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IIT RESEARCH INSTITUTE
Technology Center
Chicago, Illinois 60616

IITRI Project No. J6114

Final Report

CASUALTY PREDICTION COMPARISONS

by

D. I. Feinstein

Contract No. OCD DAHC20-67-C-0167
Work Unit No. 1614-A

for

Office of Civil Defense
Office of the Secretary of the Army
Washington, D.C. 20310

OCD Review Notice

July 1968

FOREWORD

This is the final report on IIT Research Institute project J6114, entitled "Casualty Prediction Comparisons." This work reported was conducted for the Office of Civil Defense under Contract OCD DAHC20-67-C-0167, Work Unit 1614-A. Messrs. D. I. Feinstein and J. R. Wingfield were primary contributors to this report.

Respectfully submitted
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SUMMARY

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SUMMARY

CASUALTY PREDICTION COMPARISONS

This final report presents the results of utilizing a previously developed computer model, the SEP code[1] in order to examine the extent of casualty reduction which might be attributed to the occupant posture within a shelter. Five shelter configurations were considered:

(1) Wood Frame single story/two-story
(2) Load Bearing Wall three-story residential
(3) Seven-Story Brick Load Bearing Wall (warehouse)
(4) Six-Story Steel Frame Curtain Wall Commercial
(5) Unsheltered/Outside.

Two shelter occupant postures were considered; standing and prone. A 1 to 16 psi range of incident exterior overpressures was investigated for a 10 MT surface burst on each shelter type listed above and for each of the two postures. All casualty mechanisms were examined. However, only debris and blast translation were significant in the range of investigation for shelter configurations (1) through (4). In the case of unsheltered persons the only significant casualty mechanisms were thermal radiation and again blast translation.

The absence of initial nuclear radiation as a kill mechanism was due to the high weapon yield (i.e., 10 MT) and the overpressure range of interest (i.e. below 16 psi). Effects of the thermal pulse within the shelters were minimized in that the illumination area inside the shelter was insignificant in comparison to the total plan area and personnel were considered to be uniformly distributed over the entire shelter.

In order to obtain the necessary input data for the SEP code, data developed and documented by the Research Triangle

[1]Feinstein, D. I. and Heugel, W. F., Shelter Evaluation Program IIT Research Institute Project M6088, Contract No. OCD-PS-64-50, Work Unit 1614-A, Feb, 1967.

Institute were utilized. These data on shelter structural parameters were supplemented, where necessary, with averaging techniques and assumptions.

The results of this study are presented in the form of casualty curves. Each curve is set out separately by mortality and injury. There are five casualty curves associated with each of the shelter configurations:

(1) Total Effect Standing
(2) Total Effect Prone
(3) Translation Effect Standing
(4) Translation Effect Prone
(5) Debris (Thermal Radiation for Unsheltered).

It should be noted that the posture had little or no effect on any of the casualty mechanisms other than the blast translation. Although the total effect curves are for exterior wall failure pressure levels generally held for the specific materials involved, the individual debris effect curves are developed for failure pressures generally below these levels. This takes into account the uncertainty of exterior wall failure pressure levels.

The results indicate that the casualties are most influenced by the blast translation effect and that this effect is in turn subject to the occupant posture within the shelter. The results also indicate that the model for translation in a prone position needs to be further developed; when a person begins to move in this position, there is nothing to retard him other than his frictional resistance. The standing model, on the other hand, usually rotates into the ground and is not allowed to again start moving. Thus, at higher overpressure levels one presently gets the false result that the prone model is more critically affected than the standing model, even though the threshold values of casualty have the correct opposite result. Consequently, it is apparent that proper evasive action within the shelter decreases the number of casualties. Such evasive action would include the restraint of motion by posture and also by the number of occupants in a given shelter space. This latter action might be accomplished by overcrowding a part of the shelter during the blast phase.

Tables 1 and 2 contain a summary of mortality and injury results.

The following conclusions can be made based on this research program.

(1) The predominant casualty mechanisms within shelters are blast translation and debris effects at the study overpressure levels. Outside in unsheltered areas debris is replaced by thermal radiation.

(2) Changing position (i.e. posture) within a shelter or outside of it has little effect upon casualty mechanisms other than blast translation.

(3) The effect of changing posture has a marked effect upon the thresholds of mortality and injury for the translation mechanism. Assuming a prone posture results in reduction of both injuries and deaths.

(4) The translation model is seen to give erroneous results at overpressure levels where the prone posture has negative effectiveness in comparison to a standing posture.

(5) As seen by the outdoor case a change in posture can result in a different casualty mechanism being predominant in the same overpressure regime.

TABLE 1

SUMMARY OF MORTALITY RESULTS

Building Type	Effect	% Mortality 0	50
1 Wood frame Single-story/two-story		psi	psi
	Total standing	2.5	4.2
	Total prone	2.5	4.2
	Translation standing	3.0	8.8
	Translation prone	4.7	6.0 [8.8]**
	Debris	2.5 (2.0)*	4.2
2 Load bearing brick wall Three-story residential			
	Total standing	3.5	8.4
	Total prone	6.0	7.2 [8.4]
	Translation standing	3.5	10.2
	Translation prone	6.0	6.9 [10.2]
	Debris	7.0 (5.4)	12.0
3 Brick load bearing wall Seven-story warehouse			
	Total standing	4.0	9.2
	Total prone	7.0	9.0 [9.2]
	Translation standing	4.0	11.8
	Translation prone	8.0	9.3 [11.8]
	Debris	7.0 (4.0)	12.6
4 Steel frame curtain wall Six-story commercial			
	Total standing	2.0	7.3
	Total prone	4.4	5.2 [7.3]
	Translation standing	2.0	8.3
	Translation prone	4.4	5.1 [8.3]
	Debris	7.0 (6.0)	14.2
5 Outside			
	Total standing	1.0	-
	Total prone	2.0	-
	Translation standing	1.0	-
	Translation prone	3.5	-
	Thermal	2.0	-

*Number in parentheses indicates debris threshold values for low failure levels of outside walls.

**Number in brackets indicates that 50 percent casualty levels should never be taken lower for the prone posture than for the corresponding standing posture.

TABLE 2

SUMMARY OF INJURY RESULTS

Building Type	Effect % Injury	0	50
1 Wood frame Single-story/two-story		psi	psi
	Total standing	1.0	3.6
	Total prone	2.4	3.0 [3.6]**
	Translation standing	1.0	3.6
	Translation prone	4.0	4.9 [3.6]
	Debris	(1.5)*	-
2 Load bearing brick wall Three-story residential			
	Total standing	1.0	4.2
	Total prone	4.7	5.9 [4.2]
	Translation standing	1.0	4.2
	Translation prone	4.7	5.9 [4.2]
	Debris	(3.7)	-
3 Brick load bearing wall Seven-story warehouse			
	Total standing	2.0	5.0
	Total prone	6.0	9.0 [5.0]
	Translation standing	2.0	5.0
	Translation prone	6.0	9.0 [5.0]
	Debris	(4.0)	-
4 Steel frame curtain wall Six-story commercial			
	Total standing	1.0	7.3
	Total prone	3.5	4.5 [7.3]
	Translation standing	1.0	3.2
	Translation prone	3.5	4.5 [3.2]
	Debris	(6.0)	-
5 Outside			
	Total standing	1.0	3.0
	Total prone	2.0	3.75 [3.0]
	Translation standing	1.0	3.0
	Translation prone	3.4	4.6 [3.0]
	Thermal	2.0	-

*Number in parentheses indicates debris threshold values for low failure levels of outside walls.

**Number in brackets indicates that 50 percent casualty levels should never be taken lower for the prone posture than for the corresponding standing posture.

It is recommended that:

(1) People within the shelter be instructed to assume a prone position prior to bomb detonation or [illegible] flash.

(2) Refinements to the overall model, and in particular the translation submodel, be made in order to reflect the more detailed data available and the misleading translation results obtained.

(3) The scope of SEP code should be expanded to include below ground structures.

CASUALTY PREDICTION COMPARISONS

ABSTRACT

This study utilized a previously developed computer model, the Shelter Evaluation Program (SEP) code, to investigate the effectiveness of various shelter configurations and occupant postures with regard to resisting the direct effects of a 10 MT surface burst over a range of incident pressure levels. The shelter configurations include wood frame single-story and two-story, load bearing brick wall three-story residential, seven-story brick load bearing wall (warehouse), six-story steel frame curtain wall commercial, and no shelter outside cases. Shelter occupants were considered in two postures; standing and prone. Results indicate that there is a significant reduction in casualties when shelter occupants are in a prone state.

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ILLUSTRATIONS

ILLUSTRATIONS (Contd)

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SECTION I

INTRODUCTION

This final report presents the results of utilizing a previously developed computer model, the SEP code[1], in order to examine the extent of casualty reduction which might be attributed to the occupant posture within a shelter. Five shelter configurations were considered:

(1) Wood Frame single story/two-story
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(3) Seven-Story Brick Load Bearing Wall (warehouse)
(4) Six-Story Steel Frame Curtain Wall Commercial
(5) Unsheltered/Outside.

Two shelter occupant postures were considered; standing and prone. A 1 to 16 psi range of incident exterior overpressures was investigated for a 10 MT surface burst on each shelter type listed above and for each of the two postures. All casualty mechanisms were examined. However, only debris and blast translation were significant in the range of investigation for shelter configurations (1) through (4). In the case of unsheltered persons the only significant casualty mechanisms were thermal radiation and again blast translation.

The absence of initial nuclear radiation as a kill mechanism was due to the high weapon yield (i.e., 10 MT) and the overpressure range of interest (i.e., below 16 psi). Effects of the thermal pulse within the shelters were minimized in that the illumination area inside the shelter was insignificant in comparison to the total plan area and personnel were considered to be uniformly distributed over the entire shelter.

[1]Feinsteir, D. I. and Heugel, W. F., Shelter Evaluation Program IIT Research Institute Project M6088, Contract No. OCD-PS-64-50, Work Unit 1614-A, Feb. 1967.

In order to obtain the necessary input data for the SEP code, data developed and documented by the Research Triangle Institute were utilized. These data on shelter structural parameters were supplemented, where necessary, with averaging techniques and assumptions.

The results of this study are presented in the form of casualty curves Each curve is set out separately by mortality and injury. There are five casualty curves associated with each of the shelter configurations:

(1) Total Effect Standing
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(4) Translation Effect Prone
(5) Debris (Thermal Radiation for Unsheltered).

It should be noted that the posture had little or no effect on any of the casualty mechanisms other than the blast translation. Although the total effect curves are for exterior wall failure pressure levels generally held for the specific materials involved, the individual debris effect curves are developed for failure pressures generally below these levels. This takes into account the uncertainty of exterior wall failure pressure levels

The results indicate that the casualties are most influenced by the blast translation effect and that this effect is in turn subject to the occupant posture within the shelter The results also indicate that the model for translation in a prone position needs to be further developed; when a person begins to move in this position, there is nothing to retard him other than his frictional resistance. The standing model, on the other hand, usually rotates into the ground and is not allowed to again start moving Thus, at higher overpressure levels one presently gets the false result that the prone model is more critically affected than the standing model, even though the threshold values of casualty have the correct opposite result. Consequently, it is apparent that proper evasive action within the shelter decreases the number of casualties. Such evasive action would include the restraint of motion by posture and also by the number of occupants in a given shelter space. This latter action might be accomplished by overcrowding a part of the shelter during the blast phase.

The following sections present in more detail the data collection, and the results, conclusions and recommendations.

SECTION II

DATA PREPARATION

This section describes how the input data to the SEP code for the four building types and the outside case were developed It also documents these data and the underlying assumptions that were made during preparation The input data for the four building types were developed from existing buildings in Detroit, New Orleans and Providence These data were supplied by a recent study conducted by the Research Triangle Institute[2] Approximately 60 buildings were surveyed in each of five cities; that is, Providence, New Orleans, Detroit, Albuquerque and San Jose. The data for each building included:

(1) Number of stories
(2) Height of building
(3) Floor area
(4) Year of construction
(5) For each wall of the building
- Distance to adjacent building
- Substructure data
- Percent basement exposure
- Exterior wall data
- Percent apertures
- Bay size (for floors and wall)
- Foundation data
- Frame data
- Fireproofing details for steel frames
- Roof data (slope, deck and covering)
- Floor data (frame and deck)
- .nterior partitions data

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[2] Hill, E. L. et al, Structural Characteristics of NFSS Buildings, Research Triangle Institute Project No OU-237, Contract No. B-81883 (4949A-54)-US, Work Unit 1159C, June 1967.

The data collected on exterior walls, percent apertures, floors and interior partitions were reported separately for the basement, first story, and upper stories.

It is indeed fortunate to have such a fine source of data. However, the SEP code was developed with less stringent data requirements than the data which were available. This suggests that in some respects models in the SEP code could be upgraded in complexity to reflect the superior data now available. This would include investigating separate effects for the basement, first story and upper stories instead of the averaging presently done. It would follow that personnel should be assigned to the different parts of the buildings for similar reasons.

Tables 1 through 4 contain the SEP code data for each of the four buildings investigated in this study. Comments as to appropriate assumptions and averaging techniques are furnished. Ultimately, these are existing buildings and may be referenced further as the need arises in future research efforts. The data for the outside case were void of any building characteristics and assumed that debris and shielding were absent.

TABLE 1

CASE 1/SINGLE-STORY, TWO-STORY WOOD FRAME
RTI BUILDING NO. 8, PROVIDENCE DATA

1	Height	16 ft
2	Width	45 ft
3	Length	68 ft
4	Wall panel thickness	3 in. effective
5	Wall panel material	Timber studwall
6	Roof thickness	Assume 3 in.
7	Roof material	Plywood
8	Floor thickness	3 in.
9	Floor material	Plywood
10	Number of stories	Two
11	Basement wall thickness	10 in
12	Basement wall material	Concrete cast in place
13	Sill height above floor	Assume 2.5 ft
14	Distance from exterior wall to interior wall	Assume 12 ft
15	Inner wall length	Assume 12 ft
16	Percent window opening	11

COMMENTS

a. The width and length are idealized dimensions obtained from the reported plan area of the first floor.

b. The reported wall panel thickness was 7 in. which was reduced to an effective thickness comprised of material only. Roof and floors were unchanged since the reported numbers most likely did not include any dead space or voids. The 3 in. reported in both cases is very close to our experience in computing roof and floor thickness for similarly constructed buildings.

