AD-A015 558

DESIGN CHARTS FOR COLD-FORMED STEEL PANELS AND WIDE-FLANGE BEAMS SUBJECTED TO BLAST LOADS

George Tseng, et al

Ammann and Whitney

Prepared for:

Picatinny Arsenal

August 1975

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

290087

AD A015558

COPY NO. 8

TECHNICAL REPORT 4838

DESIGN CHARTS FOR COLD-FORMED STEEL PANELS AND WIDE-FLANGE BEAMS SUBJECTED TO BLAST LOADS

GEORGE TSENG
SAMUEL WEISSMAN
NORVAL DOBBS
AMMANN & WHITNEY
CONSULTING ENGINEERS

PAUL PRICE
PROJECT COORDINATOR
PICATINNY ARSENAL

AUGUST 1975

DDC
RECEIVED
SEP 30 1975

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

PICATINNY ARSENAL

DOVER, NEW JERSEY

312

The findings in this report are not to be construed as an official Department of the Army Position.

DISPOSITION

Destroy this report when no longer needed. Do not return to the originator.

ACCESSION for
NTIS
DDC
A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 4838	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DESIGN CHARTS FOR COLD-FORMED STEEL PANELS AND WIDE-FLANGE BEAMS SUBJECTED TO BLAST LOADS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George Tseng, Samuel Weissman, Norval Ibbs (Ammann & Whitney); Paul Price, Project Coordinator (Picatinny Arsenal)		8. CONTRACT OR GRANT NUMBER(s) DAAA-21-75-C-0222
9. PERFORMING ORGANIZATION NAME AND ADDRESS Picatinny Arsenal, Dover, New Jersey 07801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE August 1975 13. NUMBER OF PAGES 308
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for public release, distribution unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Steel Design	Ammunition facilities
Structural steel	Blast-resistant design
Cold-formed steel	Accidental Explosions
Design charts	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents design charts for the selection of cold-formed steel panel and wide-flange beam sections used in structures designed to resist blast loads produced by high-explosive detonations. These steel sections are applicable to the walls, roof, and supporting members (girts, purlins, etc.) of blast-protective acceptor structures in Army Ammunition Plants and other explosive manufacturing and storage facilities. Each design chart consists of plots of steel panel or beam sections versus triangular pressure pulse, for a particular post-accident usability, span length, support condition (applicable to

(Cont.)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Item #20 (Cont.)

single and multiple spans) and beam spacing. Pressure levels up to 12 psi and pulse durations from 20 to 400 ms are covered by the charts. Illustrative examples are included.

TABLE OF CONTENTS

	Page
LIST OF TABLES	iii
LIST OF FIGURES	v
ACKNOWLEDGEMENTS	vii
SUMMARY	ix
CONCLUSIONS AND RECOMMENDATIONS	xi
SECTION 1 INTRODUCTION	1
1.1 Background	1
1.2 Objective	1
1.3 Format and Scope of Report	2
SECTION 2 CRITERIA AND USE OF CHARTS	7
2.1 General	7
2.2 Blast Pressure Loading	7
2.3 Post-Accident Usability	9
2.4 Span Length and Beam Spacing	10
2.5 Support Conditions	10
2.6 Section Properties and Allowable Stresses	11
2.7 Dead Loads	14
2.8 Rebound	14
SECTION 3 ILLUSTRATIVE EXAMPLES	15
3.1 General	15
3.2 Selection of Decking Sections	15
3.3 Selection of Beam Sections	16
3.4 Rebound Calculation	18
REFERENCES	21
DESIGN CHARTS	23
DISTRIBUTION LIST	307

LIST OF TABLES

No.	Title	Page
1	LIST OF METAL DECKING CHART NUMBERS VS. SPAN.	3
2	LIST OF BEAM CHART NUMBERS VS. SPAN.	4
3	SECTION PROPERTIES OF METAL DECKING.	12

LIST OF FIGURES

No.		Page
A	Triangular pressure pulse.	8
B	Member end rotations.	8
C	Metal decking sections.	13
1-60	Metal decking design charts (refer to Table 1).	25-84
61-282	Beam design charts (refer to Table 2).	85-306

Preceding page blank

ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the following persons for valuable contributions and assistance in the development of the design charts and preparation of this report: Messrs. I. Forsten and J. Canavan of Picatinny Arsenal; and Messrs. R. Arya, G. Pecone and W. Stea, and Drs. A. Ammar, J. Healey and J. Vellozzi of Ammann & Whitney.

 Preceding page blank

SUMMARY

This report was developed as part of a program undertaken by the Manufacturing Technology Directorate of Picatinny Arsenal in recognition of the need for expanded design information pertaining to structures subjected to blast environments due to accidental explosions within ammunition facilities. The purpose herein is to provide facility designers with design charts to facilitate the selection of steel structural elements utilized in acceptor structures located in the low to intermediate pressure level range. The report is intended to be used in conjunction with the Picatinny Arsenal Technical Report No. 4837, "Design of Steel Structures to Resist the Effect of HE Explosions".

The design charts, which include standard cold-formed steel panel sections and wide-flange beam sections, can be used in the evaluation of existing structures and in the design of new facilities. These steel panel and beam sections are appropriate for use as walls, roof, and supporting members (girts, purlins, etc.) of blast-protective steel buildings in Army Ammunition Plants and other explosive manufacturing and storage facilities. Each design chart consists of plots of steel panel or beam sections versus triangular pressure pulse, for a particular post-accident usability, span length, support condition, and beam spacing.

The criteria used in the computer analyses performed to develop the design charts, and the various design parameters involved in the use of the charts are described. Design examples which illustrate the application of the charts are included.

A total of 282 design charts are presented in the report covering steel panel span lengths up to 10 ft and beam span lengths up to 35 ft, for single and multiple spans. Pressure levels up to 12 psi and pulse durations from 20 to 400 ms are covered by the charts.

 Preceding page blank

CONCLUSIONS AND RECOMMENDATIONS

The charts presented in this report provide a useful design aid for facility designers in the selection of cold-formed steel-panel and wide-flange beam sections used in structures designed to resist blast loads produced by accidental explosions.

It is recommended that this data be implemented in the evaluation and design of structures within facilities for the manufacture and storage of explosive materials.

 Preceding page blank

SECTION 1

INTRODUCTION

1.1 Background

In the design of steel structures to withstand the effects of high-explosive (HE) detonations, standard structural members can be utilized for acceptor structures located in the low to intermediate pressure level range. However, since the design of steel elements subjected to dynamic loads involves special analytical techniques and generally requires several trial sections, it would be useful if design charts were available to aid engineers and designers in the selection of member sizes, without performing lengthy, repetitious computations.

In response to this need, design charts for the selection of single-span and multi-span cold-formed steel panels and wide-flange beam sections, subjected to blast overpressure, have been prepared and are presented in this report. These charts were developed based on the procedures and criteria contained in the Picatinny Arsenal Technical Report No. 4837, "Design of Steel Structures to Resist the Effects of HE Explosions" (Reference 1). Both of these reports were prepared by the Manufacturing Technology Directorate of Picatinny Arsenal, with the assistance of Ammann & Whitney, Consulting Engineers, as part of the overall Picatinny Arsenal Safety Engineering Support Program for the U.S. Army Armament Command.

The design of a steel building required to resist blast loads involves three general structural systems: (1) the wall and roof panels, (2) supporting members such as girts and purlins and other members which can be treated as individual beams, and (3) the main structural frame. The design charts presented herein pertain to the first two systems. For the analysis of the main structural frame, a computer program for the elasto-plastic analysis of frame structures has also been developed by Picatinny Arsenal, with the assistance of Ammann & Whitney (Reference 2). This program can be used to determine overall and local deflections and stresses of structural members comprising rigid or braced frames.

1.2 Objective

The purpose of this report is to present design charts for the selection of cold-formed steel panel and wide-flange beam sections used in structures designed to resist blast loads produced by high-explosive detonations. Steel panels and beams can

be utilized to construct the walls, roof, and supporting members (girts, purlins, etc.) of blast protective steel buildings in Army Ammunition Plants and other explosive manufacturing and storage facilities. These structures are similar to pre-engineered buildings, except that special designs and details are required for the structural components in order to withstand the blast loadings and to provide the required degree of safety on a cost-effective basis.

The design charts can be applied to evaluate the blast capacity of applicable steel elements in existing structures, as well as for preliminary and final design of new steel structural members of the type and size covered in the charts.

1.3 Format and Scope of Report

The main contents of this report consist of the design charts which follow the descriptive text in Sections 1 through 3. Section 2 describes the criteria used in the development of the charts and the various design parameters and input involved in the use of the charts. Section 3 presents design examples which illustrate the application of the charts for typical designs.

Two sets of design charts are included in the report. The first set of charts (Figures 1 through 60) pertains to cold-formed steel panel sections. These panel sections are referred to as metal decking in the charts because the type of sections included are normally used for roof and floor decking in conventional structures. The second set of design charts (Figures 61 through 282) pertains to steel beams. The members included are standard wide-flange W-Shapes.

Each design chart consists of computer plots of decking type or beam section versus peak pressure and duration of pressure pulse, for a particular post-accident usability condition, span length, support condition, and beam spacing. These charts apply to single and multiple spans. To facilitate the selection of the appropriate chart for a specific design condition, Table 1 presents a list of metal decking chart numbers versus decking span, and Table 2 presents a list of beam chart numbers versus beam span. These tables also list the applicable chart numbers by usability, support condition, and beam spacing categories.

TABLE 1 LIST OF METAL DECKING CHART NUMBERS VS. SPAN.

Span (ft)	Reusable		Non-Reusable	
	Simply Supported	Multiple Spans	Simply Supported	Multiple Spans
3.0	1	2	3	4
3.5	5	6	7	8
4.0	9	10	11	12
4.5	13	14	15	16
5.0	17	18	19	20
5.5	21	22	23	24
6.0	25	26	27	28
6.5	29	30	31	32
7.0	33	34	35	36
7.5	37	38	39	40
8.0	41	42	43	44
8.5	45	46	47	48
9.0	49	50	51	52
9.5	53	54	55	56
10.0	57	58	59	60

TABLE 2 LIST OF BEAM CHART NUMBERS VS. SPAN.

Span (ft)	Usa-bility	Support Condition	Spacing (ft)							
			3	4	5	6	7	8	9	10
8	R	S-S	61	62	63					
		F-F	64	65	66					
		S-F	67	68	69					
	NR	S-S	70	71	72					
		F-F	73	74	75					
		S-F	76	77	78					
10	R	S-S	79	80	81					
		F-F	82	83	84					
		S-F	85	86	87					
	NR	S-S	88	89	90					
		F-F	91	92	93					
		S-F	94	95	96					
12	R	S-S	97	98	99	100				
		F-F	101	102	103	104				
		S-F	105	106	107	108				
	NR	S-S	109	110	111	112				
		F-F	113	114	115	116				
		S-F	117	118	119	120				
16	R	S-S		121	122	123	124	125		
		F-F		126	127	128	129	130		
		S-F		131	132	133	134	135		
	NR	S-S		136	137	138	139	140		
		F-F		141	142	143	144	145		
		S-F		146	147	148	149	150		
20	R	S-S			151	152	153	154	155	156
		F-F			157	158	159	160	161	162
		S-F			163	164	165	166	167	168
	NR	S-S			169	170	171	172	173	174
		F-F			175	176	177	178	179	180
		S-F			181	182	183	184	185	186

TABLE 2 LIST OF BEAM CHART NUMBERS VS. SPAN (cont.).

Span (ft)	Usa-bility	Support Condition	Spacing (ft)							
			3	4	5	6	7	8	9	10
25	R	S-S			187	188	189	190	191	192
		F-F			193	194	195	196	197	198
		S-F			199	200	201	202	203	204
	NR	S-S			205	206	207	208	209	210
		F-F			211	212	213	214	215	216
		S-F			217	218	219	220	221	222
30	R	S-S				223	224	225	226	227
		F-F				228	229	230	231	232
		S-F				233	234	235	236	237
	NR	S-S				238	239	240	241	242
		F-F				243	244	245	246	247
		S-F				248	249	250	251	252
35	R	S-S				253	254	255	256	257
		F-F				258	259	260	261	262
		S-F				263	264	265	266	267
	NR	S-S				268	269	270	271	272
		F-F				273	274	275	276	277
		S-F				278	279	280	281	282

R Reusable
NR Non-reusable
S-S Simple-supported
F-F Fixed ends
S-F Simple-fixed

SECTION 2

CRITERIA AND USE OF CHARTS

2.1 General

The design charts were developed by computer analyses based on criteria for the design of cold-formed steel panels and steel beams subjected to blast loads, in accordance with Reference 1. For a detailed discussion of this criteria and for other necessary design data, the reader should consult this reference. The computer calculations consisted of a series of iterative numerical integrations of the response equation for an elasto-plastic single-degree-of-freedom system.

This section of the report describes the basis for, and the assumptions made in the development of the charts. Design parameters, and input involved in the use of the charts for the determination of decking and beam sections are also described. The design examples presented in Section 3 illustrate the procedure for using the charts. Examples of hand computations for the analysis and design of steel panels and beams are presented in Chapter 7 of Reference 1.

2.2 Blast Pressure Loading

The blast loading parameters of peak pressure (P) and pulse duration (T) shown on the design charts are for an idealized triangular pressure pulse without a rise time as depicted in Figure A. Each chart covers a range of pressures up to 12 psi and duration of pressure pulse from 20 to 400 ms.

This pressure pulse is a triangular pulse which is equivalent to the actual pressure history of the blast loading acting on the member. The pressure pulse can represent an incident pressure or a reflected pressure pulse depending on the orientation of the member with respect to the location of the detonation. Procedures for calculating equivalent triangular blast loadings are covered in TM 5-1300, "Structures to Resist the Effects of Accidental Explosions" (Reference 3). For decking, the peak pressure is increased by 10 percent per Section 3.7.2 of Reference 1.

In developing the design charts, the pressure pulse was applied to the member as a uniform load perpendicular to the major axis of bending. Members subjected to combined bending and axial loads or biaxial bending are not considered.

 Preceding page blank

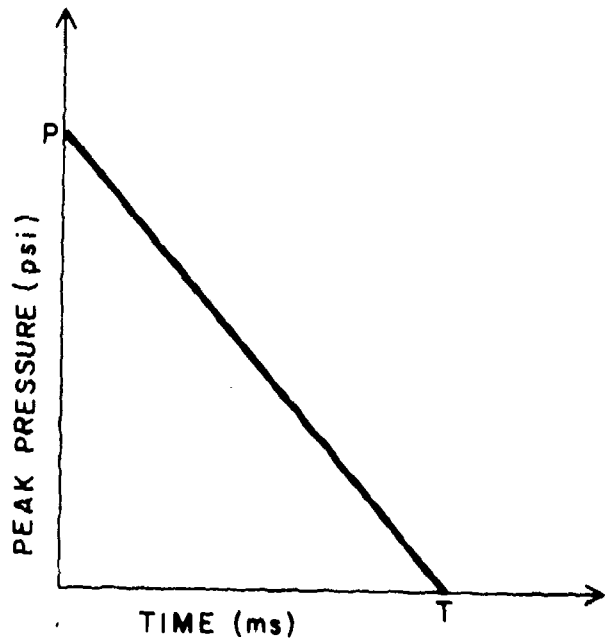


Figure A Triangular pressure pulse.

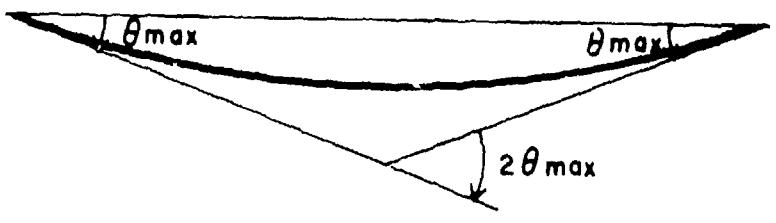


Figure B Member end rotations.

2.3 Post-Accident Usability

The usability category selected by the designer is based on the desired (or required) post-accident condition of the structure as defined in Chapter 2 of Reference 1. "Reusable" structures are intended to sustain light damage such that they are reusable with only minor repairs. Permanent deformations are tolerated to the extent that they are compatible with future structural safety and operational requirements. "Non-reusable" structures are designed to provide safety and structural integrity during the accident but are permitted to sustain moderate to severe damage. In this case, however, the post-accident condition is not compatible with future structural safety and the damage is such that the repair work necessary to restore the structure would be excessive.

The specific usability criteria used in developing the design charts is as follows:

Metal Decking

Reusable

$\theta_{max} = 0.9^{\circ}$ or $\mu_{max} = 1.25$, whichever governs

Non-reusable

$\theta_{max} = 1.8^{\circ}$ or $\mu_{max} = 1.75$, whichever governs

Beams

Reusable

$\theta_{max} = 1^{\circ}$ or $\mu_{max} = 3$, whichever governs

Non-reusable

$\theta_{max} = 2^{\circ}$ or $\mu_{max} = 6$, whichever governs

Here, μ_{max} is the maximum ductility ratio, and θ_{max} is the maximum angle of rotation permitted at the ends of the member as shown in Figure B. An asterisk (*) in the charts denotes that the design of the member is controlled by the maximum angular rotation; otherwise, the member is controlled by the maximum ductility ratio.

2.4 Span Length and Beam Spacing

As indicated in Tables 1 and 2, the decking and beam charts are presented for a range of practical span lengths. The span lengths for the decking charts are at intervals of 0.5 ft, ranging from 3 to 10 ft. Beam span lengths range from 8 to 35 ft at 2 to 5 ft intervals.

For multiple-span decking and beams, the appropriate span length pertains to each individual span between supports. The multiple-span decking charts were calculated for the given pressure pulse acting simultaneously on spans of equal length. The exterior support is a simple support and the decking is continuous over the interior supports, therefore, the end span governs the required decking section. For unequal decking span conditions, the longest span length can be used, which will generally result in a conservative design.

For multiple-span beams, each span can be evaluated separately based on its length and the appropriate support condition. See Section 2.5 for a description of support conditions.

The spacing shown on the beam charts (refer to Table 2) ranges from 3 to 10 ft at 1-ft intervals, and corresponds to a uniform spacing of the beam(s) under consideration. This spacing has been used in the development of the charts, to account for the tributary load to each beam. For an unequal spacing or an edge beam, an equivalent or average spacing corresponding to the actual tributary load should be used.

2.5 Support Conditions

The support conditions for the decking charts are based on a simply-supported condition for a single span, or a simple-partially fixed condition for multiple spans. The ultimate load capacity for the single-span condition was calculated using Equation 3.24 of Reference 1, and the ultimate load capacity for the multiple-span condition was calculated using Equation 3.25 of Reference 1.

For single-span beams, the simply-supported, fixed-ended, or simple-fixed condition should be used based on the actual support conditions. For multiple-span beams, the designer should select the appropriate support condition based on the span (end or interior) and the connection details. In general, the end span of a multiple-span beam would be simple-fixed, and the interior spans would be considered as fixed-ended. In the case of unequal span lengths, judgment should be used by the designer in

selecting the appropriate support condition for each span. The ultimate load capacities were calculated using the equations for beams with uniform loading in Table 3.1 of Reference 1.

2.6 Section Properties and Allowable Stresses

Fourteen sizes of metal decking are used in the decking design charts. The shapes and section properties of the decking types included are given in Table 3 and Figure C. These sections are standard sections available from several manufacturers, although exact properties may vary. The basic decking properties conform with the AISI "Specificiation for the Design of Cold-Formed Steel Structural Members" (Reference 4). The decking charts were prepared for metal decking of 33 ksi static yield stress plus a dynamic increase factor of 10 percent, in accordance with Chapter 2 of Reference 1. As discussed in Section 3.7 of Reference 1, the type of cross-section shown in Figure C, i.e., closed sections consisting of a flat sheet with a series of hat sections, is recommended for blast design applications.

The sections in the beam design charts are wide-flange members which are specified as W-Shapes in the AISC "Manual of Steel Construction" (Reference 5). The members included were selected from those sections commonly used as beams. Moreover, these sections satisfy requirements for maximum span length to depth ratio, and have the required flange width to thickness ratio and web depth to thickness ratio such that local buckling will not occur. The charts were prepared for beams of 36 ksi static yield stress plus a dynamic increase factor of 10 percent, in accordance with Chapter 2 of Reference 1.

The ultimate capacity of each decking and beam section given in the design charts was controlled by flexural failure, i.e., actual shear stresses were less than the allowable value.

In the development of the beam charts, it was assumed that lateral buckling will be prevented. Under the pressure pulse, the wall or roof panels will provide the necessary lateral bracing. However, additional lateral bracing of the bottom flange may be required under rebound (refer to Section 2.8).

If it is desired to use decking or beam sections other than those included in the design charts, a member with equal or greater capacity can be chosen. However, it is necessary to establish that the revised mass and stiffness do not have a significant effect on the dynamic response and hence the required capacity.

TABLE 3 SECTION PROPERTIES OF METAL DECKING.

Section and Gage*	Weight (psf)	I_{20} (in^4)	S^+ (in^3)	S^- (in^3)
Type 1 (20-20)	3.8	0.38	0.31	0.44
Type 1 (18-18)	4.8	0.57	0.47	0.59
Type 1 (16-16)	5.8	0.76	0.65	0.75
Type 1 (14-14)	7.3	1.01	0.89	0.94
Type 1 (12-12)	9.9	1.37	1.35	1.33
Type 2 (20-20)	4.2	1.43	0.60	1.03
Type 2 (18-18)	5.4	2.13	0.91	1.39
Type 2 (16-16)	6.5	2.89	1.26	1.76
Type 2 (14-14)	8.1	3.90	1.75	2.23
Type 2 (12-12)	11.1	6.05	2.83	3.18
Type 3 (18-18)	6.5	5.93	1.90	1.83
Type 3 (16-16)	7.9	7.57	2.49	2.49
Type 3 (14-14)	9.8	9.02	3.18	3.14
Type 3 (12-12)	13.4	12.59	4.10	4.38

* The numbers within each bracket refer to the gage number of the hat section and the flat sheet, respectively.

I_{20} Moment of inertia of section per ft width at a service stress of 20 ksi.

S^+, S^- Section modulus corresponding to positive and negative moments, respectively, per ft width.

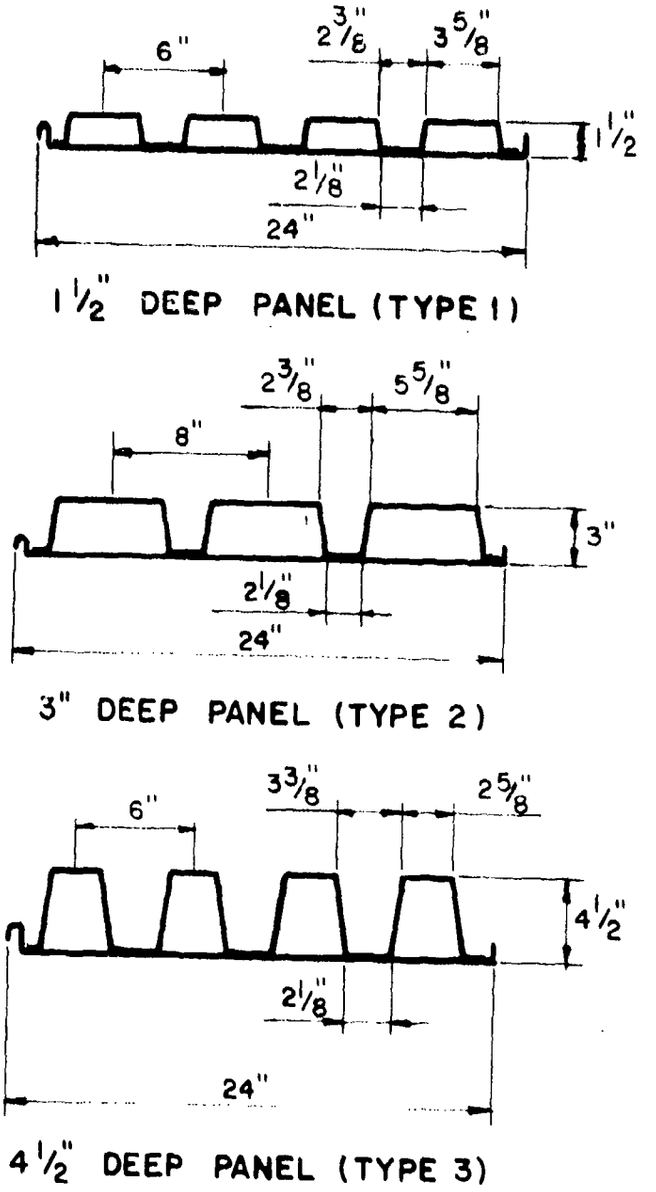


Figure C Metal decking sections.

2.7 Dead Loads

The development of the decking design charts included an allowance for the actual decking weight per Table 3. This was accomplished by subtracting the decking weight from the total ultimate capacity of the member. Similarly, the beam charts account for the dead weight of the beam plus an estimated decking weight.

In general, additional dead loads will be insignificant compared to the magnitude of the blast pressure loading. However, in certain cases it may be necessary to consider other dead loads, particularly at low pressure levels (less than 1 psi). For example, equipment supported by the roof beams may have to be considered. If such additional loads can be equated to a uniform load which is less than about 30 percent of the blast load, the design charts can be used to obtain a rough approximation of the required member size, by adding the dead load to the peak pressure. However, it will be necessary to verify this design by a separate analysis since the additional dead load will affect the mass and dynamic response of the member.

2.8 Rebound

After selection of decking and beam sections from the design charts, the effects of rebound should be considered as described below.

As discussed in Section 3.7.2 of Reference 1, the required decking resistance in rebound, in the practical design range, will be satisfied by the decking section selected for the pressure pulse. However, it is possible in some cases for the actual resistance of the decking in rebound to be less than the required response determined from Figure 3.9 of Reference 1, due to the different bending capacity in the positive and negative directions. In addition, it is necessary to calculate rebound forces for the design of connections to withstand the load reversal in rebound.

For the wide-flange beams, the section required for the pressure pulse will be adequate for rebound. However, as previously indicated additional lateral bracing of the bottom flange may be required. The designer should refer to Section 3.3.6 of Reference 1 for lateral bracing criteria. In any case, it will be necessary to provide the required beam connections for rebound reactions.

The general procedures and data for calculating the elastic rebound of structures are contained in Chapter 6 of Reference 3, and are supplemented for steel decking and beams in Chapters 3 and 7 of Reference 1. A sample rebound calculation is included in Section 3.

SECTION 3

ILLUSTRATIVE EXAMPLES

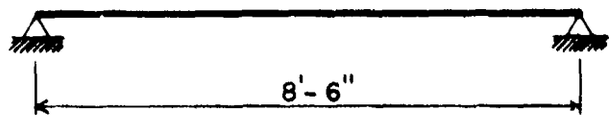
3.1 General

The following examples illustrate the use of the design charts for several typical cases involving the selection of decking and beam sections. Also included is an example showing additional calculations required to determine rebound reactions.

3.2 Selection of Decking Sections

Example 1 - Single-Span Metal Decking

Design Data



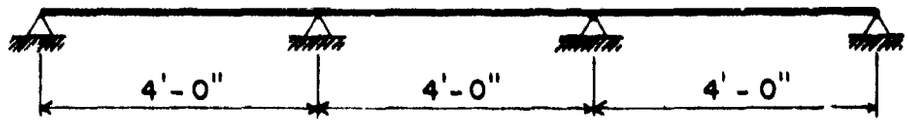
Reusable wall panel
Span = 8.5 ft
Simply supported
Peak pressure = 3.6 psi (Ref. 3)
Peak pressure for decking design,
P = 1.1 x 3.6 = 4.0 psi (Ref. 1, Sect. 3.7.2)
Pulse duration, T = 200 ms (Ref. 3)

Solution

Select the proper design chart (Figure 45) from Table 1. In Figure 45, enter values of P and T. The metal decking which satisfies the given design condition is represented by the curve which is above the intersection point of P and T. It is found that Type 3 (14-14) will be used for this design. Note that this decking section is followed by an asterisk in the chart, which denotes that the design is controlled by angular rotation (θ_{max}).

Example 2 - Multiple-Span Metal Decking

Design Data



Non-reusable roof decking
Span = 4.0 ft
Multiple spans
Peak pressure = 6.4 psi (Ref. 3)
Peak pressure for decking design,
P = 1.1 x 6.4 = 7.0 psi (Ref. 1, Sect. 3.7.2)
Pulse duration, T = 100 ms (Ref. 3)

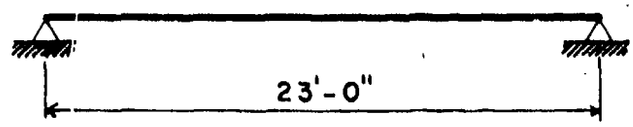
Solution

Select the proper design chart (Figure 12) from Table 1. In Figure 12, enter values of P and T. The metal decking which satisfies the given design condition is represented by the curve which passes through the intersection point of P and T. It is found that Type 2 (20-20) will be used for this design.

3.3 Selection of Beam Sections

Example 3 - Single-Span Beam

Design Data



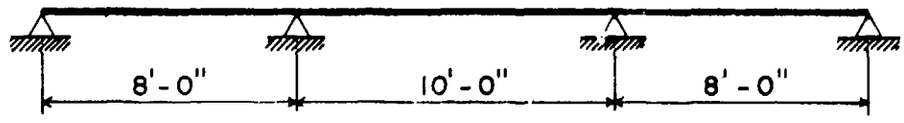
Non-reusable roof beams @ 5 ft 6 in.spacing
Span = 23.0 ft (use 25.0 ft)
Spacing = 5.5 ft (use 6.0 ft
Simply supported
Peak pressure, P = 2.0 psi (Ref. 3)
Pulse duration, T = 125 ms (Ref. 3)

Solution

Select the proper design chart (Figure 206) from Table 2. In Figure 206, enter values of P and T. The beam which satisfies the given design condition is represented by the curve which is above the intersection point of P and T. It is found that a W16x26 beam will be used for this design. Note that this beam member is followed by an asterisk in the chart, which denotes that the design is controlled by angular rotation of (θ_{max}).

Example 4 - Multiple-Span Beam

Design Data



Reusable girts @ 4 ft - 0 in. spacing
Span = 8.0 ft Simple-Fixed (end span)
= 10.0 ft Fixed-Fixed (interior span)
Spacing = 4.0 ft
Peak pressure, P = 10 psi (Ref. 3)
Pulse duration, T = 60 ms (Ref. 3)

Solution

Select the proper design charts (Figures 68 and 83) from Table 2. In Figures 68 and 83, enter values of P and T. From Figure 68 a W8x13 beam is required, and from Figure 83 a W8x15 beam is required. Since the girt is a continuous uniform beam, the larger member size is required to satisfy the given design conditions. Therefore, a W8x15 beam will be used for this design.

3.4 Rebound Calculation

Example 5 - Single-Span Metal Decking

Design Data

Same design as Example 1
For Decking Type 3 (14-14) obtain properties from Table 3:

$S^{+} = 3.18 \text{ in}^3$

$S^{-} = 3.14 \text{ in}^3$

$I_{20} = 9.02 \text{ in}^4$

Weight = 9.8 psf

Step 1. Compute maximum unit resistance r_u.

$F_{dy} = 1.1F_y$ (Ref. 1, Eq. 3.21)

$F_{dy} = 1.1 \times 33 = 36.3$ ksi

$M_{up} = F_{dy}S^{+}$ (Ref. 1, Eq. 3.22)

$M_{up} = 36.3 \times 3.18 = 115.4$ k-in

$r_u = (8.0\ M_{up})/L^2$ (Ref. 1, Eq. 3.24)

$$r_u = \frac{8.0 \times 115.4 \times 10^3}{(8.5 \times 12)^2} = 88.8 \text{ lb/in}$$
(per 1-ft width)

Step 2. Compute equivalent elastic deflection X_E.

$X_E = (0.013 r_u L^4)/EI_{eq}$ (Ref. 1, Eq. 3.26)

$$X_E = \frac{(0.013 \times 88.8 \times (8.5 \times 12)^4}{29 \times 10^6 \times 0.75 \times 9.02} = 0.64 \text{ in.}$$

Step 3. Compute natural period of vibration T_N.

$$T_N = 2\pi\sqrt{0.74mL/K_E} \qquad \text{(Ref. 1, Eq. 3.29)}$$

$$K_E = \frac{r_u L}{X_E} = \frac{88.8 \times 8.5 \times 12}{0.64} = 14{,}153 \text{ lb/in}$$

$$m = \frac{9.8}{12 \times 386} = 2.11 \times 10^{-3} \ \frac{\text{lb-sec}^2}{\text{in}^2}$$

$$T_N = 2\pi\sqrt{0.74 \times 2.11 \times 10^{-3} \times 8.5 \times 12/14{,}153}$$

$$= 0.021 \text{ sec or } 21 \text{ ms}$$

Step 4. Compute T/T_N, μ.

$$T/T_N = \frac{200}{21} = 9.5$$

$$\mu = X_m/X_E$$

Since the design is governed by θ_{max} as indicated by an asterisk,

$$X_m = L/130 \text{ for } \theta_{max} = 0.9^\circ \qquad \text{(Ref. 1, Eq. 3.28)}$$

$$X_m = 8.5 \times 12/130 = 0.79 \text{ in}$$

$$\mu = 0.79/0.64 = 1.23$$

(Note that μ can also be determined from Ref. 3, Figure 6.7)

Step 5. Determine rebound $\bar{r}$.

From Ref. 1, Fig. 3.8 using values of $T/T_N = 9.5$ and $\mu = 1.23$,

$$\bar{r}/r_u = 0.48$$

$$\bar{r} = 0.48 \times 88.8 = 42.6 \text{ lb/in (per 1-ft width)}$$

Step 5. (continued)

S^-/S^+ = 3.14/3.18 = 0.99 > 0.48,
therefore rebound capacity is adequate

Step 6. Compute rebound reaction for connection design.

For simply-supported single-span, rebound
reaction = 0.5 x 42.6 x 8.5 x 12
= 2,200 lbs (per 1-ft width)

REFERENCES

1. "Design of Steel Structures to Resist the Effects of HE Explosions", Manufacturing Technology Directorate, Picatinny Arsenal, Technical Report No. 4837, 1975.

2. "Analysis of Frame Structures Subjected to Blast Overpressures", Manufacturing Technology Directorate, Picatinny Arsenal, Technical Report No. 4839, 1975.

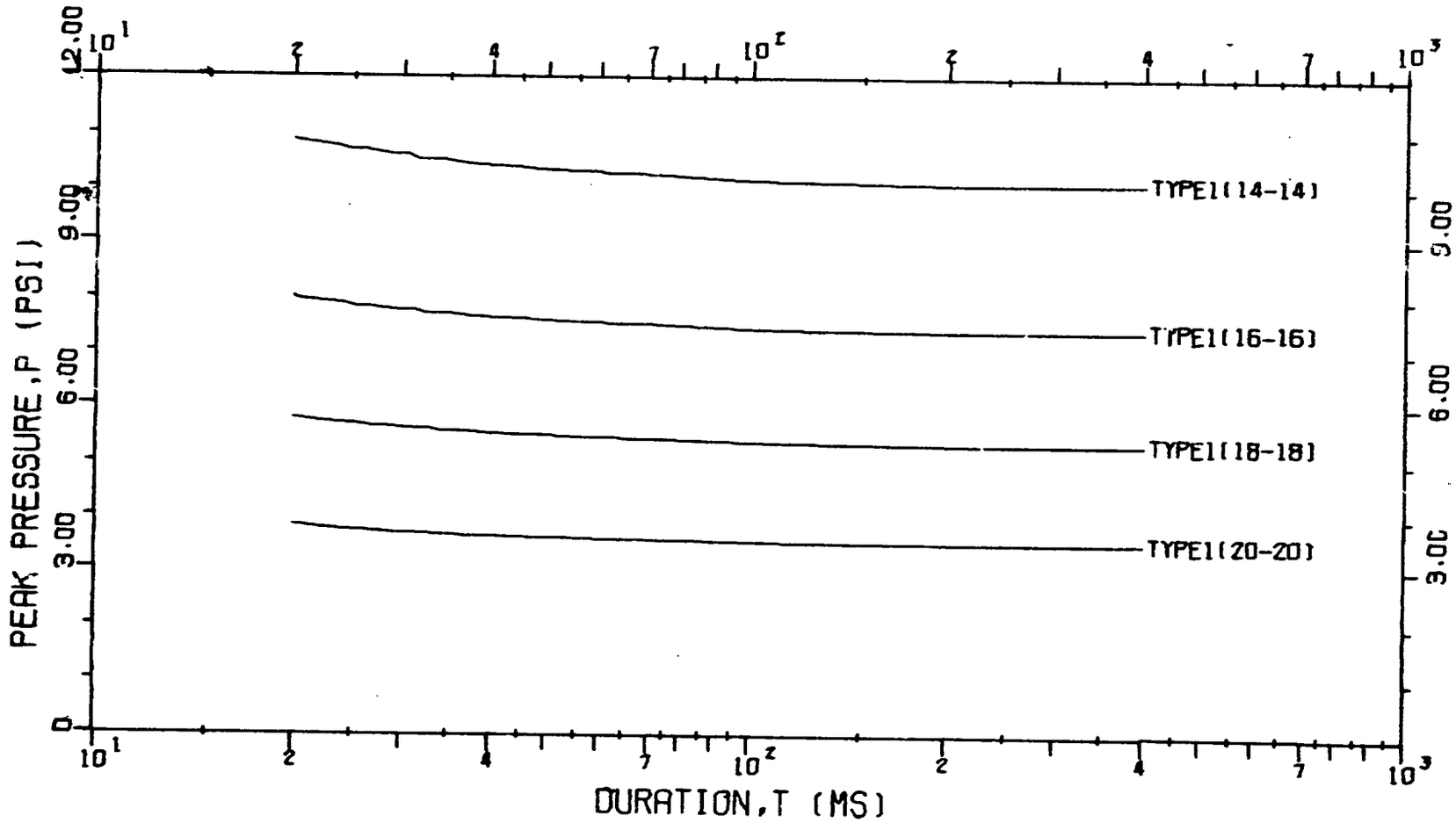
3. "Structures to Resist the Effects of Accidental Explosions (with Addenda)", Department of the Army Technical Manual, TM 5-1300, Washington, D. C., June 1969.

4. "Specification for the Design of Cold-Formed Steel Structural Members", American Iron and Steel Institute, New York, N.Y., 1968.

5. "Manual of Steel Construction", Seventh Edition, American Institute of Steel Construction, New York, N.Y., 1970.

