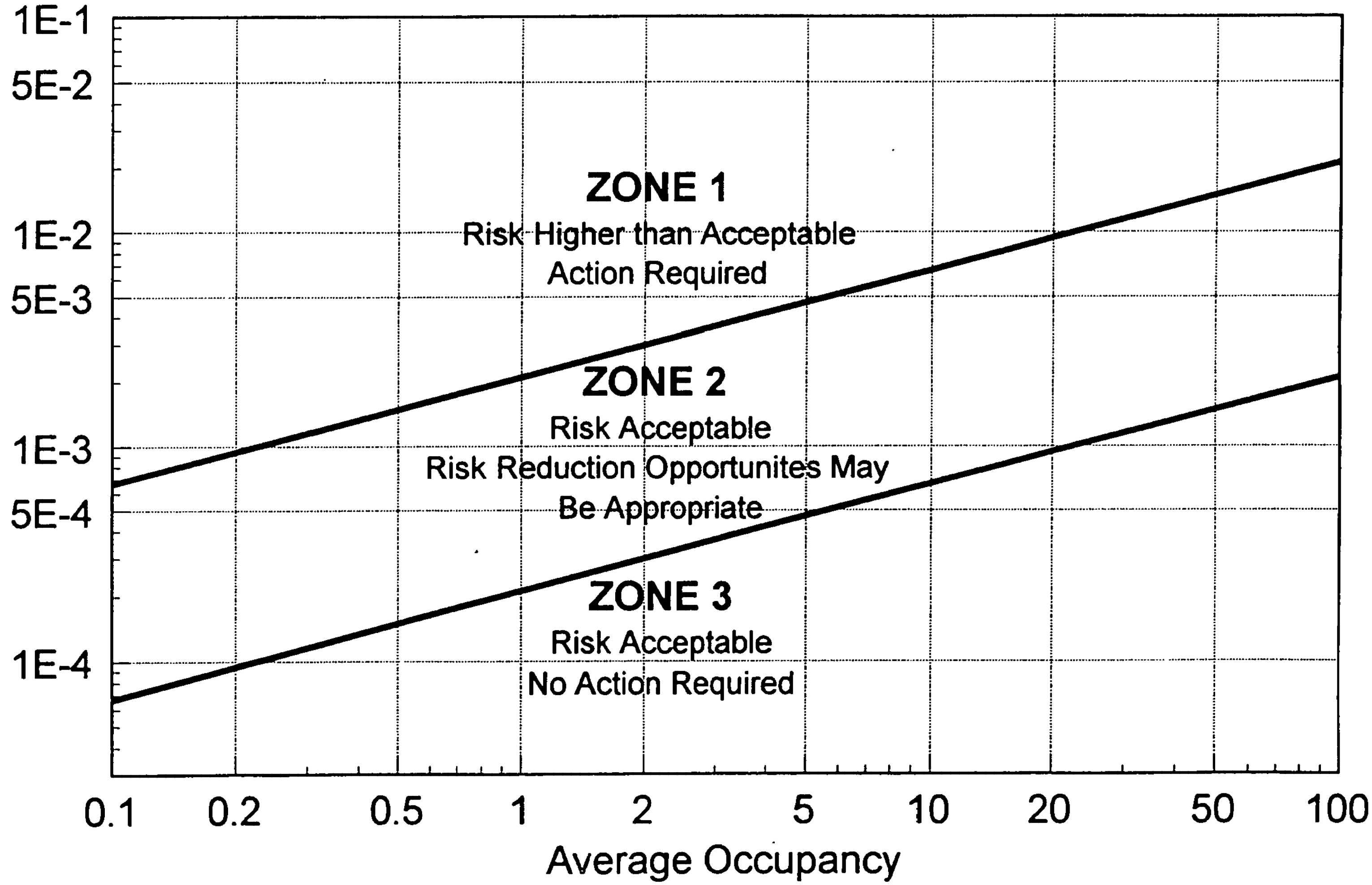


CONFIDENTIAL
BUSINESS INFORMATION

Figure 12

Amoco PPS Refining - Facility Siting

POPULATION RISK GUIDELINES



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V. RISK REDUCTION ANALYSIS

Any building for which individual or population risk has been identified as falling into zone 1 requires risk reduction analysis. Since many assumptions are made during a building siting analysis using this Workbook, consideration may also be given to identifying and pursuing risk reduction opportunities for buildings with an individual or population risk near the upper boundary of this zone.