TABLE 2

CASE 2/LOAD BEARING WALLS, THREE-STORY RESIDENTIAL
RTI BUILDING NO. 9, DETROIT DATA

1	Height	30 ft
2	Width	52 ft
3	Length	90 ft
4	Wall panel thickness	13 in.
5	Wall panel material	N/R brick
6	Roof thickness	2 in.
7	Roof material	Wood plank
8	Floor thickness	2 in.
9	Floor material	Wood plank
10	Number of stories	Three
11	Basement wall thickness	18 in.
12	Basement wall material	N/R brick
13	Sill height above floor	Assume 2.5 ft
14	Distance from exterior wall to interior wall	12 ft
15	Inner wall length	12 ft
16	Percent window opening	15

TABLE 3

CASE 3/MULTISTORY LOAD BEARING BRICK, WAREHOUSE
RTI BUILDING NO. 29, PROVIDENCE DATA

1	Height	80 ft
2	Width	84 ft
3	Length	115 ft
4	Wall panel thickness	24 in.
5	Wall panel material	N/R brick
6	Roof thickness	2 in.
7	Roof material	Wood plank
8	Floor thickness	4 in.
9	Floor material	Wood plank
10	Number of stories	Seven
11	Basement wall thickness	24 in.
12	Basement wall material	N/R brick
13	Sill height above floor	2.5 ft
14	Distance from exterior wall to interior wall	40 ft
15	Inner wall length	100 ft
16	Percent window opening	10

TABLE 4

CASE 4/STEEL FRAME CURTAIN WALL, COMMERCIAL
RTI BUILDING NO. 23, NEW ORLEANS DATA

1	Height	81 ft
2	Width	90 ft
3	Length	138 ft
4	Wall panel thickness	13 in.
5	Wall panel material	N/R brick
6	Roof thickness	4 in.
7	Roof material	Concrete cast in place
8	Floor thickness	5 in.
9	Floor material	Concrete cast in place
10	Number of stories	Six
11	Basement wall thickness	13 in.
12	Basement wall material	N/R brick
13	Sill height above floor	2.5 ft
14	Distance from exterior wall to interior wall	24 ft
15	Inner wall length	24 ft
16	Percent window opening	21

SECTION III

PRESENTATION OF RESULTS

Personnel in each of the five shelter categories were exposed to overpressures of from 1 to 16 psi The results are displayed in Fig 1 through 25 following Section IV. Each figure represents both injury and mortality for a 10 MT surface burst. With the exception of the no shelter category, all cases revealed that translation and debris casulaty mechanisms were the only significant effects in this overpressure range The outside case also resulted in significant translation but supplanted debris with thermal radiation as the other major mechanism. Tables 5 and 6 are a summary of casualty information from the figures

Perhaps the greatest significance of Table 5 is the effect of personnel posture upon the threshold mortality level due to the blast translation effect; ranging from 57 percent effect in the wood frame building to 120 percent in the seven-story brick building. By simply changing from a standing position to a prone one, a substantial saving of life is possible Also displayed in this table is an undesirable feature of the present translation model; that is, that at 50 percent mortality the standing to prone posture change seems to show negative effectivensss. This is due to the fact that the prone person slides rather than overturning and sliding as the standing person. With sliding, only friction acts to retard acceleration, whereas the standing person is assumed to stop motion by rotating into the ground. Thus, under the long duration loading of a 10 MT surface burst the higher velocity of the sliding model is to be expected and little importance, if any, should be attached to it at those overpressure levels where negative effectiveness is displayed. In Table 5 overpressure values for the 50 percent casualty levels should never be taken lower for the prone posture than for the standing posture.

It should also be noted that at lower overpressure levels debris effects predominate. In the figures which illustrate the total effect of all the casualty mechanisms, debris effects begin to act when wall failure pressure is reached. In showing individual effects the failure pressure of the walls was set sufficiently low to permit full development of the debris curve regardless of the wall strength. Therefore, if there is any disagreement in the chosen wall failure pressures for each building type, the additional debris effect may be seen at the lower overpressure levels shown for the individual effect.

The outdoor free-field case, exhibits how the major effect may change with posture. Translation predominates in the standing case here; however, when the posture is changed to prone, thermal radiation becomes primary.

It is also to be noted that there is a slight thermal radiation effect which begins to appear in the total effect curves at the 50 percent mortality range. This accounts for the total effect being lower than either the translation or debris effect for type 2, 3 and 4 buildings in Table 1.

TABLE 5

SUMMARY OF MORTALITY RESULTS

Building Type	Effect	% Mortality 0	50
1 Wood frame Single-story/two-story		psi	psi
	Total standing	2.5	4.2
	Total prone	2.5	4.2
	Translation standing	3.0	8.8
	Translation prone	4.7	6.0 [8.8]**
	Debris	2.5 (2.0)*	4.2
2 Load bearing brick wall Three-story residential			
	Total standing	3.5	8.4
	Total prone	6.0	7.2 [8.4]
	Translation standing	3.5	10.2
	Translation prone	6.0	6.9 [10.2]
	Debris	7.0 (5.4)	12.0
3 Brick load bearing wall Seven-story warehouse			
	Total standing	4.0	9.2
	Total prone	7.0	9.0 [9.2]
	Translation standing	4.0	11.8
	Translation prone	8.0	9.3 [11.8]
	Debris	7.0 (4.0)	12.6
4 Steel frame curtain wall Six-story commercial			
	Total standing	2.0	7.3
	Total prone	4.4	5.2 [7.3]
	Translation standing	2.0	8.3
	Translation prone	4.4	5.1 [8.3]
	Debris	7.0 (6.0)	14.2
5 Outside			
	Total standing	1.0	-
	Total prone	2.0	-
	Translation standing	1.0	-
	Translation prone	3.5	-
	Thermal	2.0	-

*Number in parentheses indicates debris threshold values for low failure levels of outside walls.

**Number in brackets indicates that 50 percent casualty levels should never be taken lower for the prone posture than for the corresponding standing posture.

TABLE 6

SUMMARY OF INJURY RESULTS

Building Type	Effect % Injury	0 psi	50 psi
1 Wood frame Single-story/two-story			
	Total standing	1.0	3.6
	Total prone	2.4	3.0 [3.6]**
	Translation standing	1.0	3.6
	Translation prone	4.0	4.9 [3.6]
	Debris	(1.5)*	-
2 Load bearing brick wall Three-story residential			
	Total standing	1.0	4.2
	Total prone	4.7	5.9 [4.2]
	Translation standing	1.0	4.2
	Translation prone	4.7	5.9 [4.2]
	Debris	(3.7)	-
3 Brick load bearing wall Seven-story warehouse			
	Total standing	2.0	5.0
	Total prone	6.0	9.0 [5.0]
	Translation standing	2.0	5.0
	Translation prone	6.0	9.0 [5.0]
	Debris	(4.0)	-
4 Steel frame curtain wall Six-story commercial			
	Total standing	1.0	7.3
	Total prone	3.5	4.5 [7.3]
	Translation standing	1.0	3.2
	Translation prone	3.5	4.5 [3.2]
	Debris	(6.0)	-
5 Outside			
	Total standing	1.0	3.0
	Total prone	2.0	3.75 [3.0]
	Translation standing	1.0	3.0
	Translation prone	3.4	4.6 [3.0]
	Thermal	2.0	-

*Number in parentheses indicates debris threshold values for low failure levels of outside walls.

**Number in brackets indicates that 50 percent casualty levels should never be taken lower for the prone posture than for the corresponding standing posture.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be made based on this research program.

(1) The predominant casualty mechanisms within shelters are blast translation and iebris effects at the study overpressu~e levels. Outside in unsheltered areas debris is replaced by thermal radiation.

(2) Changing position (i.e. posture) within a shelter or outside of it has little effect upon casualty mechanisms other than blast translation.

(3) The effect of changing posture has a marked effect upon the thresholds of mortality and injury for the translation mechanism. <u>Assuming a prone posture results in reduction of both injuries and deaths</u>.

(4) The translation model is seen to give erroneous results at overpressure levels where the prone posture has negative effectiveness in comparison to a standing posture.

(5) As seen by the outdoor case a change in posture can result in a different casualty mechanism being predominant in the same overpressure regime.

It is recommended that:

(1) People within the shelter be instructed to assume a prone position prior to bomb detonation or at flash.

(2) Refinements to the overall model, and in particular the translation submodel, be made in order to reflect the more detailed data available and the misleading translation results obtained.

(3) The scope of SEP code should be expanded to include below ground structures.