DESIGN CHARTS

Preceding page blank



FIGURE

REUSABLE METAL DECKING,SPAN= 3.0 FT, SIMPLY-SUPPORTED

Preceding page blank

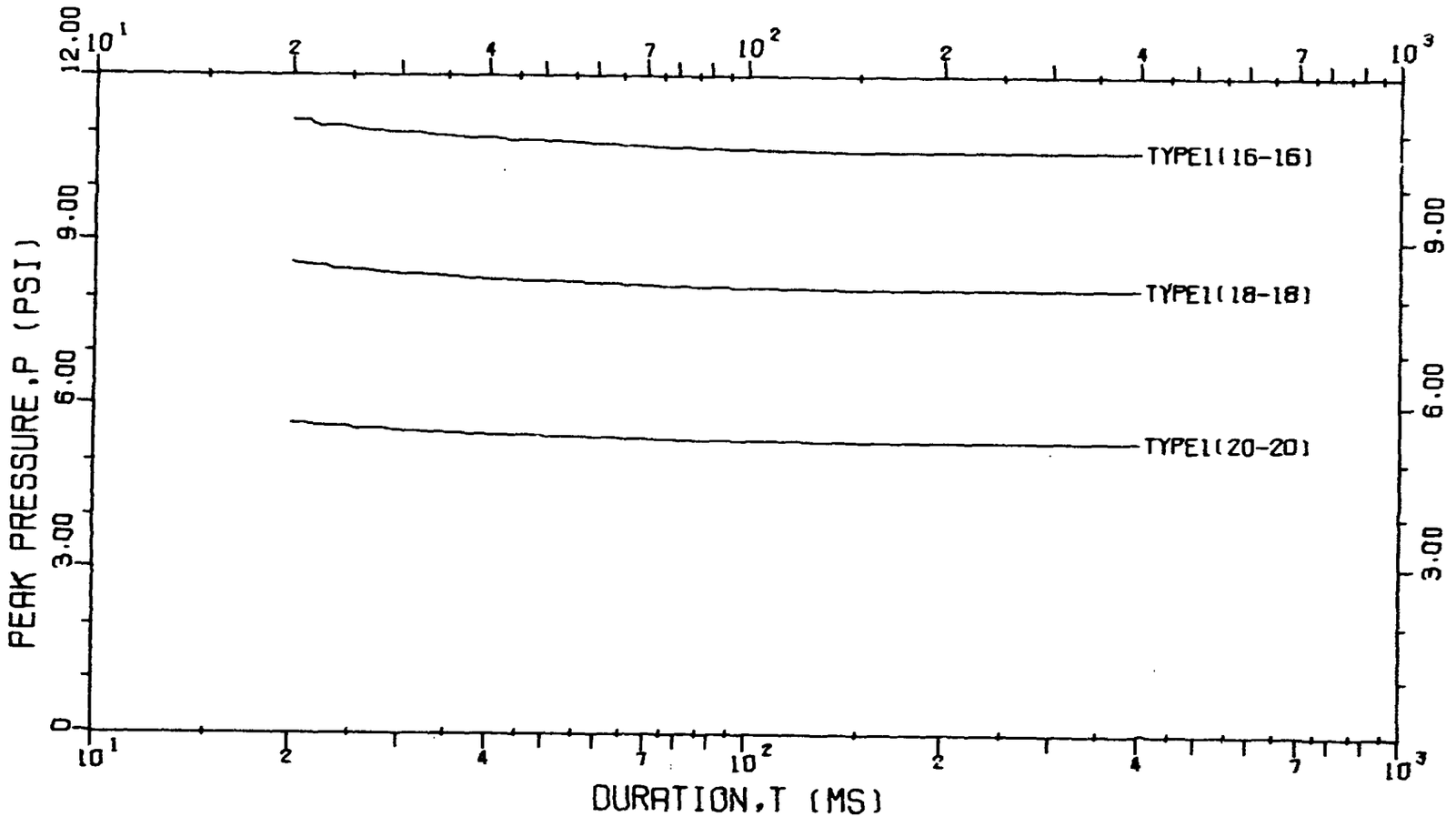


FIGURE 2

REUSABLE METAL DECKING,SPAN= 3.0 FT, MULTIPLE SPANS

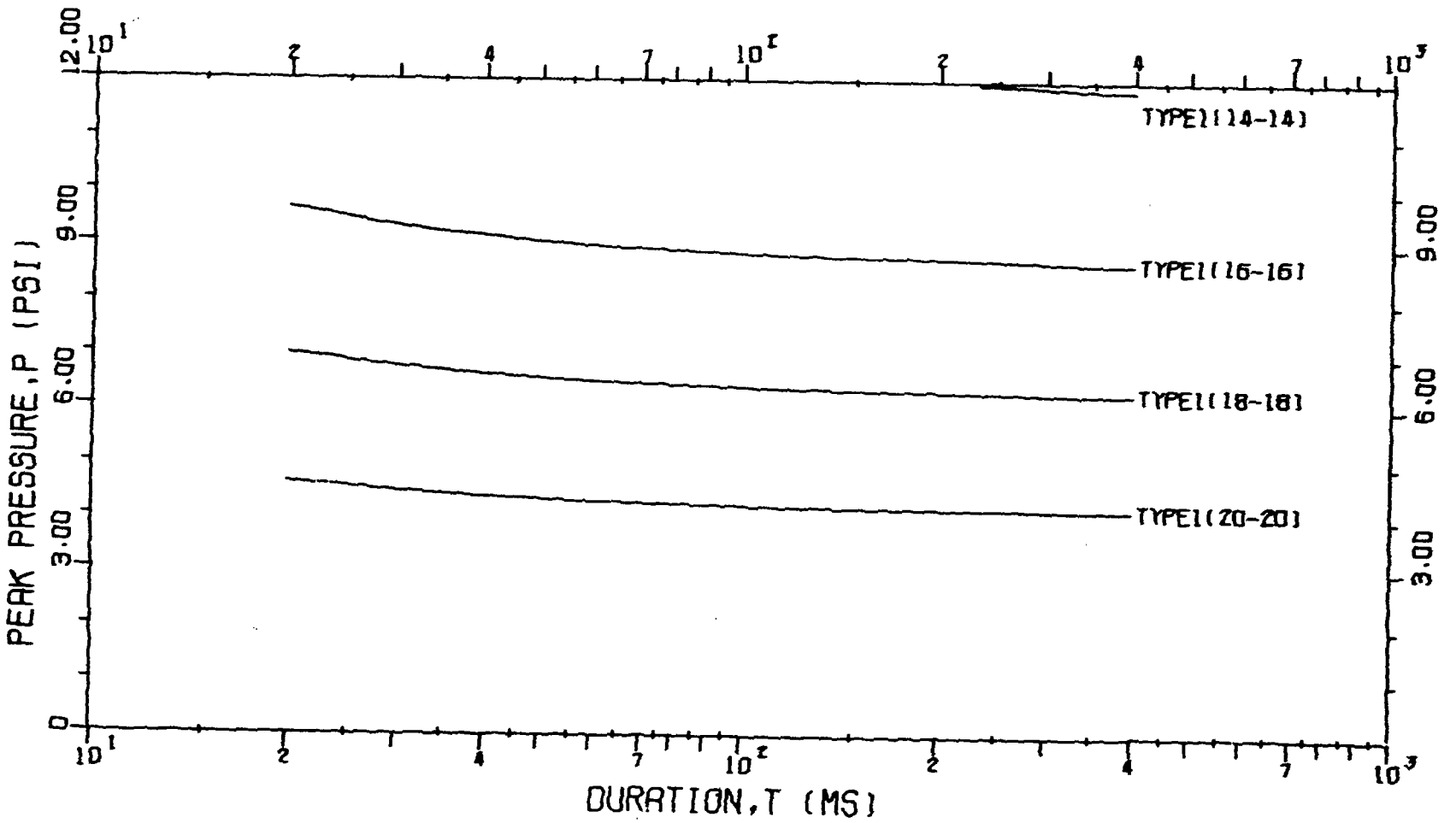


FIGURE 3

NON-REUSABLE METAL DECKING,SPAN= 3.0 FT,SIMPLY-SUPPORTED

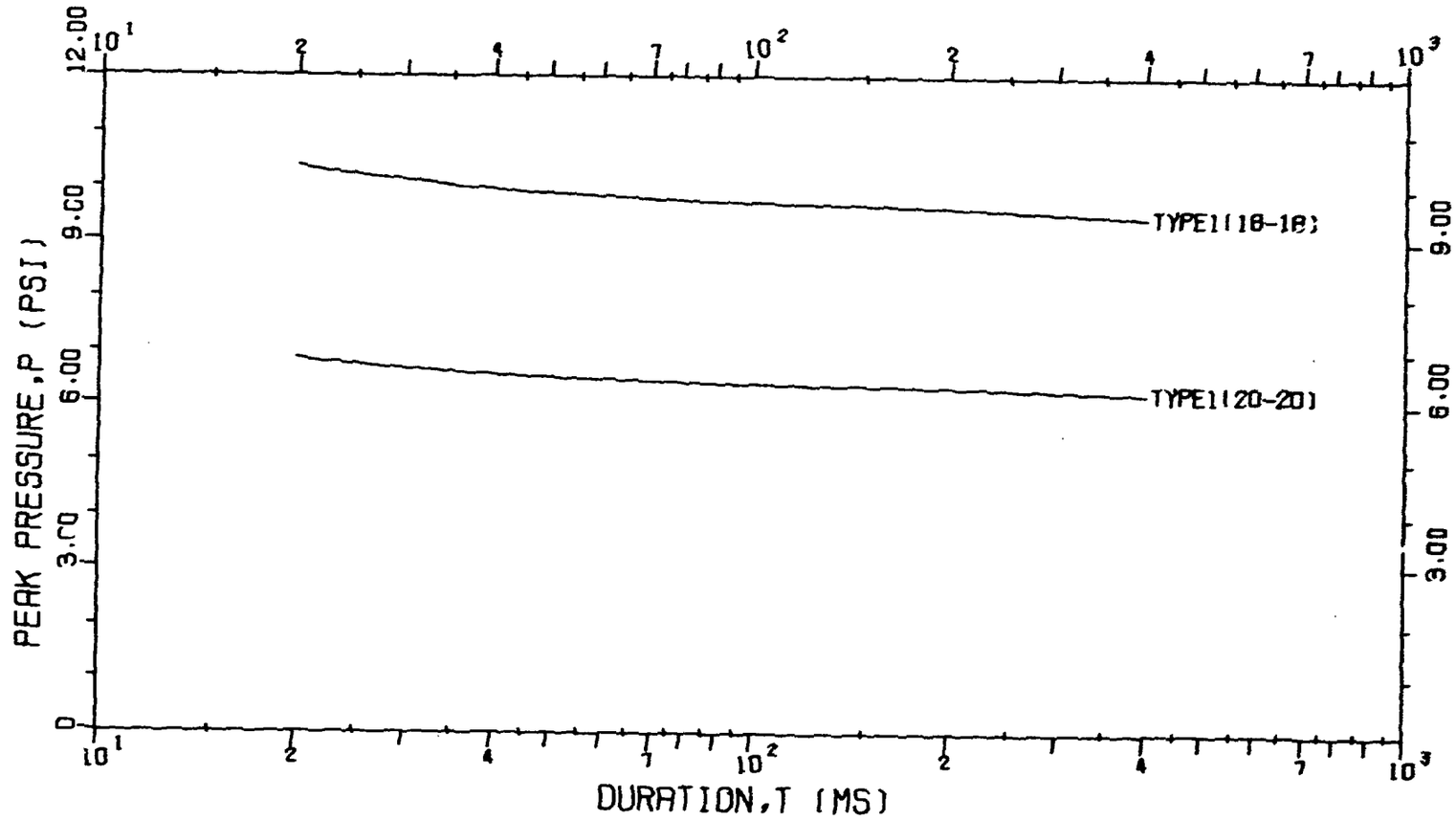


FIGURE 4

NON-REUSABLE METAL DECKING,SPAN= 3.0 FT,MULTIPLE SPANS

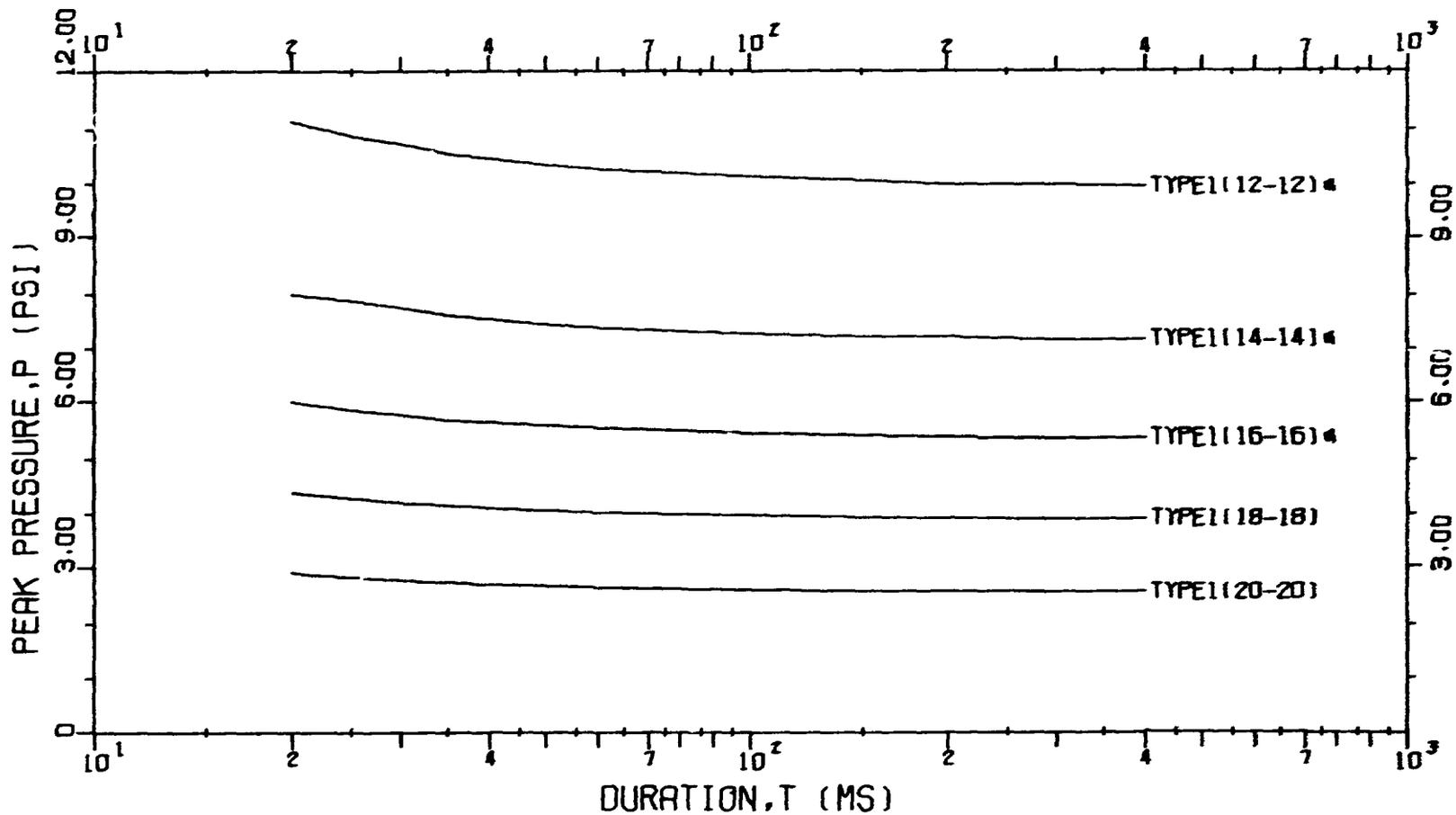


FIGURE 5

REUSABLE METAL DECKING,SPAN= 3.5 FT, SIMPLY-SUPPORTED

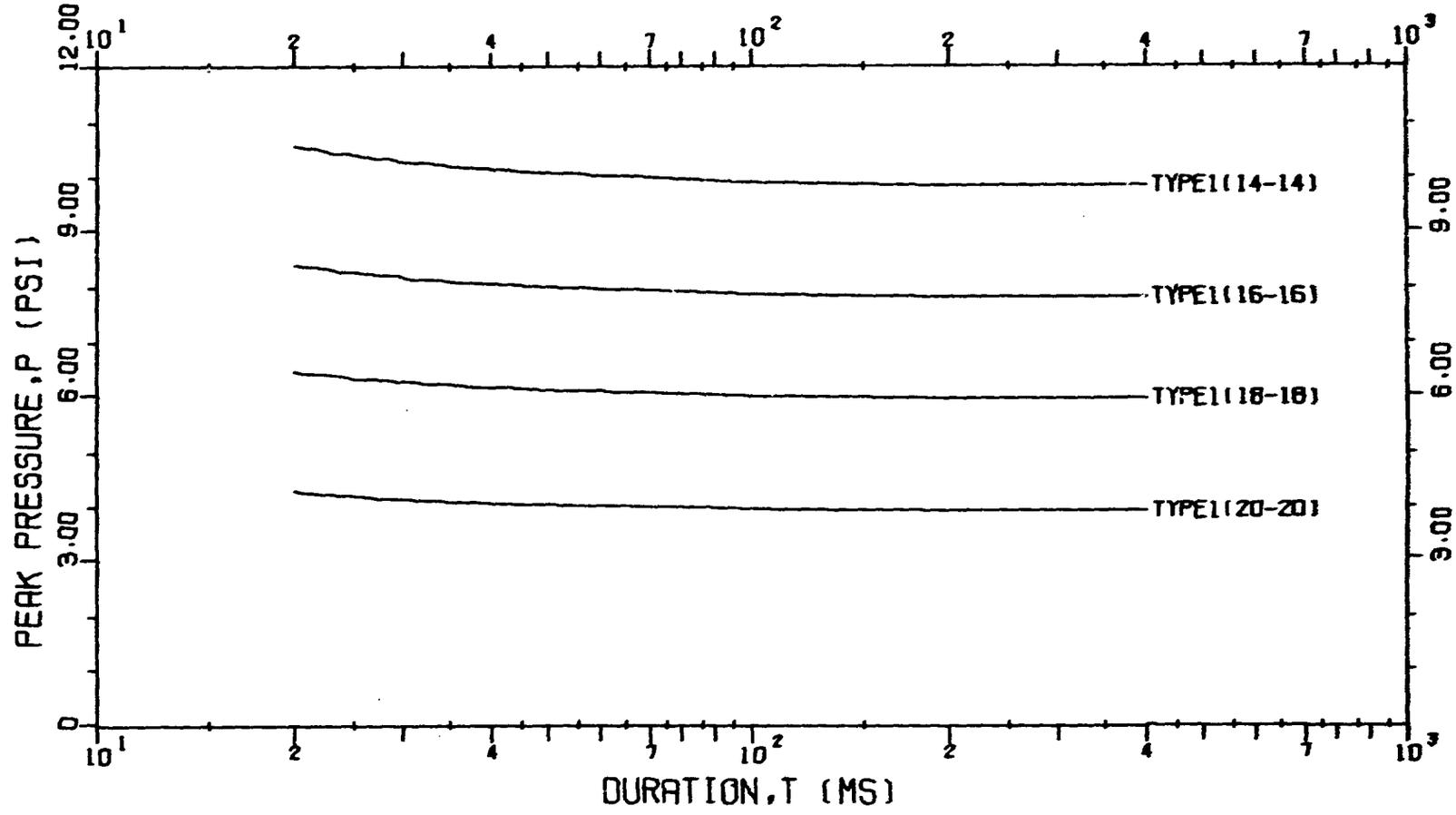


FIGURE 6

REUSABLE METAL DECKING,SPAN= 3.5 FT, MULTIPLE SPANS

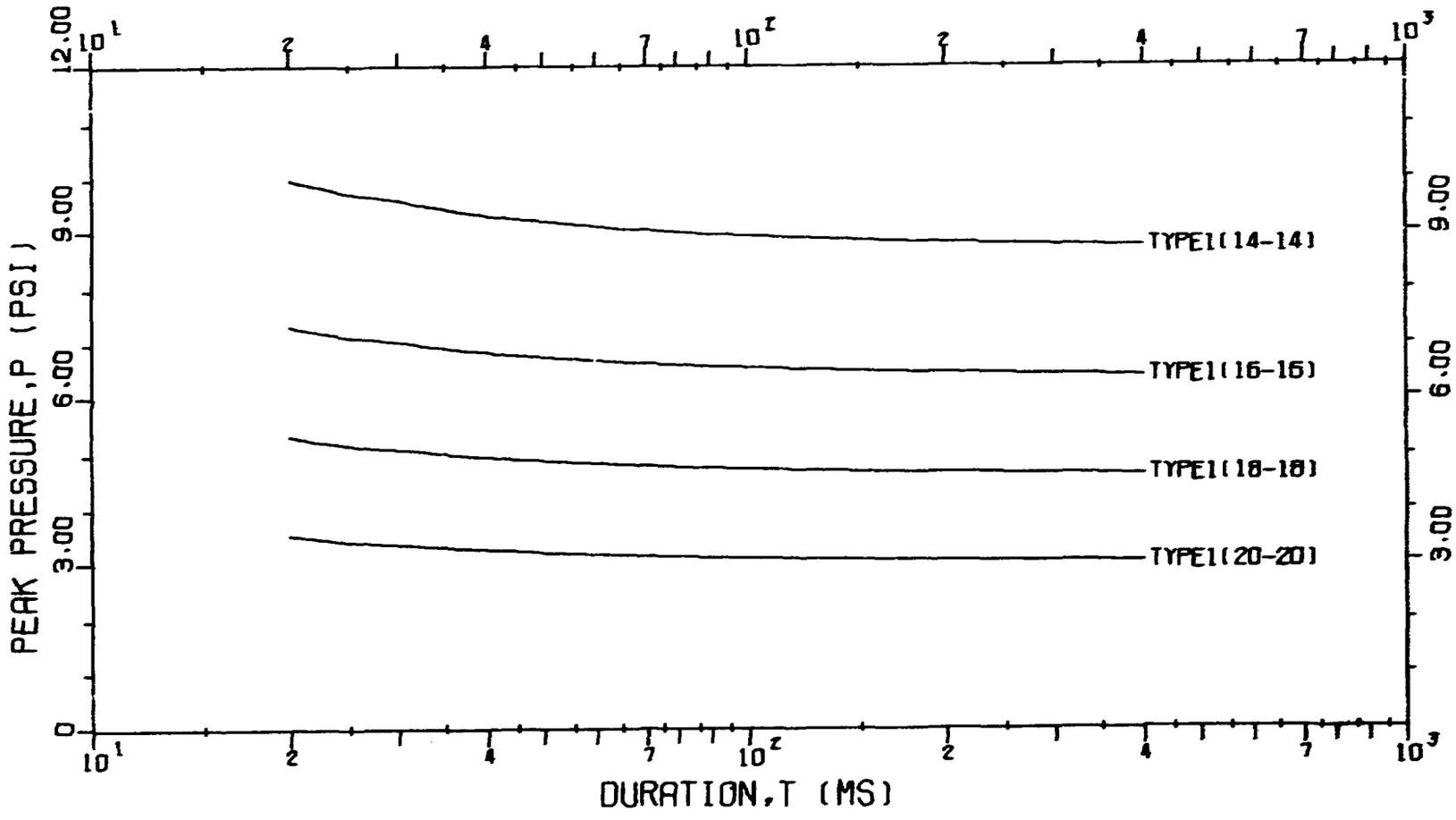


FIGURE 7

NON-REUSABLE METAL DECKING,SPAN= 3.5 FT,SIMPLY-SUPPORTED

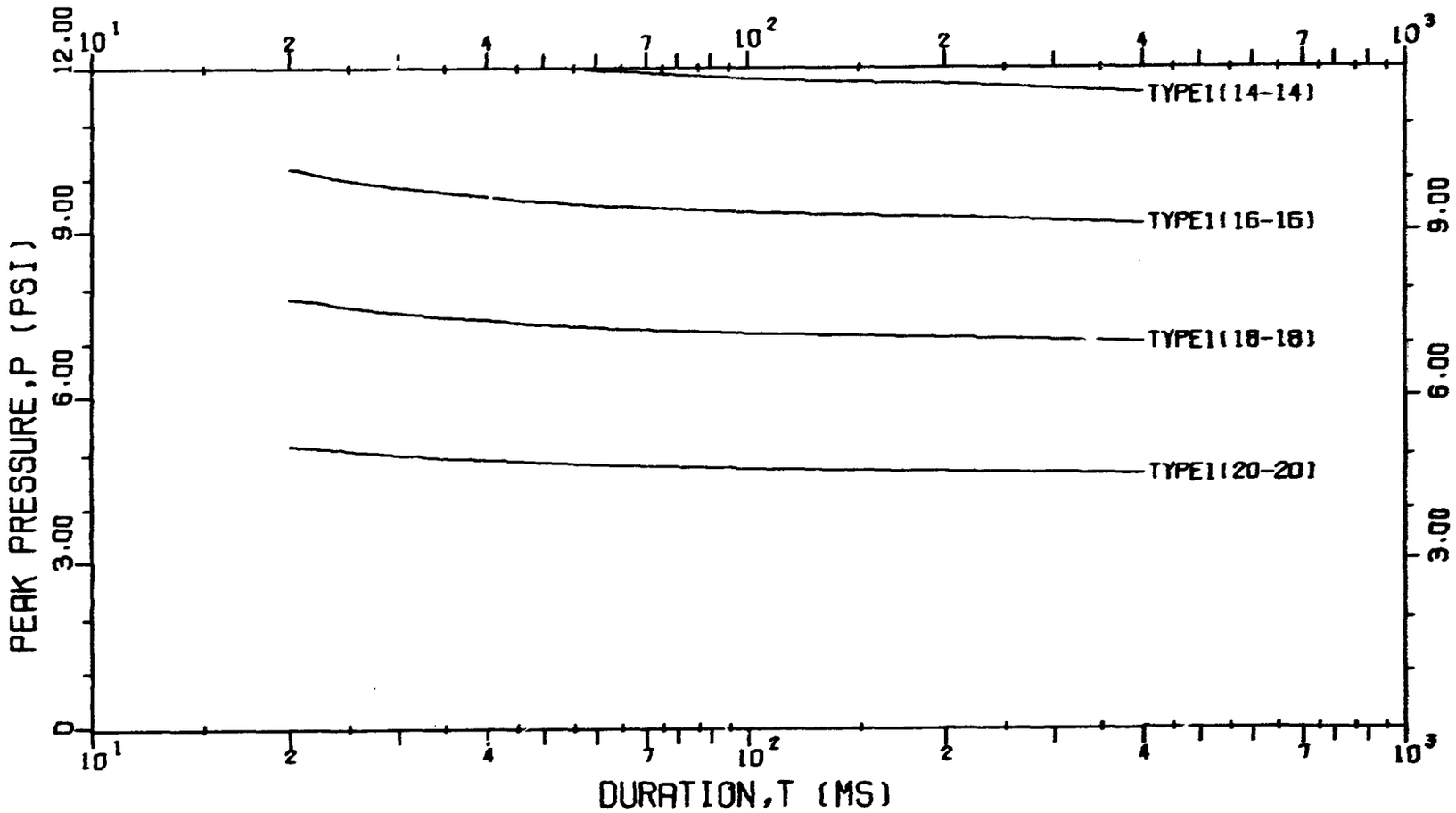


FIGURE 8

NON-REUSABLE METAL DECKING,SPAN= 3.5 FT,MULTIPLE SPANS

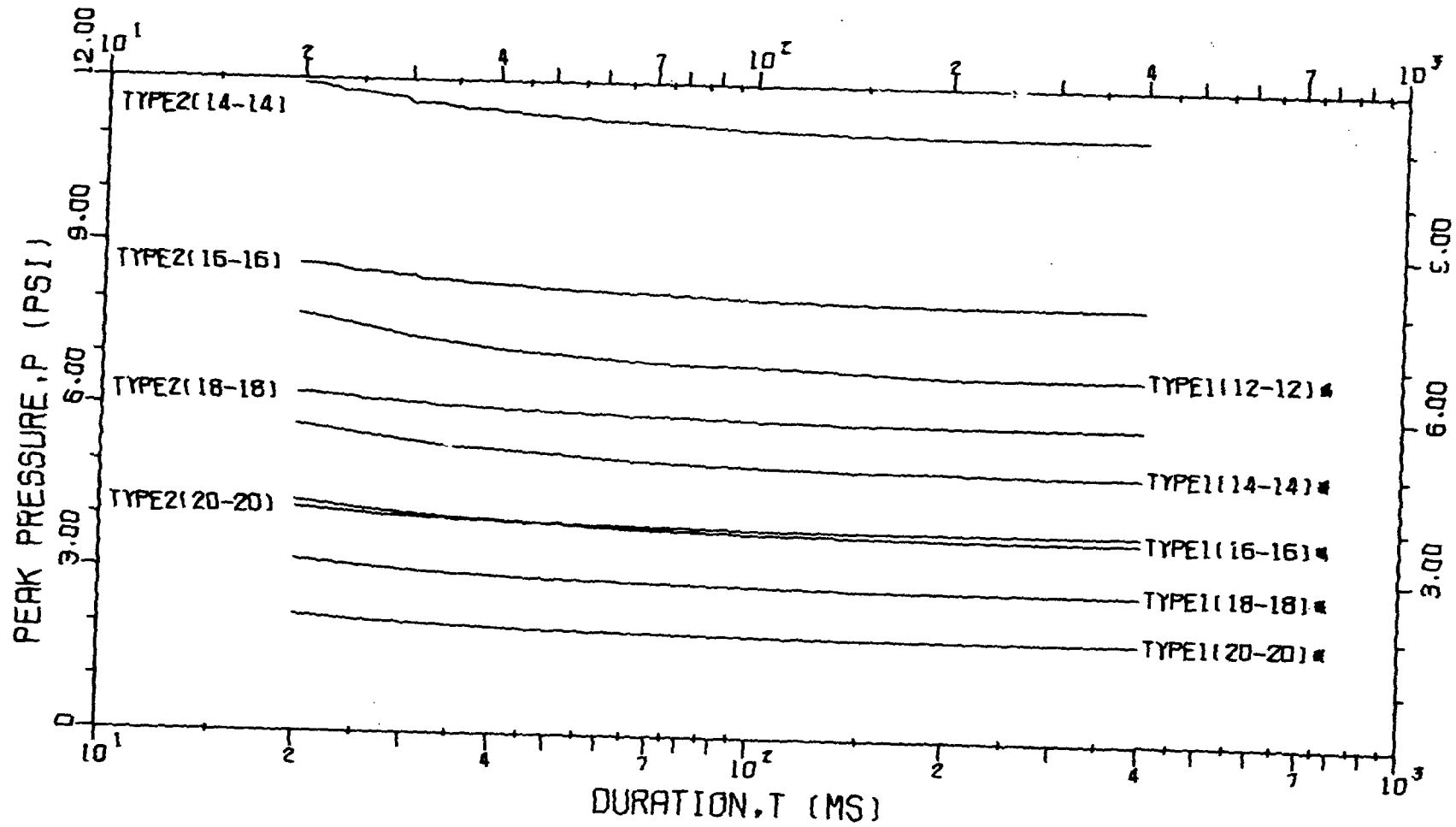


FIGURE 9

REUSABLE METAL DECKING,SPAN= 4.0 FT, SIMPLY-SUPPORTED

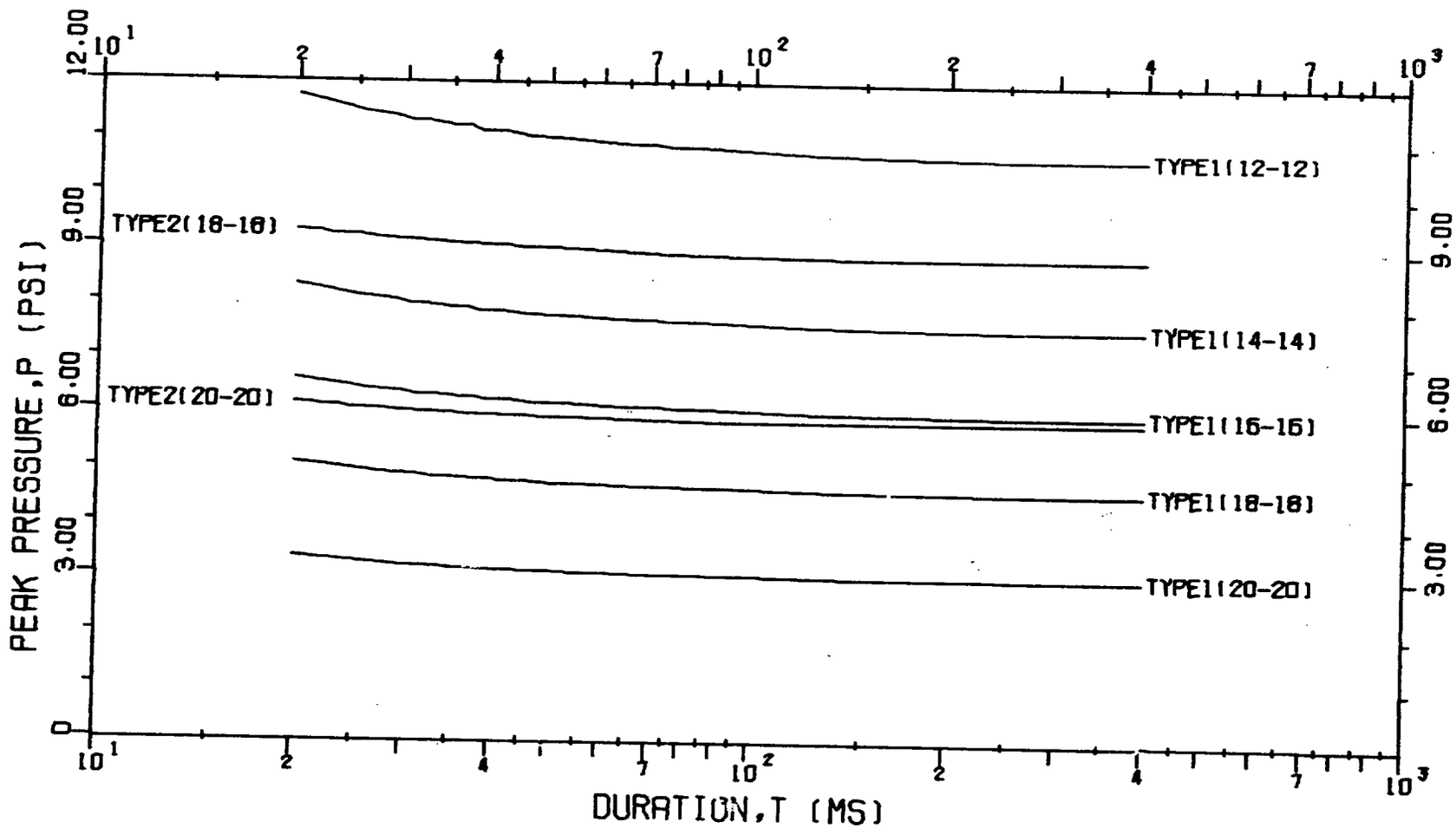


FIGURE 10

REUSABLE METAL DECKING,SPAN= 4.0 FT, MULTIPLE SPANS

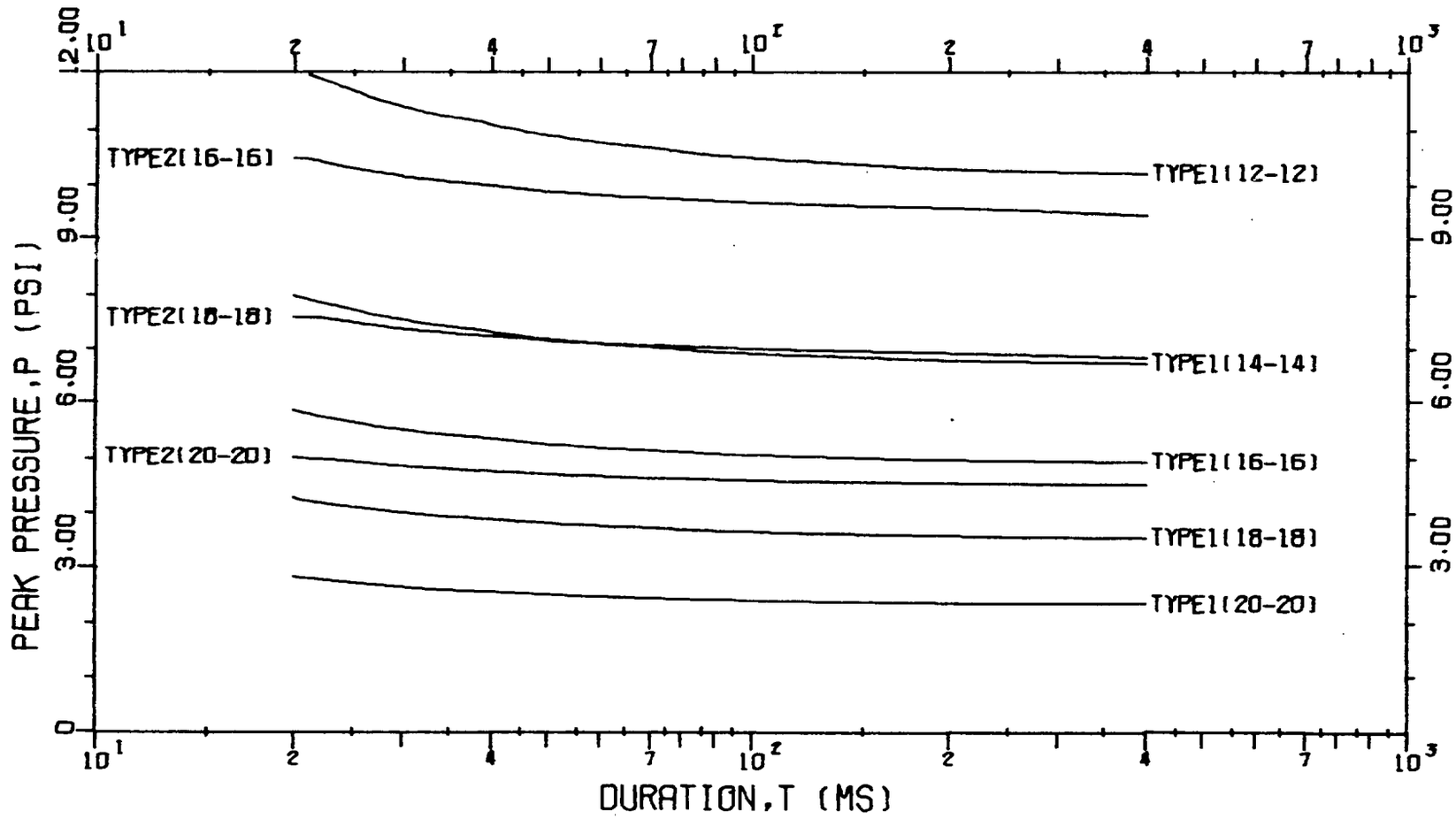


FIGURE 11

NON-REUSABLE METAL DECKING,SPAN= 4.0 FT,SIMPLY-SUPPORTED

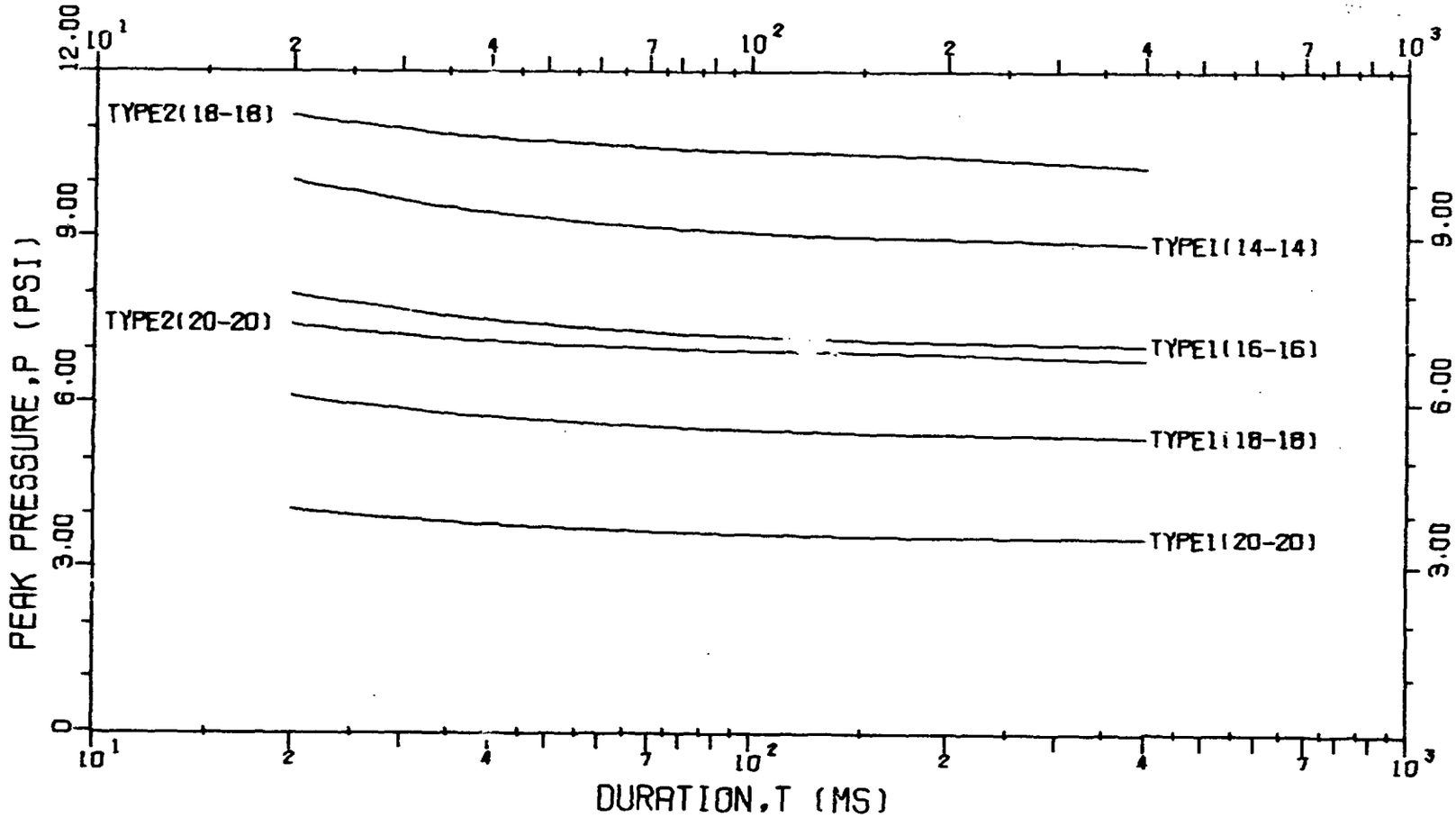


FIGURE 12

NON-REUSABLE METAL DECKING,SPAN= 4.0 FT,MULTIPLE SPANS

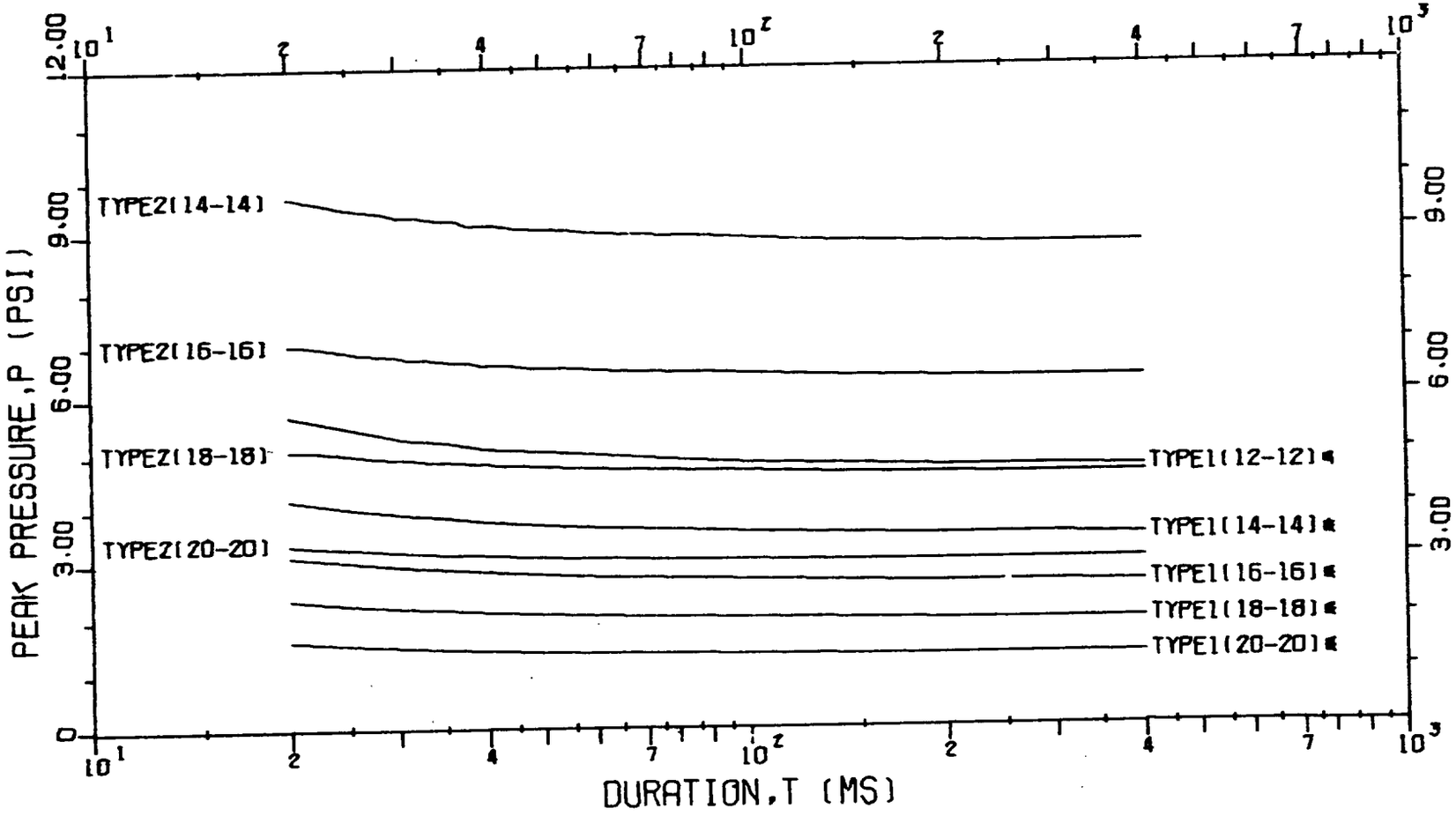


FIGURE 13

REUSABLE METAL DECKING,SPAN= 4.5 FT, SIMPLY-SUPPORTED

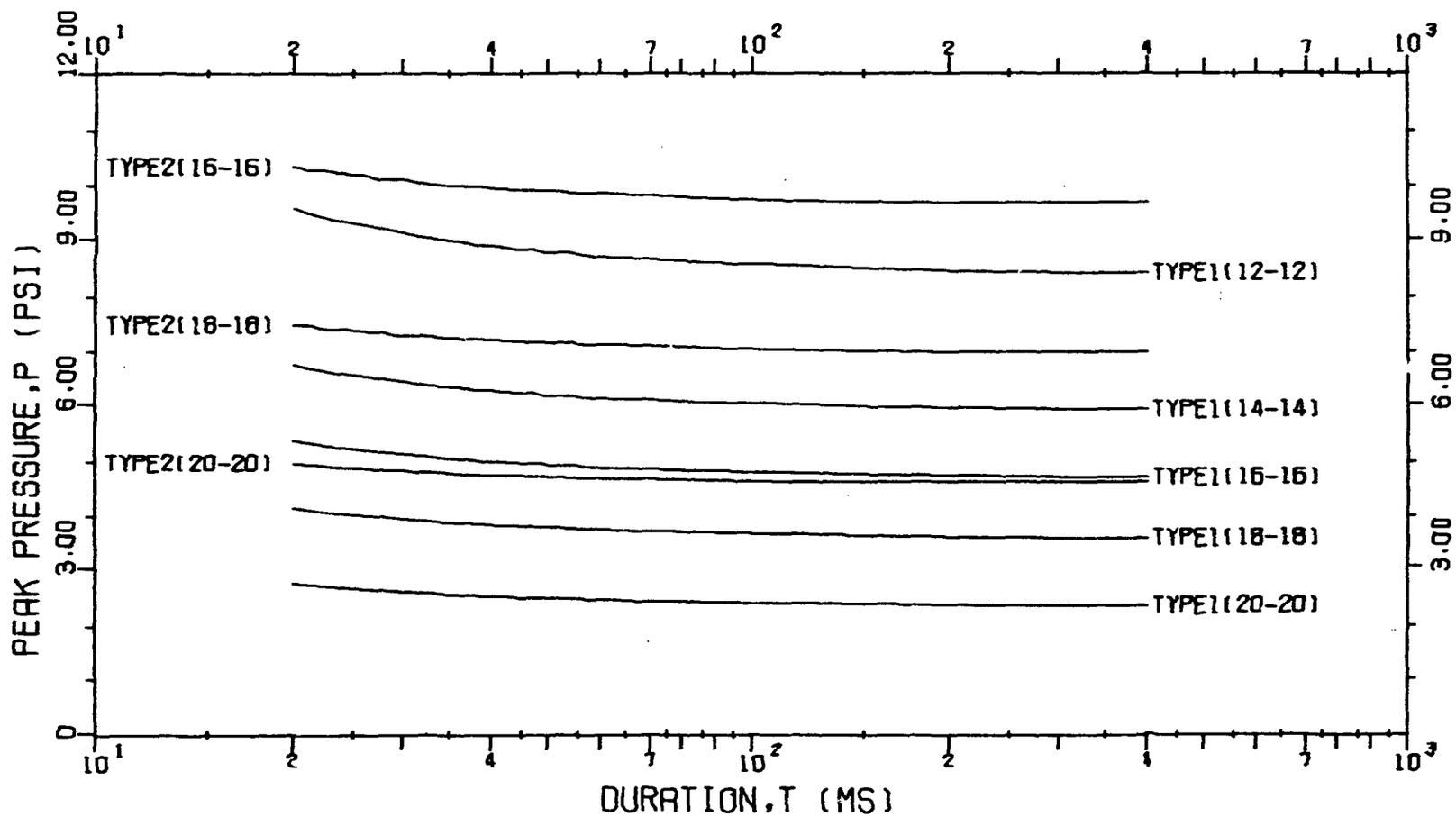


FIGURE 14

REUSABLE METAL DECKING,SPAN= 4.5 FT, MULTIPLE SPANS

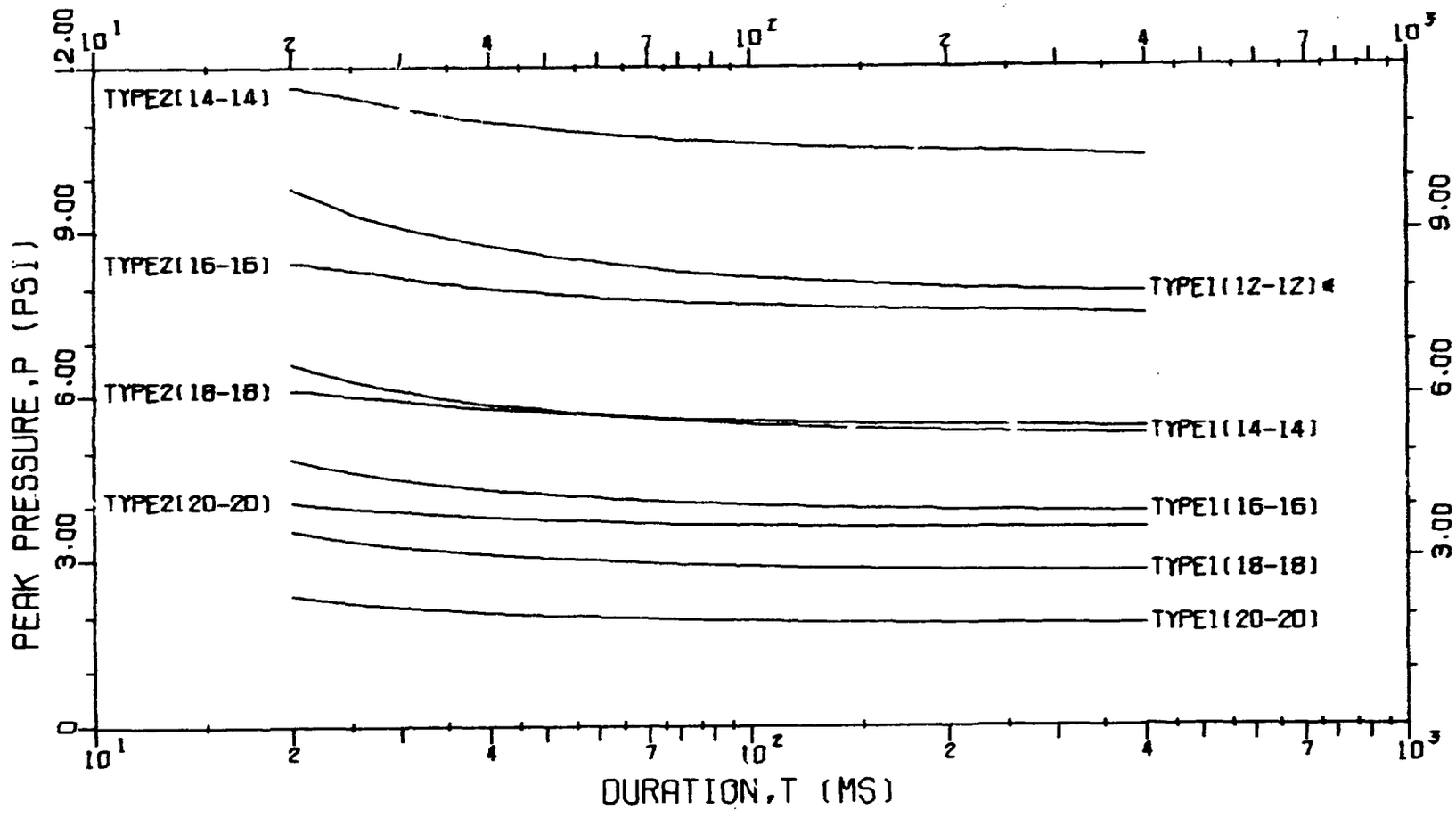


FIGURE 15

NON-REUSABLE METAL DECKING,SPAN= 4.5 FT,SIMPLY-SUPPORTED

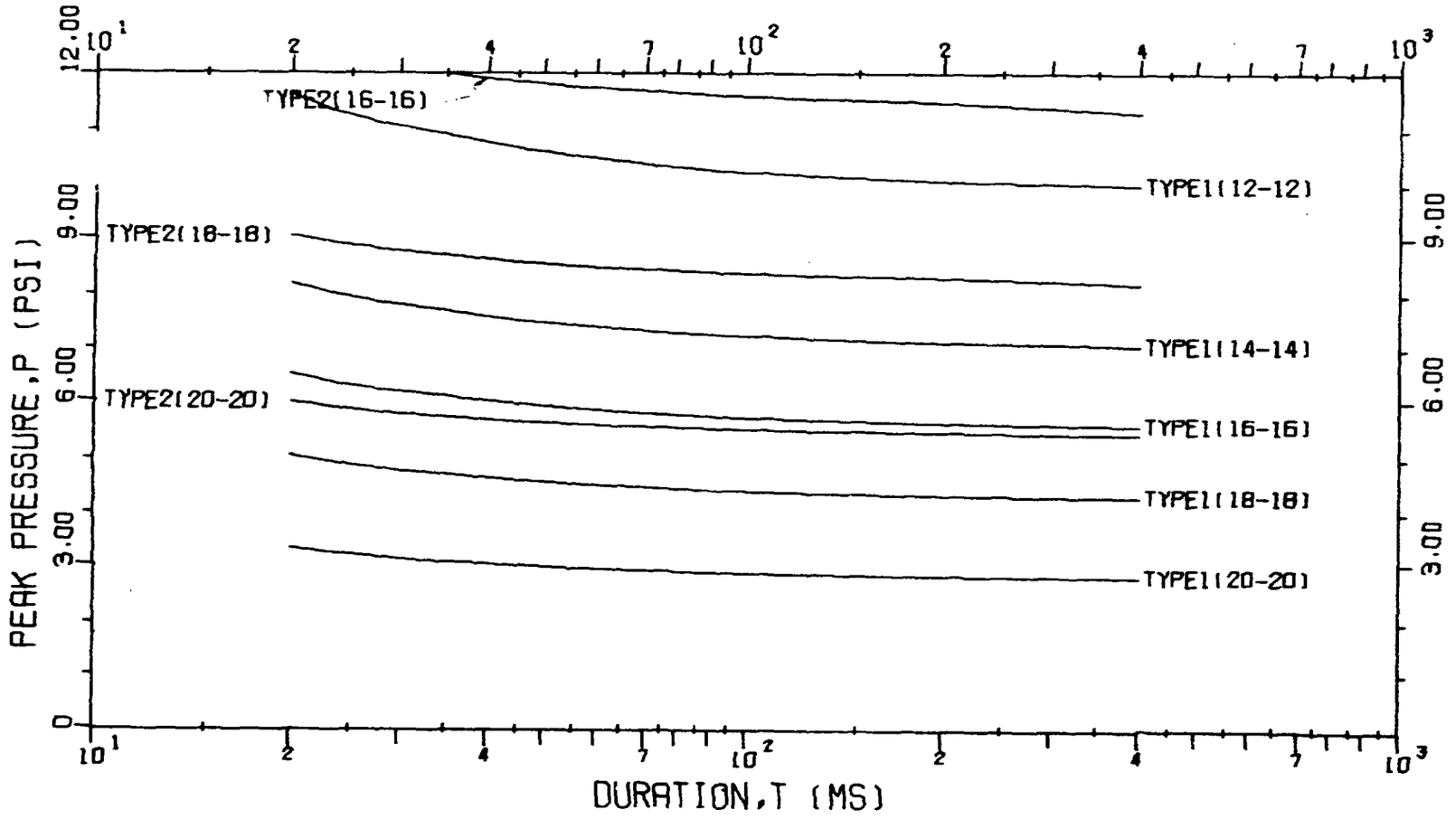


FIGURE 16

NON-REUSABLE METAL DECKING,SPAN= 4.5 FT,MULTIPLE SPANS

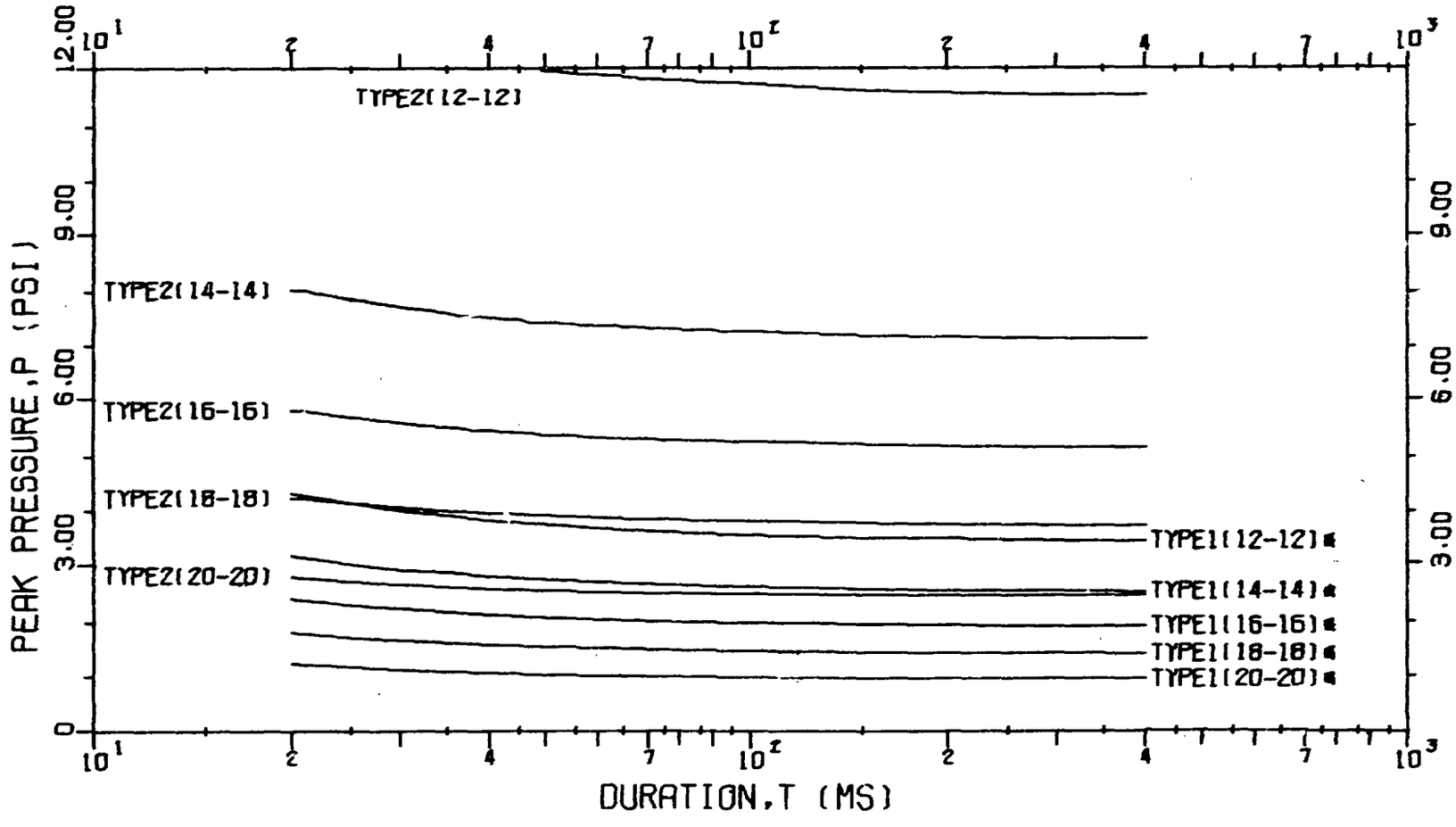


FIGURE 17

REUSABLE METAL DECKING,SPAN= 5.0 FT, SIMPLY-SUPPORTED

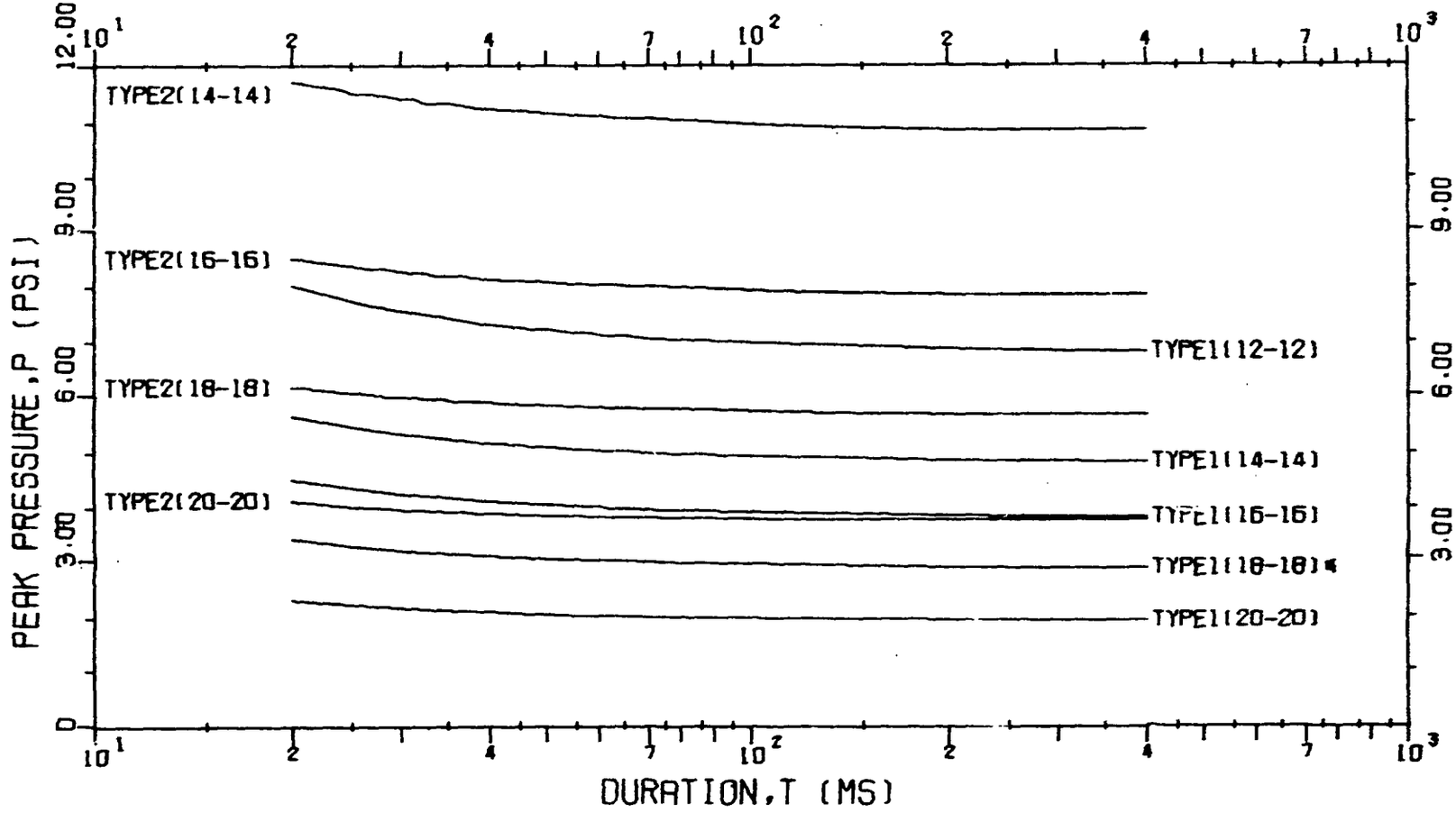


FIGURE 18

REUSABLE METAL DECKING,SPAN= 5.0 FT, MULTIPLE SPANS

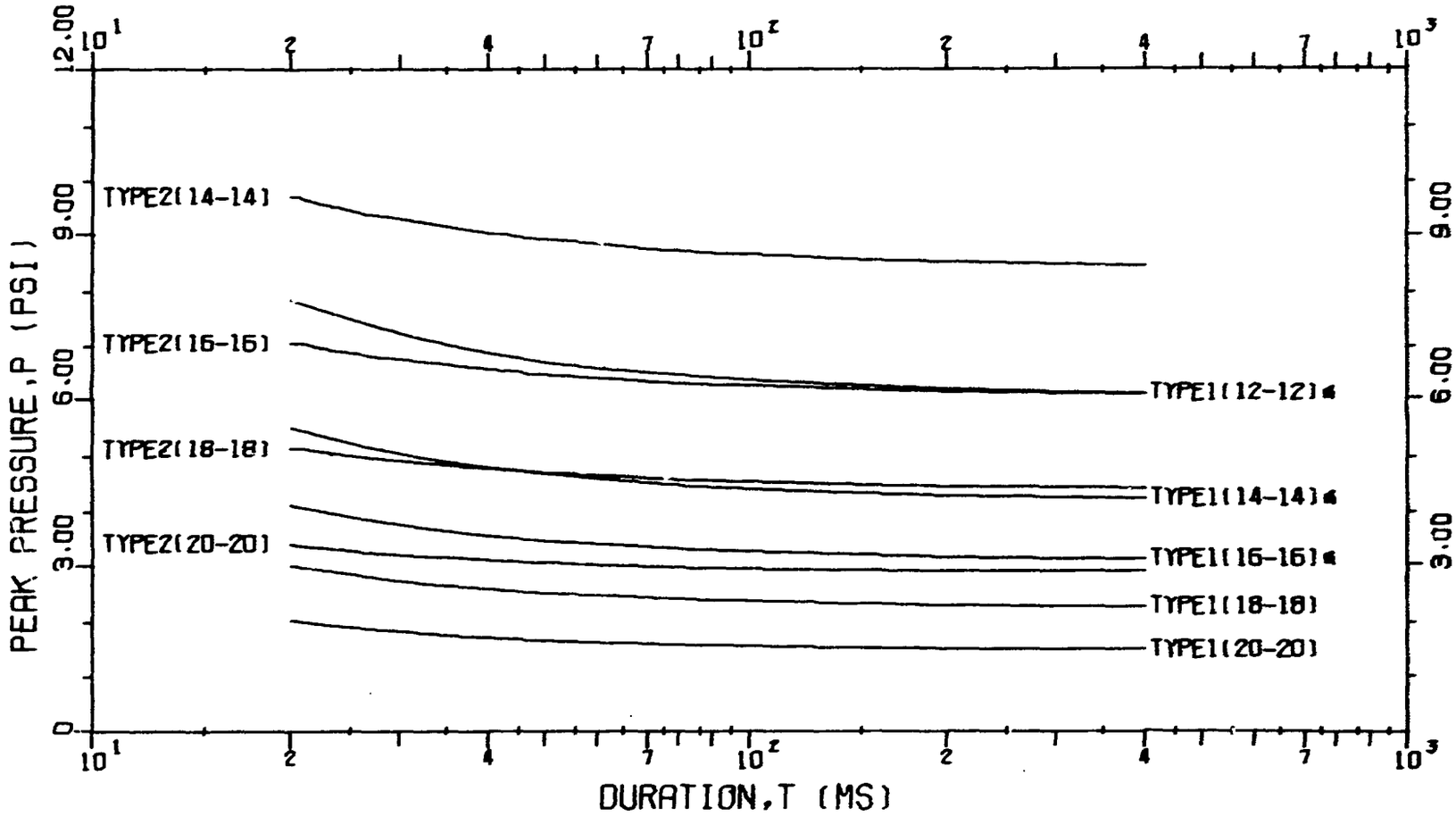


FIGURE 19

NON-REUSABLE METAL DECKING,SPAN= 5.0 FT,SIMPLY-SUPPORTED

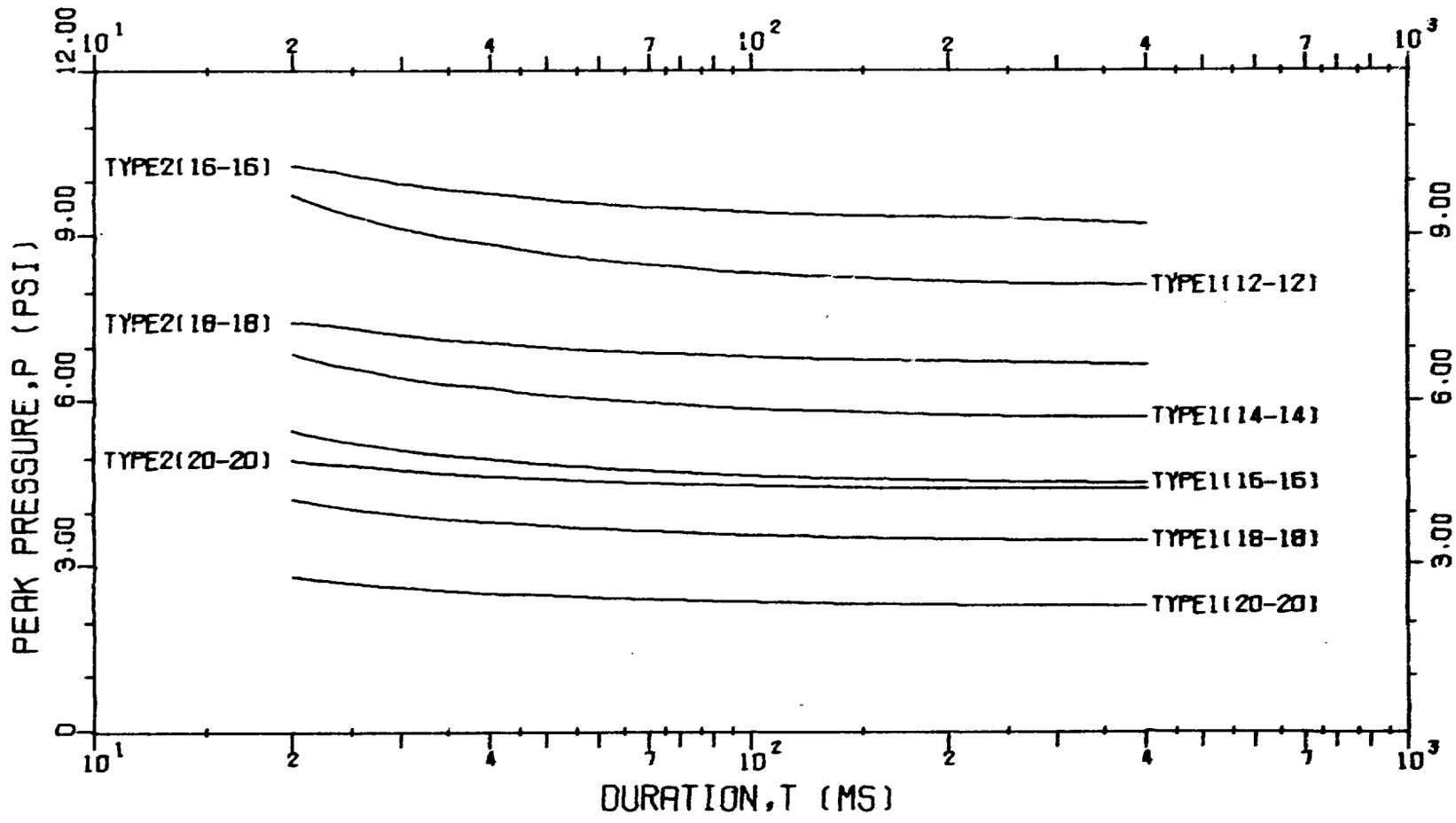


FIGURE 20

NON-REUSABLE METAL DECKING,SPAN= 5.0 FT,MULTIPLE SPANS

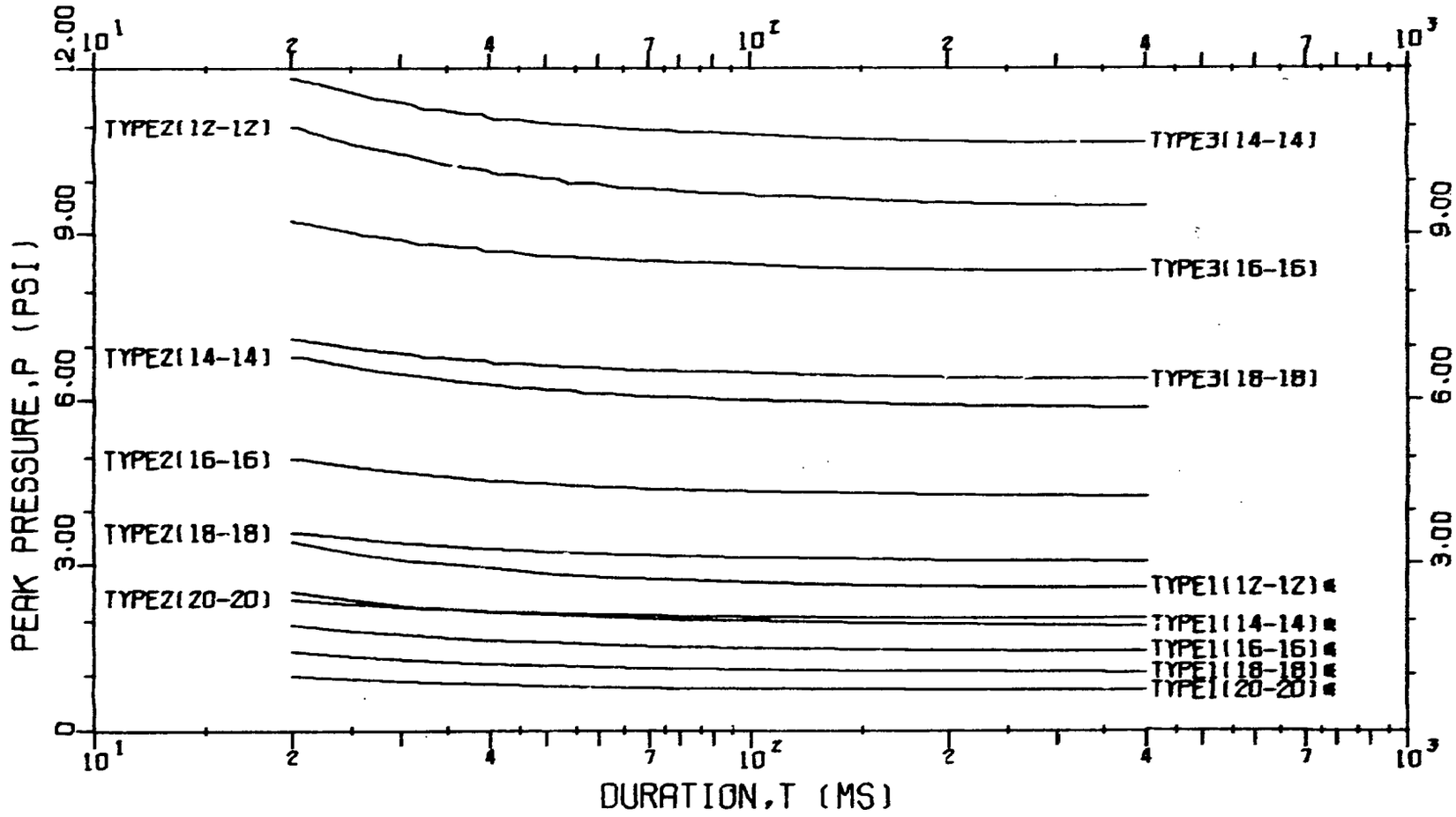


FIGURE 21

REUSABLE METAL DECKING,SPAN= 5.5 FT, SIMPLY-SUPPORTED

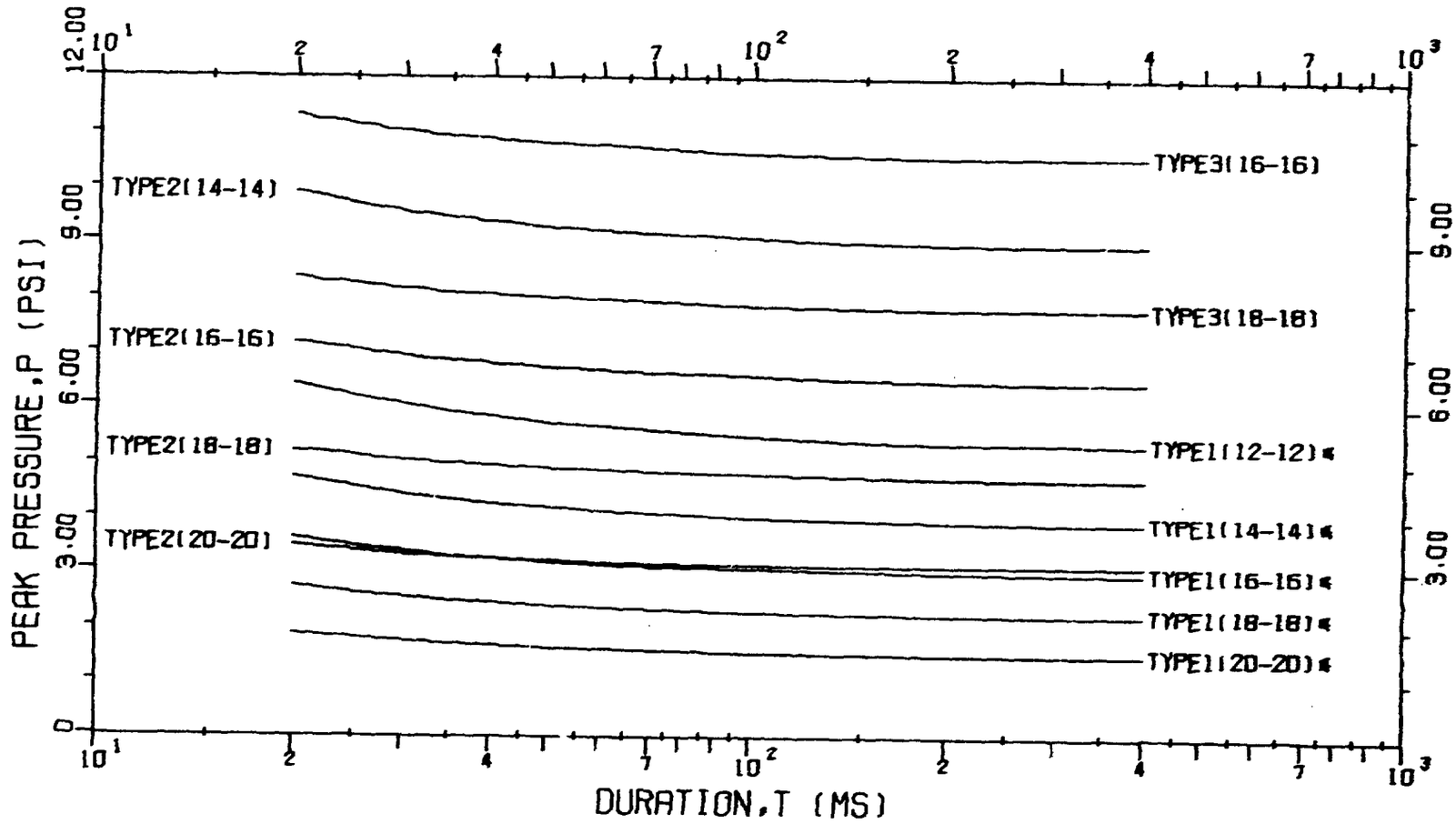


FIGURE 22

REUSABLE METAL DECKING,SPAN=5.5 FT, MULTIPLE SPANS

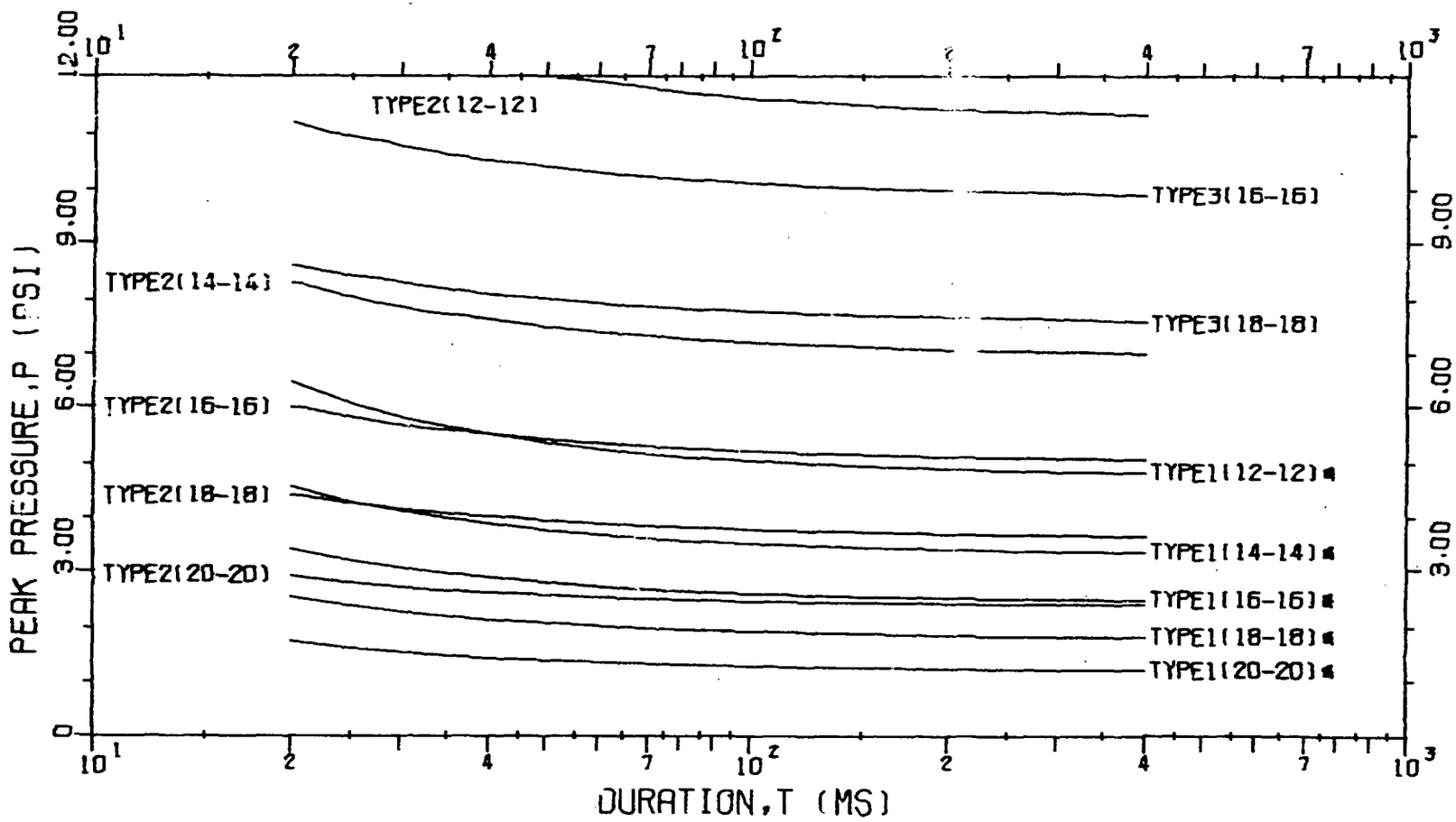


FIGURE 23

NON-REUSABLE METAL DECKING,SPAN= 5.5 FT,SIMPLY-SUPPORTED

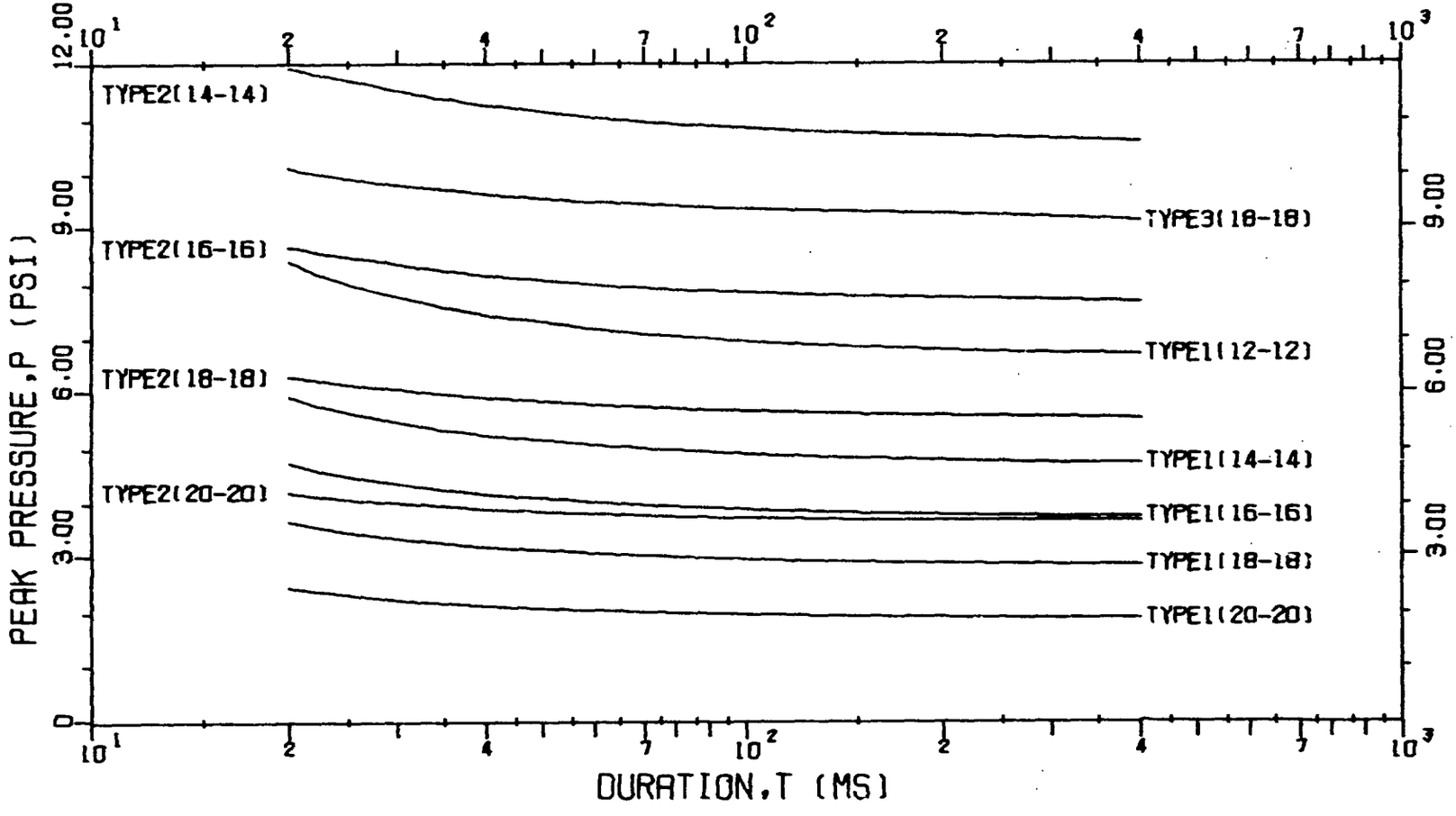


FIGURE 24

NON-REUSABLE METAL DECKING,SPAN= 5.5 FT,MULTIPLE SPANS

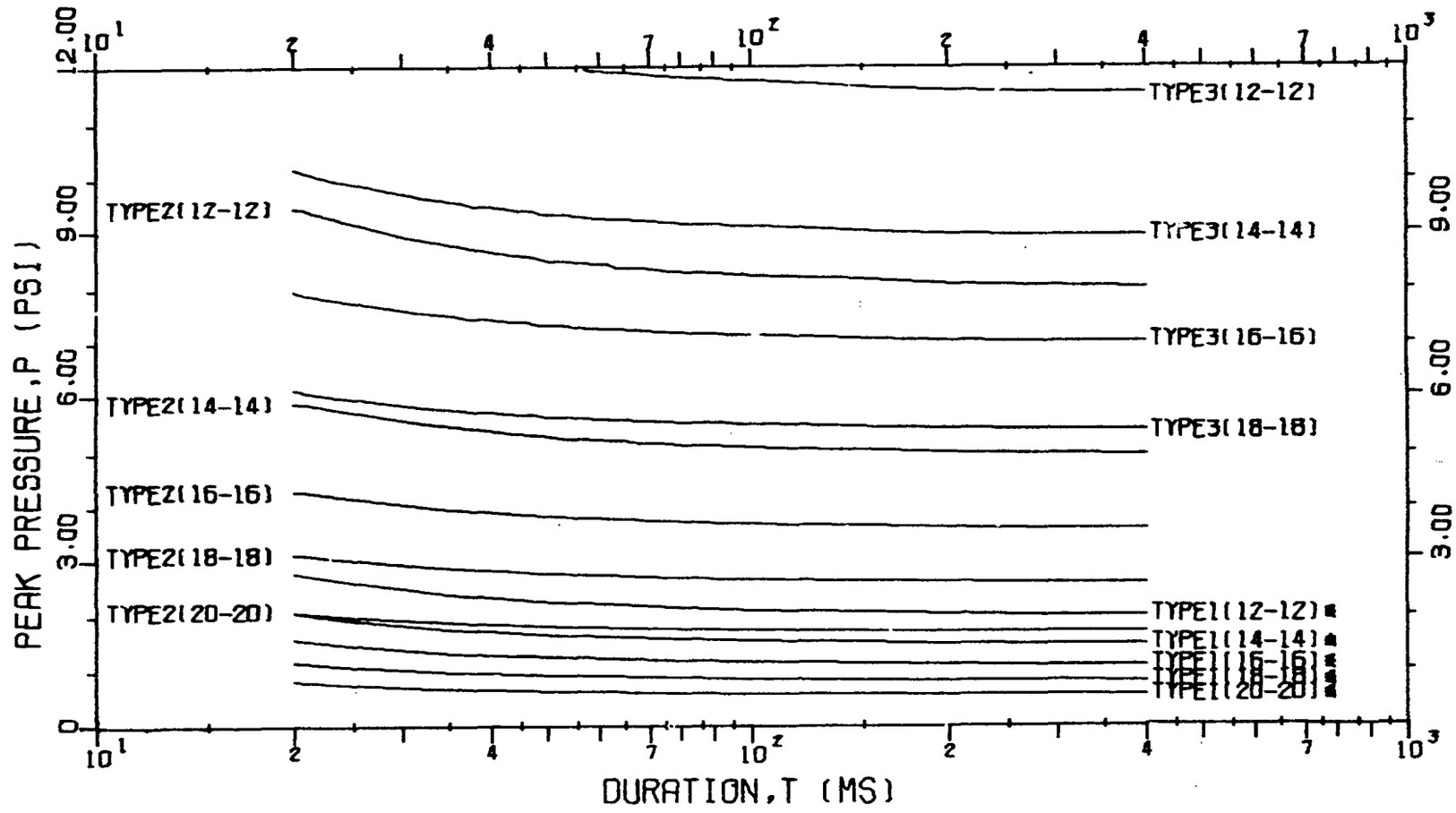


FIGURE 25

REUSABLE METAL DECKING,SPAN= 6.0 FT, SIMPLY-SUPPORTED

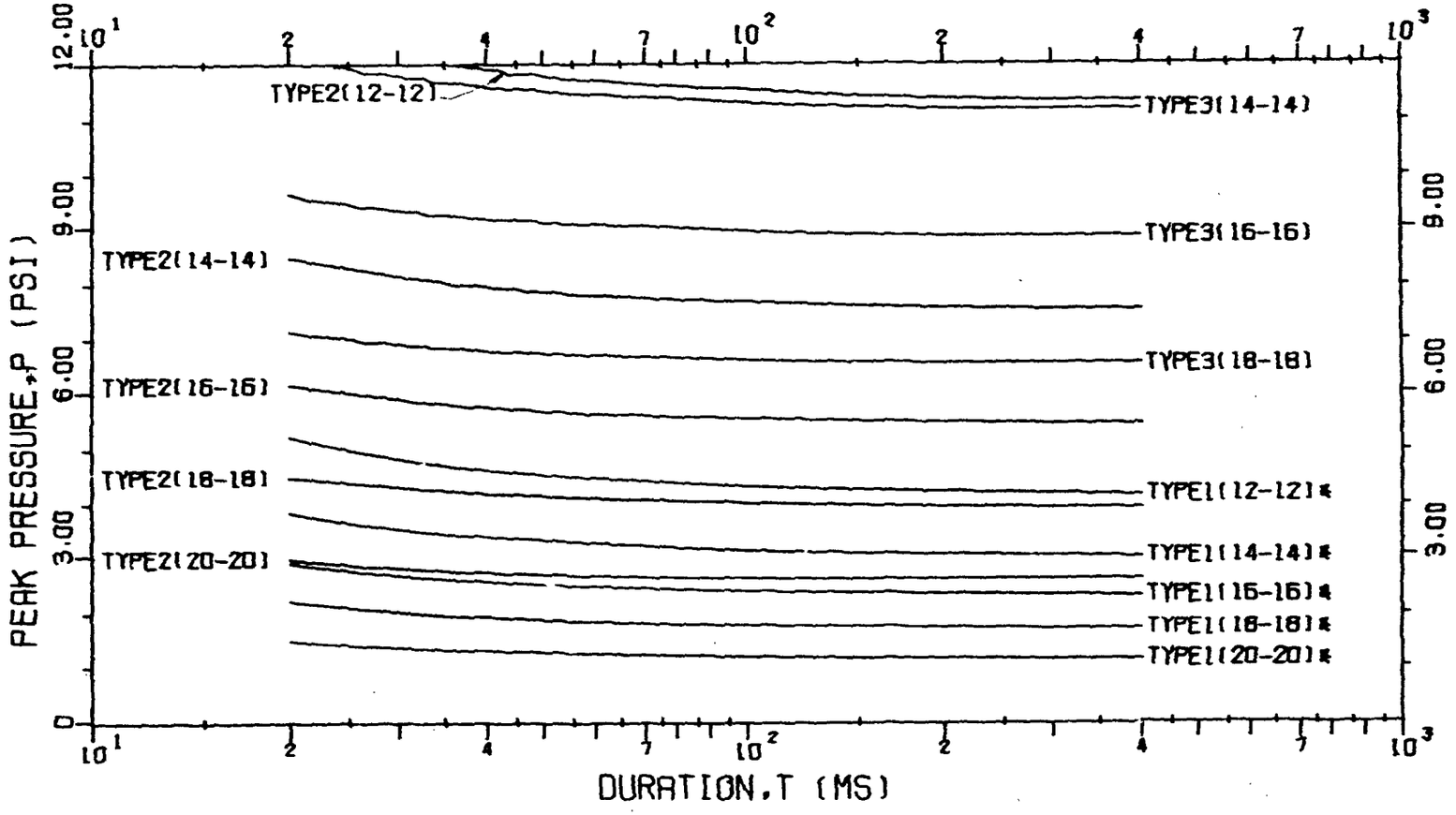


FIGURE 26

REUSABLE METAL DECKING,SPAN=6.0 FT, MULTIPLE SPANS

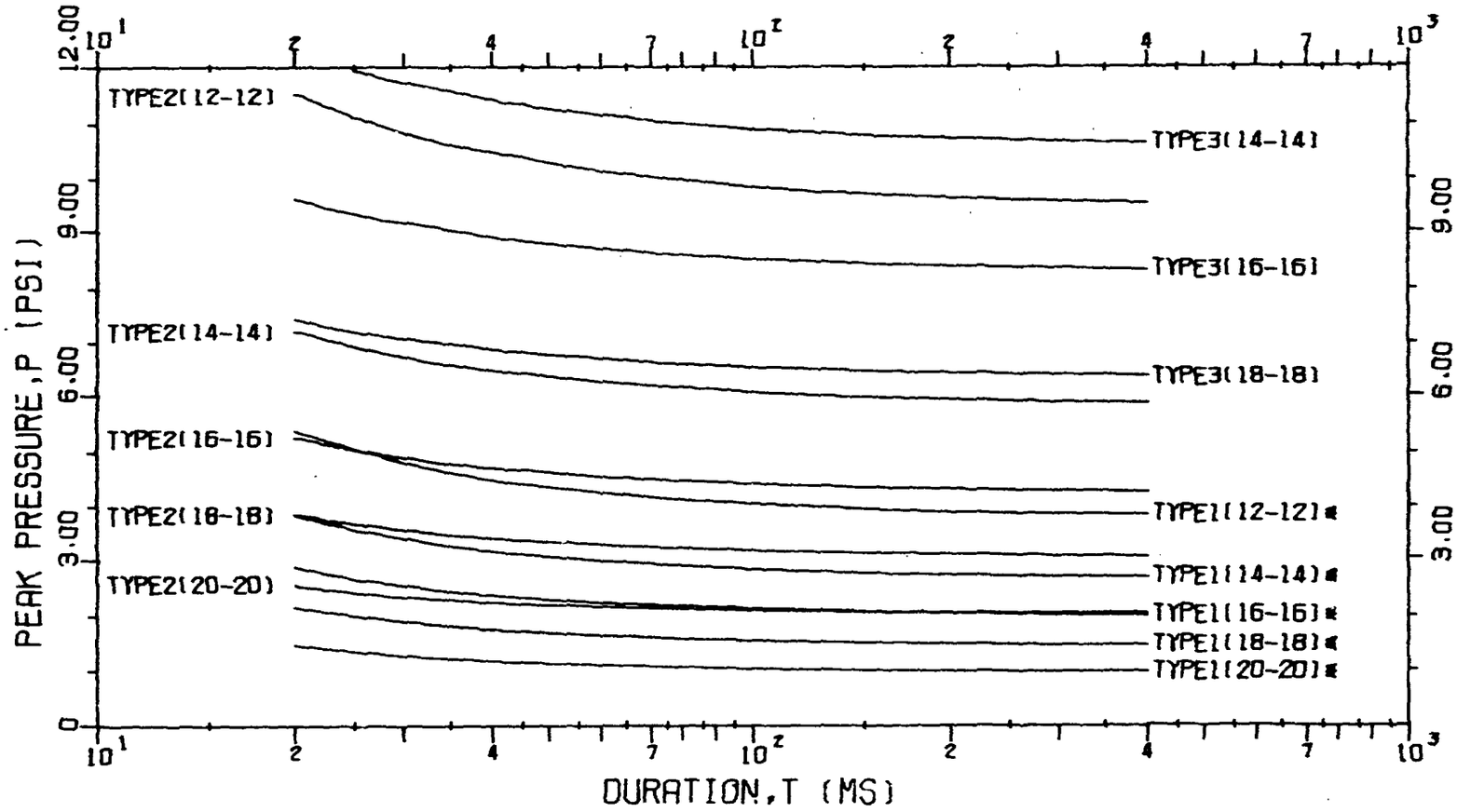


FIGURE 27

NON-REUSABLE METAL DECKING,SPAN= 5.0 FT,SIMPLY-SUPPORTED

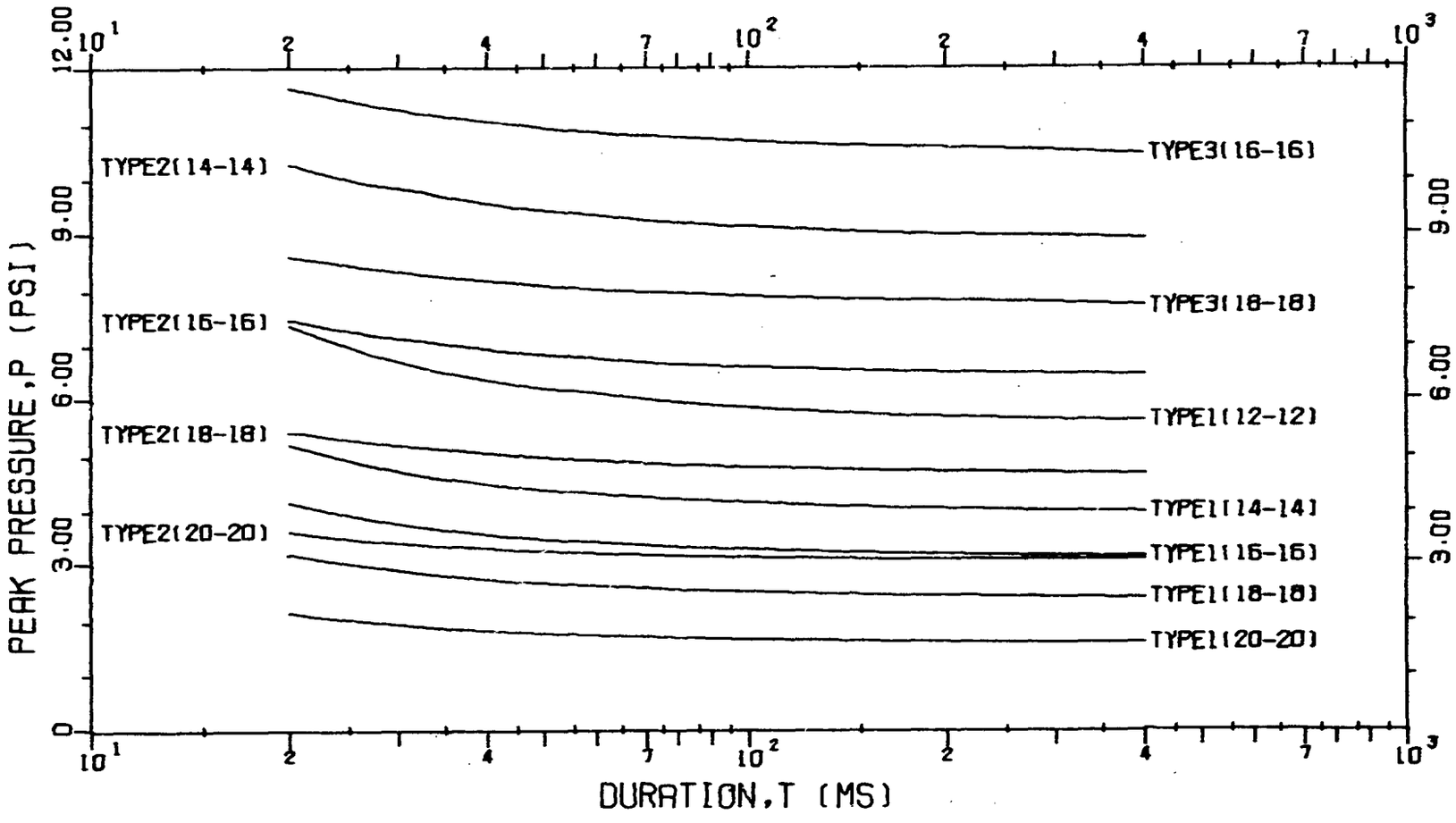


FIGURE 28

NON-REUSABLE METAL DECKING,SPAN= 6.0 FT,MULTIPLE SPANS

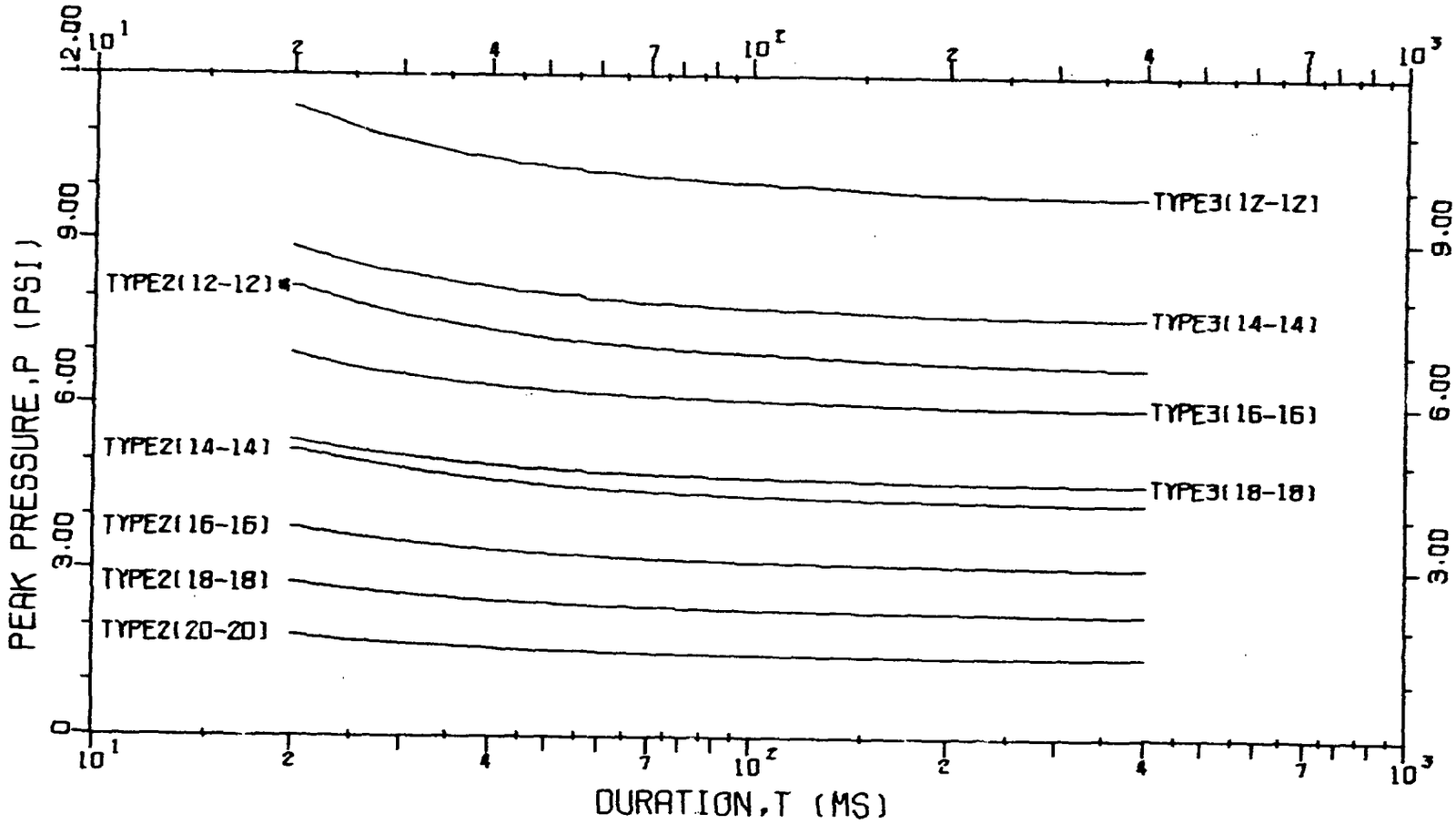


FIGURE 29