A wide range of potential remedial measures may result from a risk reduction analysis. Some steps to consider when analyzing the risk to building occupants are outlined below.

A. Analytical Actions

The actions listed below are generally options that can be implemented quickly and expeditiously to address building occupant risk concerns. They therefore should be reviewed before considering the Engineering Actions listed in the following section (V.A.2).

1. Review Facility Siting Analysis Thoroughly

A study team should review the basis, details, and assumptions of the building's facility siting analysis before a complex engineering study or a costly building revamp project is initiated. Because the initial phases of the facility siting analysis are simple screening steps, it is appropriate to review the information used by the initial evaluation team. It may have been assumed, for example, that there was no reinforcement in the walls because drawings were not readily available. In this case, it may be prudent to obtain more information pertaining to the building structure, and determine if reinforcement exists in the walls. Occupancy data may have changed since the original study, so reviewing this information could prove useful as well.

2. Determine If Blast Source Volume Can Be Accumulated

A study team should review the blast source volume calculations (see section III.C.5) to discern if a credible release scenario exists that has the potential to create a vapor cloud large enough to fill the calculated blast source volumes. Consideration should be given to any existing remote detection devices/cameras, automatic isolation valves, shutdown interlocks, and water-spray systems when determining the potential for the blast source volume to be released and accumulated. If the calculated blast source volumes are adjusted, the reasoning should be clearly documented and the vulnerability and individual/population risks should be recalculated and reanalyzed.

3. Consider the Potential for Building Evacuation

A study team could review the likelihood that the building occupants may be evacuated before the building is affected by an event. Building evacuation procedures should clearly state that all occupants must evacuate immediately. If the study team is convinced that a leak can be detected and the building occupants evacuated prior to the occurrence of any VCE that could seriously damage the building, this should be clearly documented.

4. Perform Detailed Engineering Studies

A detailed engineering study could be initiated to review the facility siting evaluation to determine if an identified congested area can actually affect the building under concern. Some examples of where this type of study may make sense include: (1) the congested area is inside of another building (such as a pumphouse); (2) there is a barrier (another building, for example) between the congested area and the building under concern; or (3) a blast barrier exists to shield the building under concern. Performing detailed vapor cloud (and VCE) modelling, which takes into account the prevailing meteorological conditions, might indicate that one, or more, of the congested areas identified may not fully affect a building of concern, and thus reduce the risk.

In some cases, such as with buildings that have more than three stories or buildings that do not cleanly fit into one of the categories identified in this Workbook, it may be prudent to initiate a building structural analysis study to determine the actual building strength and blast response. If it is determined that the building can withstand the effect of all identified potential VCEs without suffering substantial structural damage, it may be concluded that no further action is required except to perform a review using the Building Analysis Checklist (Table 1).

5. Reduce Building Occupancy

One option that can be quickly implemented to reduce either individual or population risk is to adjust the building staffing level. A determination should be made if all personnel assigned to the building are absolutely required to be stationed in the building. Reducing occupancy has a proportional effort on the calculated risk. It should be noted that when employees are relocated to a different building, the population will increase in the new building; and the definition of the building's most exposed individual may change as well. Thus, the risk levels of all affected buildings should be reevaluated.

As stated earlier, buildings of similar construction which are located in the same area of the plant (e.g., a cluster of turnaround or office trailers), should be treated as one building for the purposes of the siting evaluation, even if these buildings are not physically connected. Moving personnel from one trailer to another nearby trailer will not affect the occupancy of this cluster of buildings.

6. Perform a Quantitative Risk Analysis

A quantitative risk analysis (QRA) can be performed to specifically calculate the individual and population risk to building occupants. A QRA can determine a range of specific improvements that can be made to the building or to the operating unit to help reduce the risk to building occupants.

7. Other Analysis Methods

Another option to be considered is hiring an outside consultant to apply their own facility siting methodology to a building under consideration. It is also possible that a consultant may chose to follow the basic facility siting philosophy presented in this Workbook, but modify some of the criteria presented based on their building evaluation experience.

A list of consultants that specialize in building evaluation can be obtained from the General Office Process Safety group.

B. Engineering Actions

If the individual and population risk associated with a particular building is still unfavorable after reviewing the Analytical Actions (section V.A.), then one or more of the following engineering actions to reduce risk should be considered. In general, a building design endpoint will have to be specified for these potential actions so that the risk reduction options can be evaluated. Someone familiar with VCE blast modeling methodologies will likely be required to analyze the building response to the potential pressure waves which can be created from VCEs, and help to establish the design endpoint. The Multi-Energy VCE blast modeling methodology, which is discussed at some length in the Facility Siting Reference Manual, was used to create the correlations presented in this Workbook.