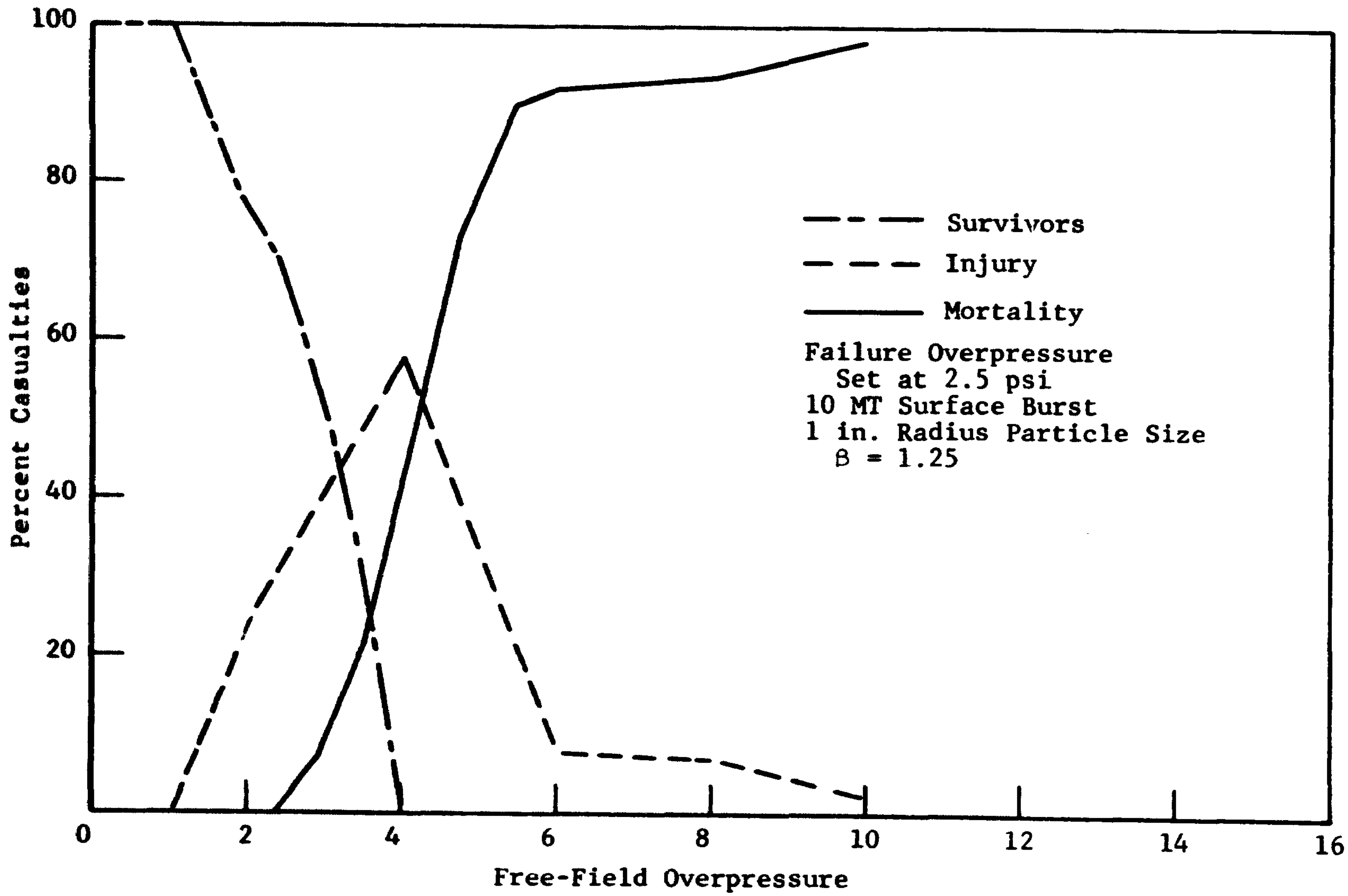

Fig. 1 CASE 1 WOOD TWO-STORY, TOTAL CASUALTIES, STANDING POSTURE

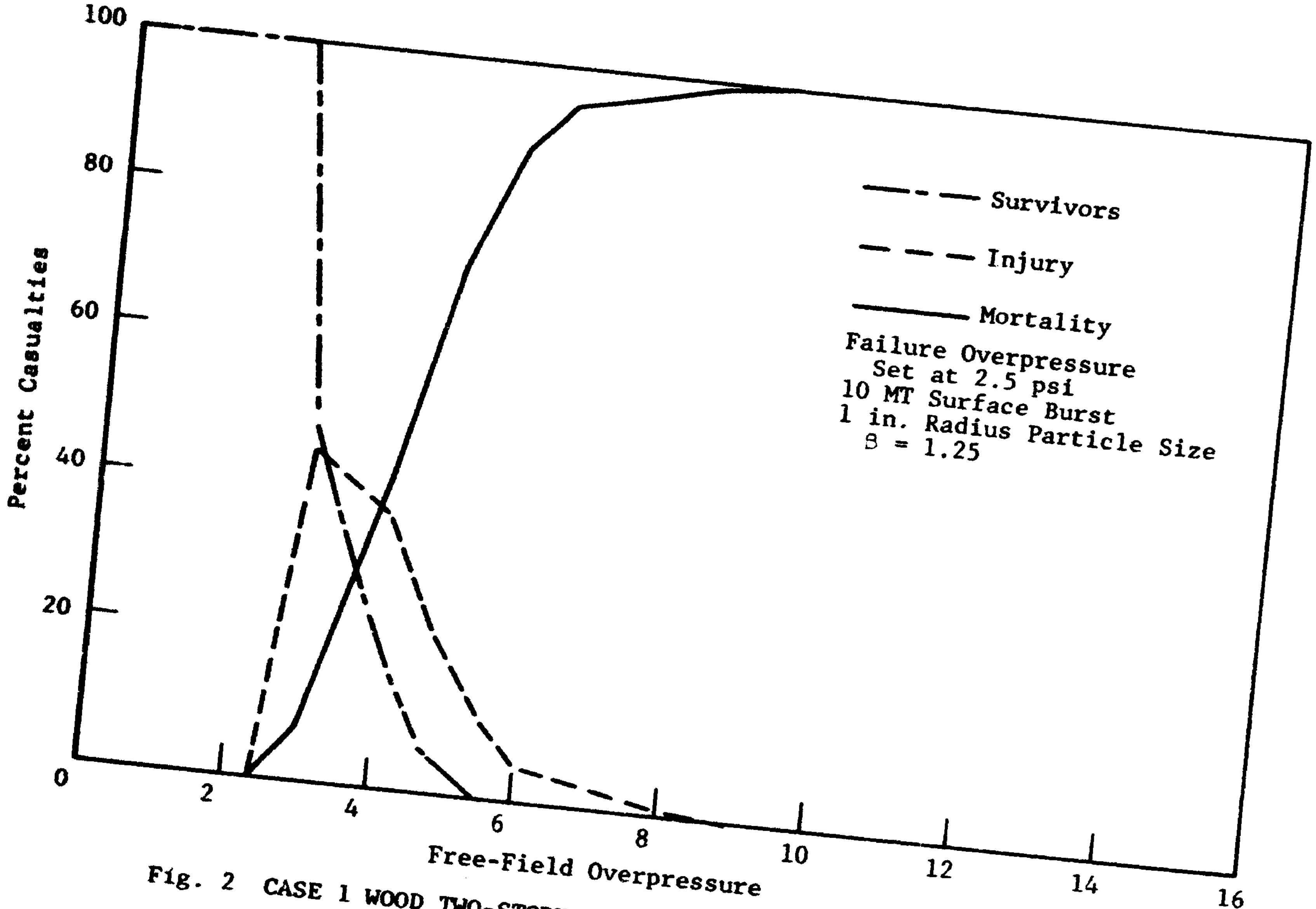

Fig. 2 CASE 1 WOOD TWO-STORY, TOTAL CASUALTIES, PRONE POSTURE

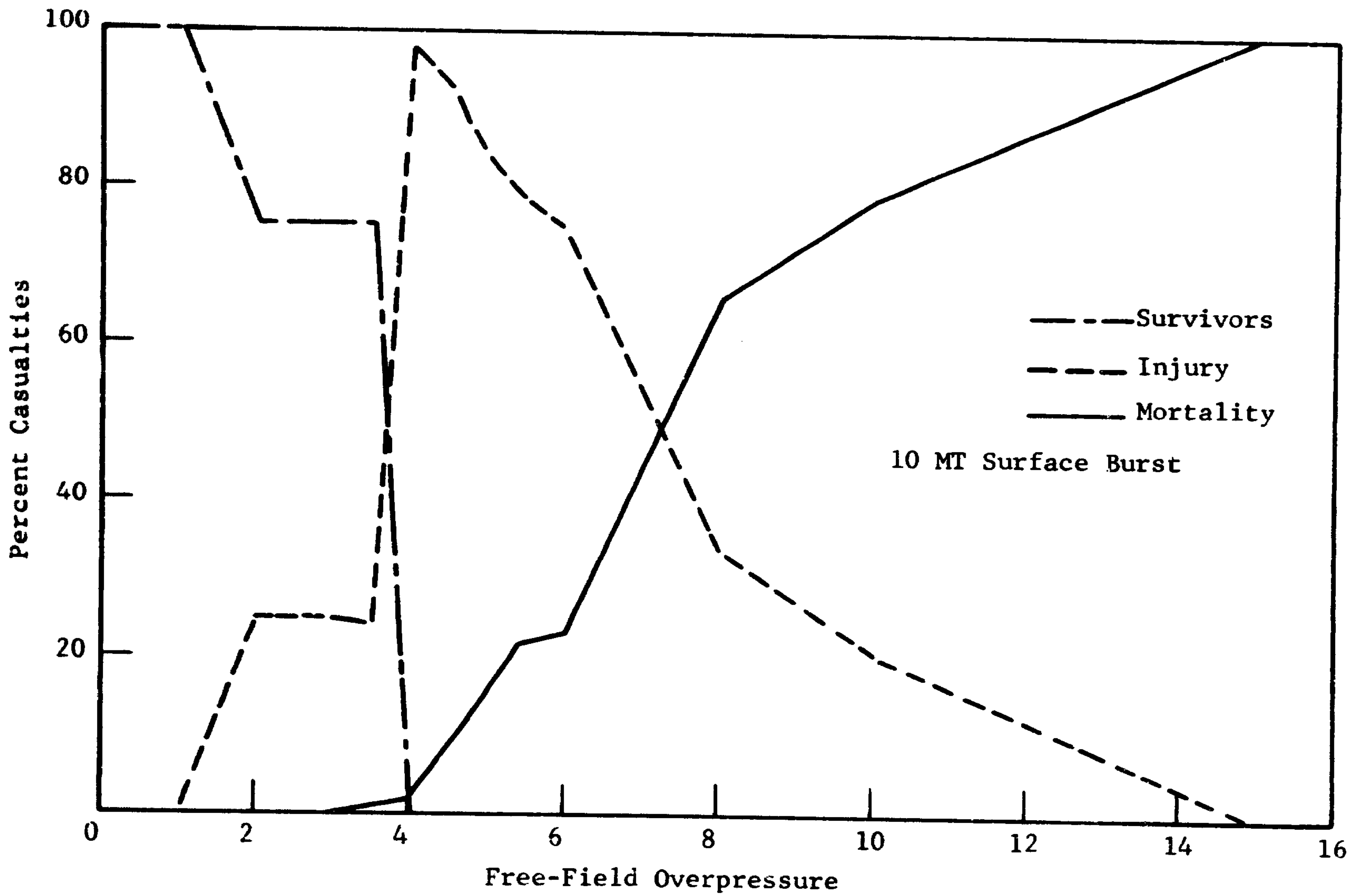

Fig. 3 CASE 1 WOOD TWO-STORY, TRANSLATION CASUALTIES, STANDING POSTURE

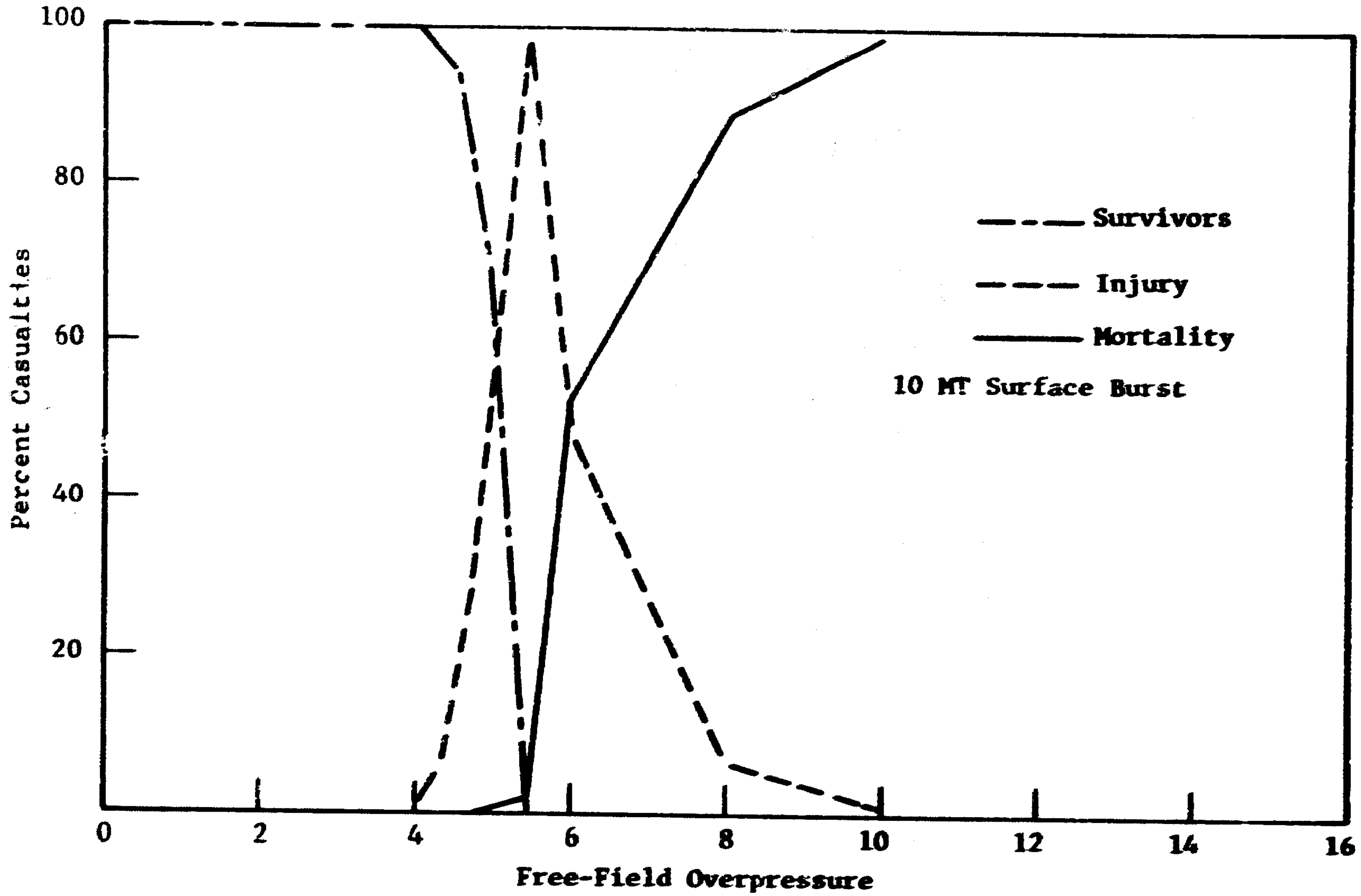

Fig. 4 CASE 1 WOOD TWO-STORY, TRANSLATION CASUALTIES, PRONE POSTURE

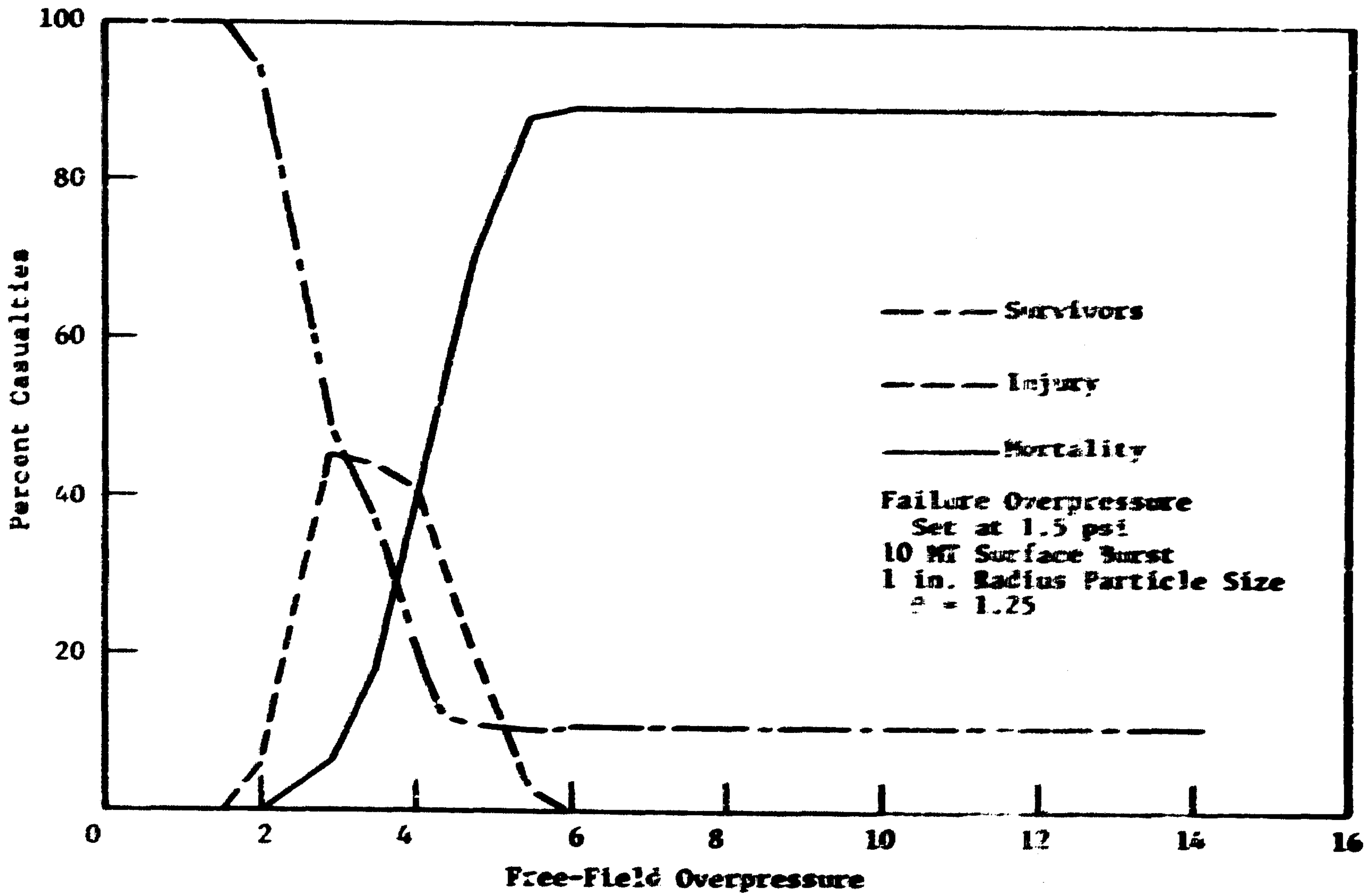

Fig. 5 CASE 1 WOOD TWO-STORY, DEBRIS CASUALTIES, STANDING AND PRONE POSTURE

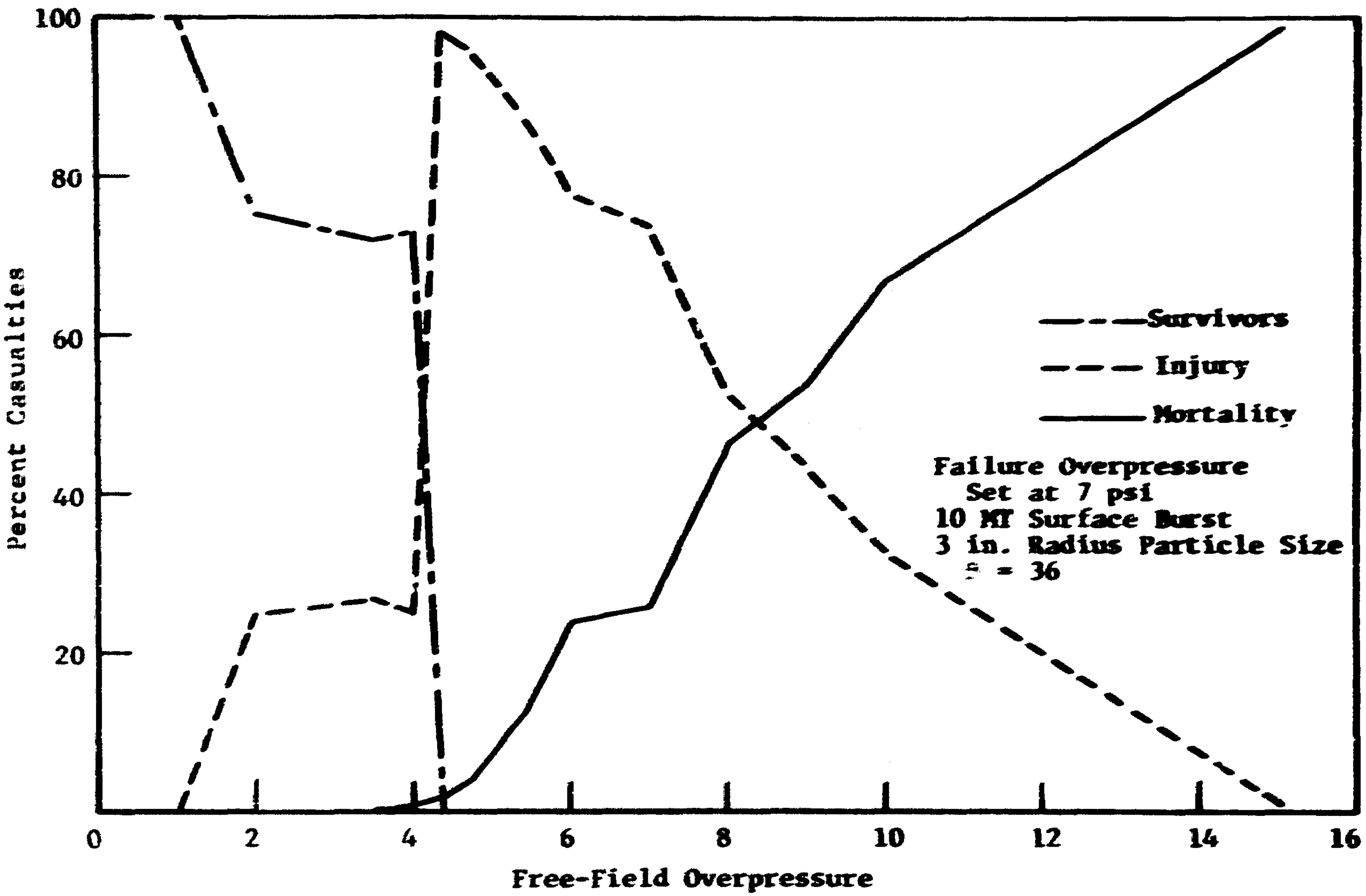

Fig. 6 CASE 2 THREE-STORY RESIDENTIAL, TOTAL CASUALTIES, STANDING POSTURE

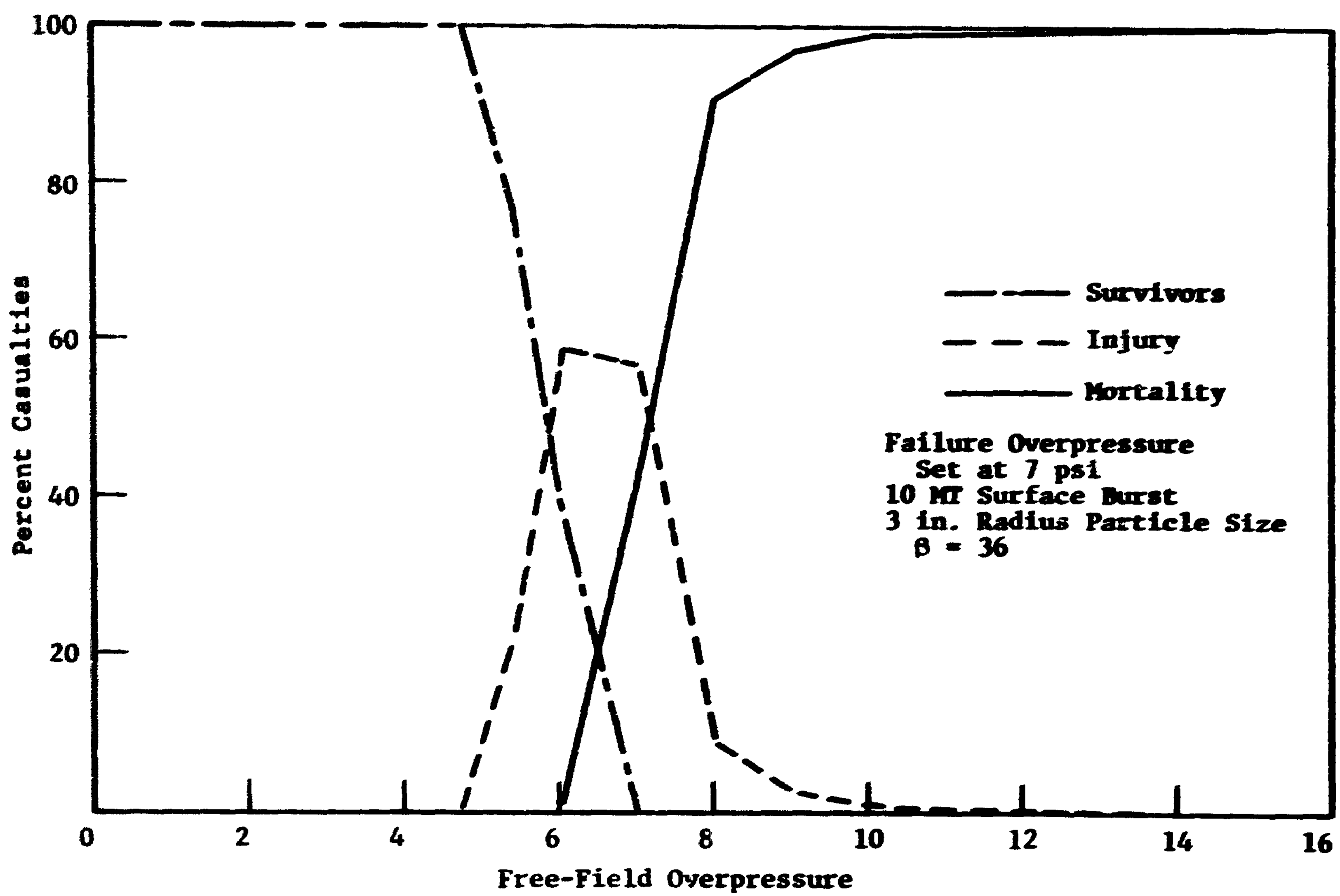

Fig. 7 CASE 2 THREE-STORY RESIDENTIAL, TOTAL CASUALTIES, PRONE POSTURE