REUSABLE METAL DECKING,SPAN= 6.5 FT, SIMPLY-SUPPORTED

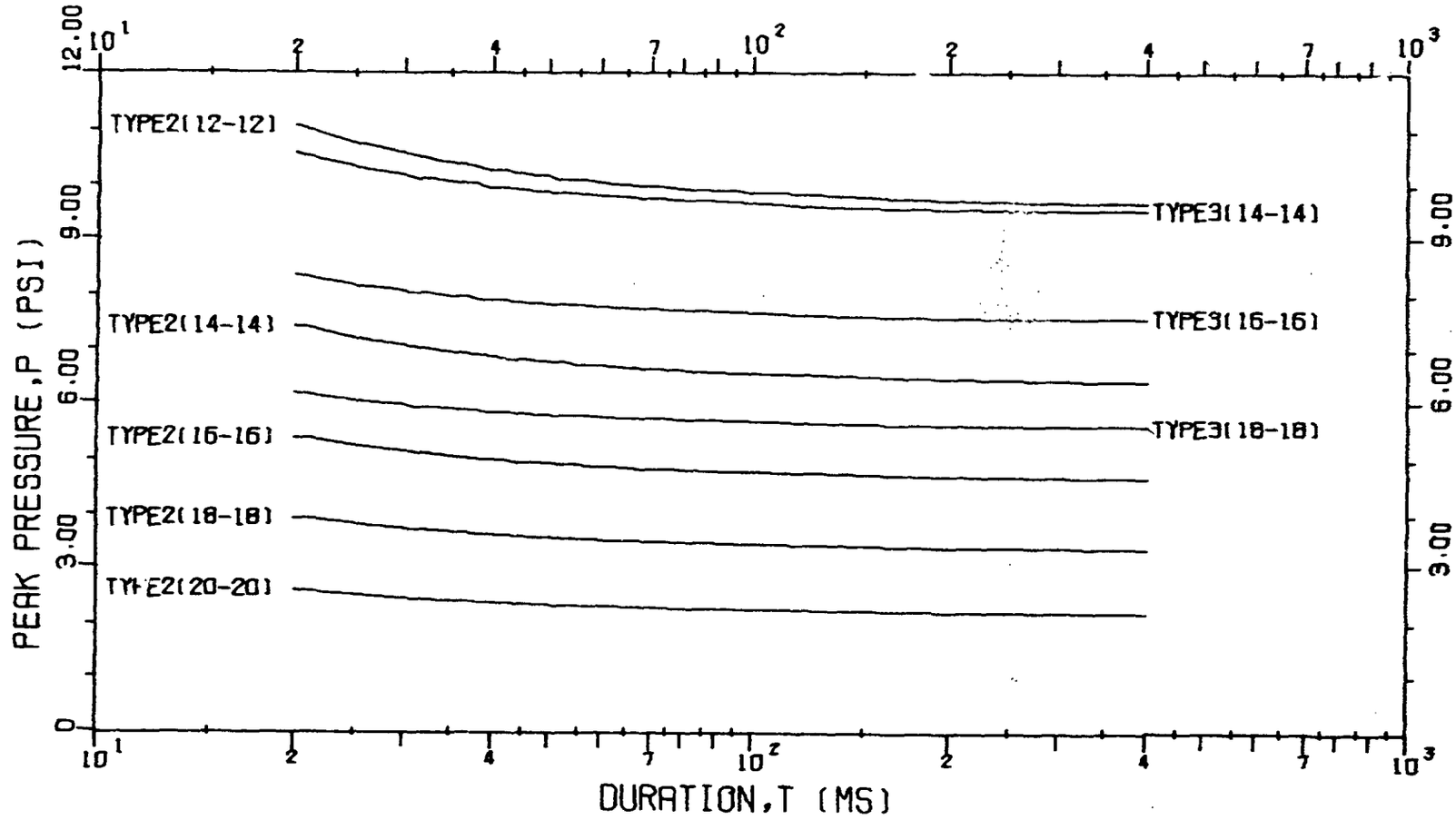


FIGURE 30

REUSABLE METAL DECKING,SPAN= 6.5 FT, MULTIPLE SPANS

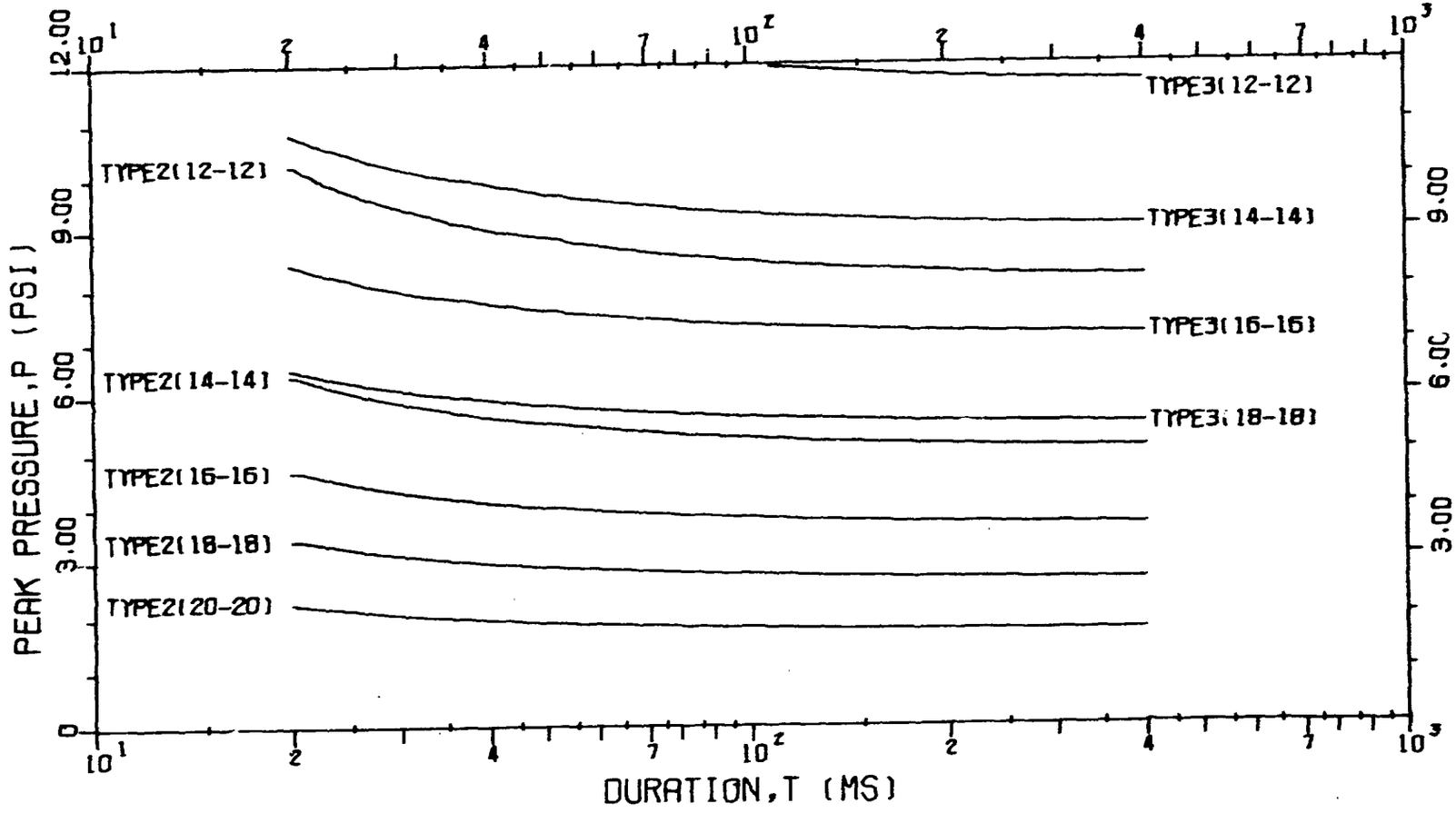


FIGURE 31

NON-REUSABLE METAL DECKING,SPAN= 6.5 FT, SIMPLY-SUPPORTED

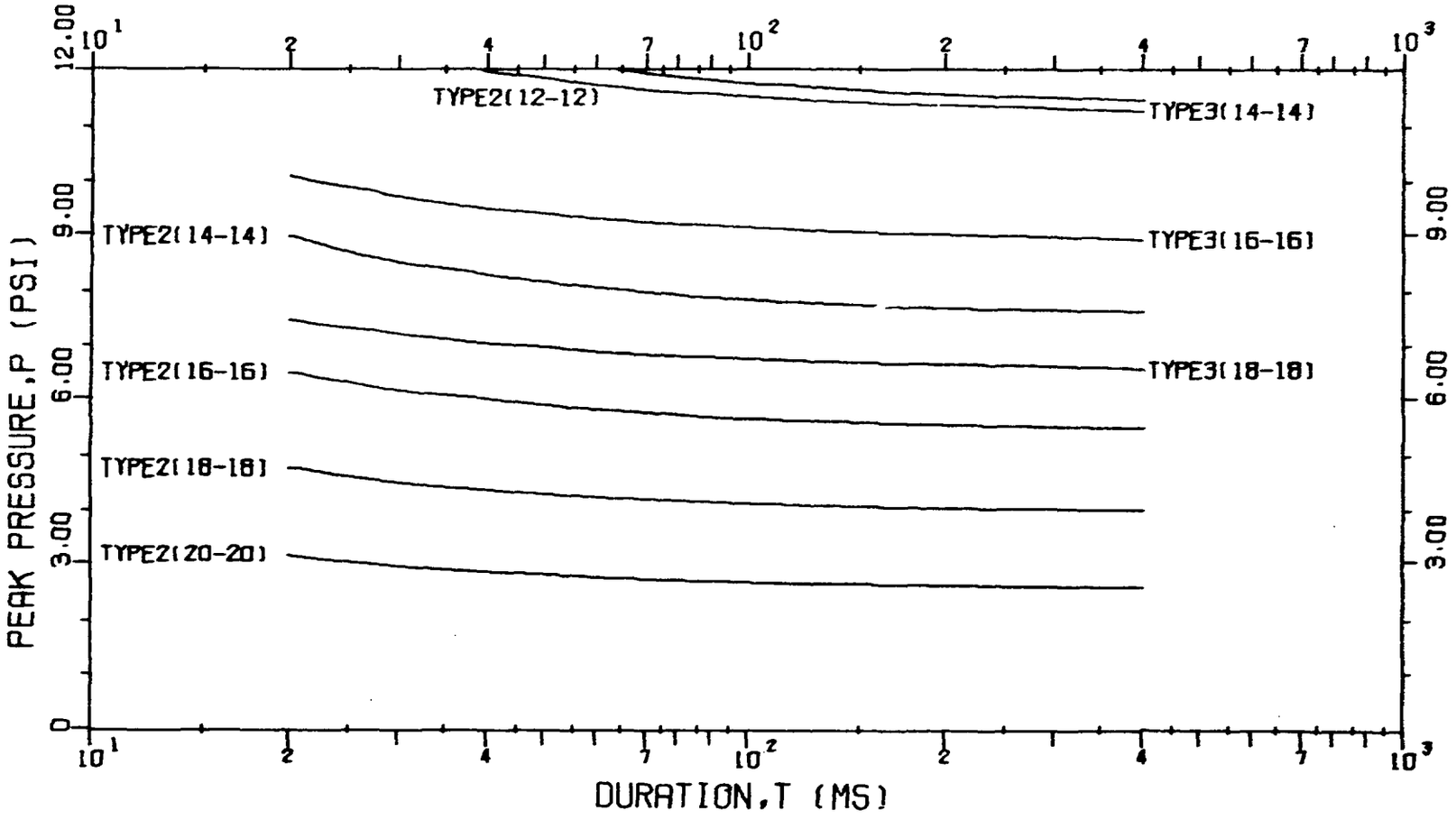


FIGURE 32

NON-REUSABLE METAL DECKING,SPAN= 6.5 FT,MULTIPLE SPANS

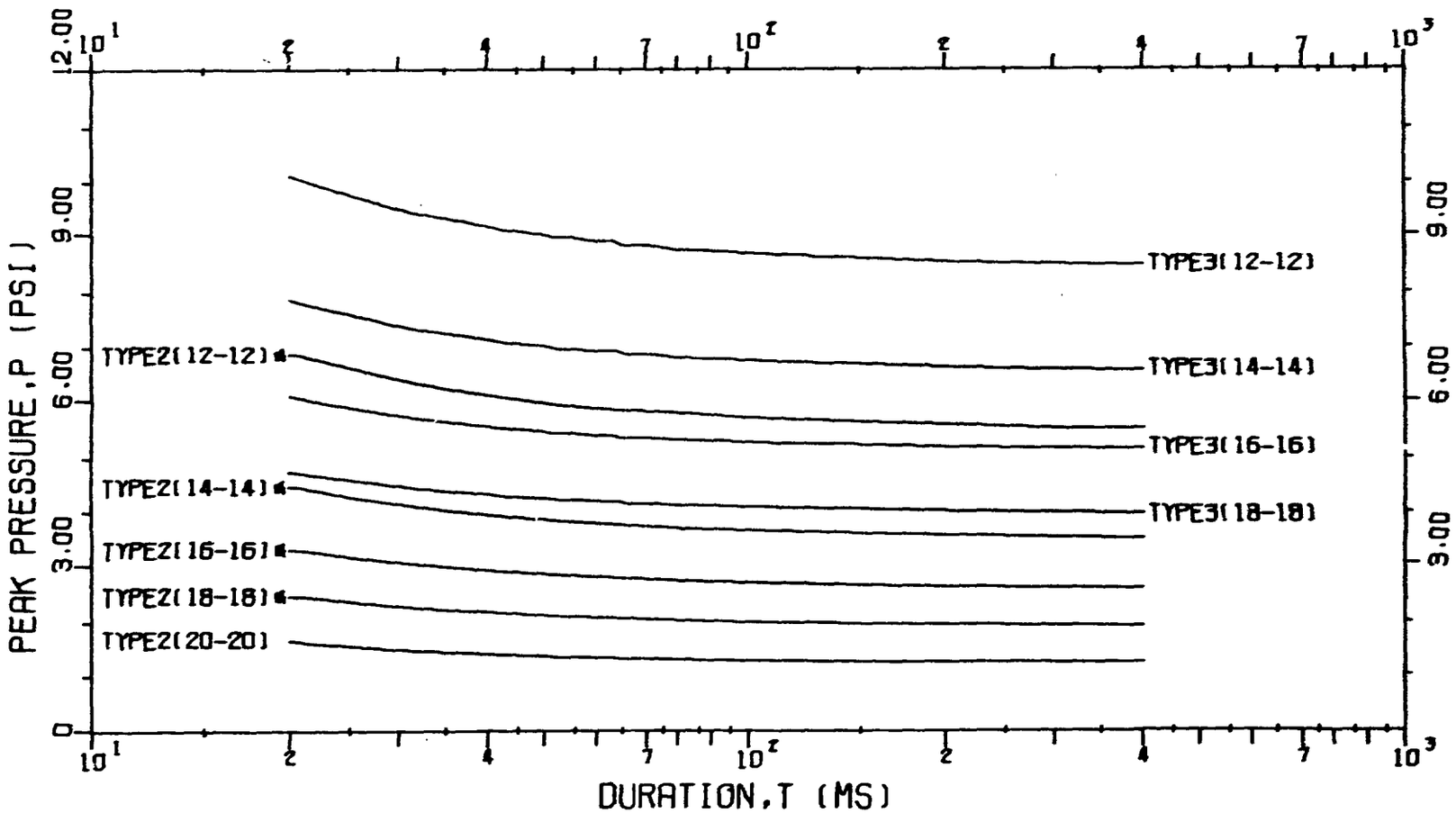


FIGURE 33

REUSABLE METAL DECKING,SPAN= 7.0 FT, SIMPLY-SUPPORTED

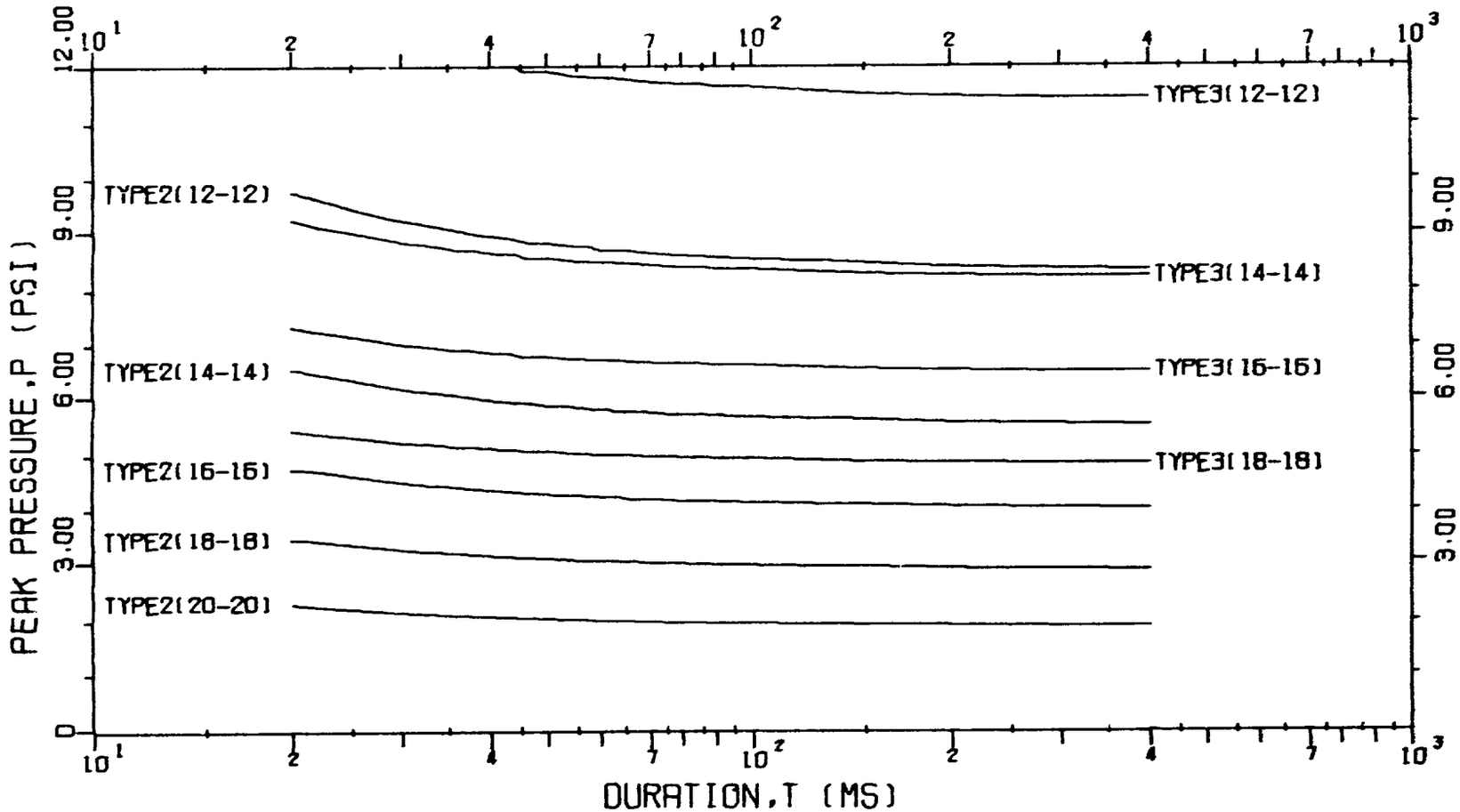


FIGURE 34

REUSABLE METAL DECKING,SPAN= 7.0 FT, MULTIPLE SPANS

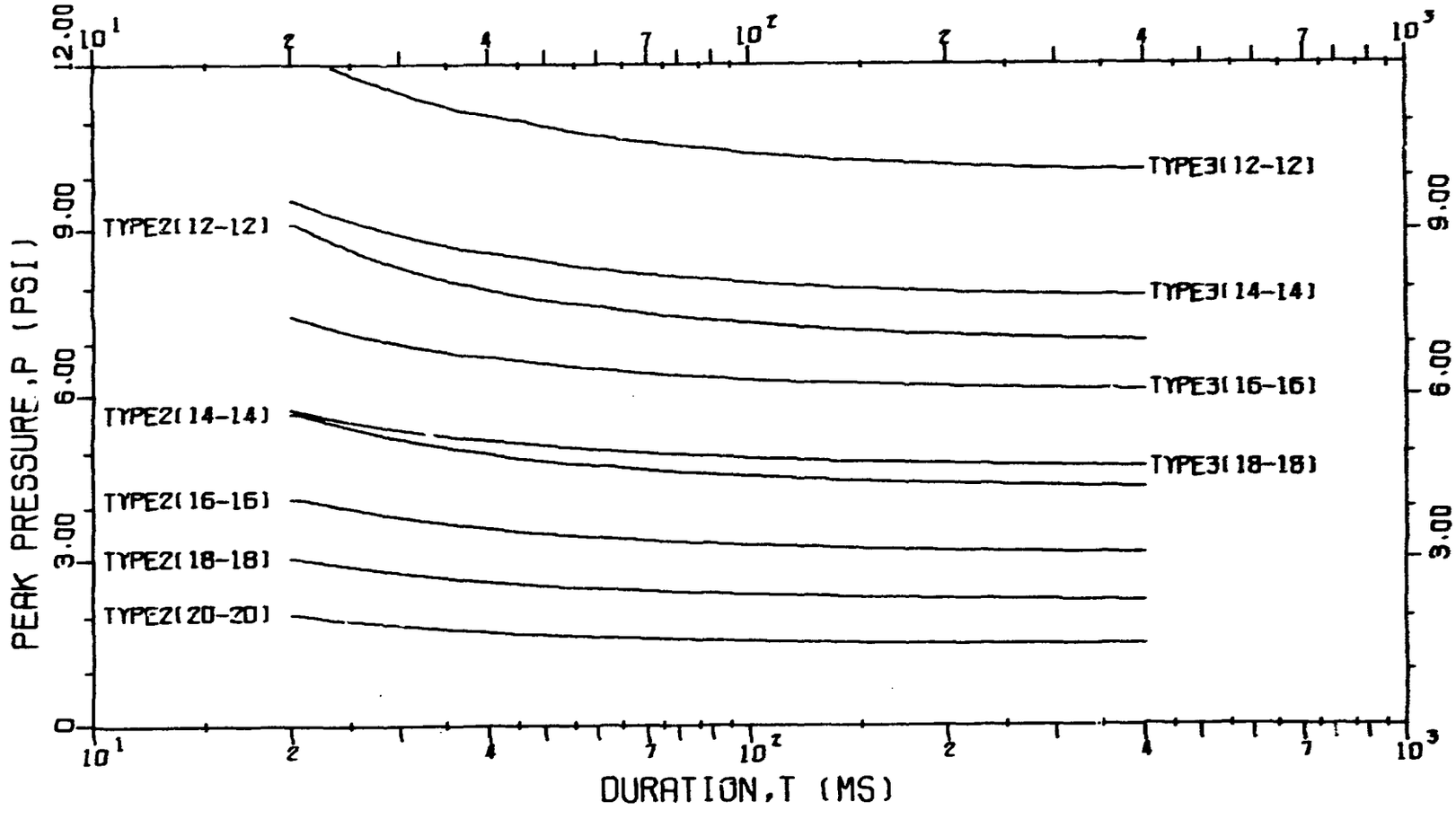


FIGURE 35

NON-REUSABLE METAL DECKING,SPAN= 7.0 FT,SIMPLY-SUPPORTED

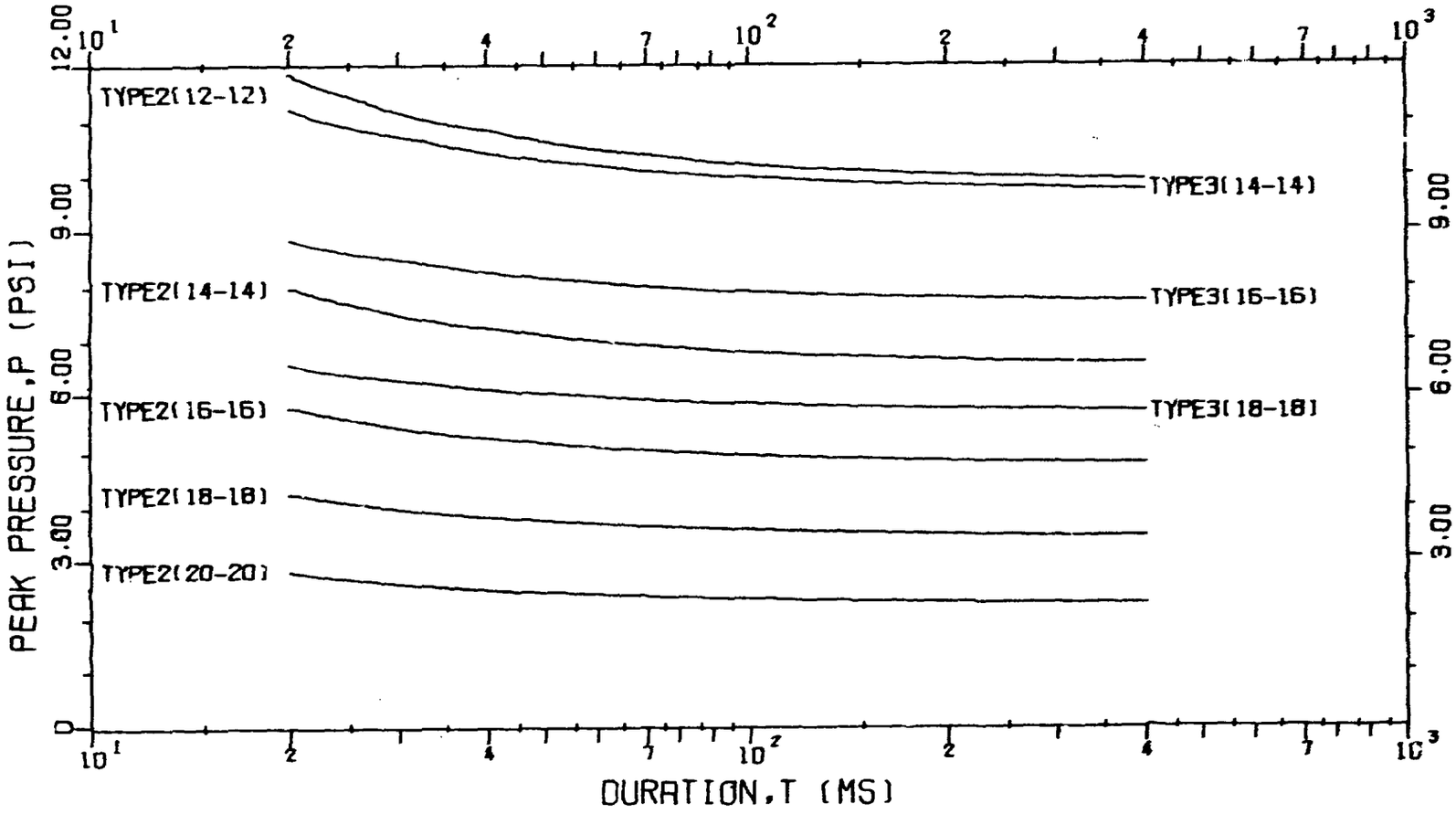


FIGURE 36

NON-REUSABLE METAL DECKING,SPAN= 7.0 FT,MULTIPLE SPANS

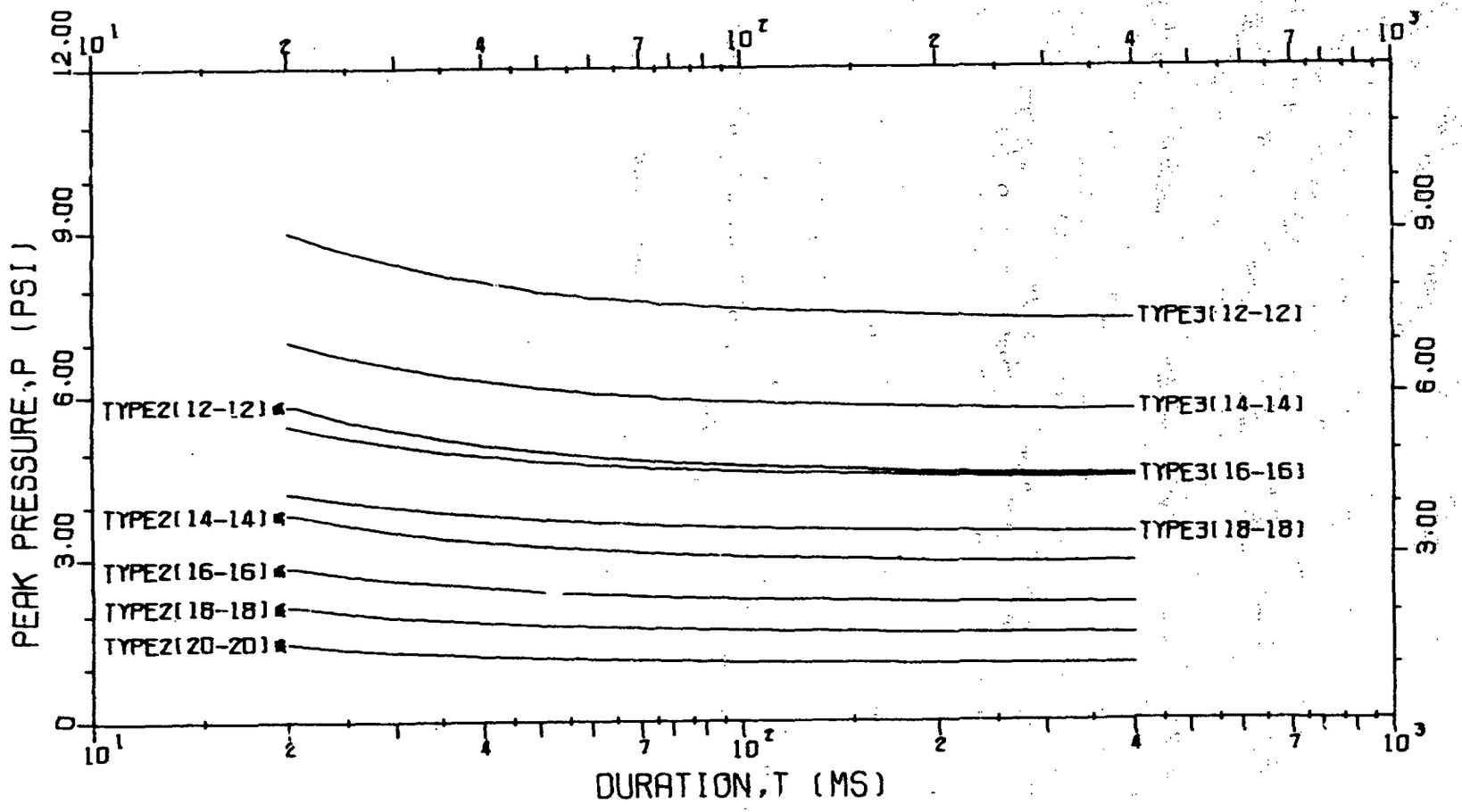


FIGURE 37

REUSABLE METAL DECKING,SPAN= 7.5 FT, SIMPLY-SUPPORTED

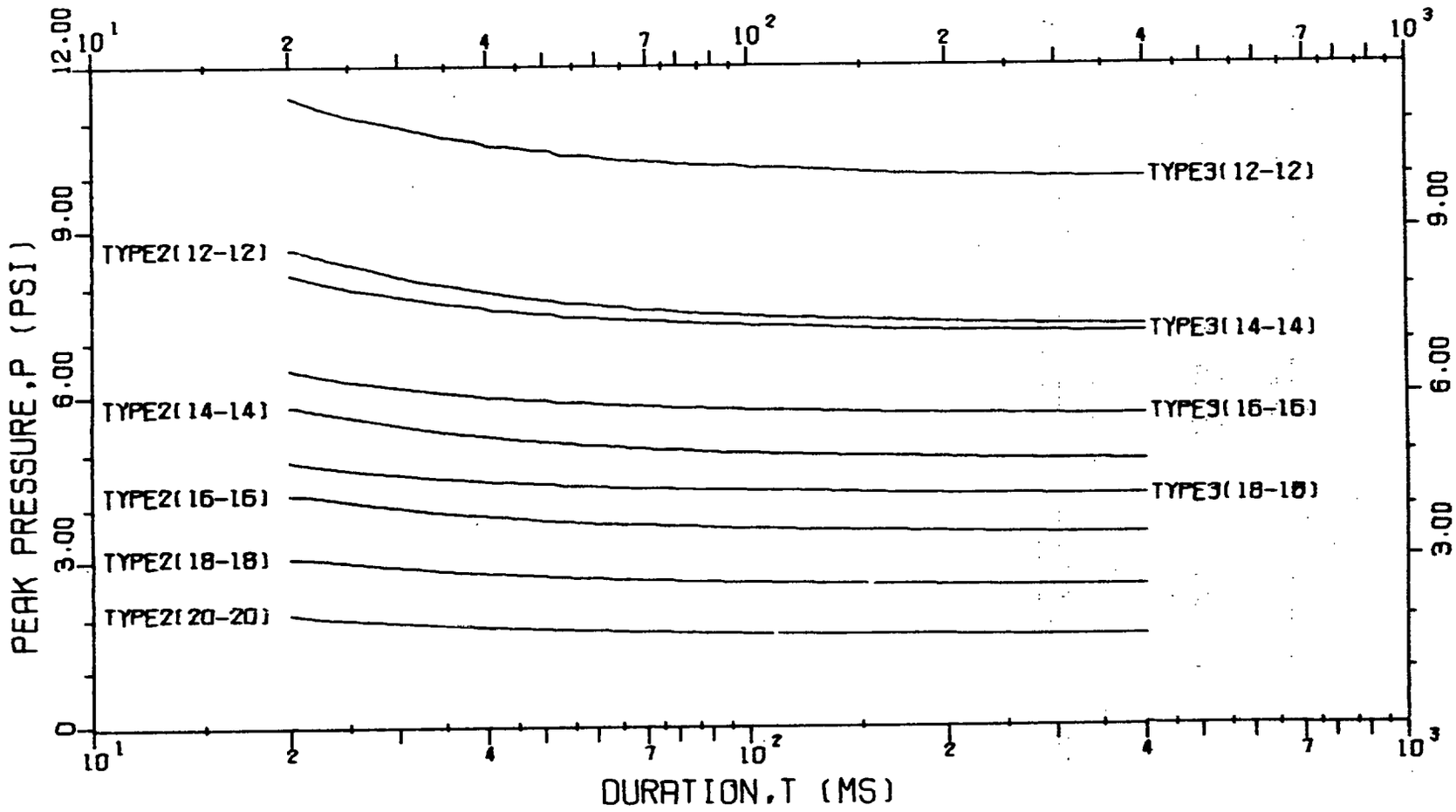


FIGURE 38

REUSABLE METAL DECKING,SPAN= 7.5 FT, MULTIPLE SPANS

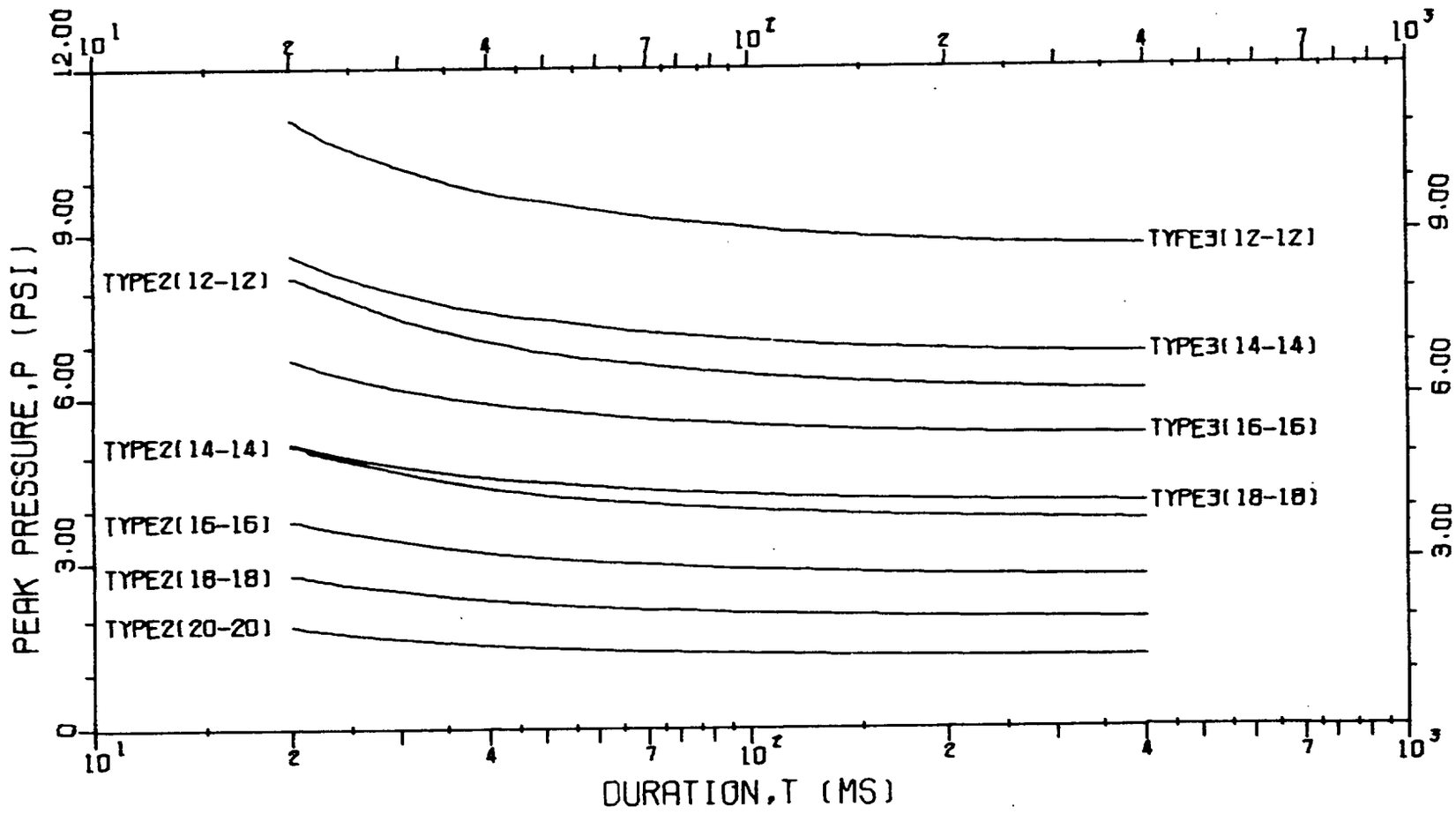


FIGURE 39

NON-REUSABLE METAL DECKING,SPAN= 7.5 FT,SIMPLY-SUPPORTED

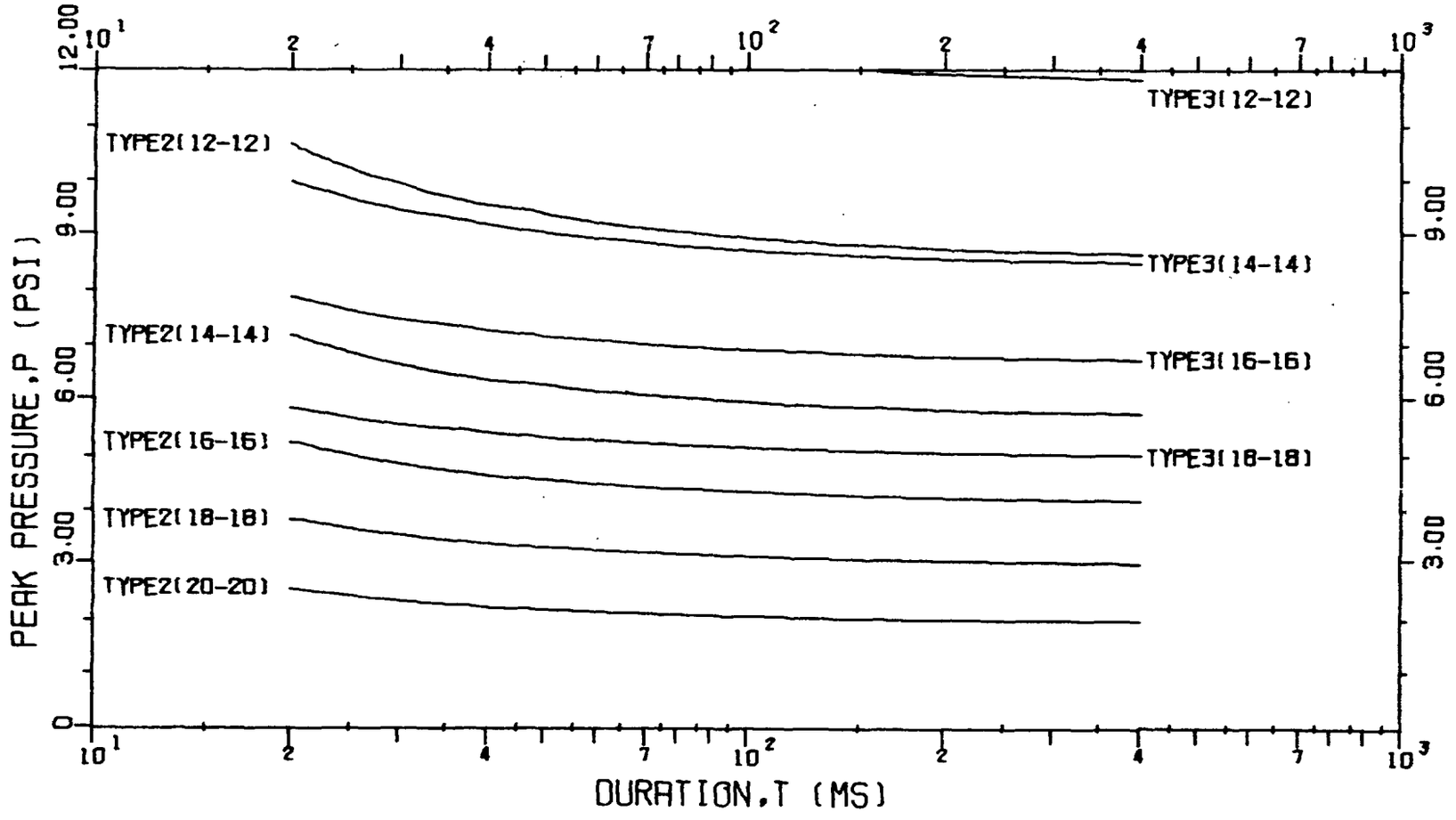


FIGURE 40

NON-REUSABLE METAL DECKING,SPAN= 7.5 FT,MULTIPLE SPANS

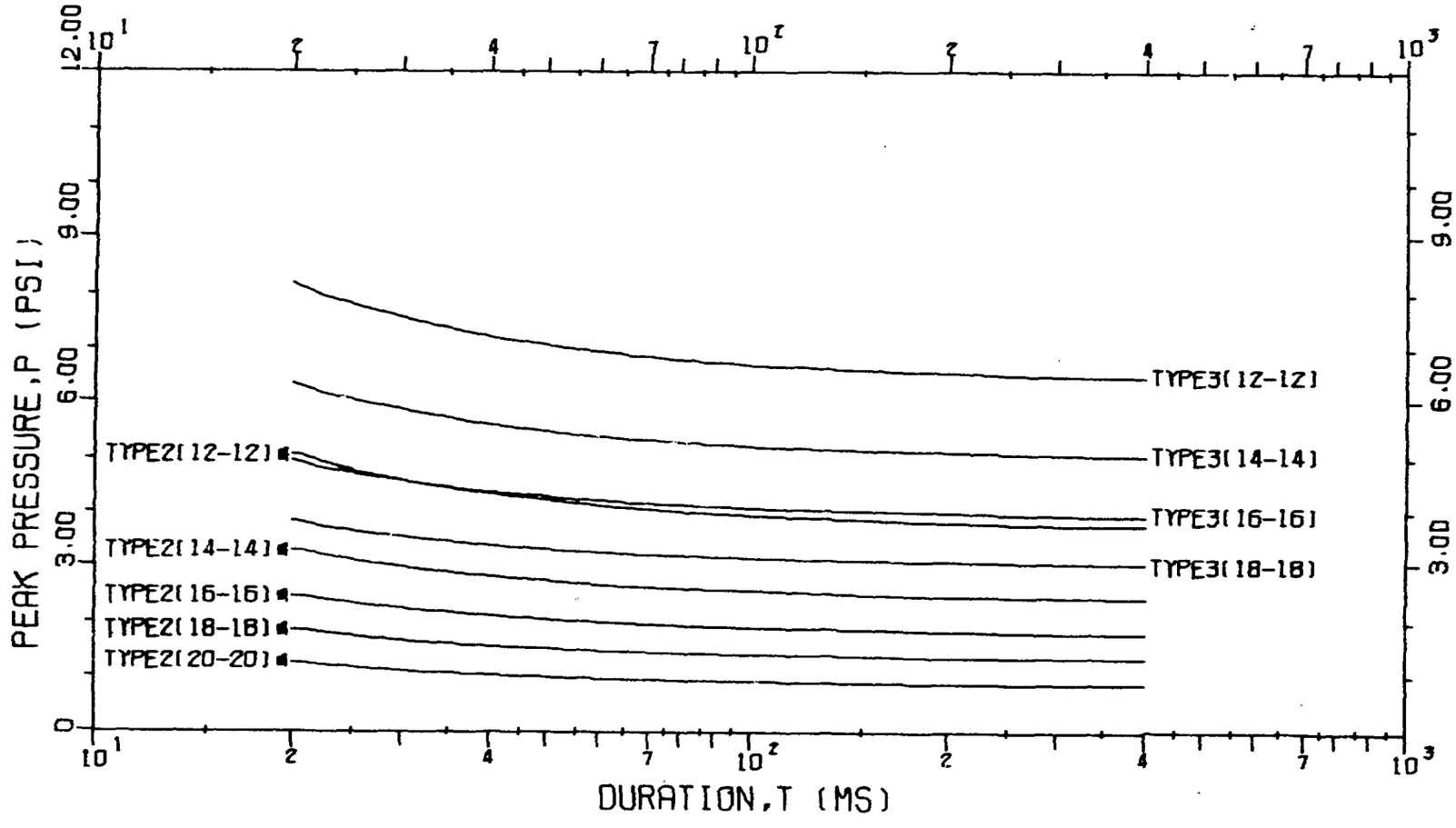


FIGURE 41

REUSABLE METAL DECKING,SPAN= 8.0 FT, SIMPLY-SUPPORTED

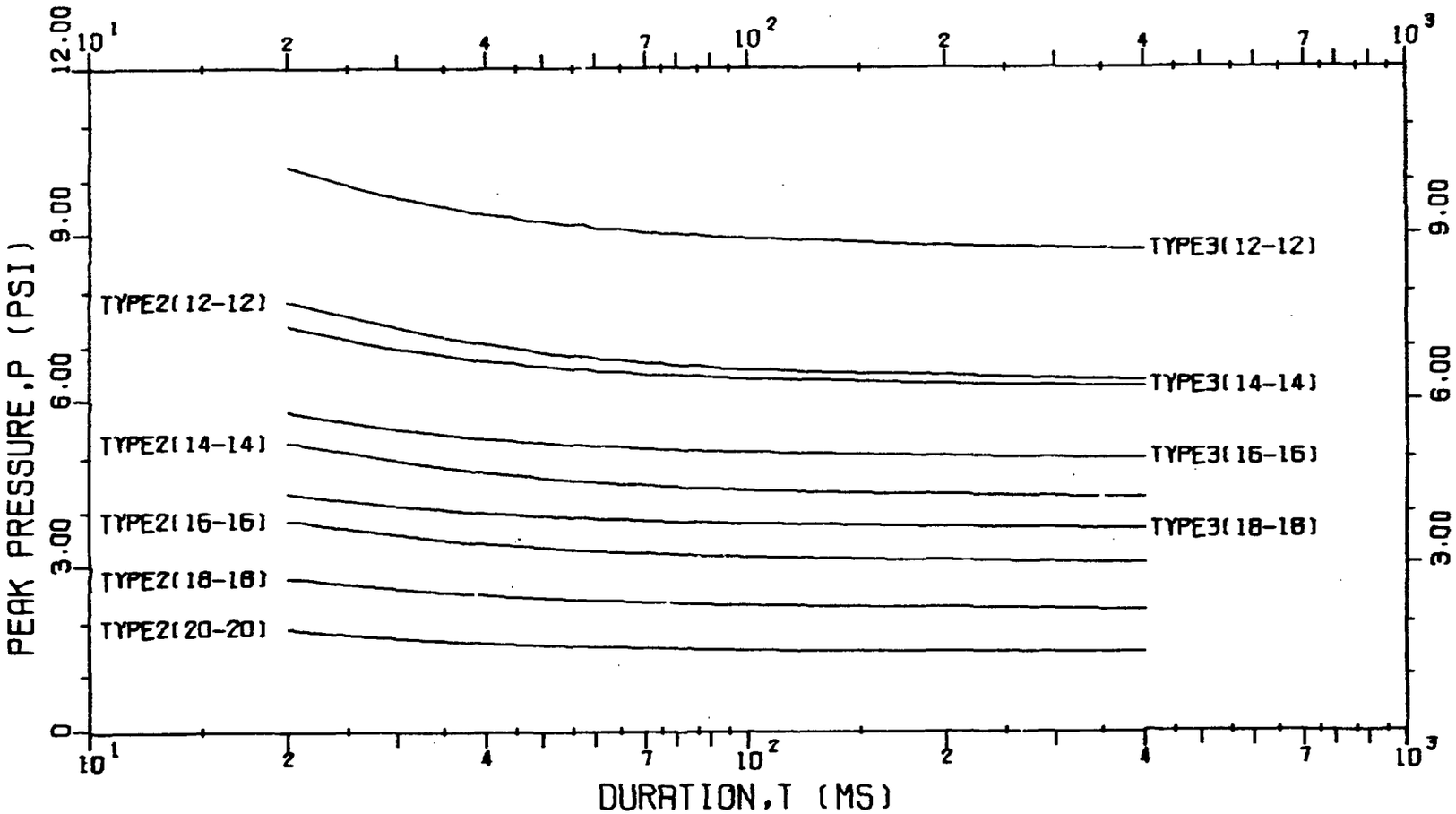


FIGURE 42

REUSABLE METAL DECKING,SPAN= 8.0 FT, MULTIPLE SPANS

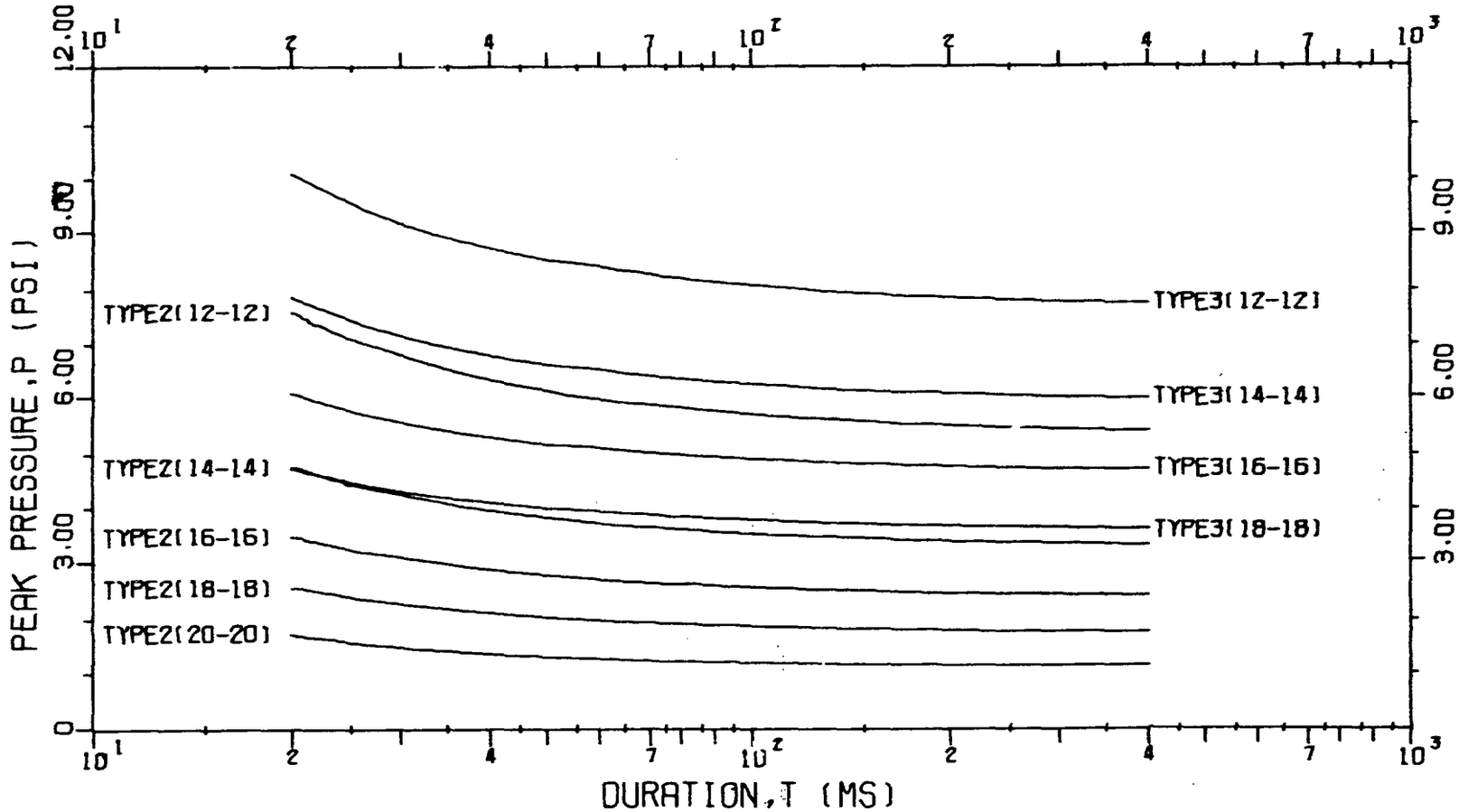


FIGURE 43

NON-REUSABLE METAL DECKING,SPAN= 8.0 FT,SIMPLY-SUPPORTED

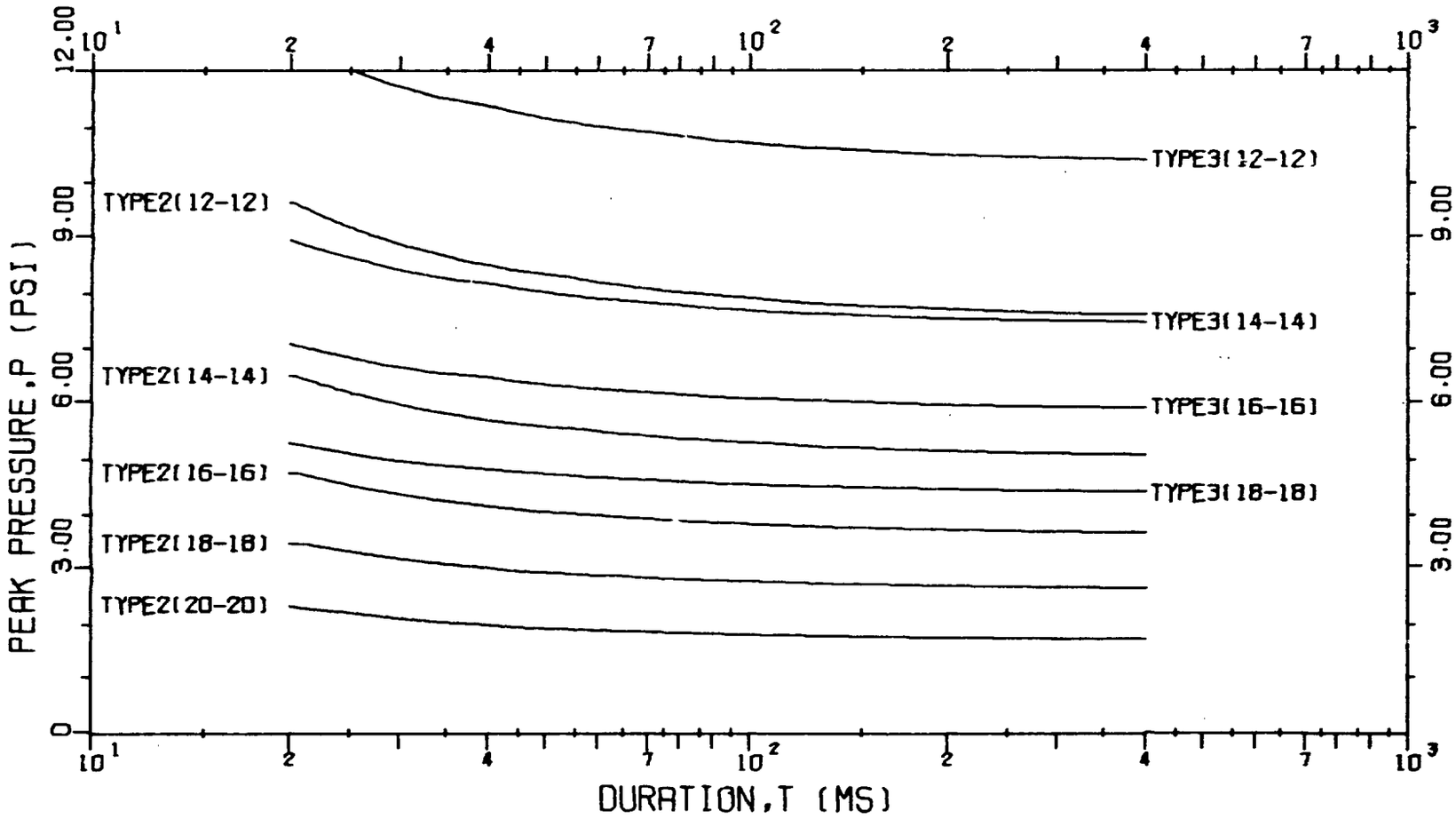


FIGURE 44

NON-REUSABLE METAL DECKING,SPAN= 8.0 FT,MULTIPLE SPANS

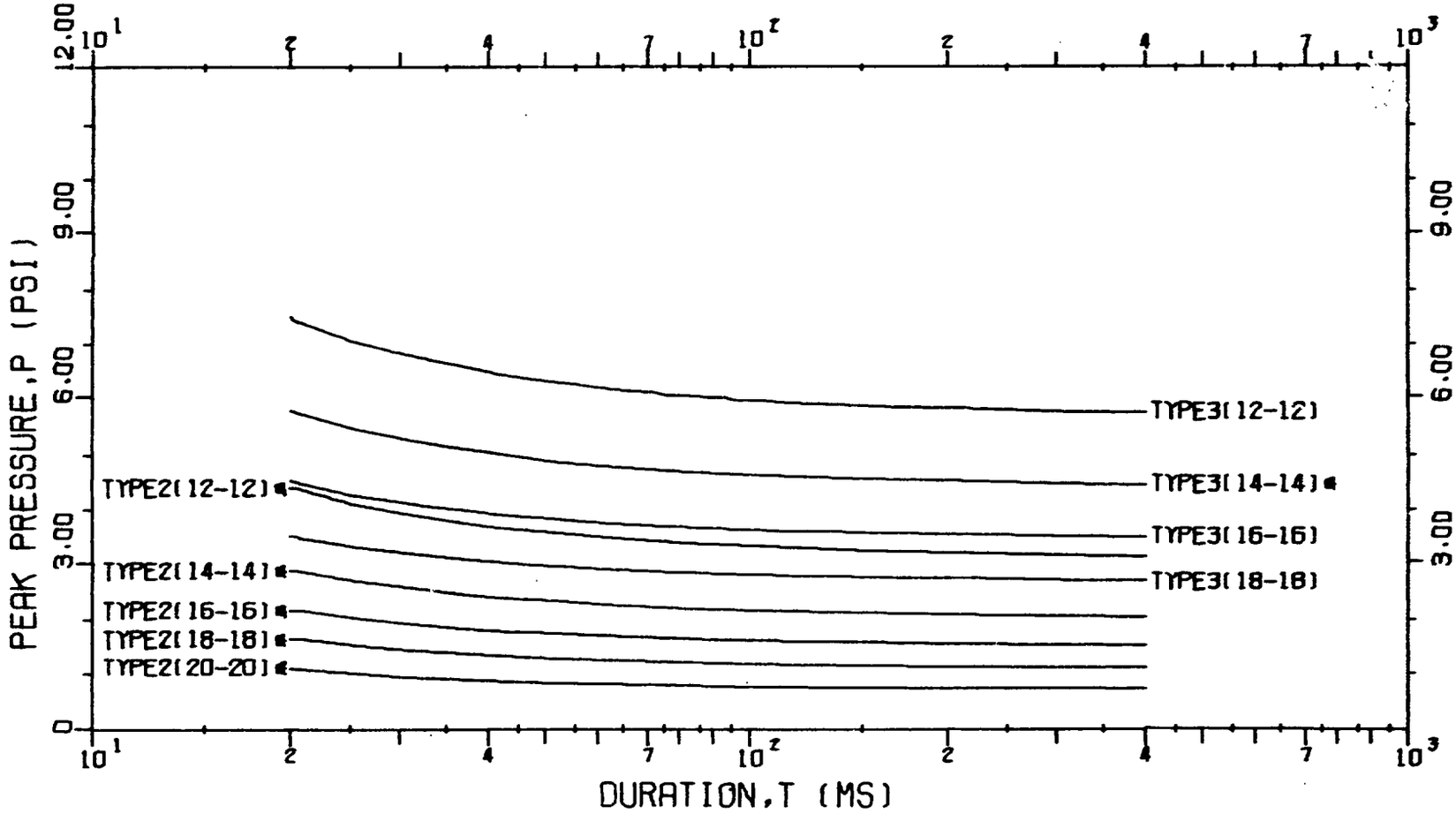


FIGURE 45

REUSABLE METAL DECKING,SPAN= 8.5 FT, SIMPLY-SUPPORTED

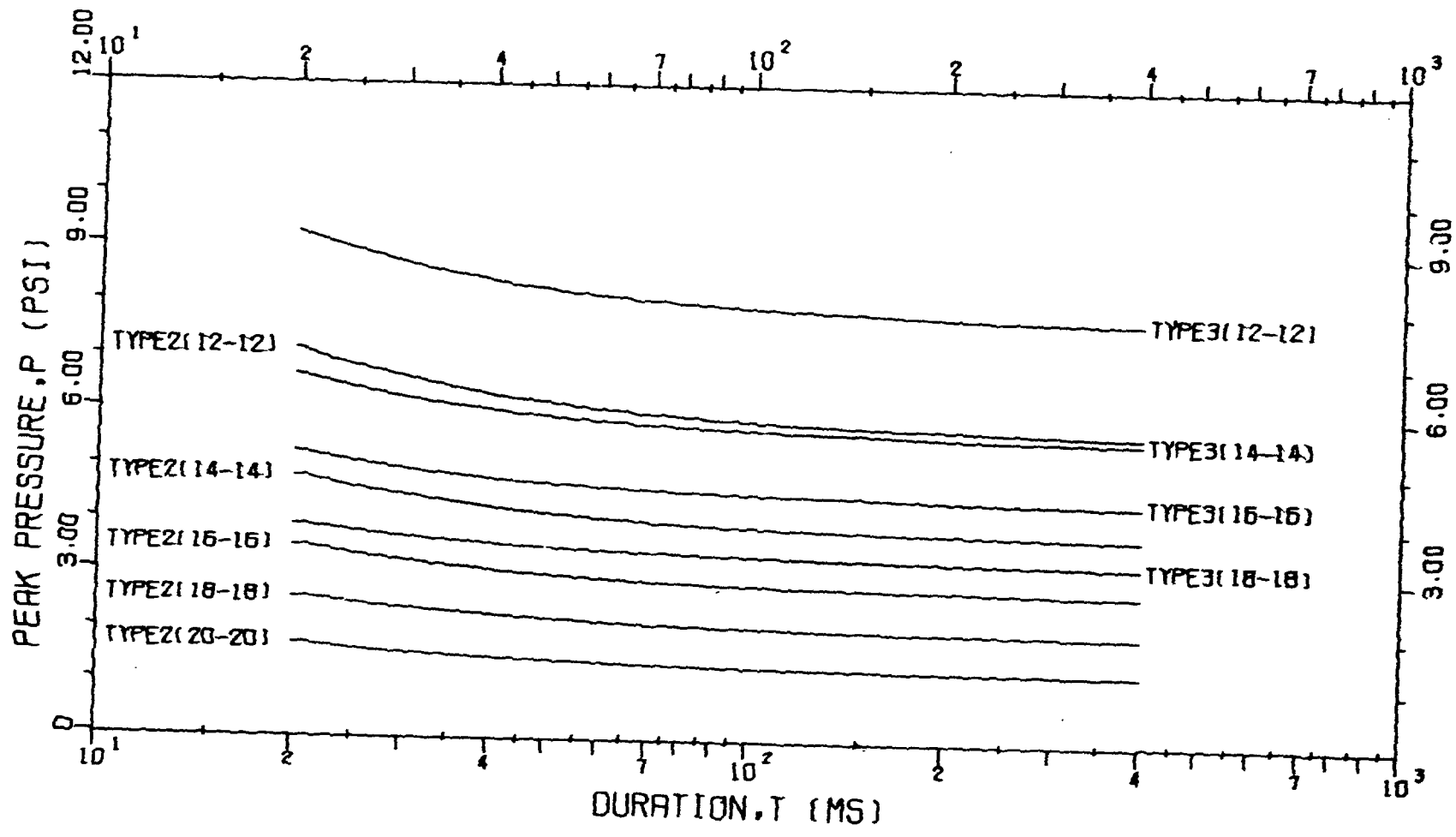


FIGURE 46

REUSABLE METAL DECKING,SPAN= 8.5 FT, MULTIPLE SPANS

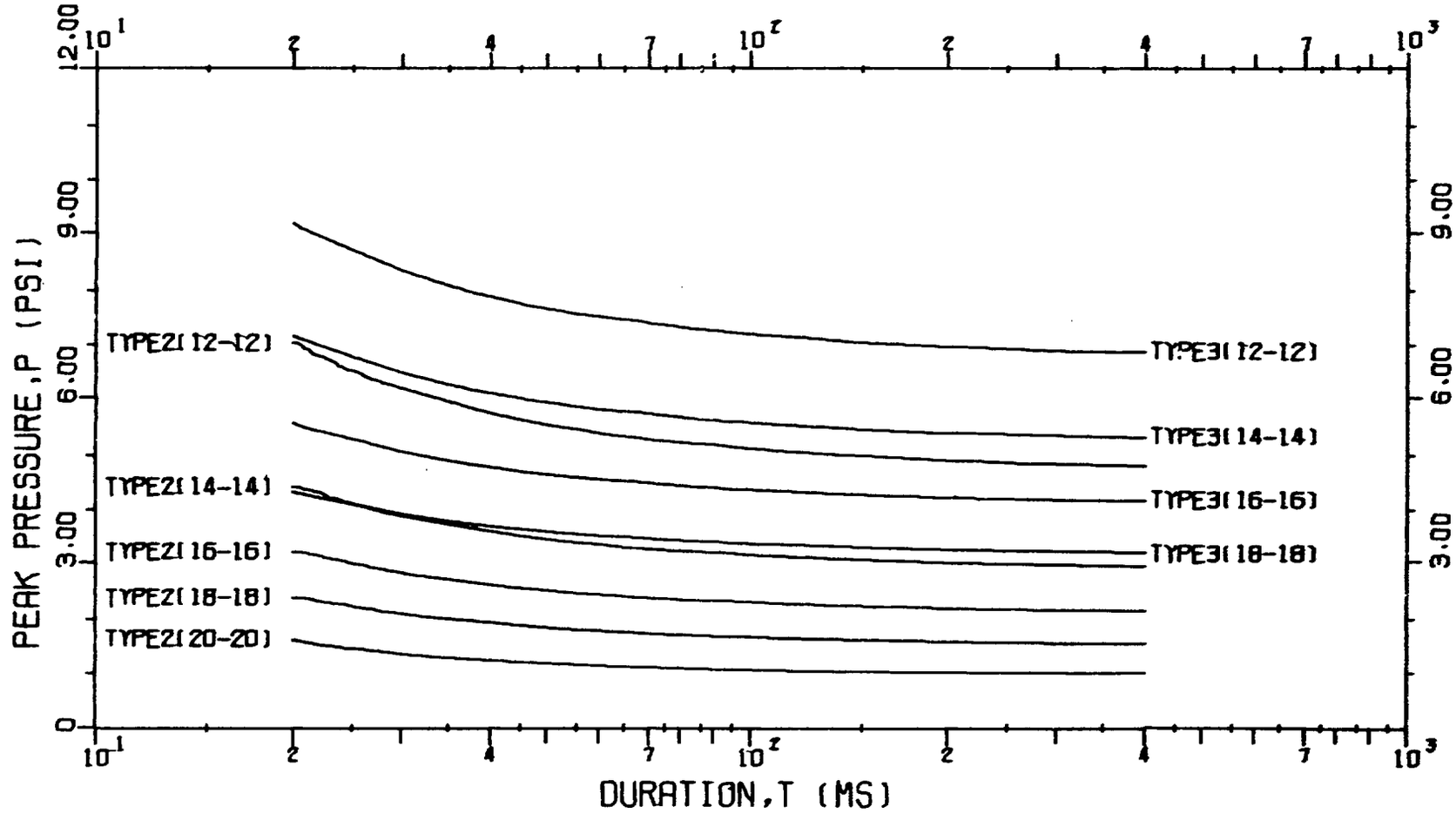


FIGURE 47

NON-REUSABLE METAL DECKING,SPAN= 8.5 FT,SIMPLY-SUPPORTED

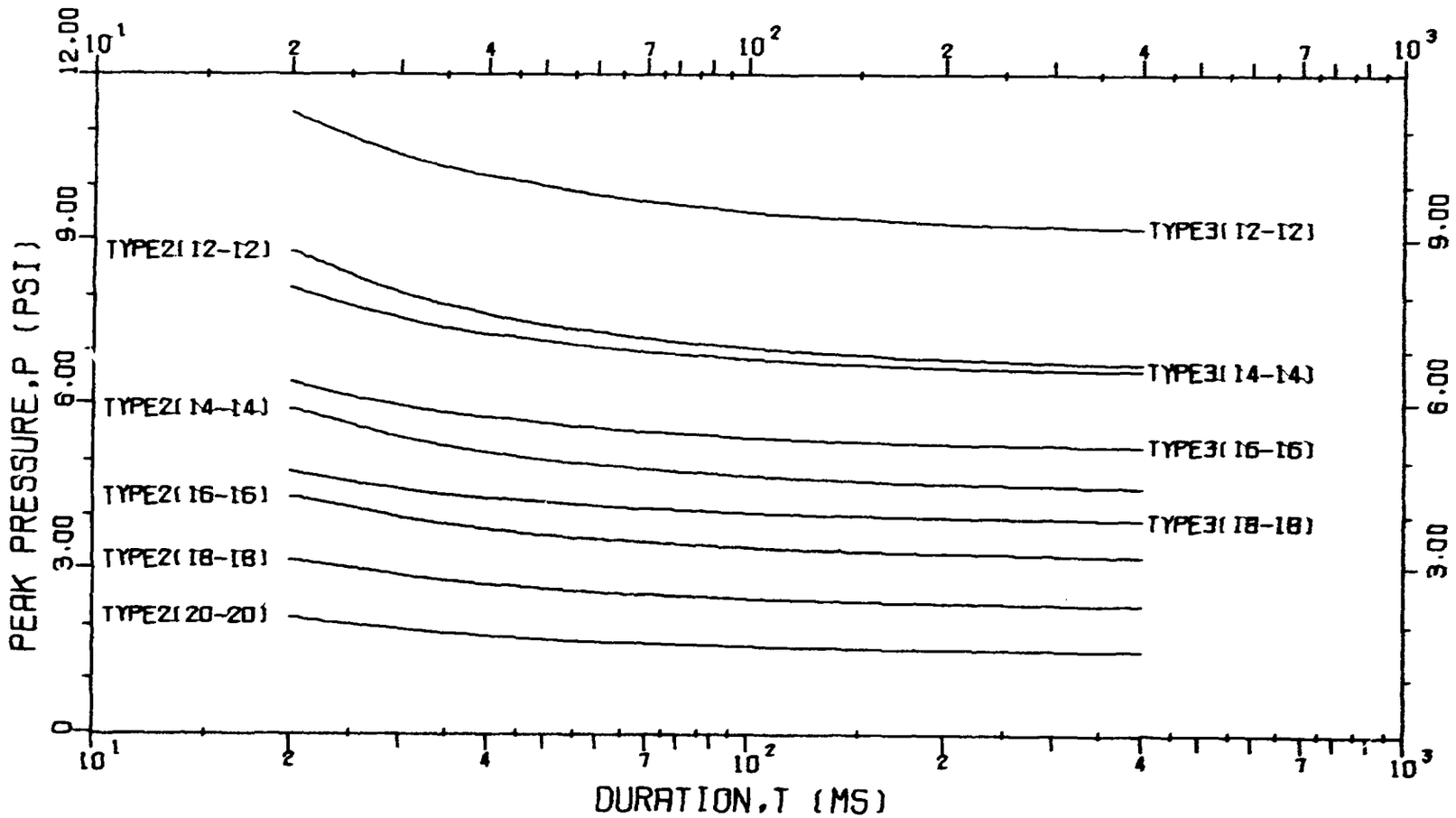


FIGURE 48

NON-REUSABLE METAL DECKING,SPAN= 8.5 FT,MULTIPLE SPANS

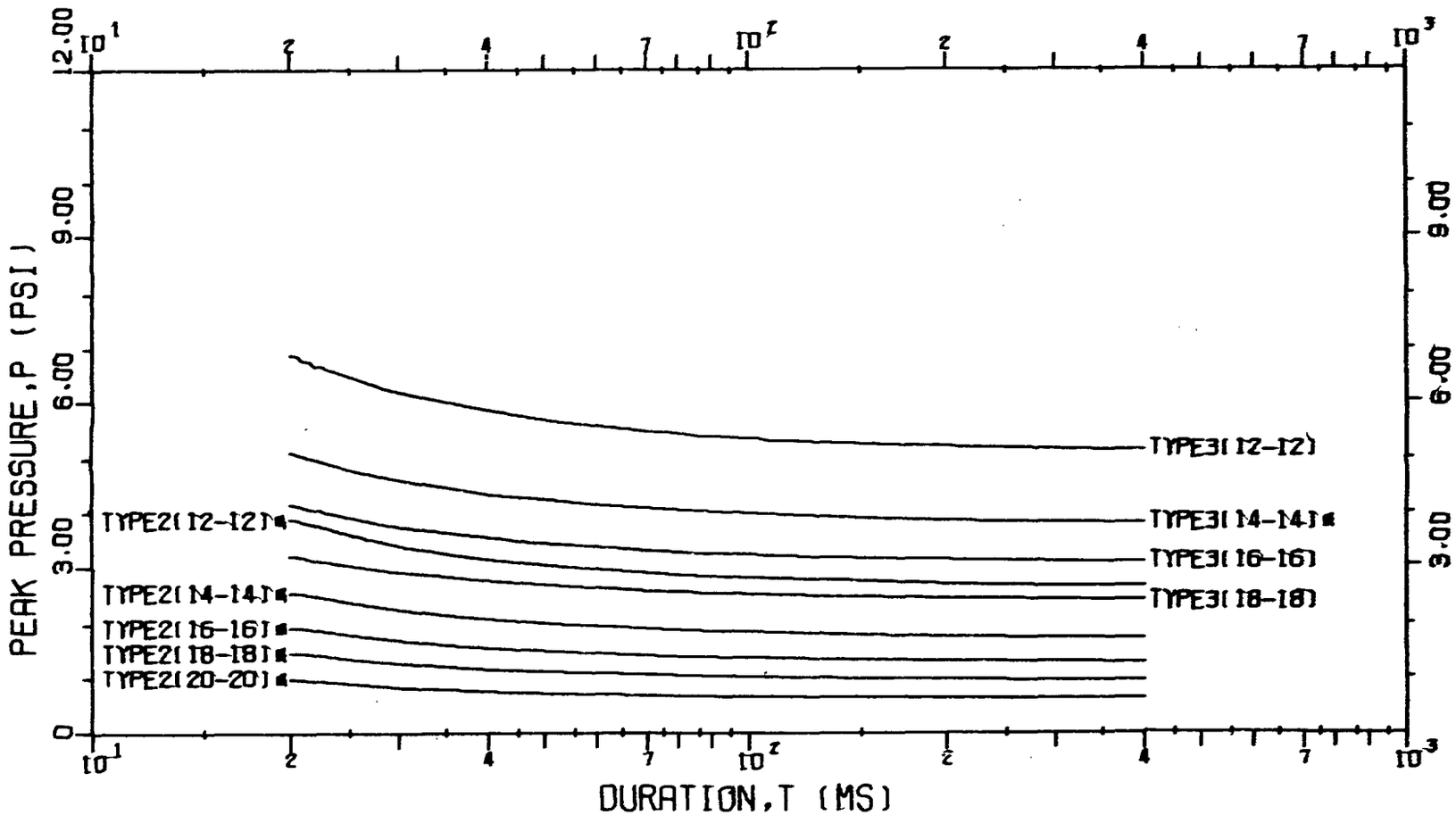


FIGURE 49

REUSABLE METAL DECKING,SPAN= 9.0 FT, SIMPLY-SUPPORTED

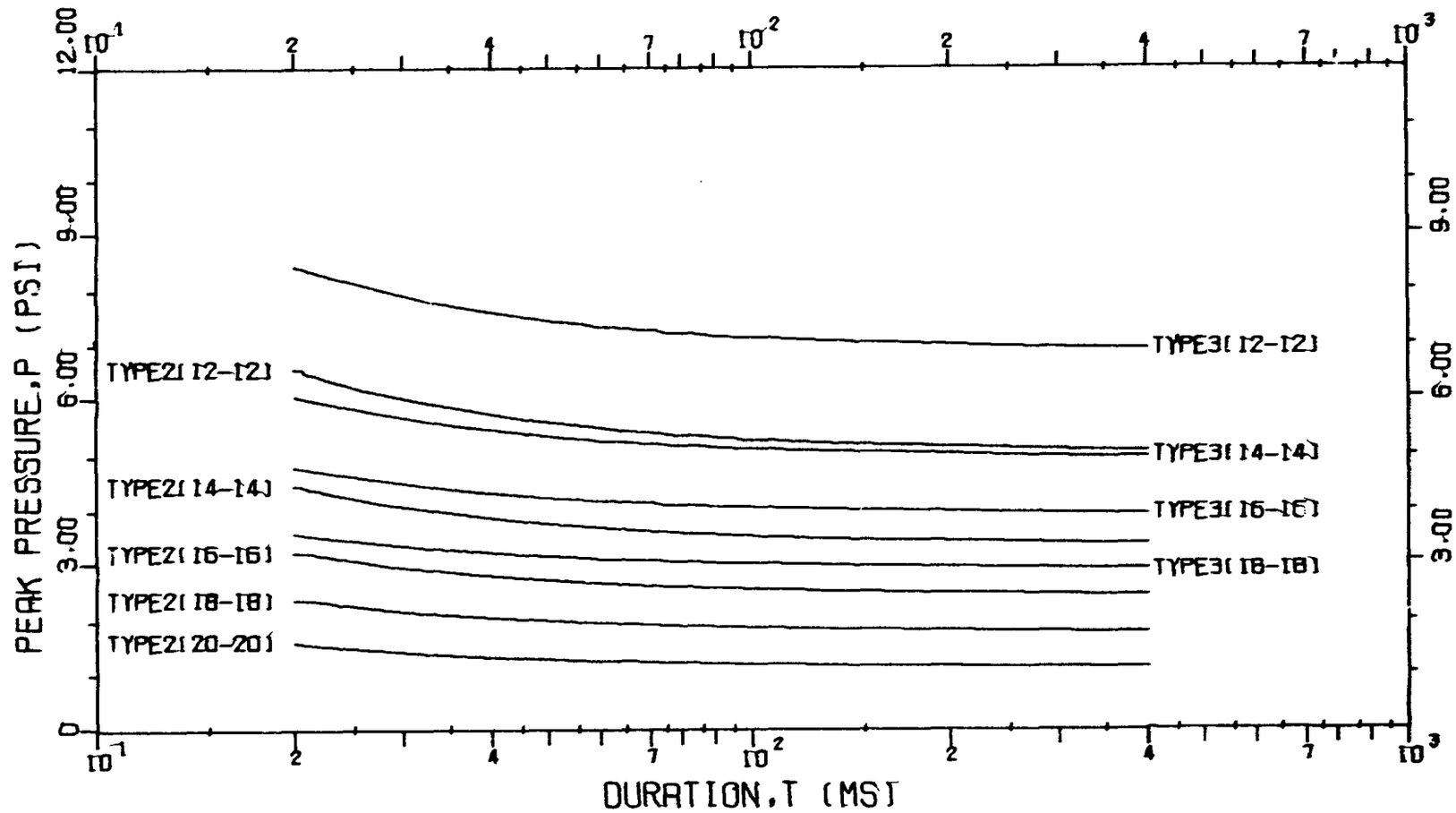


FIGURE 50

REUSABLE METAL DECKING,SPAN= 9.0 FT, MULTIPLE SPANS

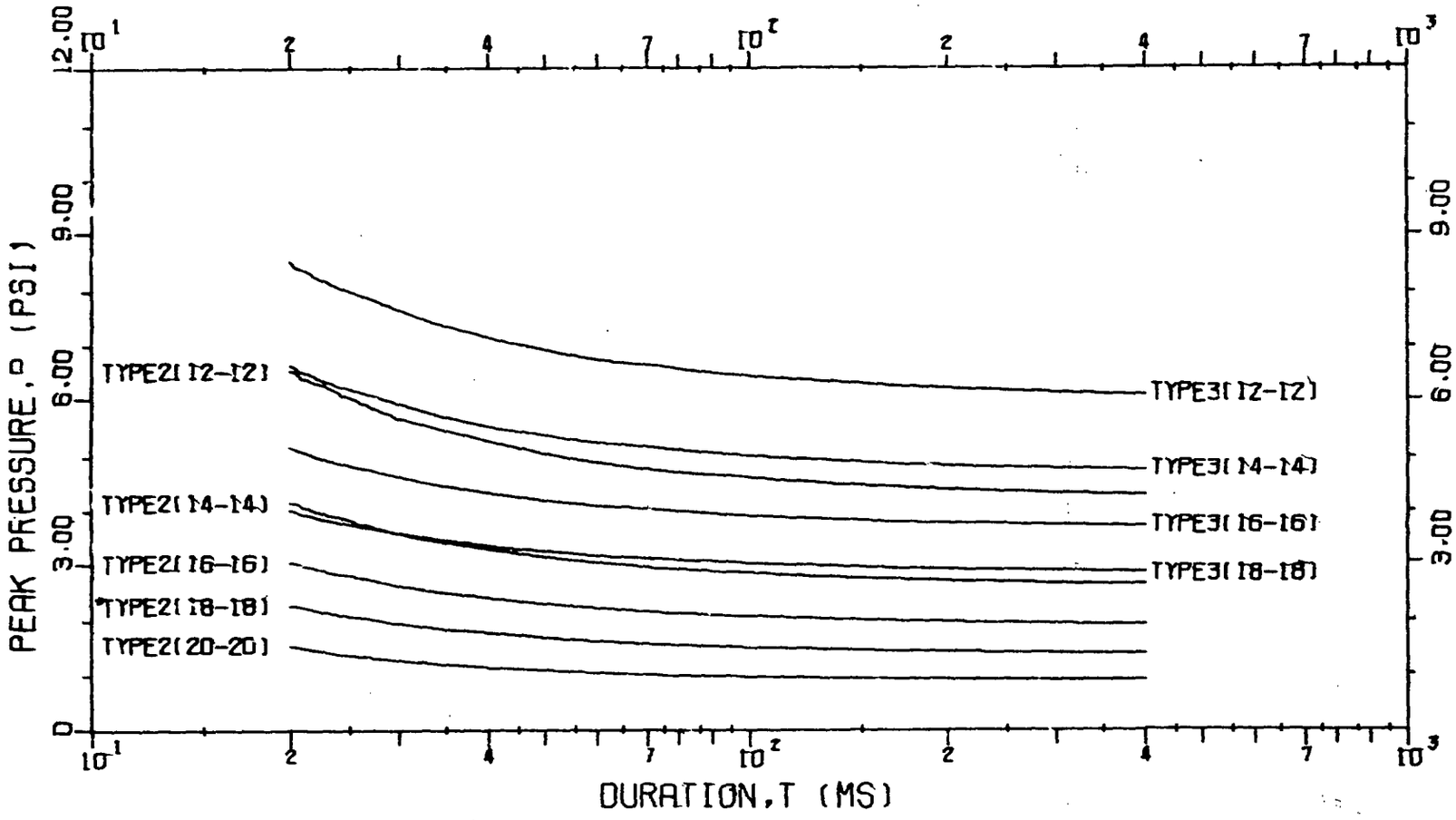


FIGURE 51

NON-REUSABLE METAL DECKING, SPAN= 9.0 FT, SIMPLY-SUPPORTED

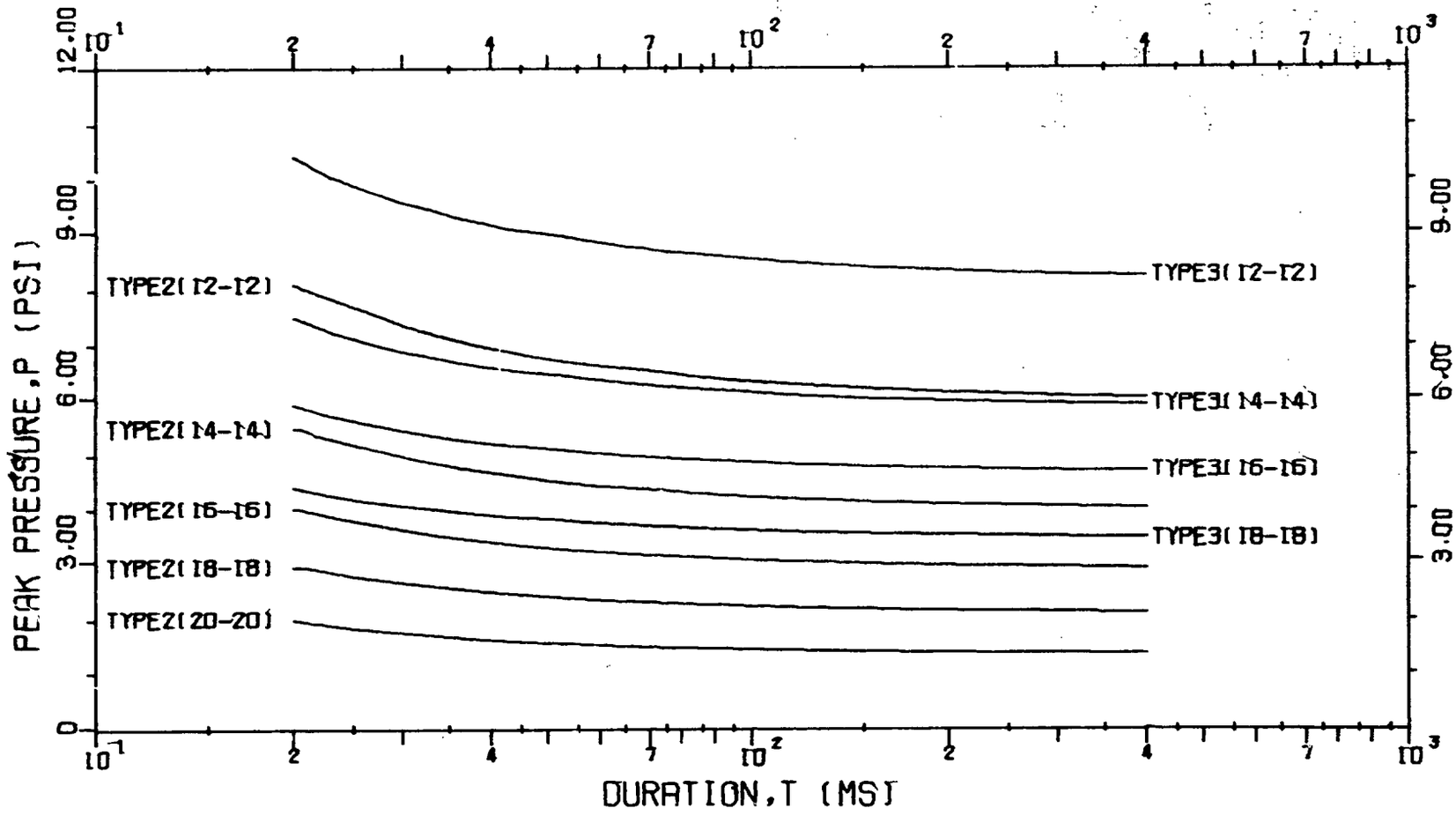


FIGURE 52

NON-REUSABLE METAL DECKING,SPAN= 9.0 FT,MULTIPLE SPANS

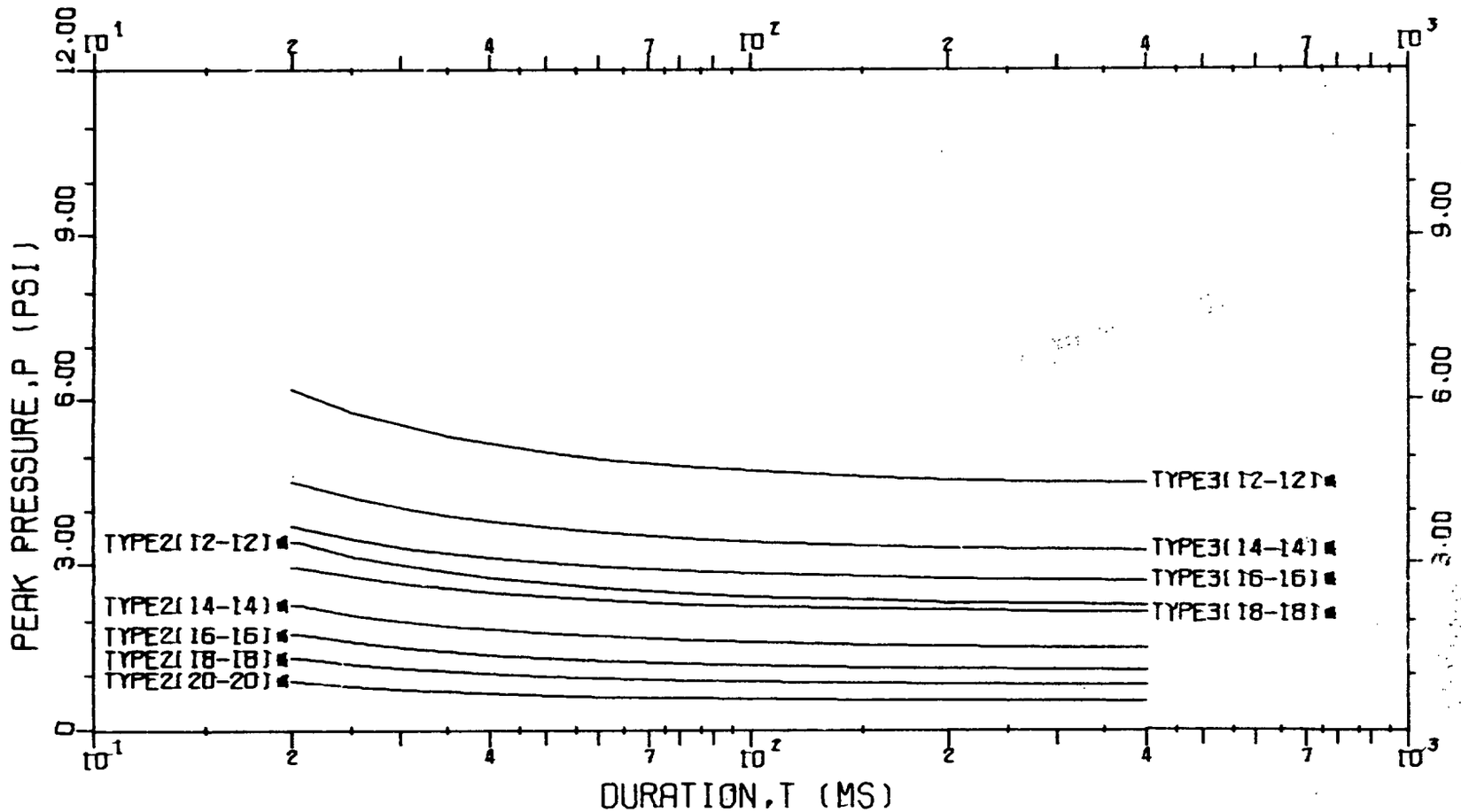


FIGURE 53

REUSABLE METAL DECKING,SPAN= 9.5 FT, SIMPLY-SUPPORTED

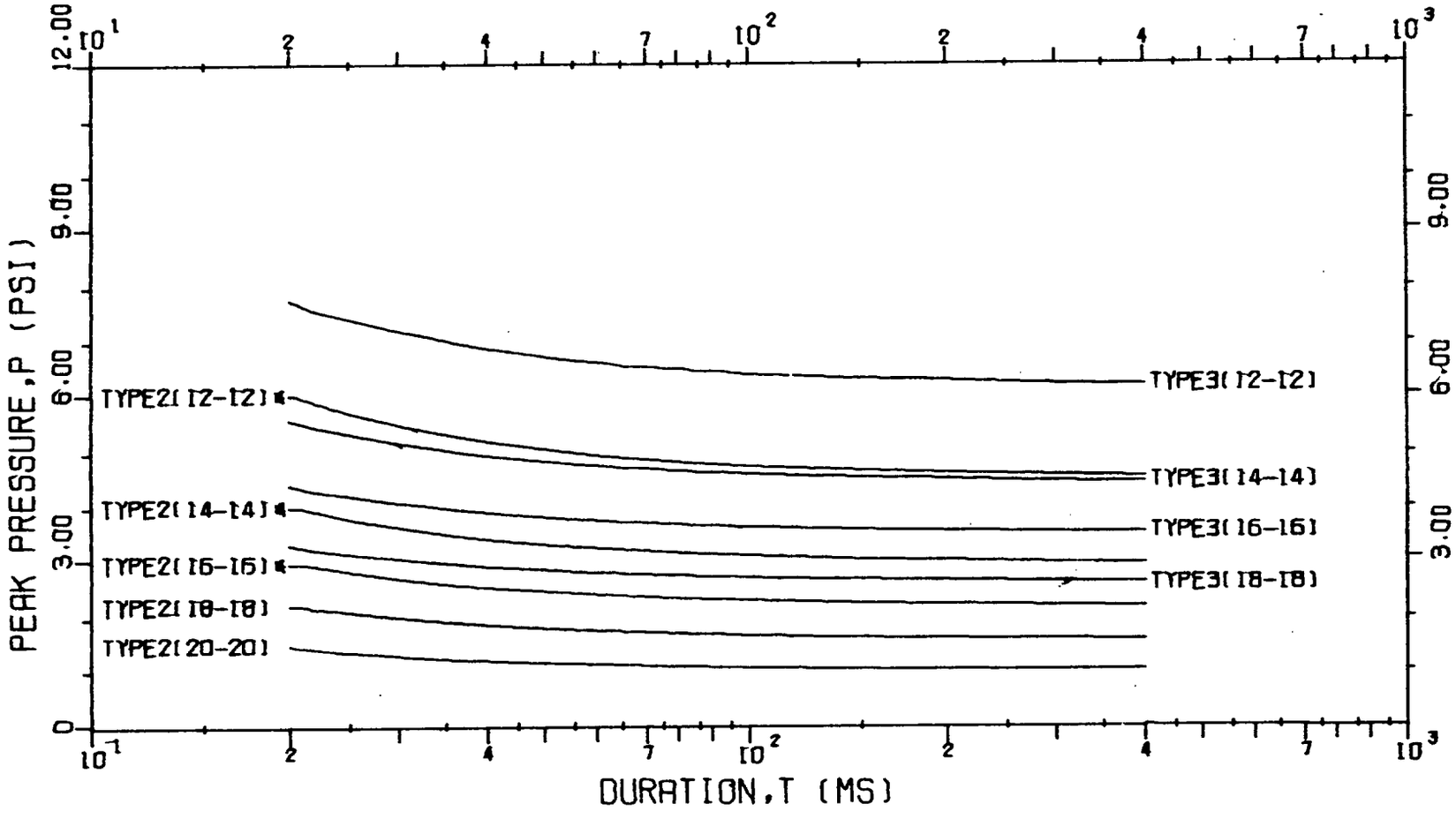


FIGURE 54

REUSABLE METAL DECKING,SPAN= 9.5 FT, MULTIPLE SPANS

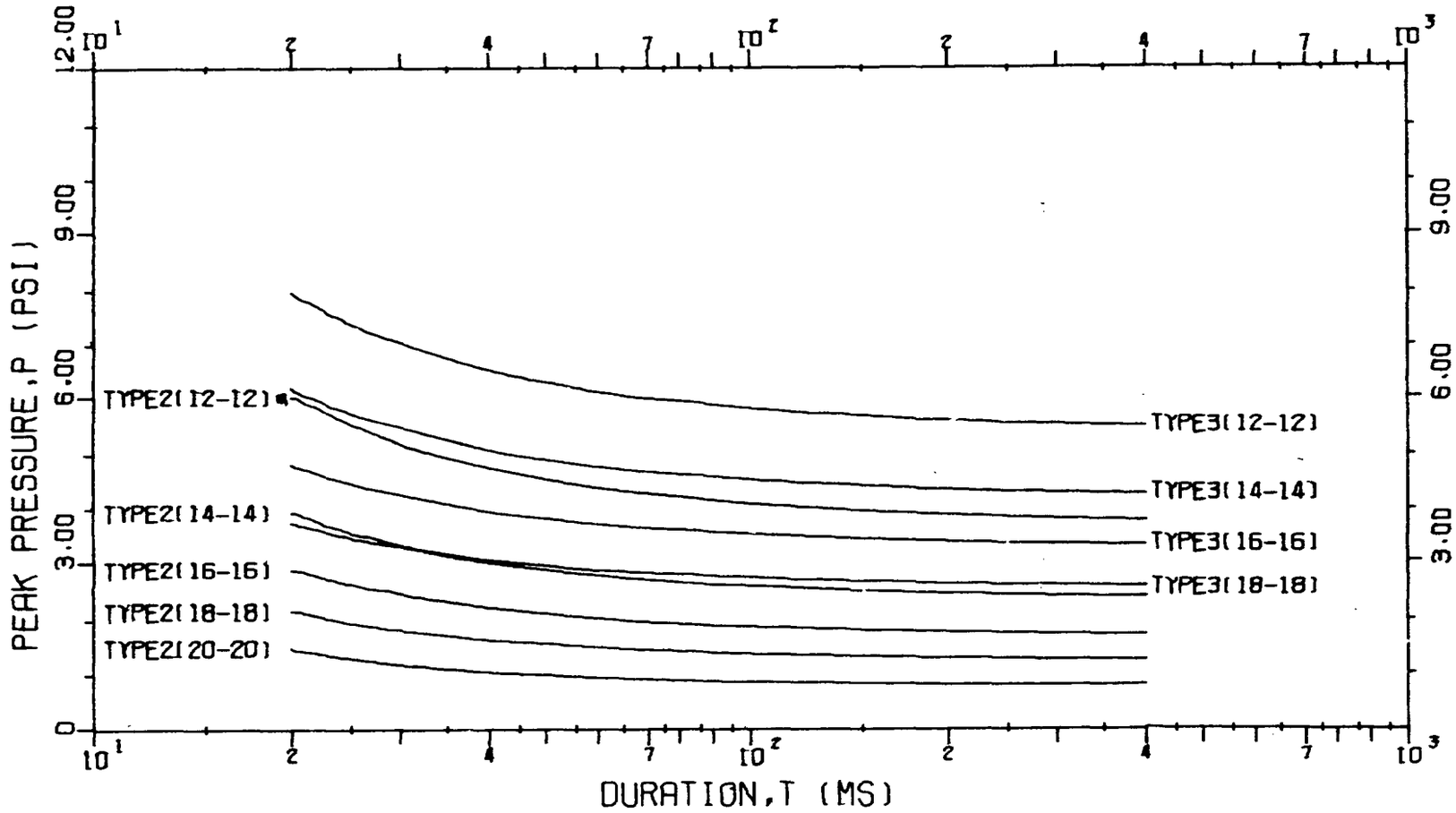


FIGURE 55

NON-REUSABLE METAL DECKING,SPAN= 9.5 FT,SIMPLY-SUPPORTED

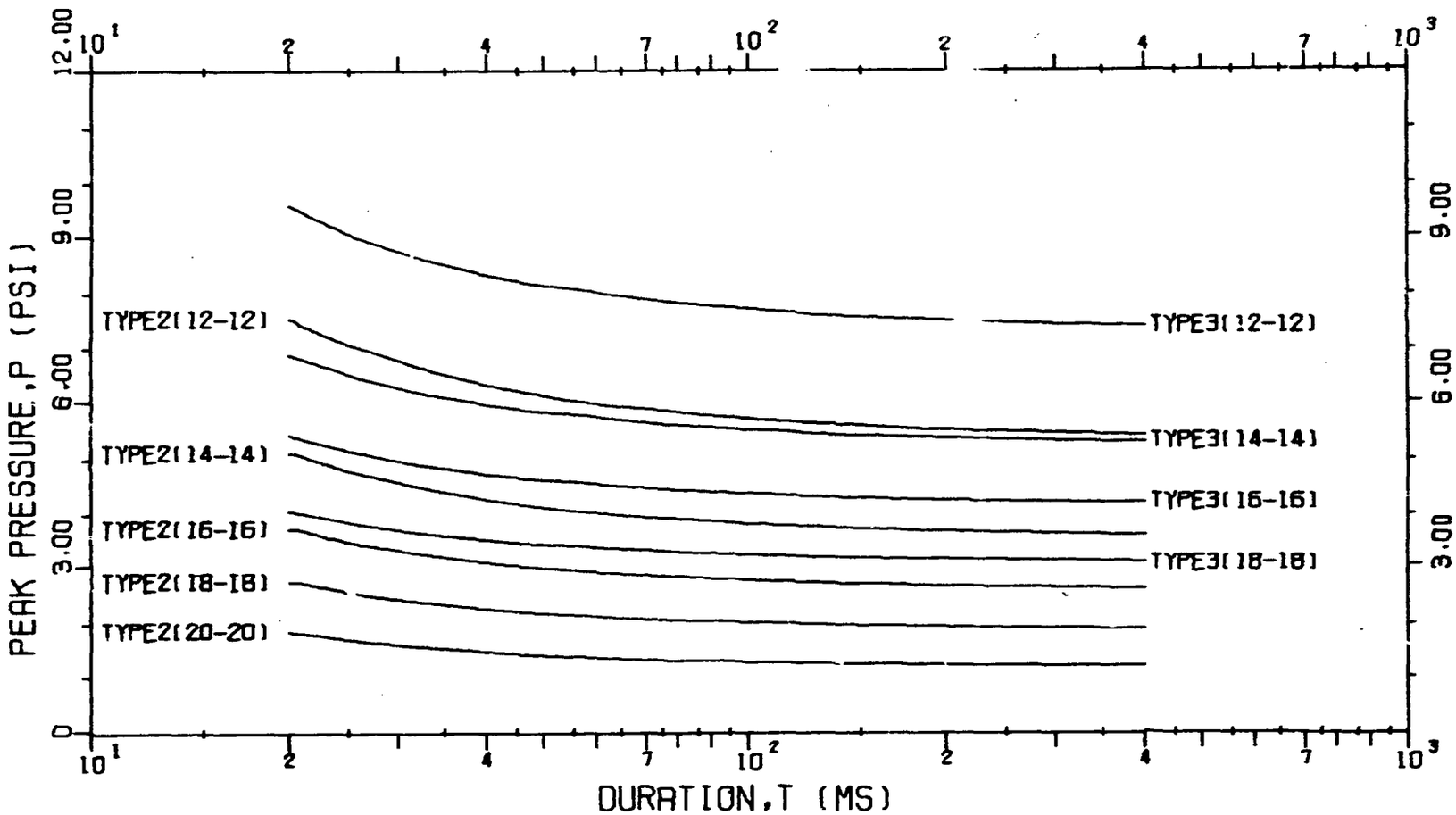


FIGURE 56

NON-REUSABLE METAL DECKING,SPAN= 9.5 FT,MULTIPLE SPANS

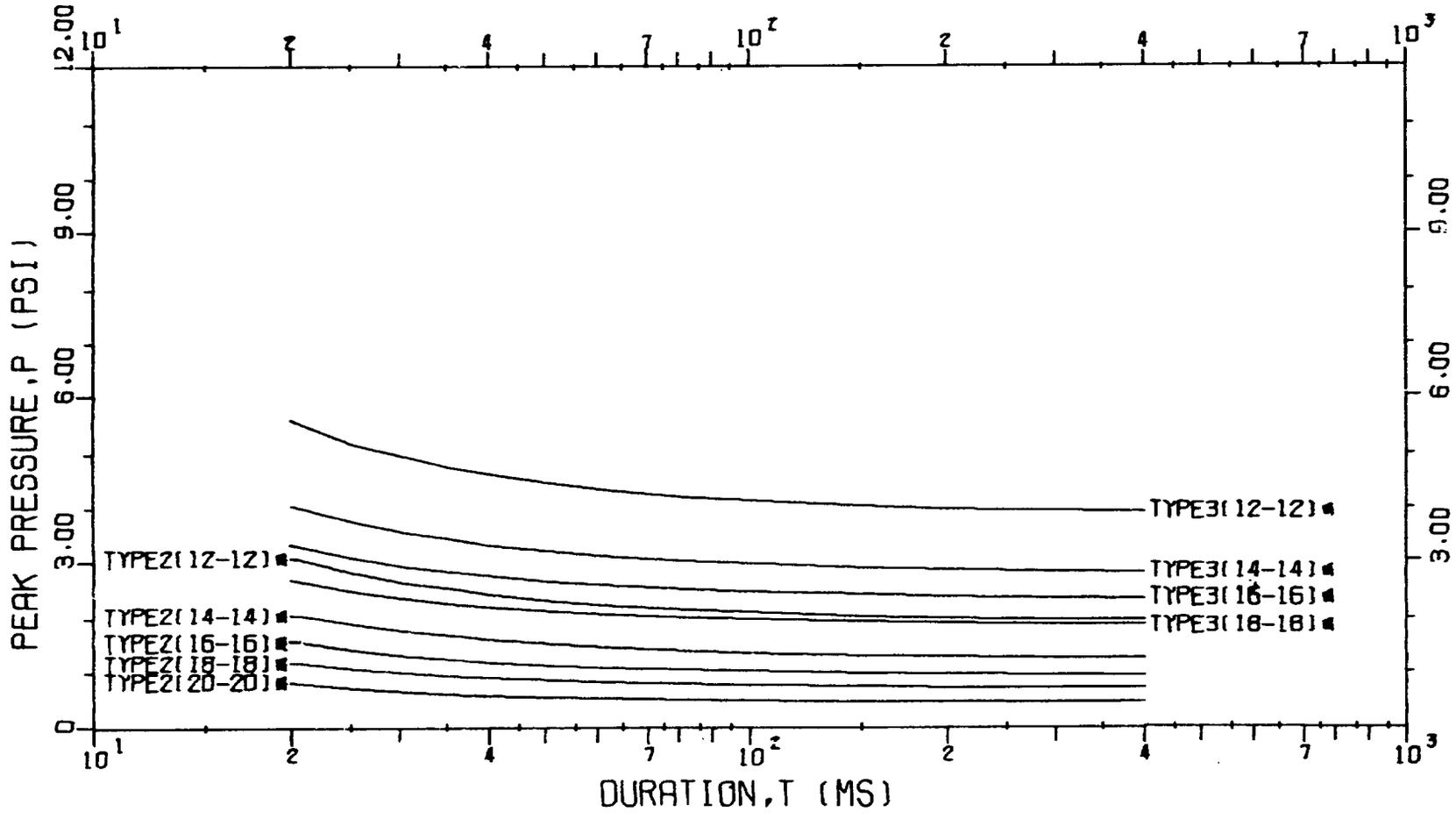


FIGURE 57

REUSABLE METAL DECKING,SPAN= 10.0FT, SIMPLY-SUPPORTED

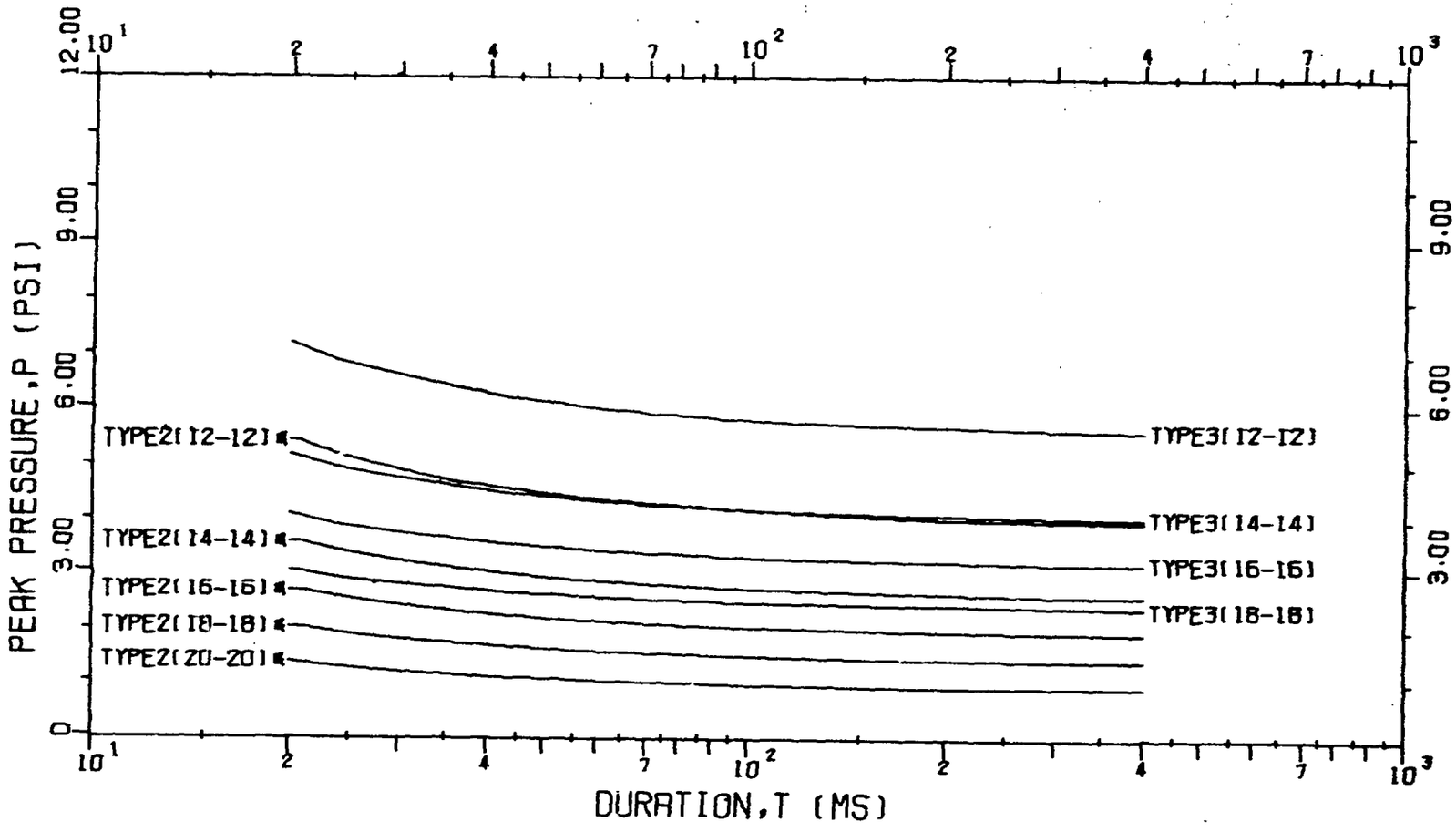