1. Improve the Building Response to a VCE

A building can be modified in various ways to improve its ability to withstand overpressure waves from a VCE. The building can be strengthened. The roof of the building can be made to be self-supported. The walls of the building can be reinforced or the amount of reinforcement increased. Implementing these types of solutions will reduce the vulnerability of the building occupants.

2. Pressure Wave Reduction

The ability of a building to withstand the effect of a VCE without suffering substantial structural damage can be enhanced if the pressure wave is deflected or absorbed by another structure. There are several potential ways to accomplish this including: (1) erecting a building around an existing building; (2) creating a sloped earthen berm near the affected building wall(s); or (3) installing a blast wall to protect the building.

3. Relocation of the Building

This solution may be practical if the building is a trailer. For most buildings, this is not a solution that can be quickly implemented. It therefore should be considered after all other risk reduction methods have been reviewed.

Example: Risk Reduction

The population risk was found to be acceptable (section IV.E.2) for the example building which has been utilized throughout this Workbook, but it's location in the upper region of the zone suggested that risk reduction options may be appropriate. This analysis could produce the following options:

1. Reduce the building occupancy by relocating one of the unit board operators, one of the shift supervisors, and one of the outside operators to another building further away from the process area. Occupancy is reduced to 4.29 and the population risk is reduced to 3.91×10^{-3}.

2. Alternately, improve the building construction so that the walls do not support the roof. This allows use of the W4 curve in Figure 9 instead of the W3 curve. The population risk is reduced to 4.74×10^{-3}.

3. Implement both of the above options. The population risk is reduced to 3.07×10^{-3} which represents a point just above the midpoint in zone 2.

C. Management Review Option

It is recognized that in some cases it may be difficult to justify extensive modifications to a particular building even though it has a risk level of concern. In these instances, safety must not be compromised by a lack of proper review. These situations should be reviewed by the local Refinery Process Safety Committee (RPSC), and that group should determine if upgrading of the building is required to meet the intent of this Workbook. Factors to consider could include: (1) the requirements of this Workbook, (2) the previous VCE event occurrence experience for facilities of this type, (3) the current and expected operating conditions, (4) the anticipated duration of exposure, (5) the estimated cost involved and, (6) other appropriate considerations.

The details of the RPSC review should be documented and included in the facility siting analysis files.

Once all anticipated individual and population risk concerns have been resolved, the building facility siting analysis should be concluded by completing a Building Analysis Checklist (Table 1) to ensure that personal safety concerns from events that would not normally be expected to seriously affect the building integrity are properly addressed in the design and use of the building.

VI. FIRE CONCERNS

Fire exposes refinery buildings to radiant heat and to products of combustion. In general, these effects occur over a period of time. Emergency response planning and a properly designed building reduce the risk to building occupants by providing adequate egress time and routes. Amoco Engineering Specification 12C-4 discusses the minimum requirements for design and construction of new concrete block buildings, and many of these requirements are items on the Building Analysis Checklist (Table 1).

All buildings that have a routine presence of personnel, or that contain critical equipment which is expected to be accessed and operated during an emergency will be reviewed for compliance with the Building Analysis Checklist. The successful completion of the Checklist review will help to ensure that any fire-related safety concerns to building occupants are properly addressed in the emergency response planning effort and by the building design and use.

VII. TOXIC MATERIAL CONCERNS

Normally, toxic materials do not affect building integrity, but ingress of the toxic materials may occur and expose building occupants. Toxic exposure effects generally occur over a period of time, and remote detection devices and/or emergency response actions can reduce the risk to building occupants. A properly designed building that is covered by an appropriate emergency response plan can reduce the risk to building occupants from toxic releases. Amoco Engineering Specification 12C-4 discusses the minimum requirements for design and construction of new concrete block buildings. It includes some requirements to prevent toxic or flammable gas ingress into buildings. Amoco PPS - Refining Process Safety Guideline No. 24, "Securing a Building for a Major Toxic Gas Release," provides further guidance on this subject. Many of the requirements from these documents are items on the Building Analysis Checklist (Table 1).

All buildings that have a routine presence of personnel, or that contain critical equipment which is expected to be accessed and operated during an emergency, will be reviewed for compliance using the Checklist. The successful completion of the Checklist review will help to ensure that any toxic-related safety concerns to building occupants are properly addressed in the emergency response planning effort and by the building design and operation.