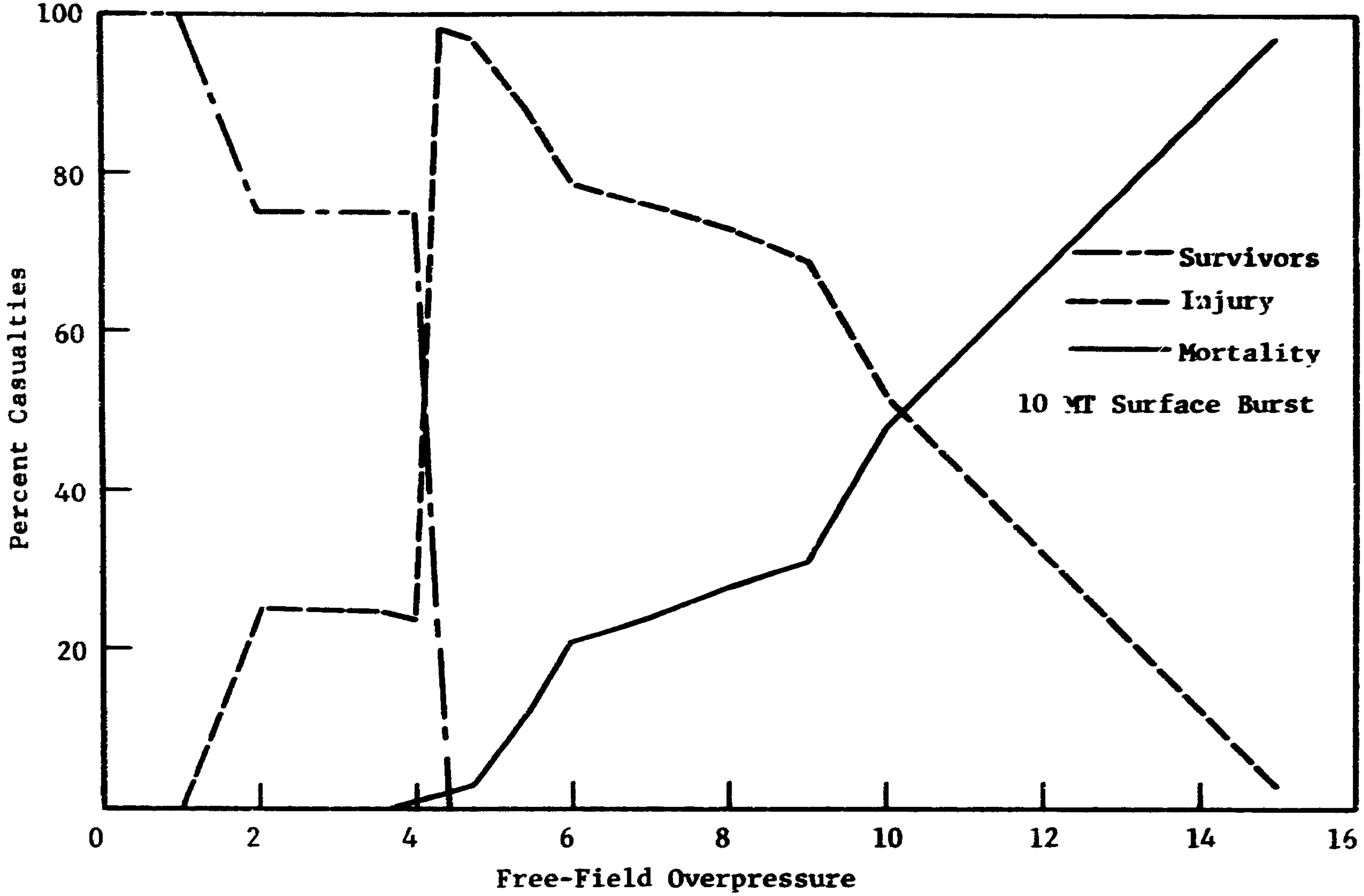

Fig. 8 CASE 2 THREE-STORY RESIDENTIAL, TRANSLATION CASUALTIES, STANDING POSTURE

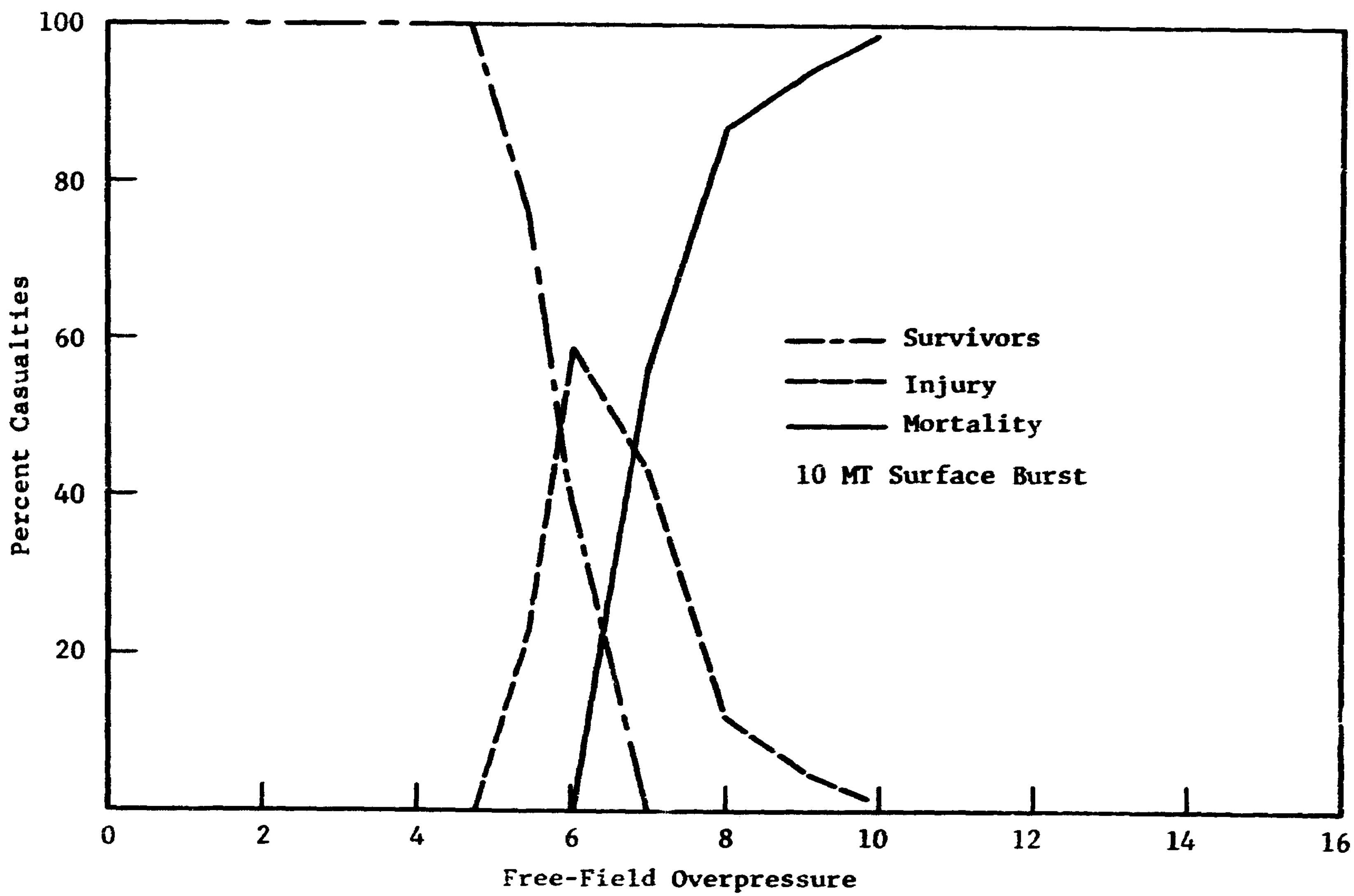

Fig. 9 CASE 2 THREE-STORY RESIDENTIAL, TRANSLATION CASUALTIES, PRONE POSTURE

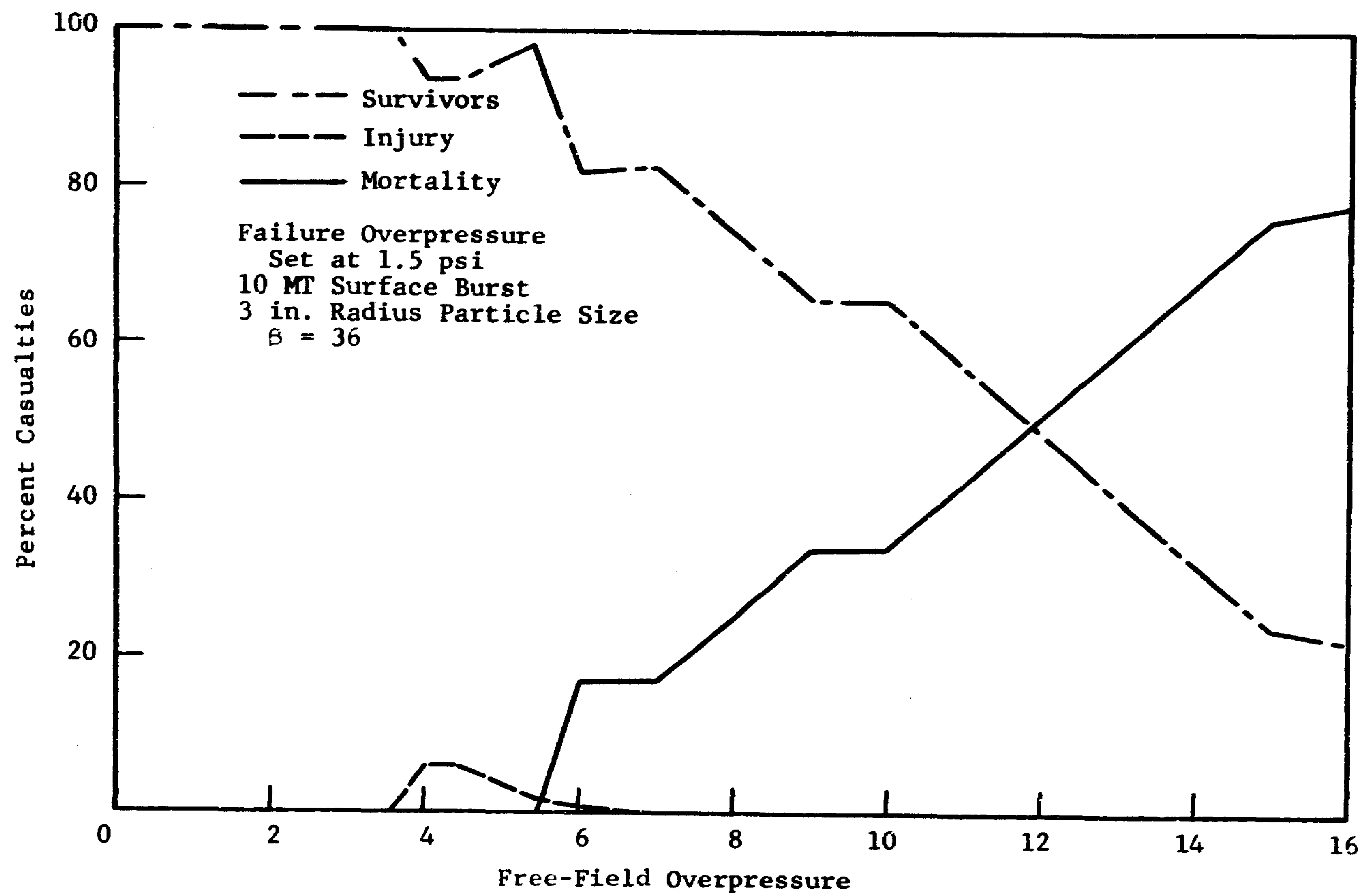

Fig. 10 CASE 2 THREE-STORY RESIDENTIAL, DEBRIS CASUALTIES, STANDING AND PRONE POSTURE

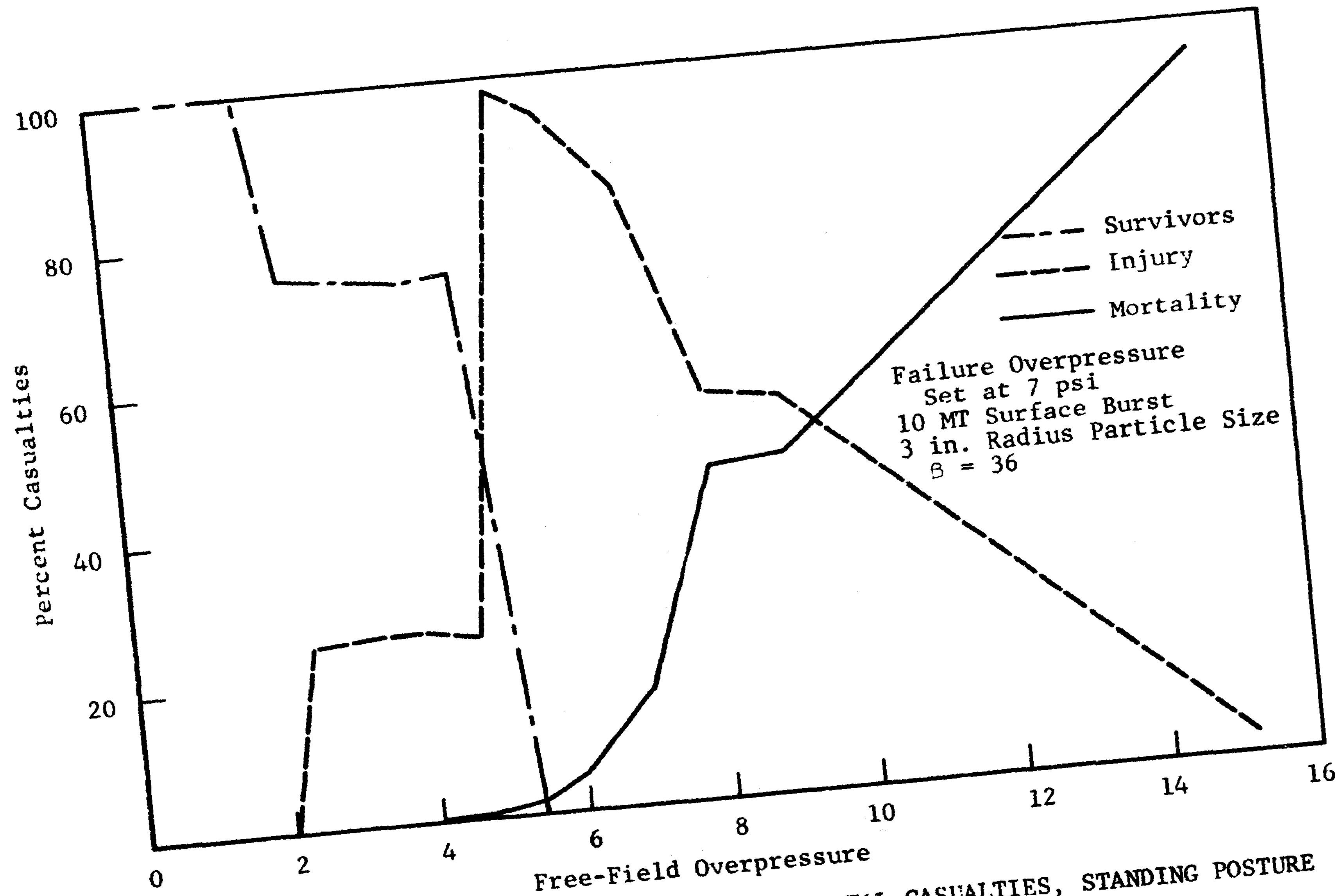

Fig. 11 CASE 3 SEVEN-STORY BRICK WAREHOUSE, TOTAL CASUALTIES, STANDING POSTURE

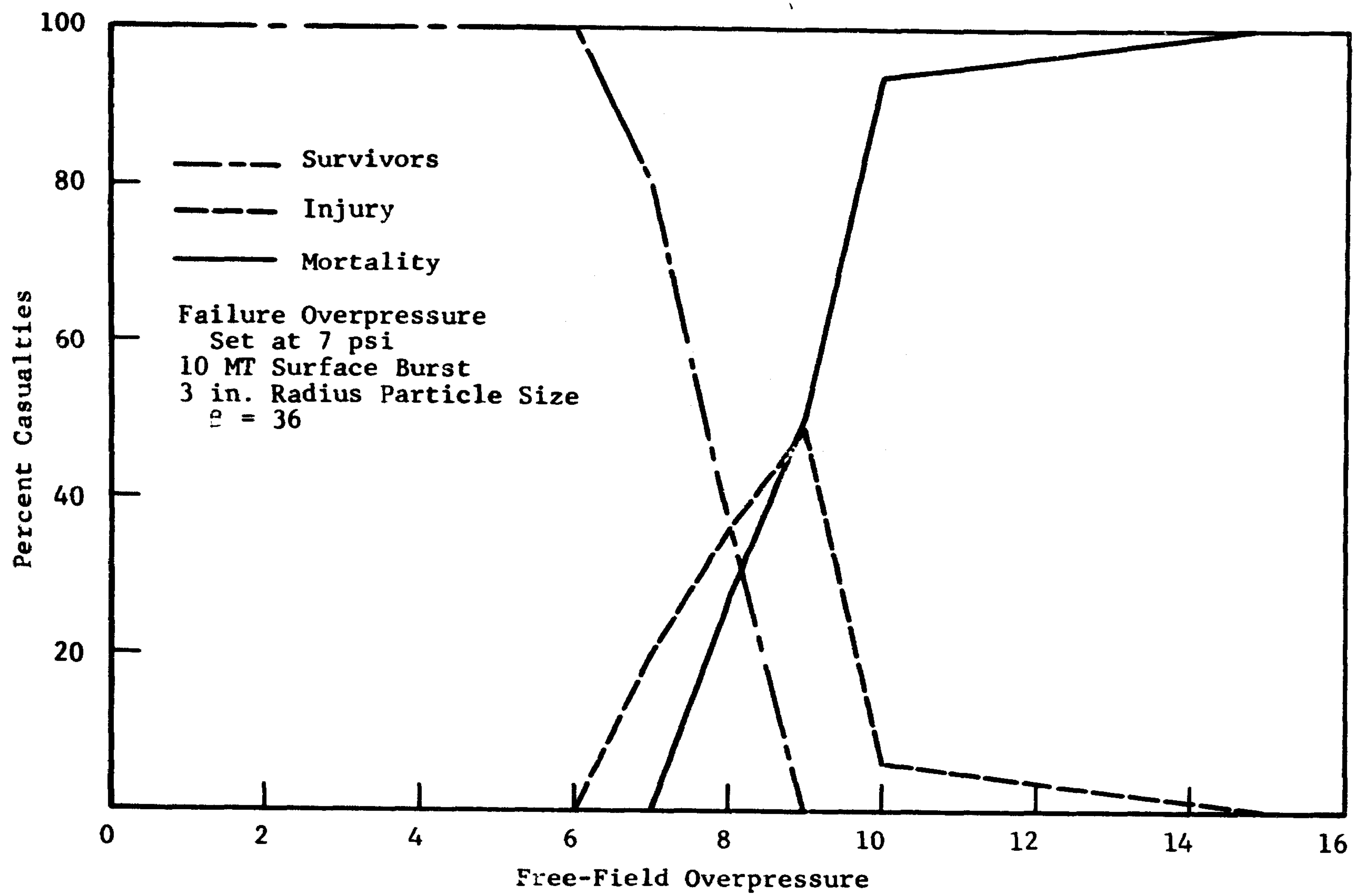

Fig. 12 CASE 3 SEVEN-STORY BRICK WAREHOUSE, TOTAL CASUALTIES, PRONE POSTURE

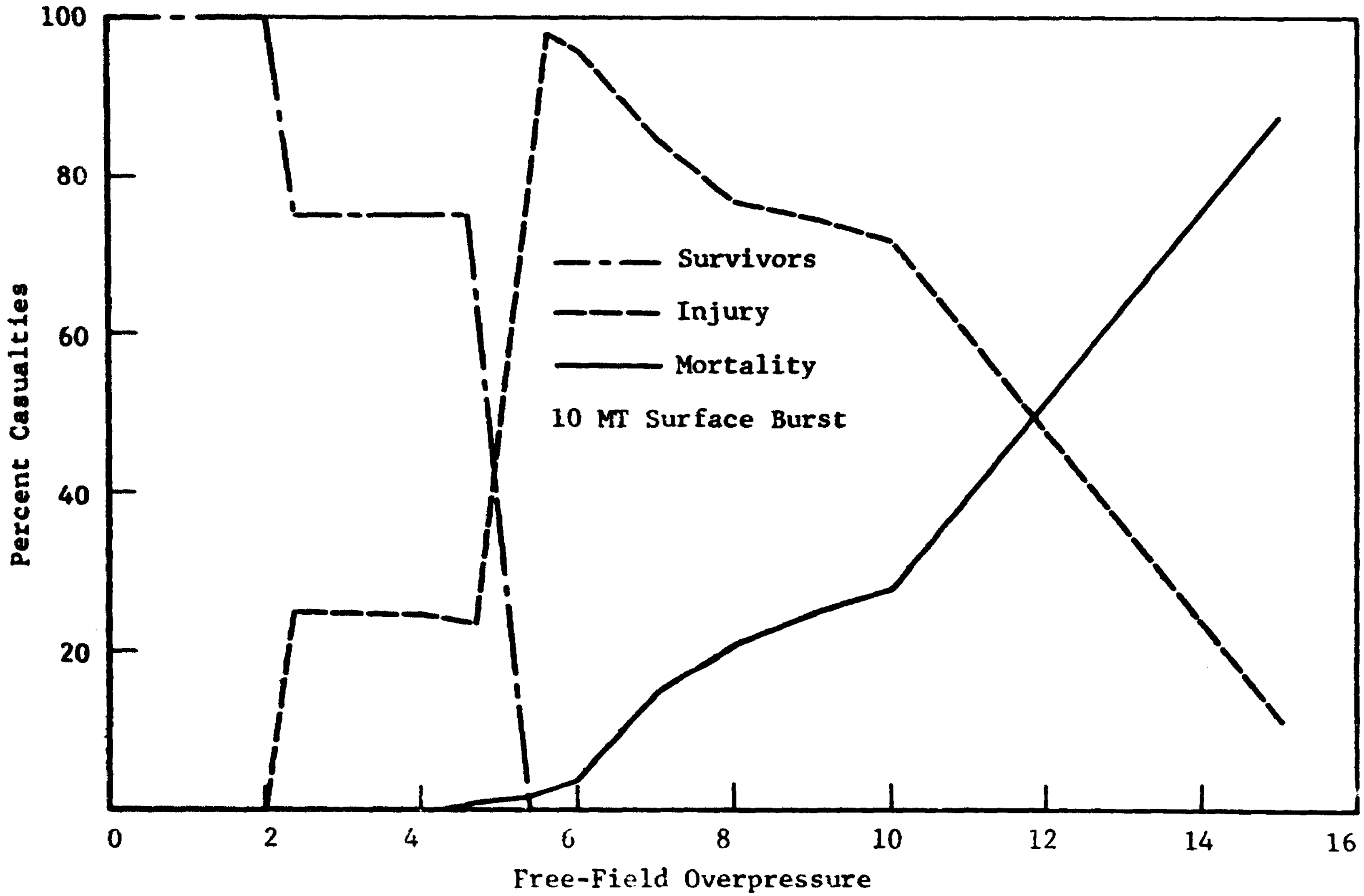

Fig. 13 CASE 3 SEVEN-STORY BRICK WAREHOUSE, TRANSLATION CASUALTIES, STANDING POSTURE

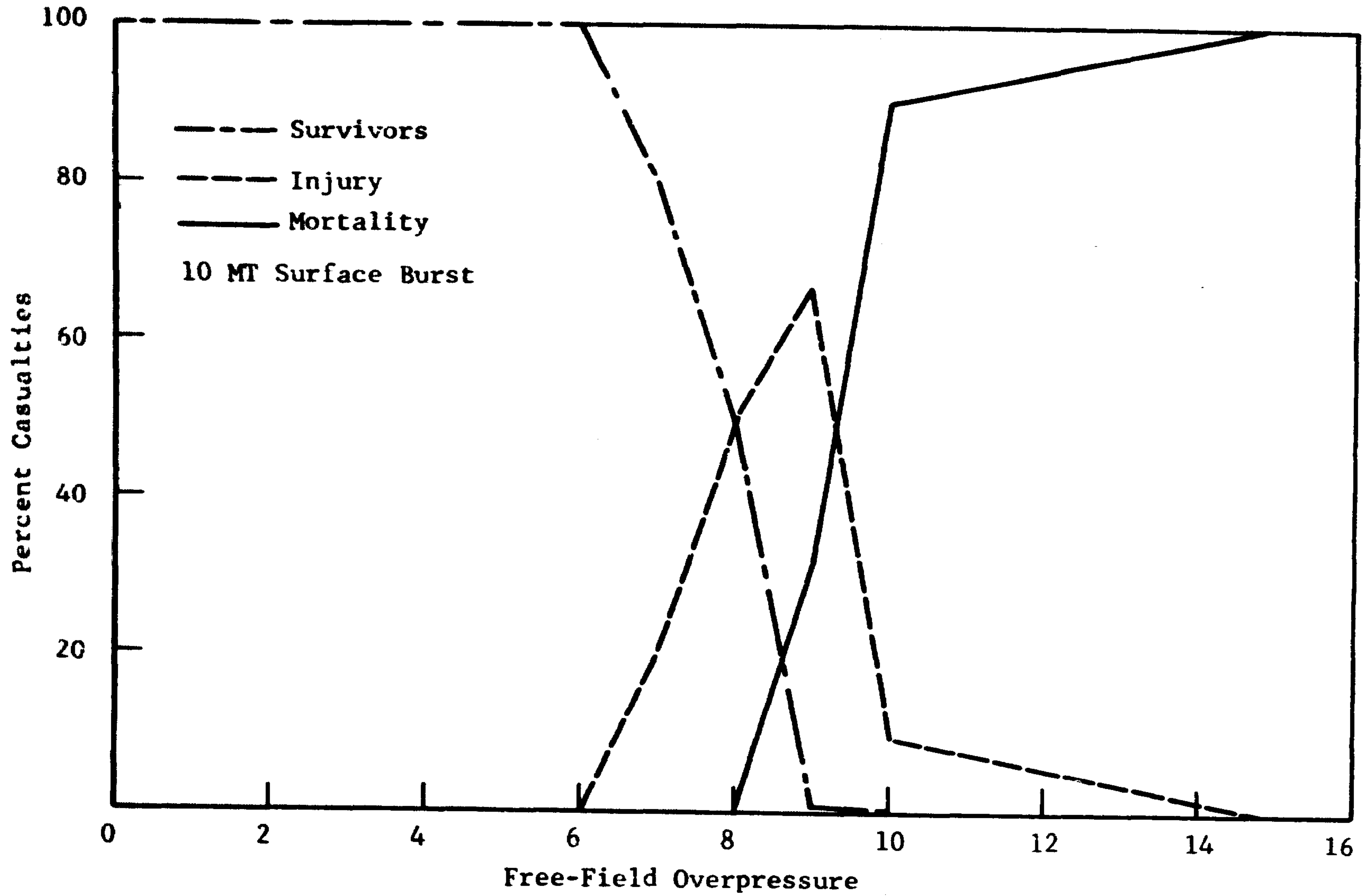