FIGURE 58

REUSABLE METAL DECKING,SPAN= 10.0FT, MULTIPLE SPANS

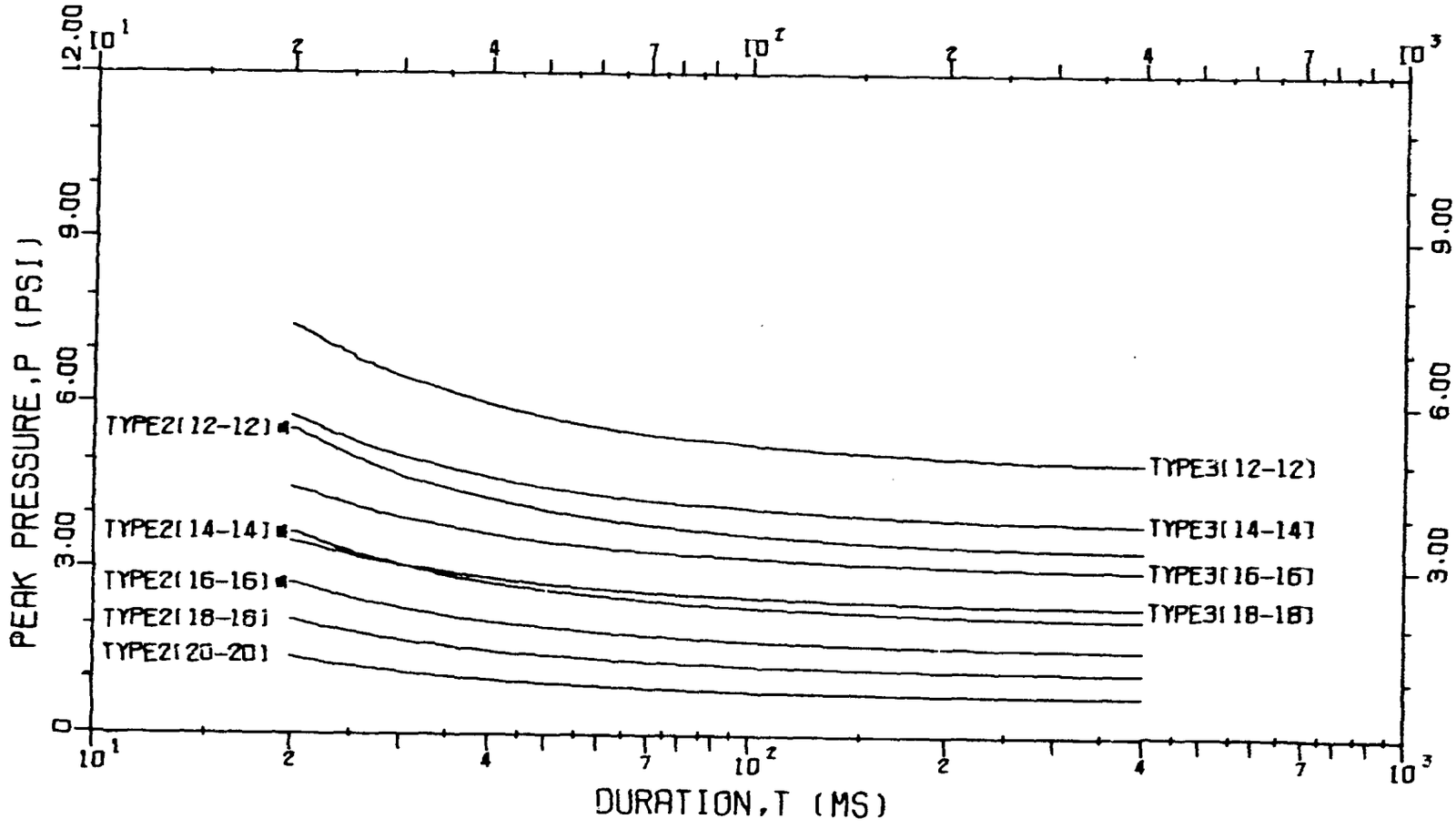


FIGURE 59

NON-REUSABLE METAL DECKING,SPAN= 10.0FT,SIMPLY-SUPPORTED

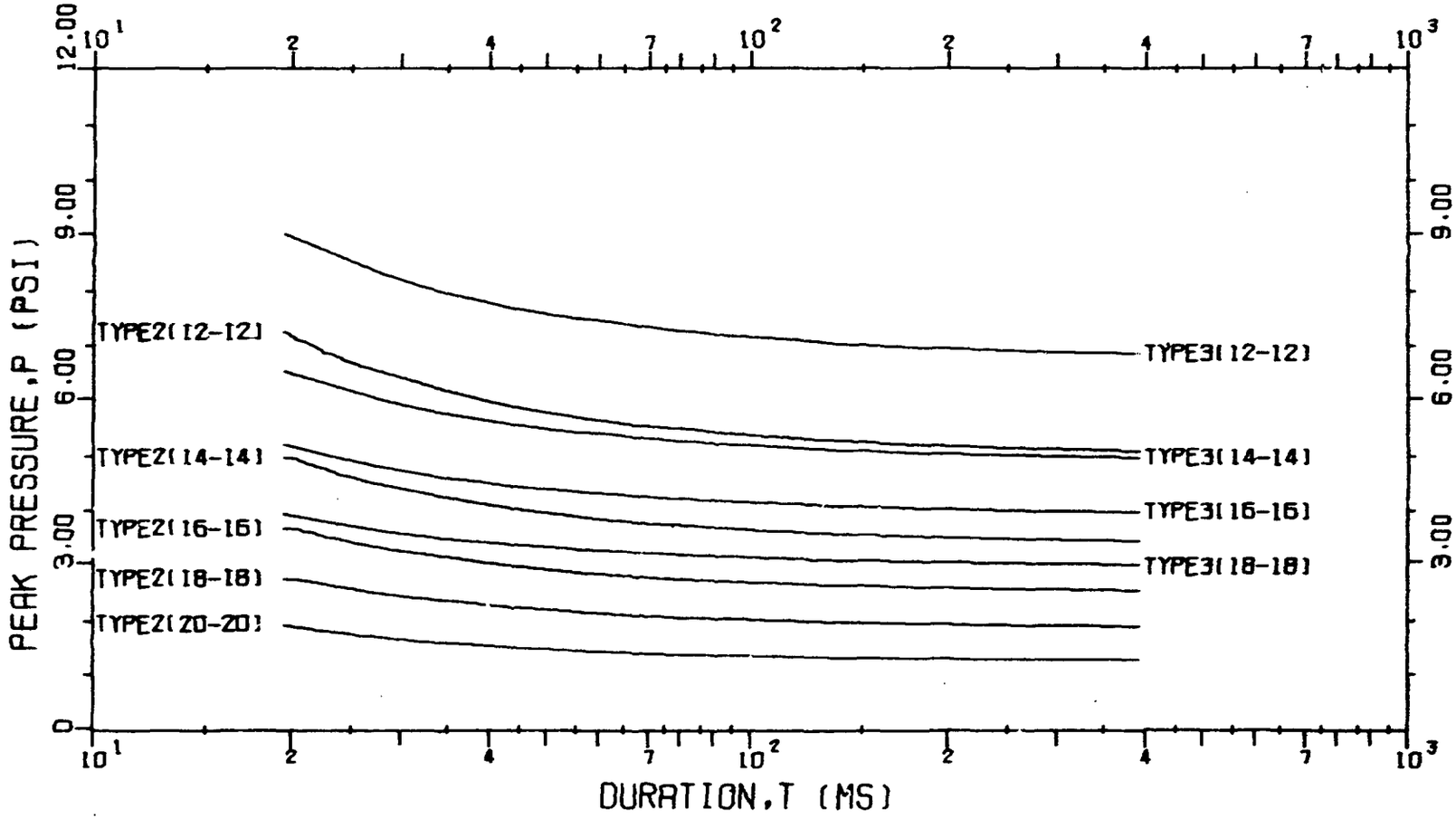


FIGURE 60

NON-REUSABLE METAL DECKING,SPAN= 10.0FT,MULTIPLE SPANS

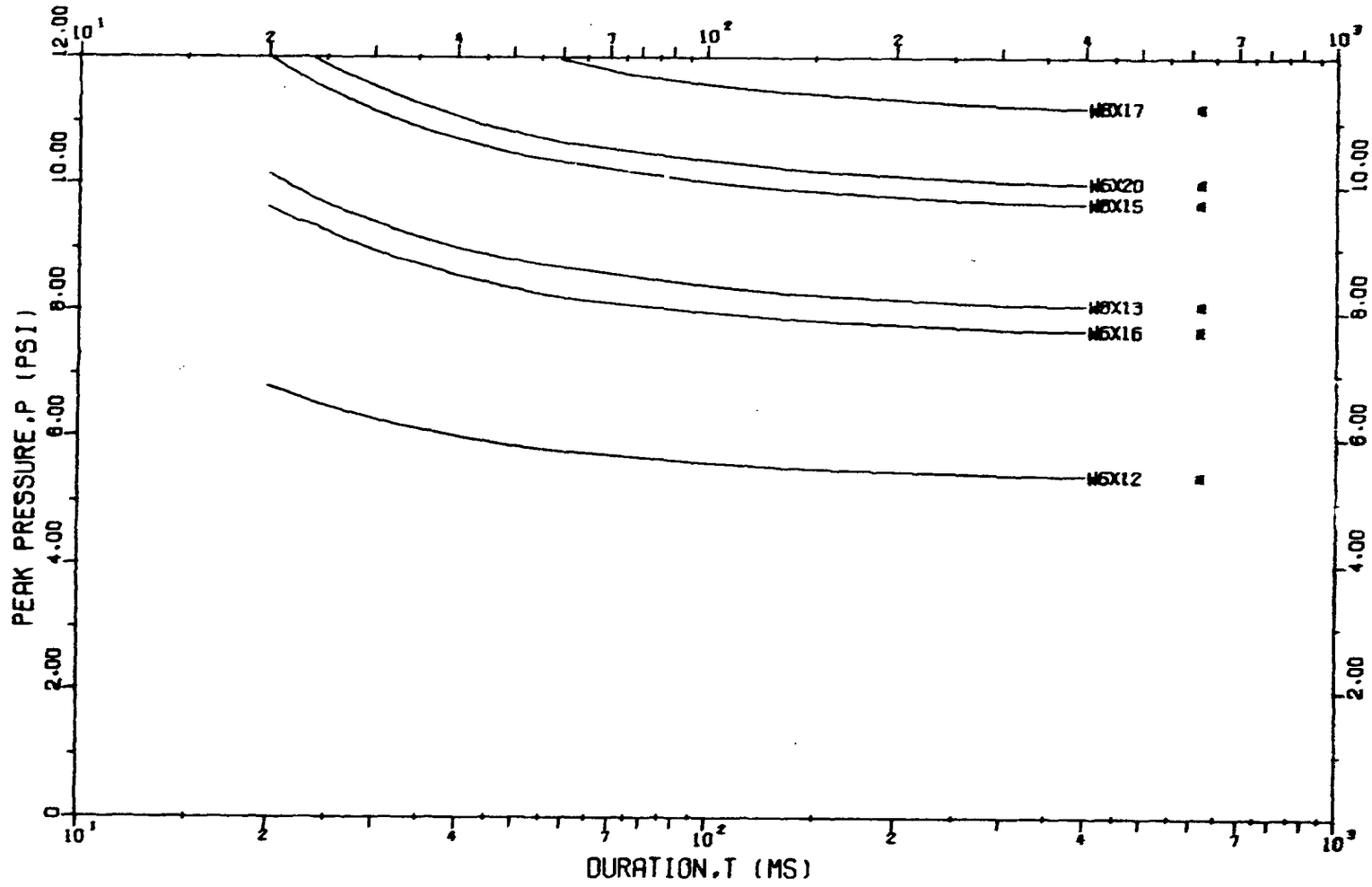


FIGURE 61

REUSABLE BEAM,SPAN=8 FT,SPACING=3 FT, SIMPLY-SUPPORTED

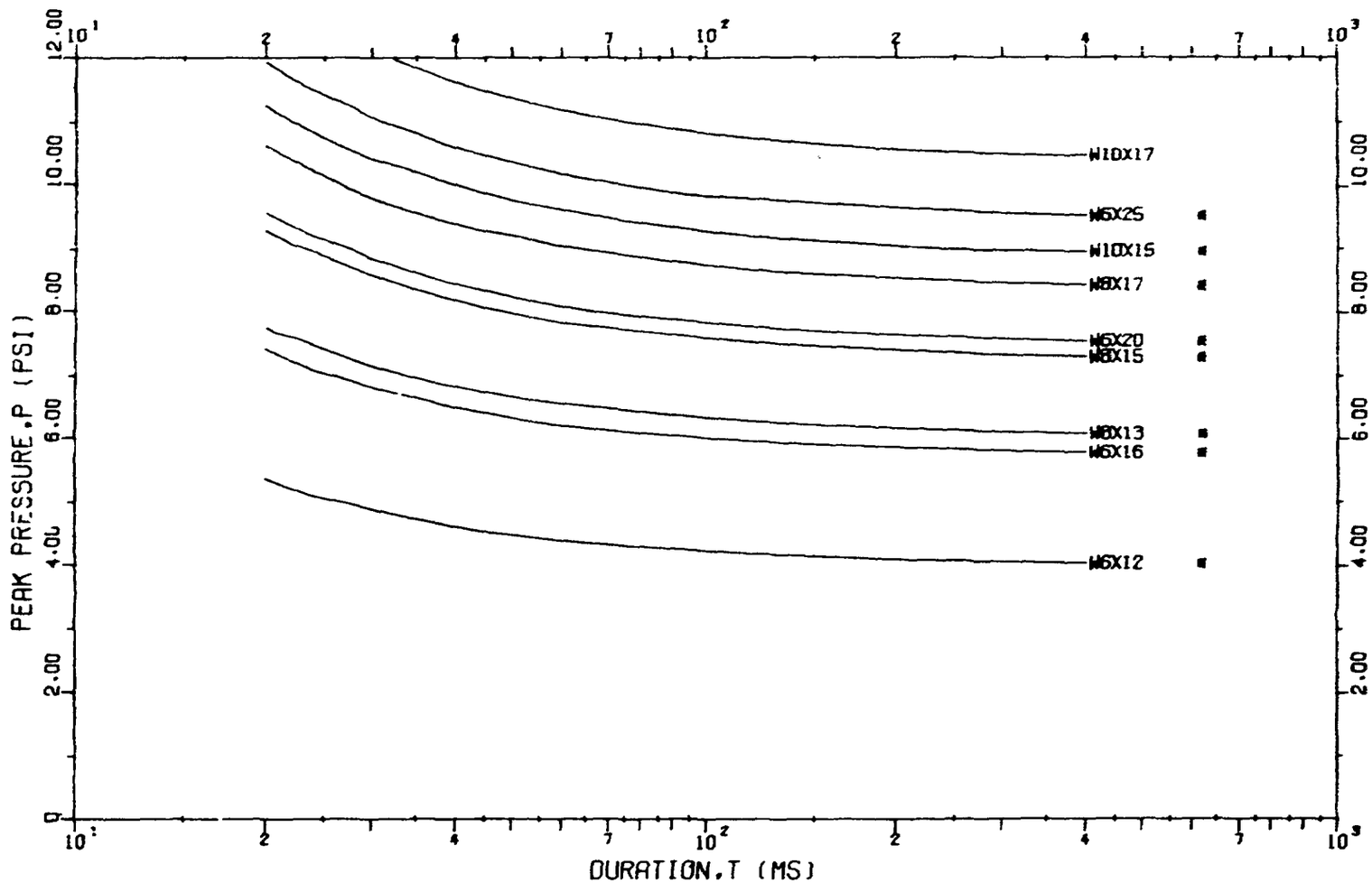


FIGURE 62

REUSABLE BEAM,SPAN=8 FT,SPACING=4 FT, SIMPLY-SUPPORTED

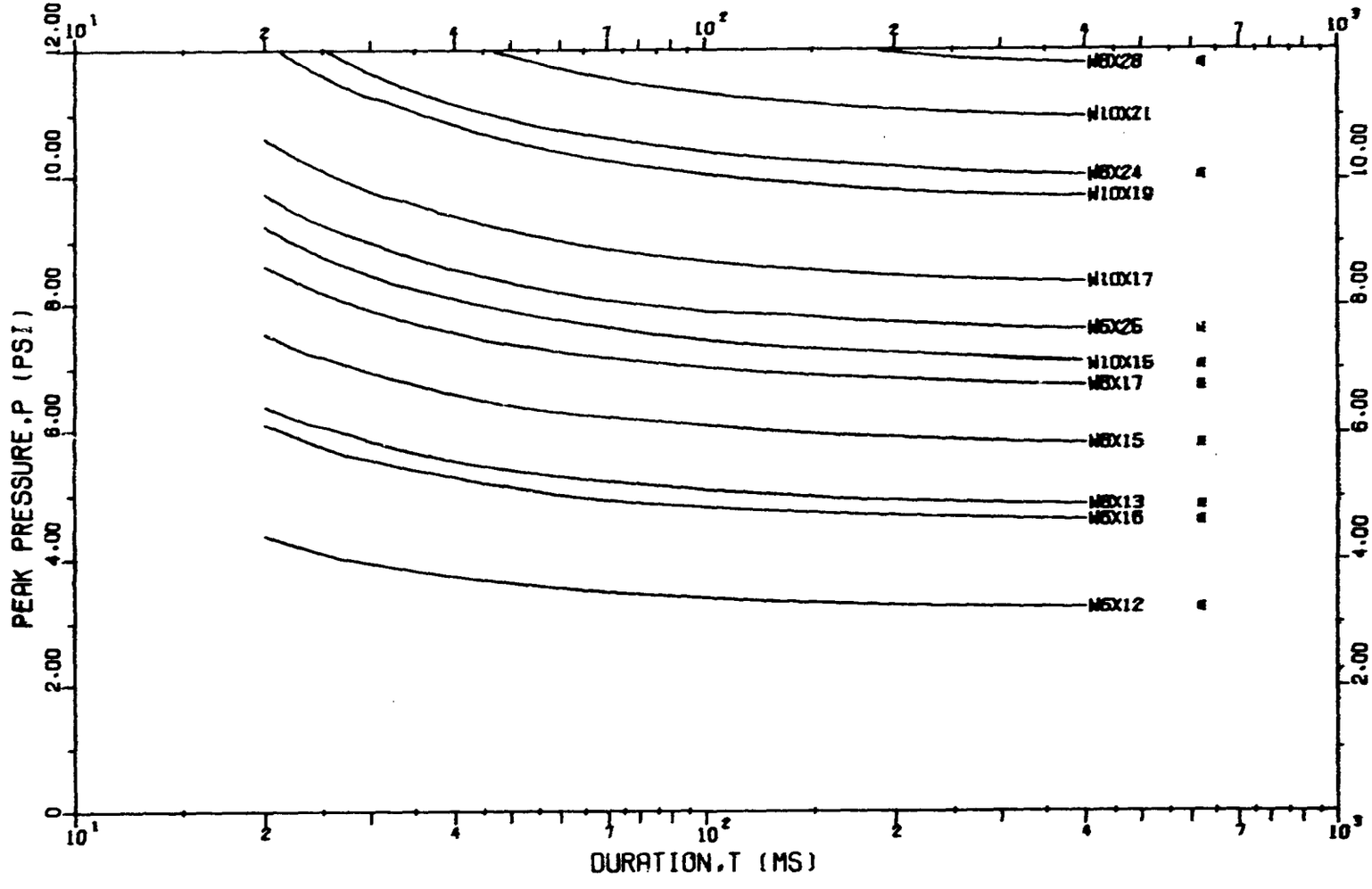


FIGURE 63

REUSABLE BEAM,SPAN=8 FT,SPACING=5 FT, SIMPLY-SUPPORTED

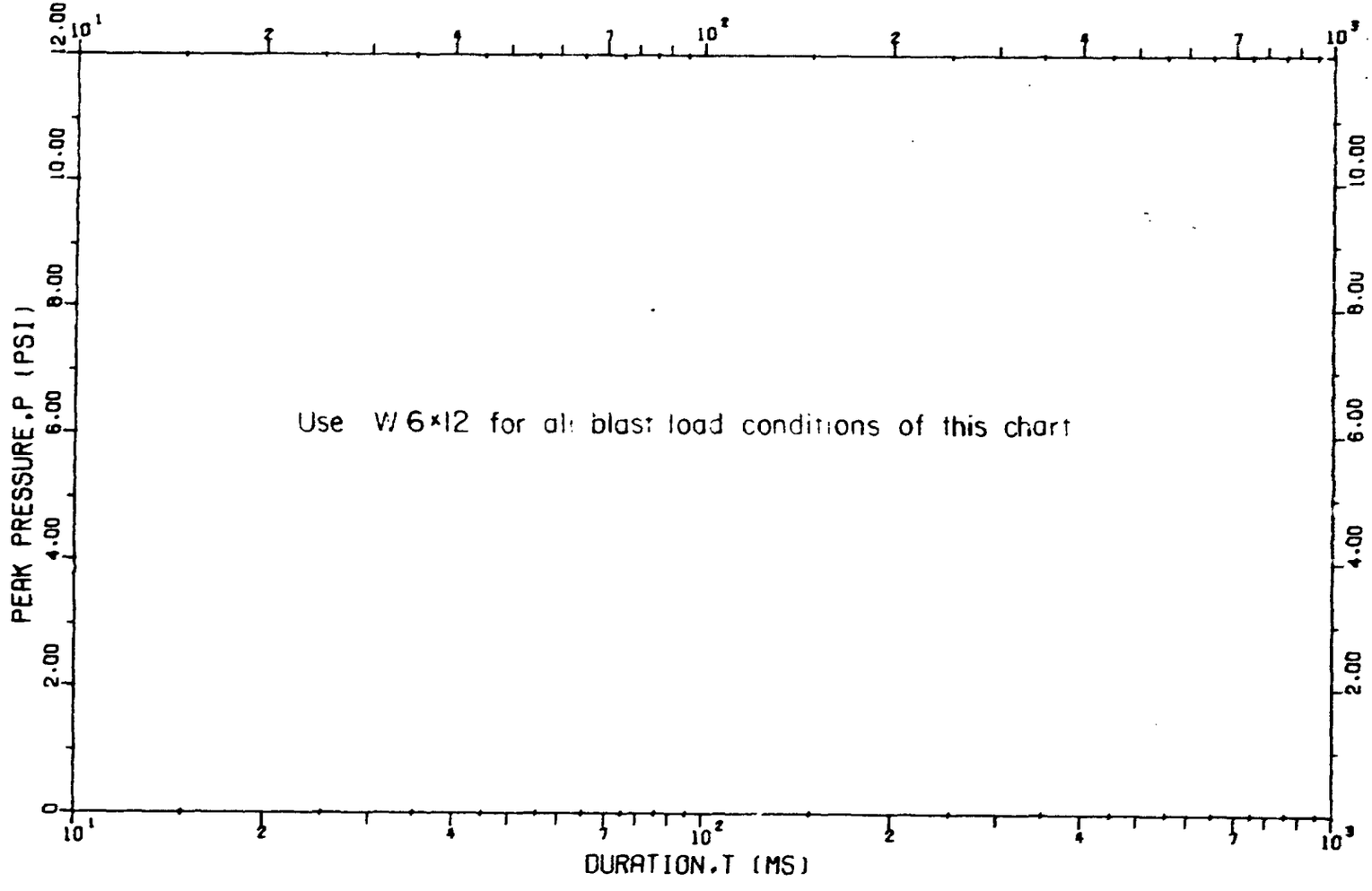


FIGURE 64

REUSABLE BEAM,SPAN=8 FT,SPACING=3 FT, FIXED ENDS

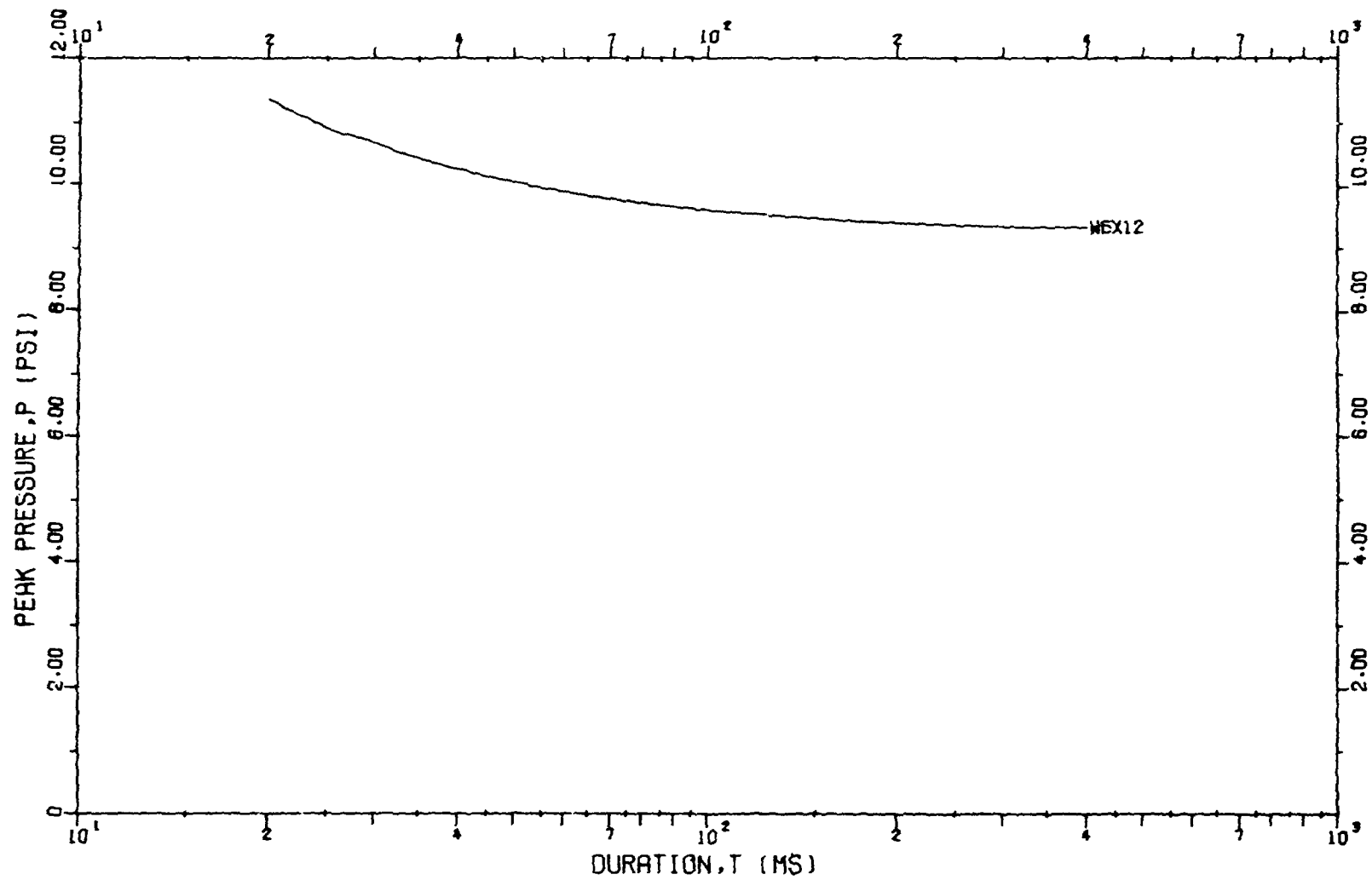


FIGURE 65

REUSABLE BEAM,SPAN=8 FT.SPACING=4 FT. FIXED ENDS

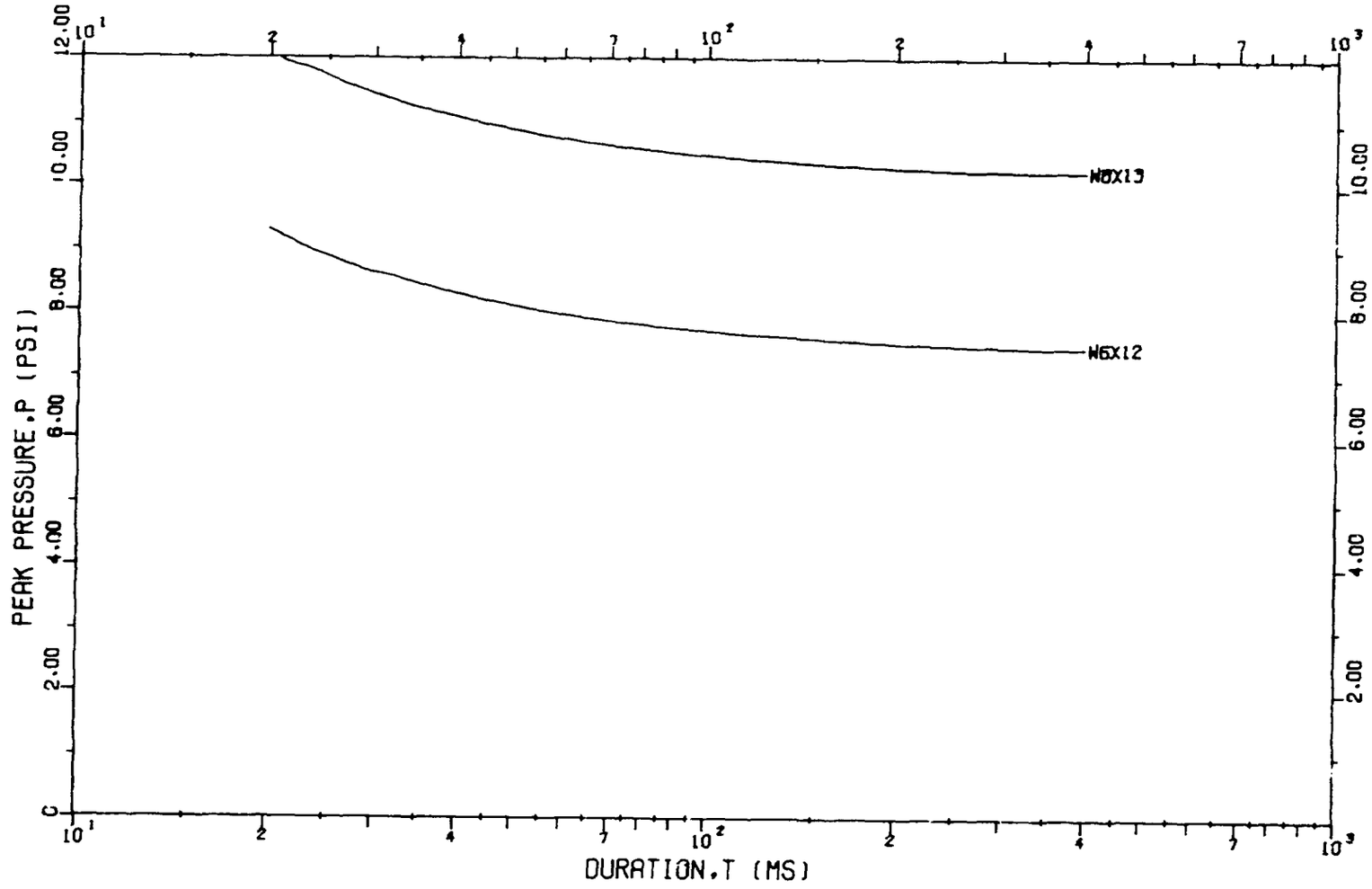


FIGURE 66

REUSABLE BEAM,SPAN=8 FT,SPACING=5 FT, FIXED ENDS

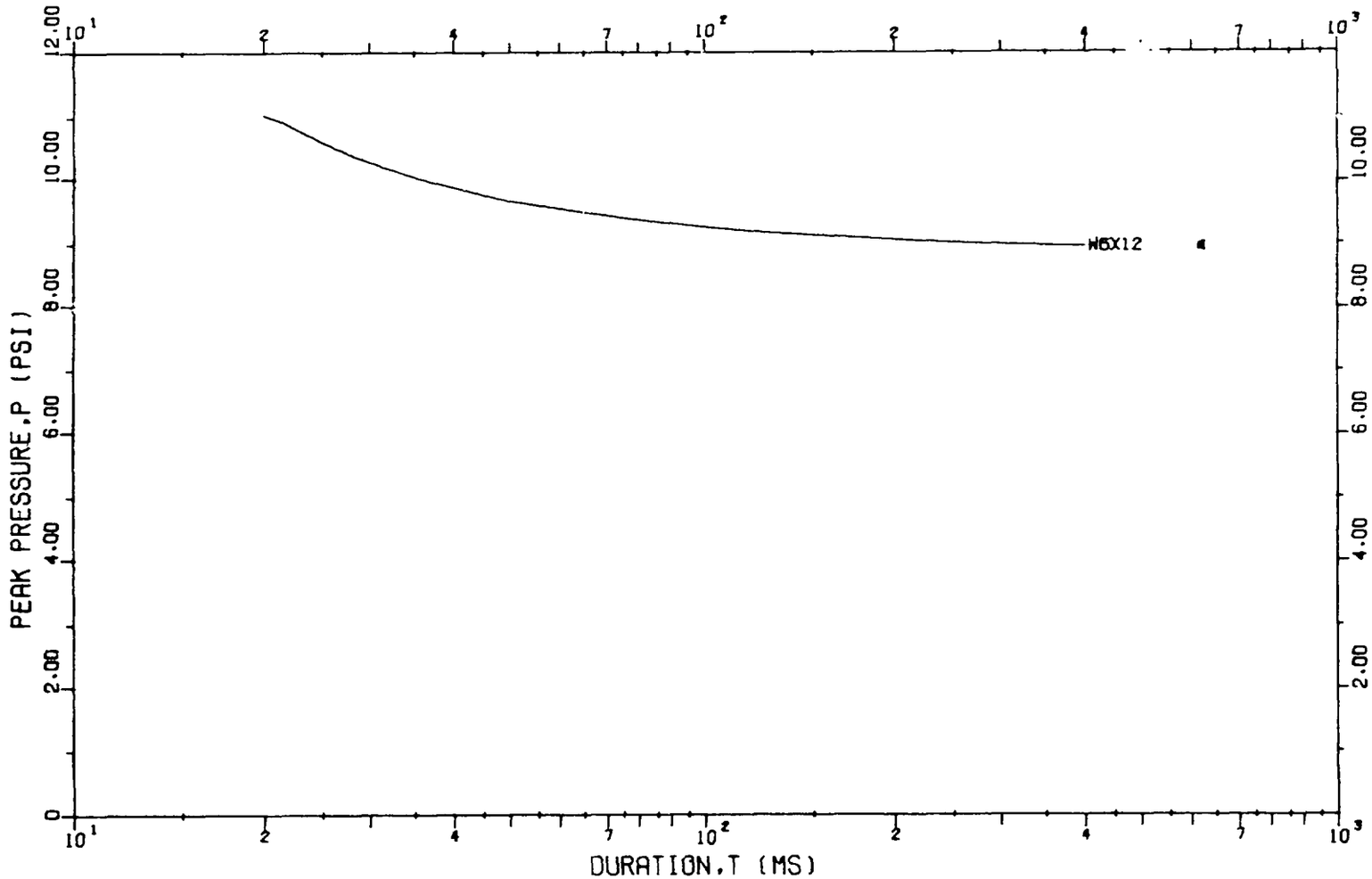


FIGURE 67

REUSABLE BEAM,SPAN=8 FT,SPACING=3 FT, SIMPLE-FIXED

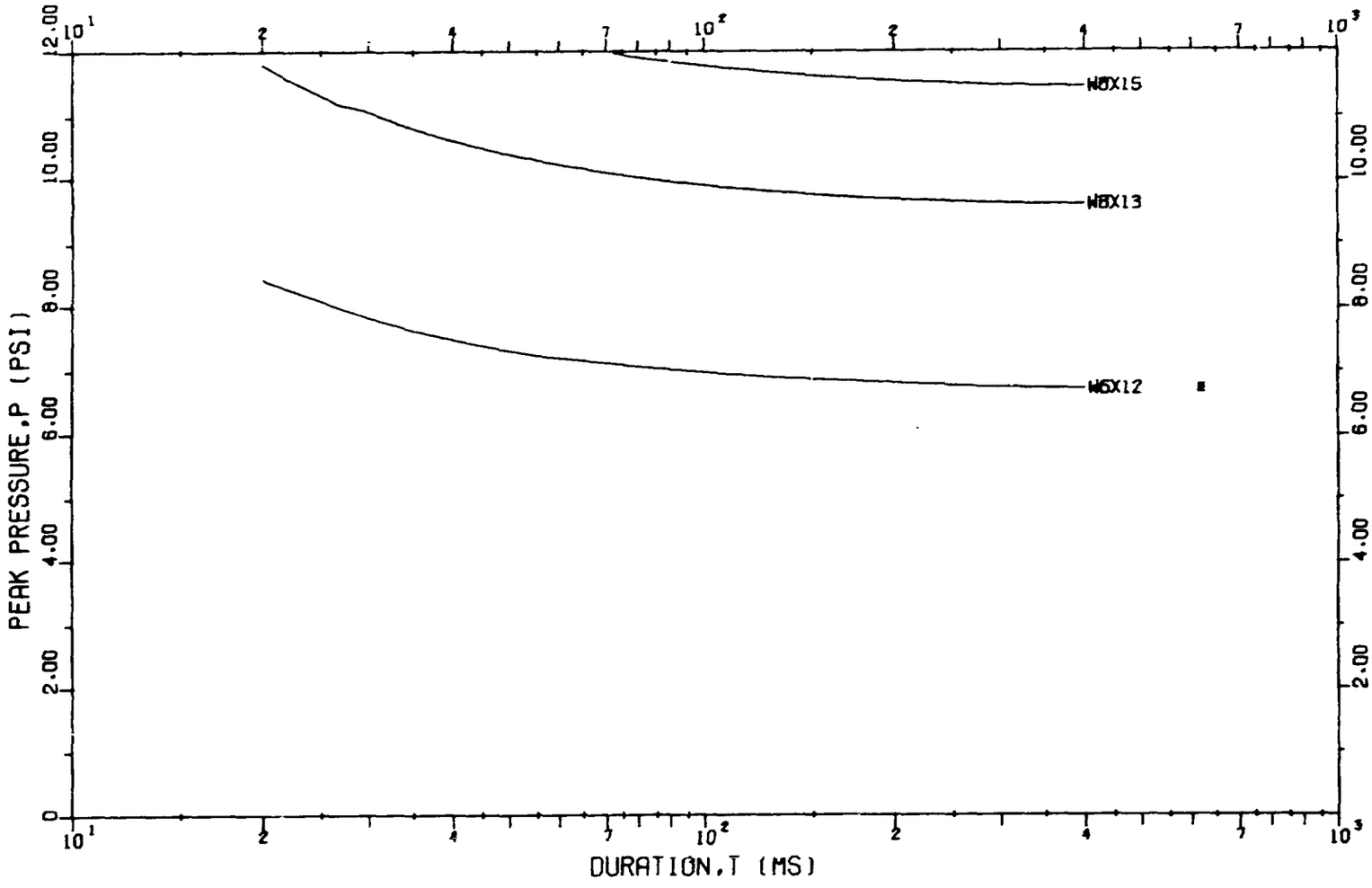


FIGURE 68

REUSABLE BEAM,SPAN=8 FT,SPACING=4 FT, SIMPLE-FIXED

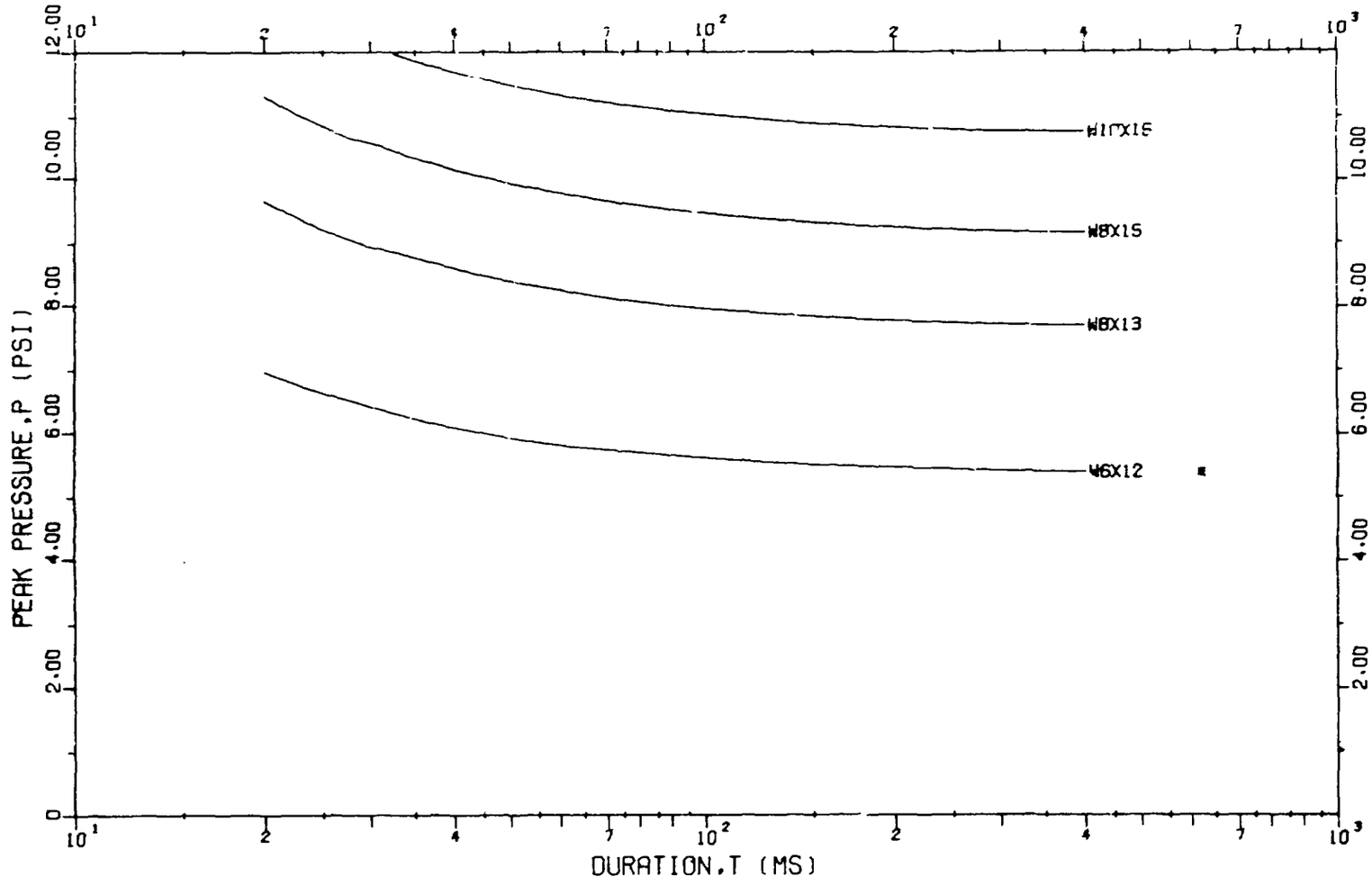


FIGURE 69

REUSABLE BEAM,SPAN=8 FT,SPACING=5 FT, SIMPLE-FIXED

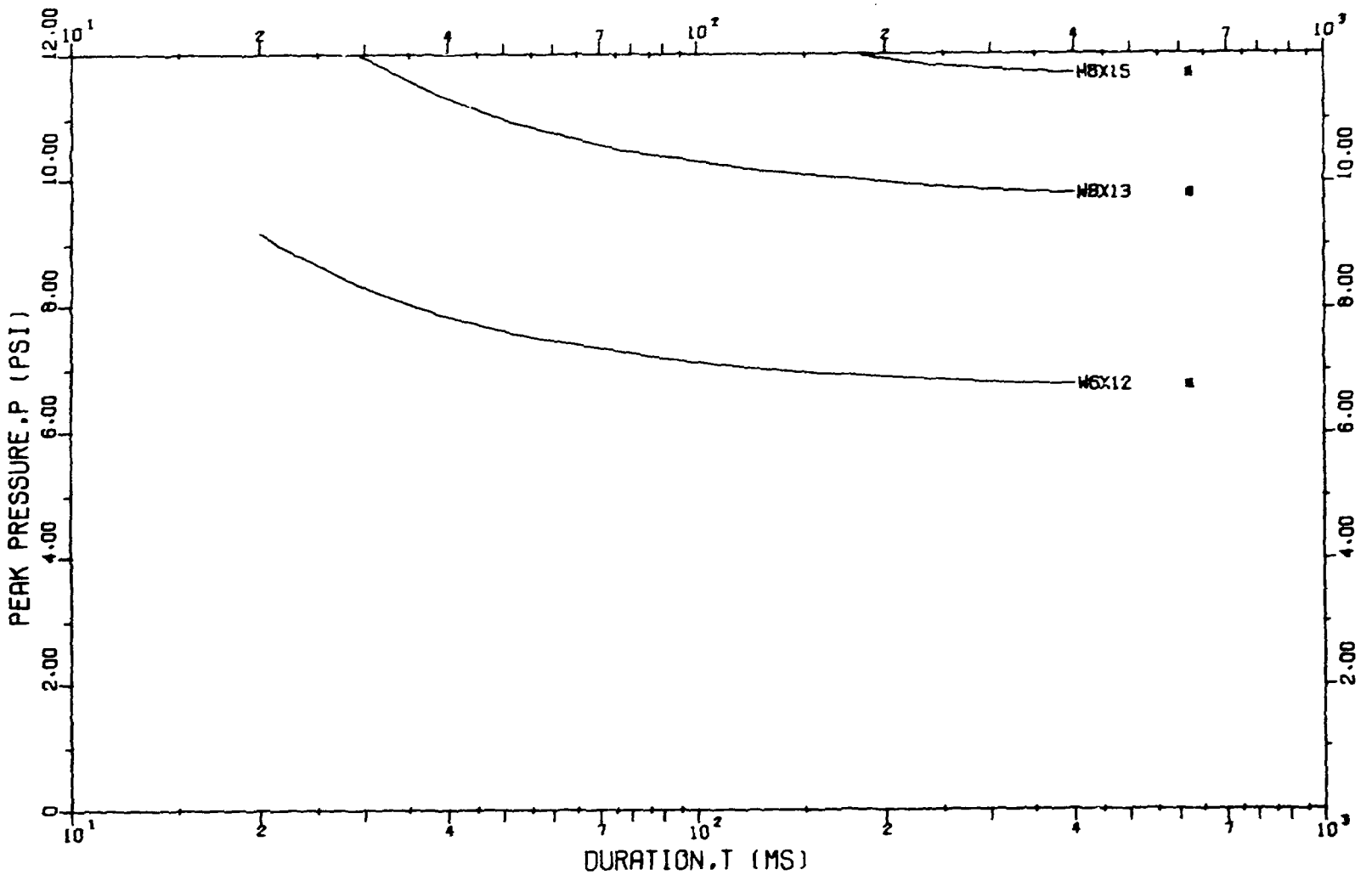


FIGURE 70

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING=3 FT. SIMPLY-SUPPORTED

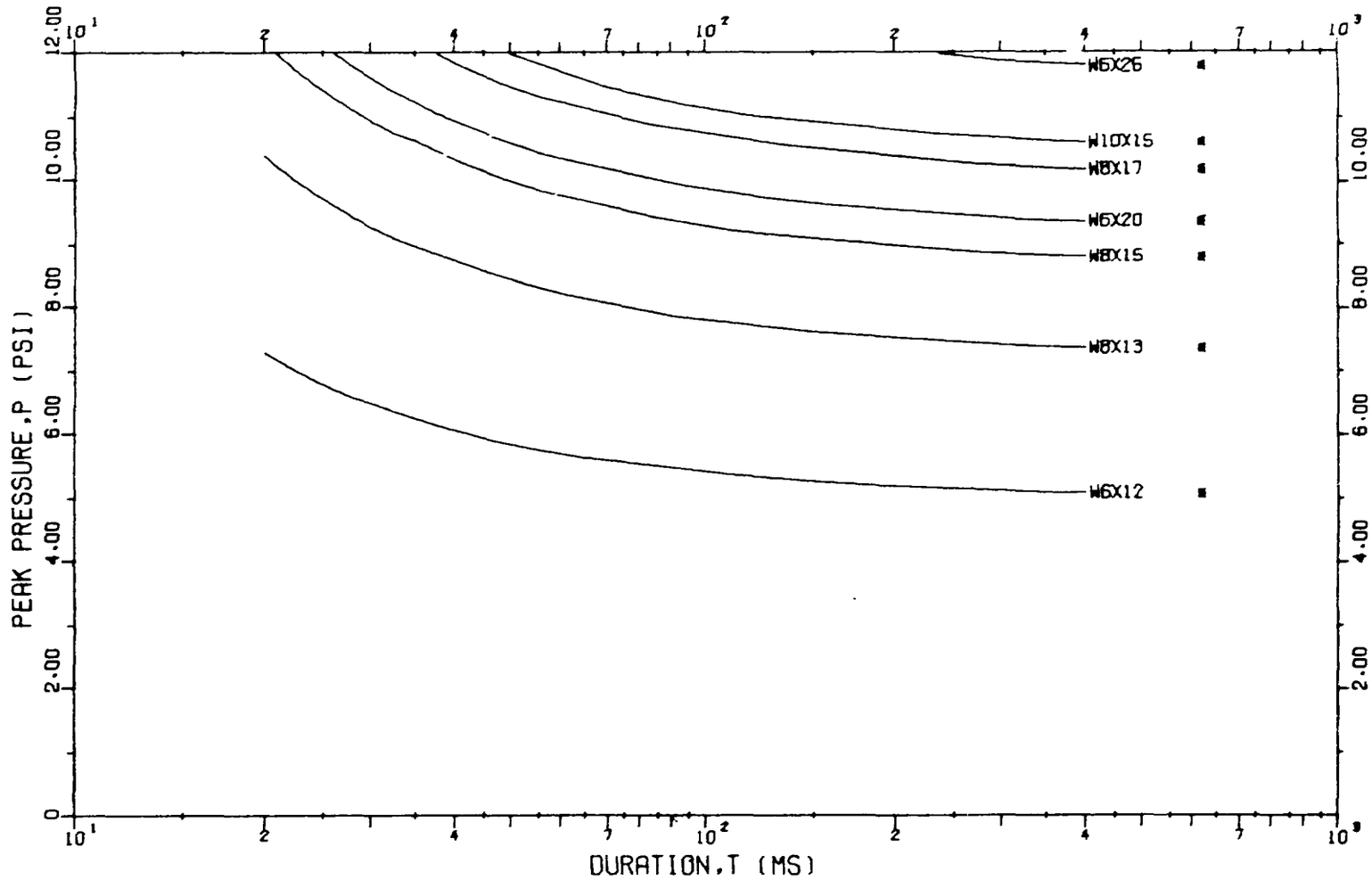


FIGURE 71

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING= 4 FT, SIMPLY-SUPPORTED

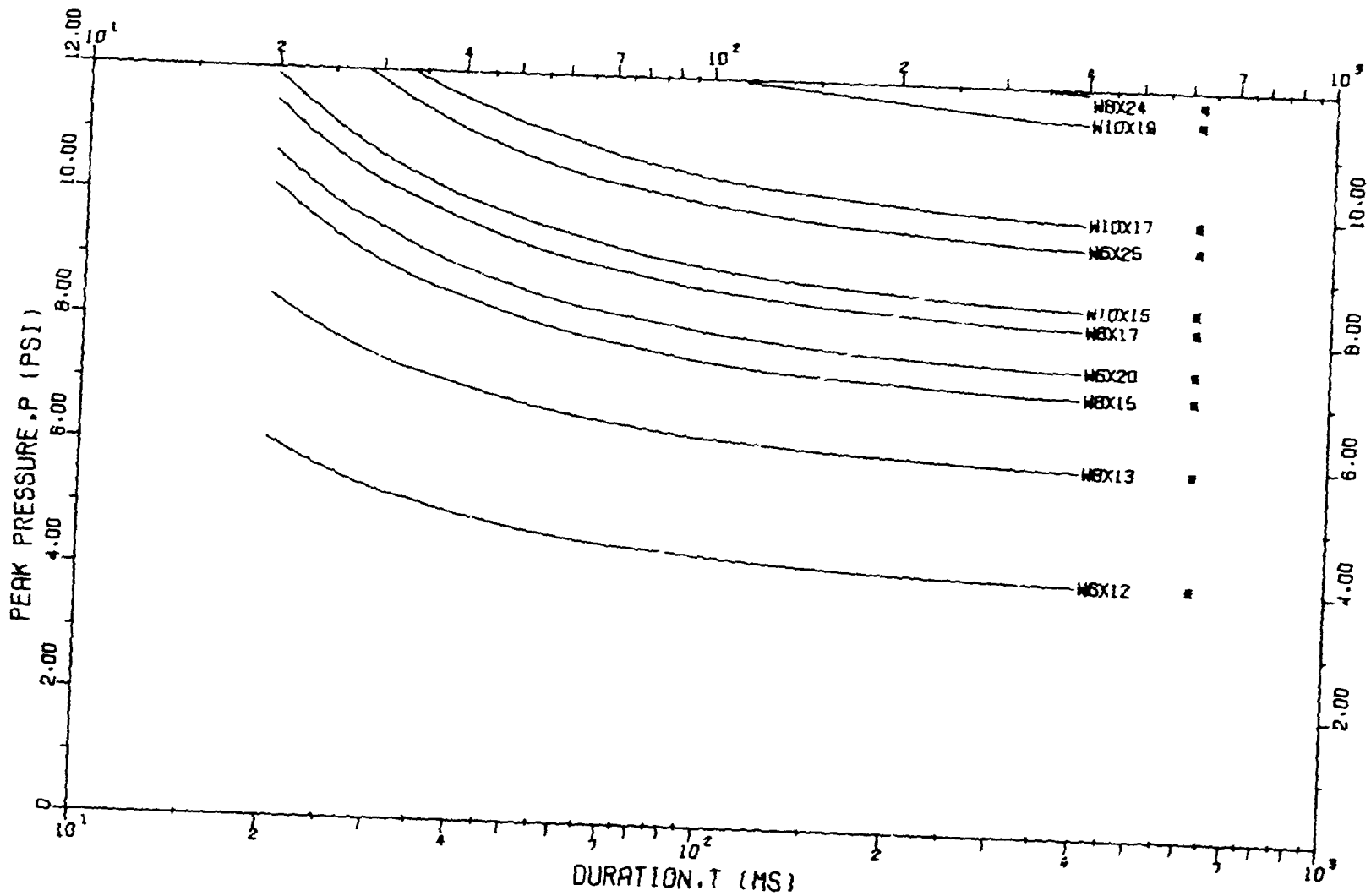


FIGURE 72

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING=5 FT, SIMPLY-SUPPORTED

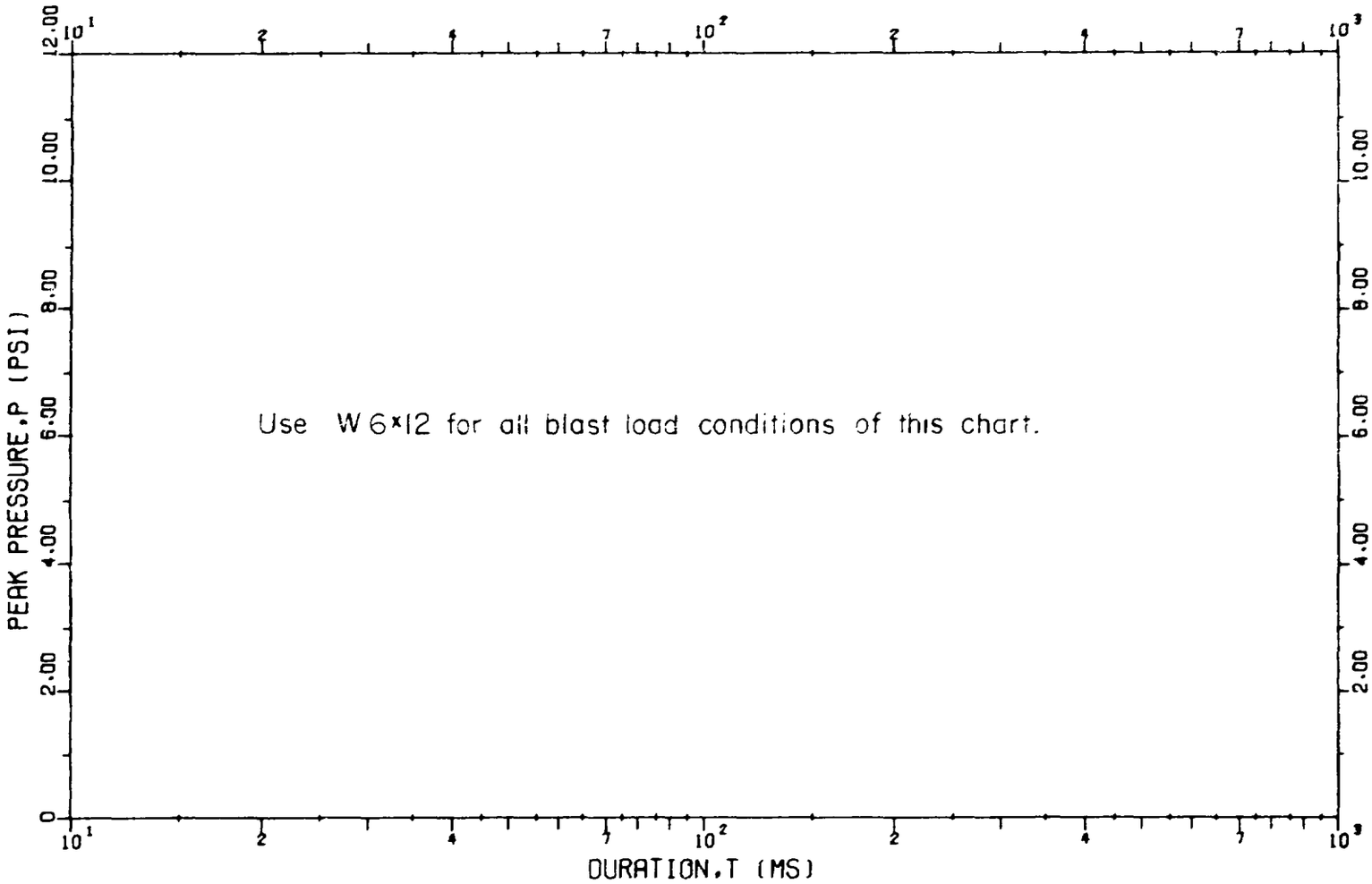


FIGURE 73

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING=3 FT, FIXED ENDS

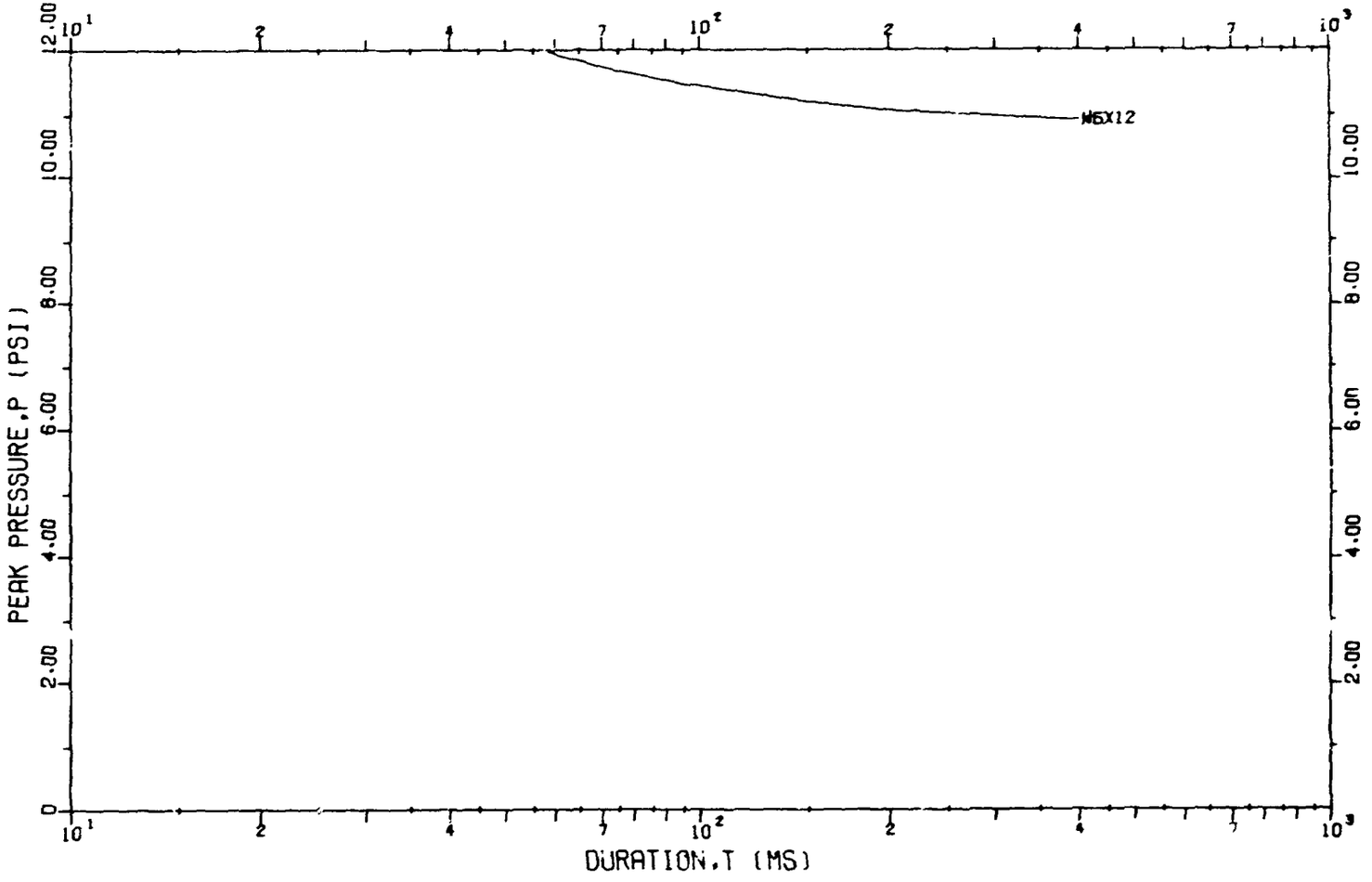


FIGURE 74

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING= 4 FT, FIXED ENDS

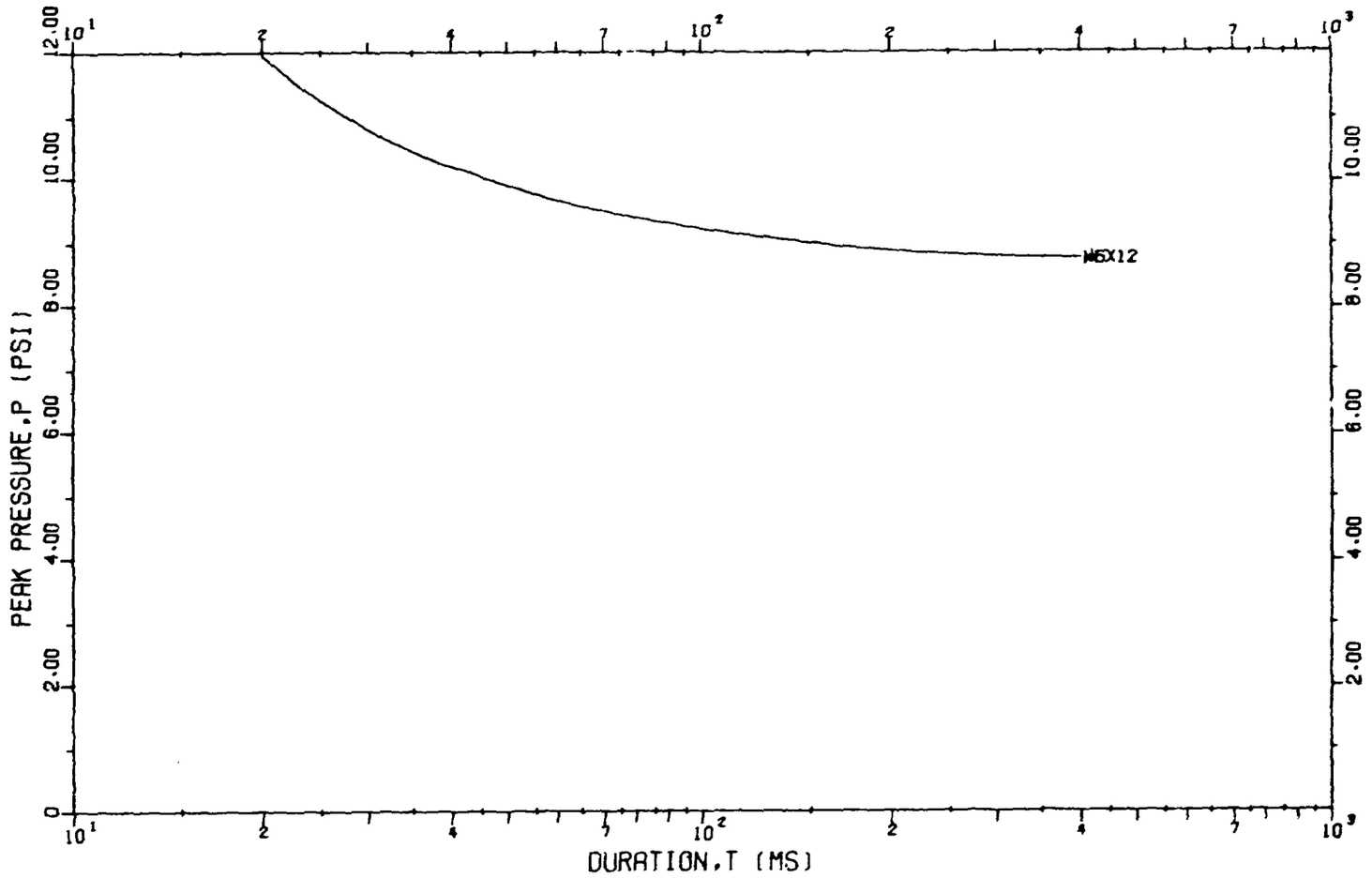


FIGURE 75

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING=5 FT. FIXED ENDS

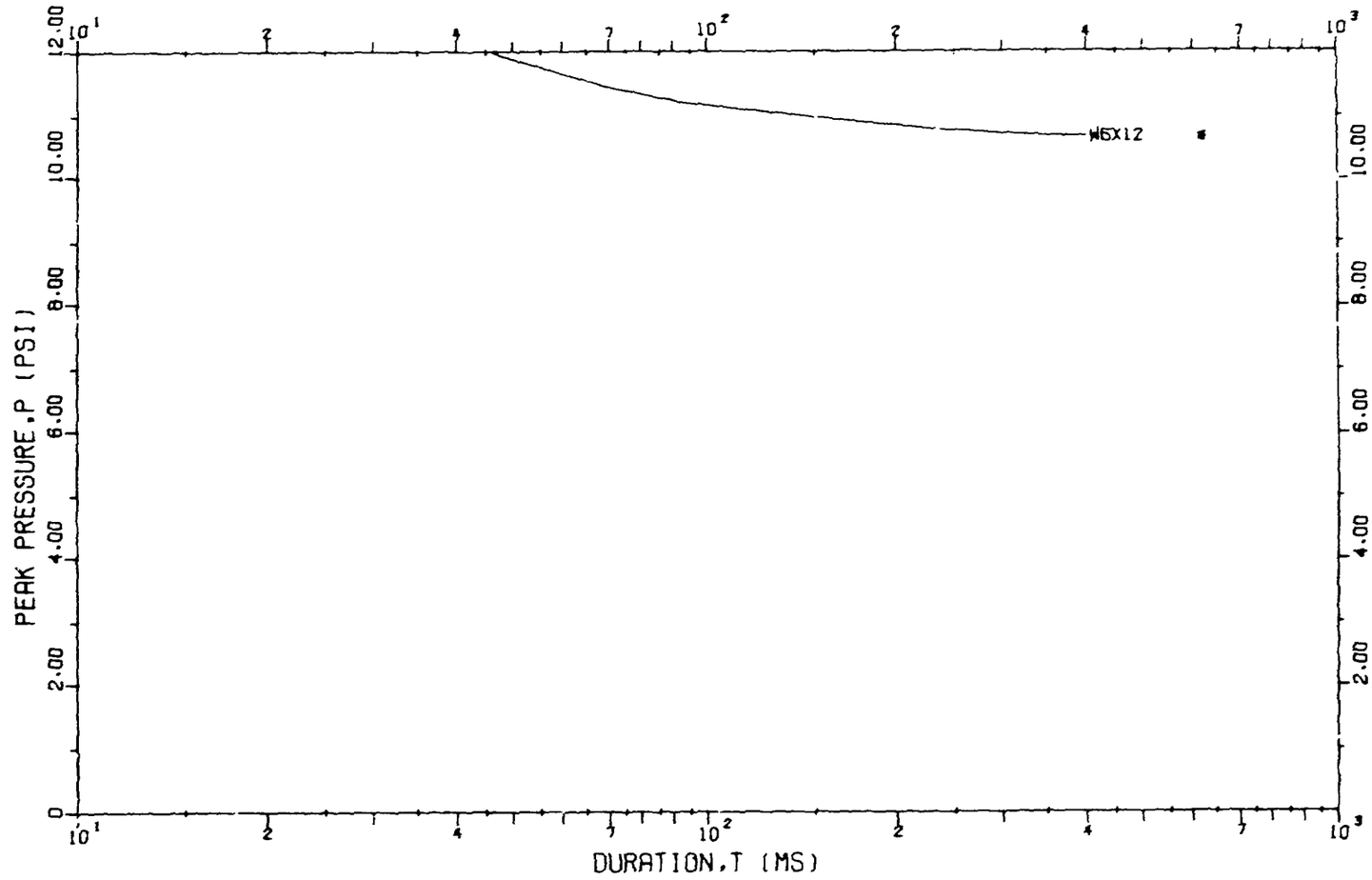


FIGURE 76

NON-REUSABLE BEAM,SPAN=8 FT,SPACING=3 FT. SIMPLE-FIXED

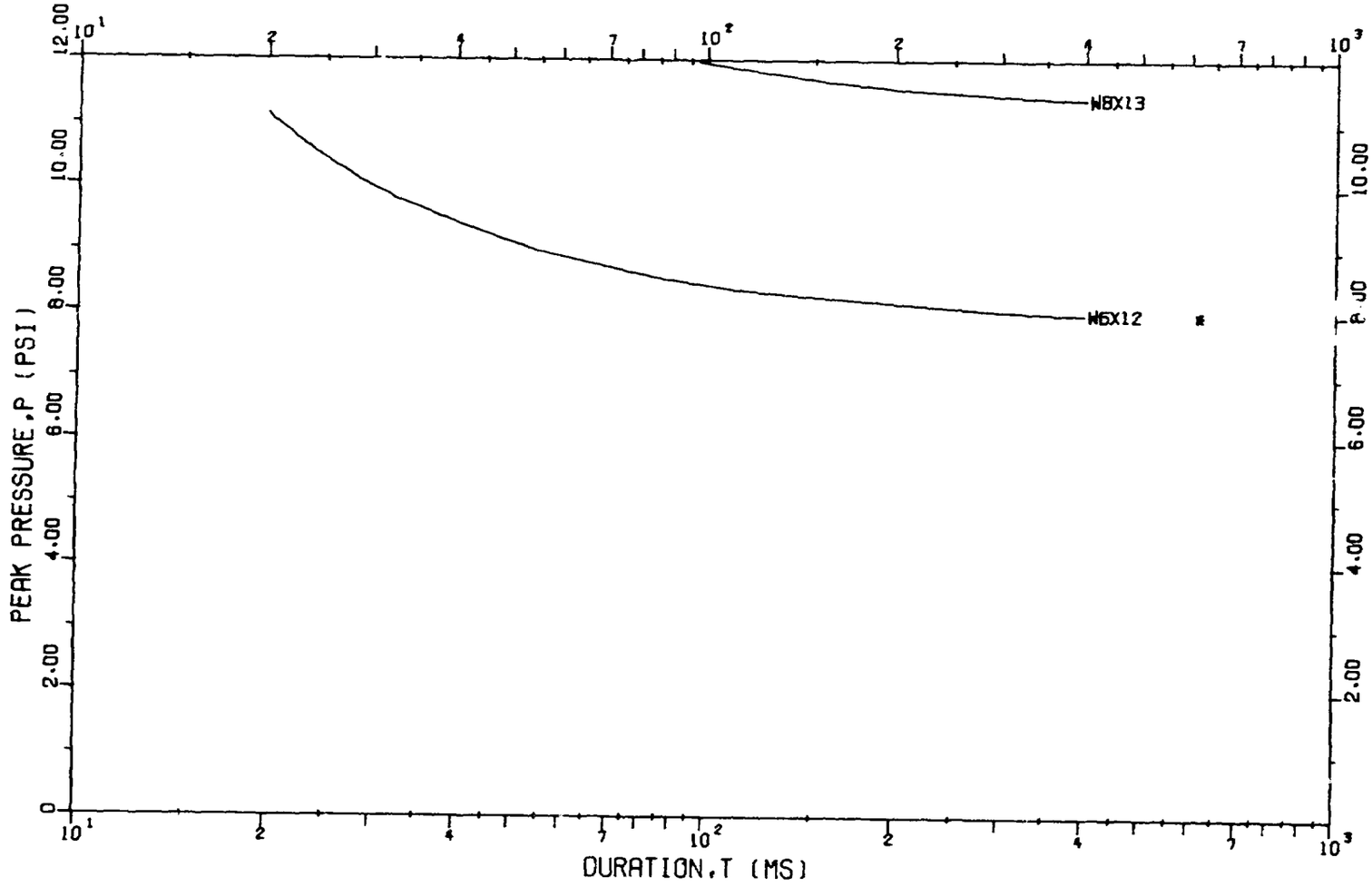


FIGURE 77

NON-REUSABLE BEAM,SPAN= 8 FT.SPACING= 4 FT. SIMPLE-FIXED

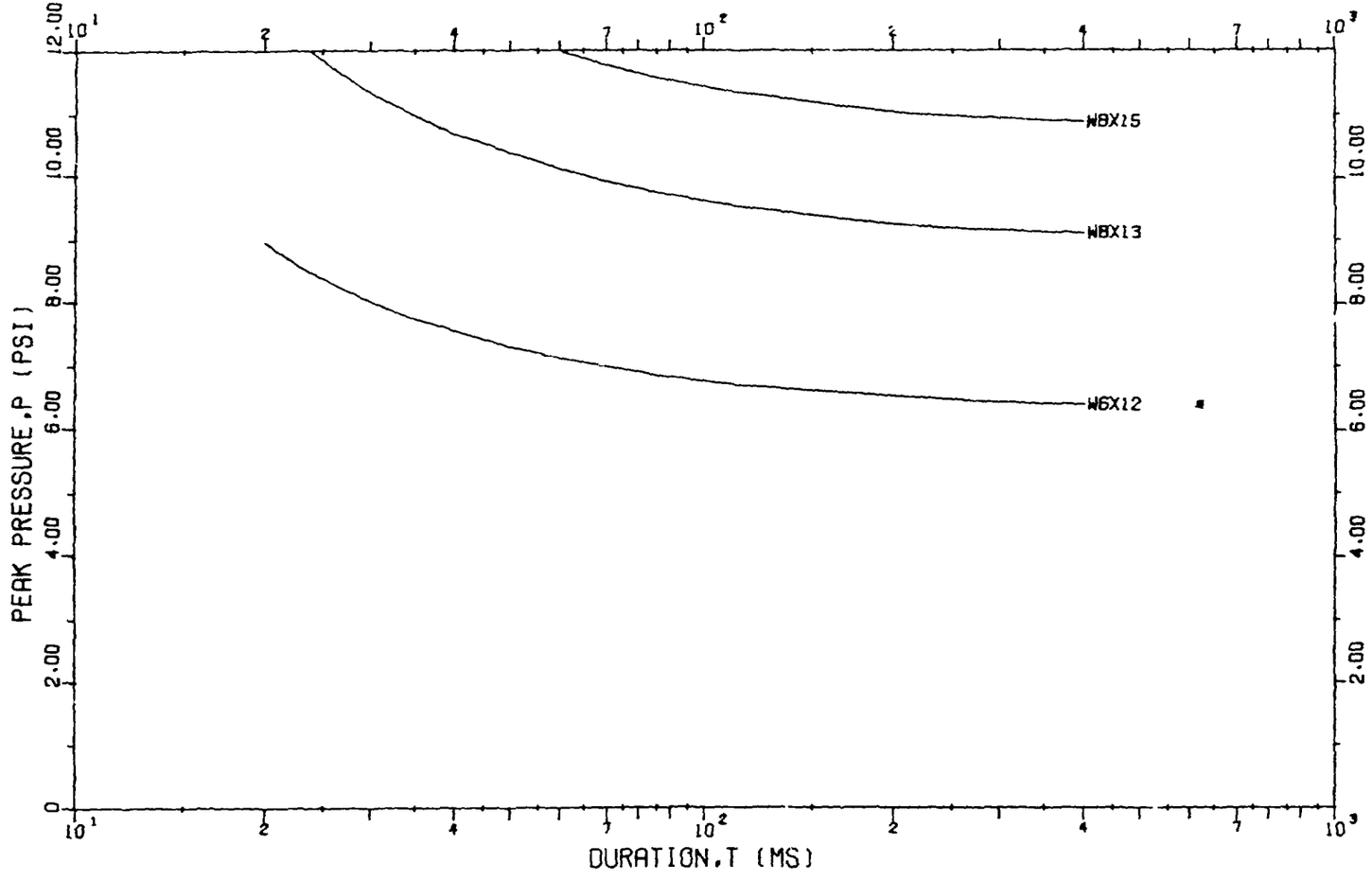


FIGURE 78

NON-REUSABLE BEAM,SPAN= 8 FT,SPACING=5 FT. SIMPLE-FIXED

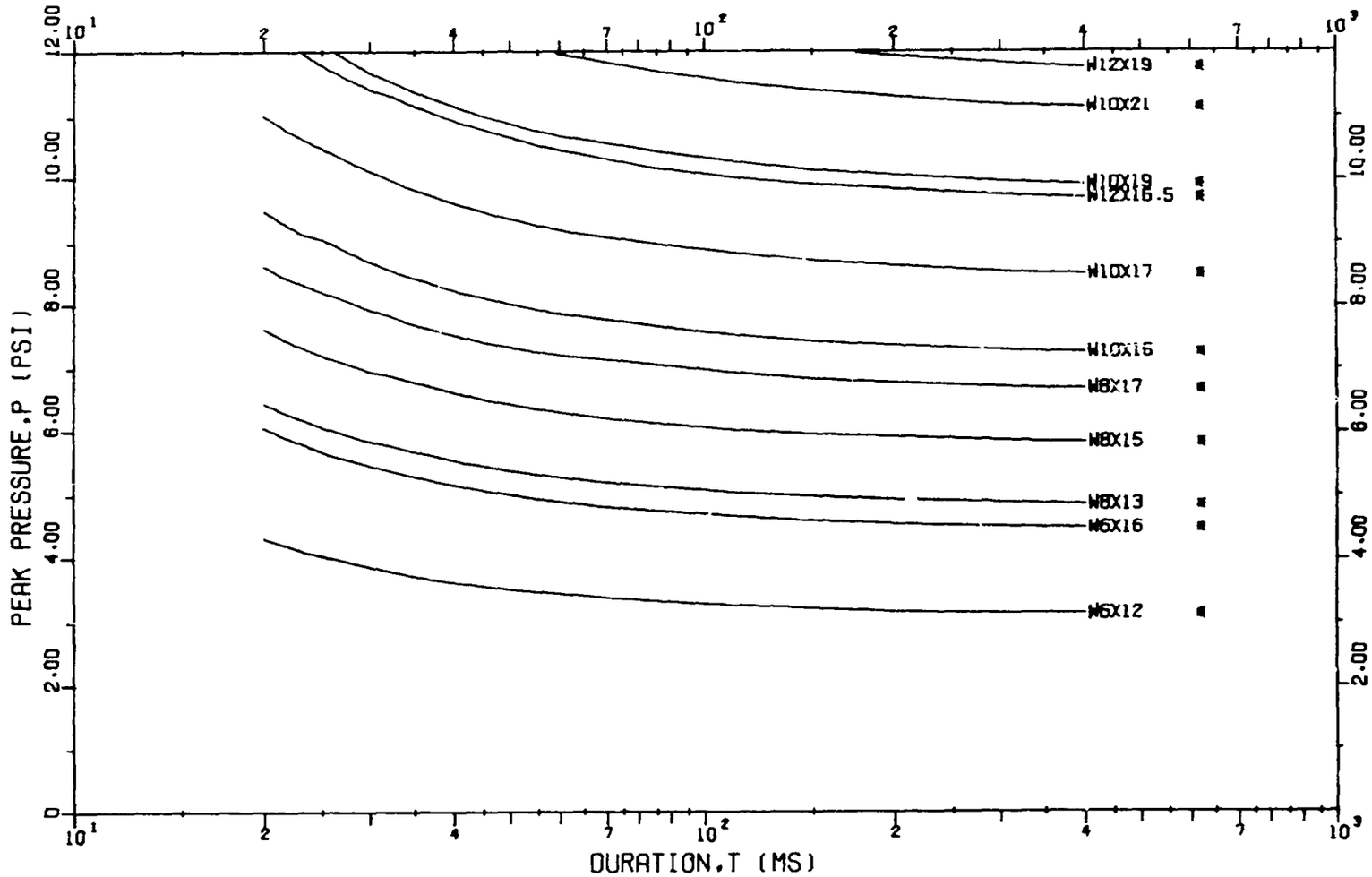


FIGURE 79

REUSABLE BEAM,SPAN=10 FT,SPACING=3 FT, SIMPLY-SUPPORTED

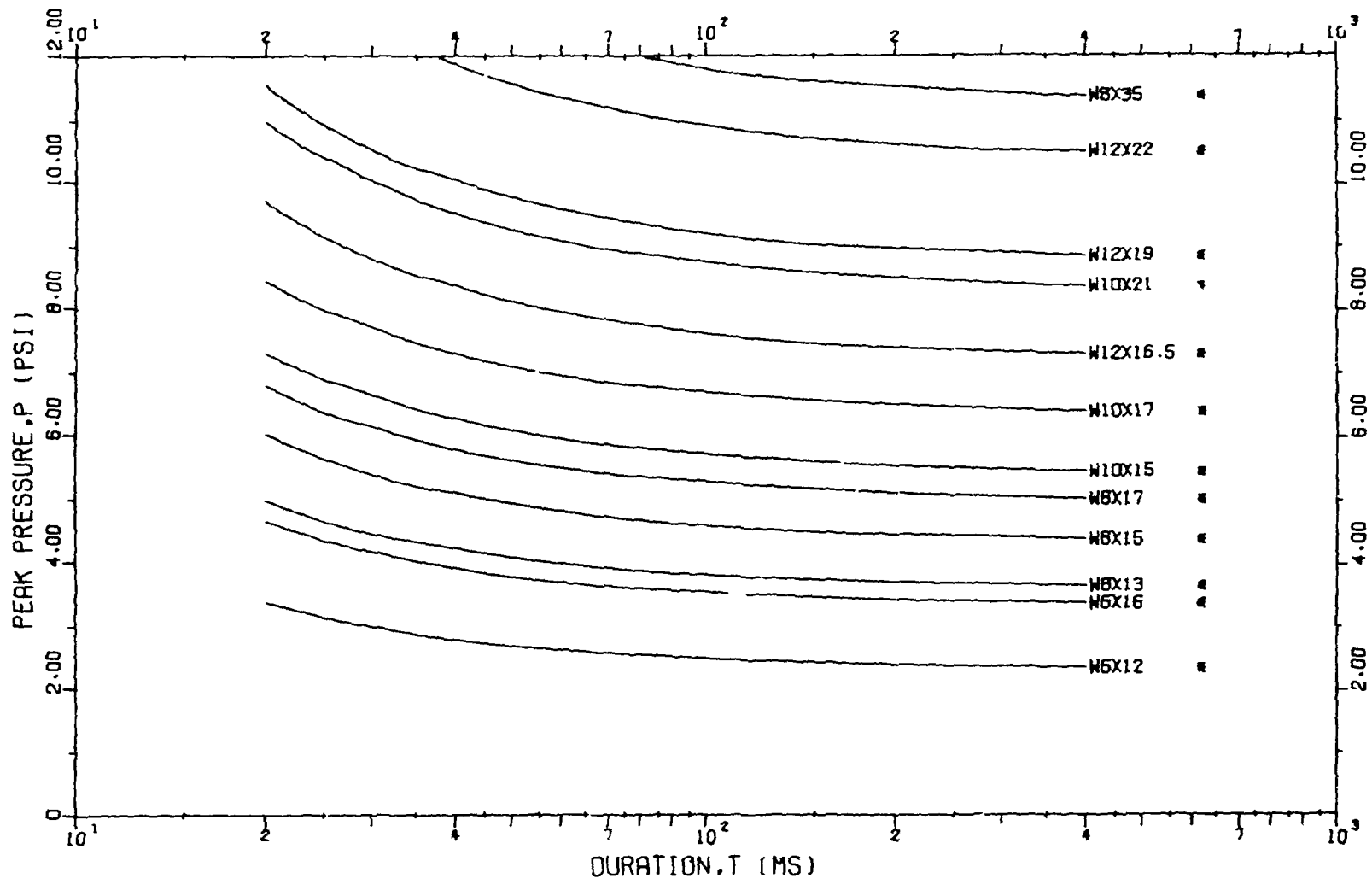


FIGURE 80

REUSABLE BEAM,SPAN= 10 FT,SPACING= 4 FT. SIMPLY-SUPPORTED

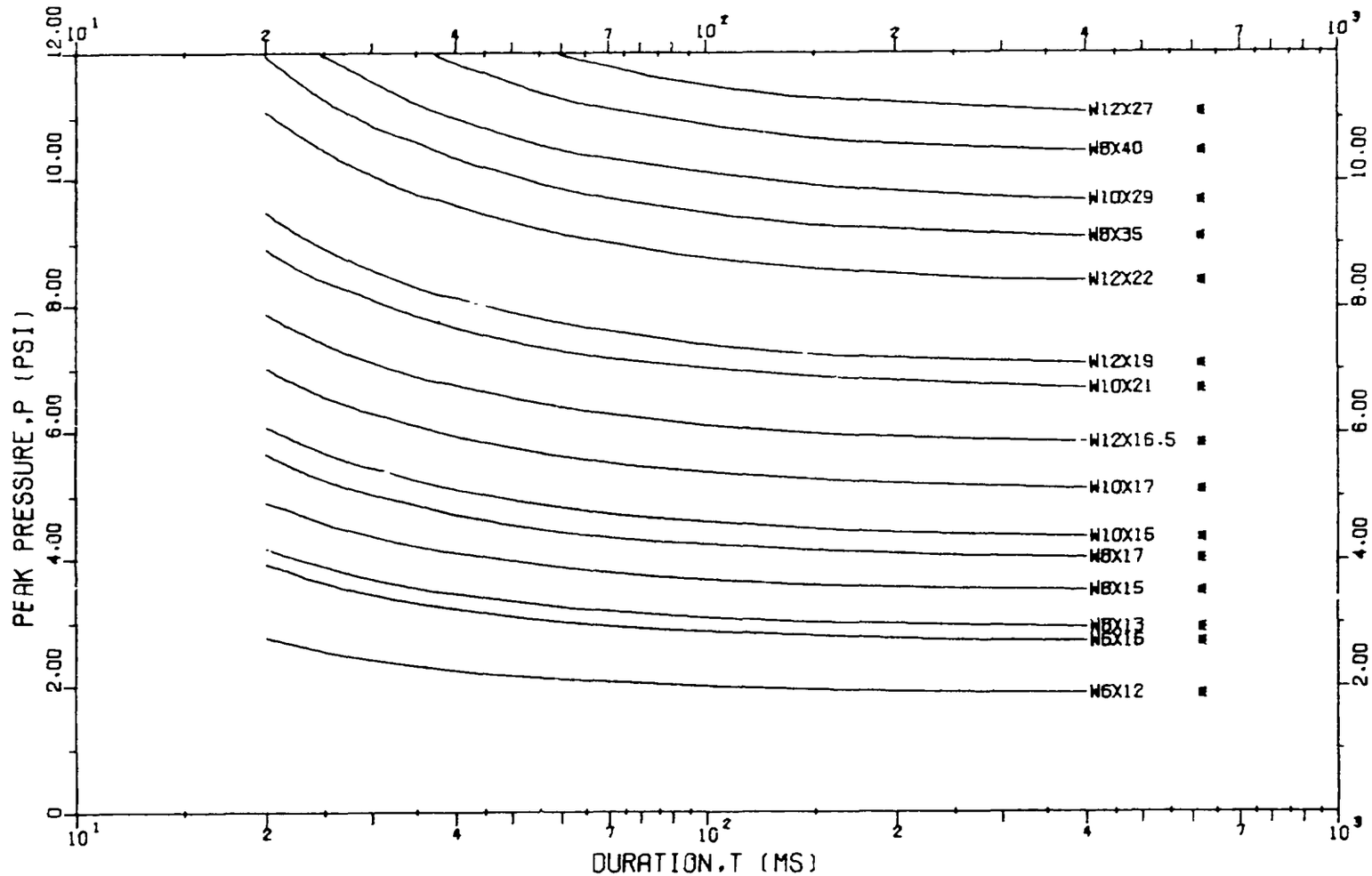


FIGURE 21

REUSABLE BEAM,SPAN= 10 FT,SPACING= 5 FT, SIMPLY-SUPPORTED

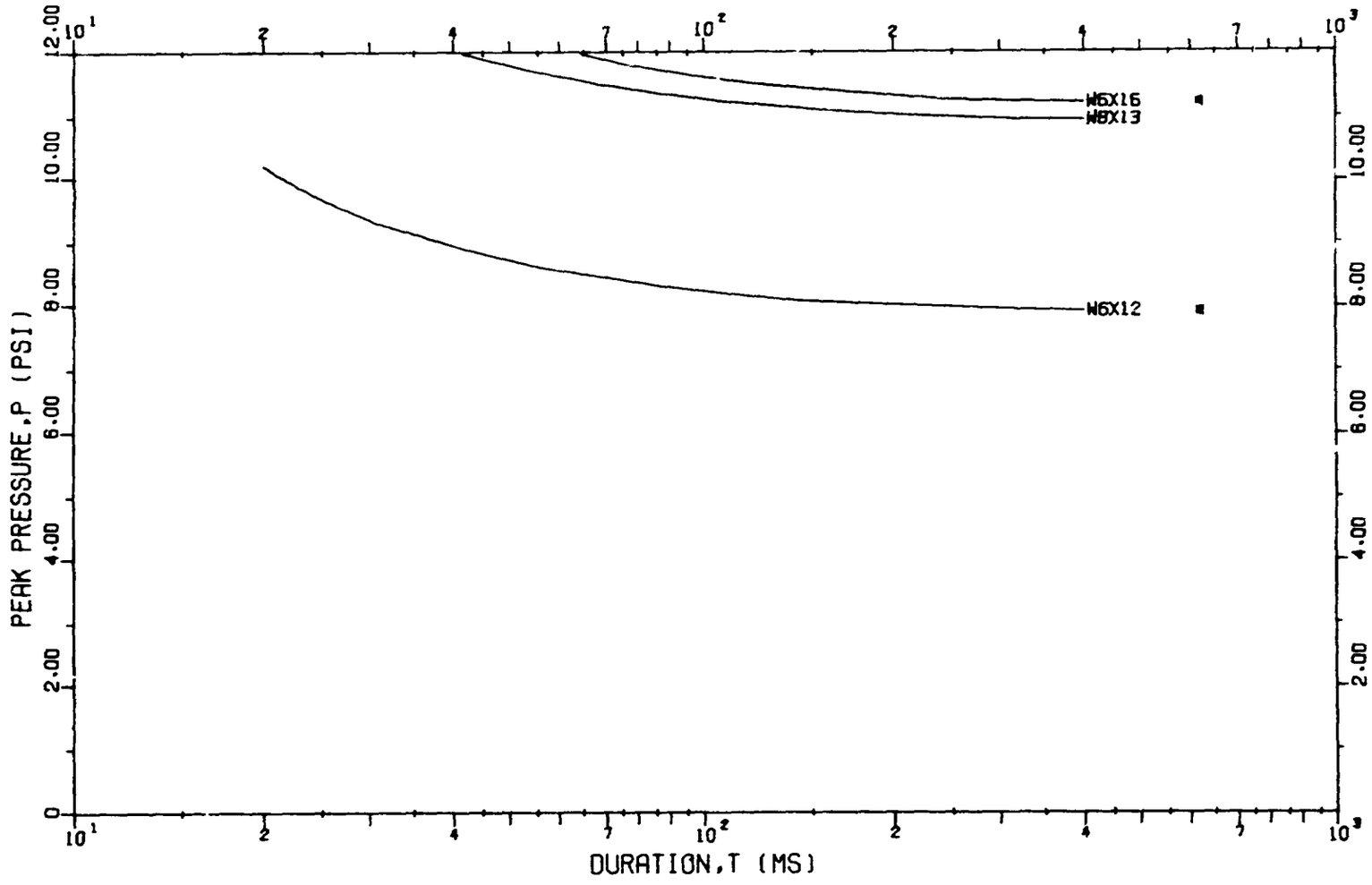


FIGURE 82

REUSABLE BEAM,SPAN= 10 FT,SPACING= 3 FT, FIXED ENDS

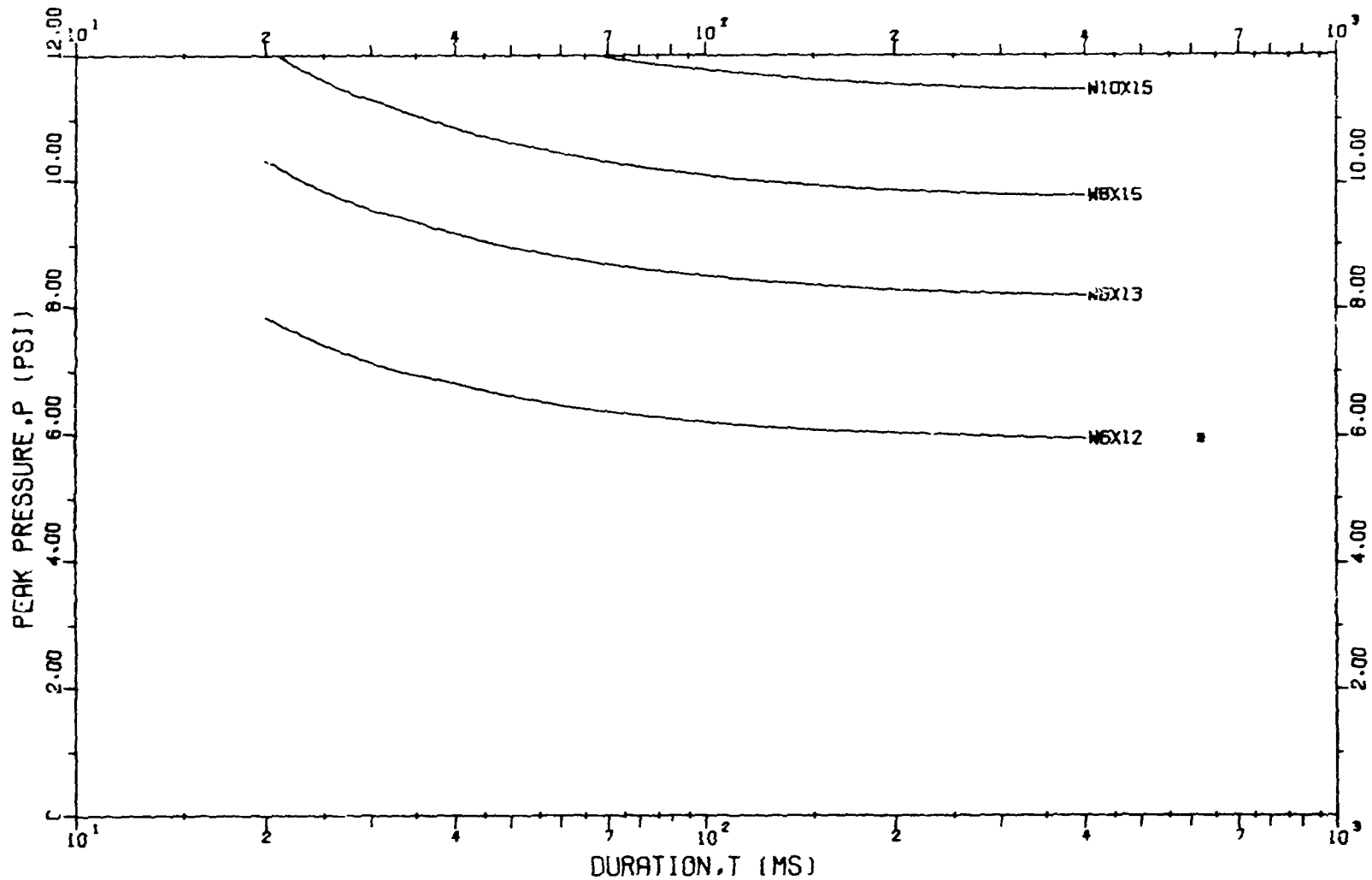


FIGURE 33

REUSABLE BEAM,SPAN=10 FT.SPACING=4 FT. FIXED ENDS

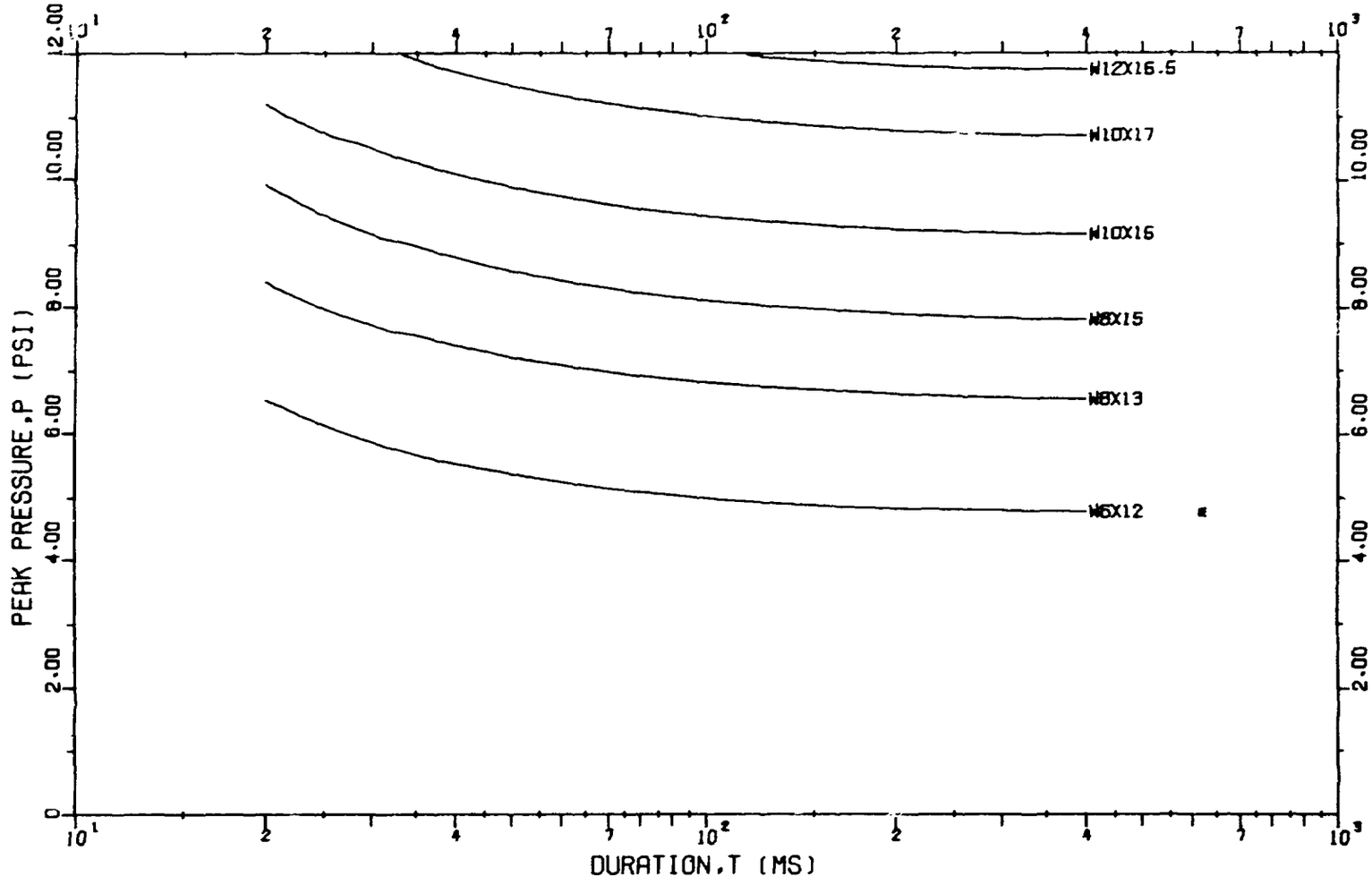


FIGURE 84

REUSABLE BEAM,SPAN=10 FT,SPACING=5 FT, FIXED ENDS

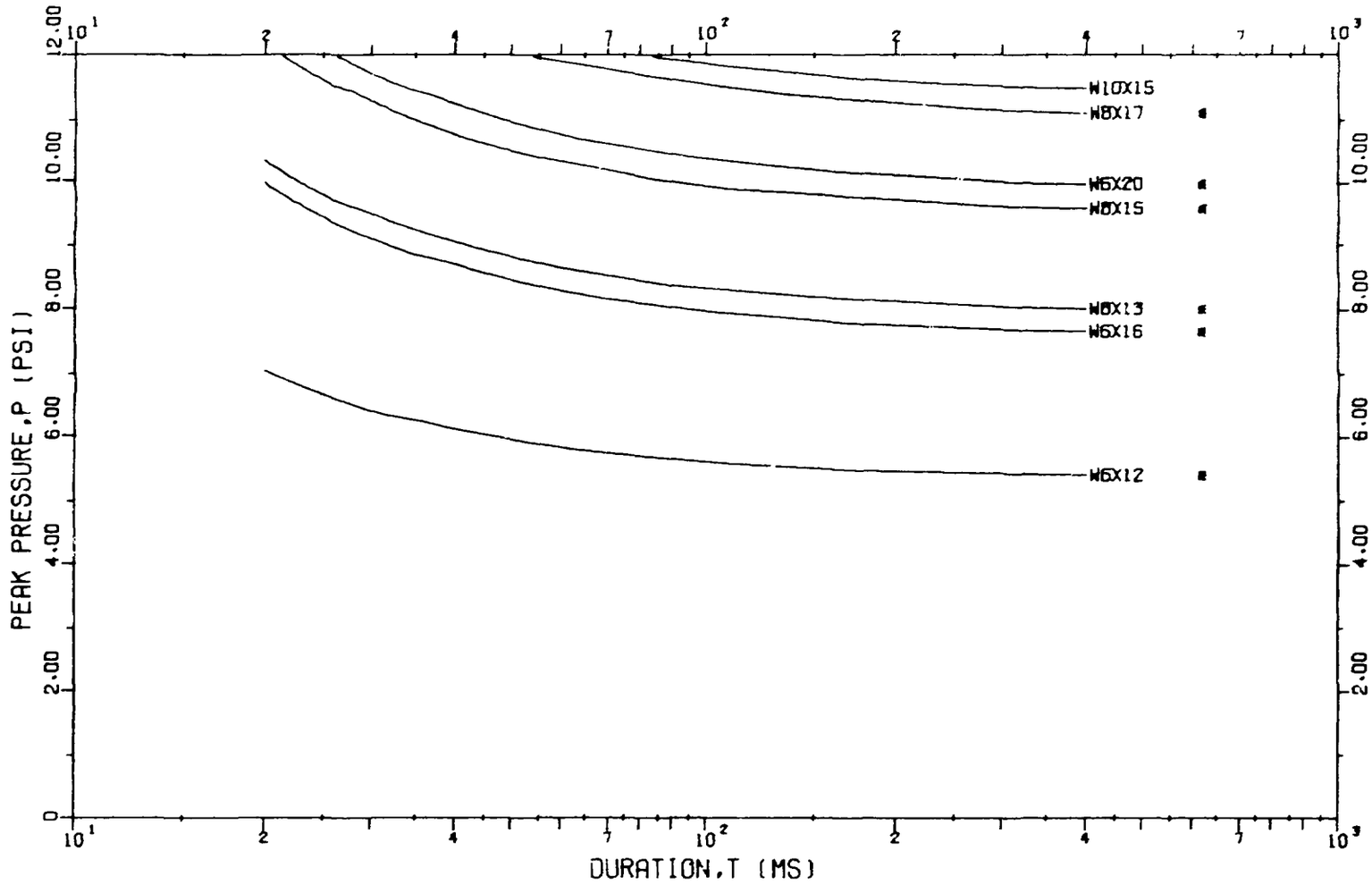


FIGURE 85

REUSABLE BEAM,SPAN= 10 FT,SPACING= 3 FT, SIMPLE-FIXED

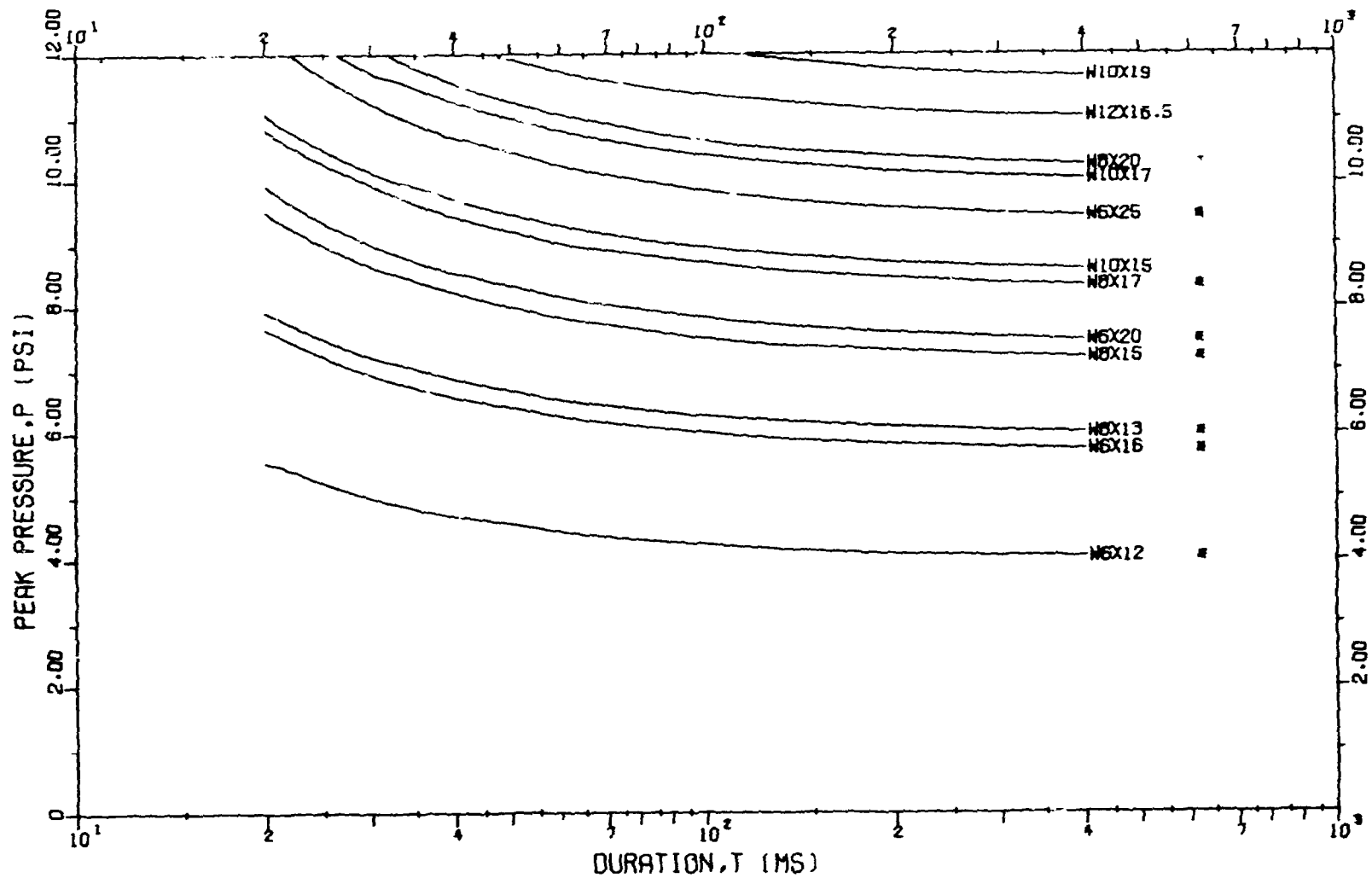


FIGURE 86

REUSABLE BEAM,SPAN= 10 FT,SPACING= 4 FT, SIMPLE-FIXED

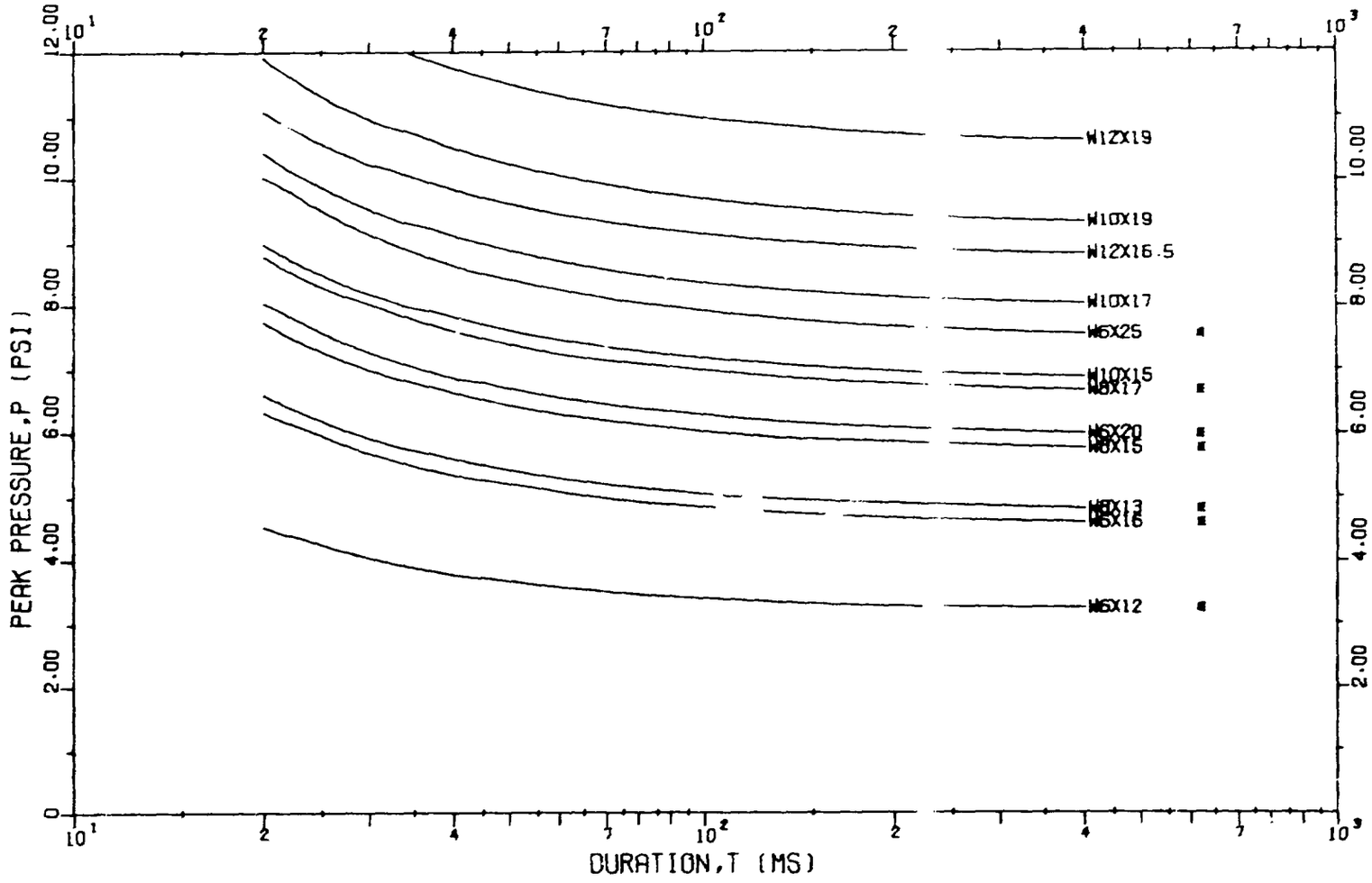


FIGURE 87

REUSABLE BEAM,SPAN= 10 FT,SPACING= 5 FT, SIMPLE-FIXED

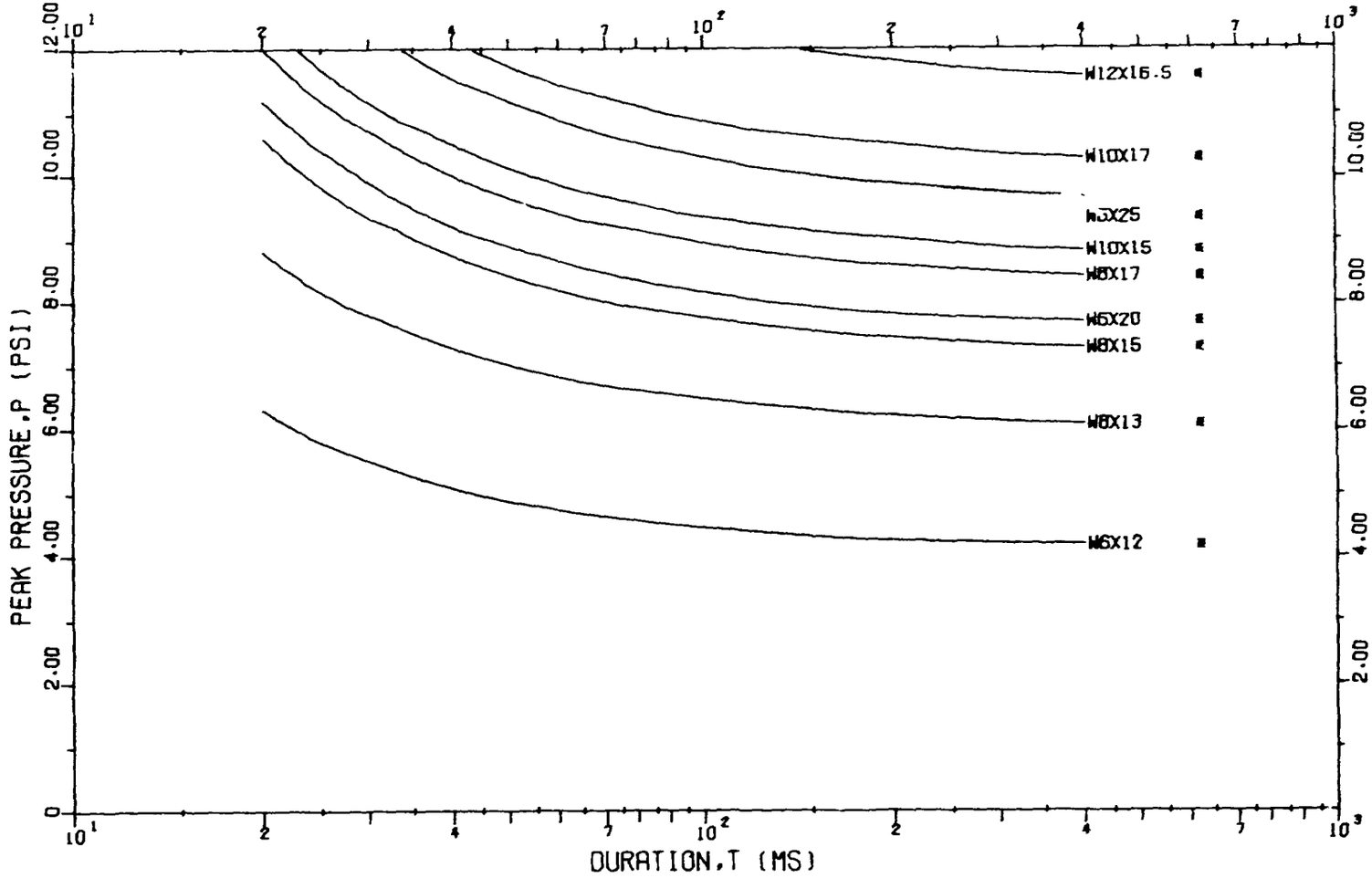


FIGURE 88

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=3 FT, SIMPLY-SUPPORTED

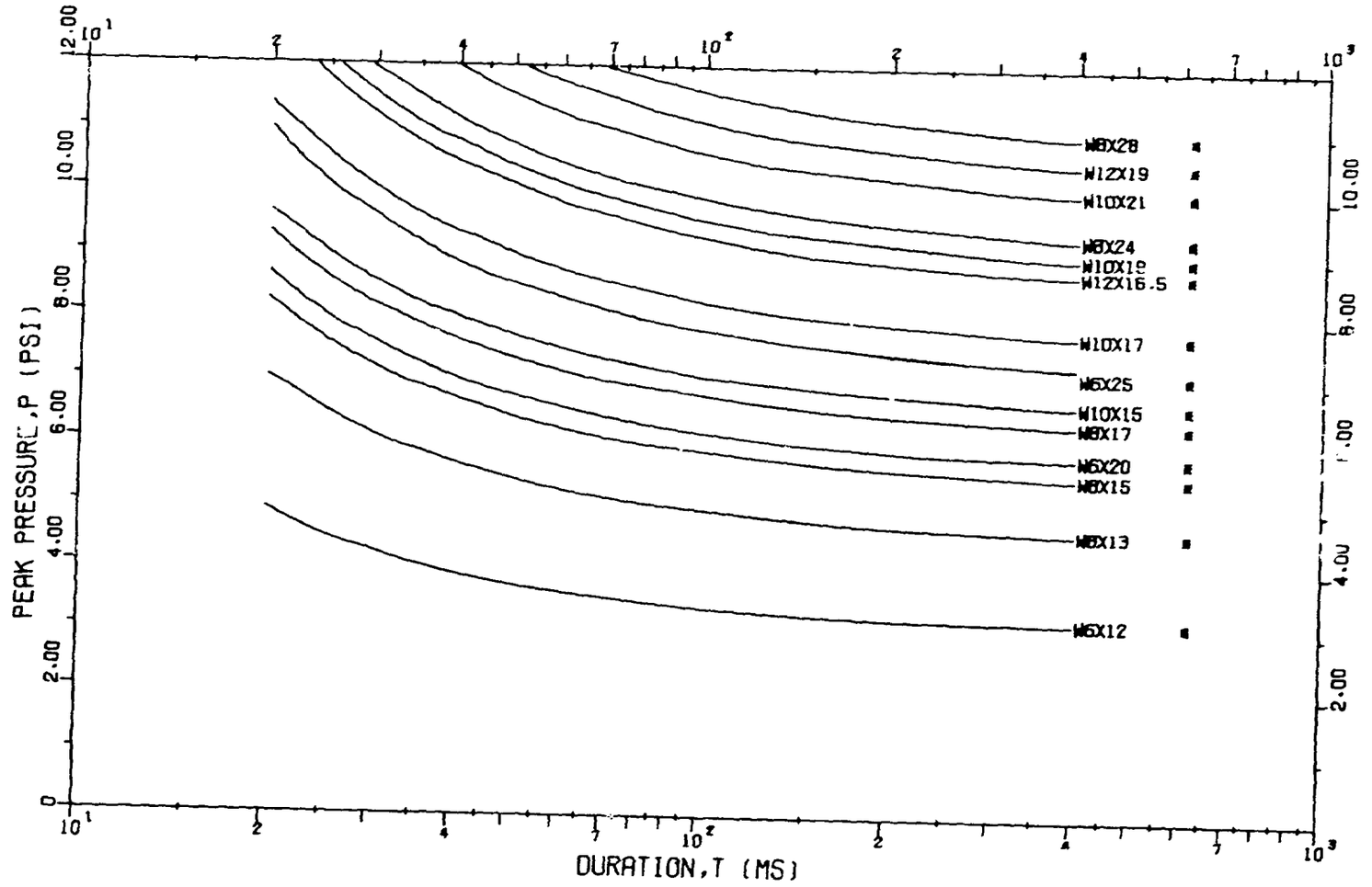


FIGURE 89

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=4 FT, SIMPLY-SUPPORTED

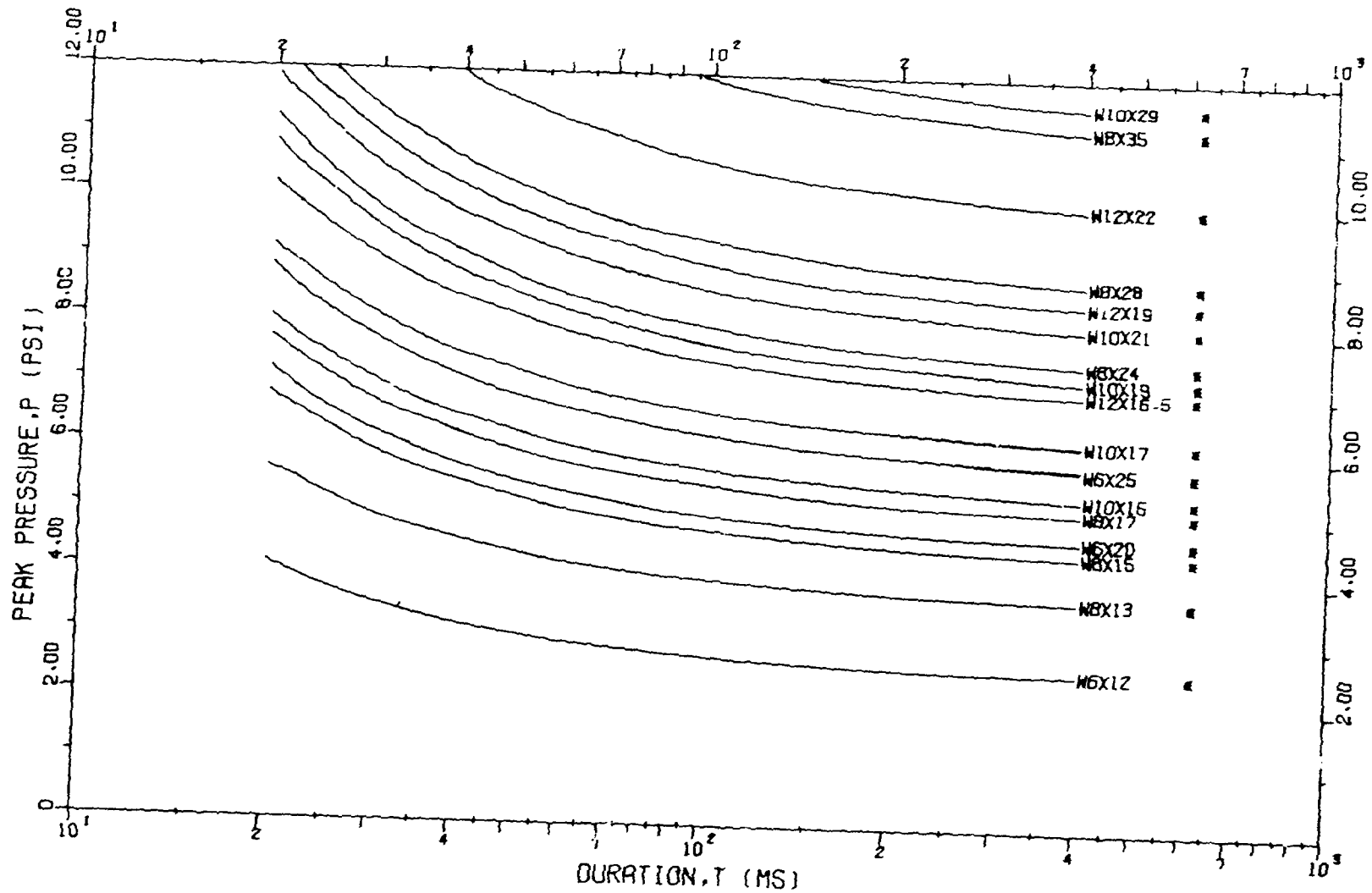


FIGURE 90

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=5 FT, SIMPLY-SUPPORTED

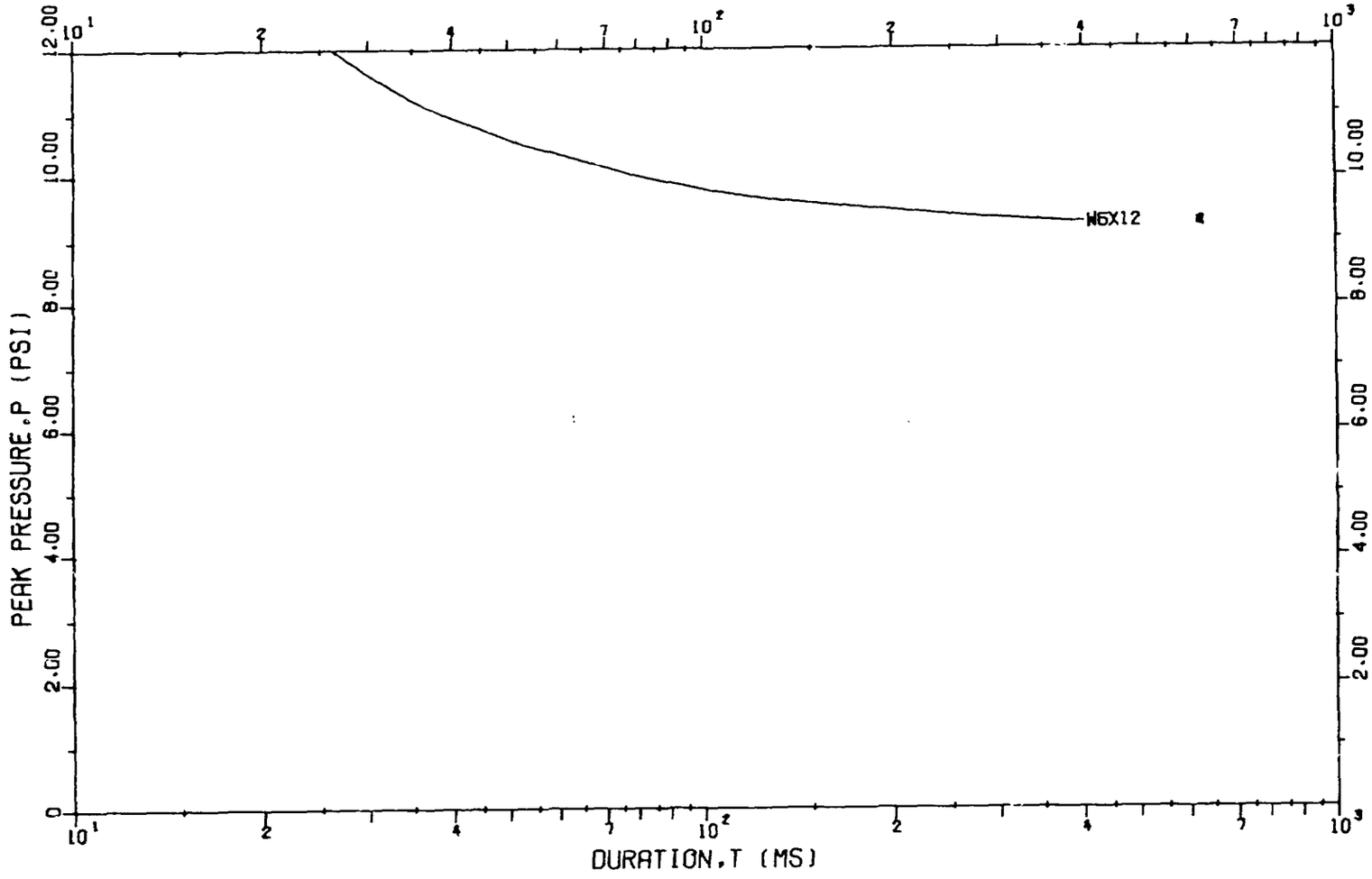


FIGURE 91

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=3 FT, FIXED ENDS

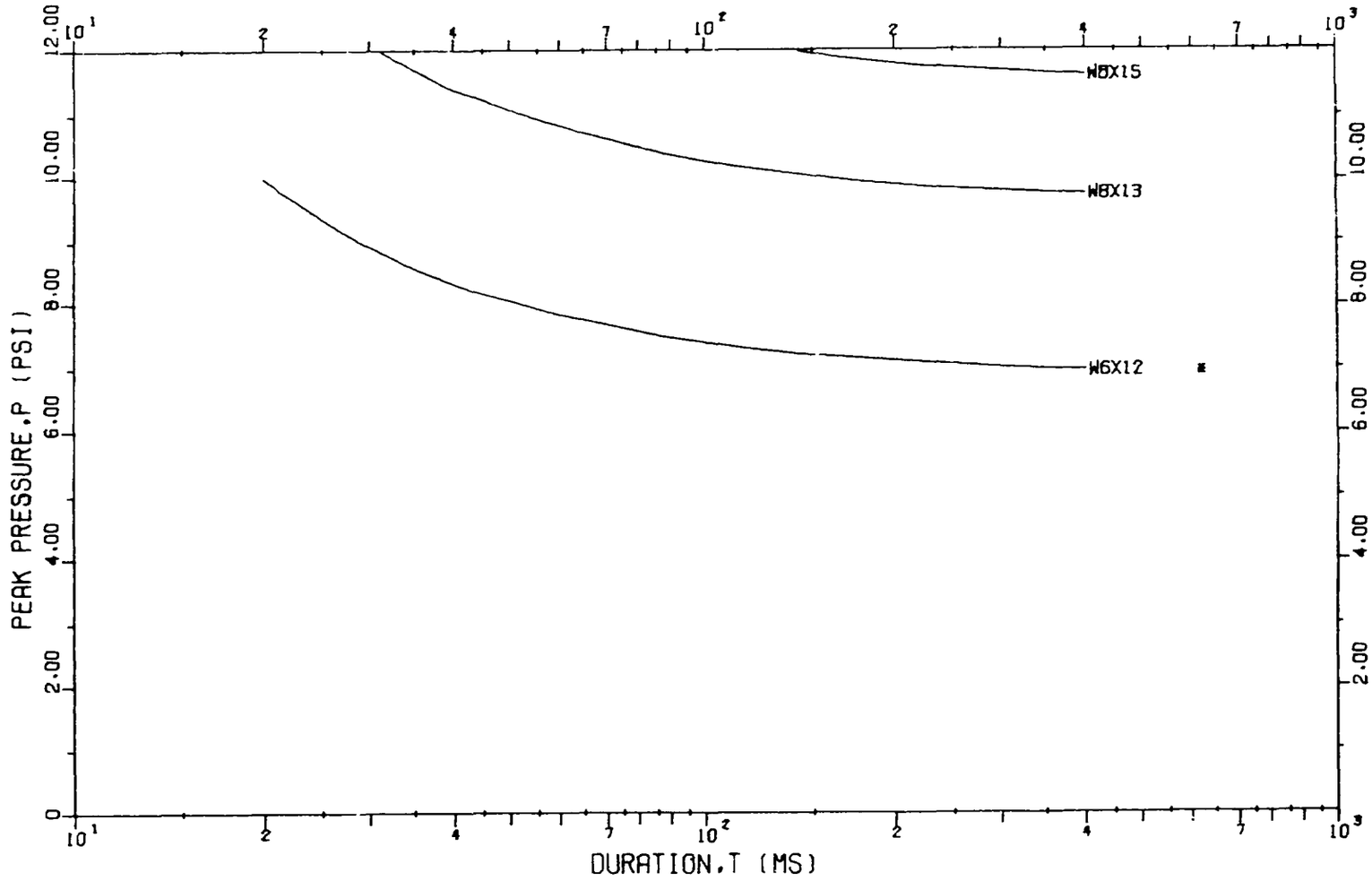


FIGURE 92

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING= 4 FT. FIXED ENDS

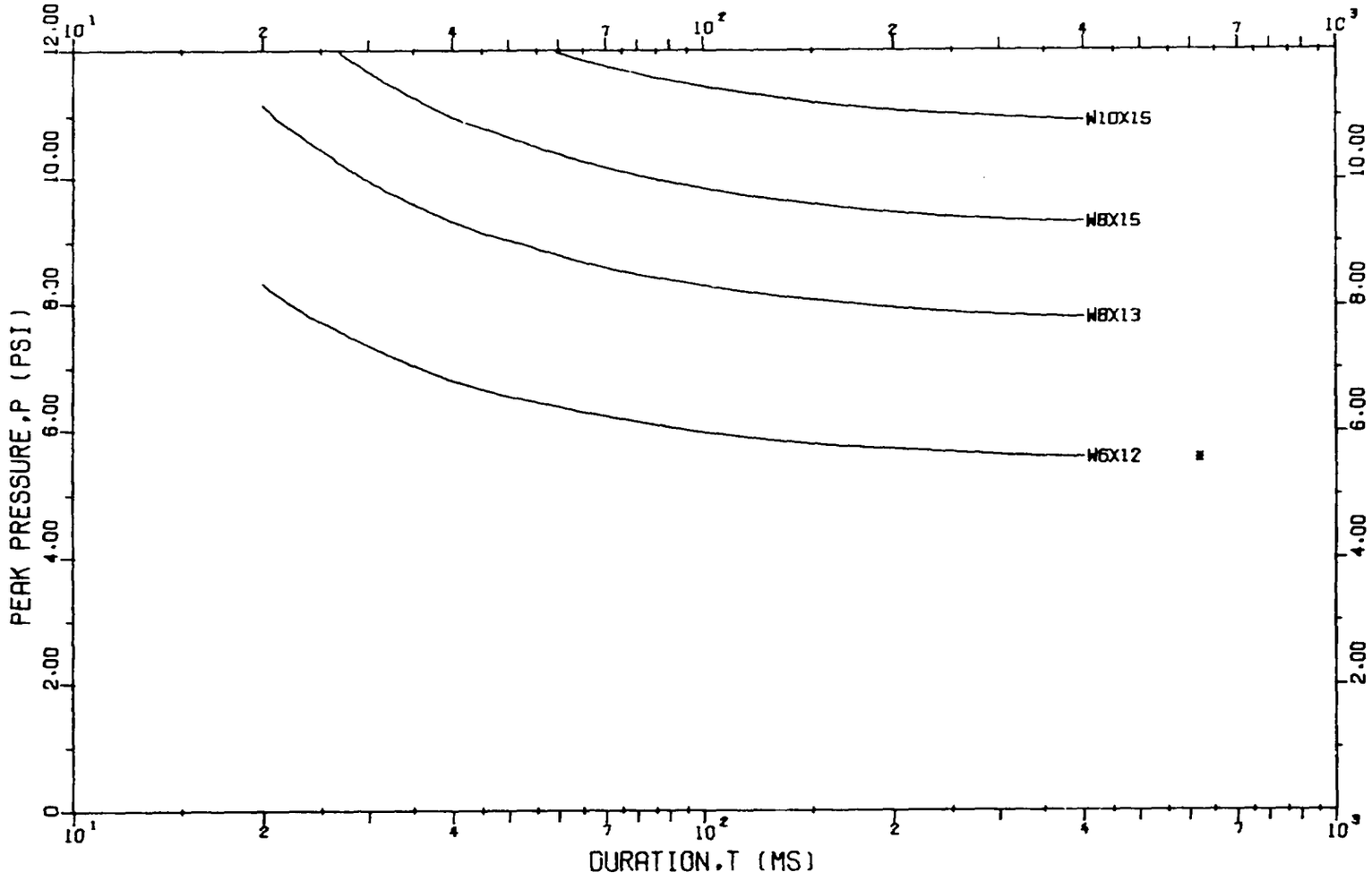


FIGURE 93

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=5 FT, FIXED ENDS

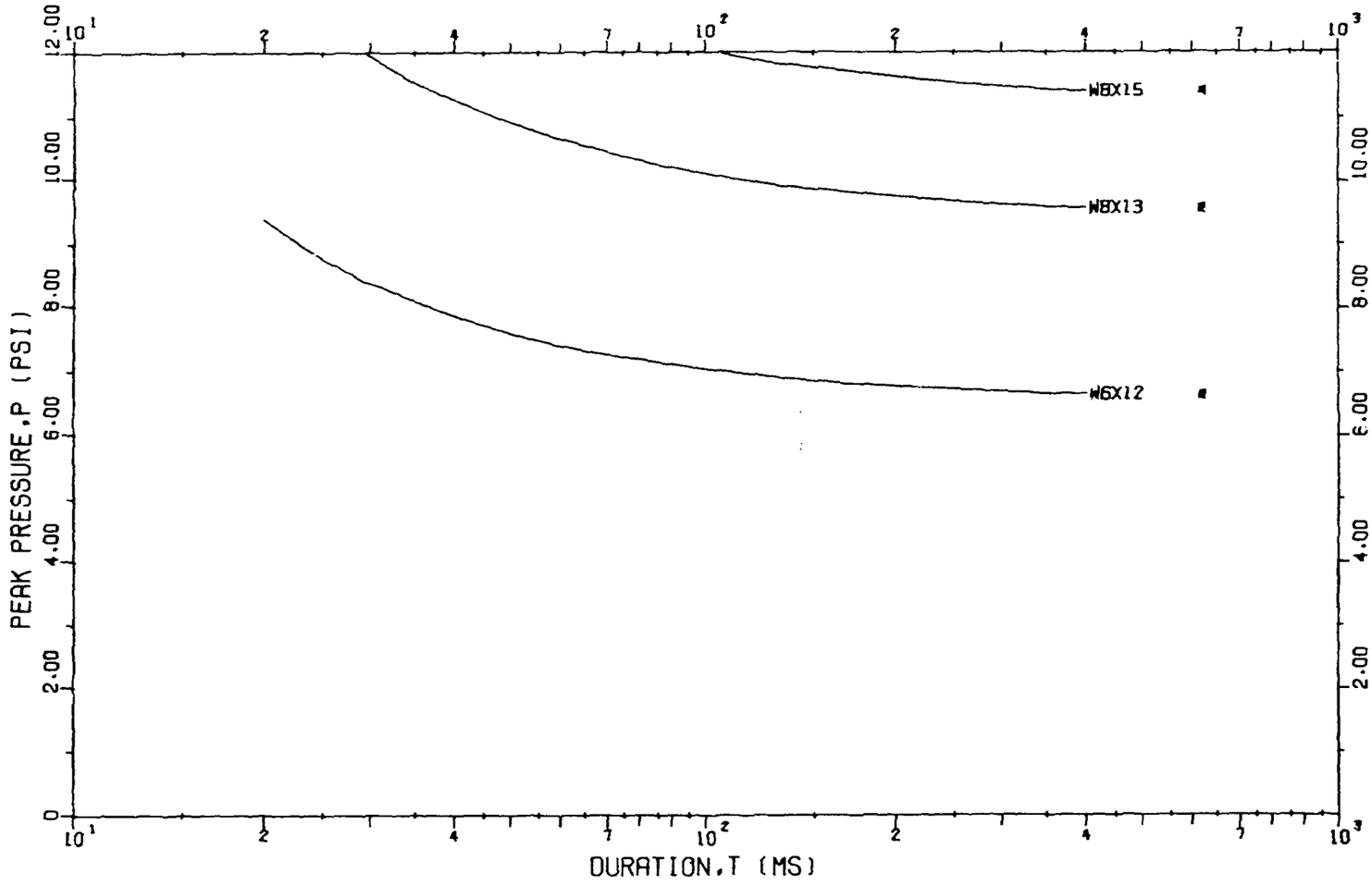


FIGURE 94

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=3 FT, SIMPLE-FIXED

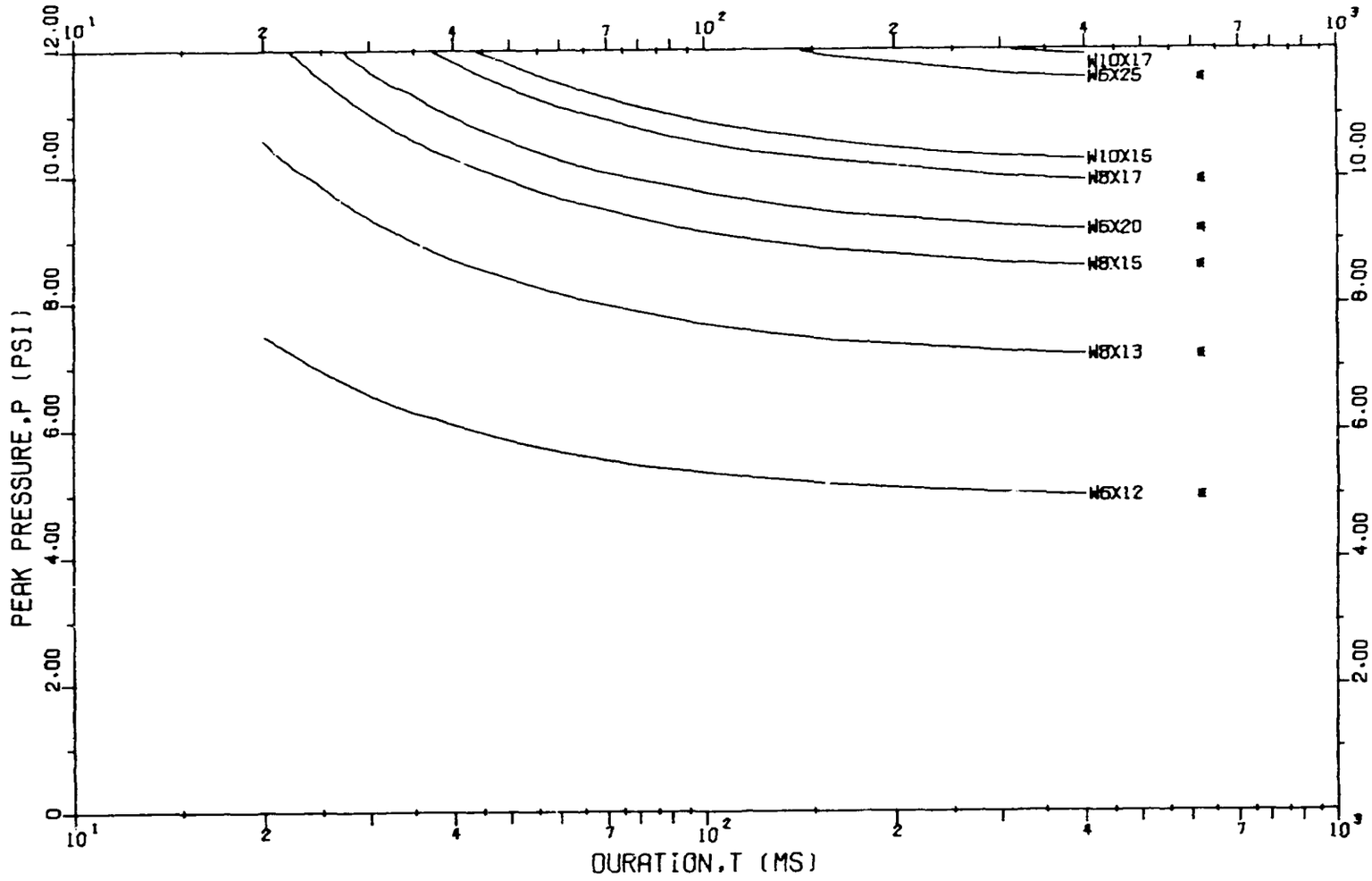


FIGURE 95

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=4 FT, SIMPLE-FIXED

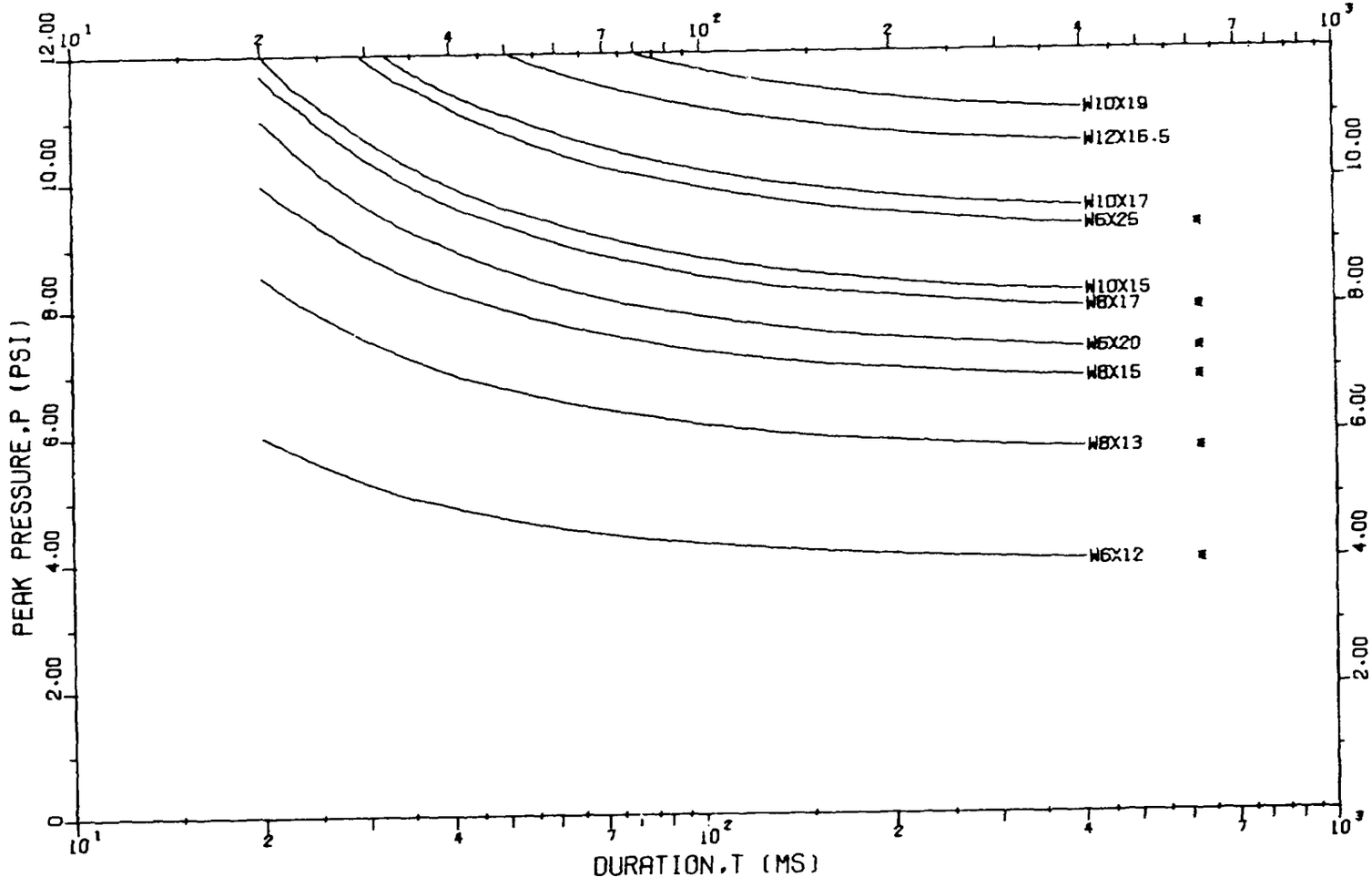


FIGURE 9C

NON-REUSABLE BEAM,SPAN= 10 FT,SPACING=5 FT, SIMPLE-FIXED

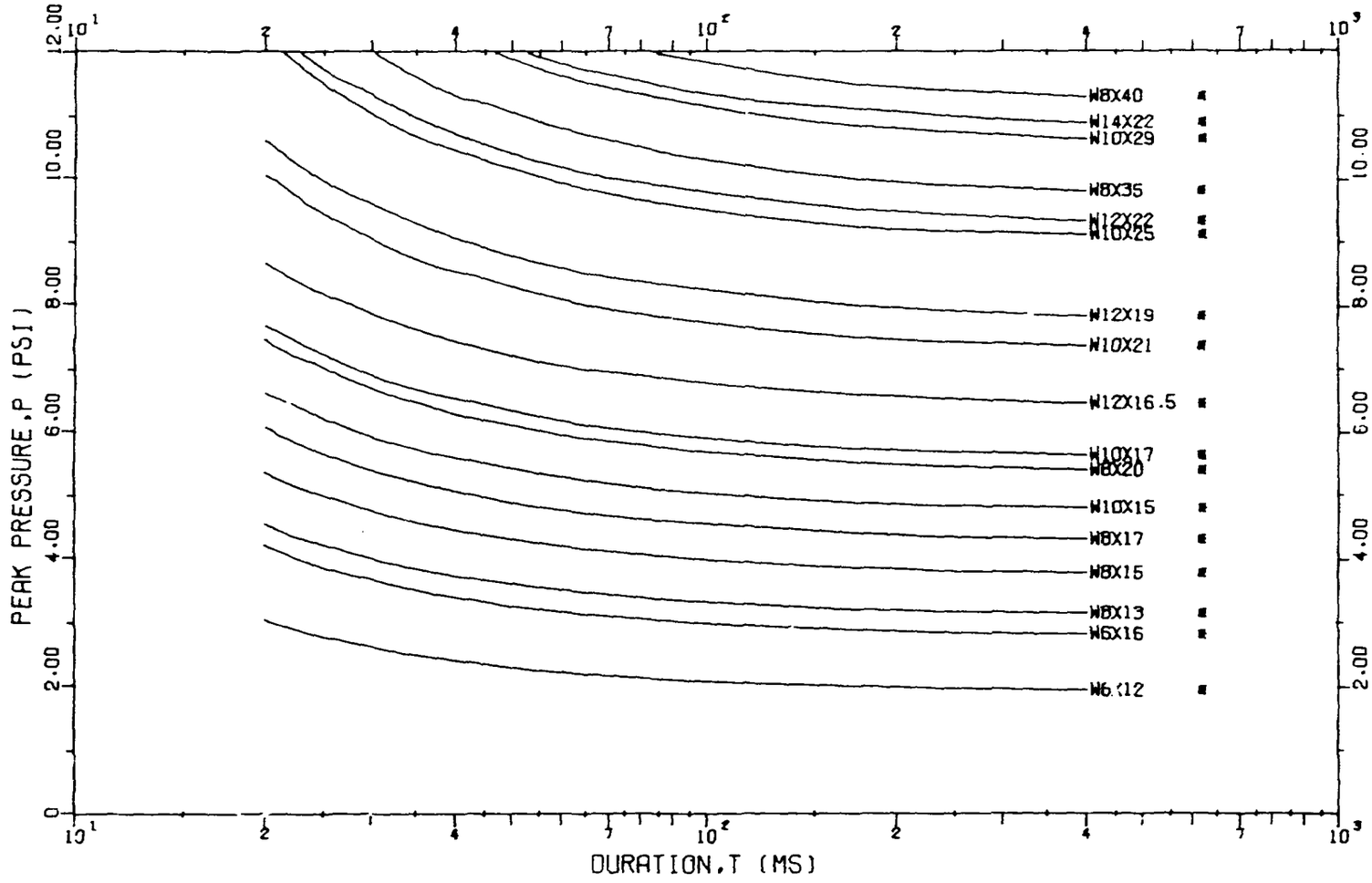


FIGURE 97

REUSABLE BEAM,SPAN= 12 FT,SPACING= 3 FT, SIMPLY-SUPPORTED

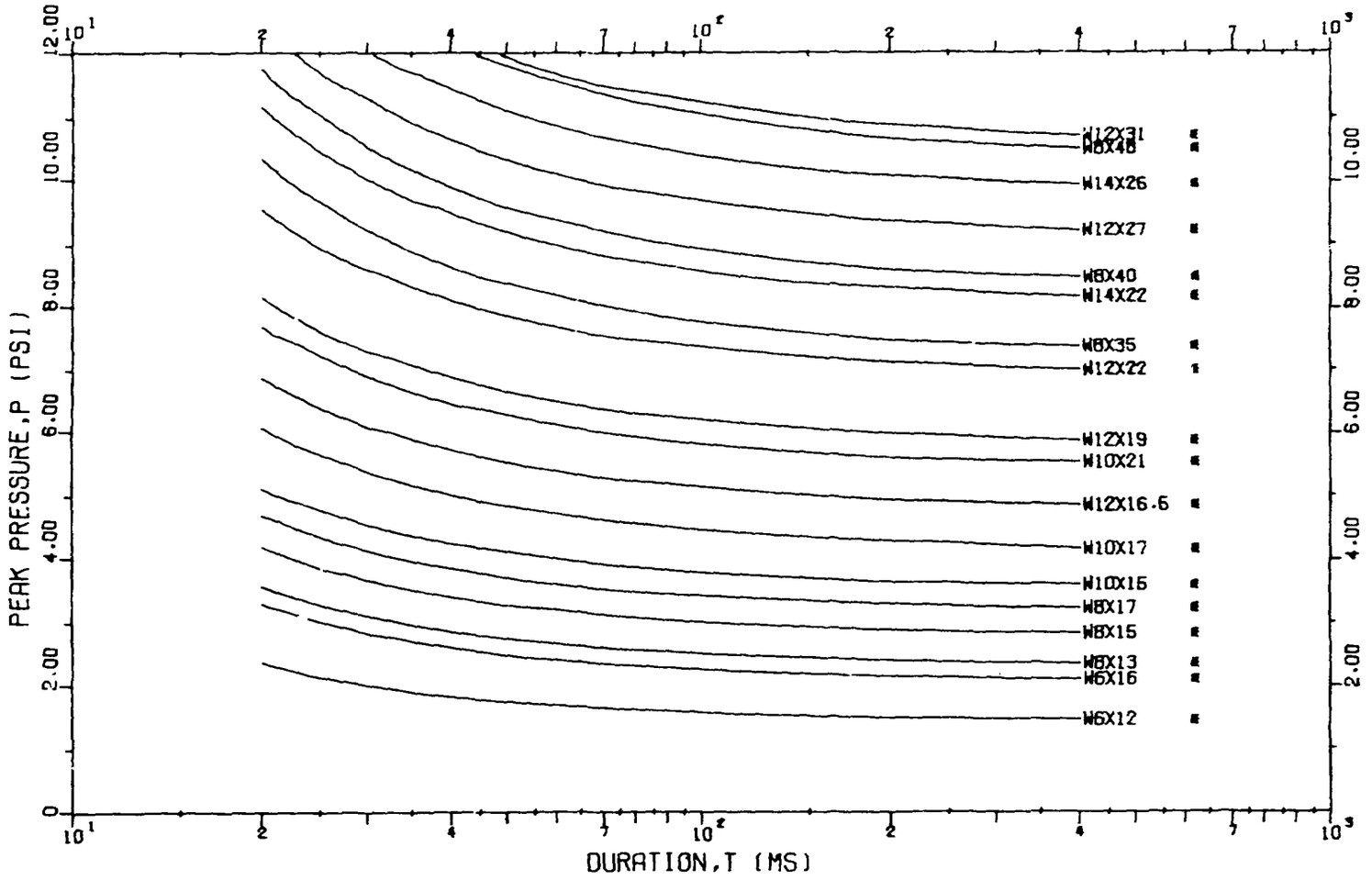


FIGURE 98

REUSABLE BEAM,SPAN= 12 FT,SPACING= 4 FT, SIMPLY-SUPPORTED

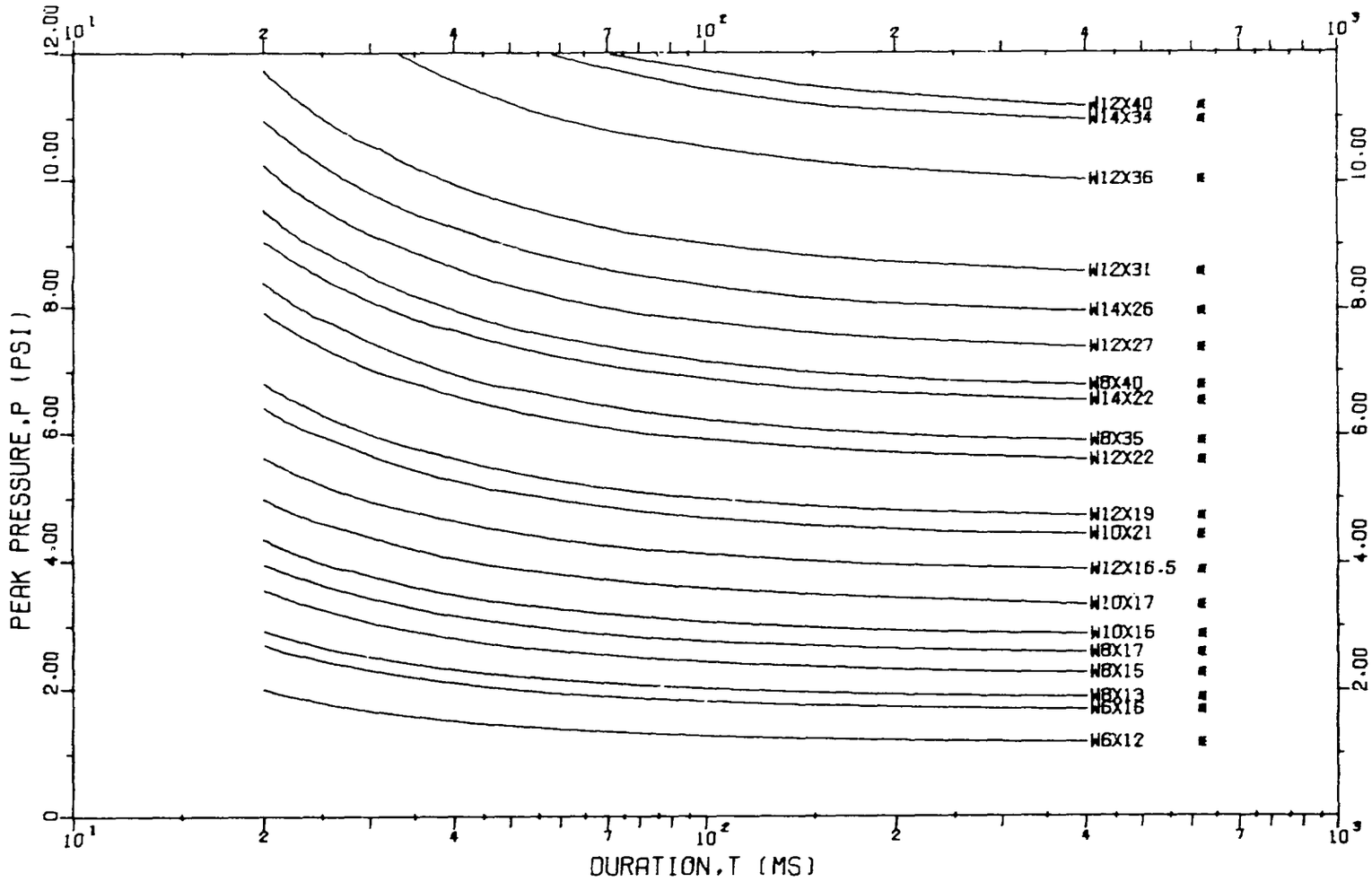


FIGURE 99

REUSABLE BEAM,SPAN= 12 FT,SPACING= 5 FT, SIMPLY-SUPPORTED

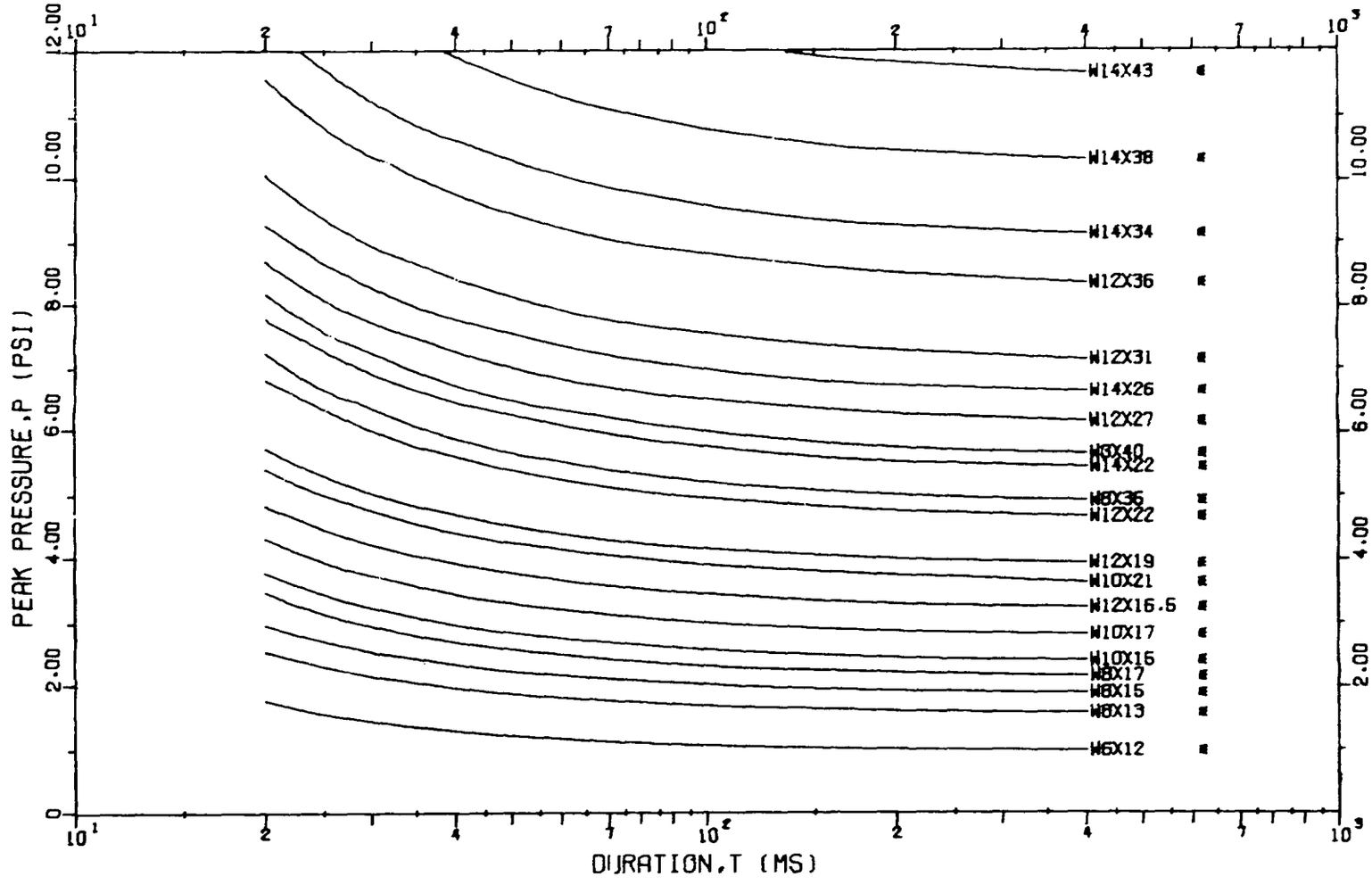


FIGURE 100

REUSABLE BEAM,SPAN= 12 FT,SPACING= 6 FT, SIMPLY-SUPPORTED

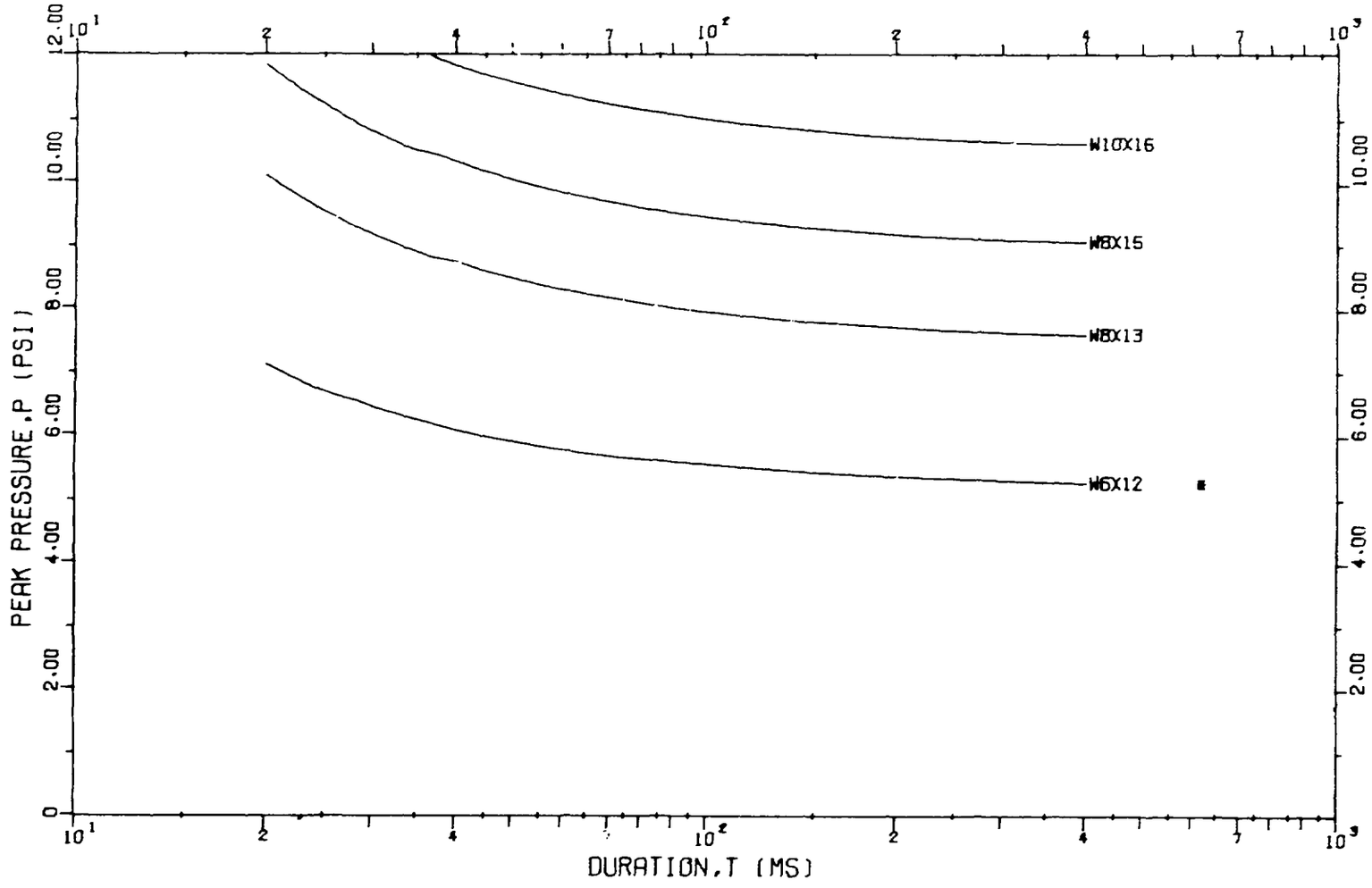


FIGURE 101

REUSABLE BEAM,SPAN= 12 FT,SPACING= 3 FT, FIXED ENDS

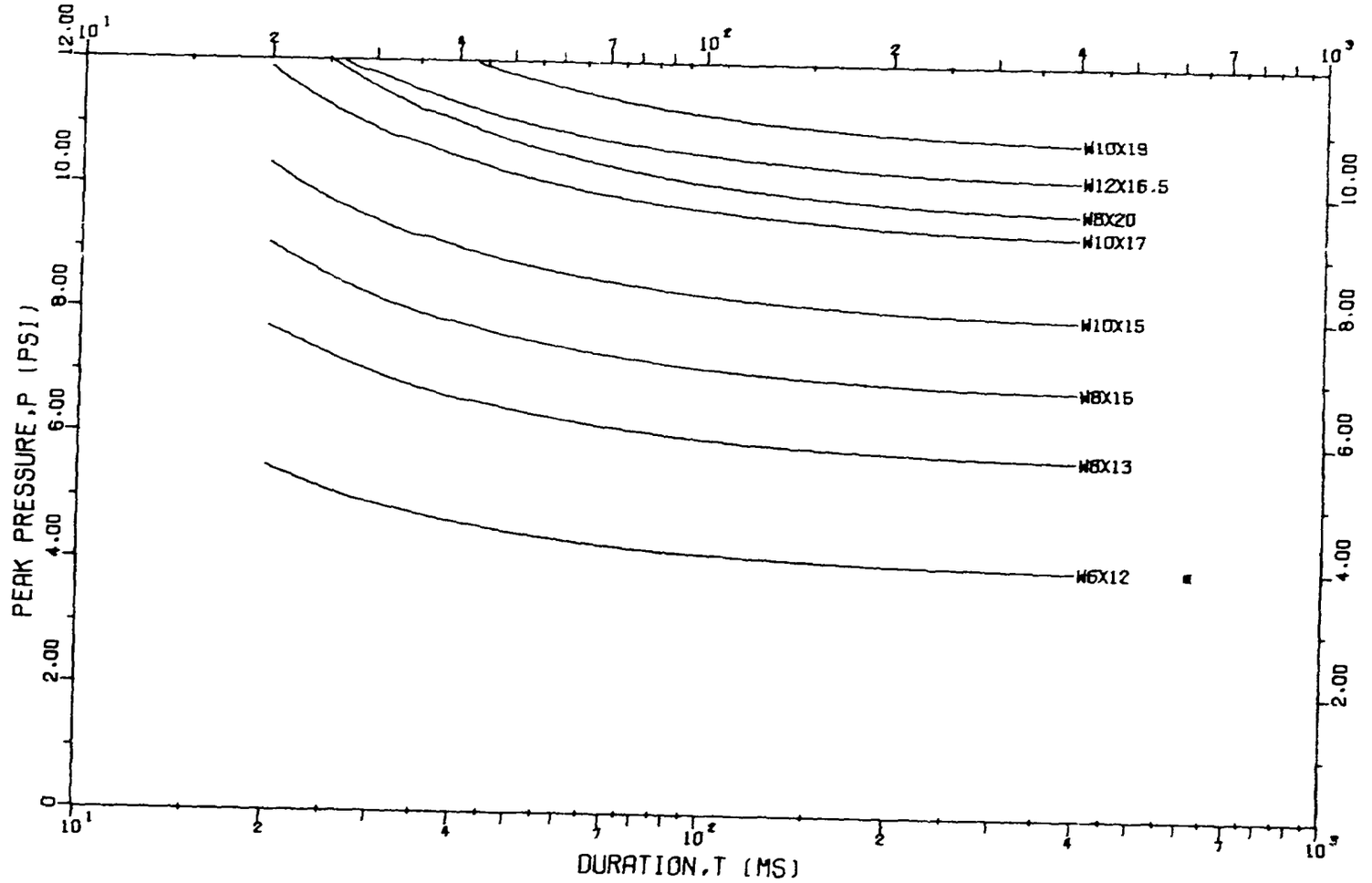


FIGURE 102

REUSABLE BEAM,SPAN= 12 FT,SPACING= 4 FT, FIXED ENDS

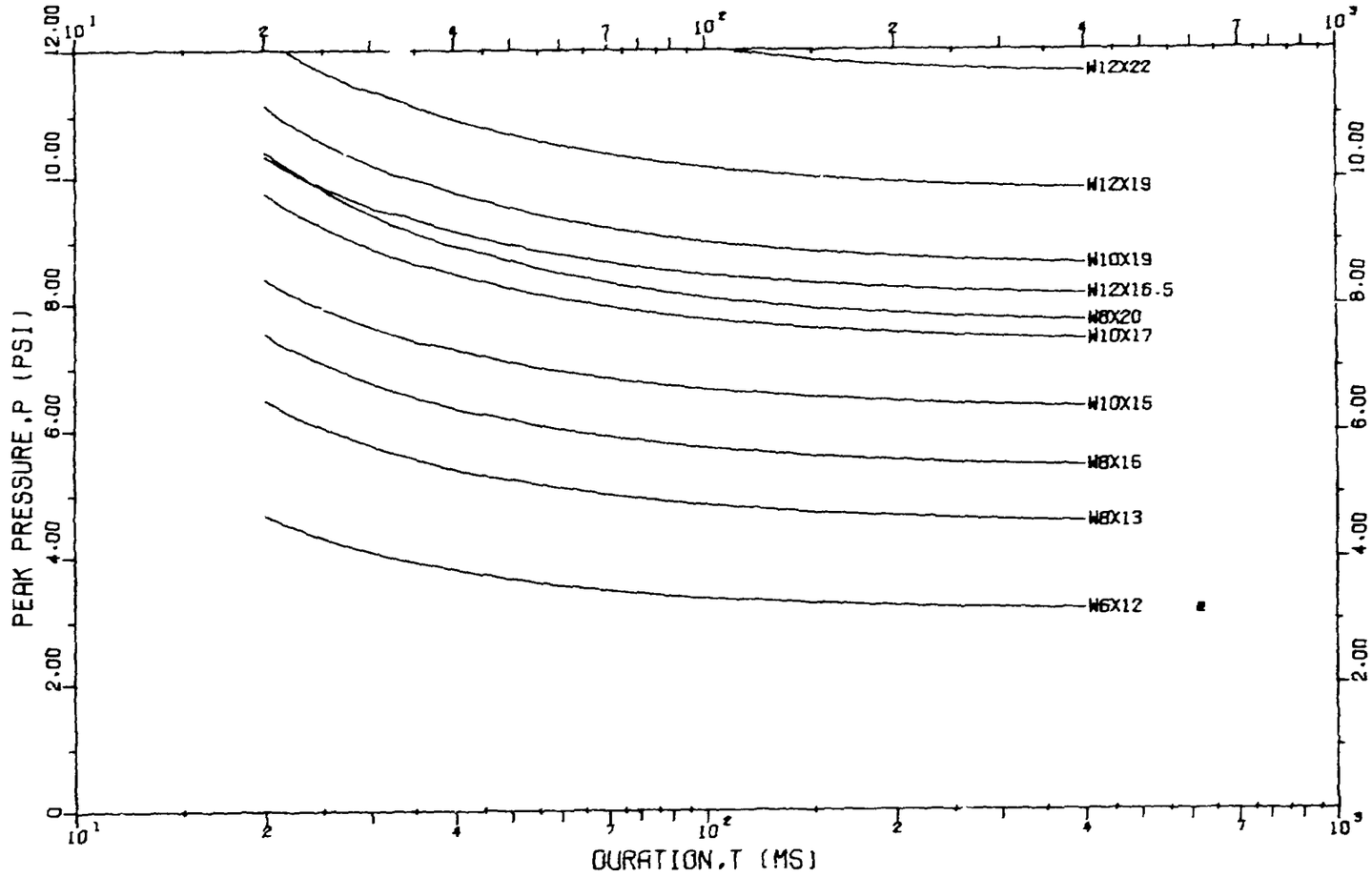


FIGURE 103

REUSABLE BEAM,SPAN= 12 FT,SPACING= 5 FT, FIXED ENDS

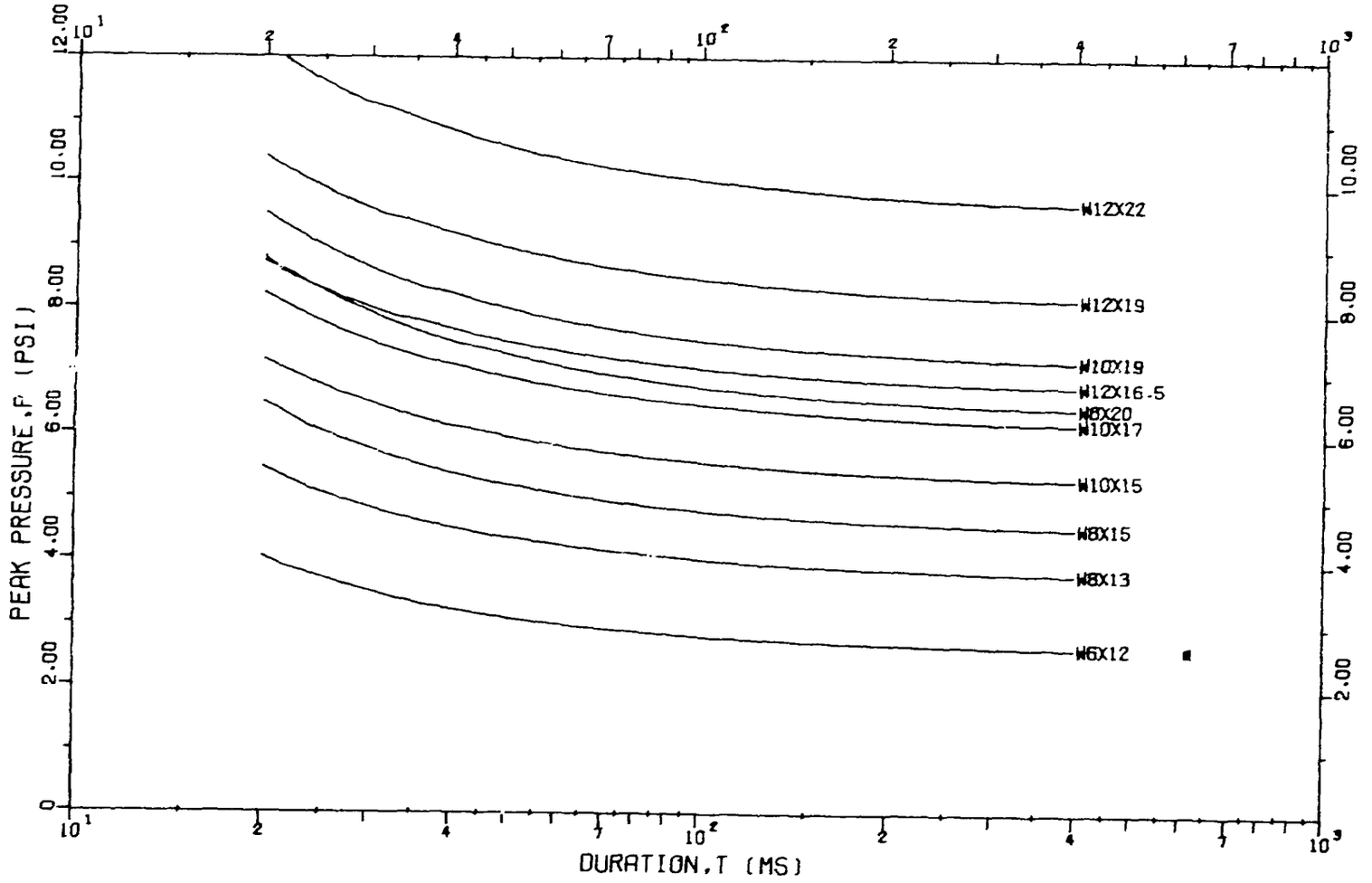


FIGURE 104

REUSABLE BEAM,SPAN= 12 FT,SPACING= 6 FT, FIXED ENDS

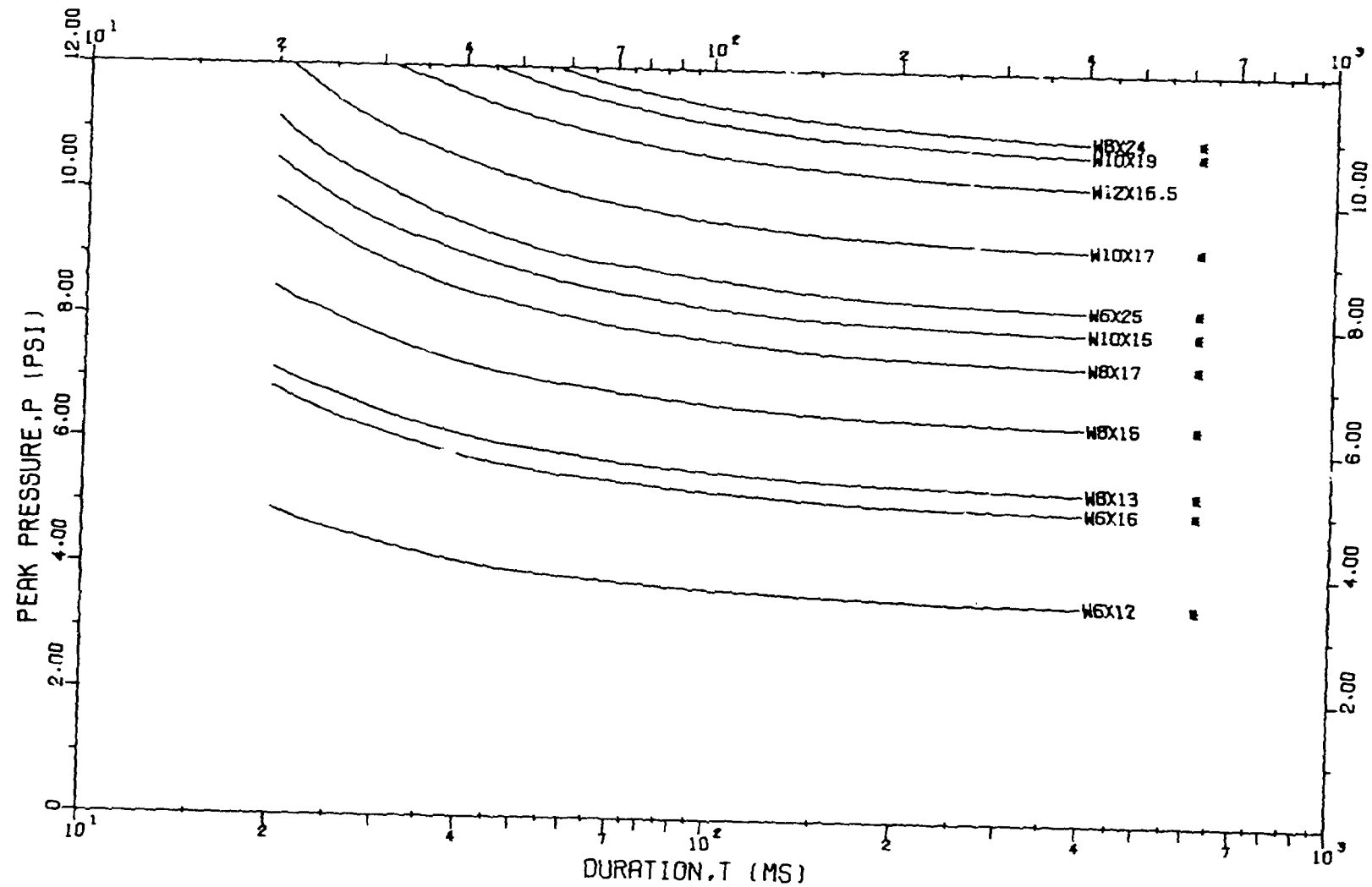


FIGURE 105

REUSABLE BEAM,SPAN= 12 FT,SPACING= 3 FT, SIMPLE-FIXED

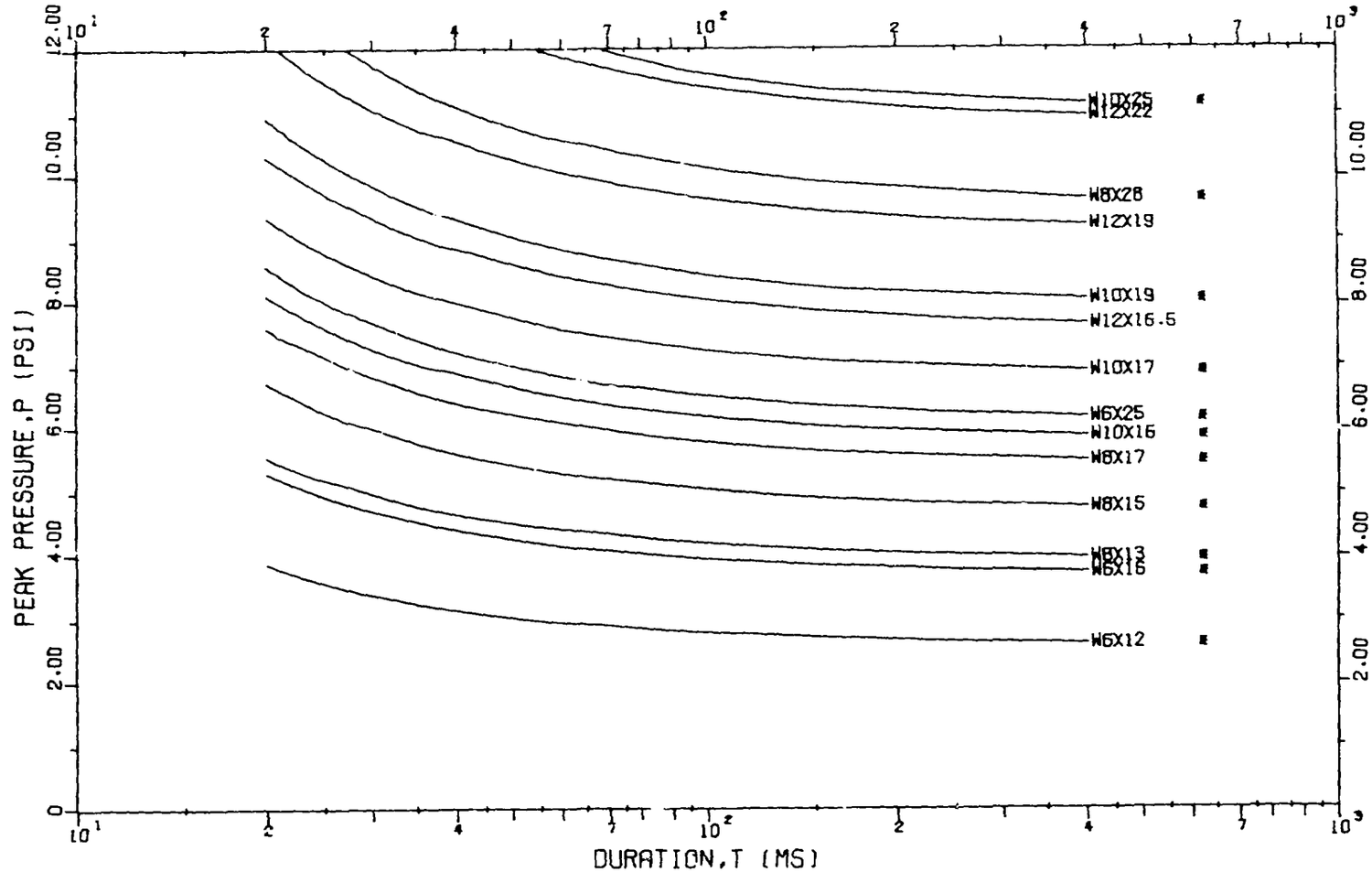


FIGURE 106

REUSABLE BEAM,SPAN= 12 FT,SPACING= 4 FT, SIMPLE-FIXED

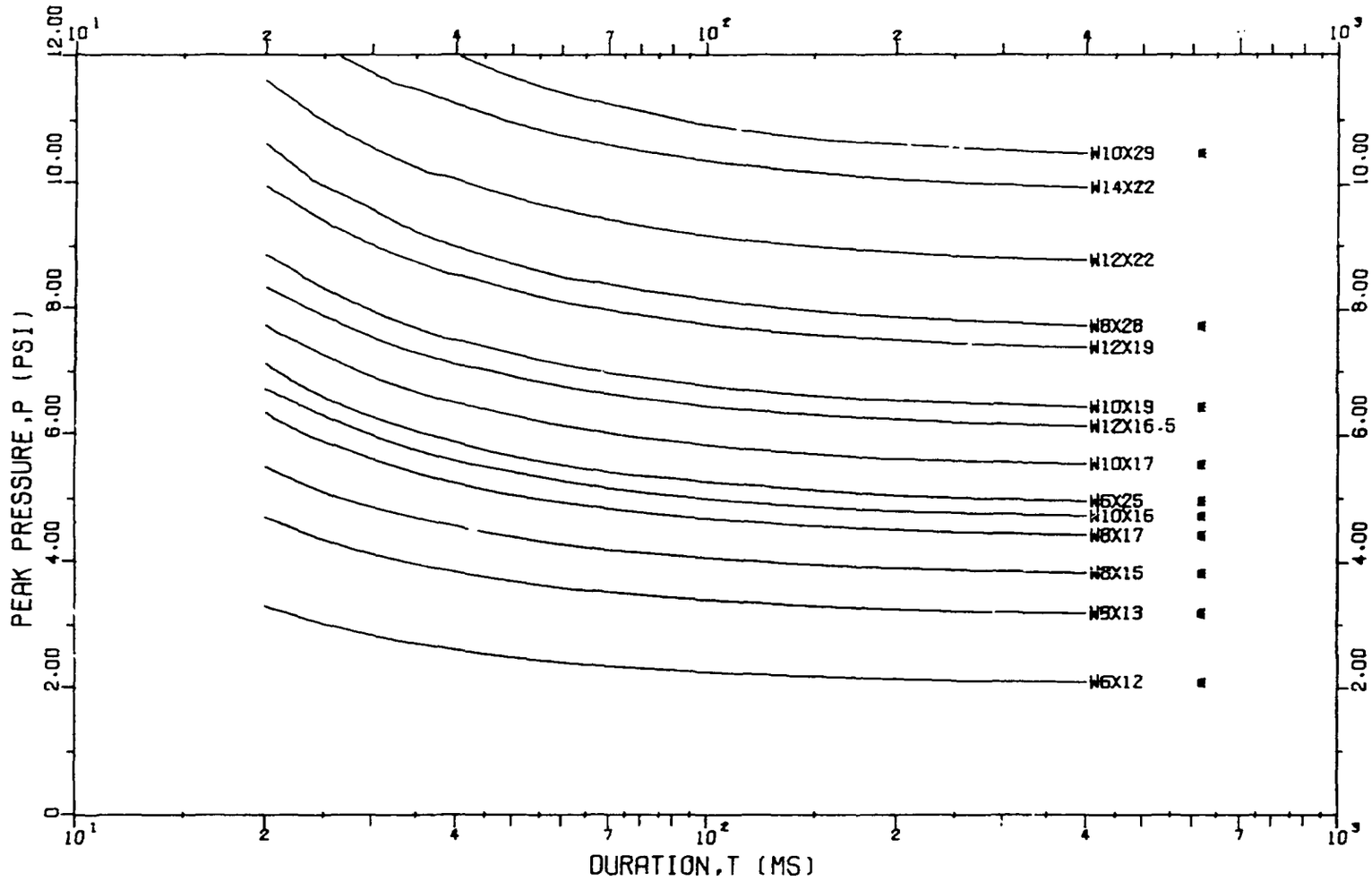


FIGURE 107

REUSABLE BEAM,SPAN= 12 FT,SPACING=5 FT. SIMPLE-FIXED

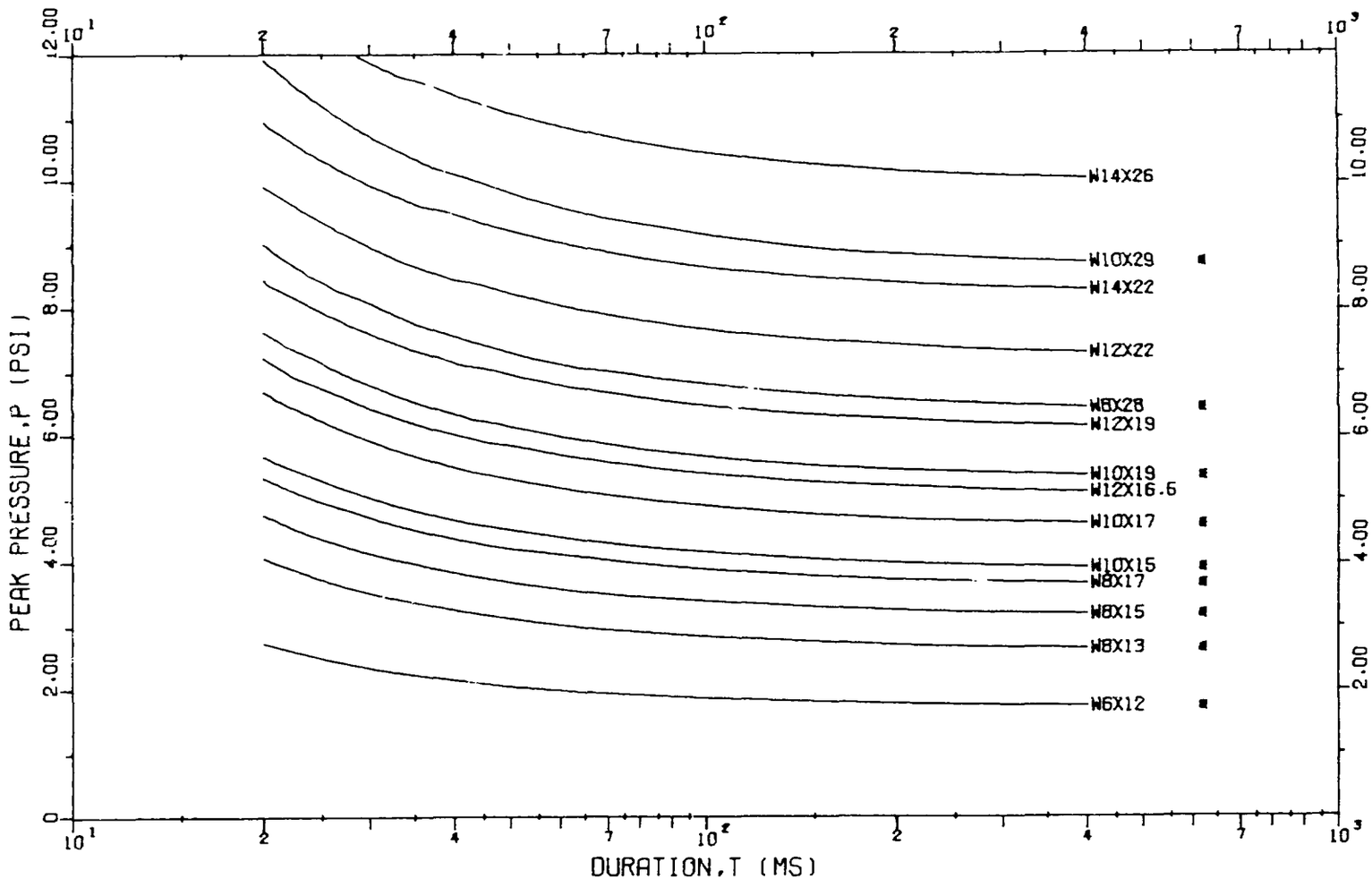


FIGURE 105

REUSABLE BEAM,SPAN= 12 FT,SPACING= 6 FT, SIMPLE-FIXED

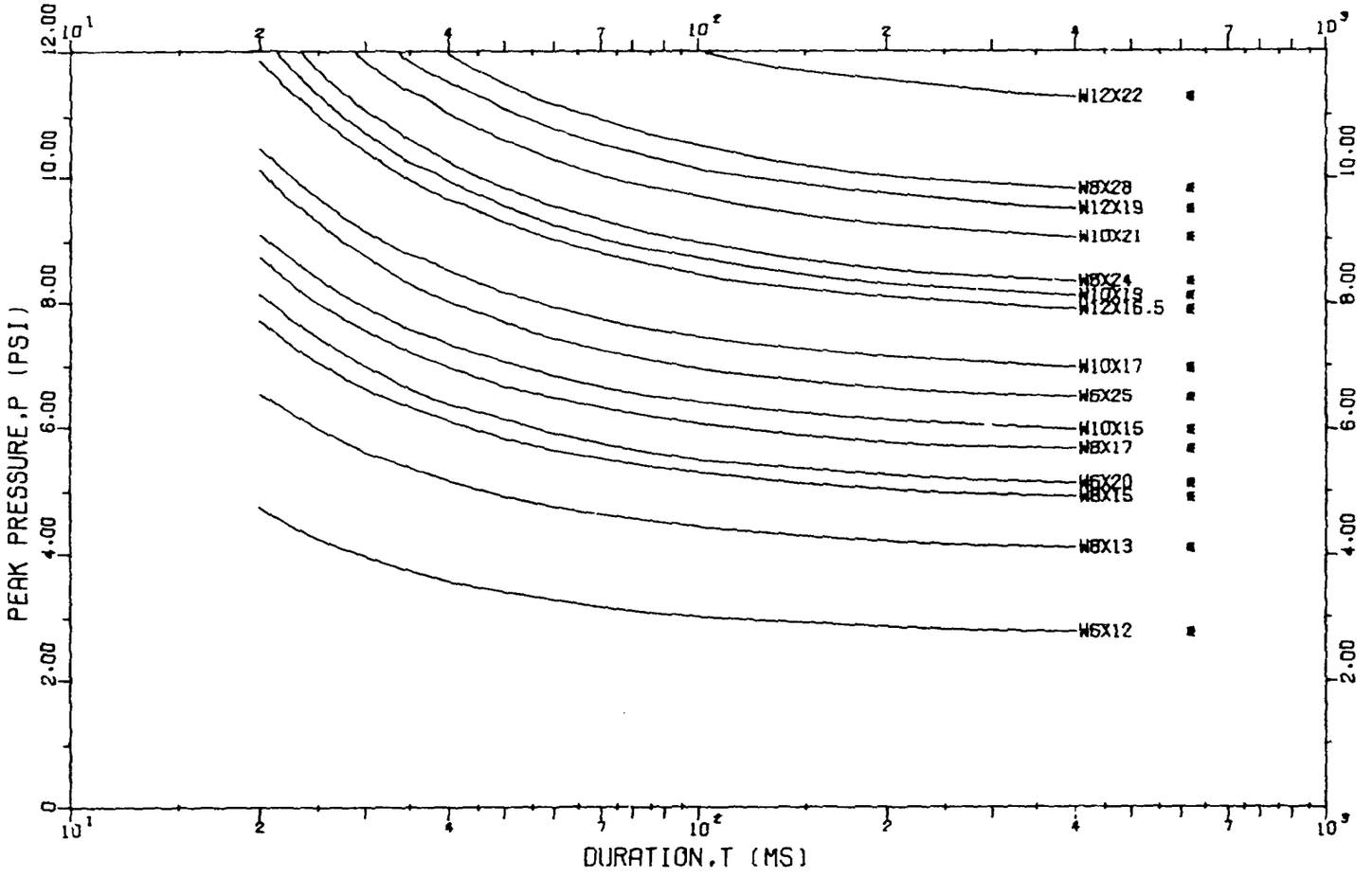


FIGURE 109

NON-REUSABLE BEAM,SPAN= 12 FT,SPACING=3 FT. SIMPLY-SUPPORTED

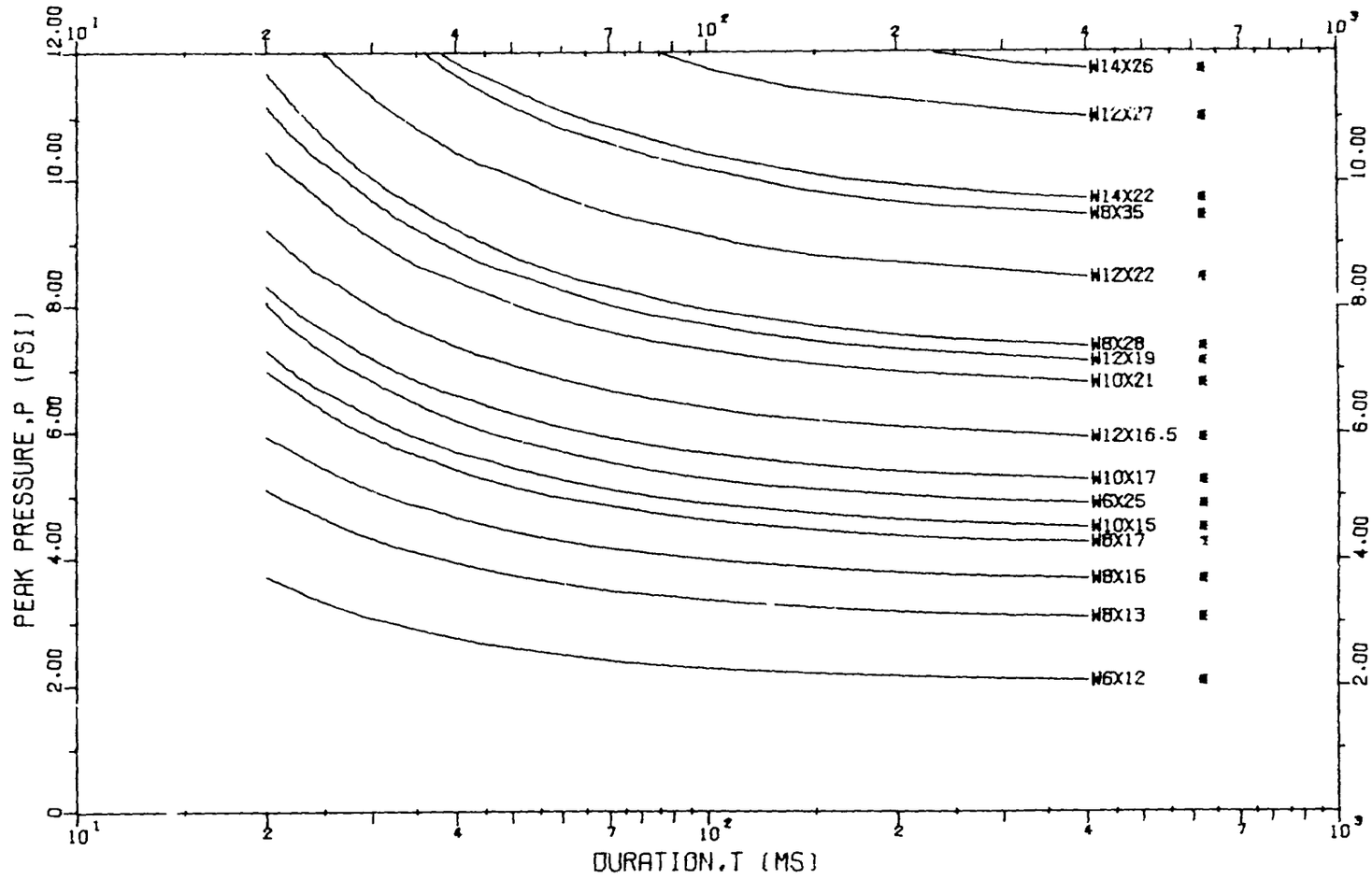


FIGURE 110

NON-REUSABLE BEAM,SPAN= 12 FT,SPACING=4 FT, SIMPLY-SUPPORTED

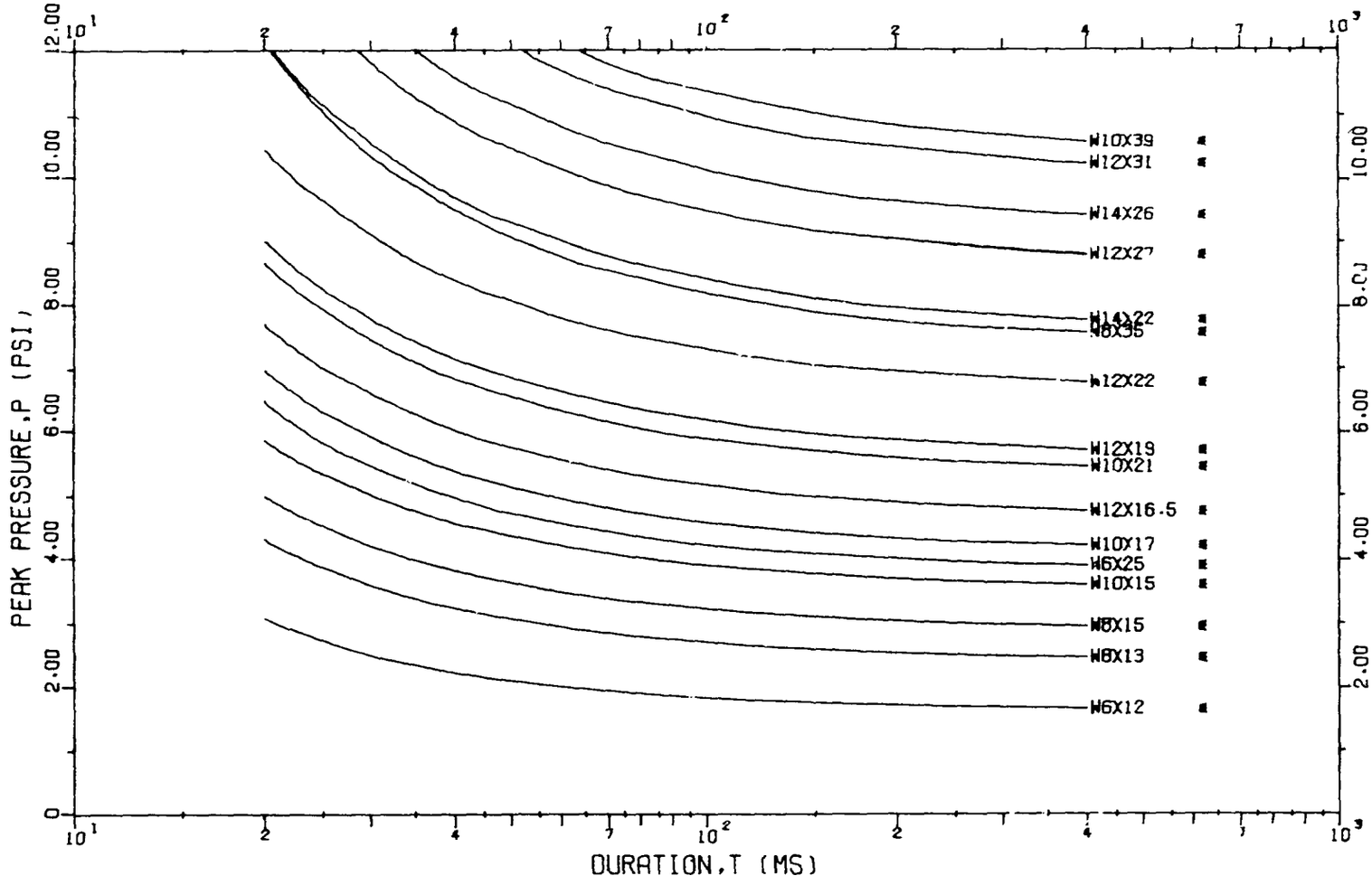


FIGURE 111

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=5 FT. SIMPLY-SUPPORTED

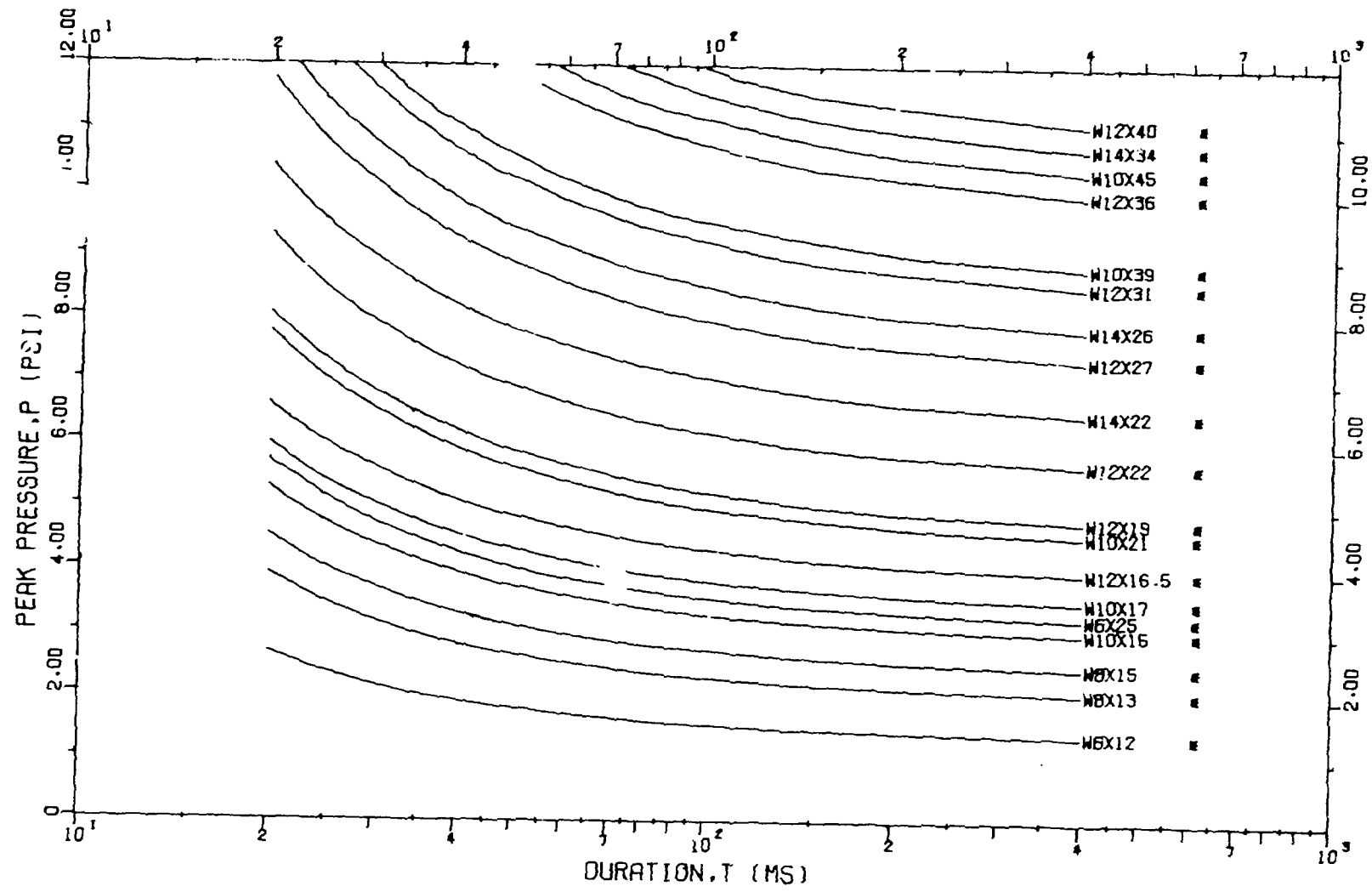


FIGURE 112

NON-REUSABLE BEAM.SPAN= 12 FT.SPACING=6 FT. SIMPLY-SUPPORTED