Fig. 14 CASE 3 SEVEN-STORY BRICK WAREHOUSE, TRANSLATION CASUALTIES, PRONE POSTURE

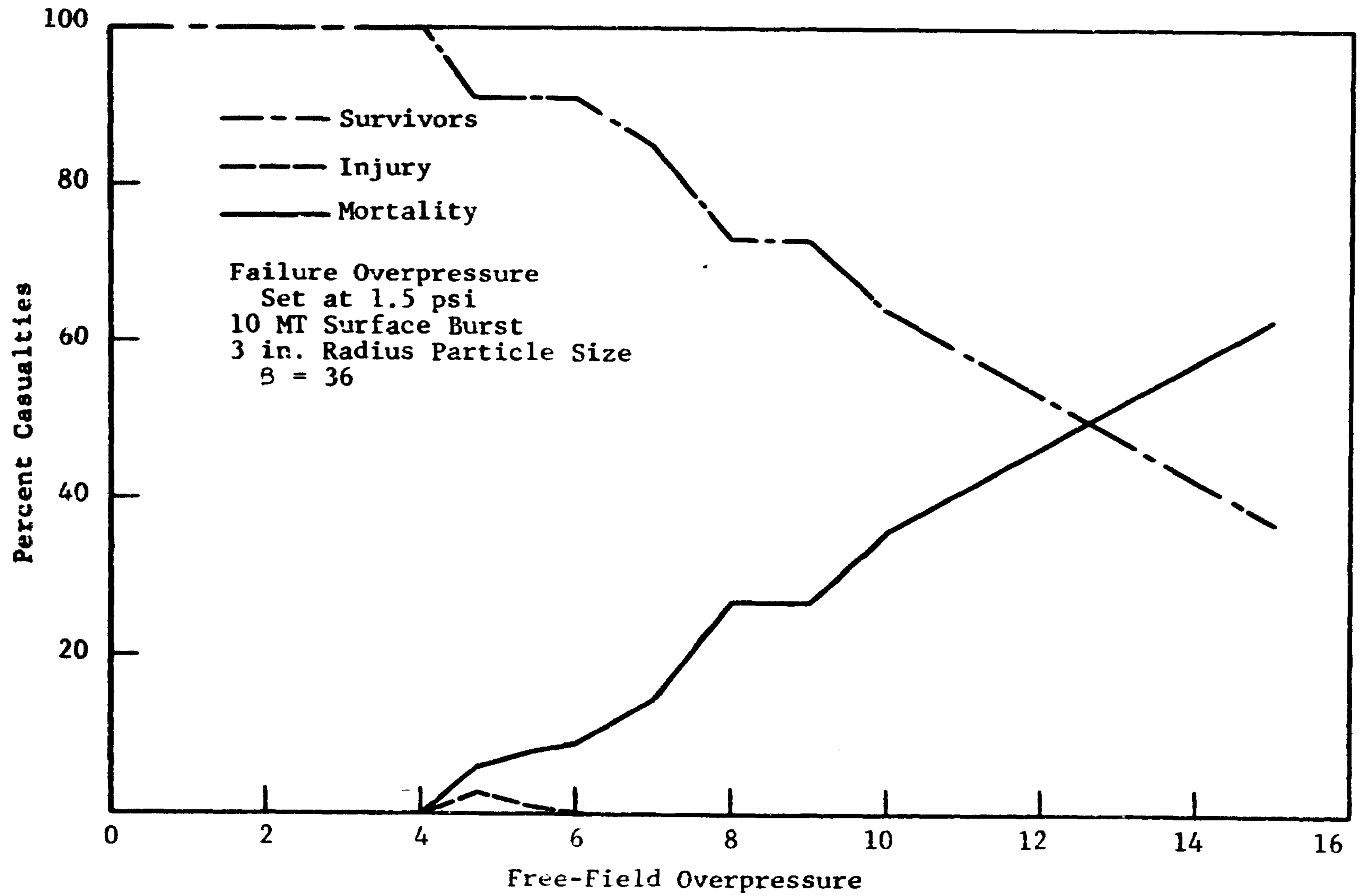

Fig. 15 CASE 3 SEVEN-STORY BRICK WAREHOUSE, DEBRIS CASUALTIES, STANDING AND PRONE POSTURE

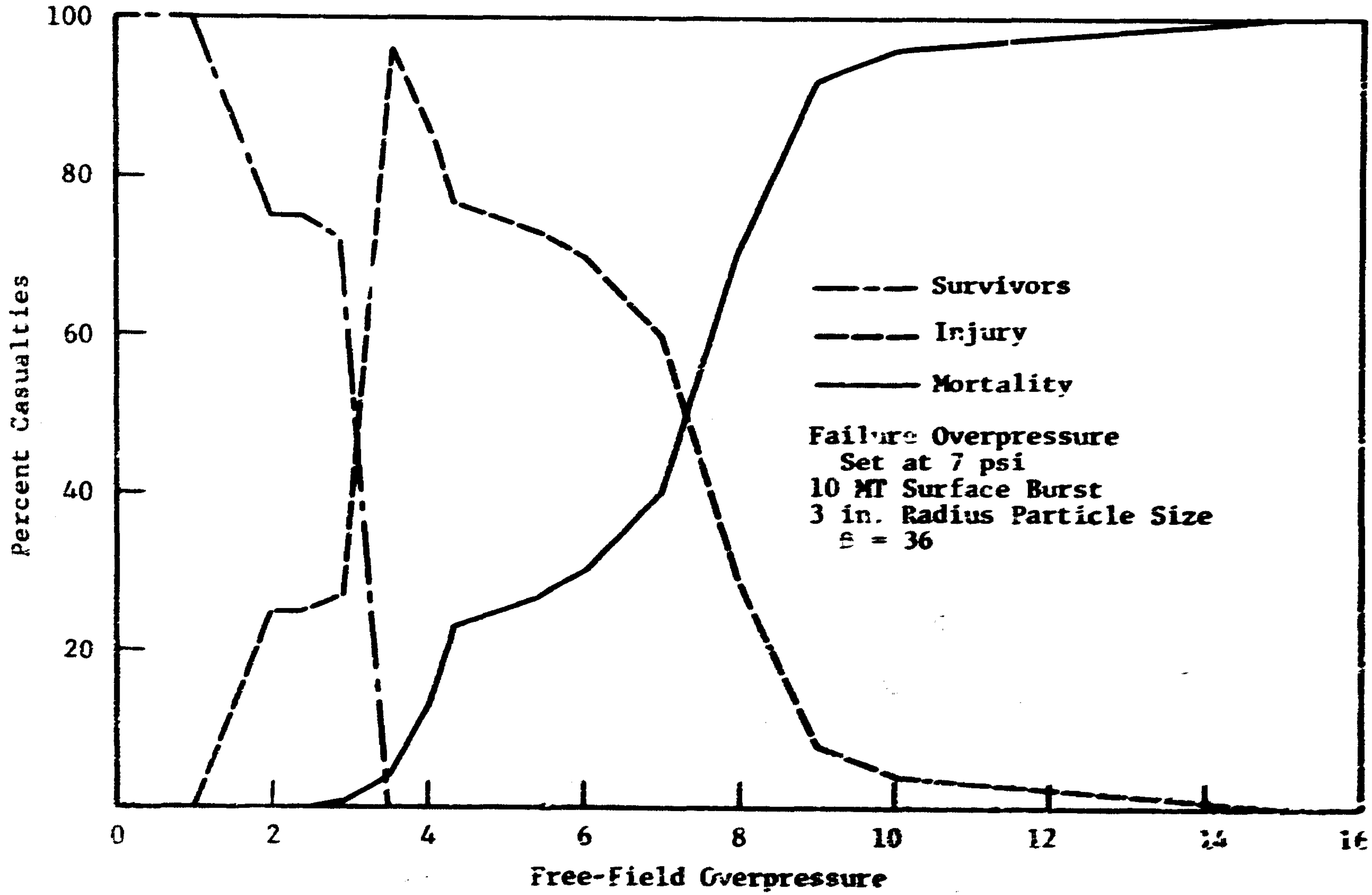

Fig. 16 CASE 4 SIX-STORY COMMERCIAL, TOTAL CASUALTIES, STANDING POSTURE

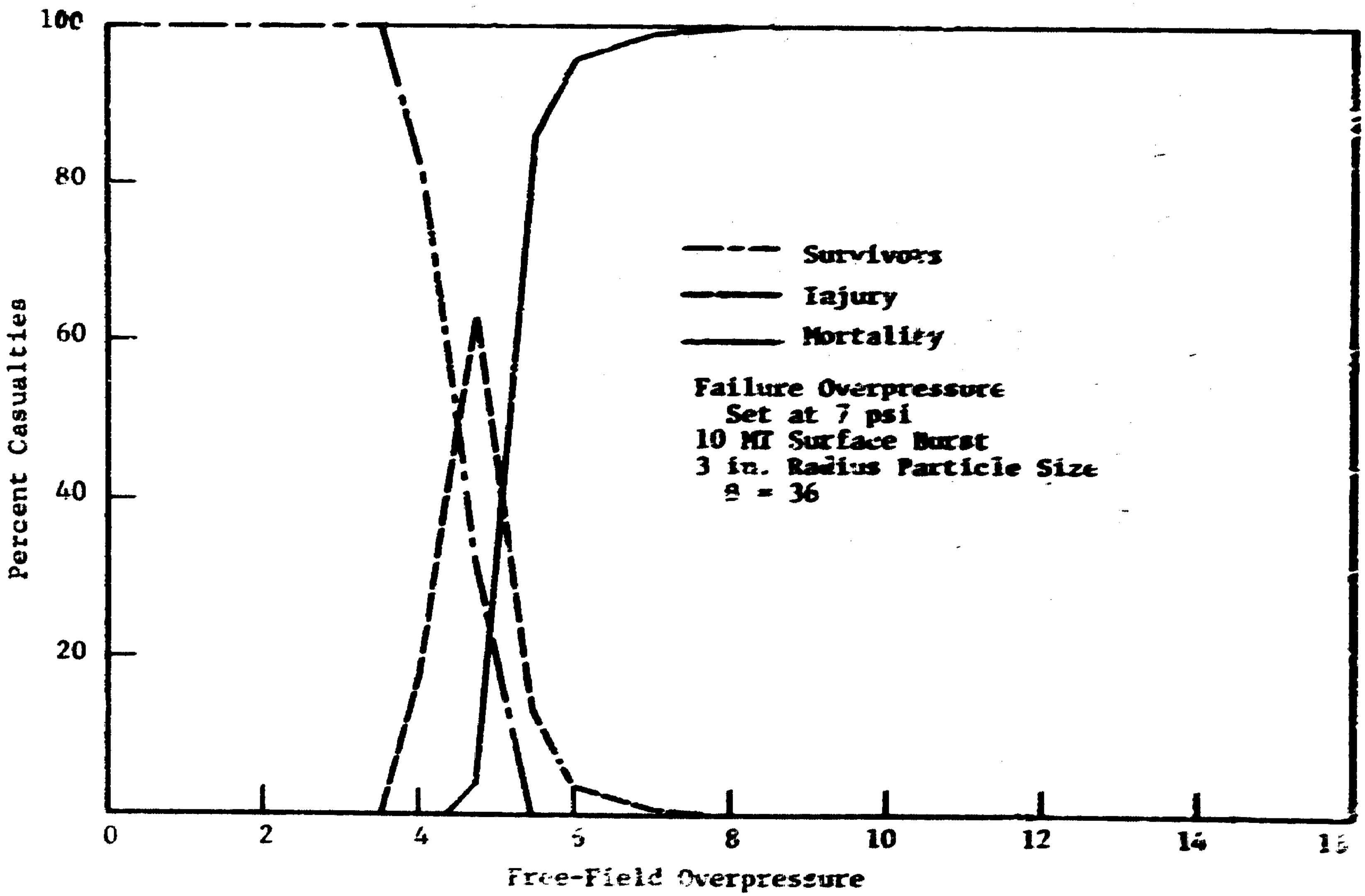

Fig. 17 CASE 4 SIX-STORY COMMERCIAL, TOTAL CASUALTIES, PRONE POSTURE

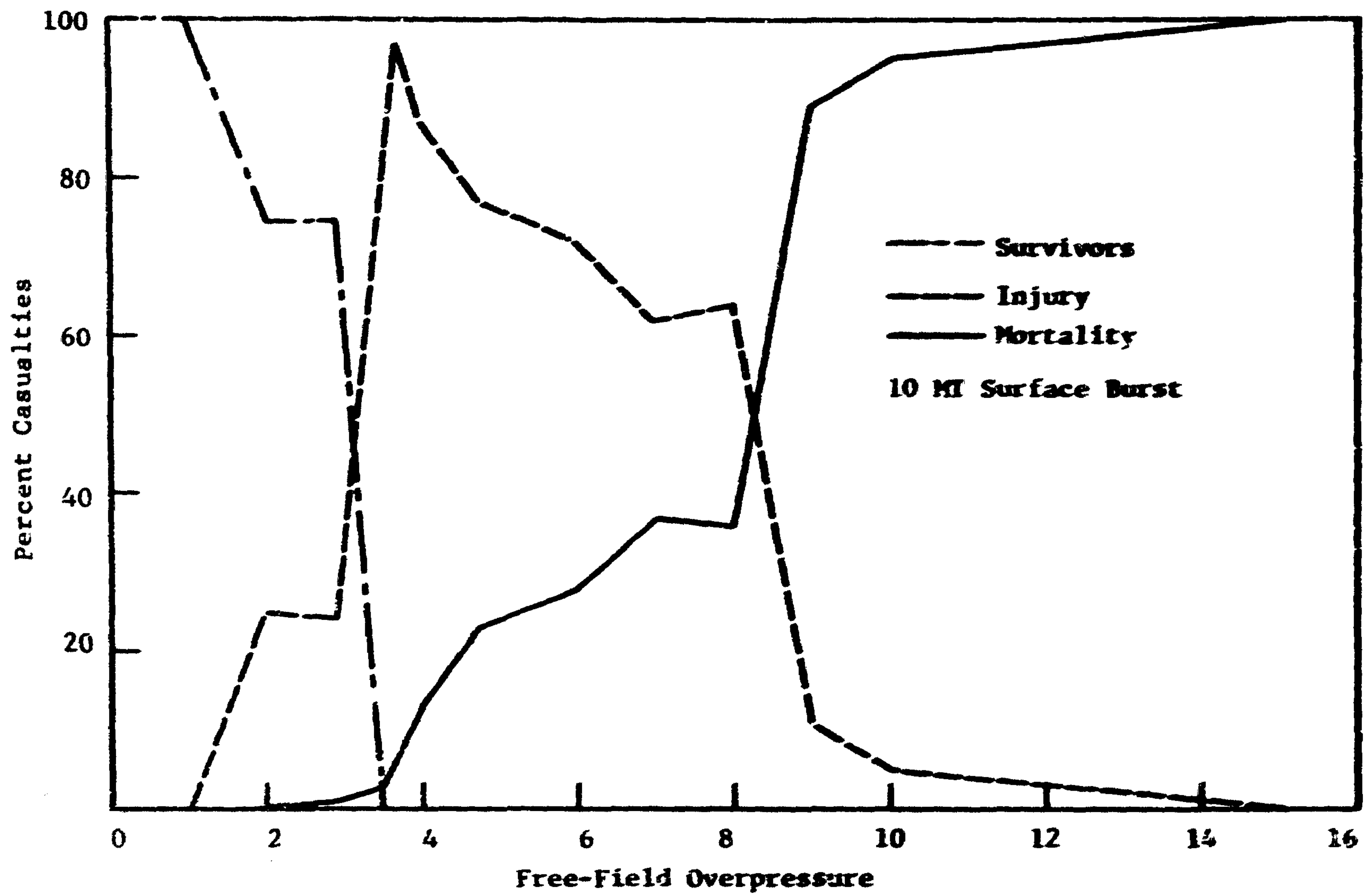

Fig. 18 CASE 4 SIX-STORY COMMERCIAL, TRANSLATION CASUALTIES, STANDING POSTURE

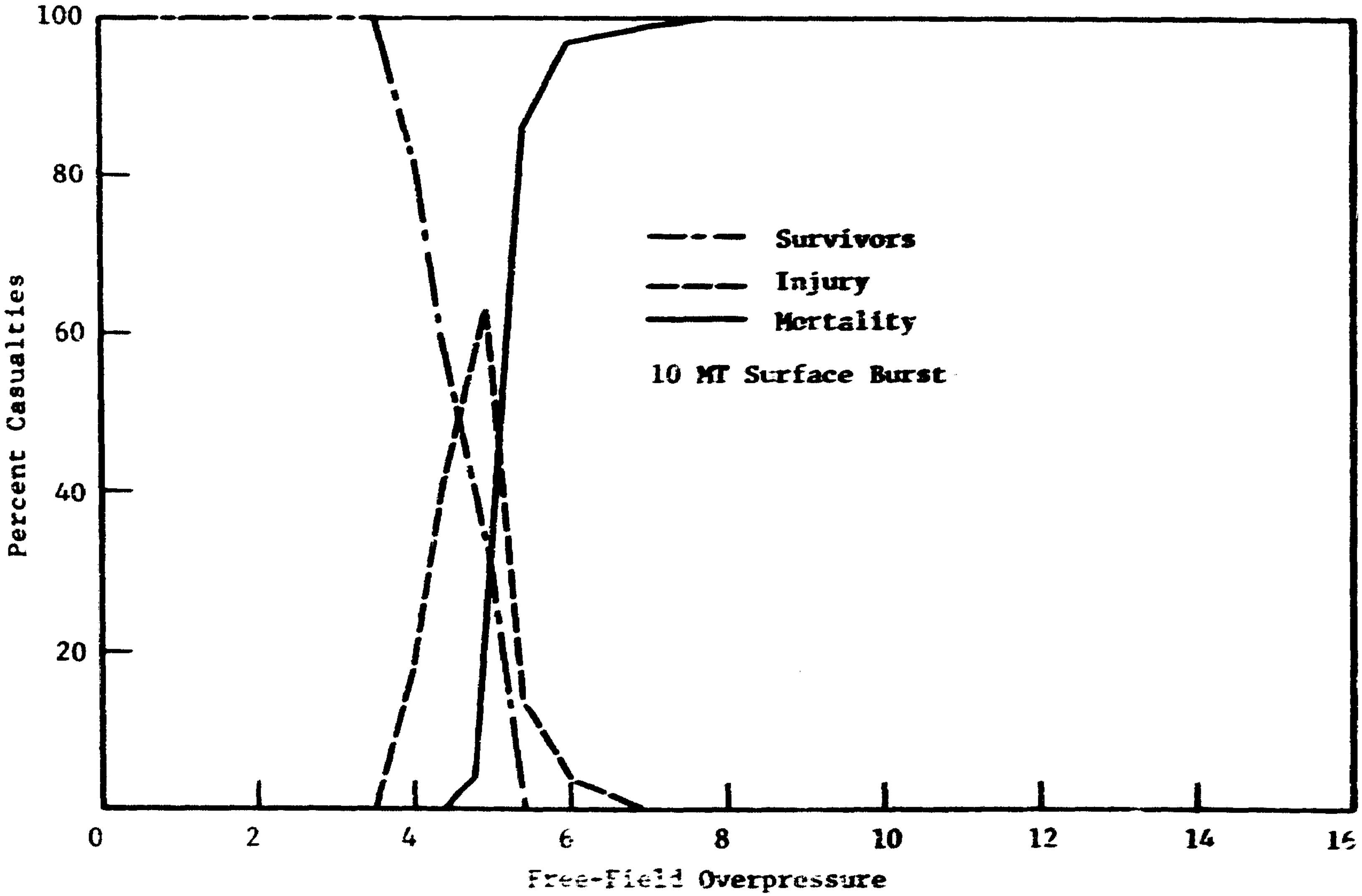

Fig. 19 CASE 4 SIX-STORY COMMERCIAL, TRANSLATION CASUALTIES, PRONE POSTURE

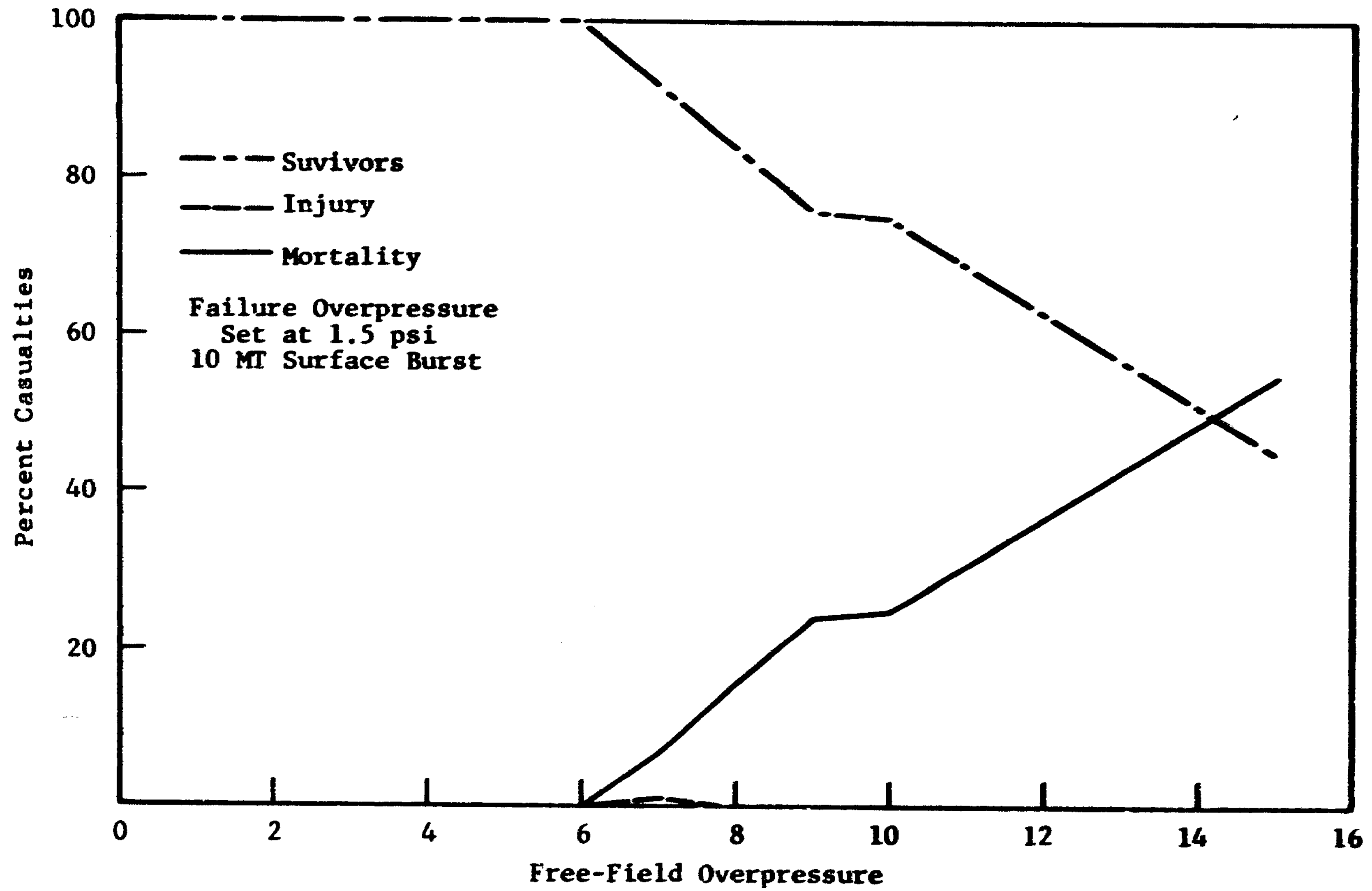

Fig. 20 CASE 4 SIX-STORY COMMERCIAL, DEBRIS CASUALTIES, STANDING AND PRONE POSTURE

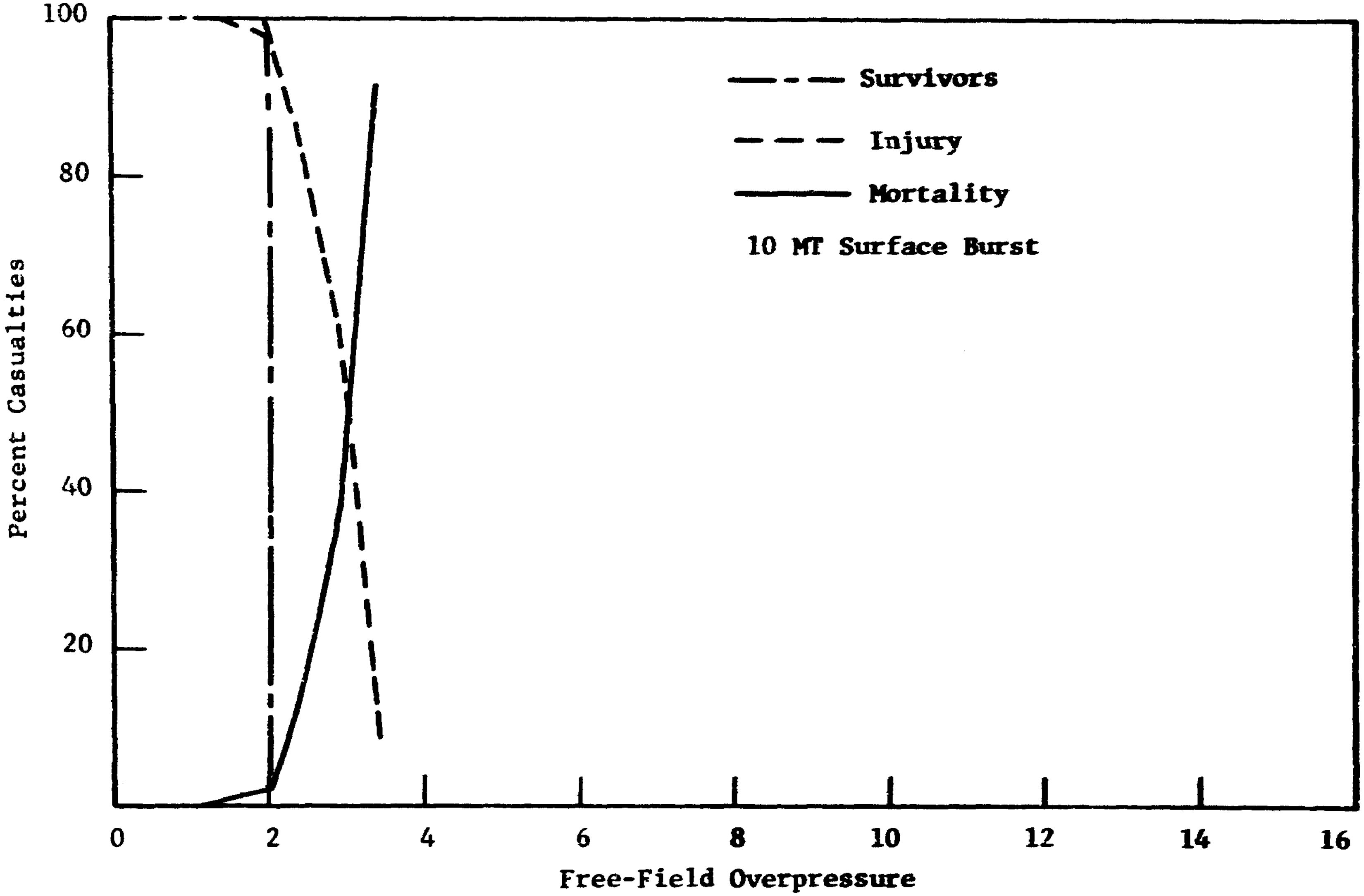

Fig. 21 CASE 5 PERSONNEL 100 PERCENT OUTSIDE, TOTAL CASUALTIES, 100 PERCENT STANDING POSTURE

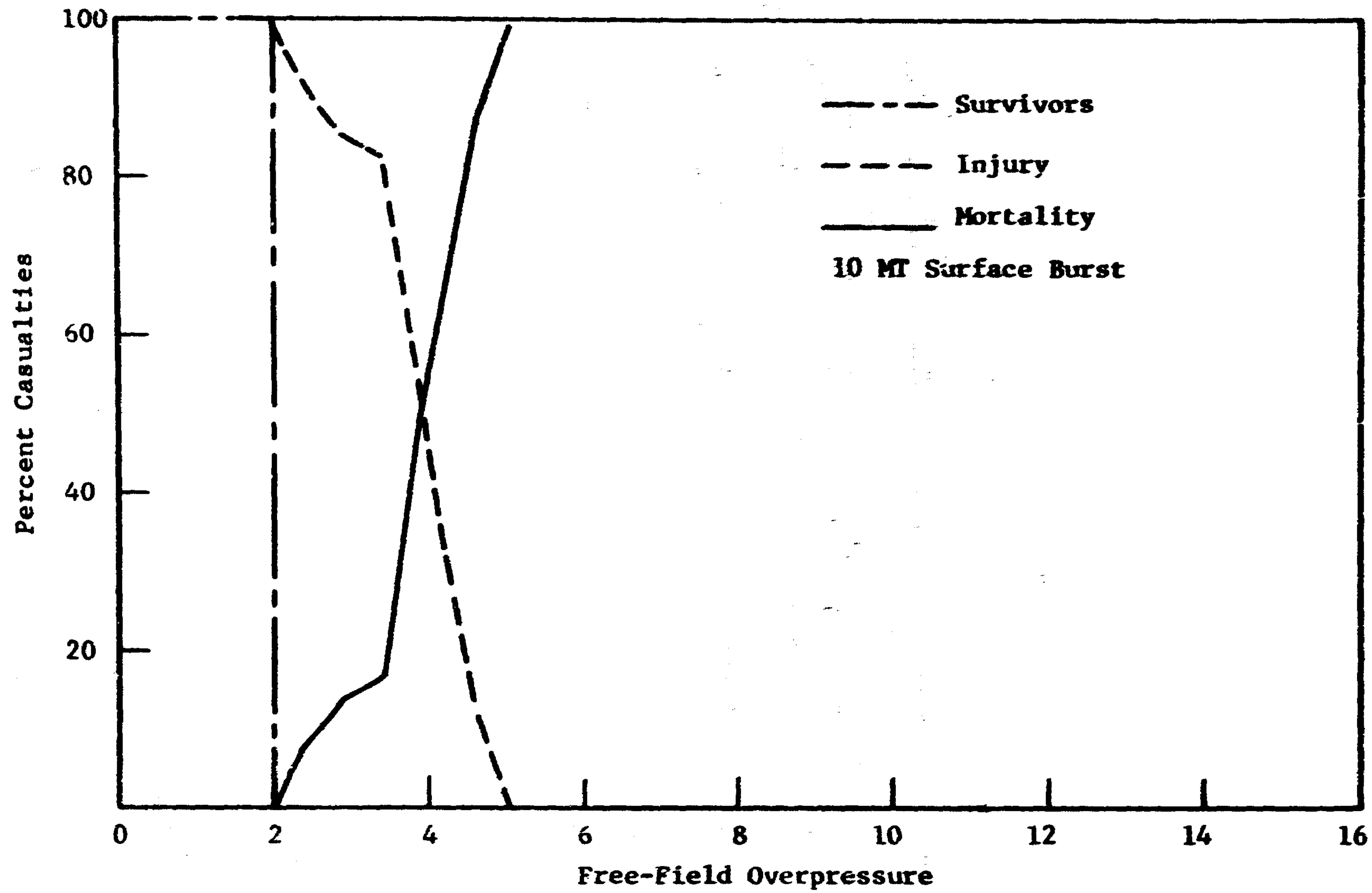

Fig. 22 CASE 5 PERSONNEL 100 PERCENT OUTSIDE, TOTAL CASUALTIES, 100 PERCENT PRONE POSTURE

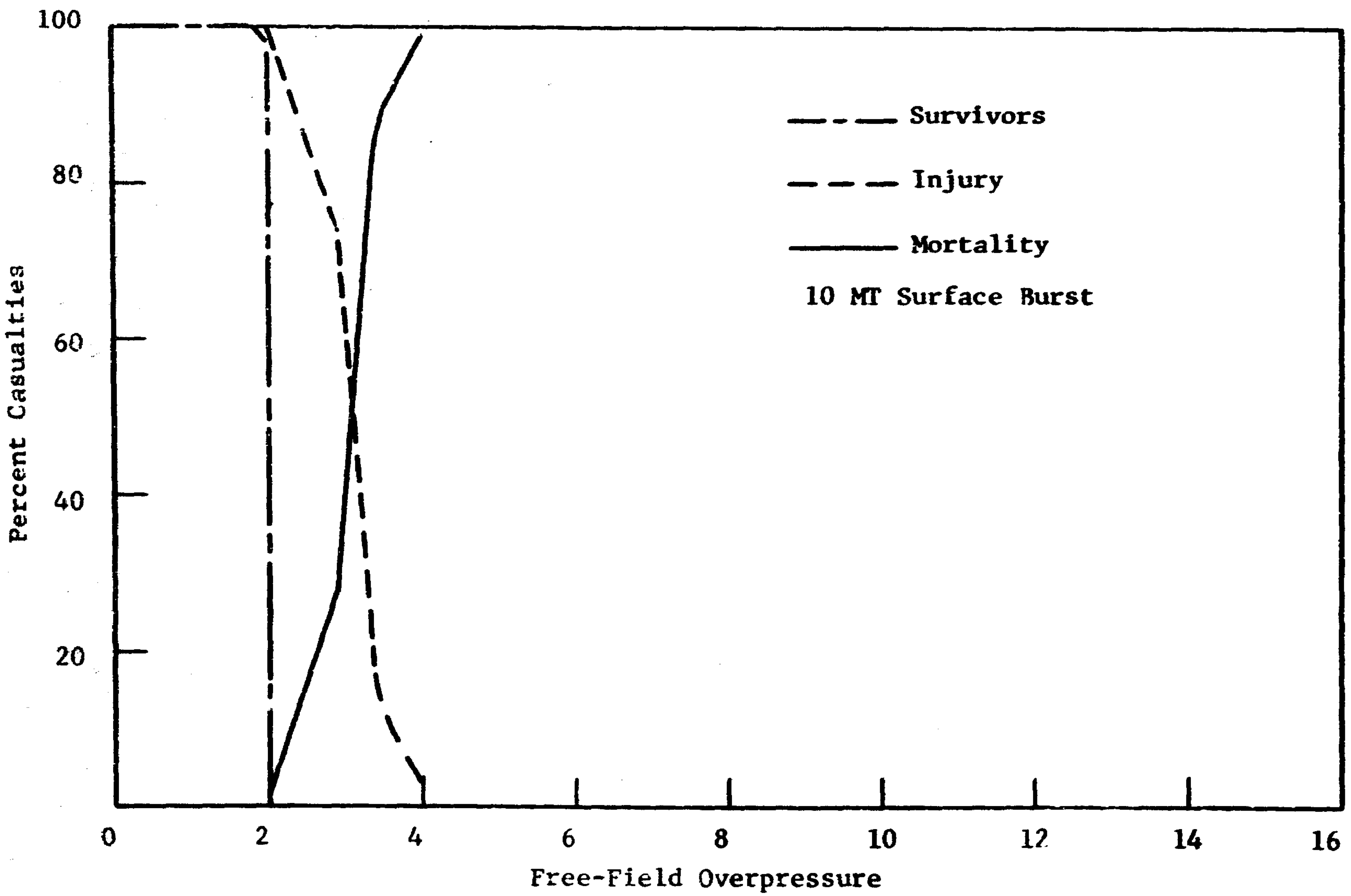

Fig. 23 CASE 5 PERSONNEL 100 PERCENT OUTSIDE, TRANSLATION CASUALTIES, 100 PERCENT STANDING POSTURE

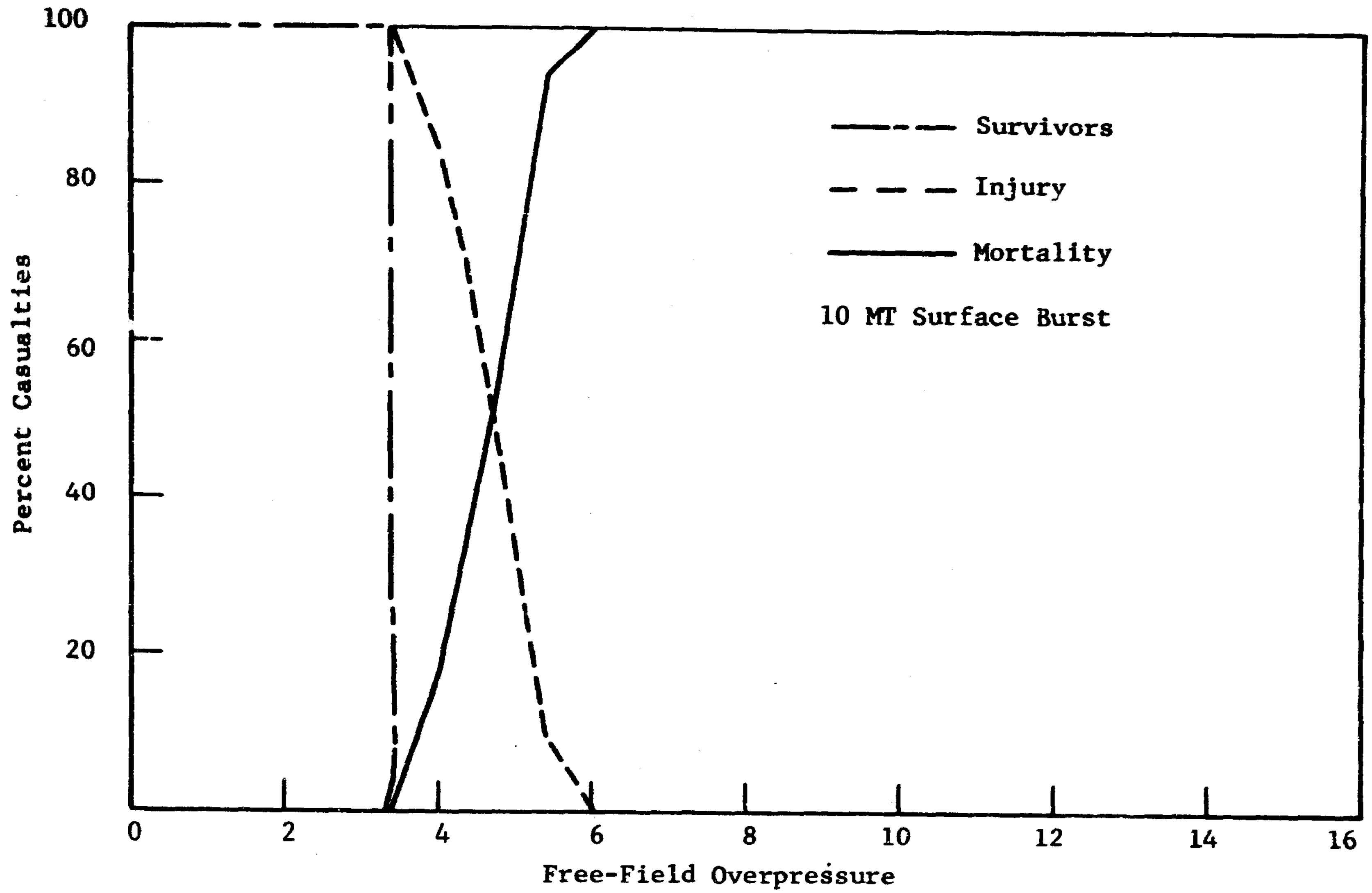

Fig. 24 CASE 5 PERSONNEL 100 PERCENT OUTSIDE, TRANSLATION CASUALTIES, 100 PERCENT PRONE POSTURE

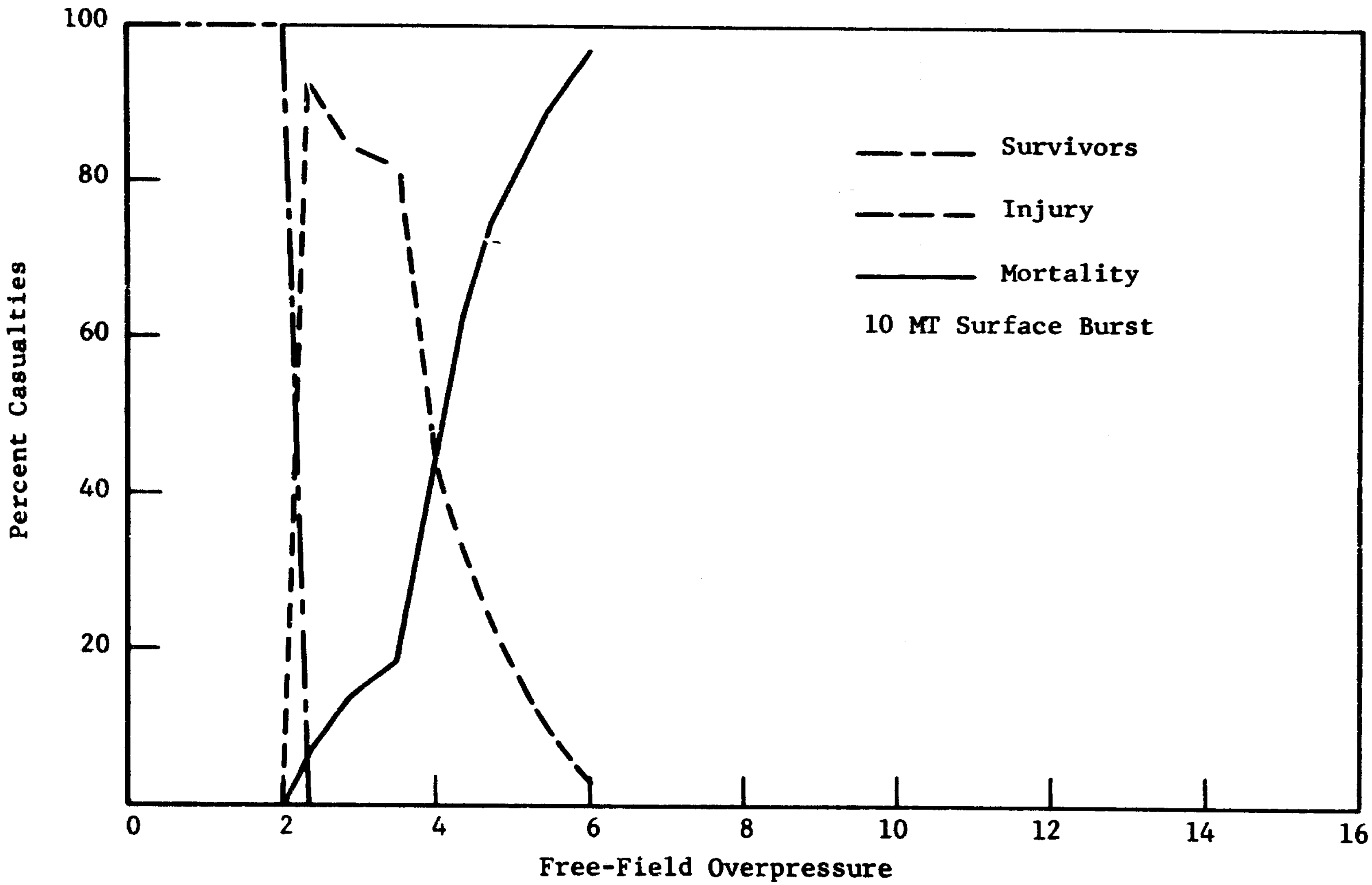

Fig. 25 CASE 5 PERSONNEL 100 PERCENT OUTSIDE, THERMAL RADIATION CASUALTIES, STANDING AND PRONE POSTURE