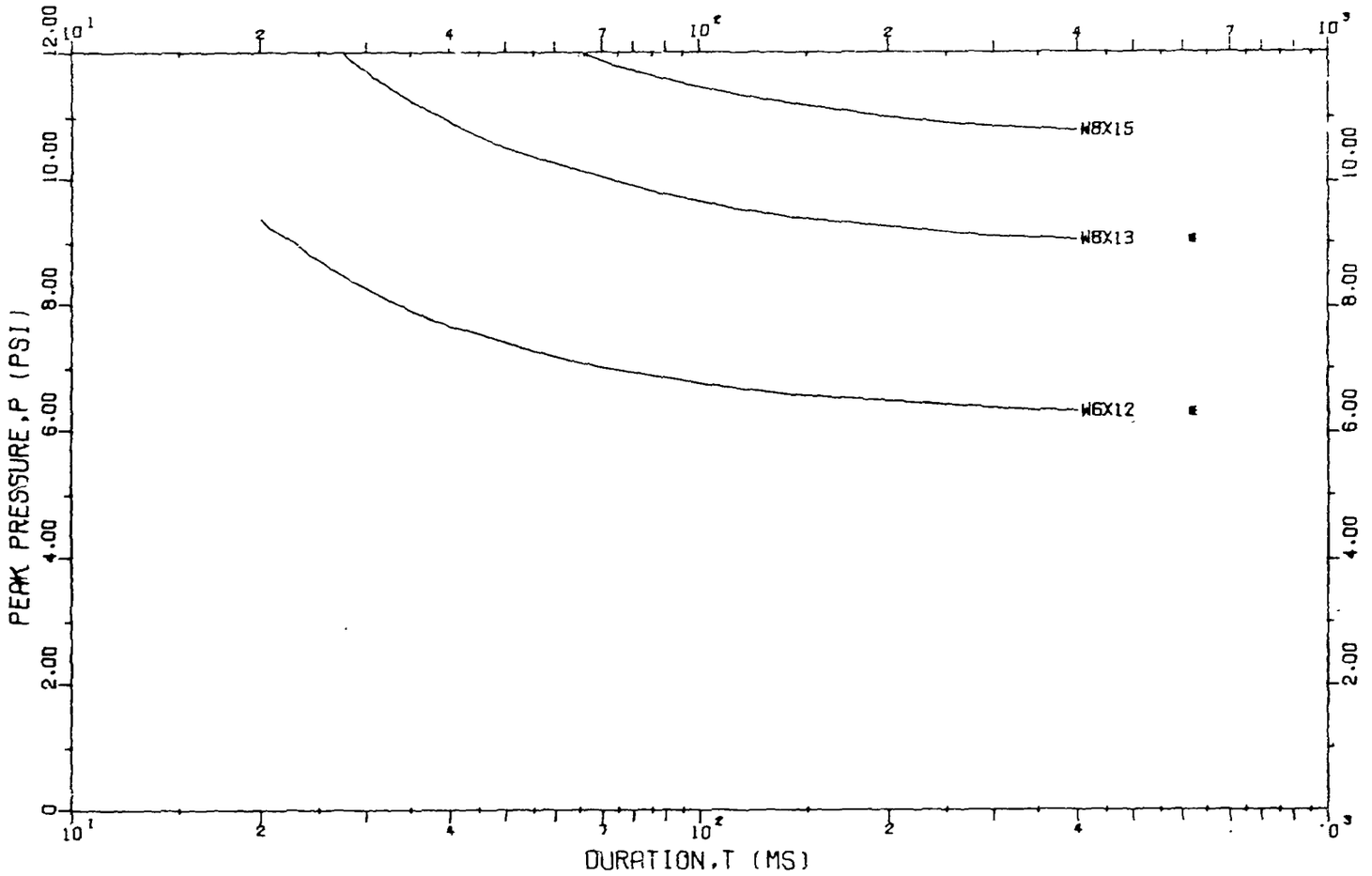


FIGURE 113

NON-REUSABLE BEAM,SPAN= 12 FT,SPACING=3 FT, FIXED ENDS

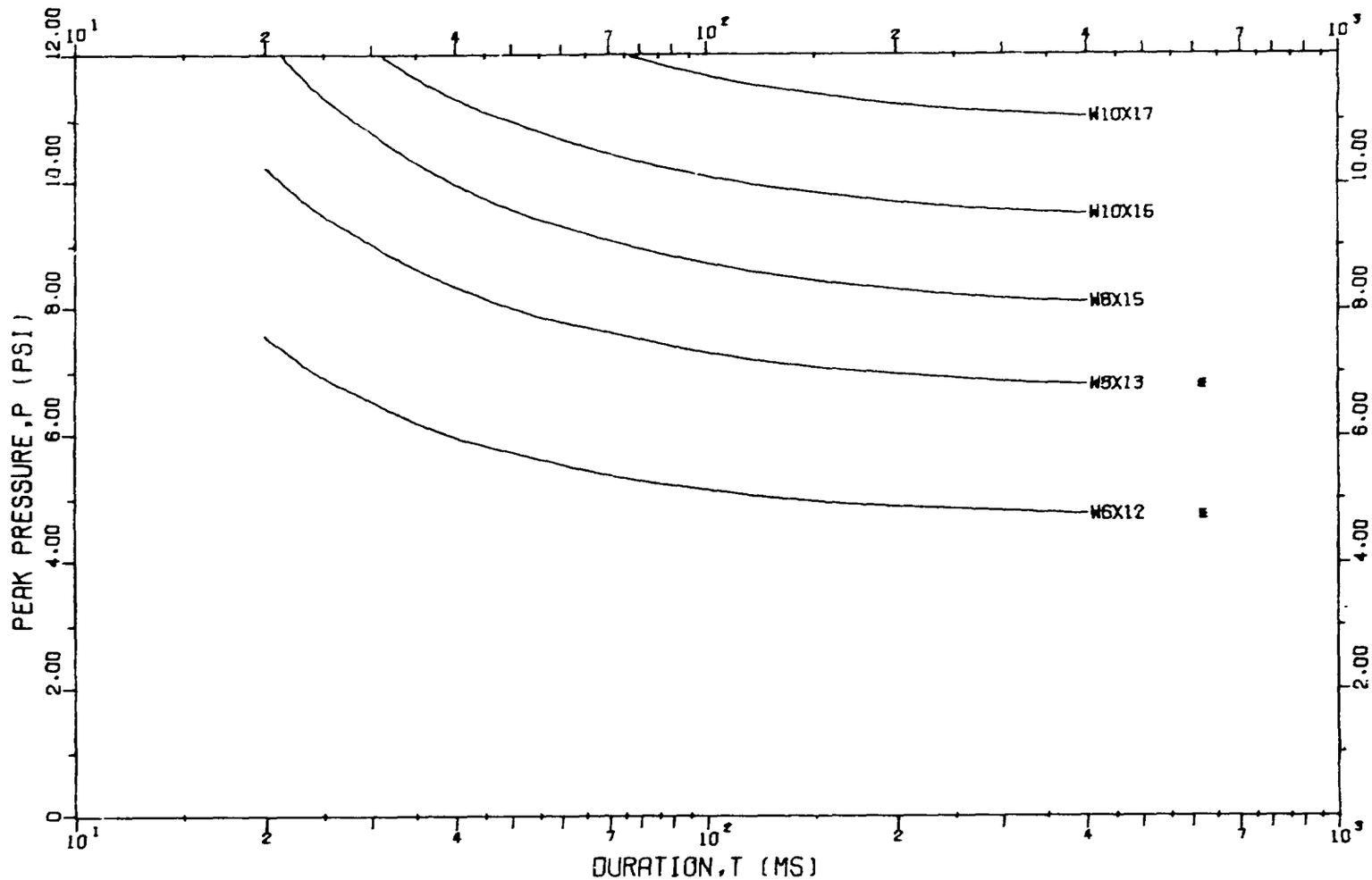


FIGURE 114

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=4 FT, FIXED ENDS

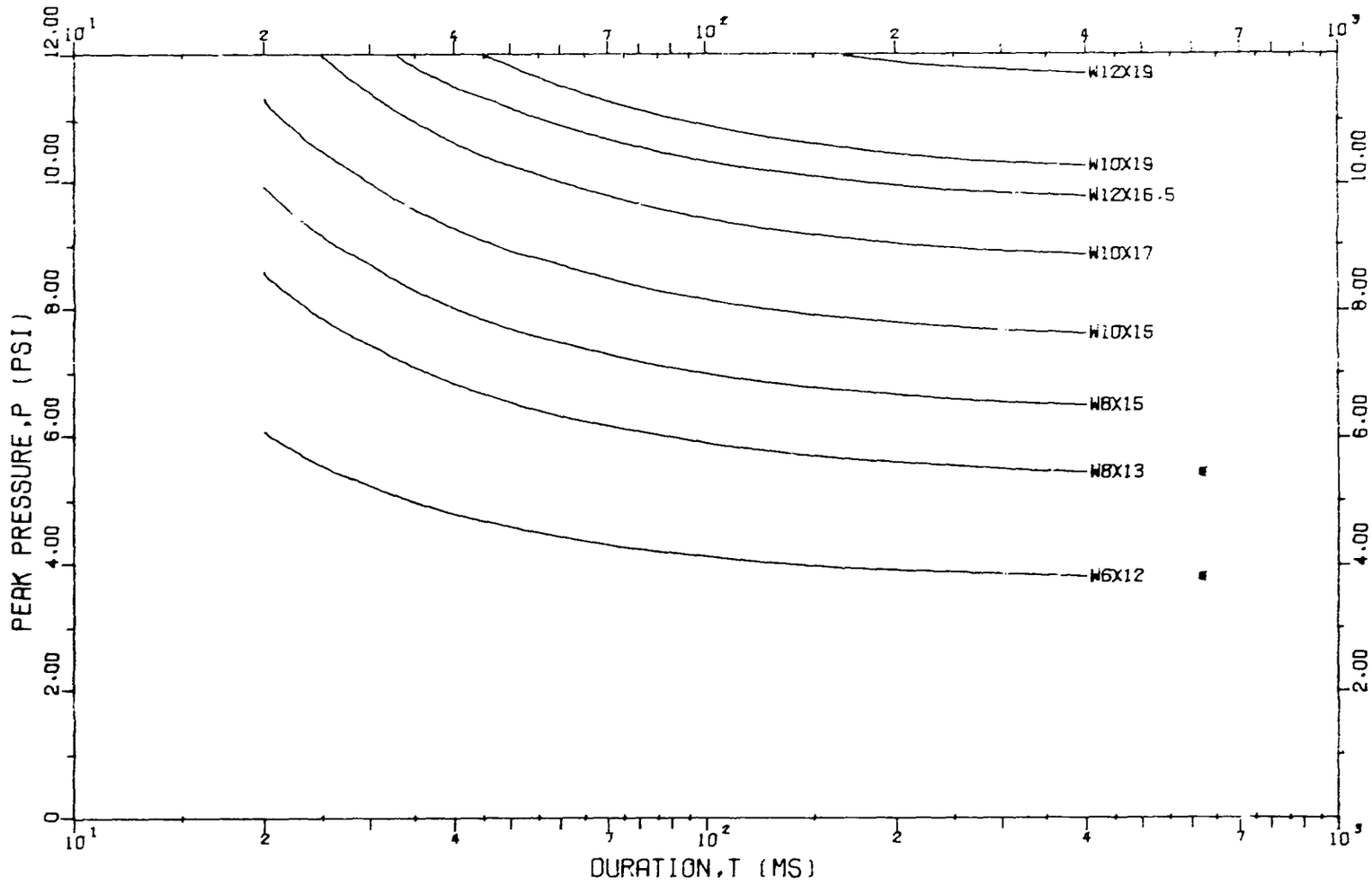


FIGURE 115

NON-REUSABLE BEAM,SPAN= 12 FT,SPACING=5 FT, FIXED ENDS

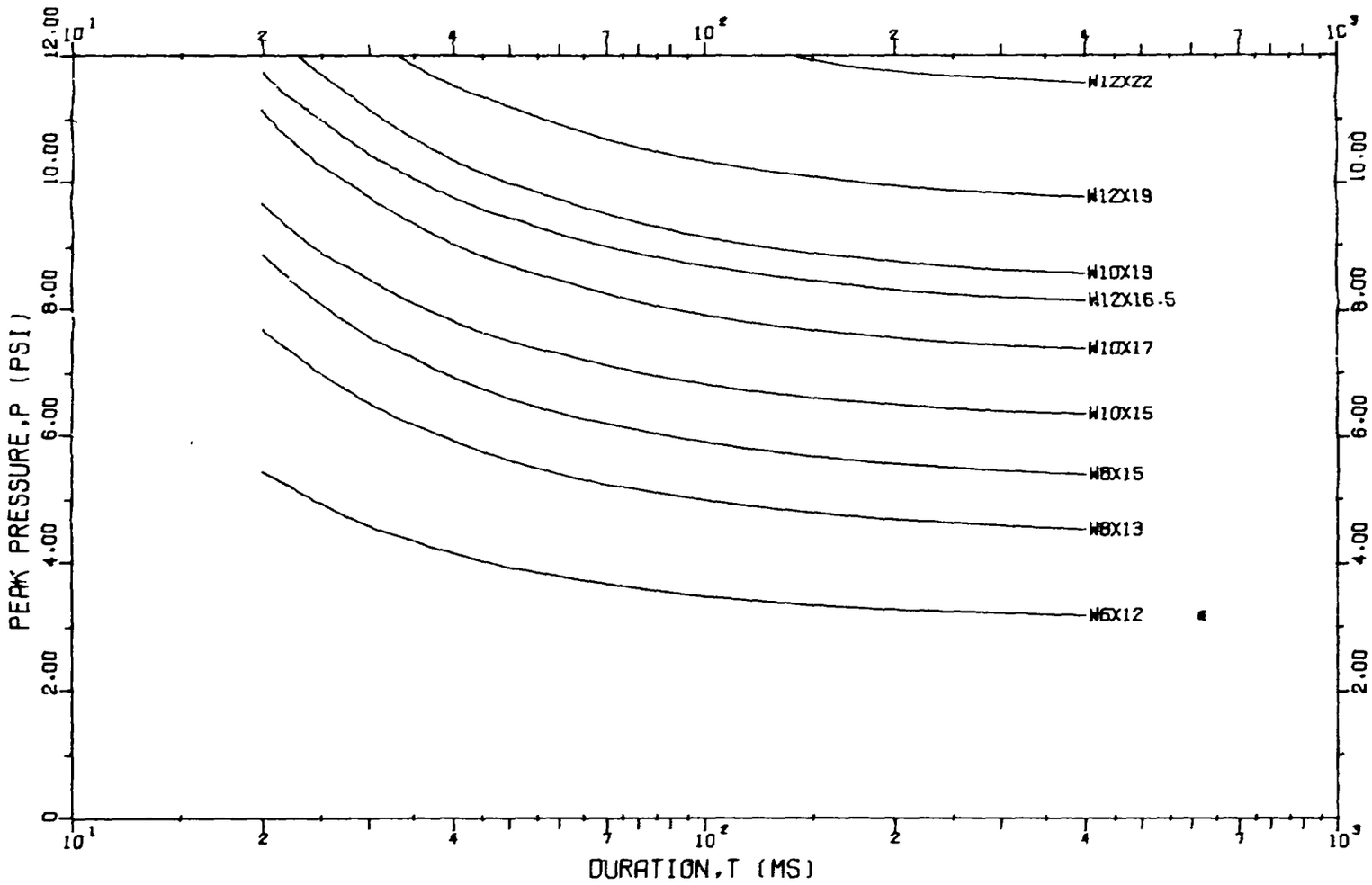


FIGURE 116

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=6 FT, FIXED ENDS

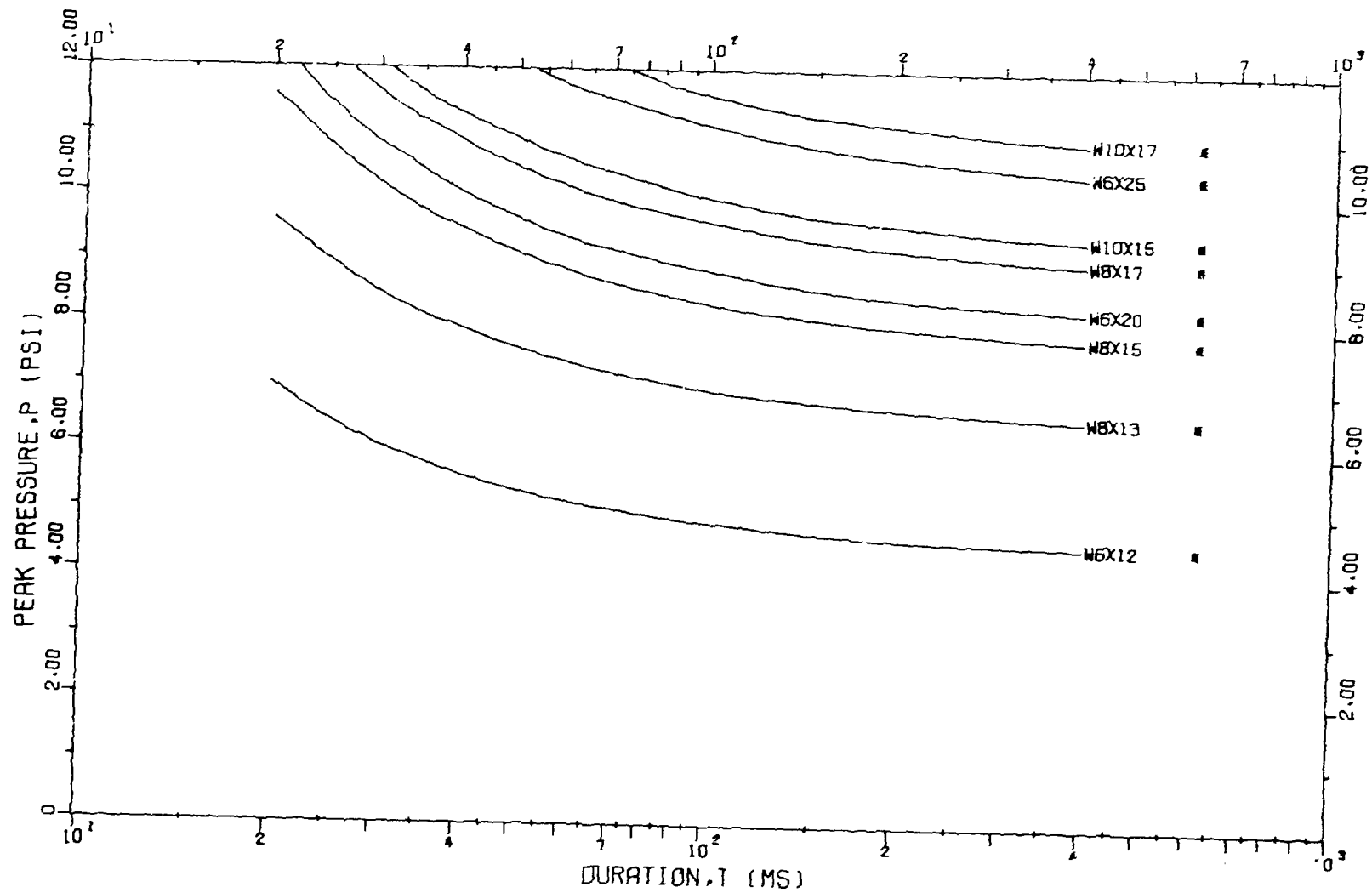


FIGURE 117

NON-REUSABLE BEAM,SPAN= 12 FT,SPACING=3 FT, SIMPLE-FIXED

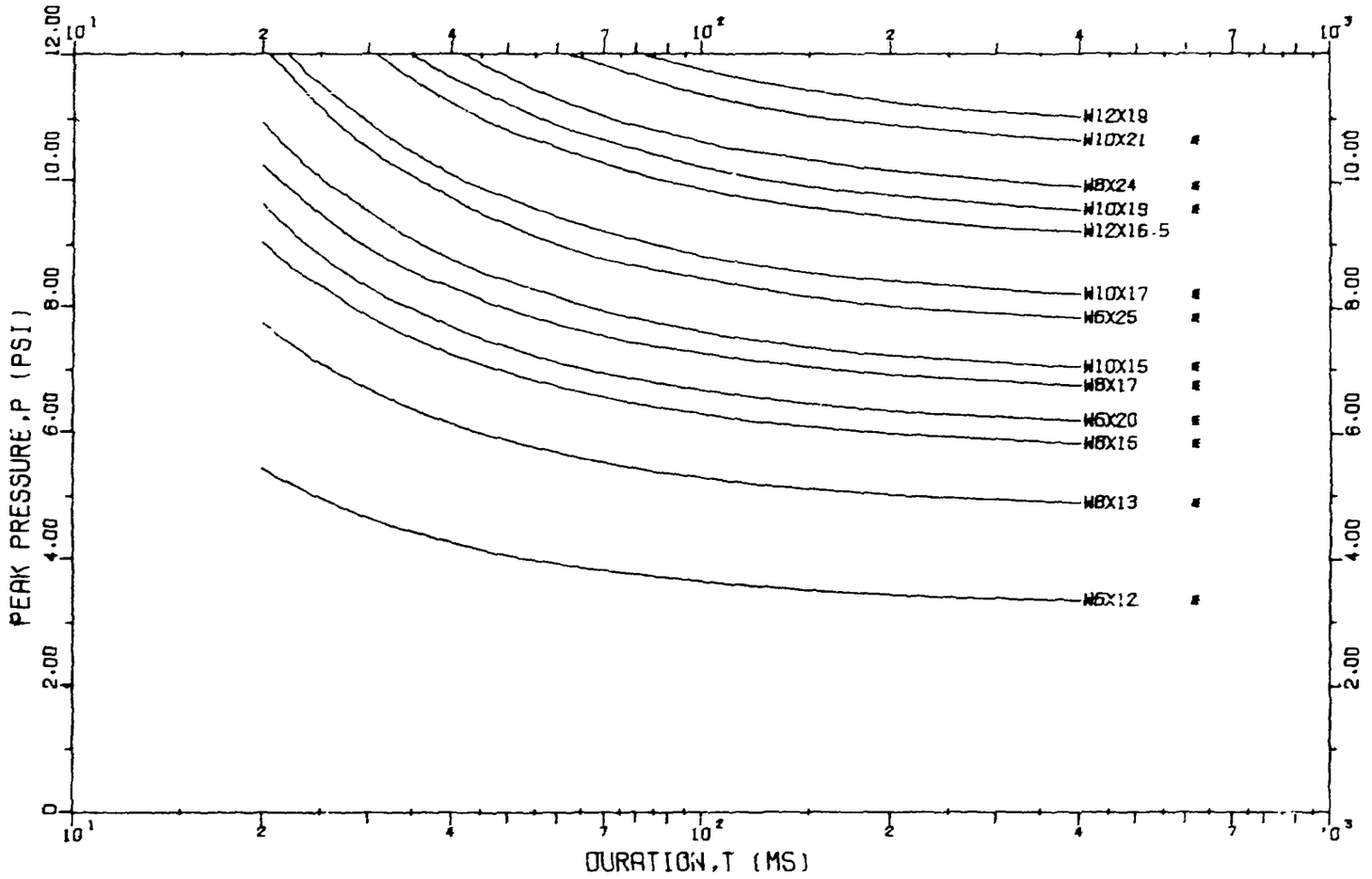


FIGURE 118

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=4 FT, SIMPLE-FIXED

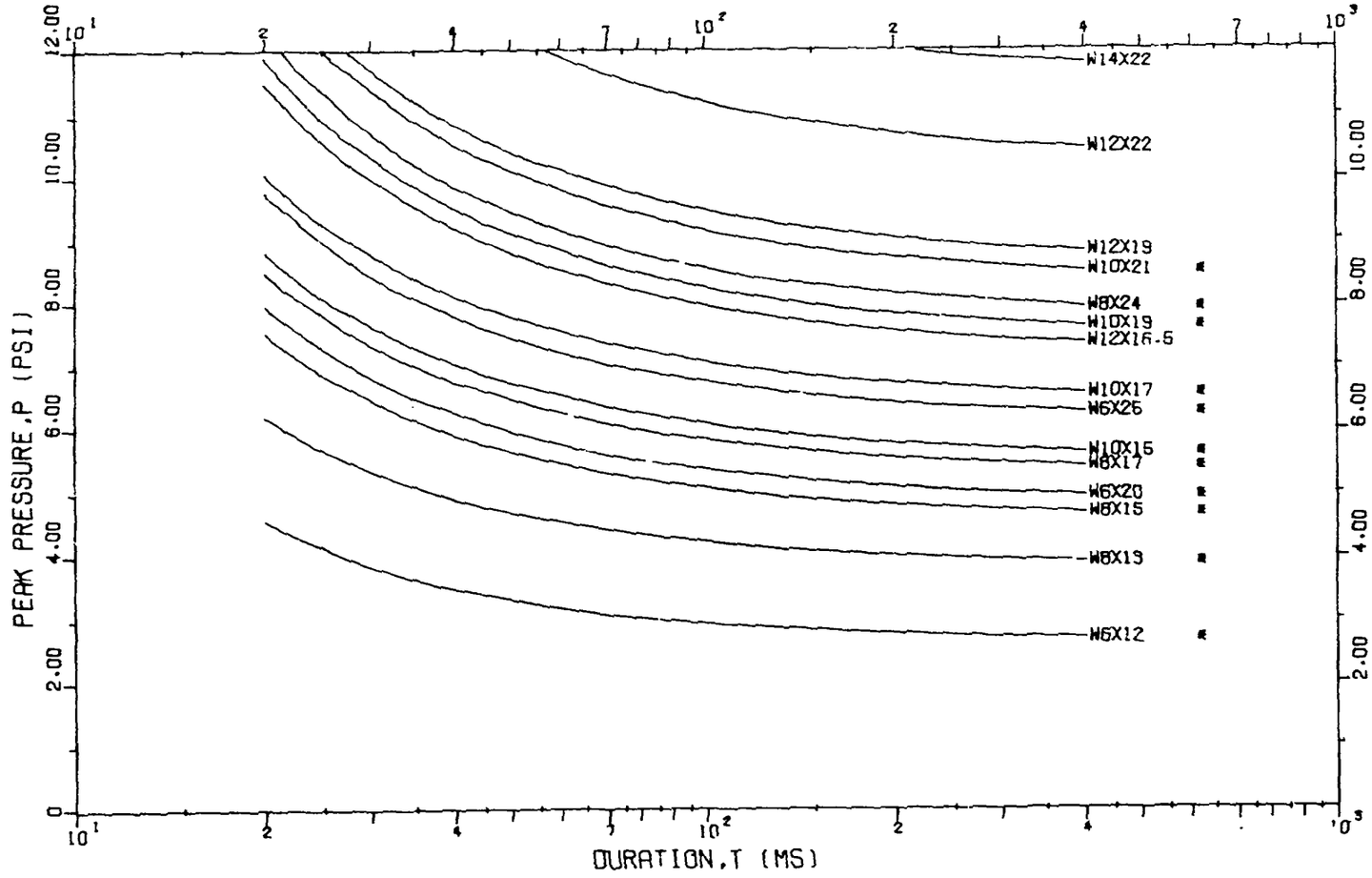


FIGURE 119

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=5 FT, SIMPLE-FIXED

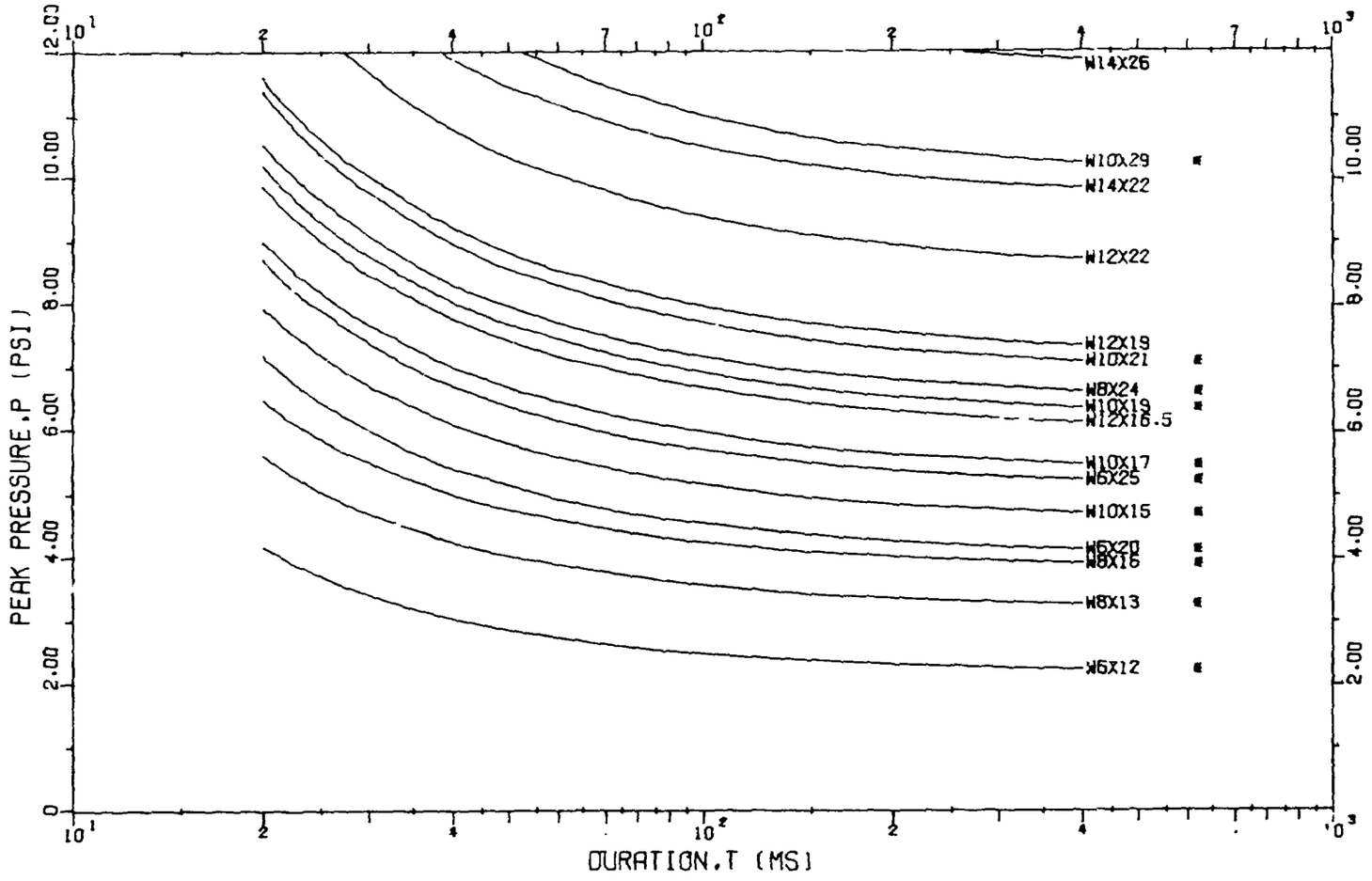


FIGURE 120

NON-REUSABLE BEAM,SPAN=12 FT,SPACING=6 FT, SIMPLE-FIXED

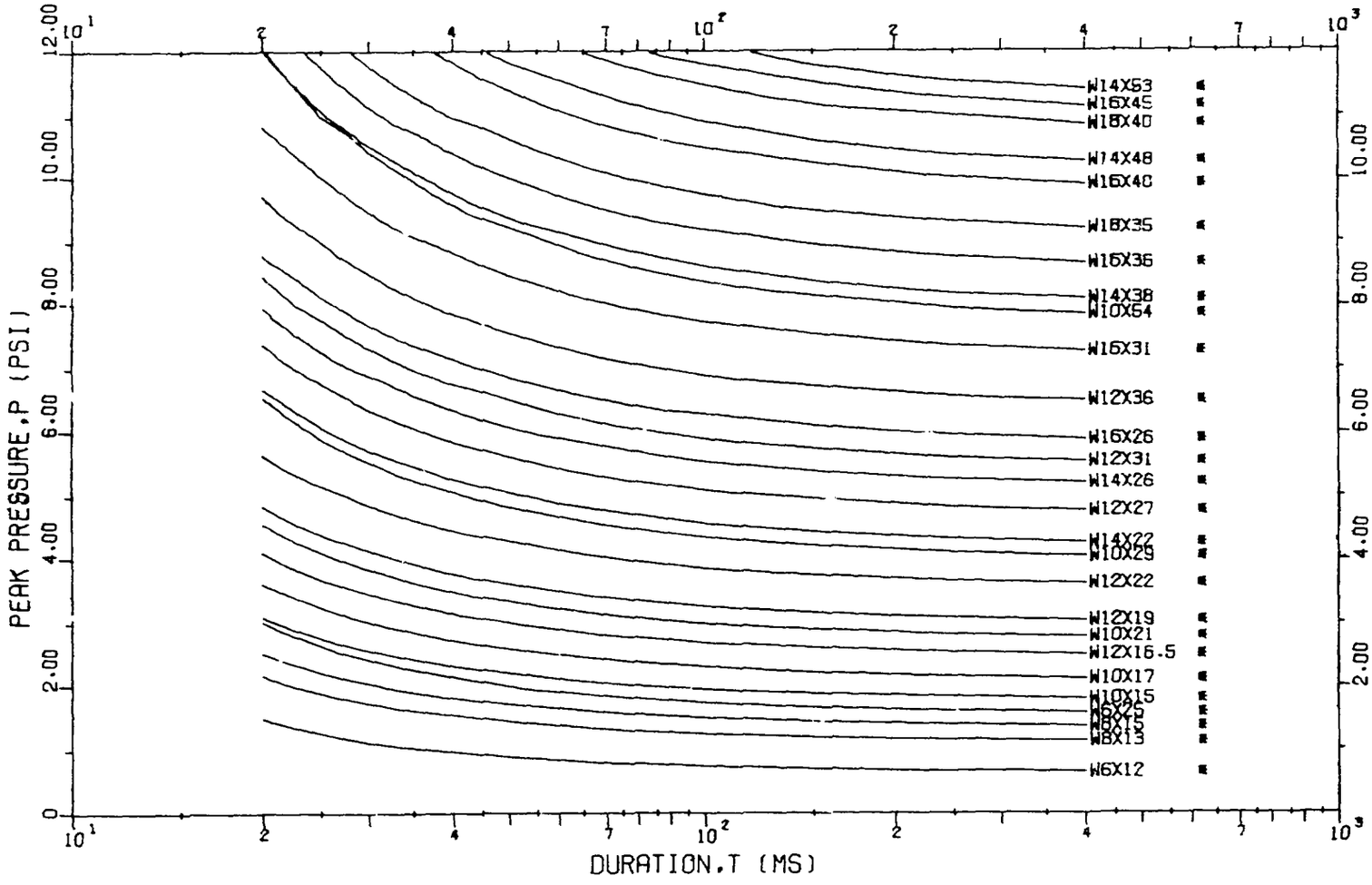


FIGURE 121

REUSABLE BEAM,SPAN= 16 FT,SPACING= 4 FT, SIMPLY-SUPPORTED

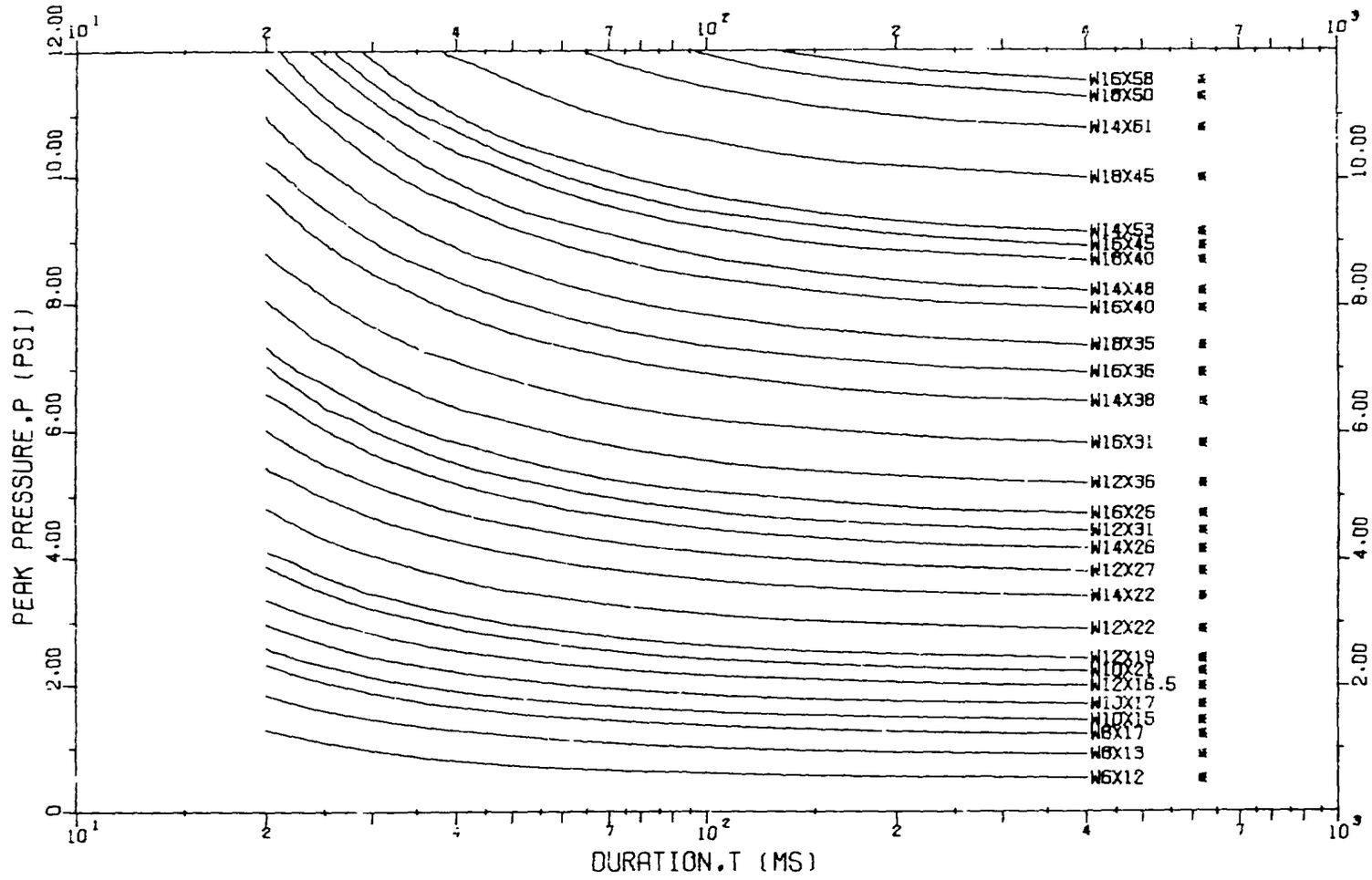


FIGURE 122

REUSABLE BEAM,SPAN= 16 FT,SPACING= 5 FT, SIMPLY-SUPPORTED

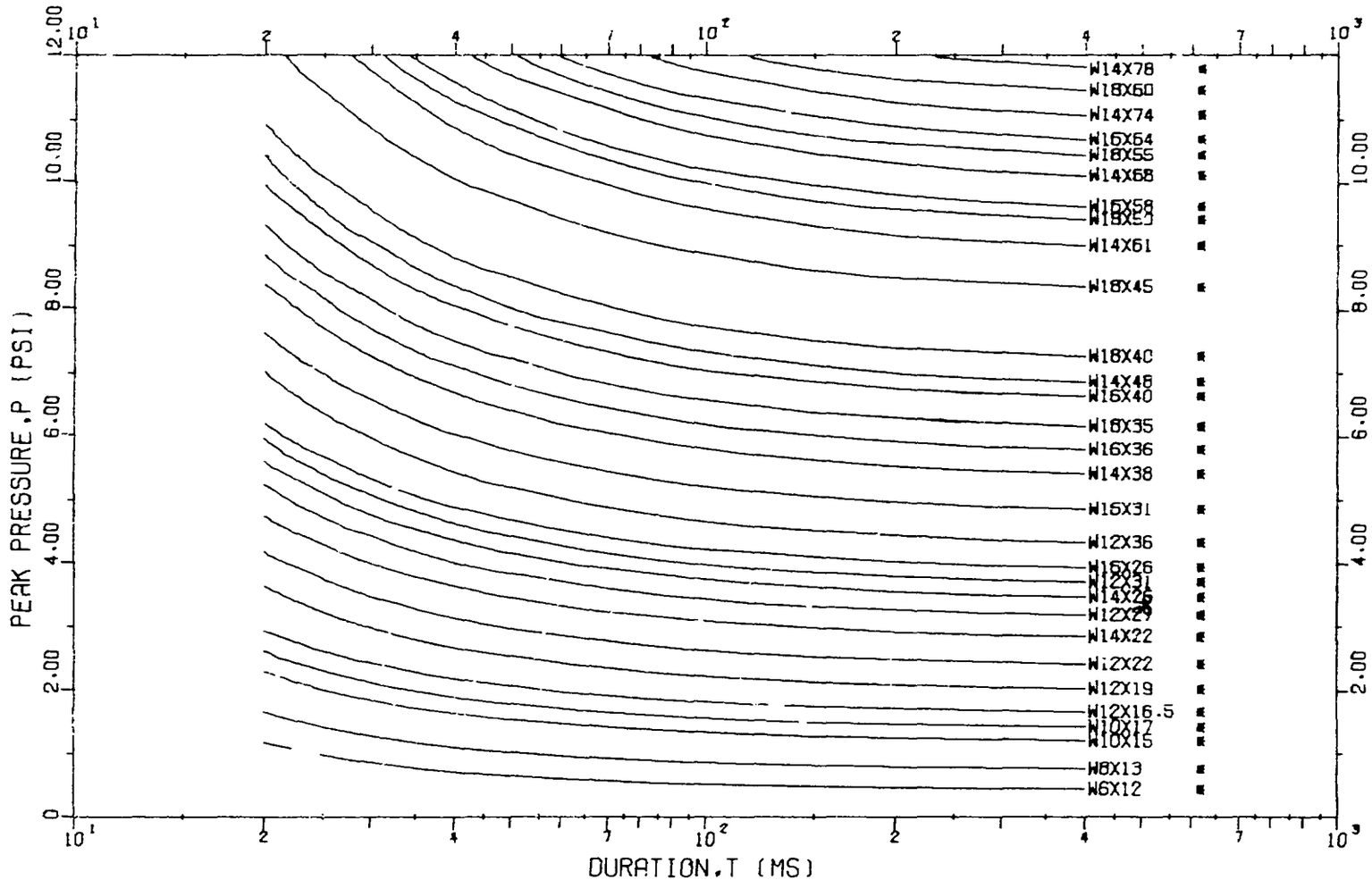


FIGURE 123

REUSABLE BEAM,SPAN= 16 FT,SPACING= 6 FT, SIMPLY-SUPPORTED

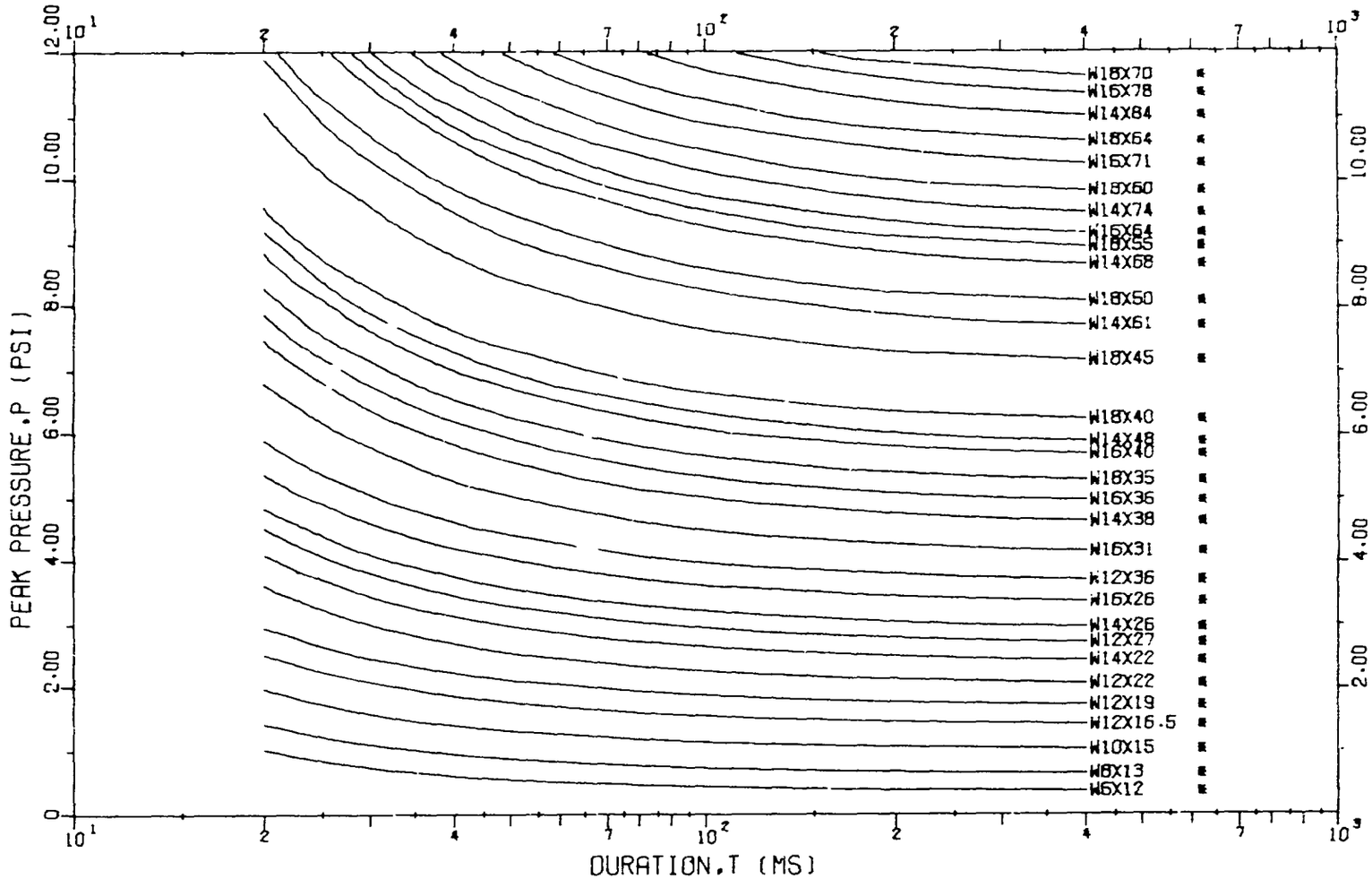


FIGURE 124

REUSABLE BEAM,SPAN= 16 FT,SPACING= 7 FT, SIMPLY-SUPPORTED

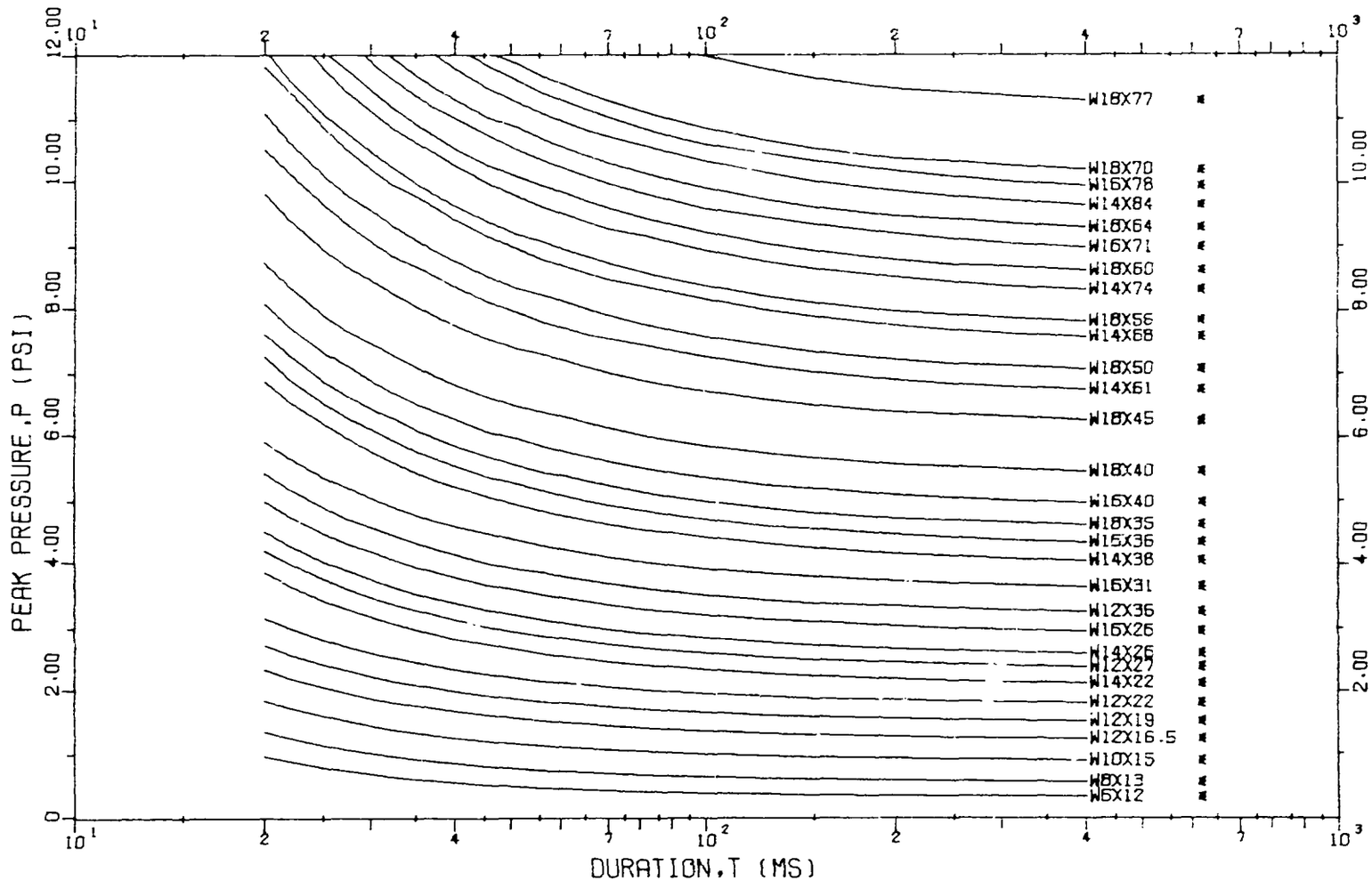


FIGURE 125

REUSABLE BEAM,SPAN=16 FT,SPACING=8 FT, SIMPLY-SUPPORTED

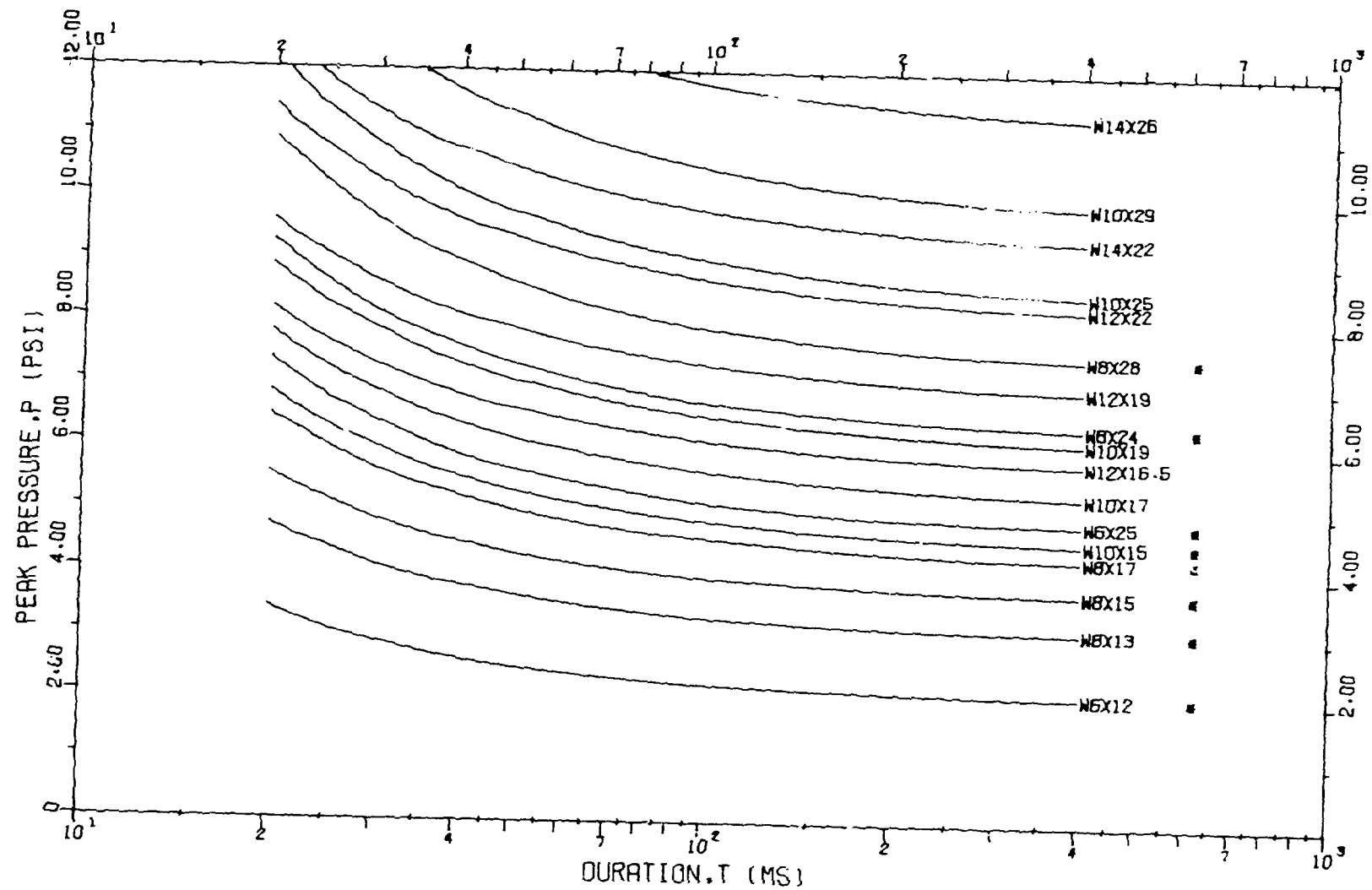


FIGURE 126

REUSABLE BEAM,SPAN= 16 FT,SPACING= 4 FT, FIXED ENDS

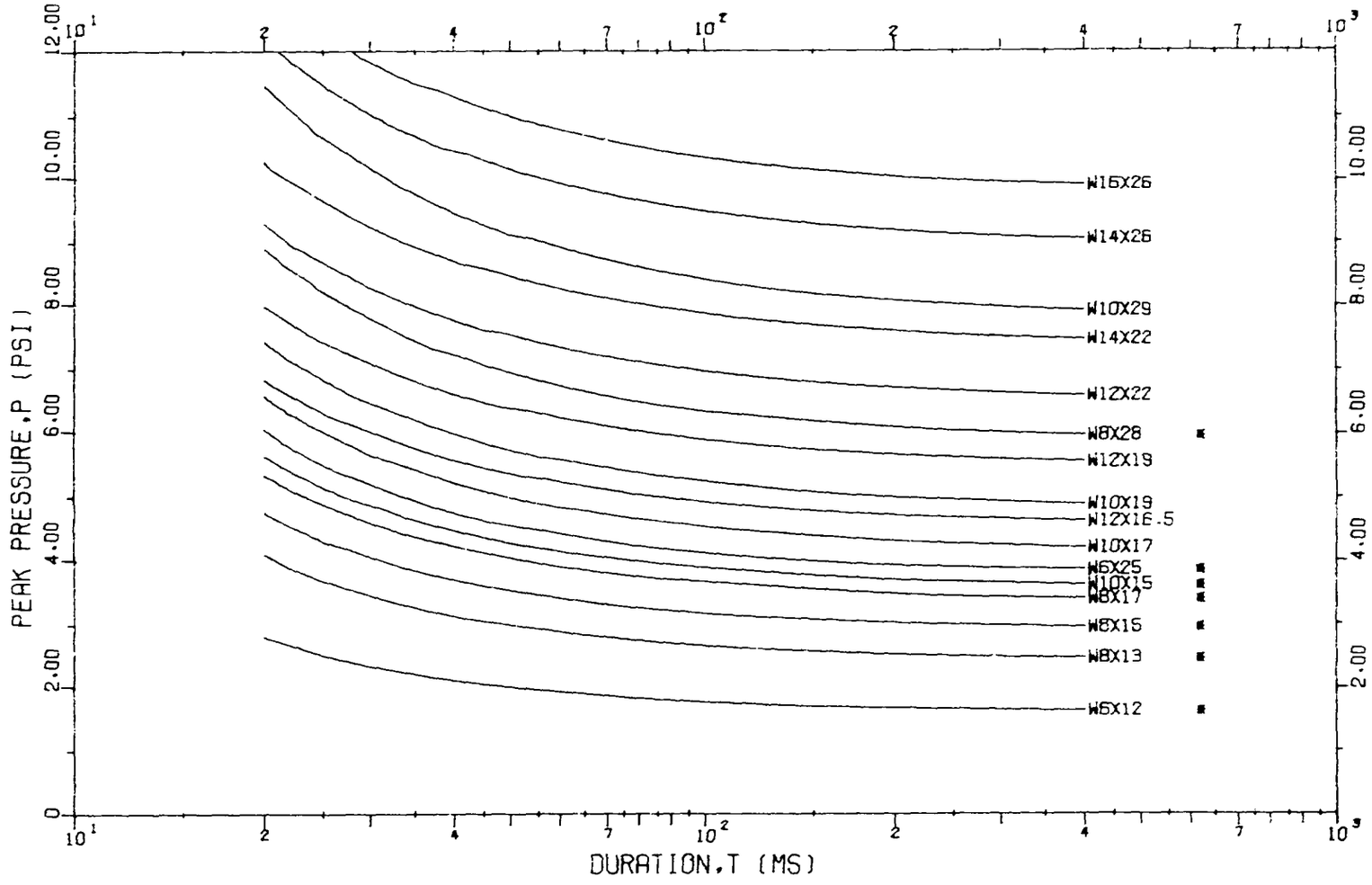


FIGURE 127

REUSABLE BEAM,SPAN= 16 FT,SPACING= 5 FT, FIXED ENDS

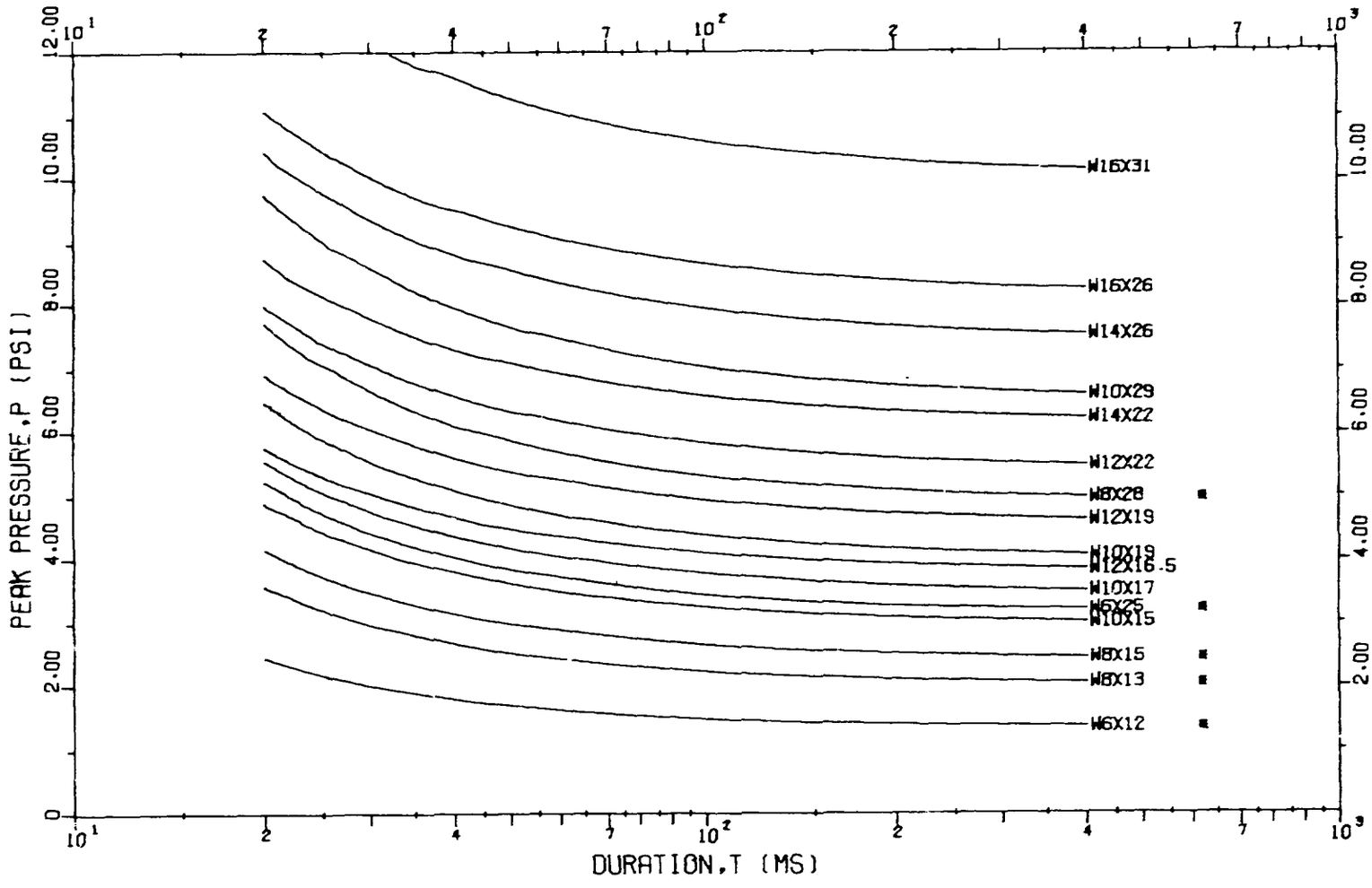


FIGURE 128

REUSABLE BEAM,SPAN= 16 FT,SPACING= 6 FT, FIXED ENDS

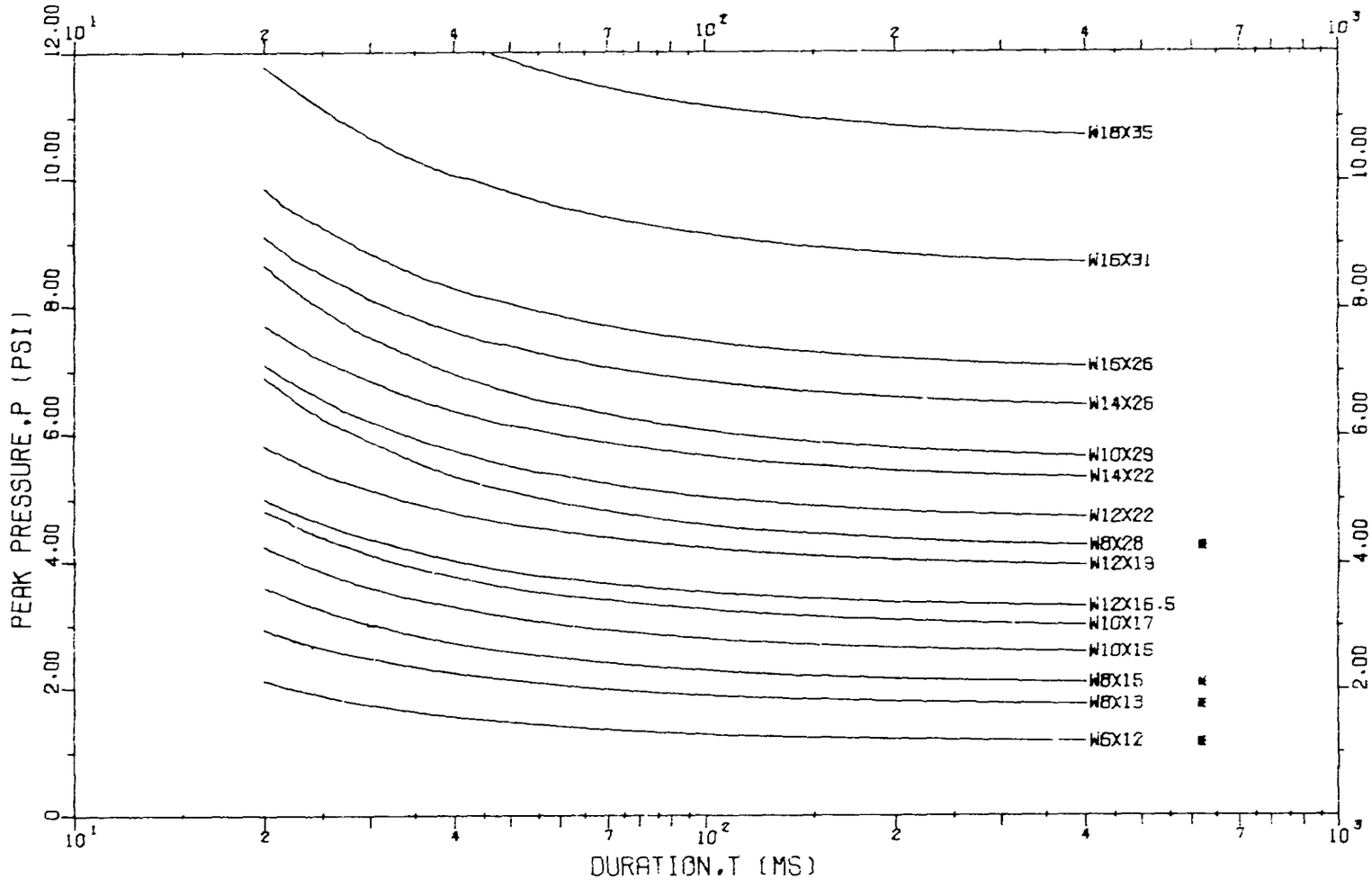


FIGURE 129

REUSABLE BEAM,SPAN= 16 FT,SPACING= 7 FT, FIXED ENDS

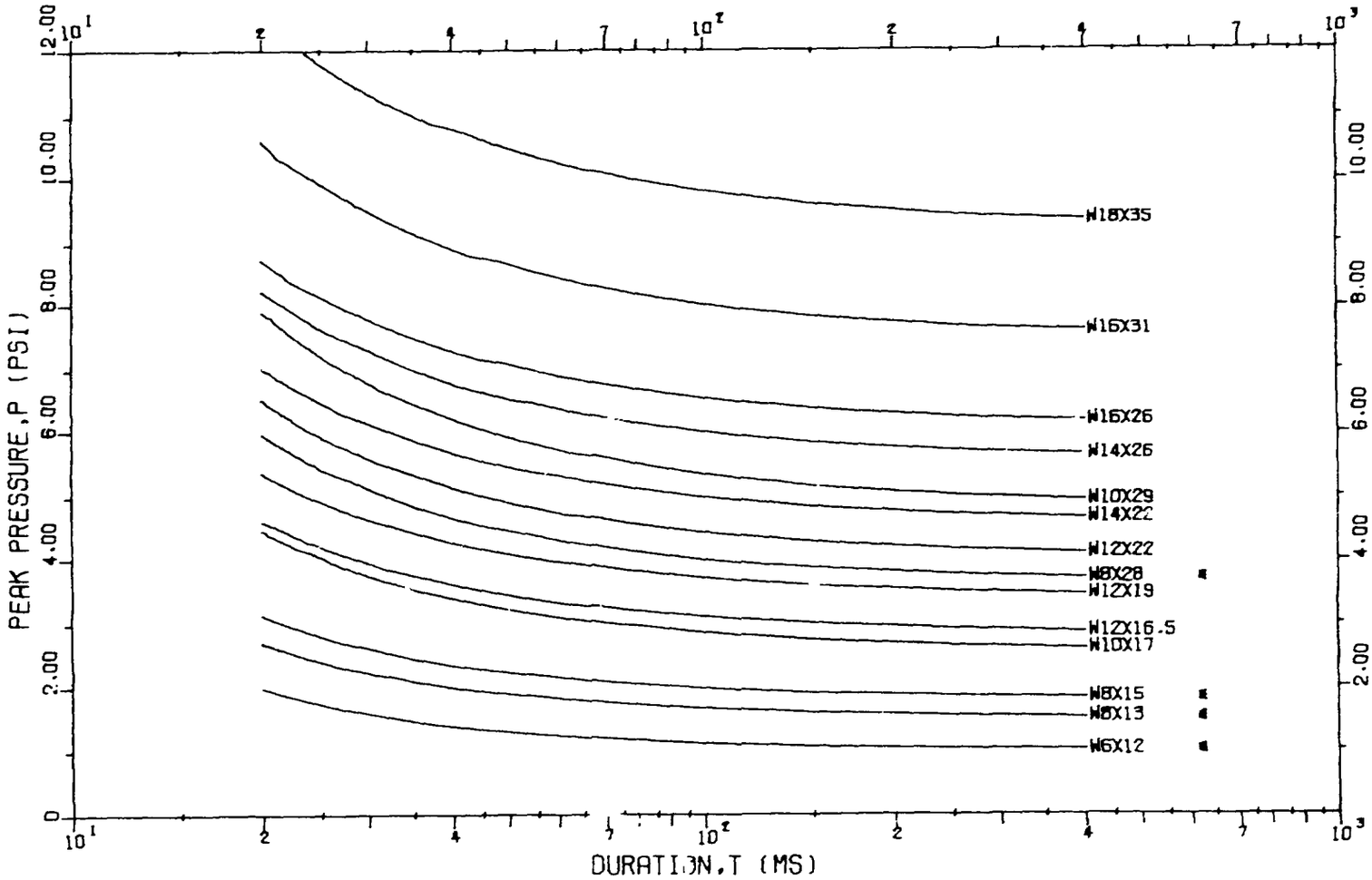


FIGURE 150

REUSABLE BEAM,SPAN= 16 FT,SPACING= 8 FT, FIXED ENDS

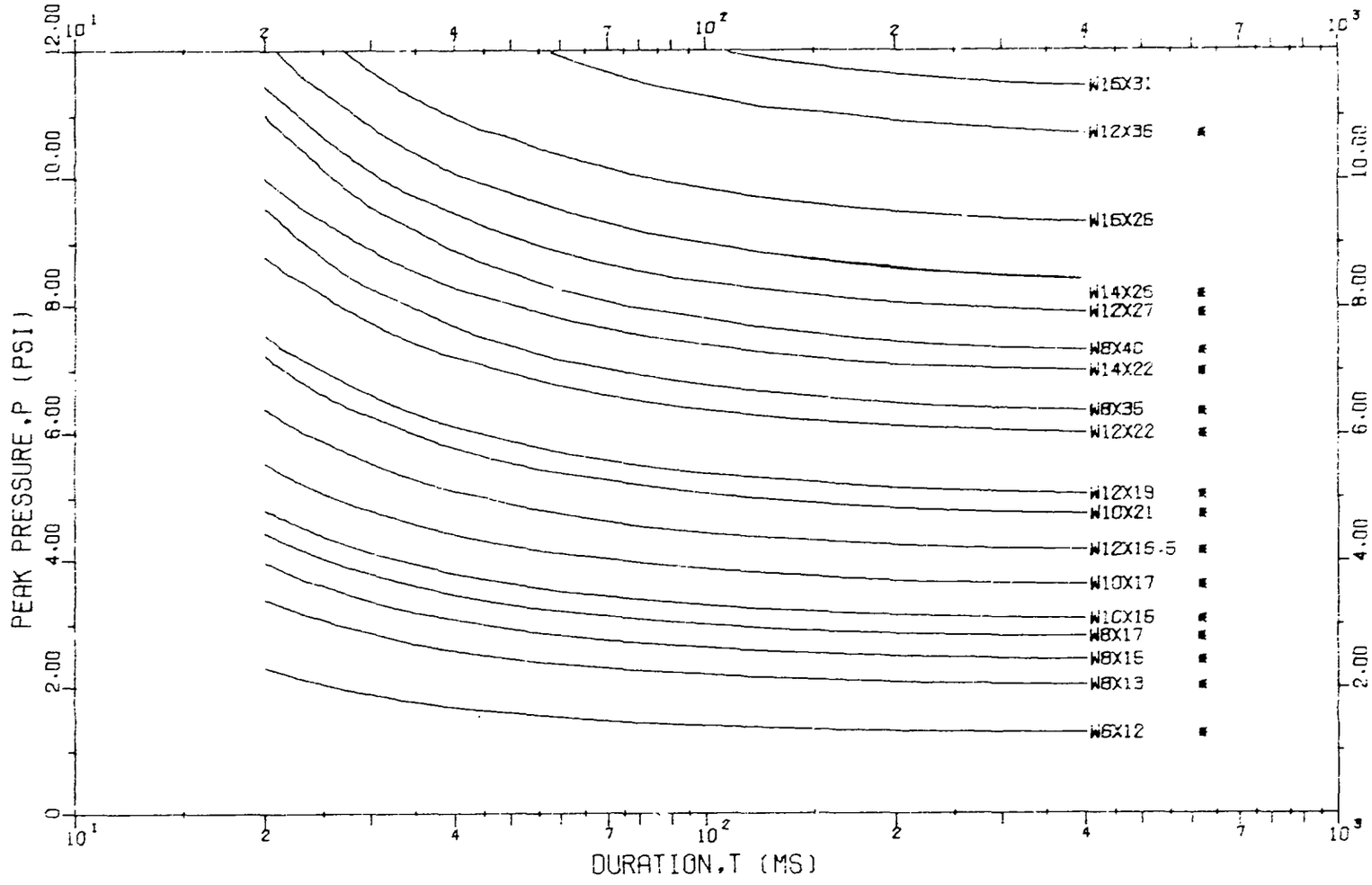


FIGURE 131

REUSABLE BEAM,SPAN= 16 FT,SPACING= 4 FT, SIMPLE-FIXED

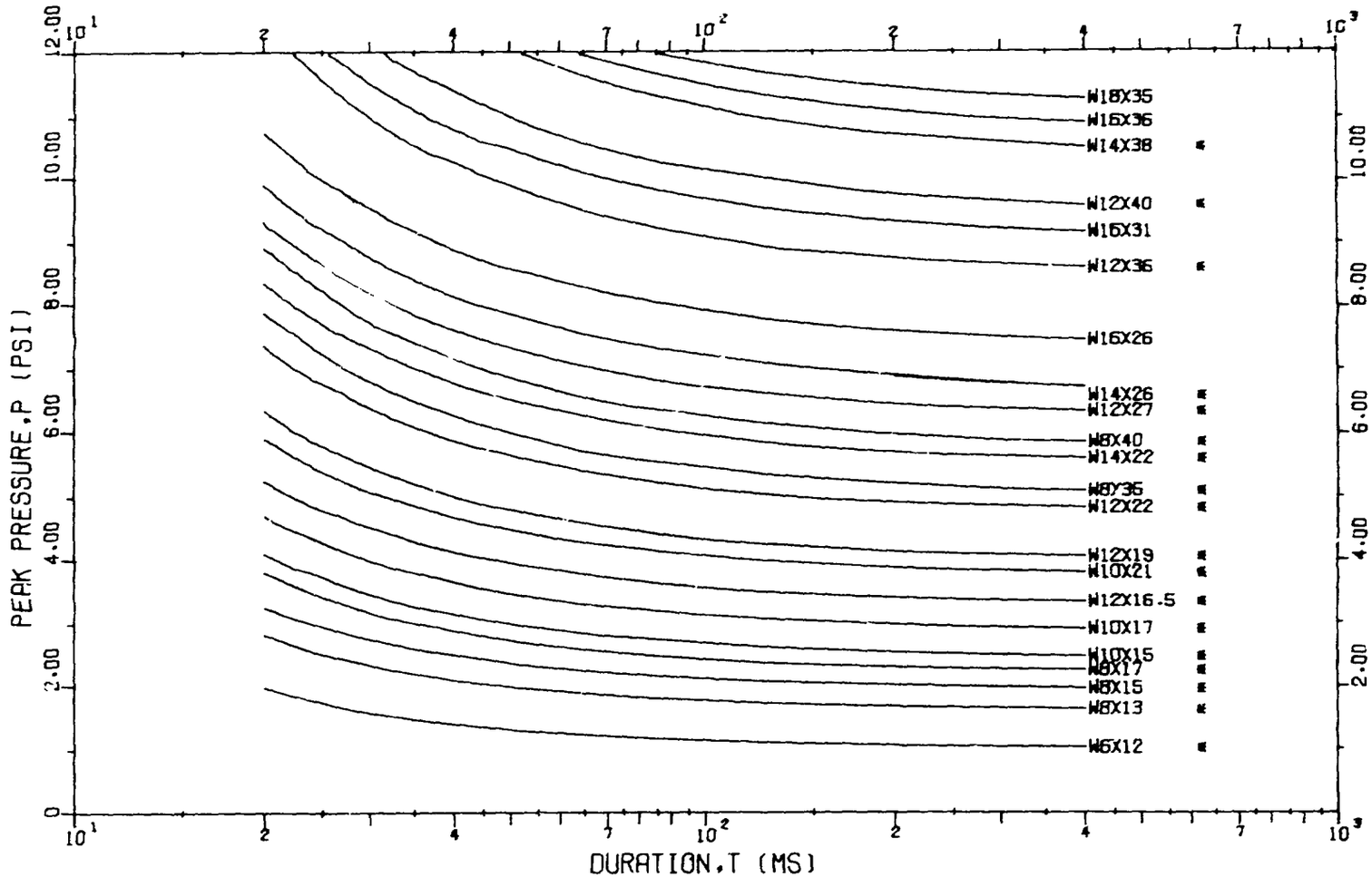


FIGURE 132

REUSABLE BEAM,SPAN= 16 FT,SPPCING= 5 FT, SIMPLE-FIXED

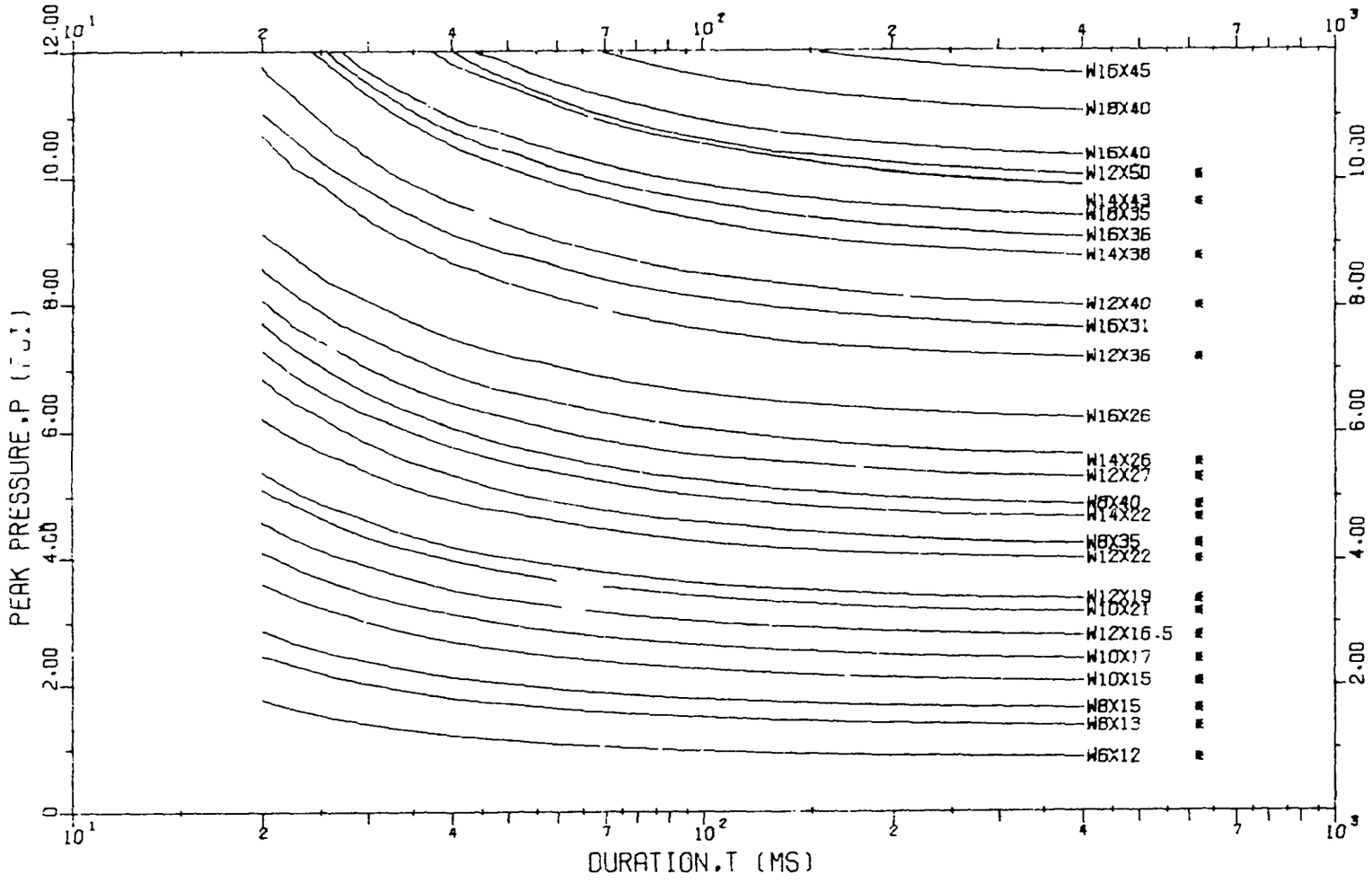


FIGURE 133

REUSABLE BEAM,SPAN= 16 FT,SPACING= 6 FT, SIMPLE-FIXED

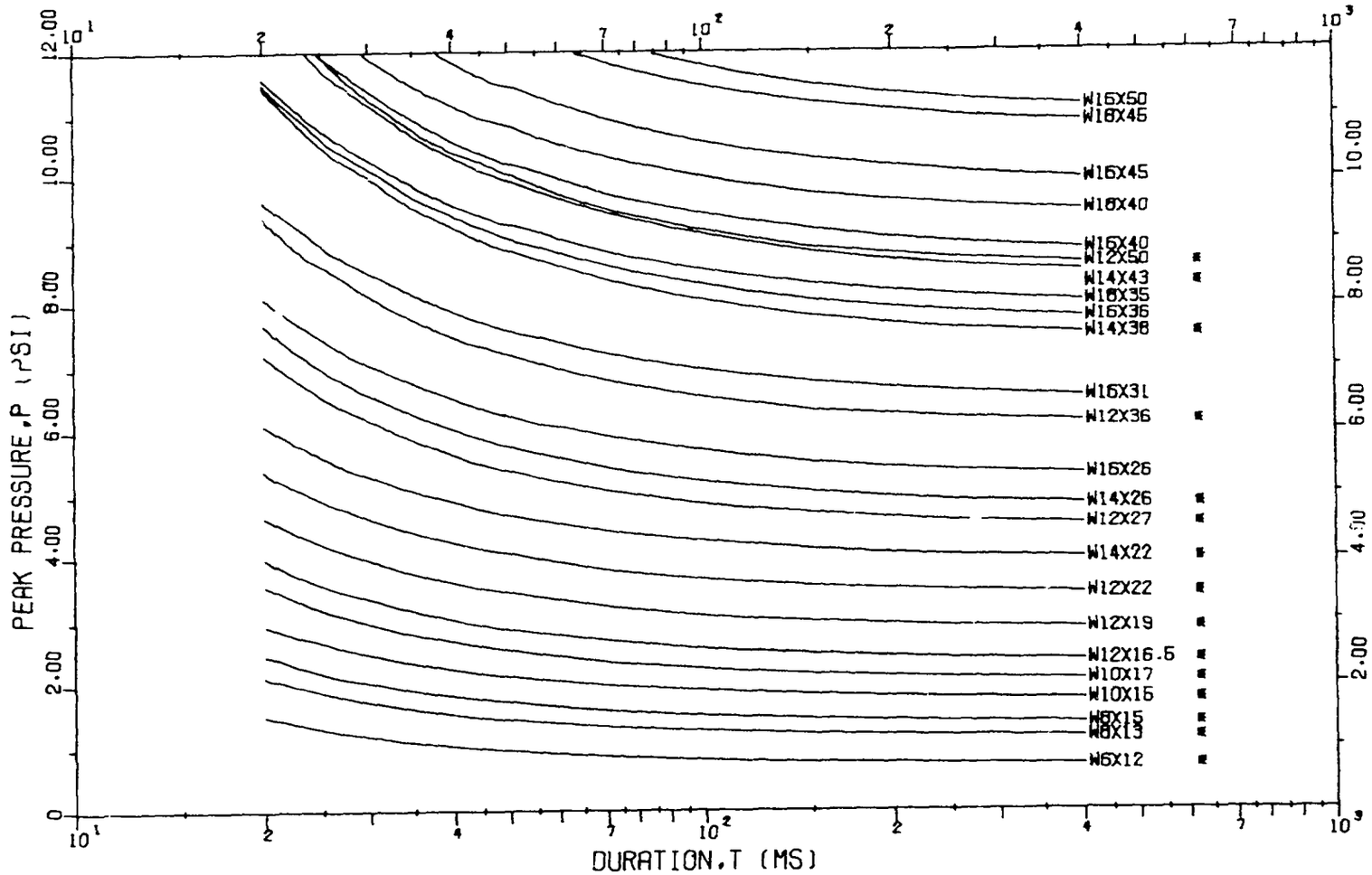


FIGURE 134

REUSABLE BEAM,SPAN= 16 FT,SPACING= 7 FT, SIMPLE-FIXED

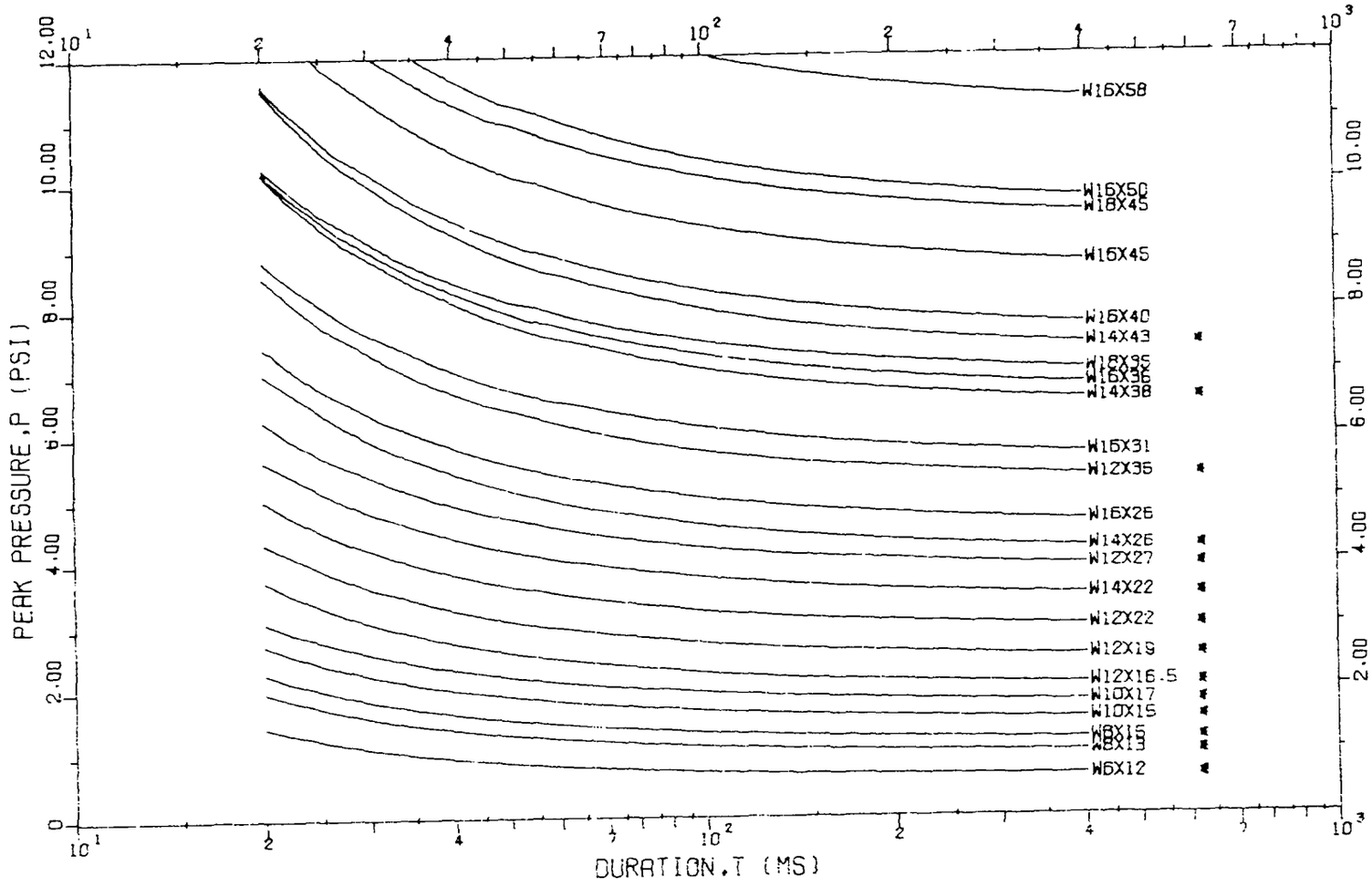


FIGURE 135

REUSABLE BEAM.SPAN= 16 FT.SPACING= 8 FT. SIMPLE-FIXED

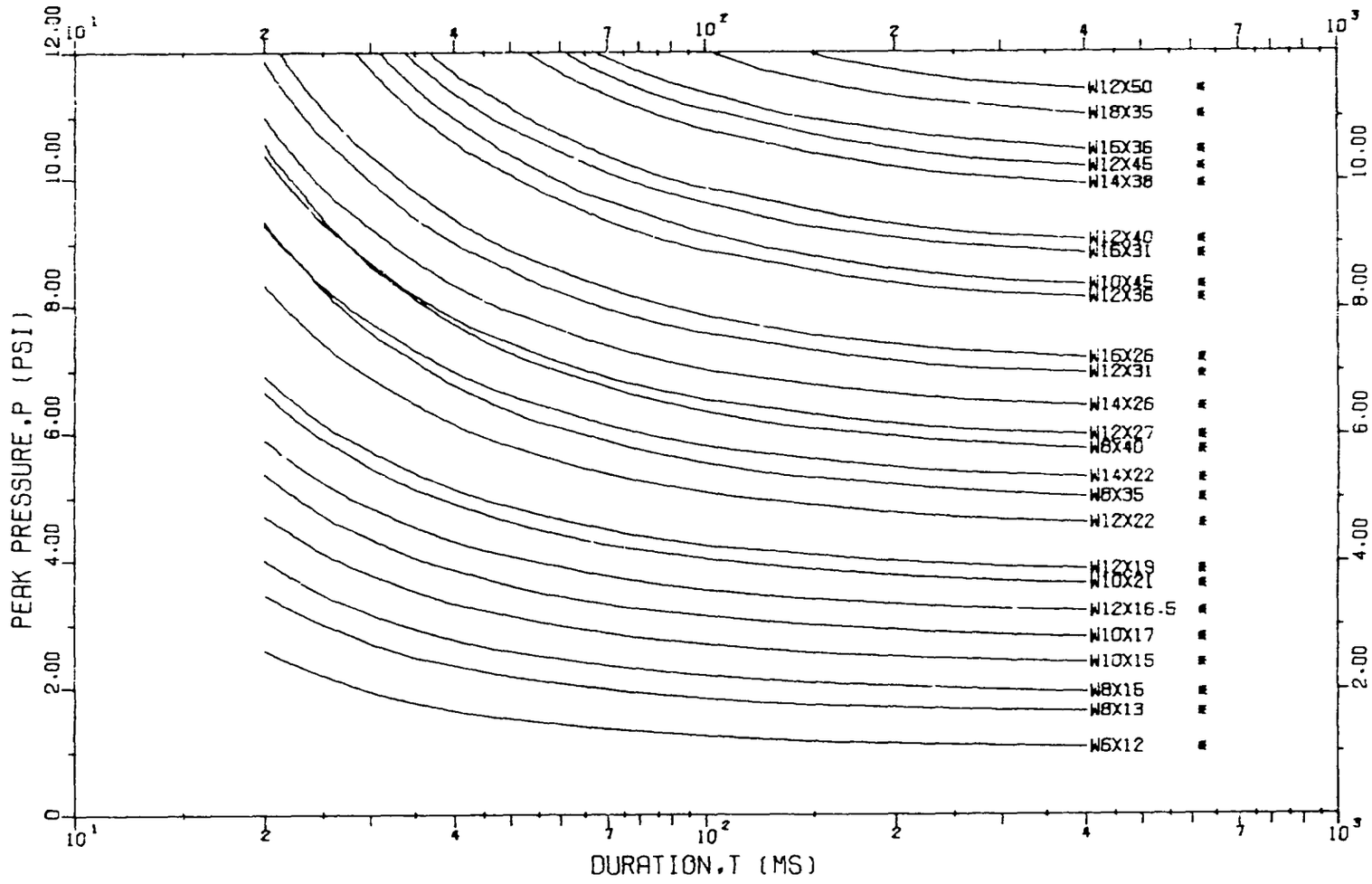


FIGURE 136

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=4 FT, SIMPLY-SUPPORTED

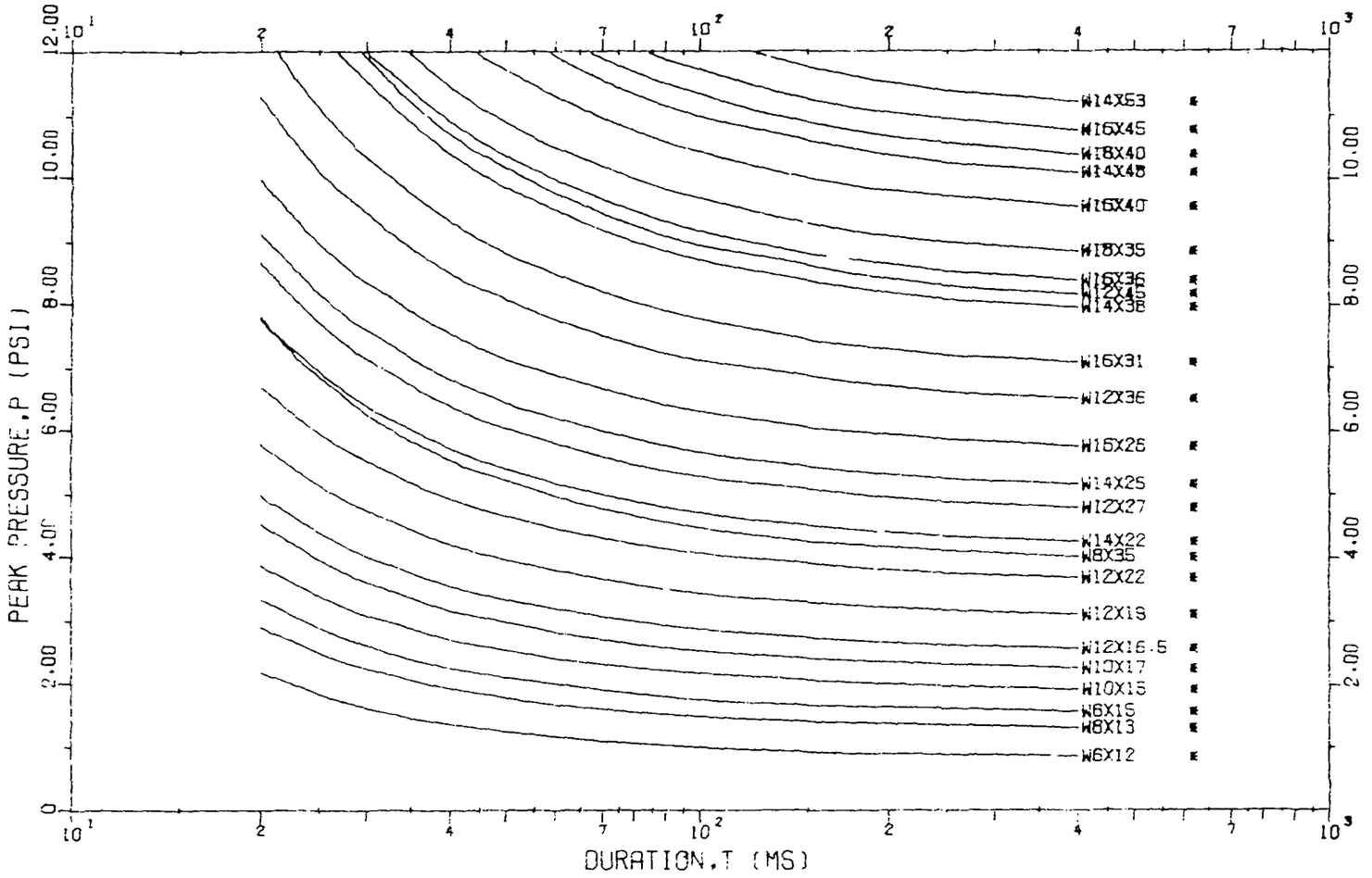


FIGURE 137

NON-REUSABLE BEAM.SPAN= 16 FT.SPACING=5 FT. SIMPLY-SUPPORTED

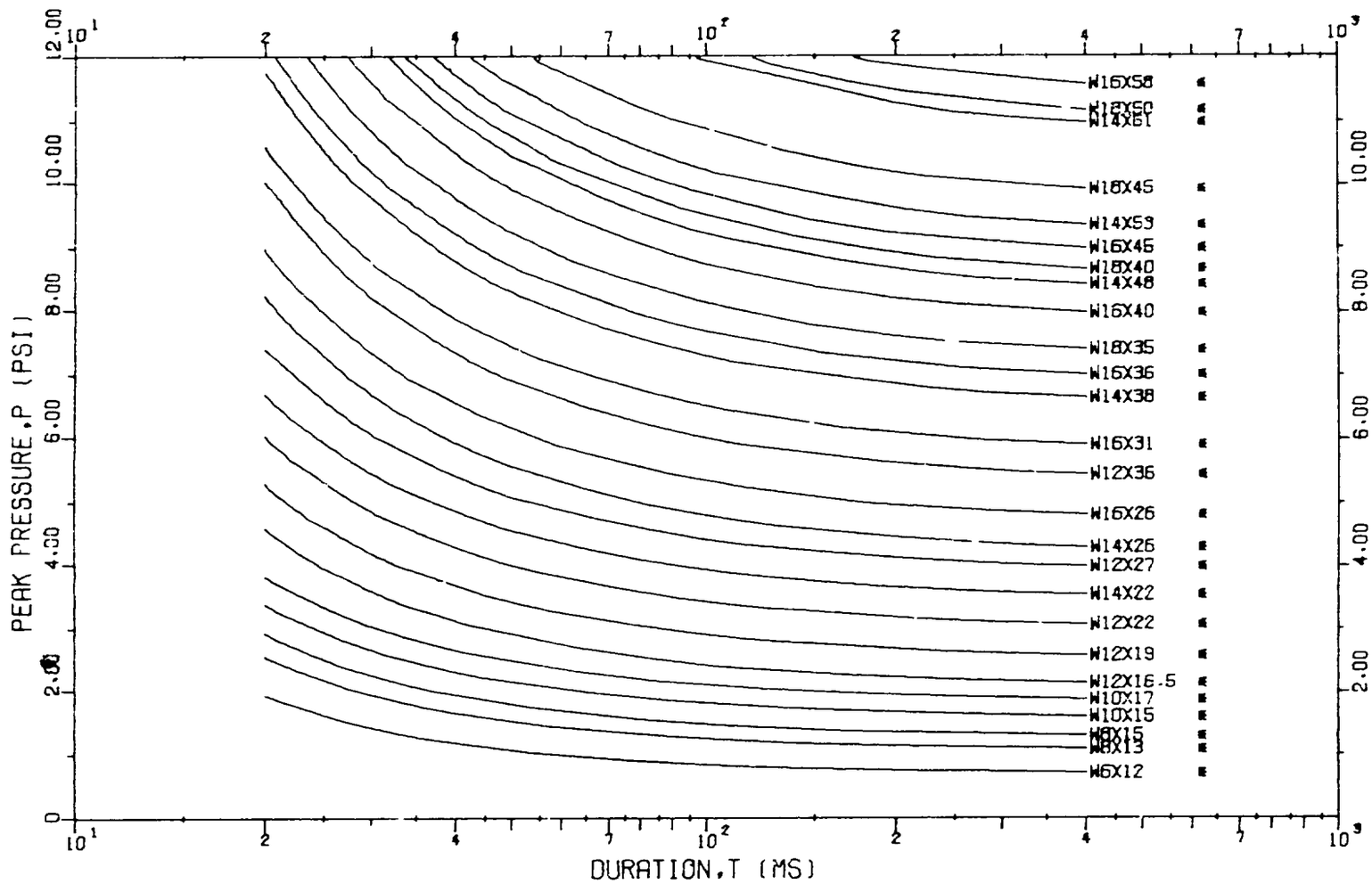


FIGURE 138

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=6 FT, SIMPLY-SUPPORTED

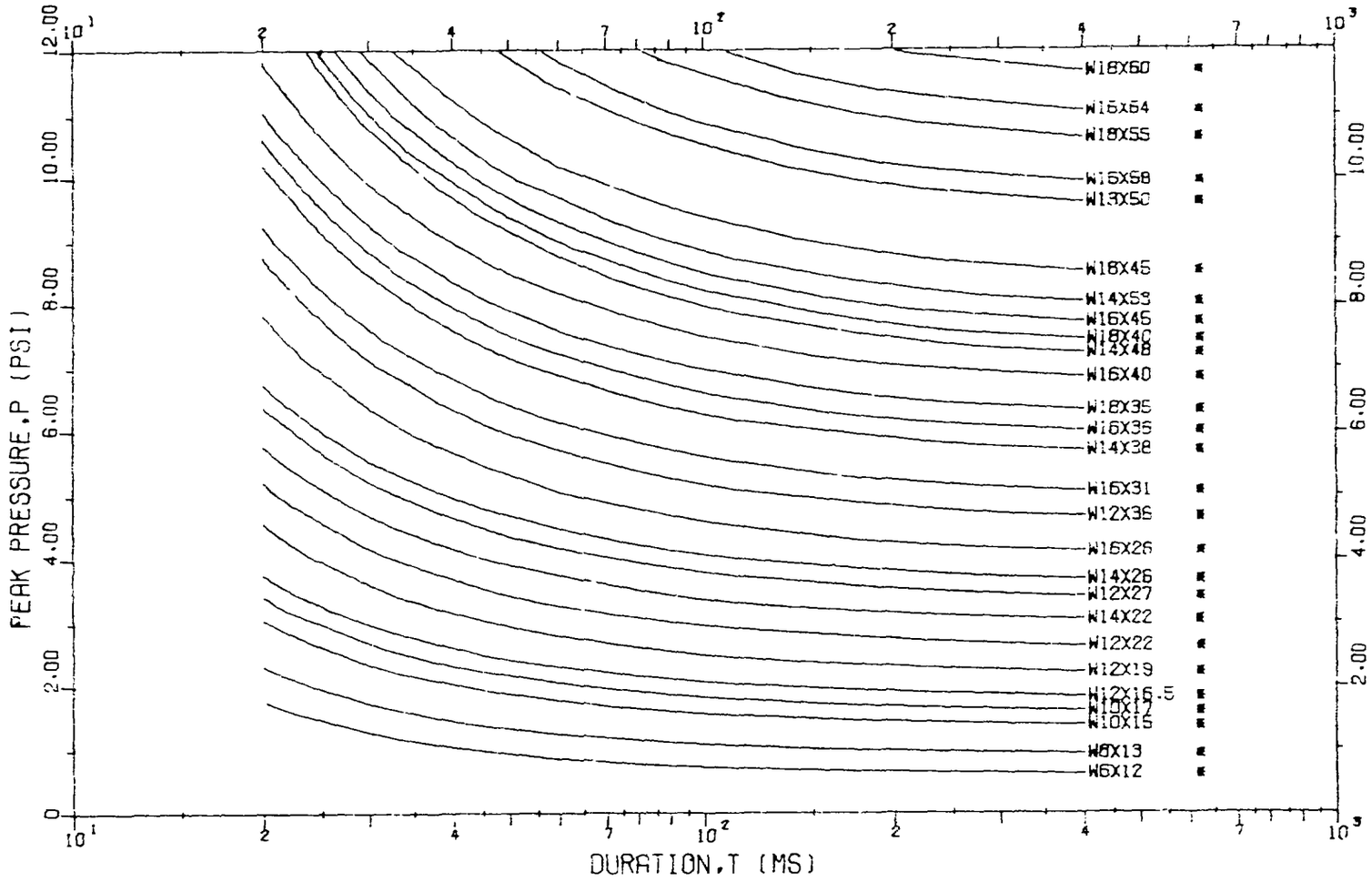


FIGURE 139

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=7 FT, SIMPLY-SUPPORTED

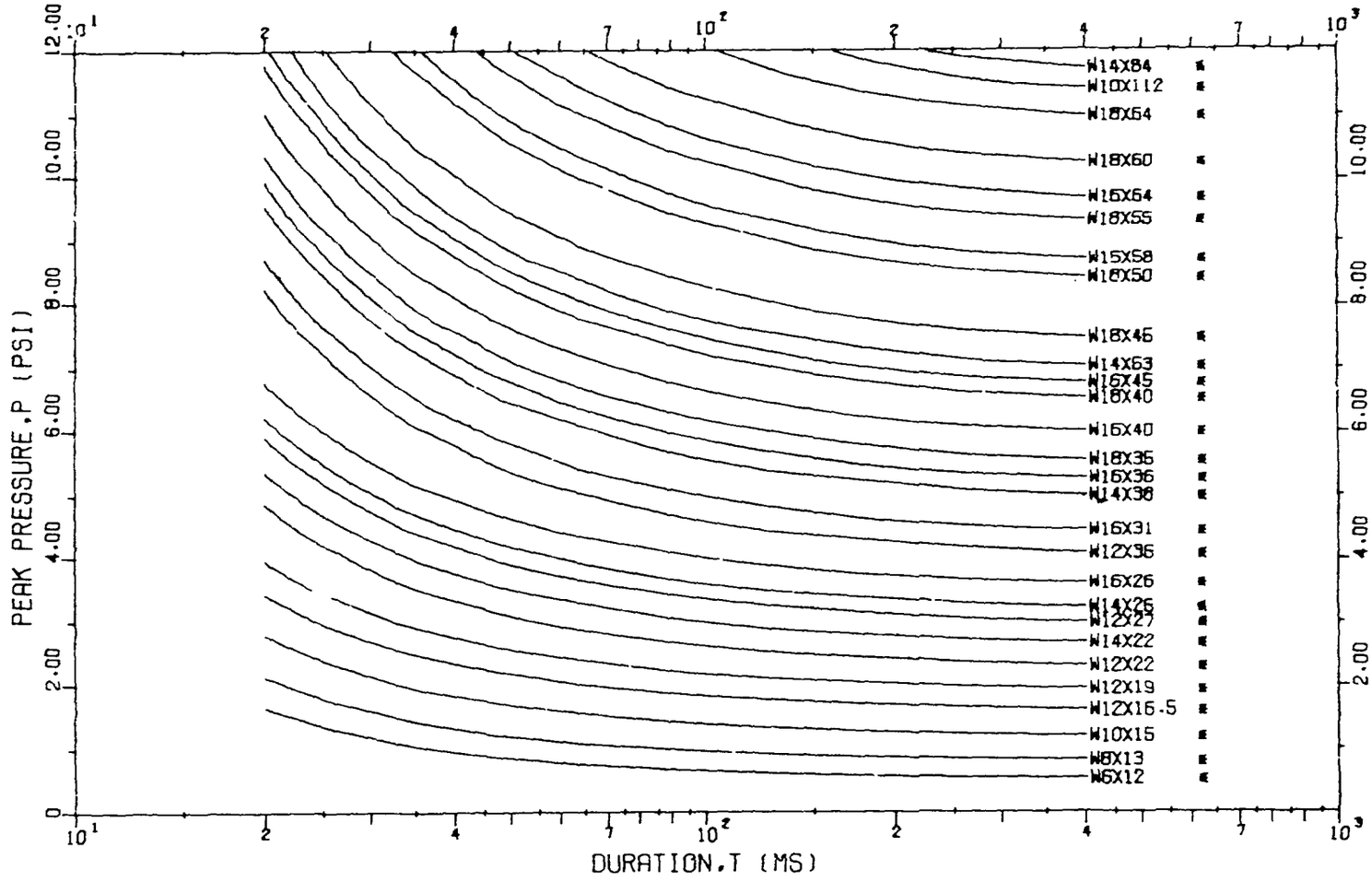


FIGURE 140

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=8 FT, SIMPLY-SUPPORTED

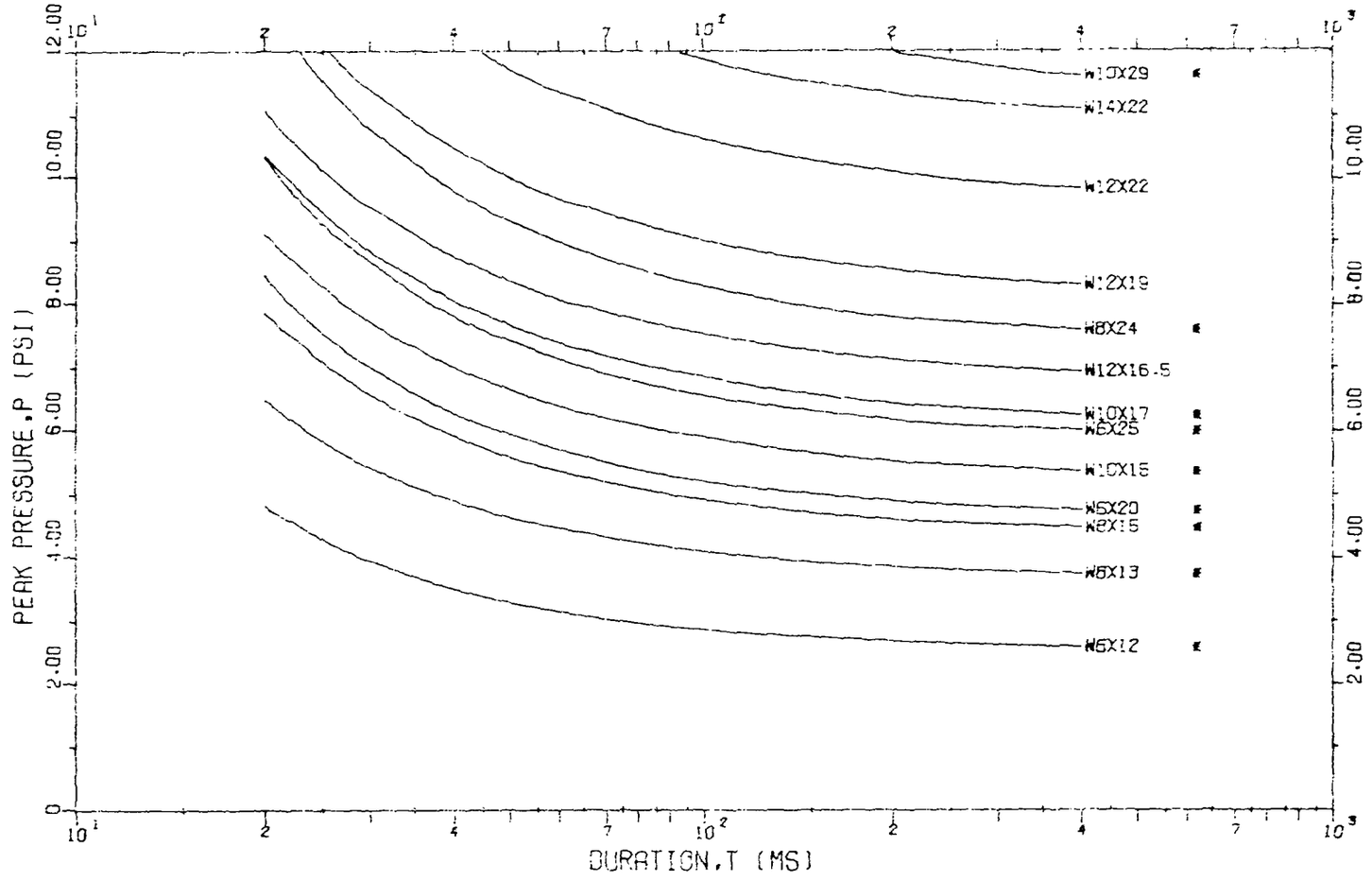


FIGURE 141

NON-REUSABLE BEAM.SPAN= 16 FT.SPACING=4 FT. FIXED ENDS

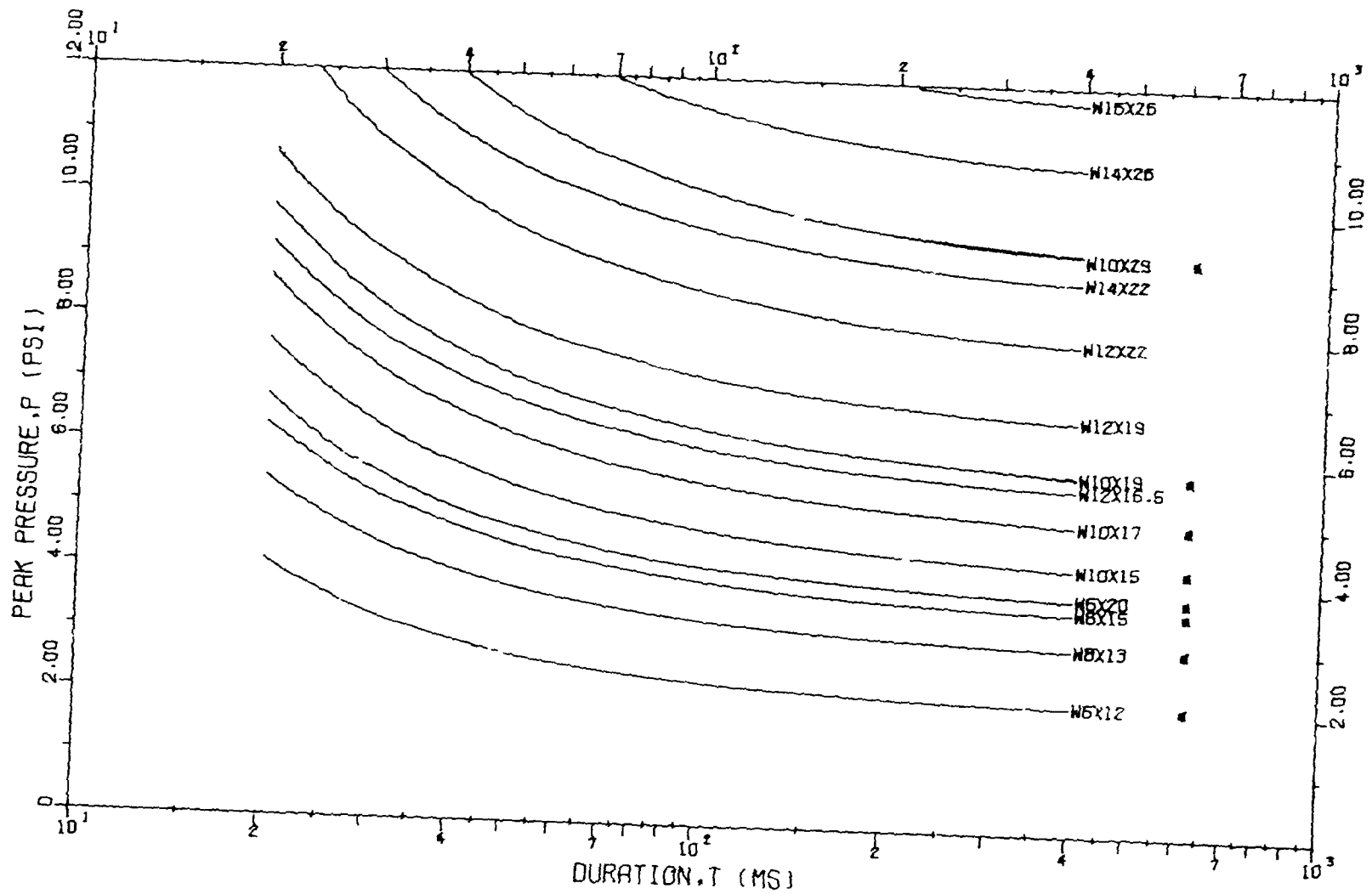


FIGURE 142

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=5 FT. FIXED ENDS

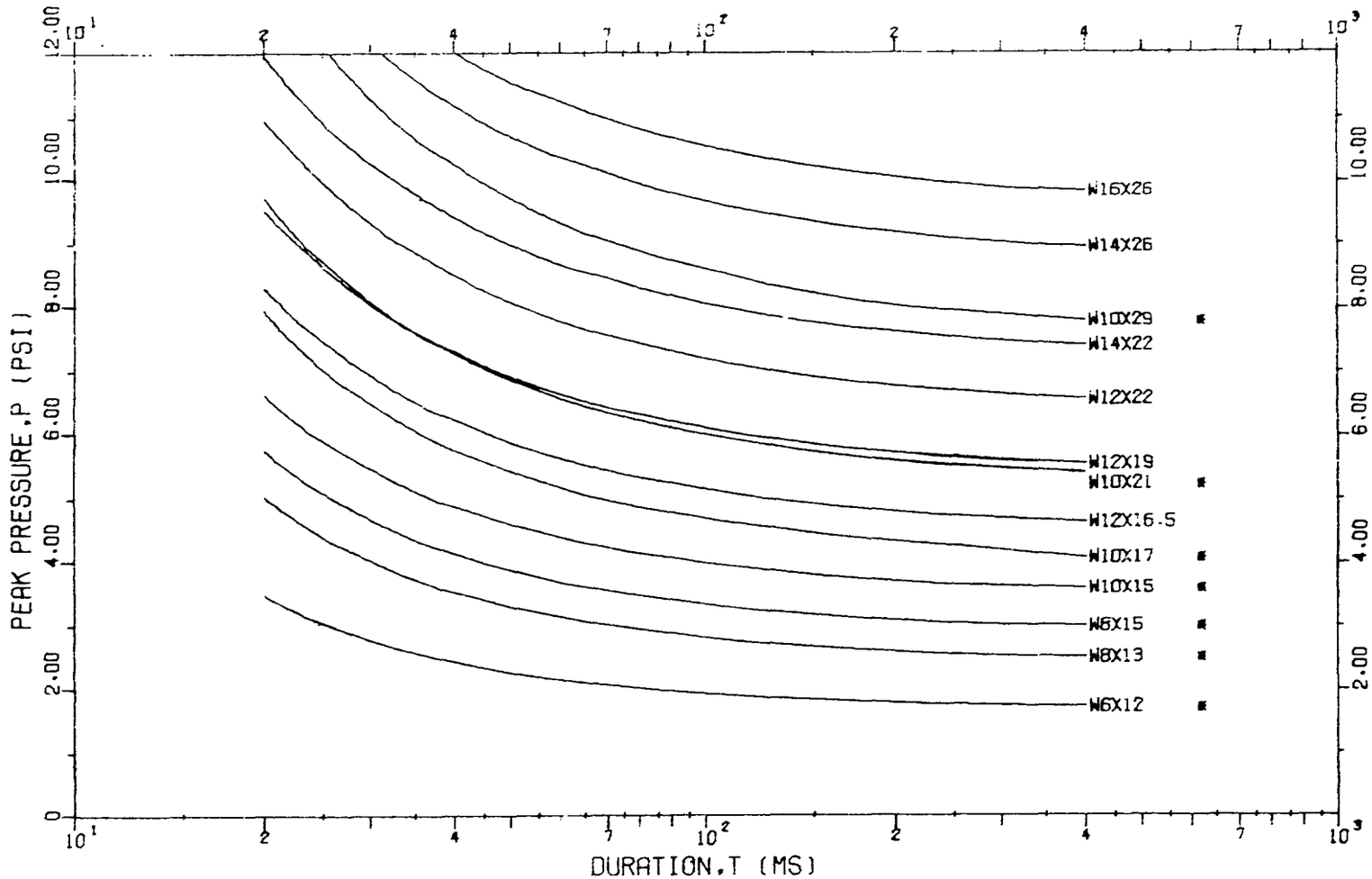


FIGURE 143

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=6 FT, FIXED ENDS

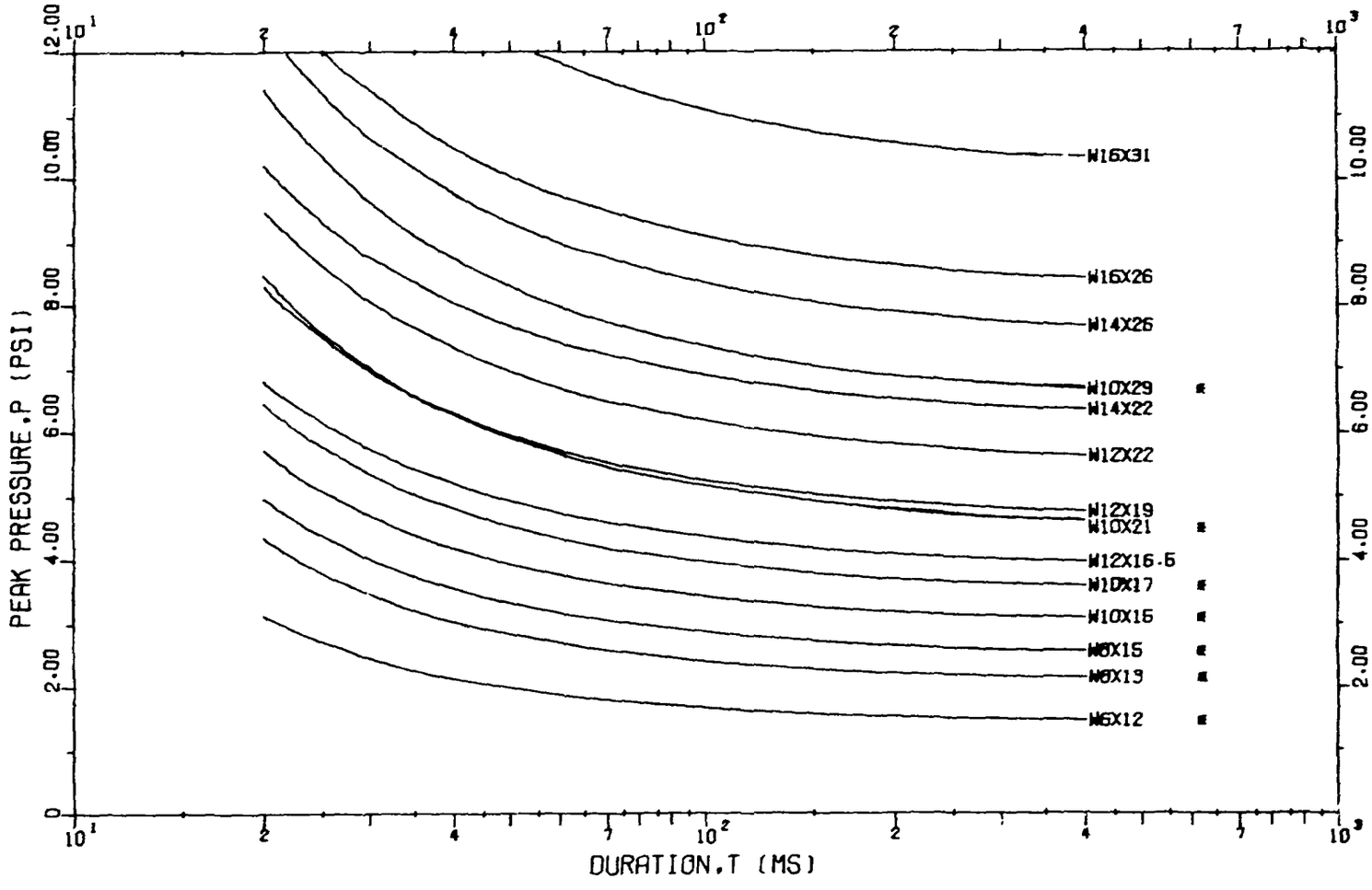


FIGURE 144

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=7 FT, FIXED ENDS

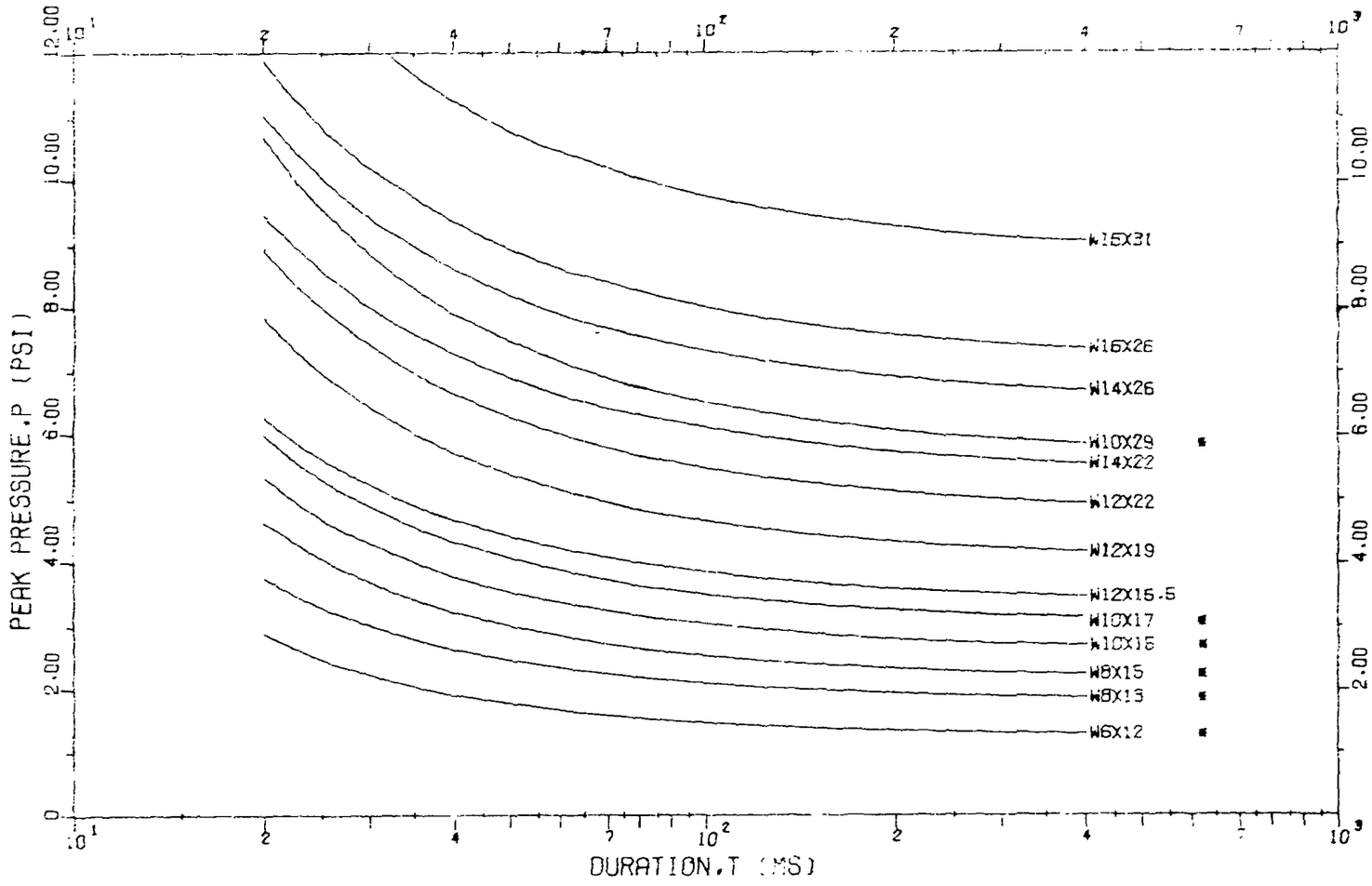


FIGURE 145

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=8 FT. FIXED ENDS

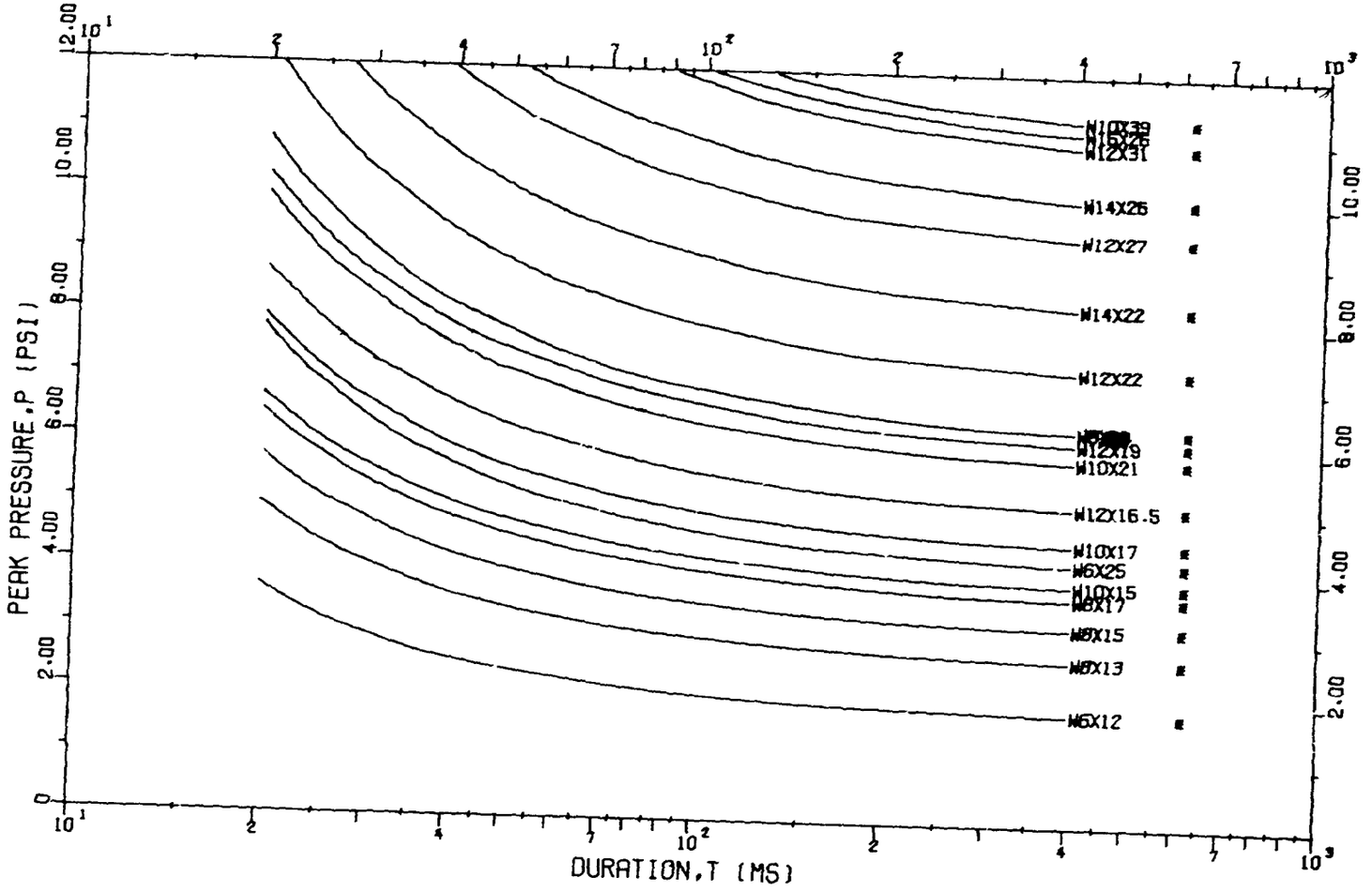


FIGURE 146

NON-REUSABLE BEAM.SPAN= 16 FT.SPACING=4 FT. SIMPLE-FIXED

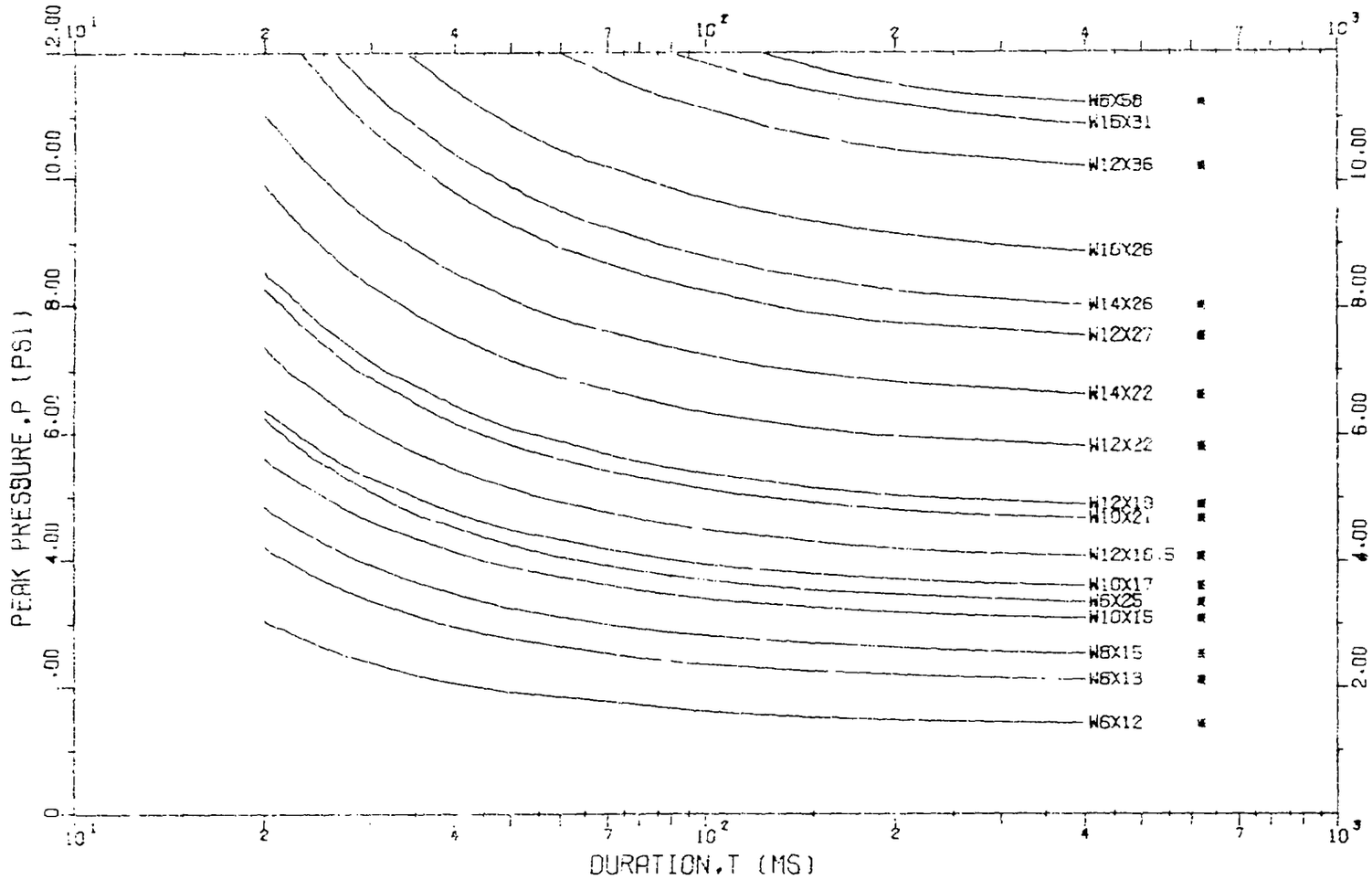


FIGURE 147

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=5 FT. SIMPLE-FIXED

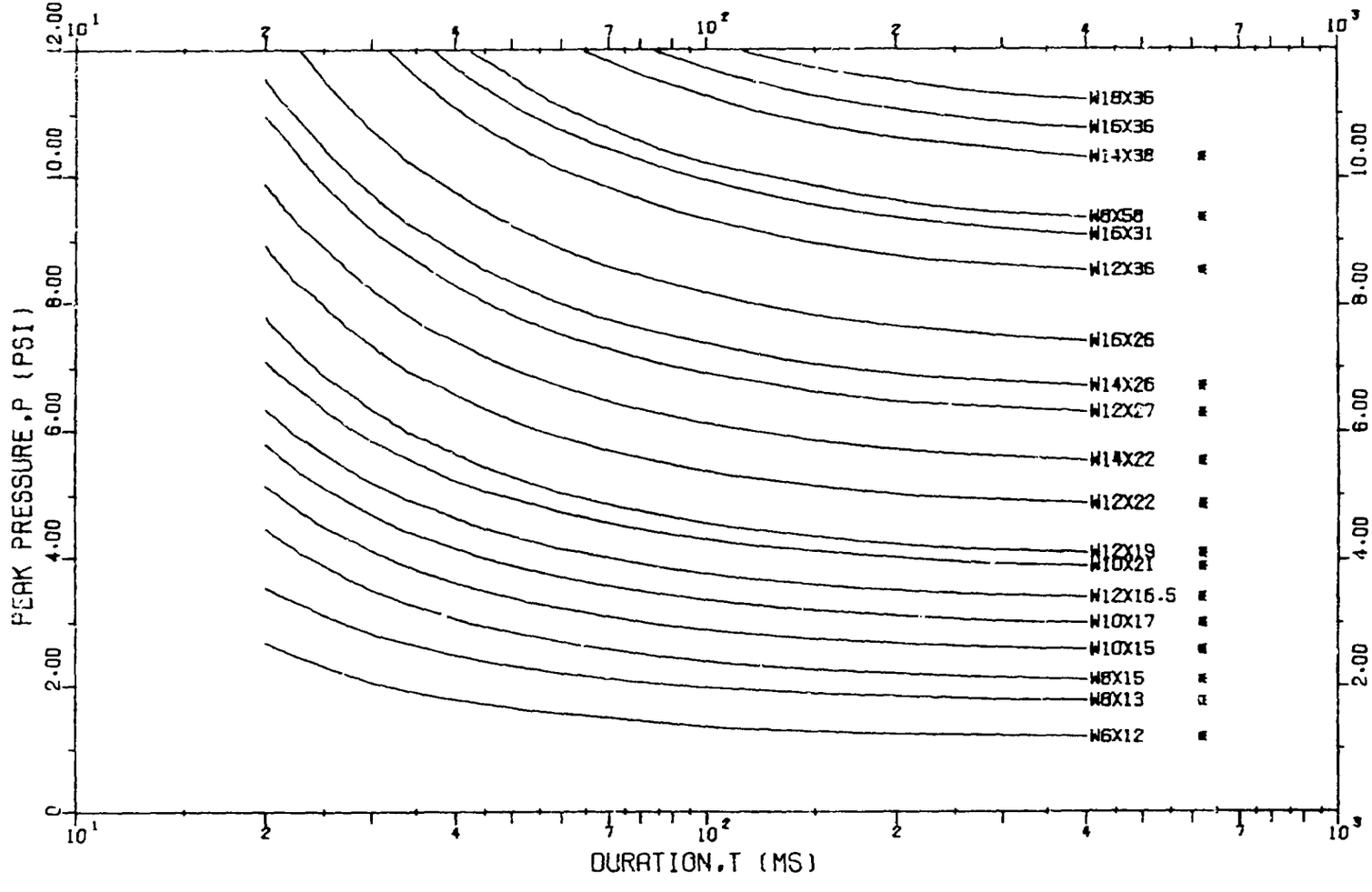


FIGURE 148

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=6 FT, SIMPLE-FIXED

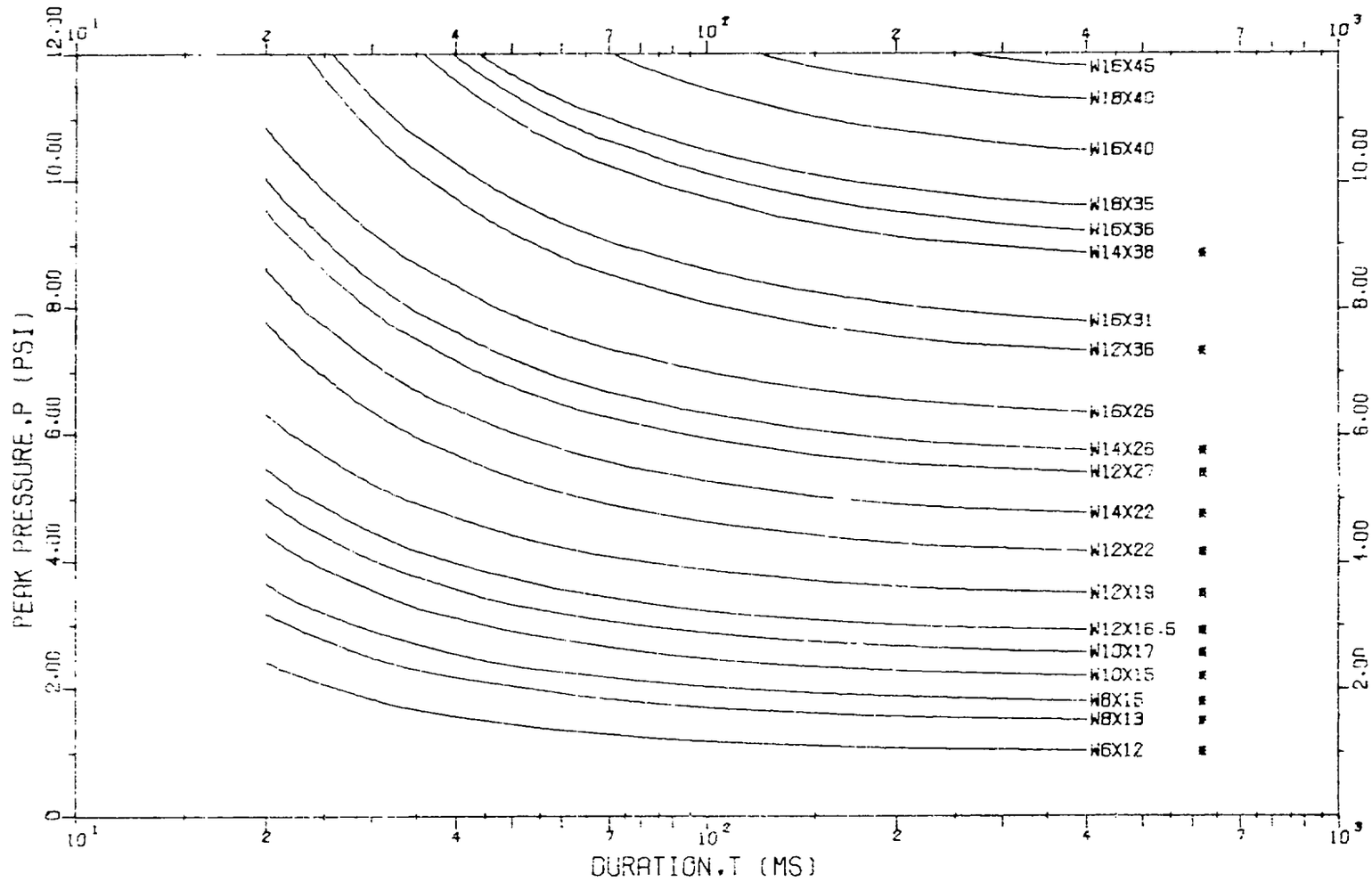


FIGURE 149

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=7 FT, SIMPLE-FIXED

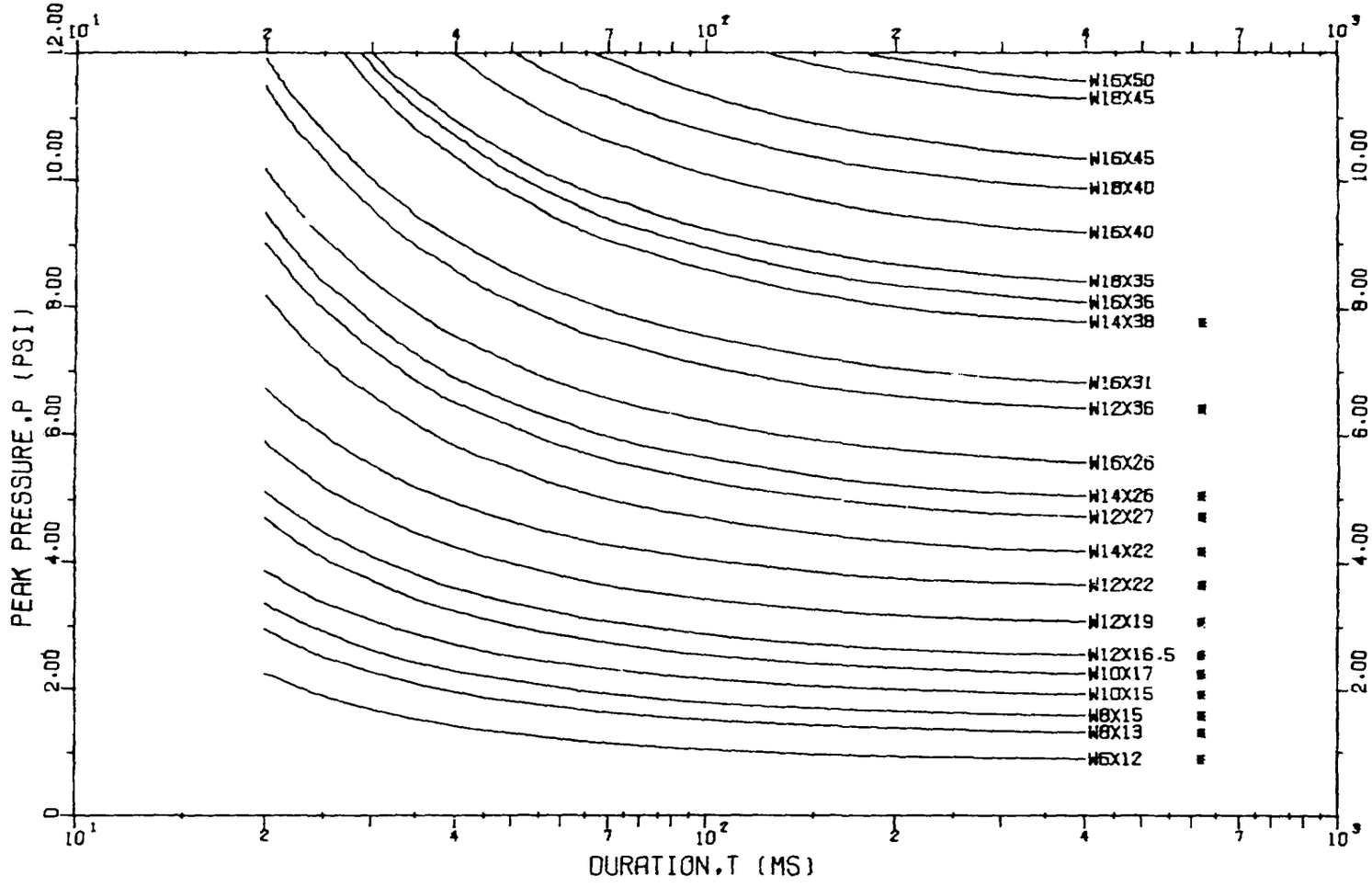


FIGURE 150

NON-REUSABLE BEAM,SPAN= 16 FT,SPACING=8 FT. SIMPLE-FIXED

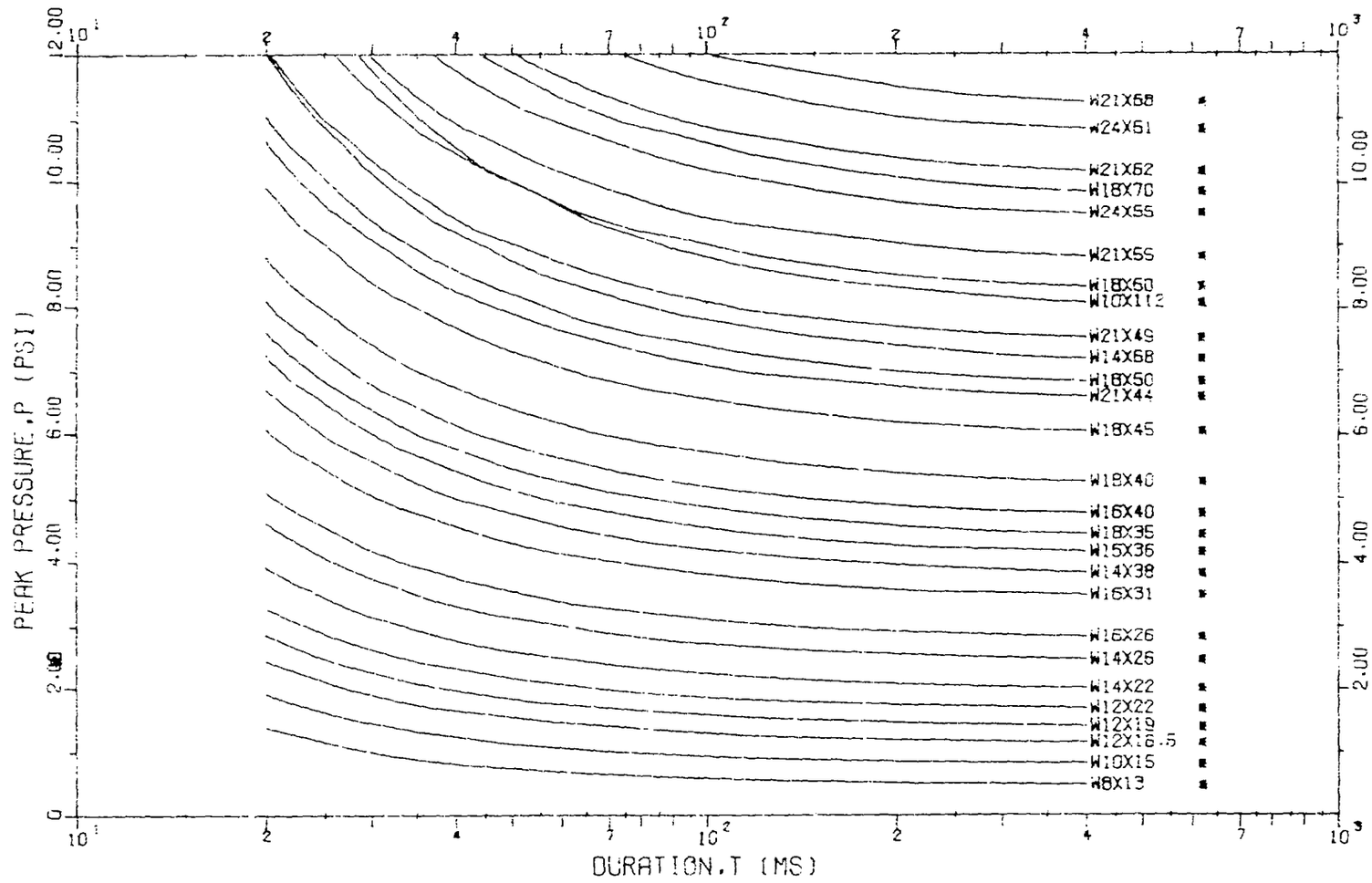


FIGURE 151

REUSABLE BEAM,SPAN=20 FT,SPACING=5 FT. SIMPLY-SUPPORTED

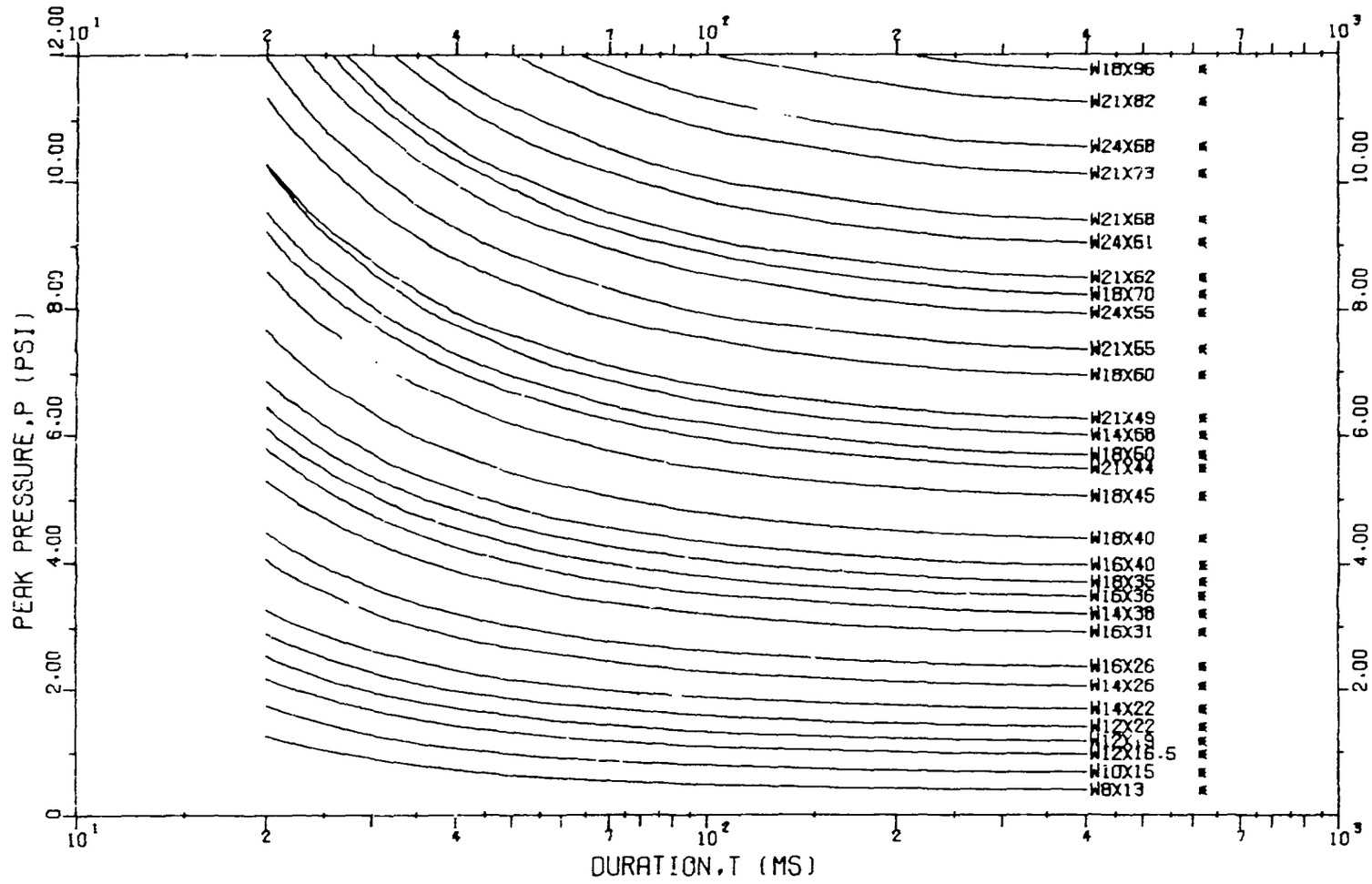


FIGURE '52

REUSABLE BEAM,SPAN=20 FT,SPACING=6 FT, SIMPLY-SUPPORTED

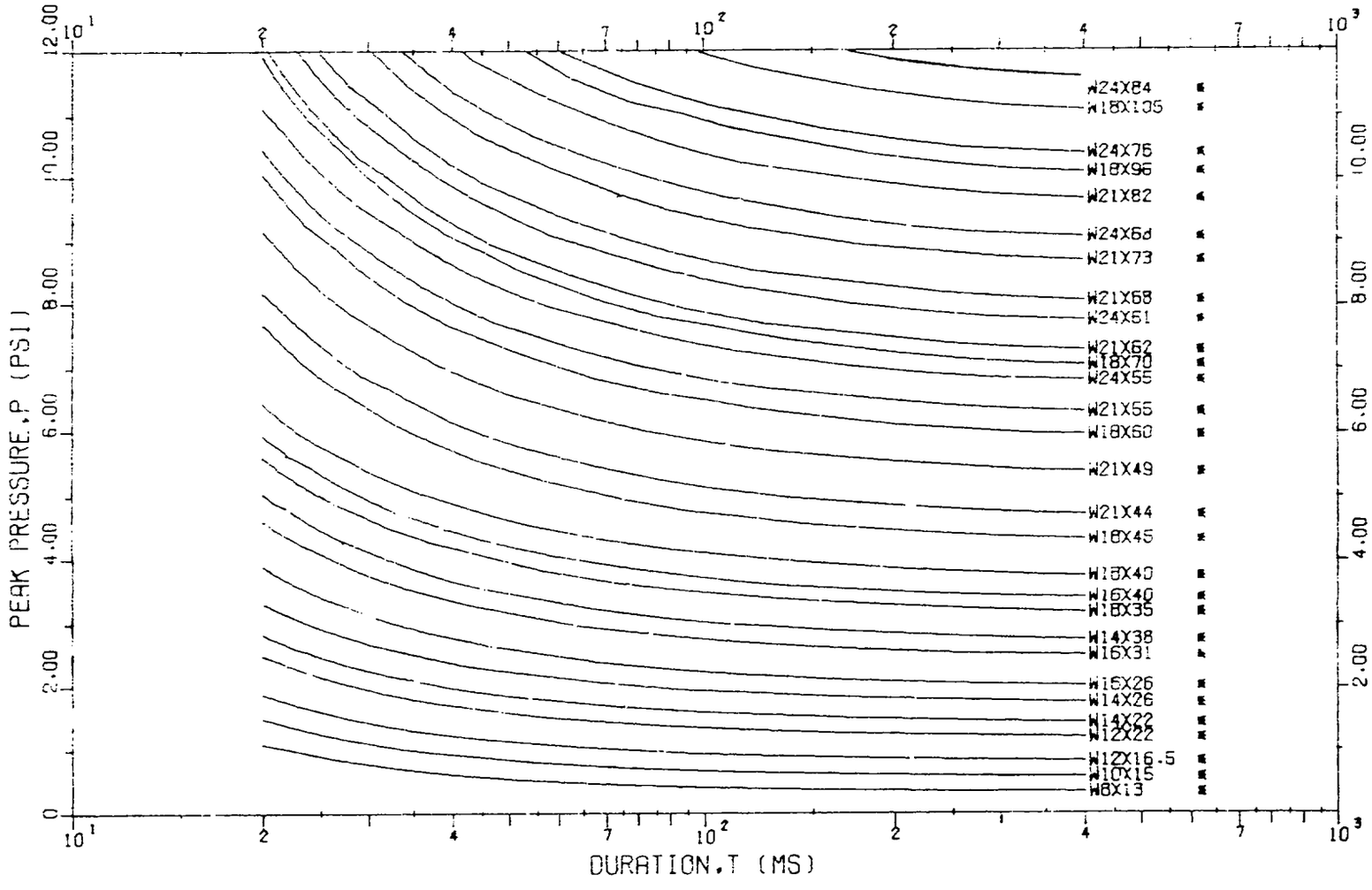


FIGURE 153

REUSABLE BEAM,SPAN=20 FT,SPACING=7 FT, SIMPLY-SUPPORTED

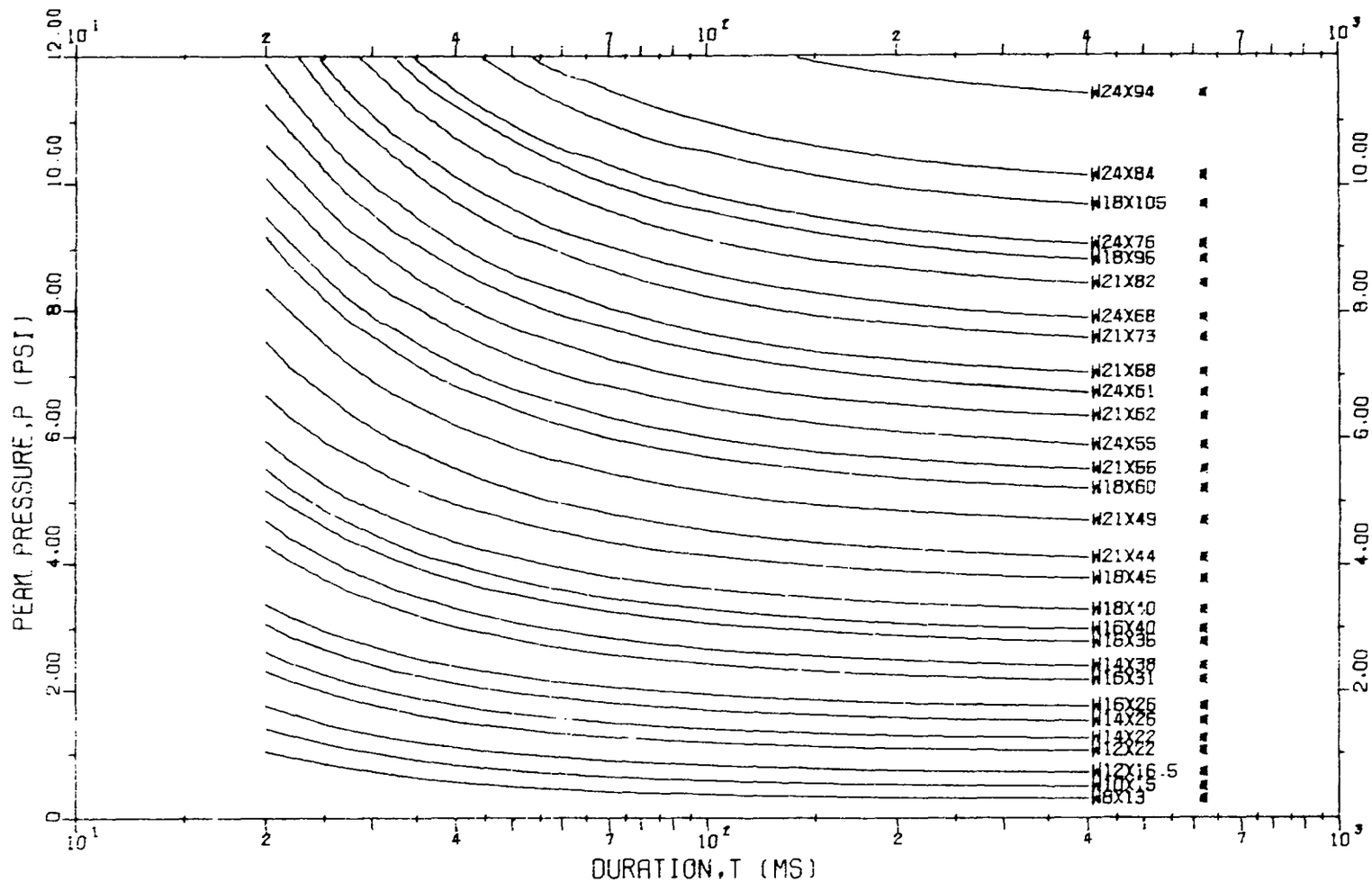


FIGURE 154

REUSABLE BEAM,SPAN=20 FT,SPACING=8 FT, SIMPLY-SUPPORTED

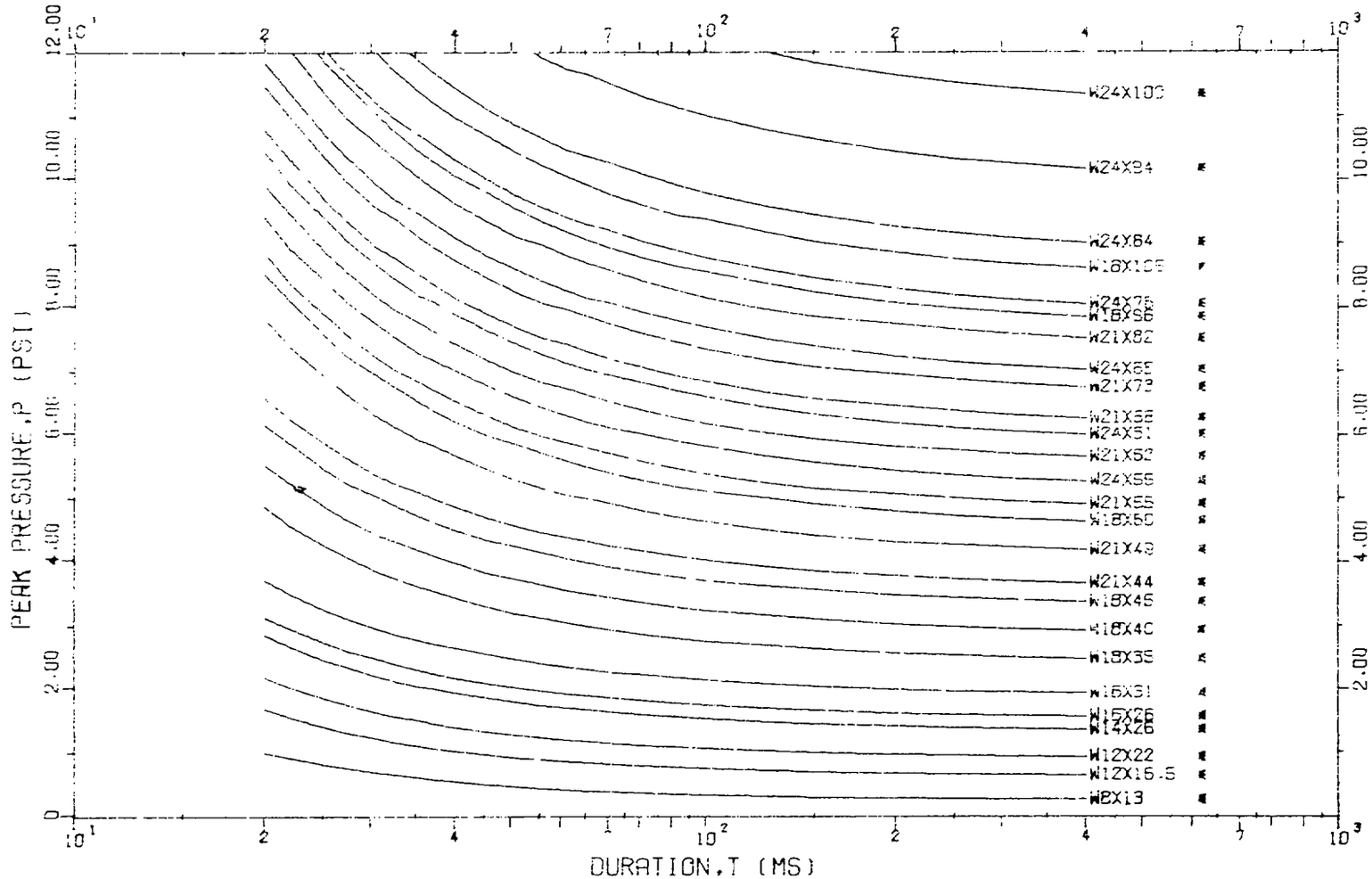


FIGURE 155

REUSABLE BEAM.SPAN= 20 FT.SPACING= 9 FT. SIMPLY-SUPPORTED

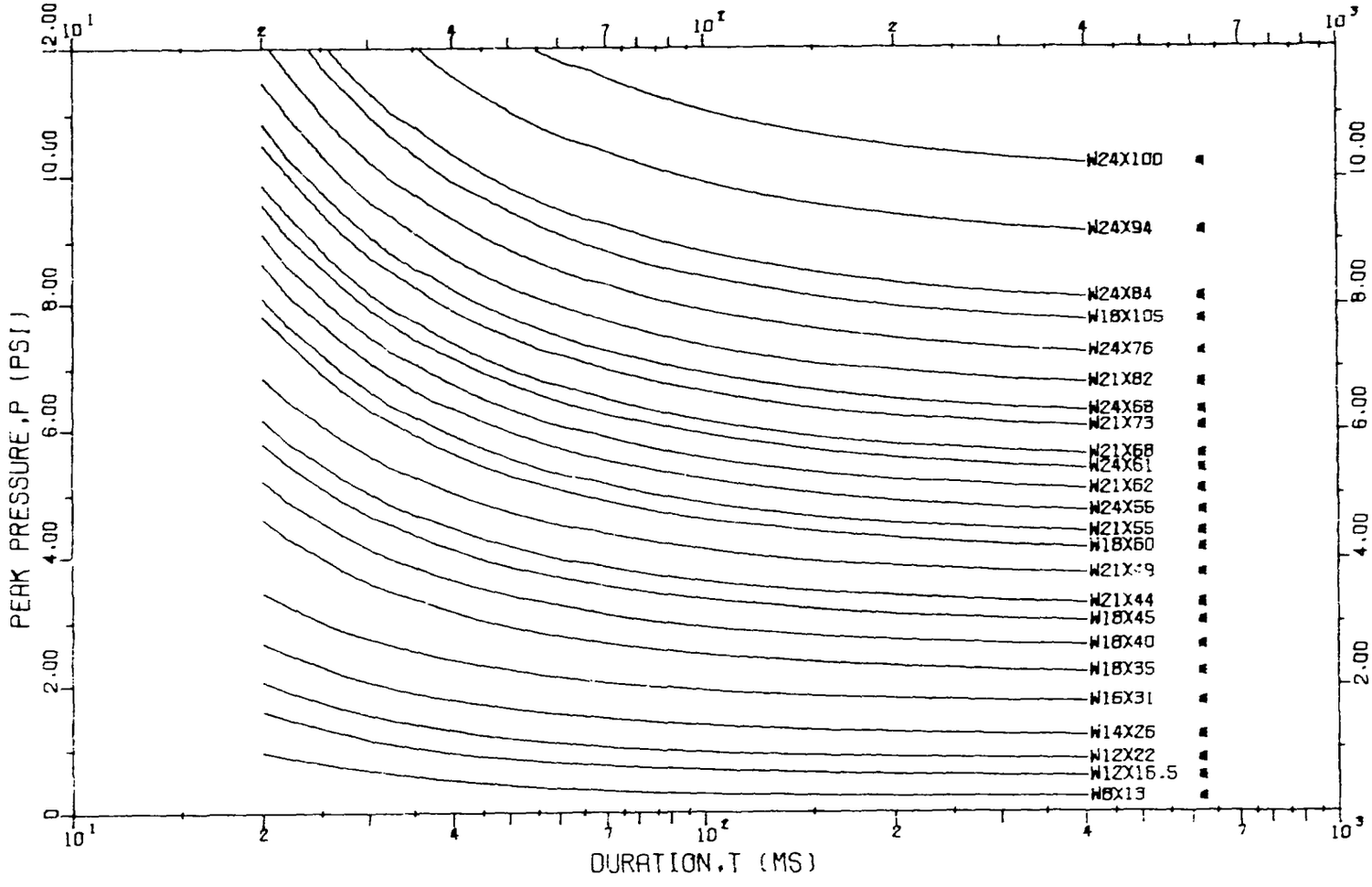


FIGURE 156

REUSABLE BEAM.SPAN=20 FT.SPACING=10FT. SIMPLY-SUPPORTED

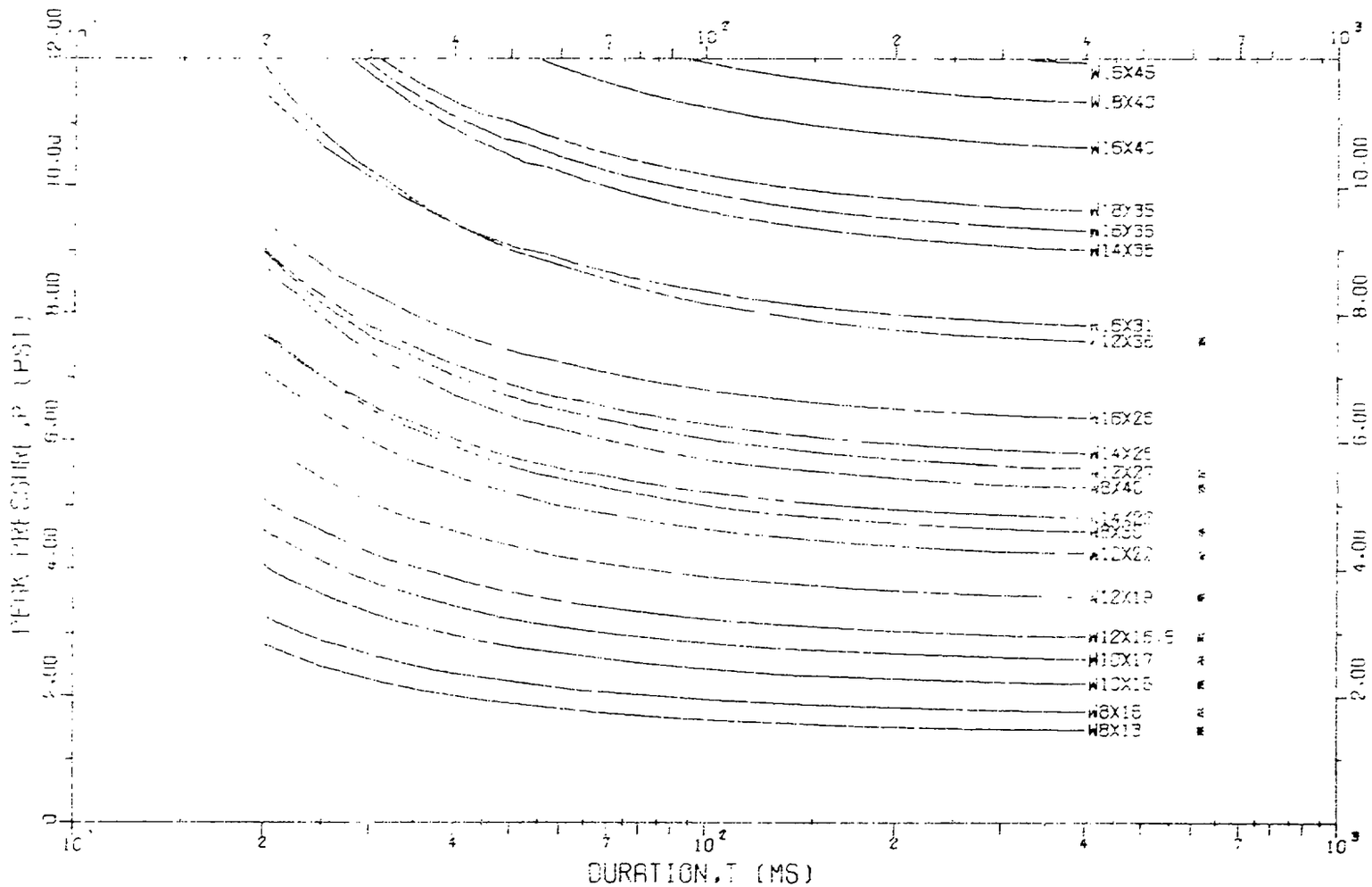


FIGURE 157

REUSABLE BEAM,SPAN=20 FT,SPACING=5 FT, FIXED ENDS

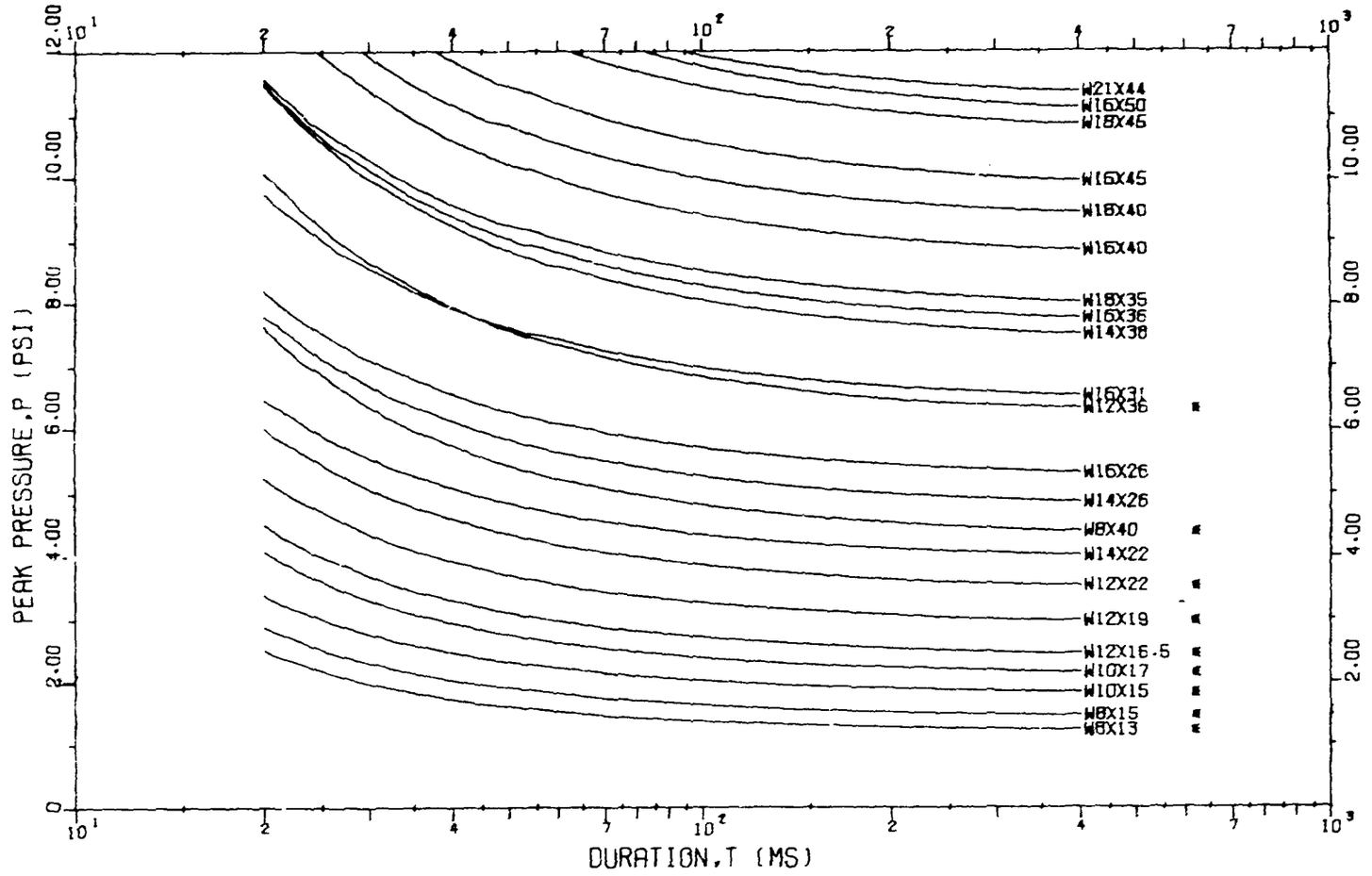


FIGURE 158

REUSABLE BEAM,SPAN=20 FT,SPACING=6 FT, FIXED ENDS

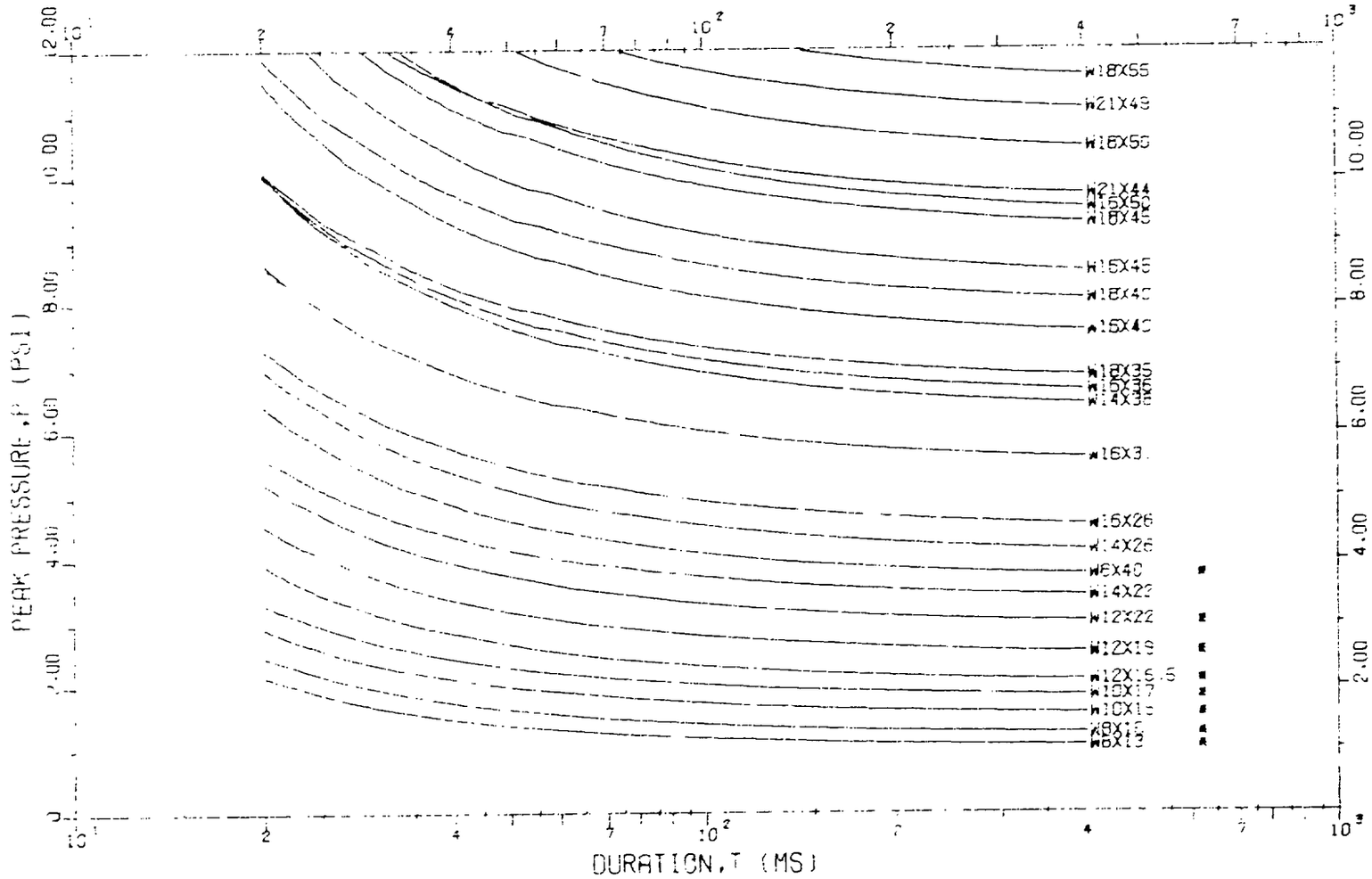


FIGURE 15.9

REUSABLE BEAM.SPAN= 20 FT.SPACING= 7 FT. FIXED ENDS

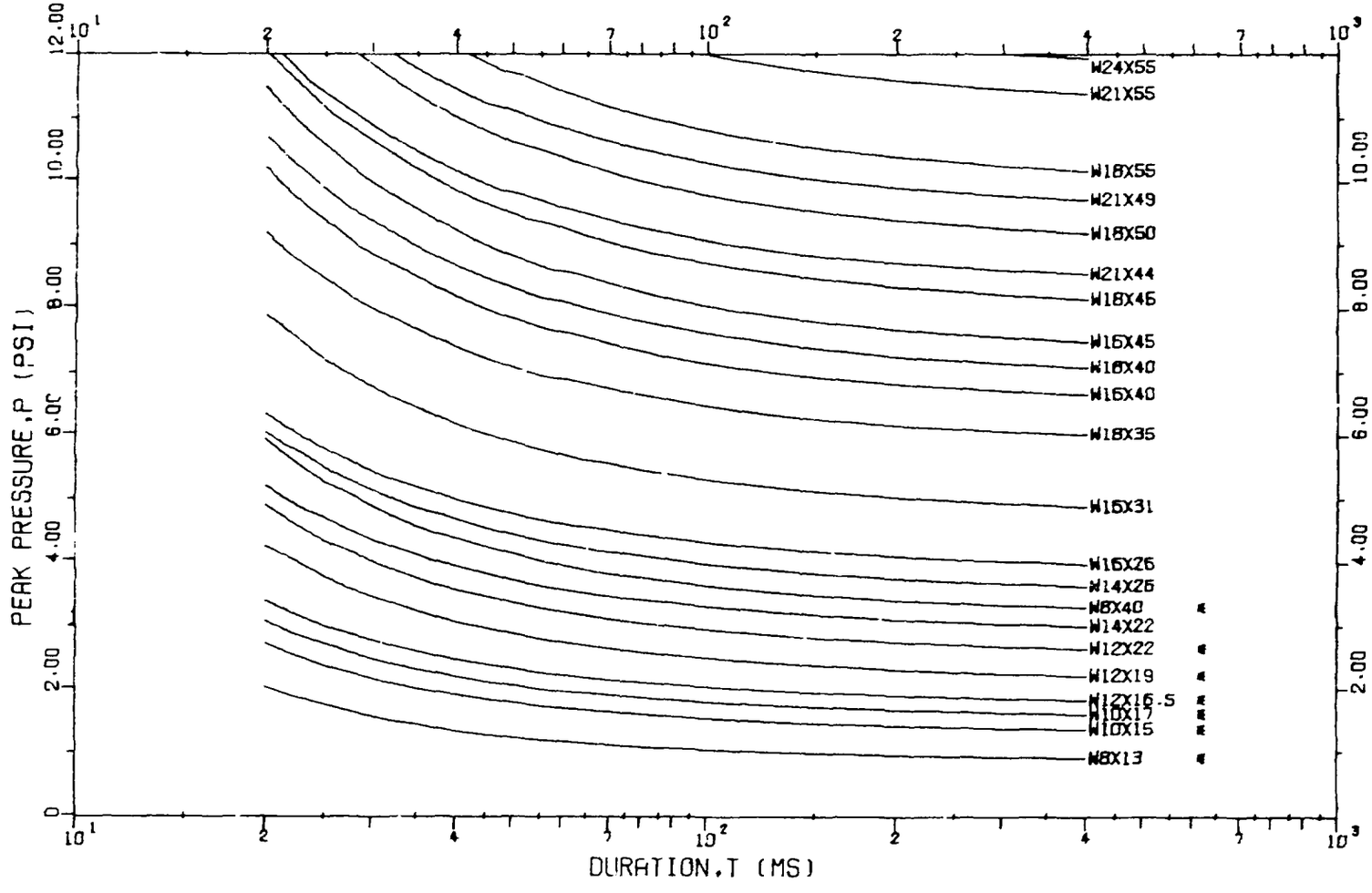


FIGURE 160

REUSABLE BEAM.SPAN=20 FT.SPACING=8 FT. FIXED ENDS

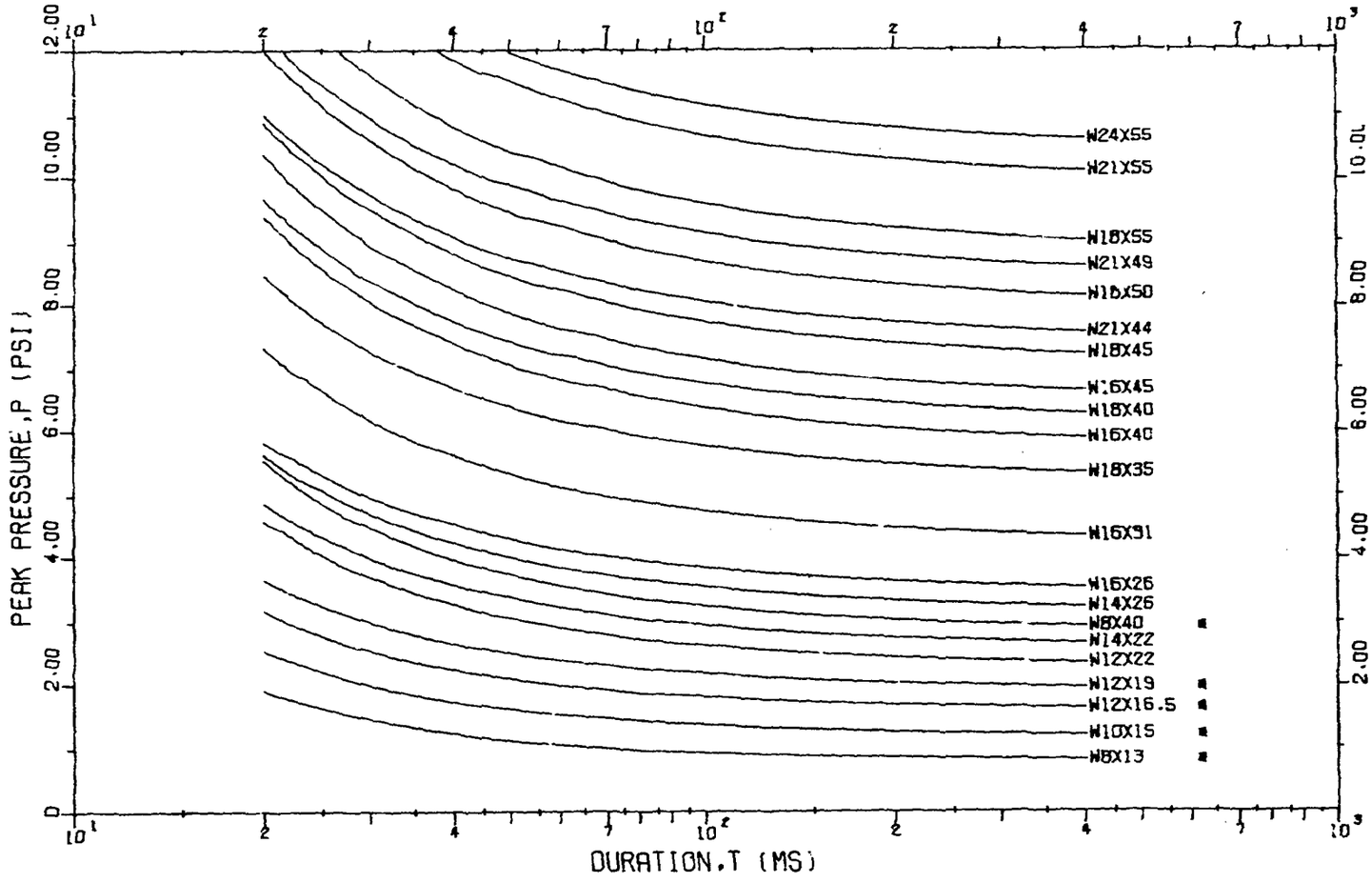


FIGURE 161

REUSABLE BEAM,SPAN=20 FT,SPACING=9 FT, FIXED ENDS

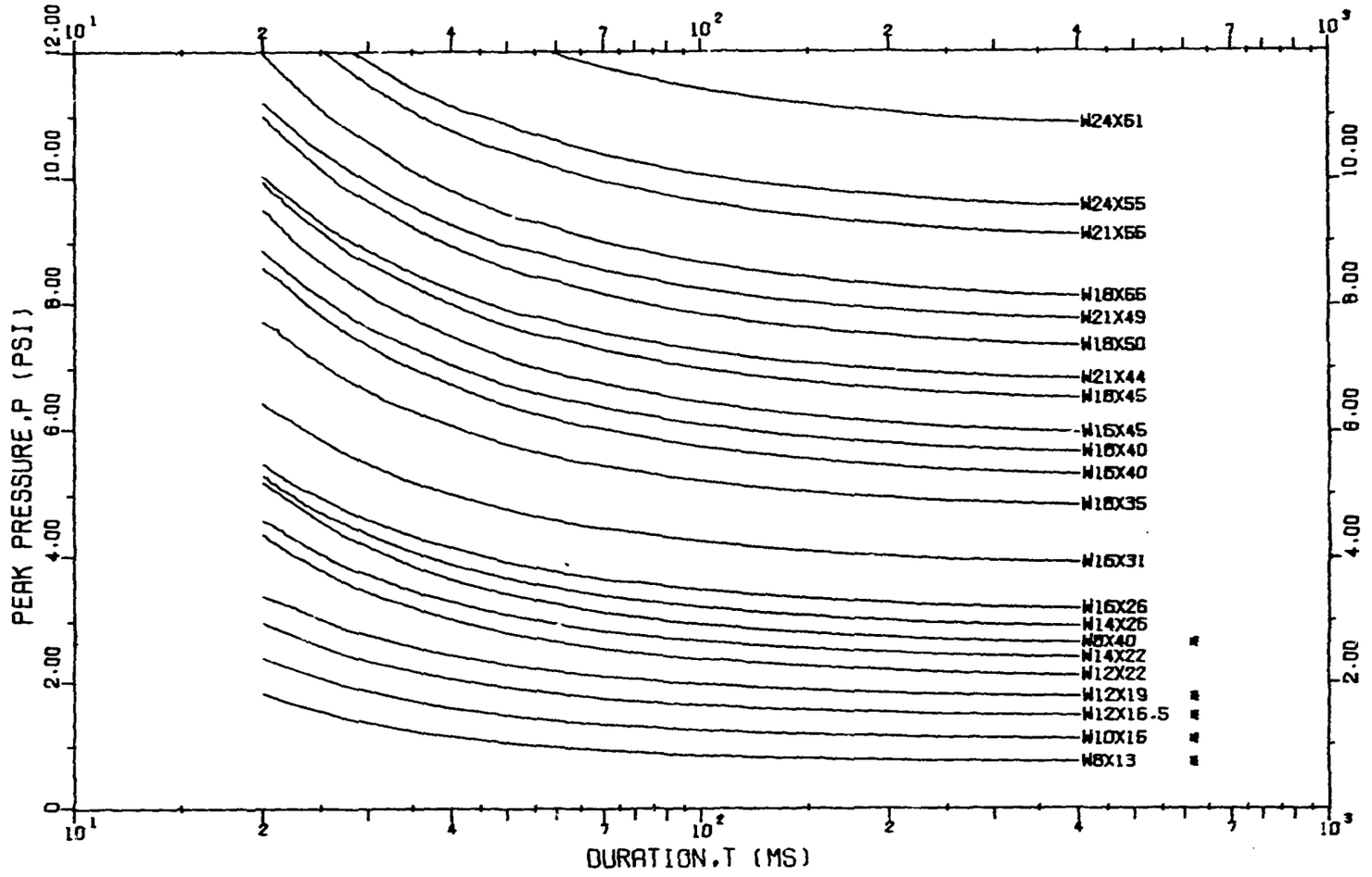


FIGURE 162

REUSABLE BEAM.SPAN=20 FT.SPACING=10FT. FIXED ENDS

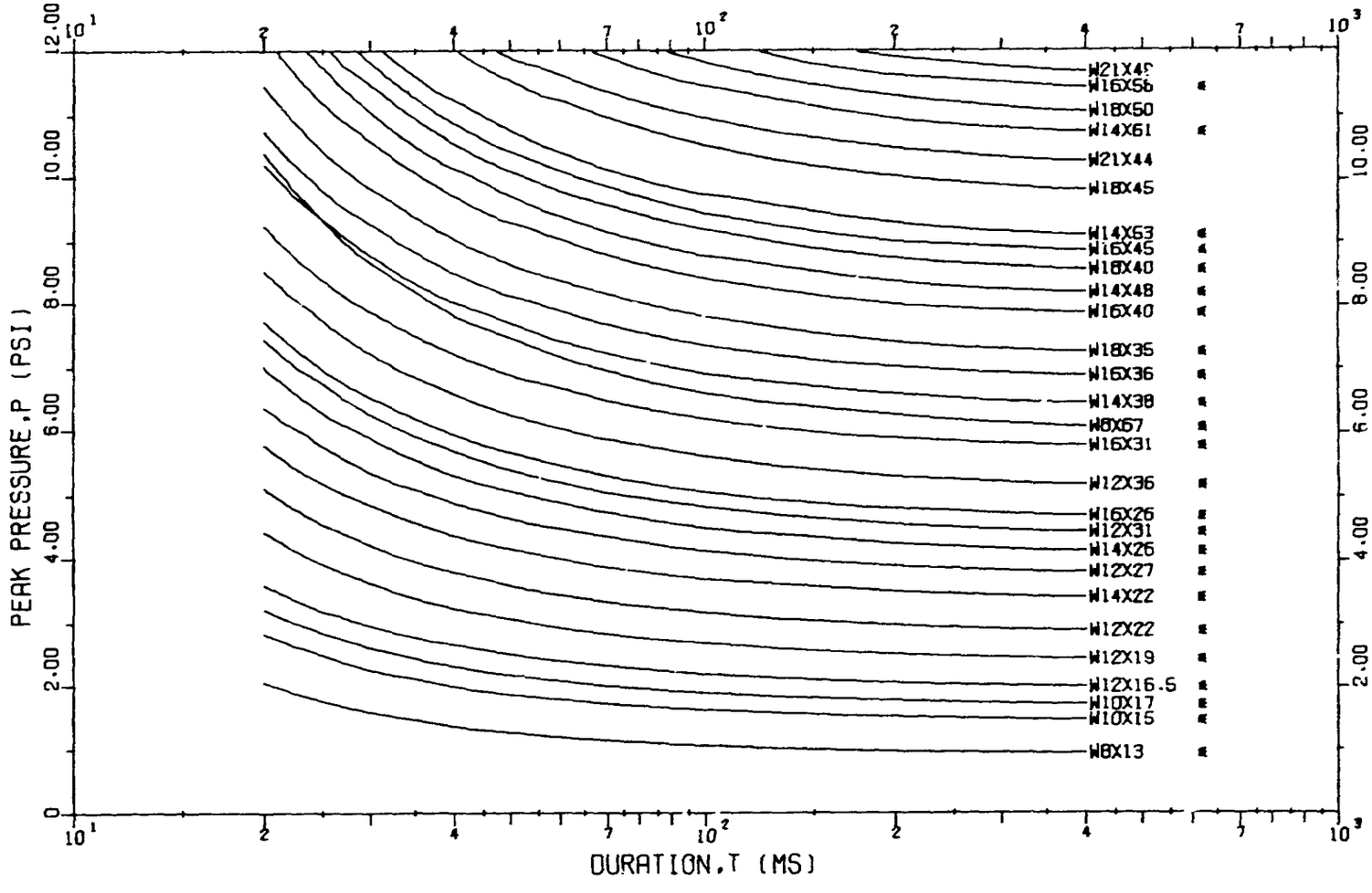


FIGURE 163

REUSABLE BEAM,SPAN= 20 FT,SPACING= 5 FT, SIMPLE-FIXED

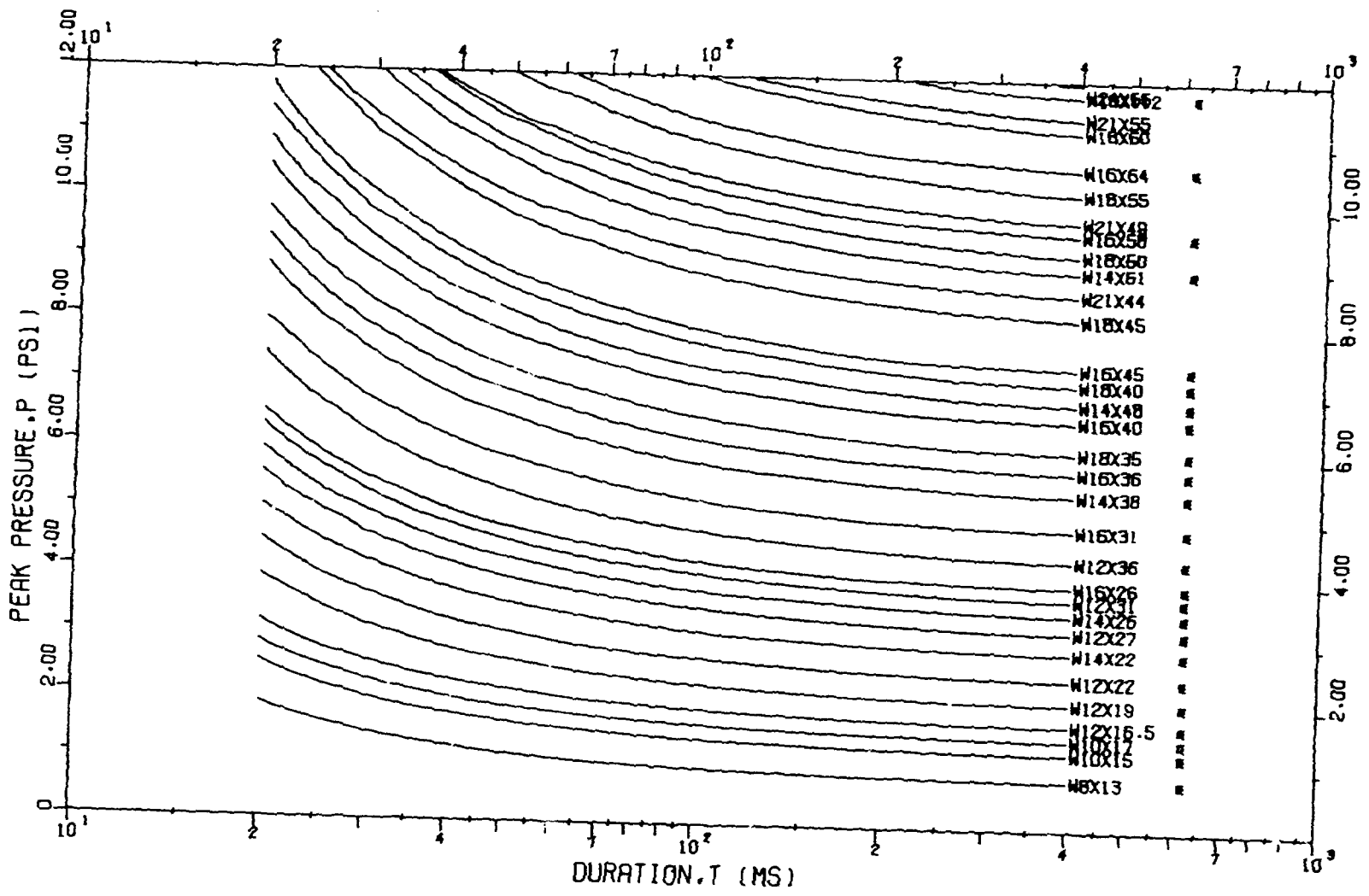


FIGURE 164

REUSABLE BEAM,SPAN=20 FT,SPACING=6 FT, SIMPLE-FIXED

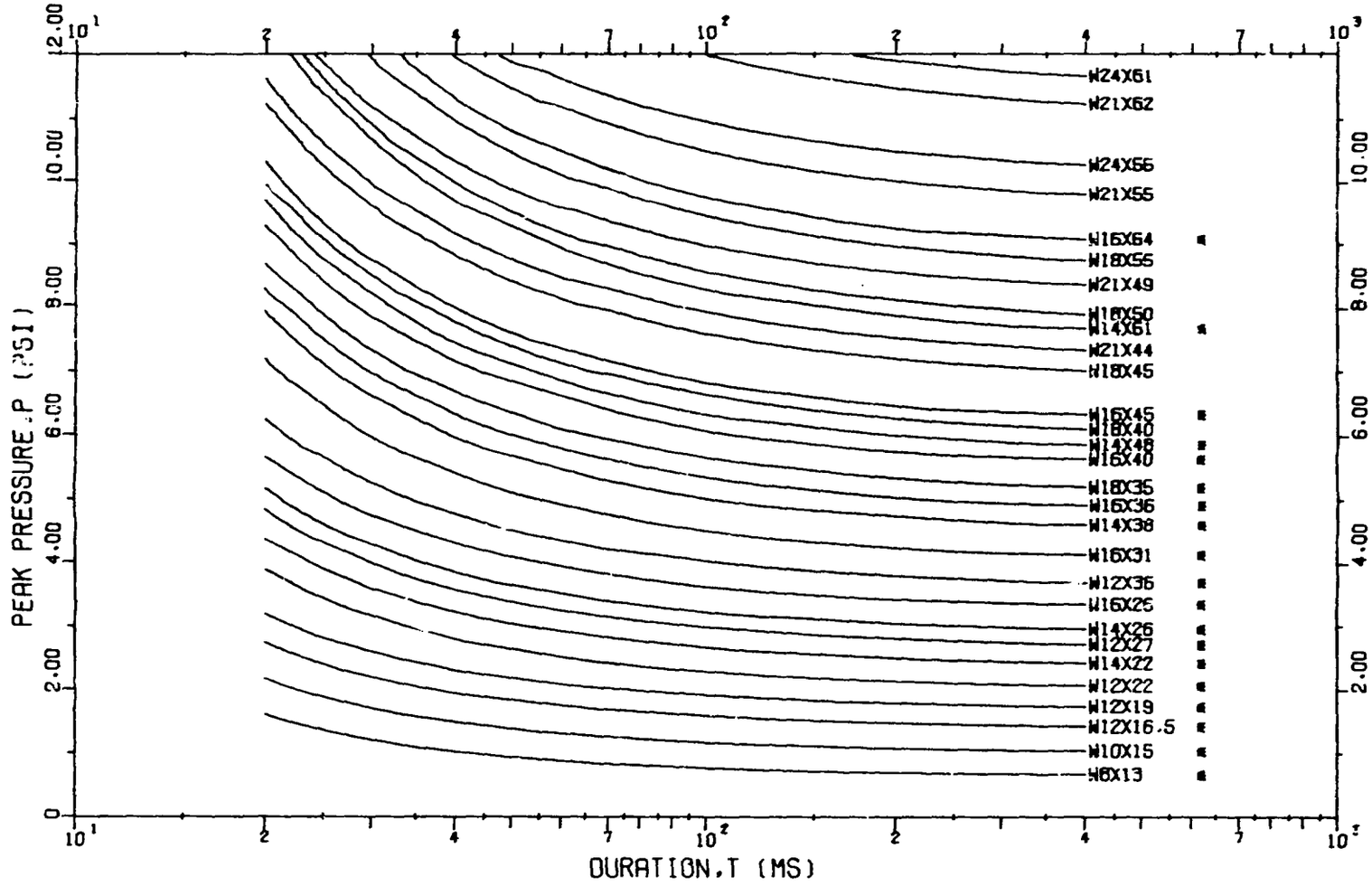


FIGURE 165

REUSABLE BEAM,SPAN=20 FT,SPACING=7 FT, SIMPLE-FIXED

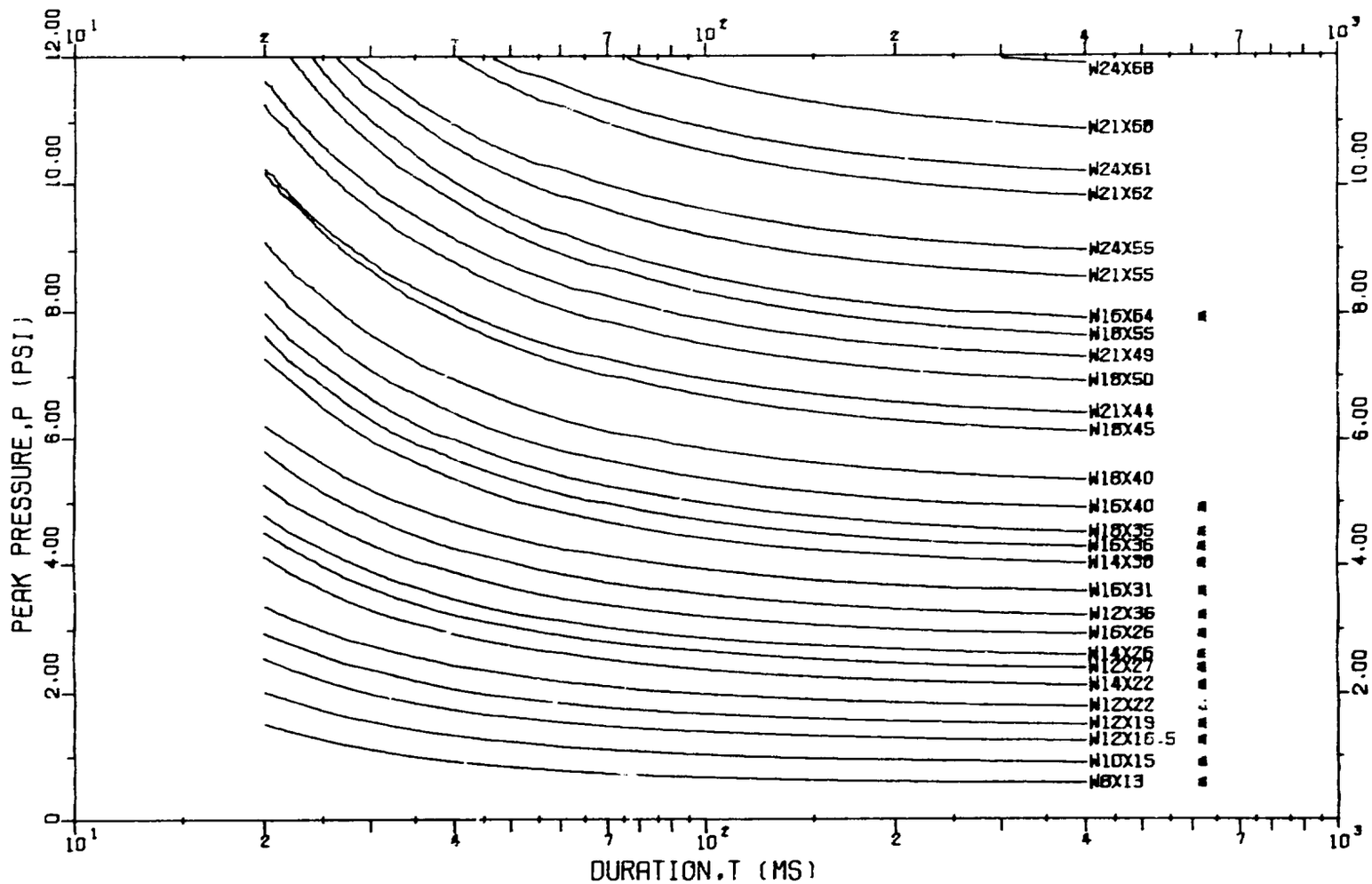


FIGURE 166

REUSABLE BEAM.SPAN=20 FT.SPACING=8 FT. SIMPLE-FIXED