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) IIT Research Institute Technology Center Chicago, Illinois 60616	2a. REPORT SECURITY CLASSIFICATION N/A 2b. GROUP

3. REPORT TITLE

CASUALTY PREDICTION COMPARISONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5. AUTHOR(S) (First name, middle initial, last name)

David I. Feinstein

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1968	40	2

8a. CONTRACT OR GRANT NO. OCD DAHC20-67-C-0167 b. PROJECT NO. Work Unit No. 1614-A c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) J6114 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Civil Defense Office of the Secretary of the Army Washington, D. C. 20310

13. ABSTRACT

This study utilized a previously developed computer model, the Shelter Evaluation Program (SEP) code, to investigate the effectiveness of various shelter configurations and occupant postures with regard to resisting the direct effects of a 10 MT surface burst over a range of incident pressure levels. The shelter configurations include wood frame single-story and two-story, load bearing brick wall three-story residential, seven-story brick load bearing wall (warehouse), six-story steel frame curtain wall commercial, and no shelter outside cases. Shelter occupants were considered in two postures; standing and prone. Results indicate that there is a significant reduction in casualties when shelter occupants are in a prone state.

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Civil Defense Blast Shelters Computer Program Casualty Prediction Nuclear Warfare						

UNCLASSIFIED
Security Classification

END