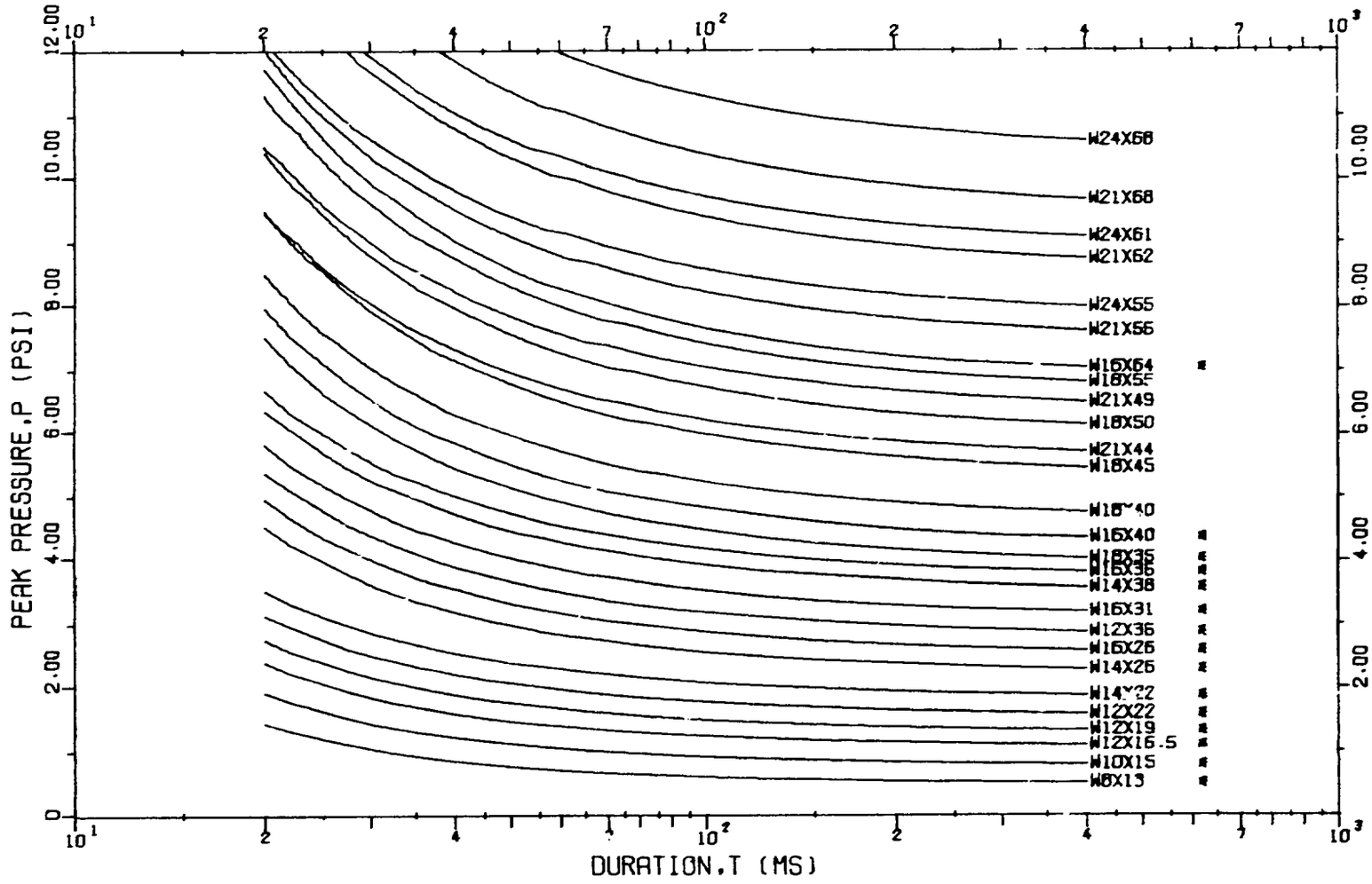


FIGURE 167

REUSABLE BEAM.SPAN= 20 FT.SPACING= 9 FT. SIMPLE-FIXED

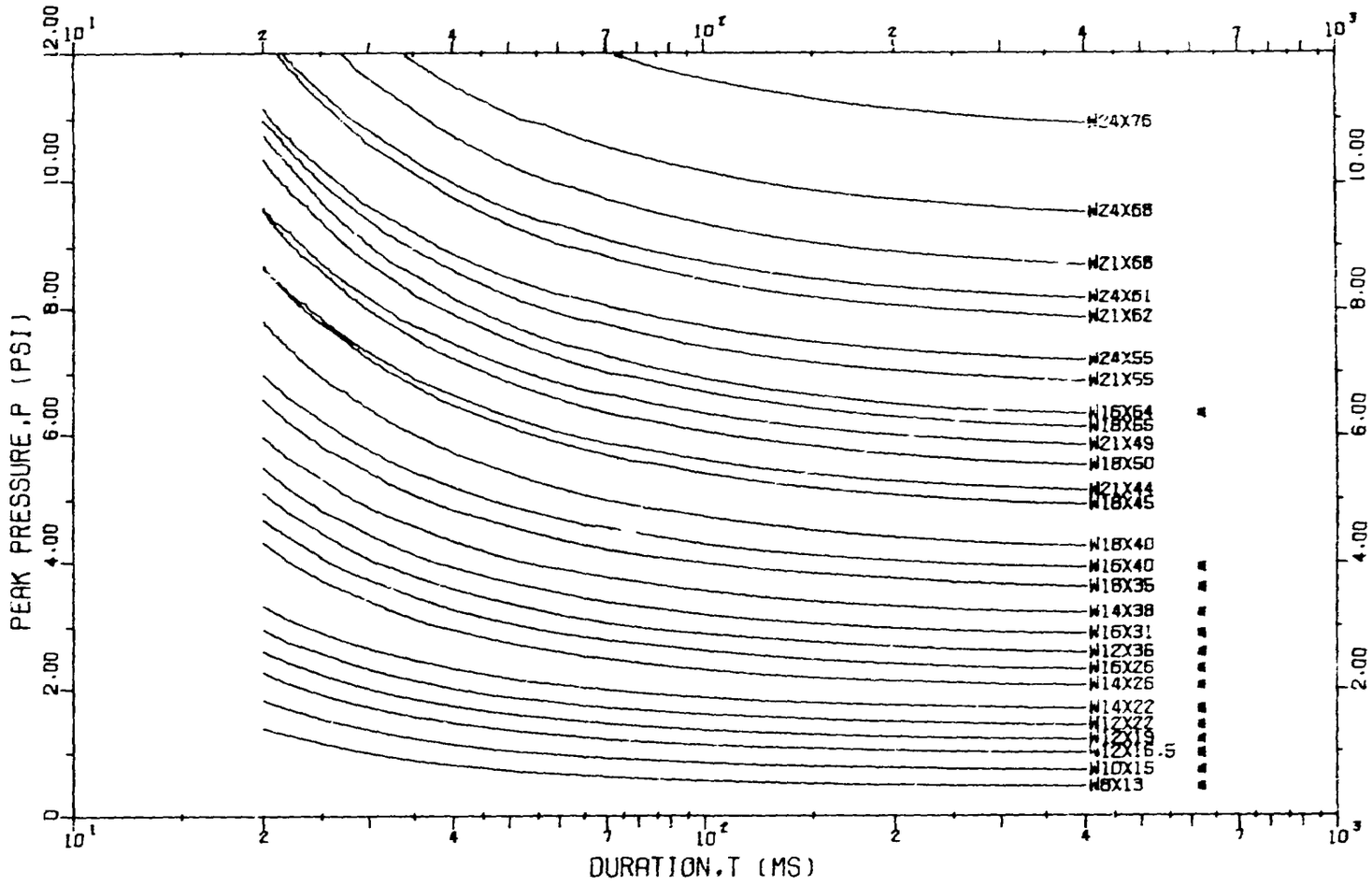


FIGURE 165

REUSABLE BEAM,SPAN=20 FT,SPACING=10FT, SIMPLE-FIXED

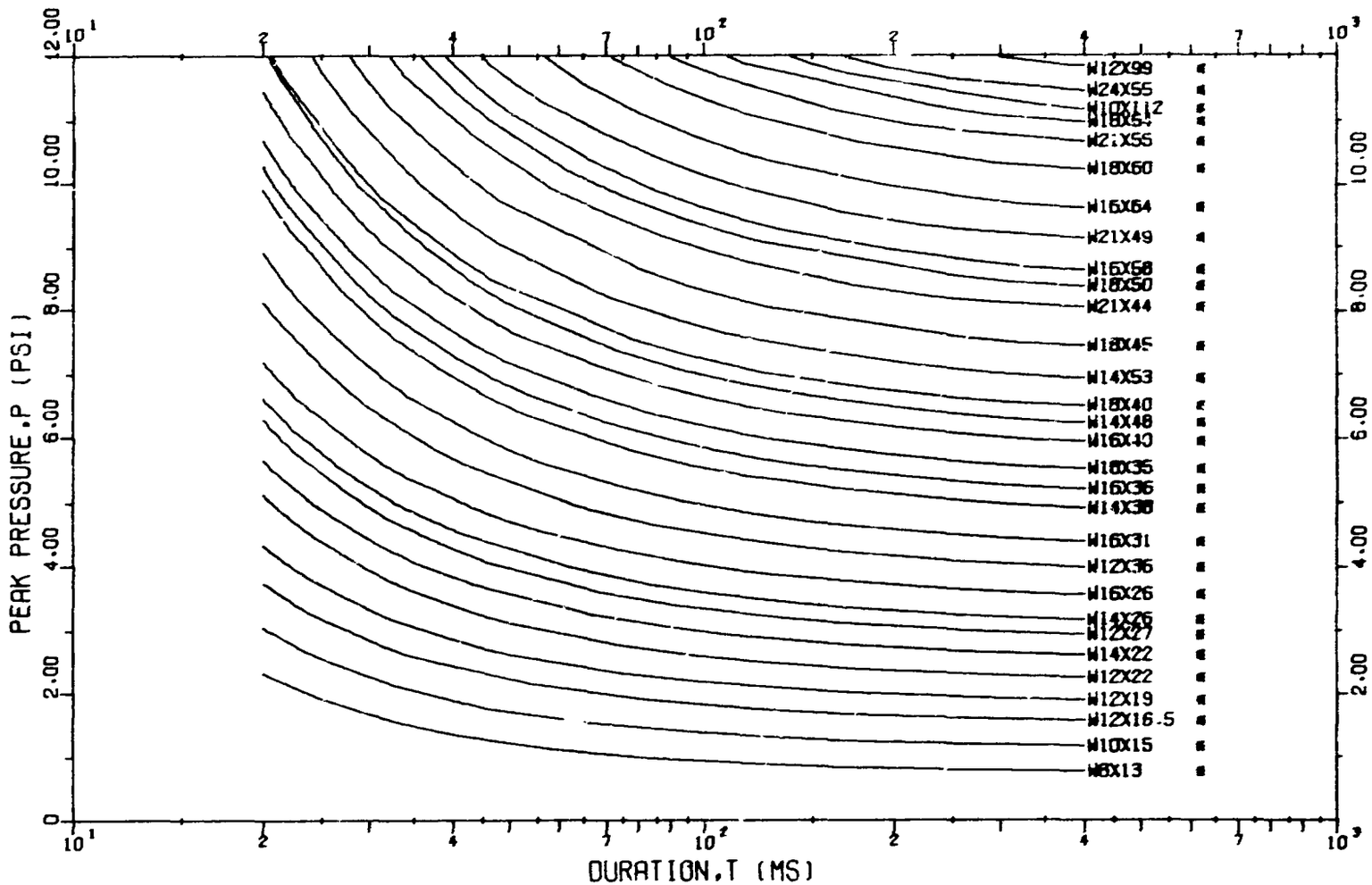


FIGURE 169

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=5 FT, SIMPLY-SUPPORTED

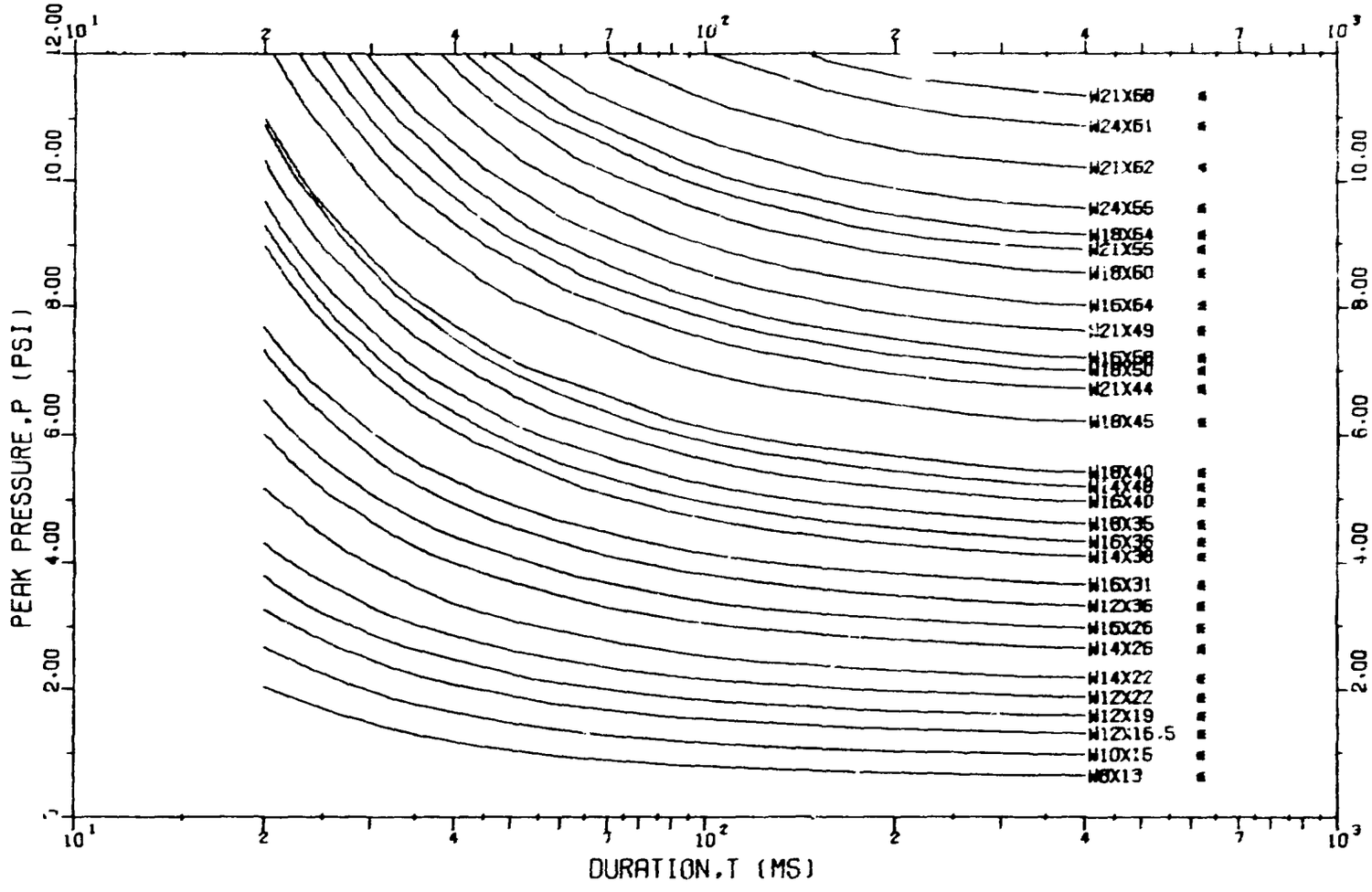


FIGURE 170

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=6 FT, SIMPLY-SUPPORTED

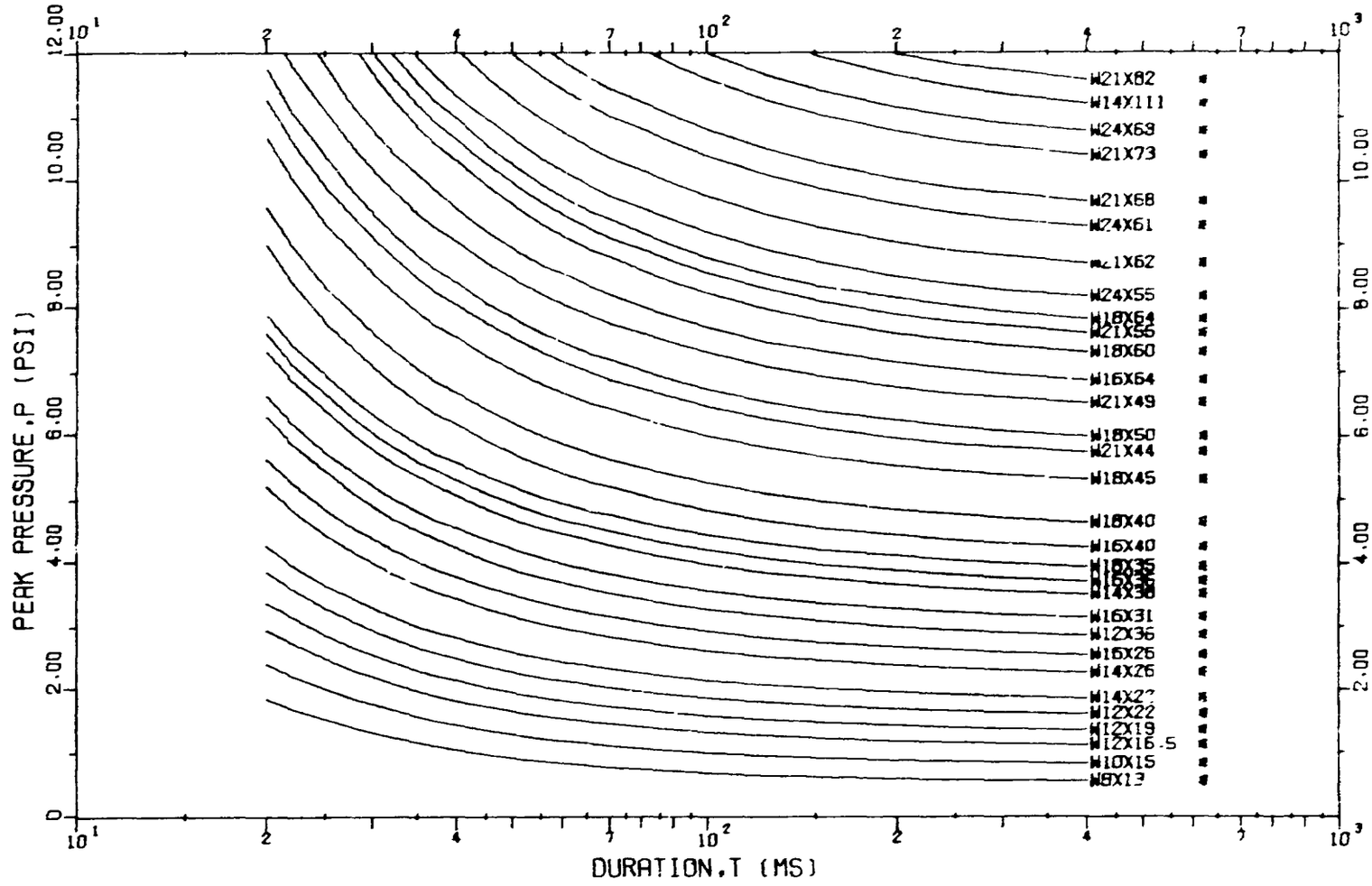


FIGURE 171

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING= 7 FT, SIMPLY-SUPPORTED

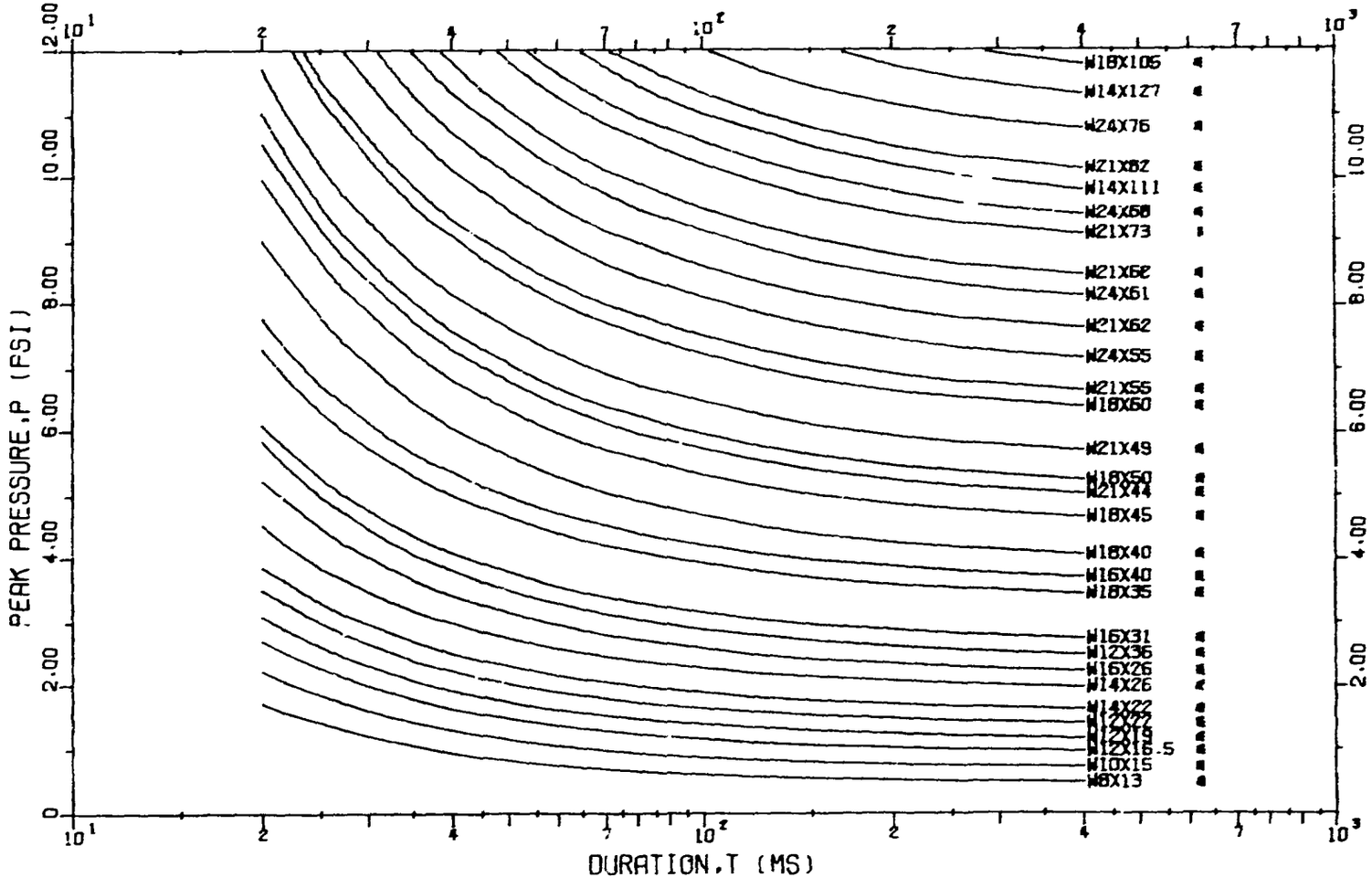


FIGURE 172

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=8 FT, SIMPLY-SUPPORTED

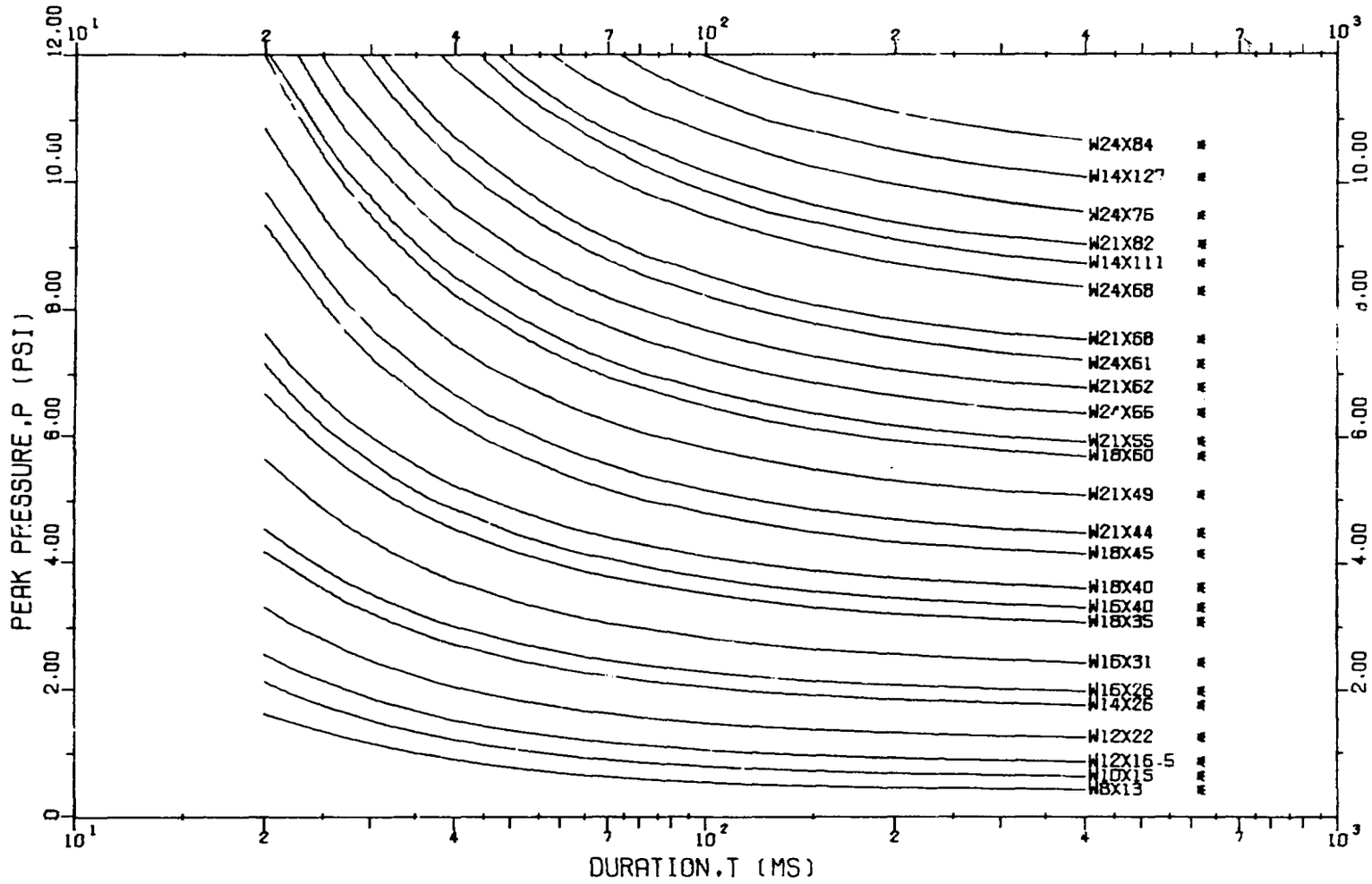


FIGURE 173

NON-REUSABLE BEAM.SPAN= 20 FT.SPACING= 9 FT. SIMPLY-SUPPORTED

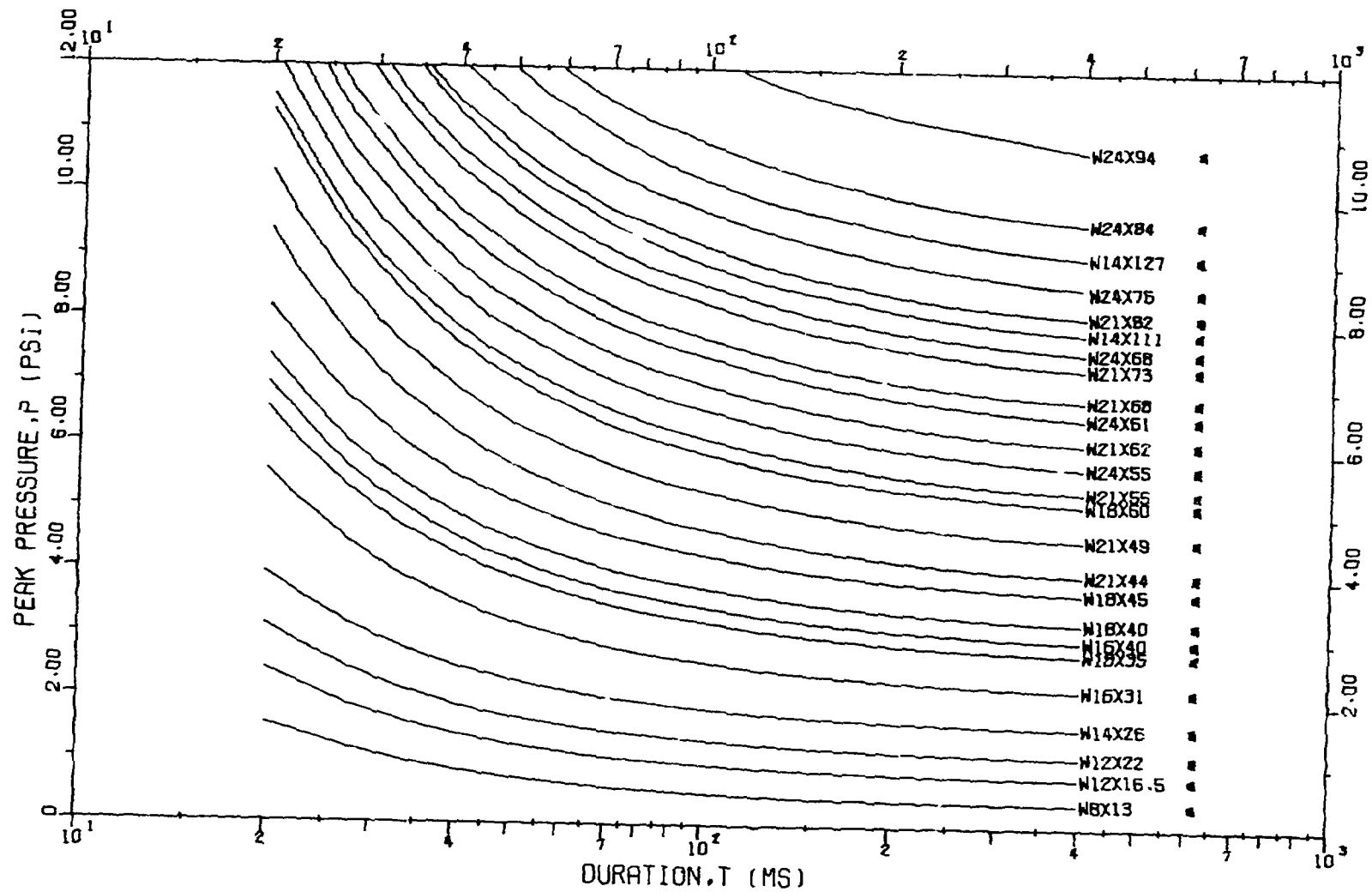


FIGURE 174

NON-REUSABLE BEAM.SPAN= 20 FT.SPACING= 10 FT. SIMPLY-SUPPORTED

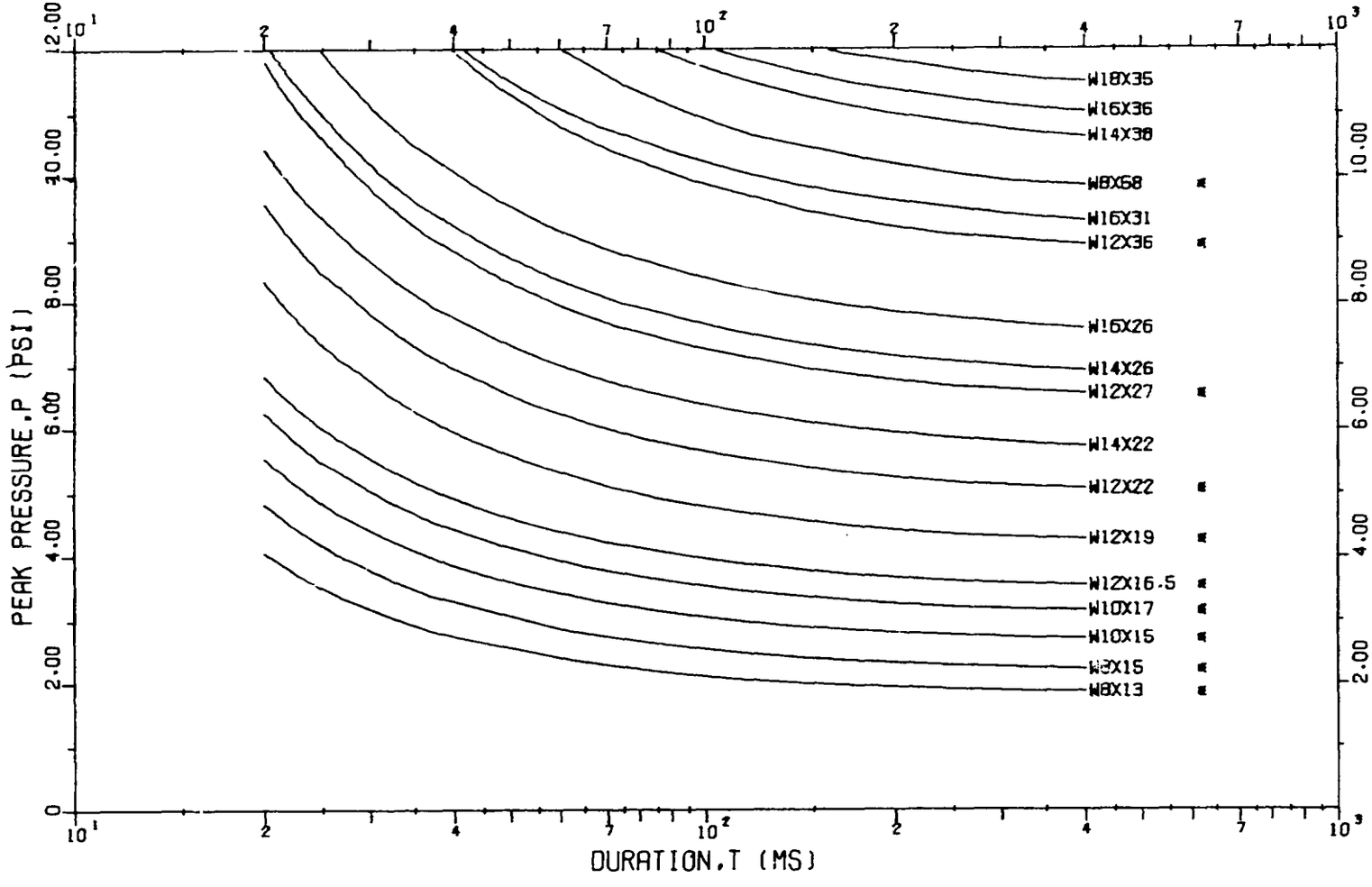


FIGURE 175

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=5 FT, FIXED ENDS

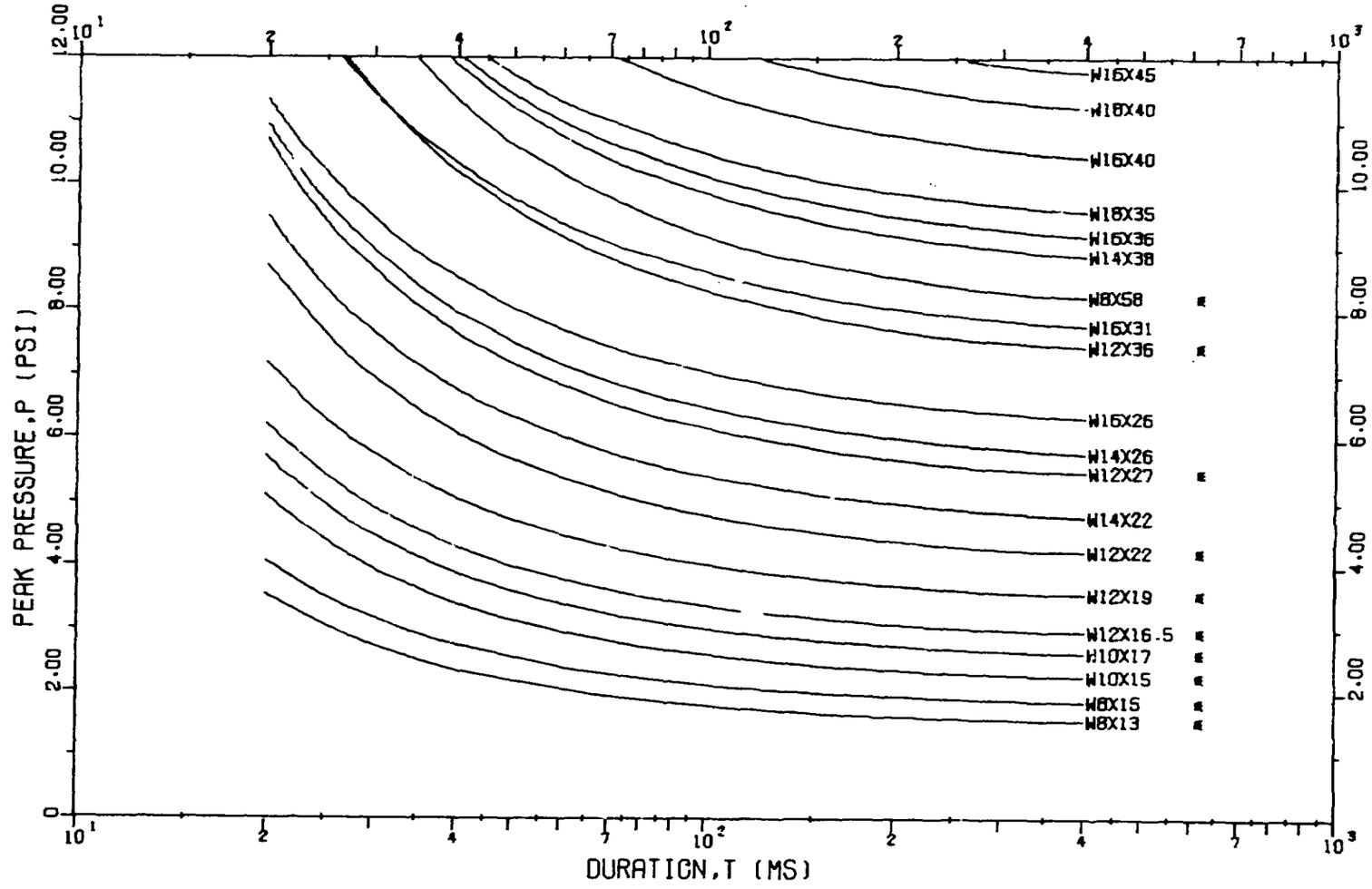


FIGURE 176

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=6 FT, FIXED ENDS

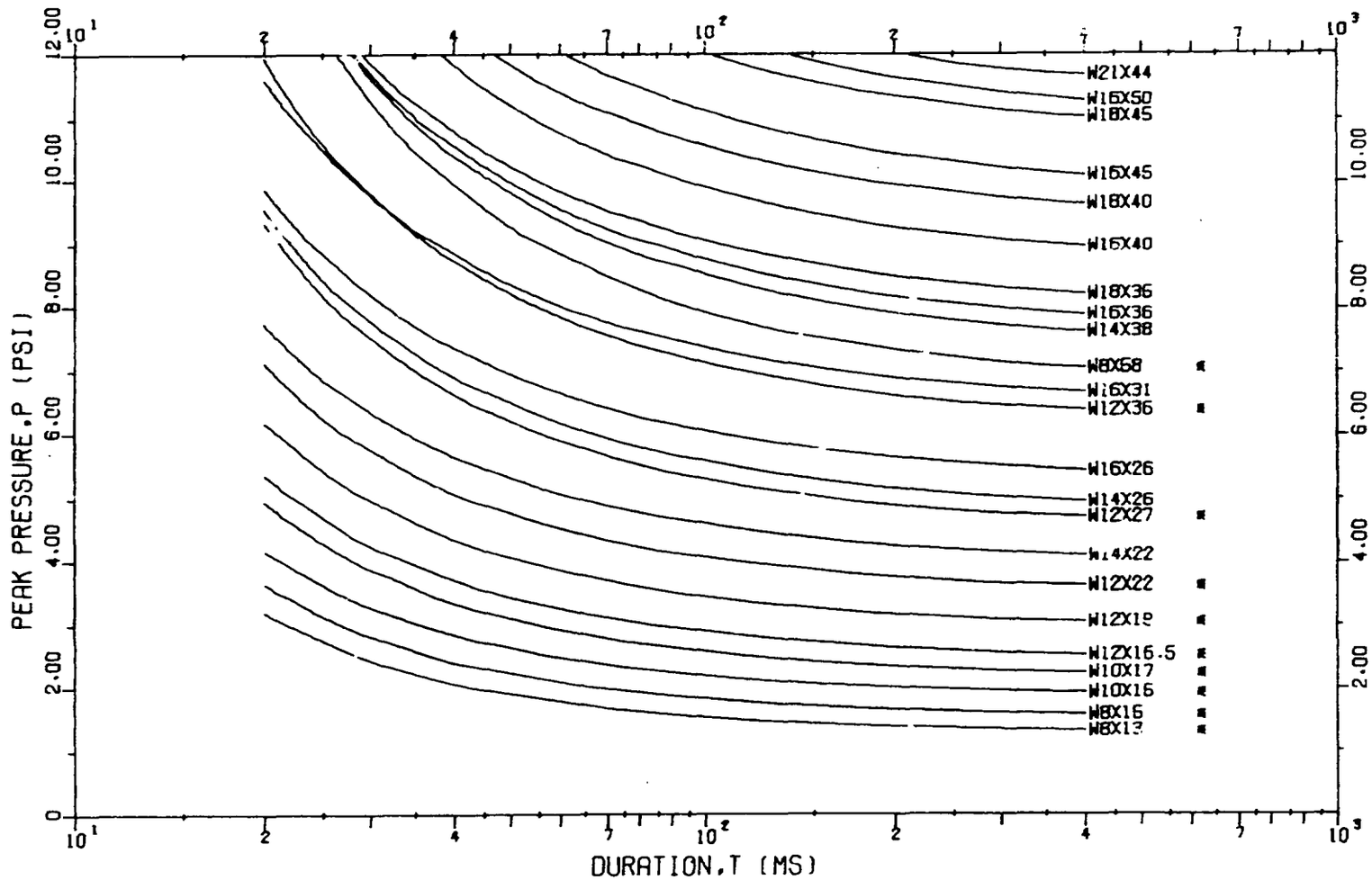


FIGURE 177

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=7 FT, FIXED ENDS

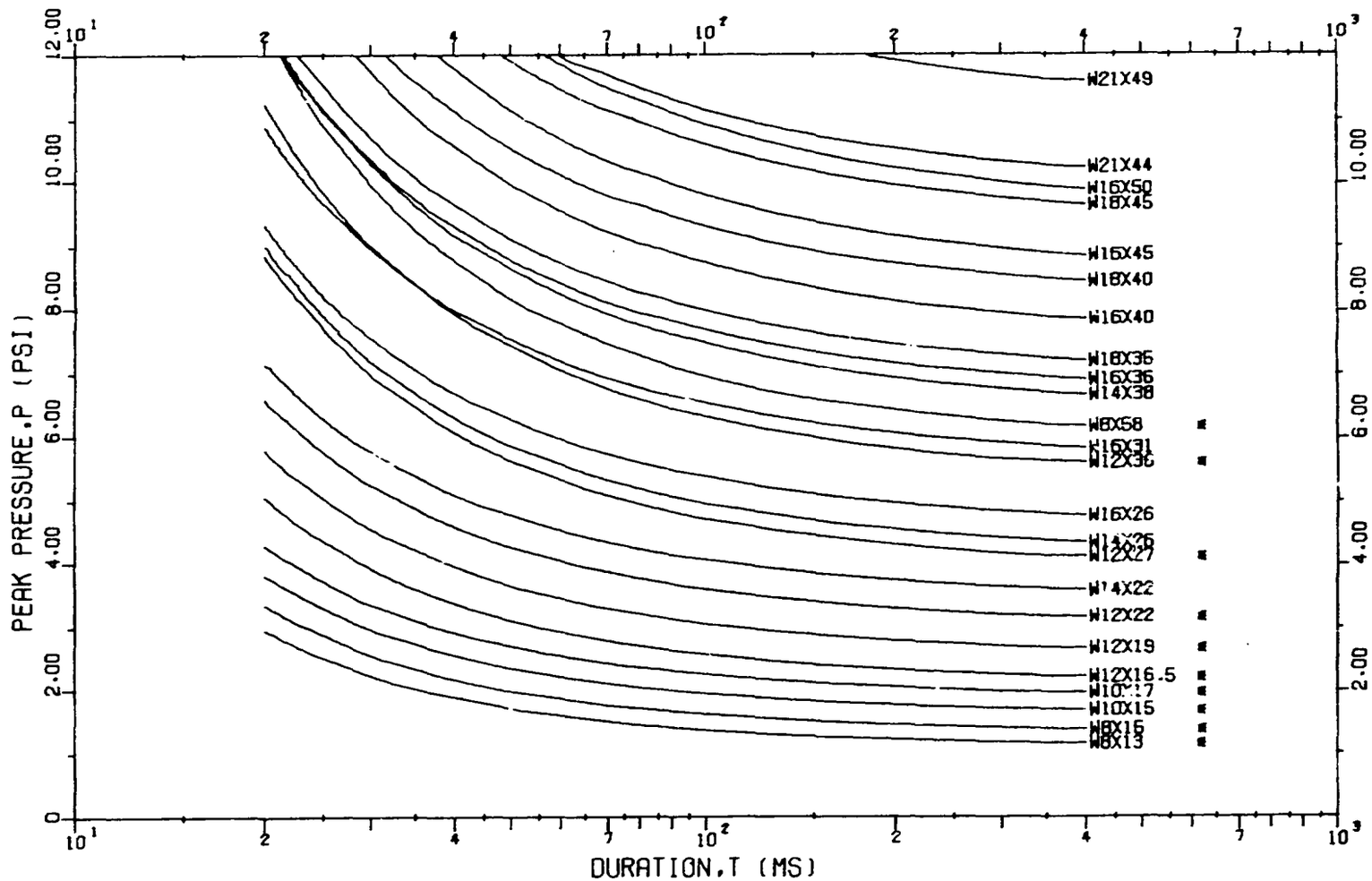


FIGURE 178

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=8 FT, FIXED ENDS

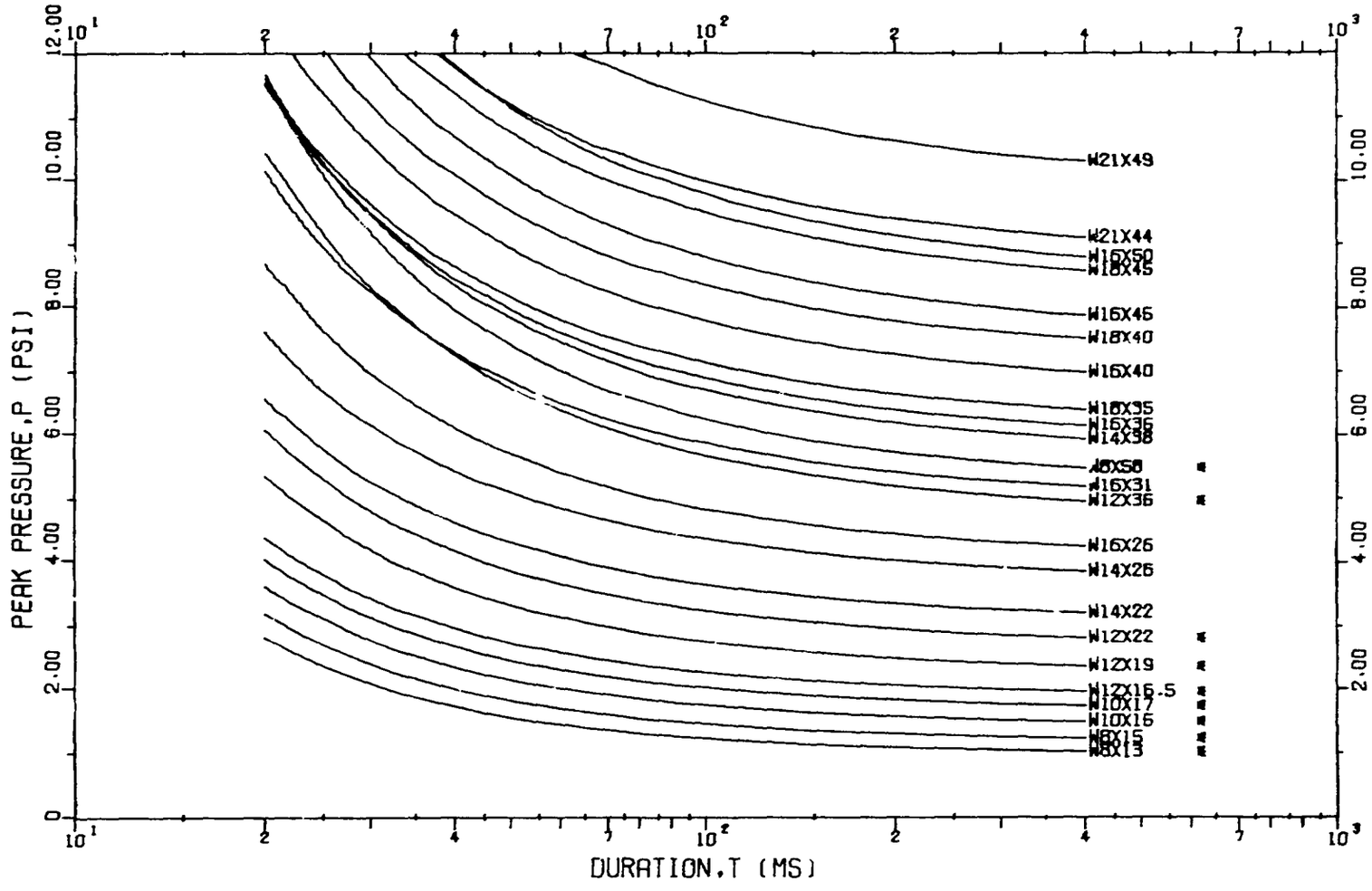


FIGURE 179

NON-REUSABLE BEAM.SPAN= 20 FT.SPACING=9 FT. FIXED ENDS

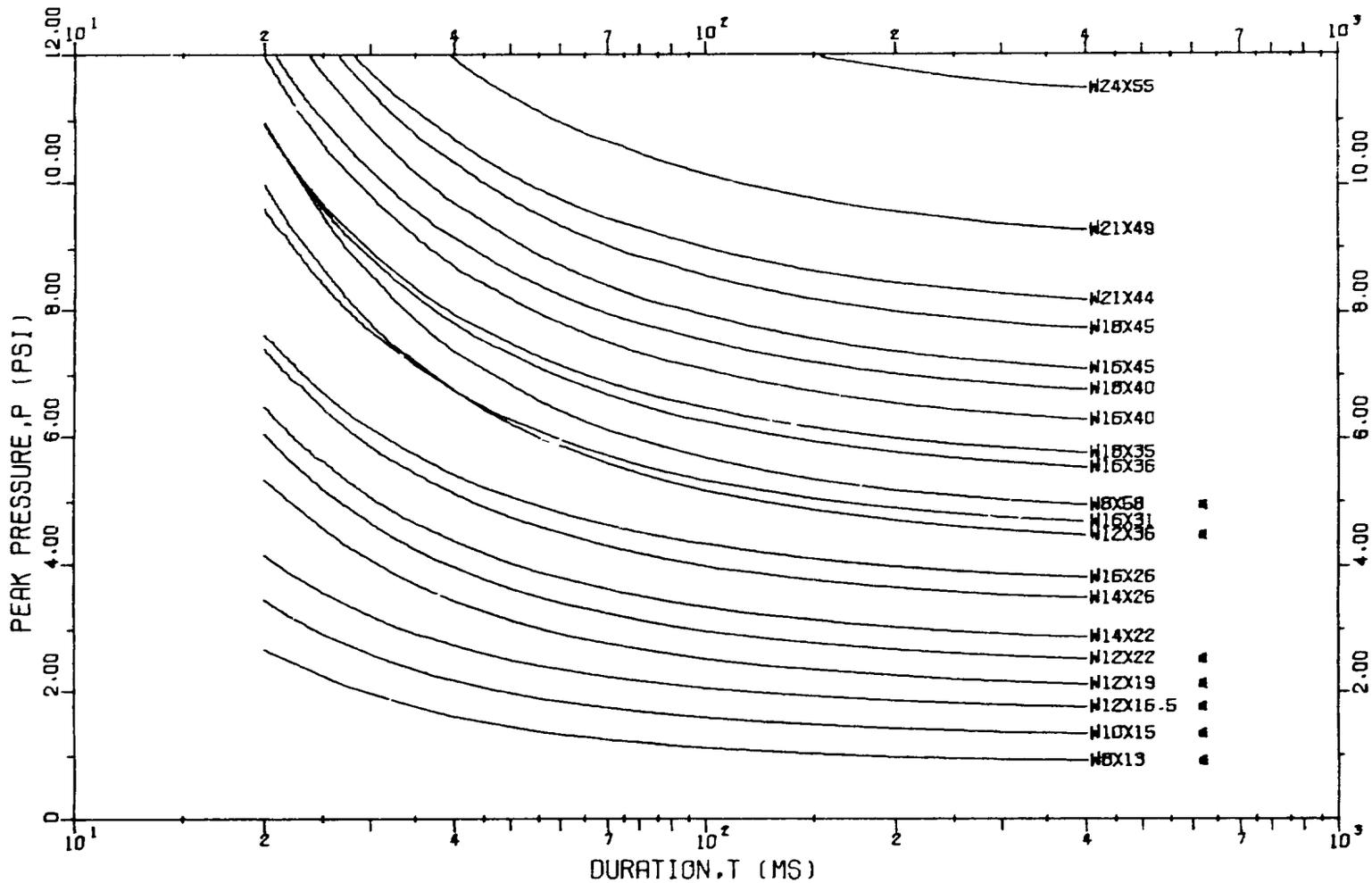


FIGURE 180

NON-REUSABLE BEAM.SPAN= 20 FT.SPACING= 10 FT. FIXED ENDS

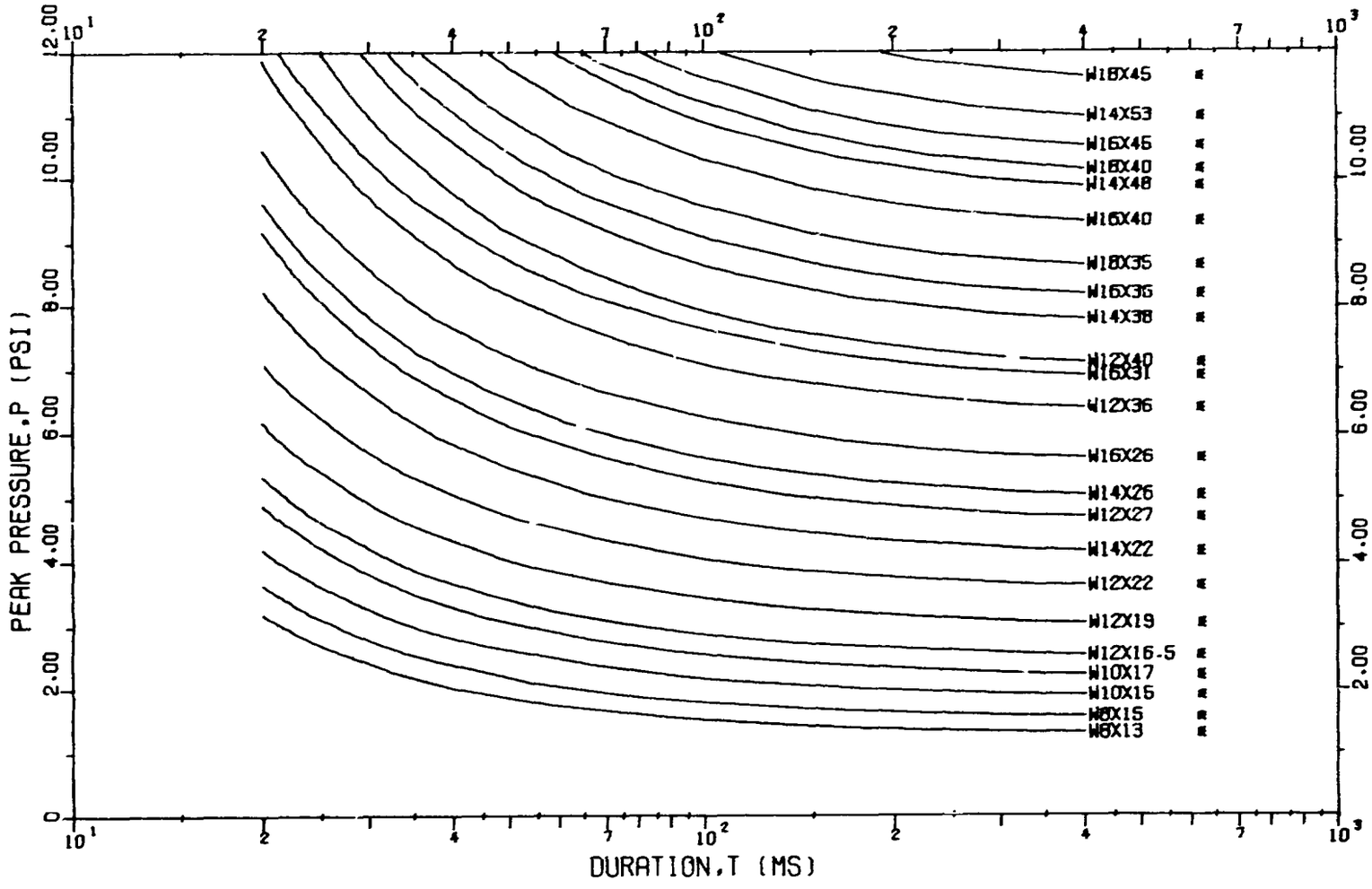


FIGURE 181

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=5 FT. SIMPLE-FIXED

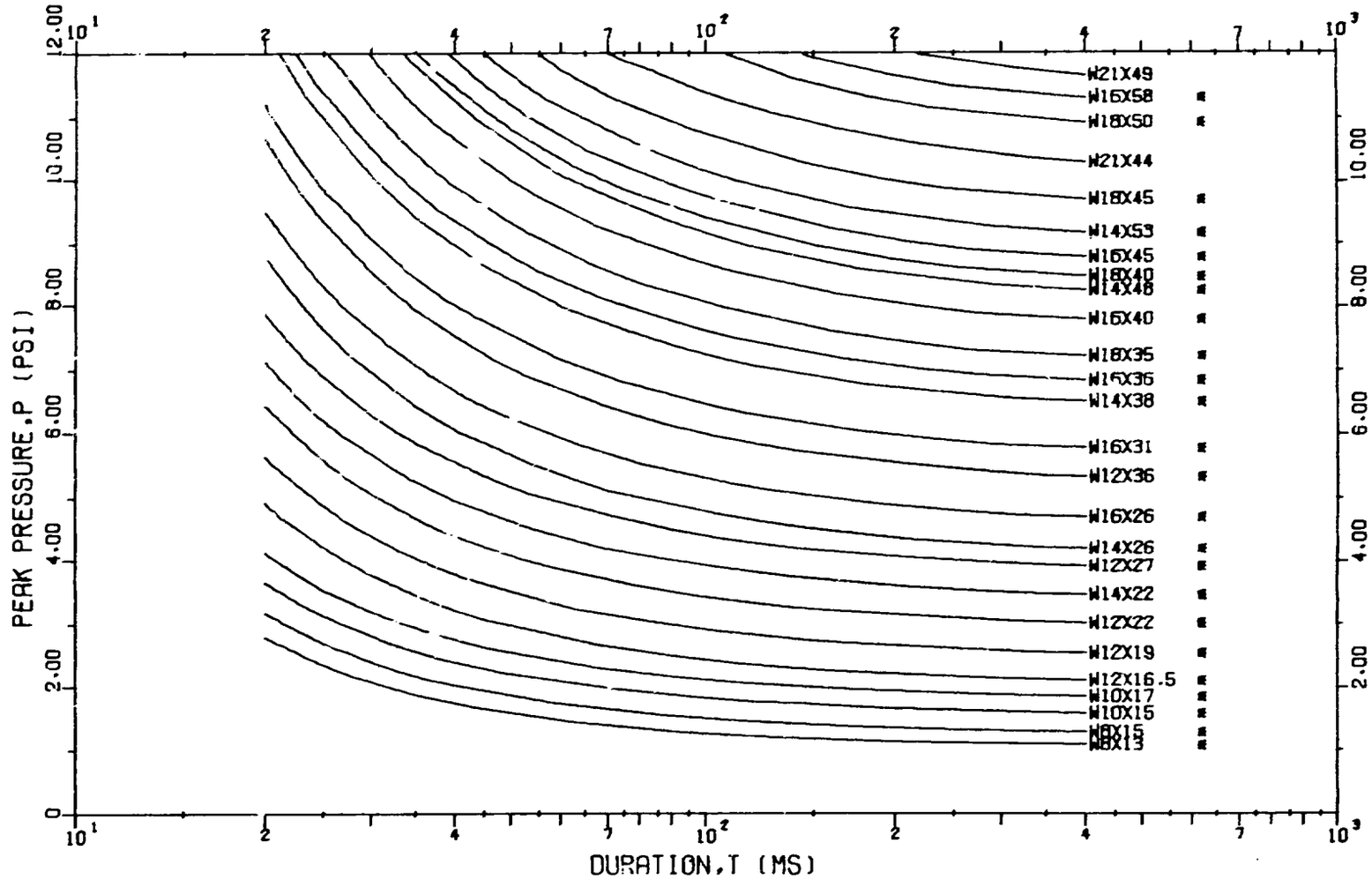


FIGURE 182

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=6 FT, SIMPLE-FIXED

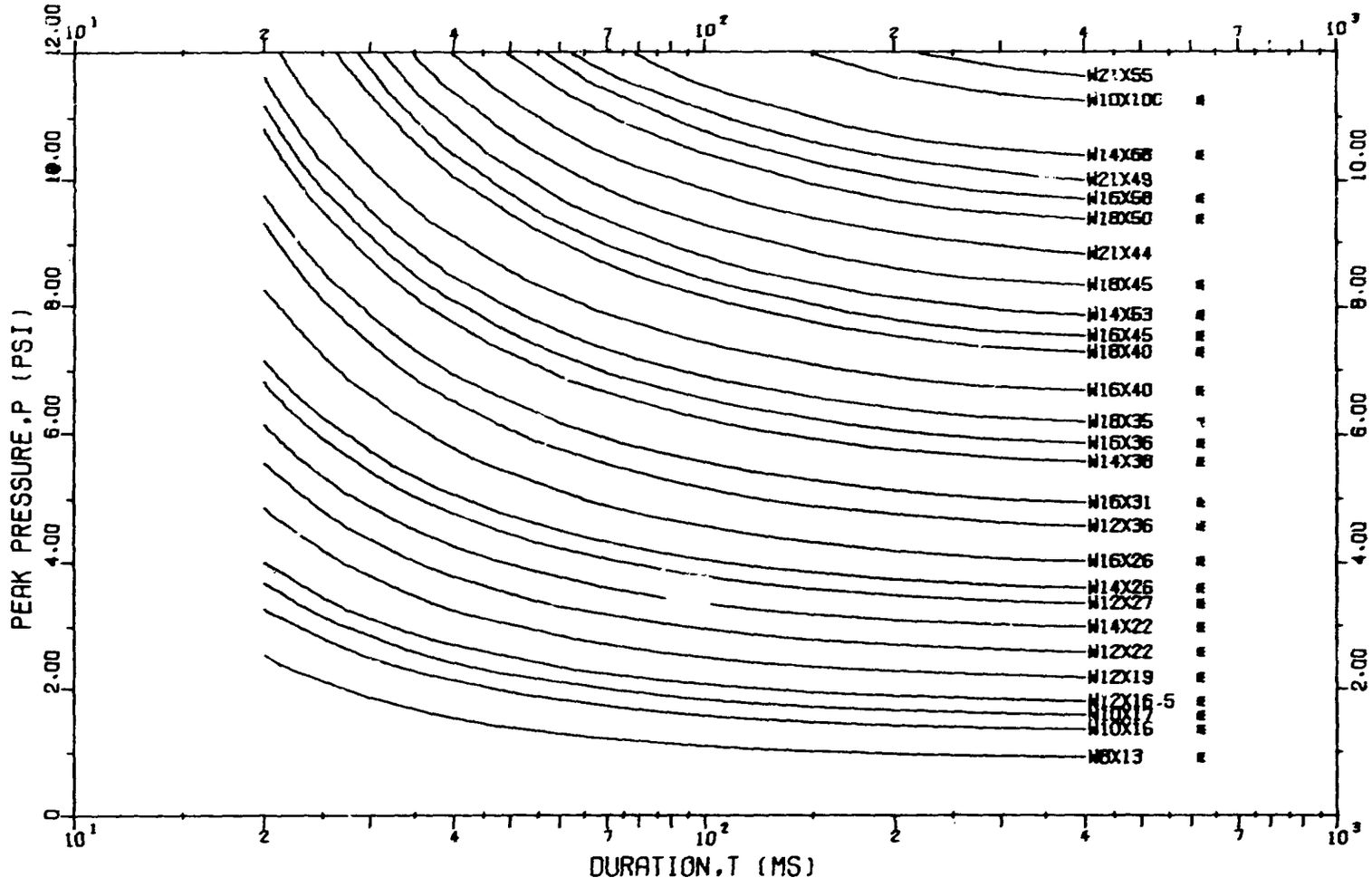


FIGURE 183

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=7 FT, SIMPLE-FIXED

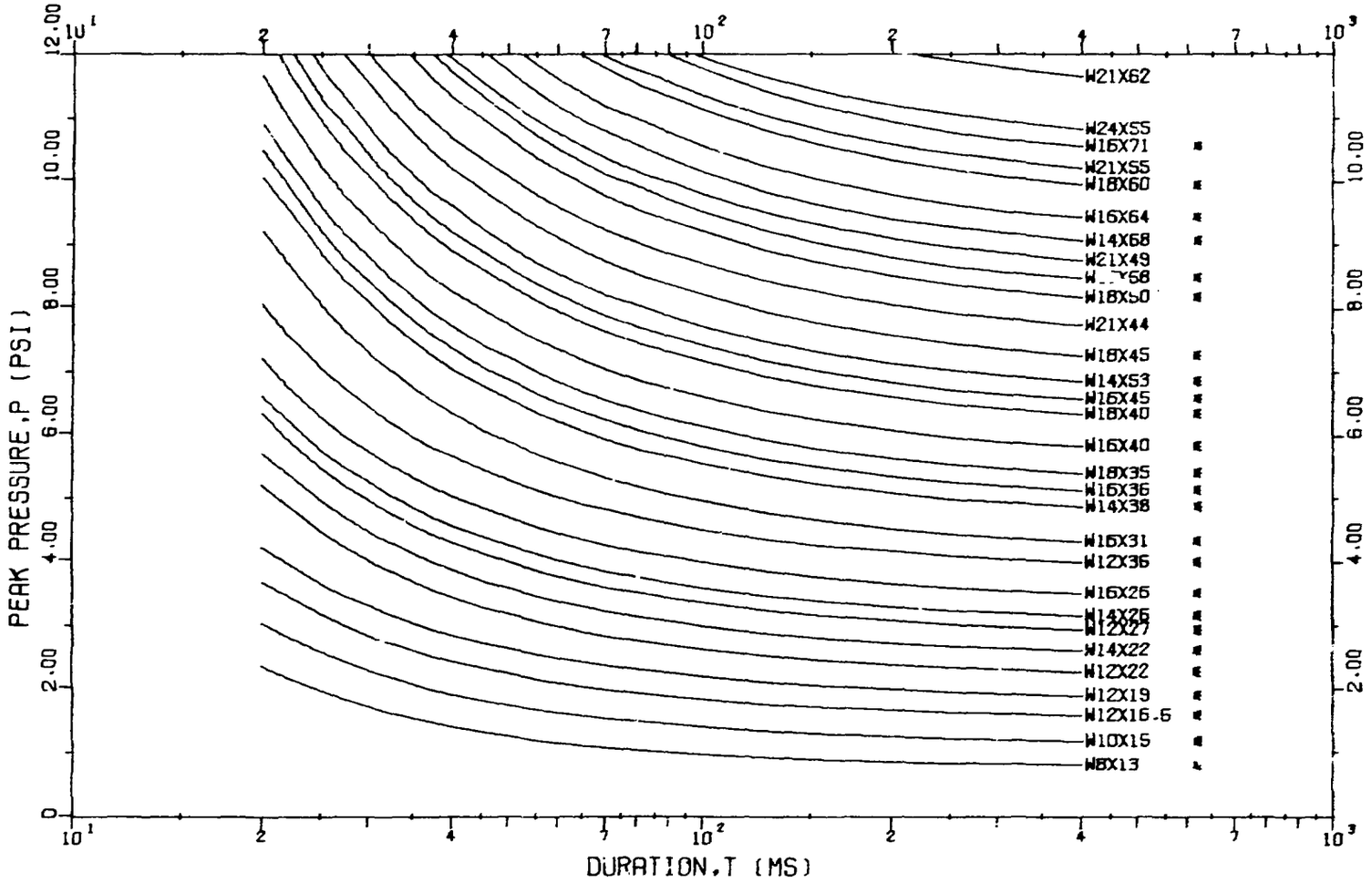


FIGURE 164

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=8 FT, SIMPLE-FIXED

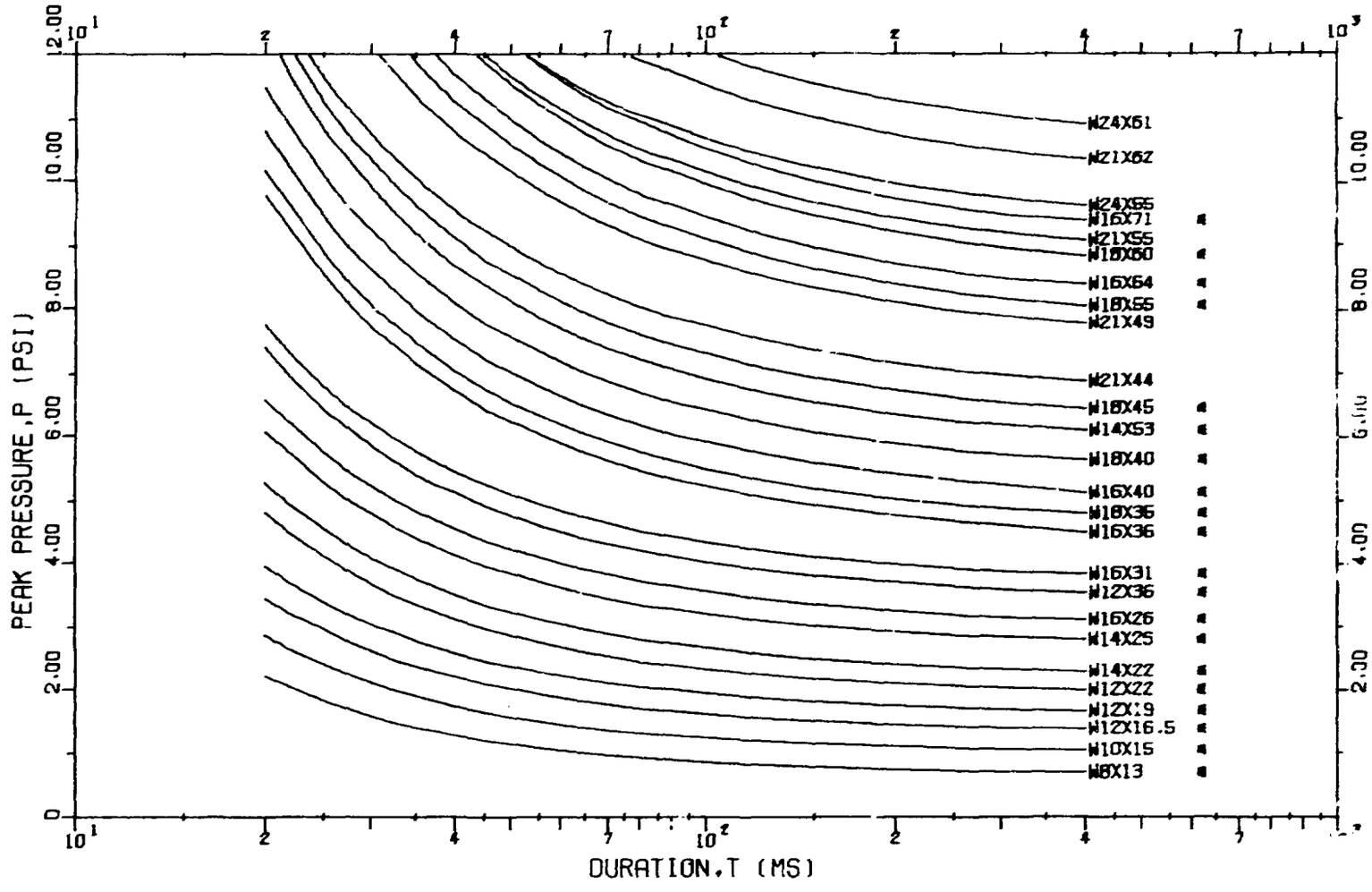


FIGURE 185

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING=9 FT, SIMPLE-FIXED

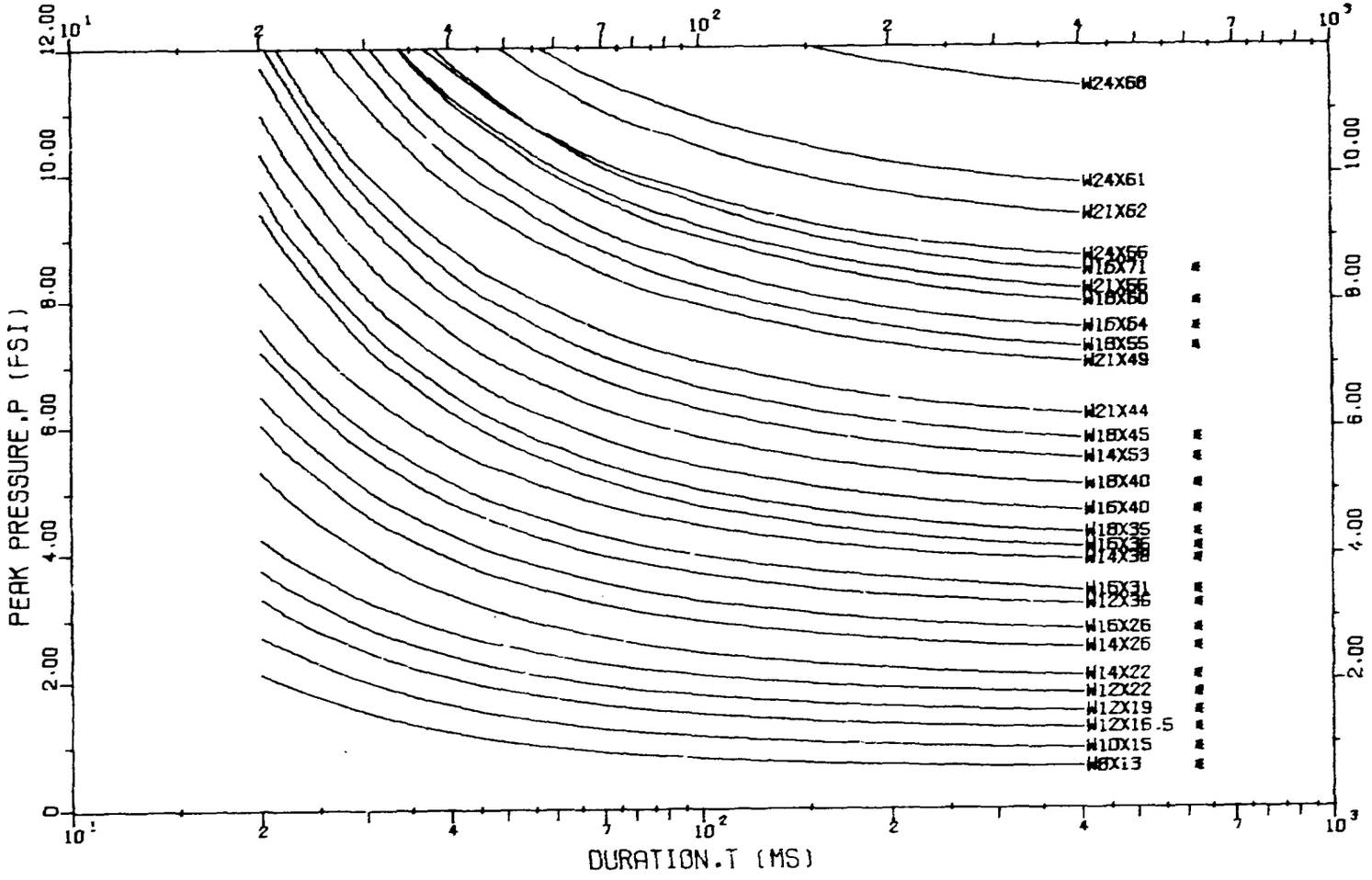


FIGURE 186

NON-REUSABLE BEAM,SPAN= 20 FT,SPACING= 10 FT. SIMPLE-FIXED

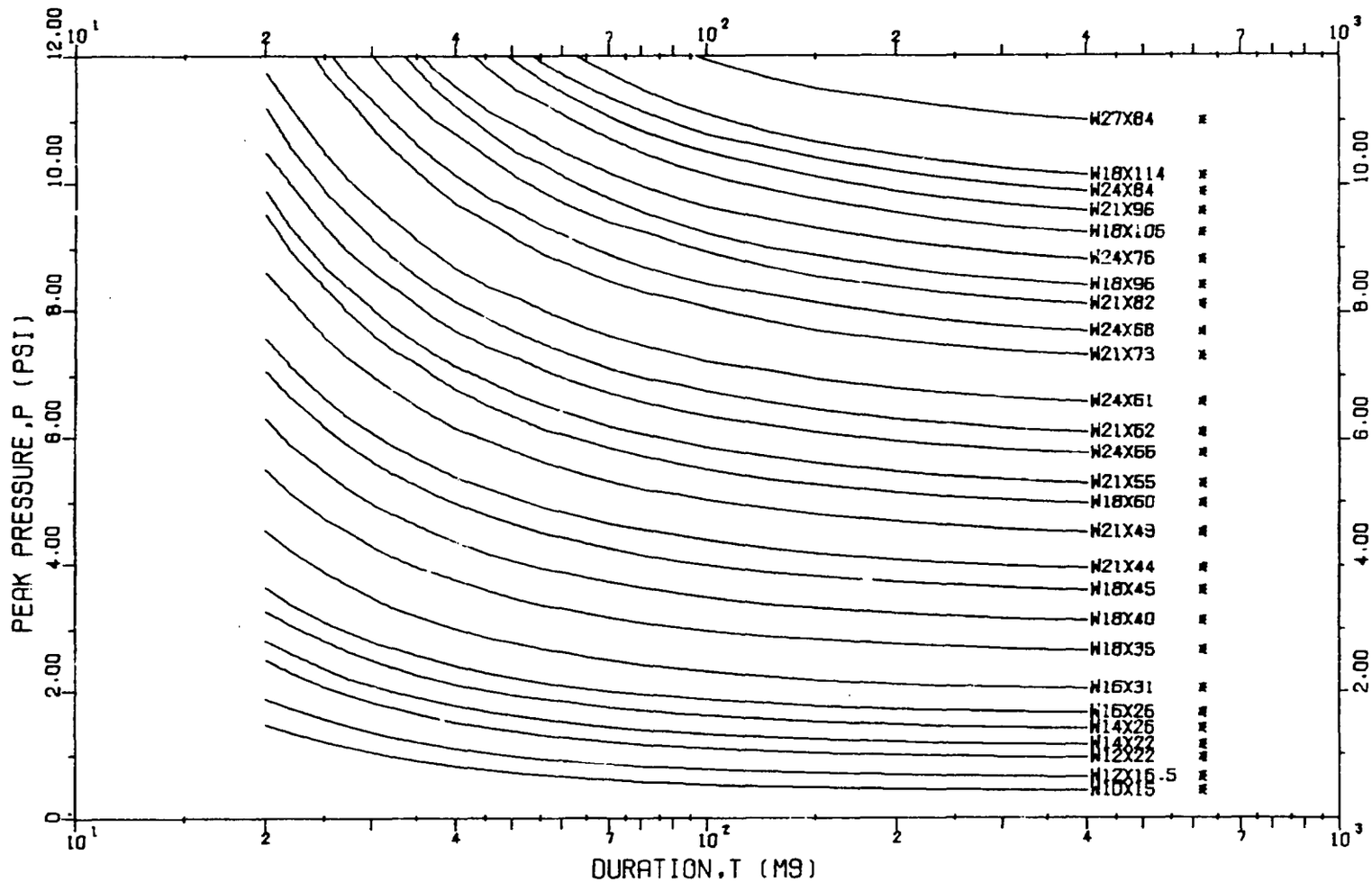


FIGURE 187

REUSABLE BEAM,SPAN=25 FT,SPACING=5 FT, SIMPLY-SUPPORTED

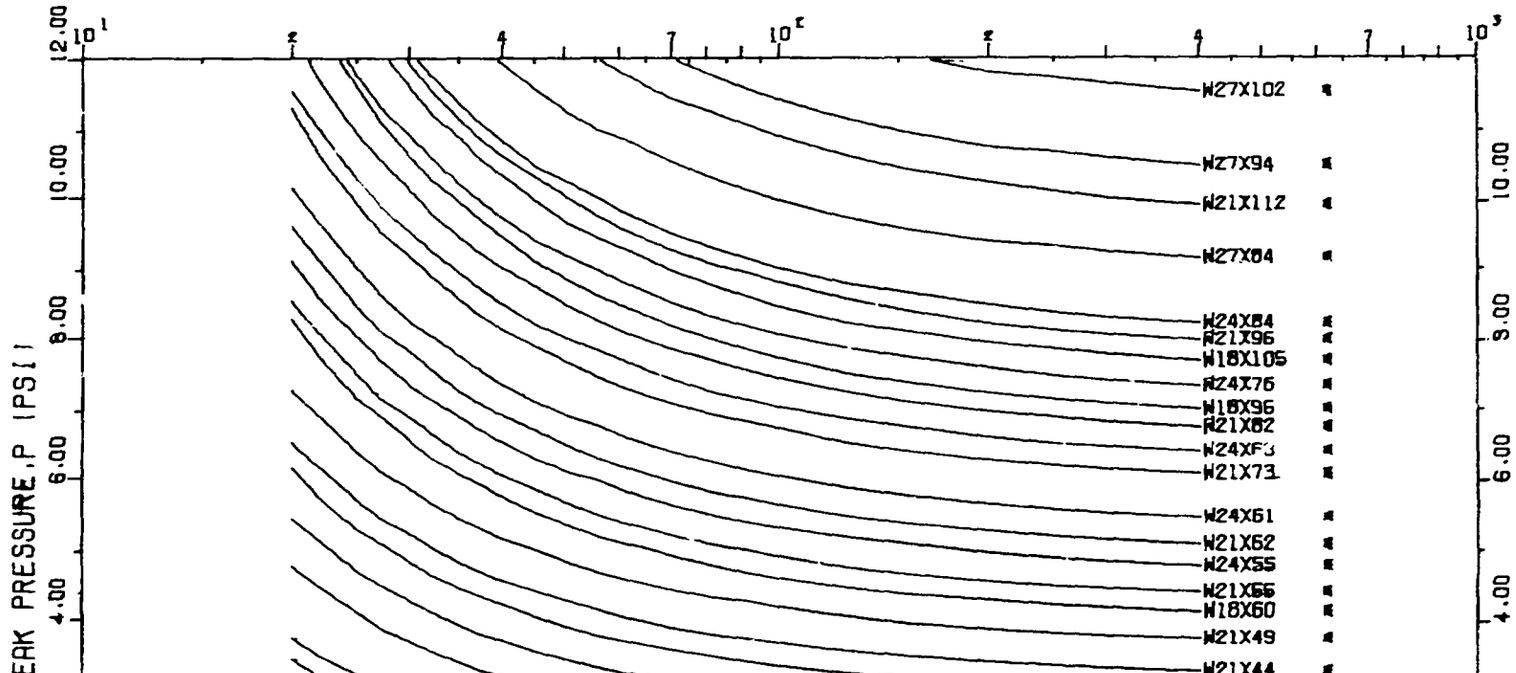


FIGURE 188

REUSABLE BEAM,SPAN=25 FT,SPACING=6 FT, SIMPLY-SUPPORTED

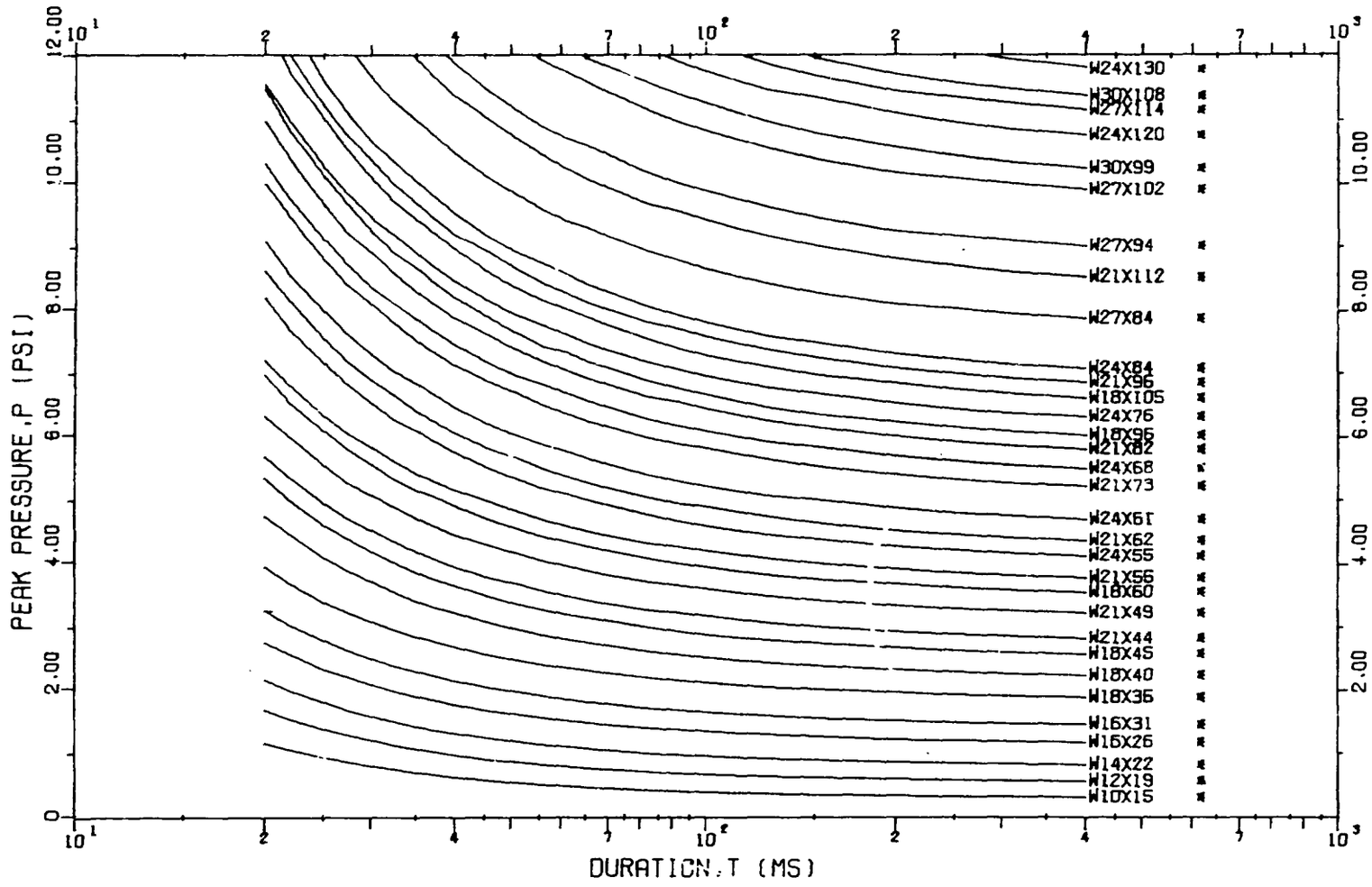


FIGURE 189

REUSABLE BEAM.SPAN=25 FT.SPACING=7 FT. SIMPLY-SUPPORTED

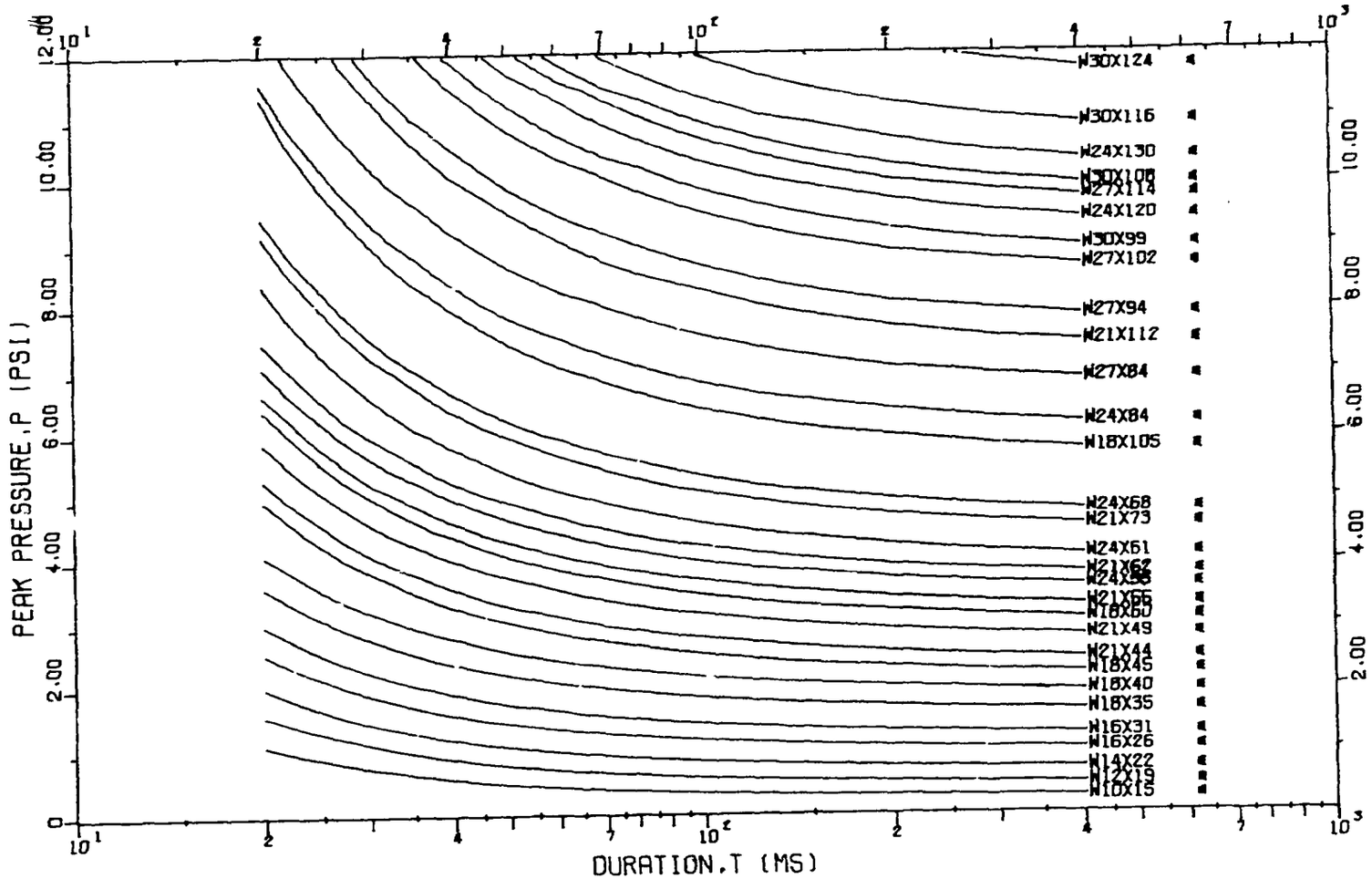


FIGURE 190

REUSABLE BEAM,SPAN= 25 FT,SPACING= 8 FT, SIMPLY-SUPPORTED

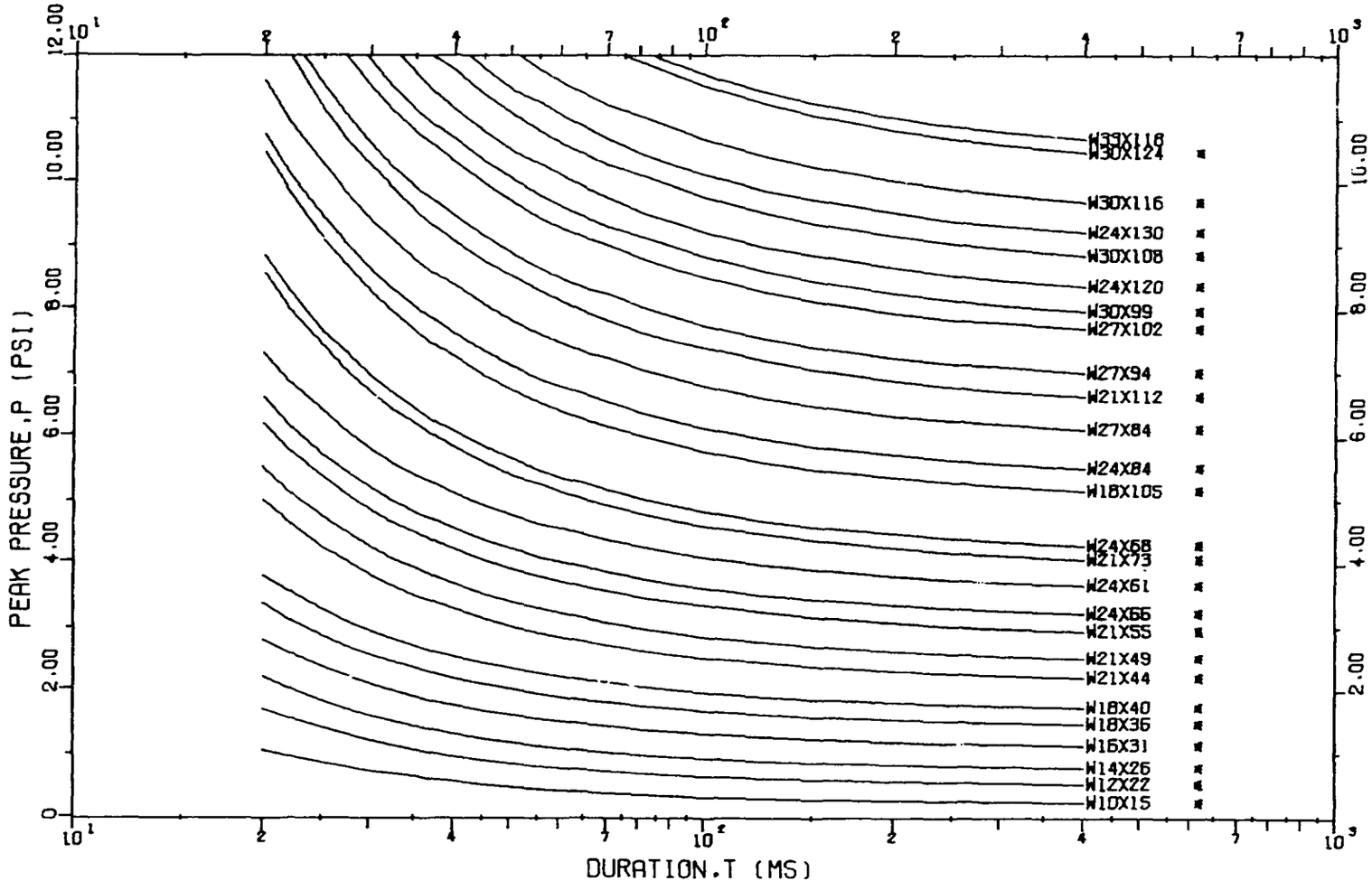


FIGURE 19.

REUSABLE BEAM.SPAN=25 FT.SPACING=9 FT. SIMPLY-SUPPORTED

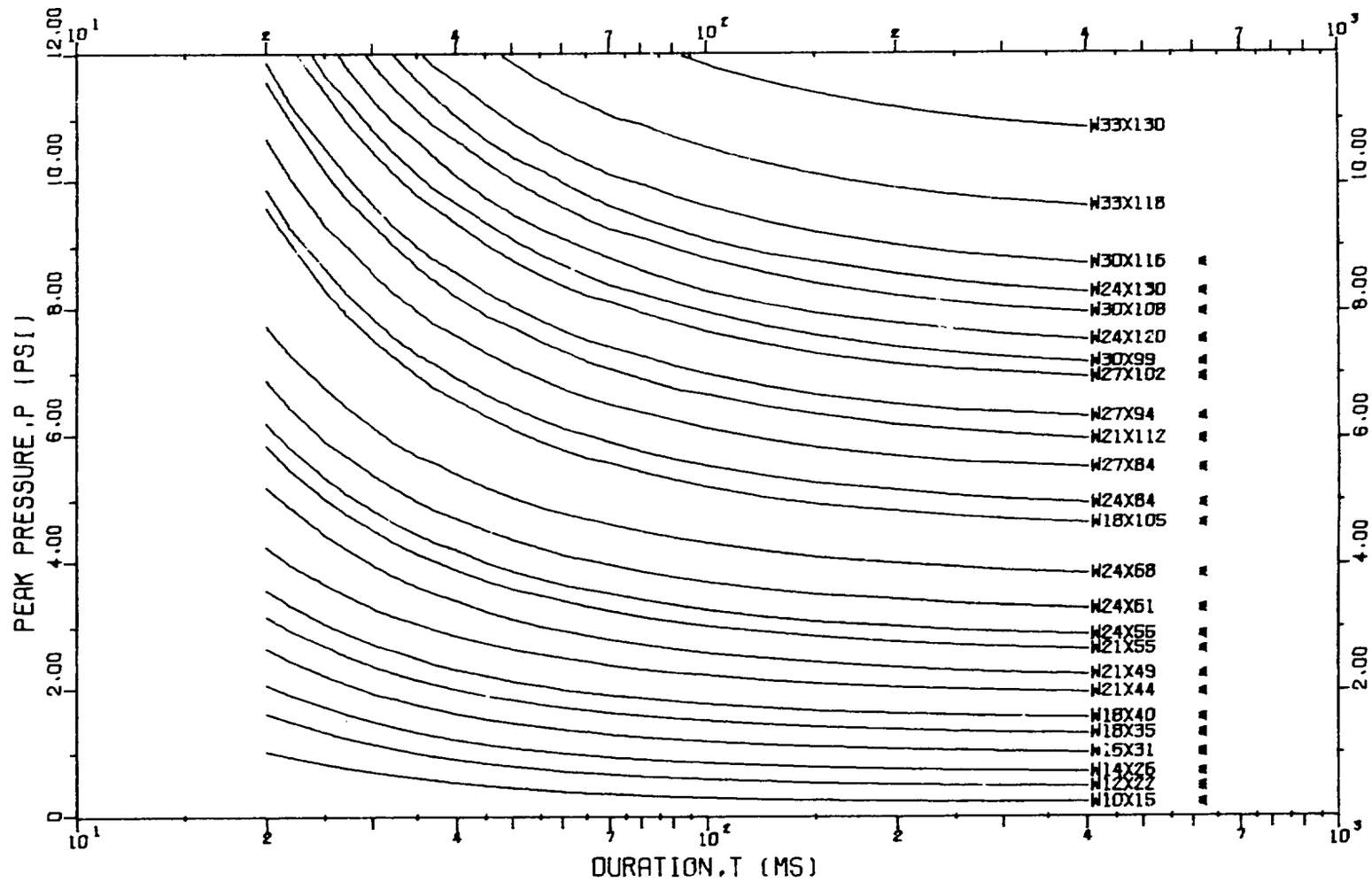


FIGURE 192

REUSABLE BEAM,SPAN=25 FT,SPACING=10FT, SIMPLY-SUPPORTED

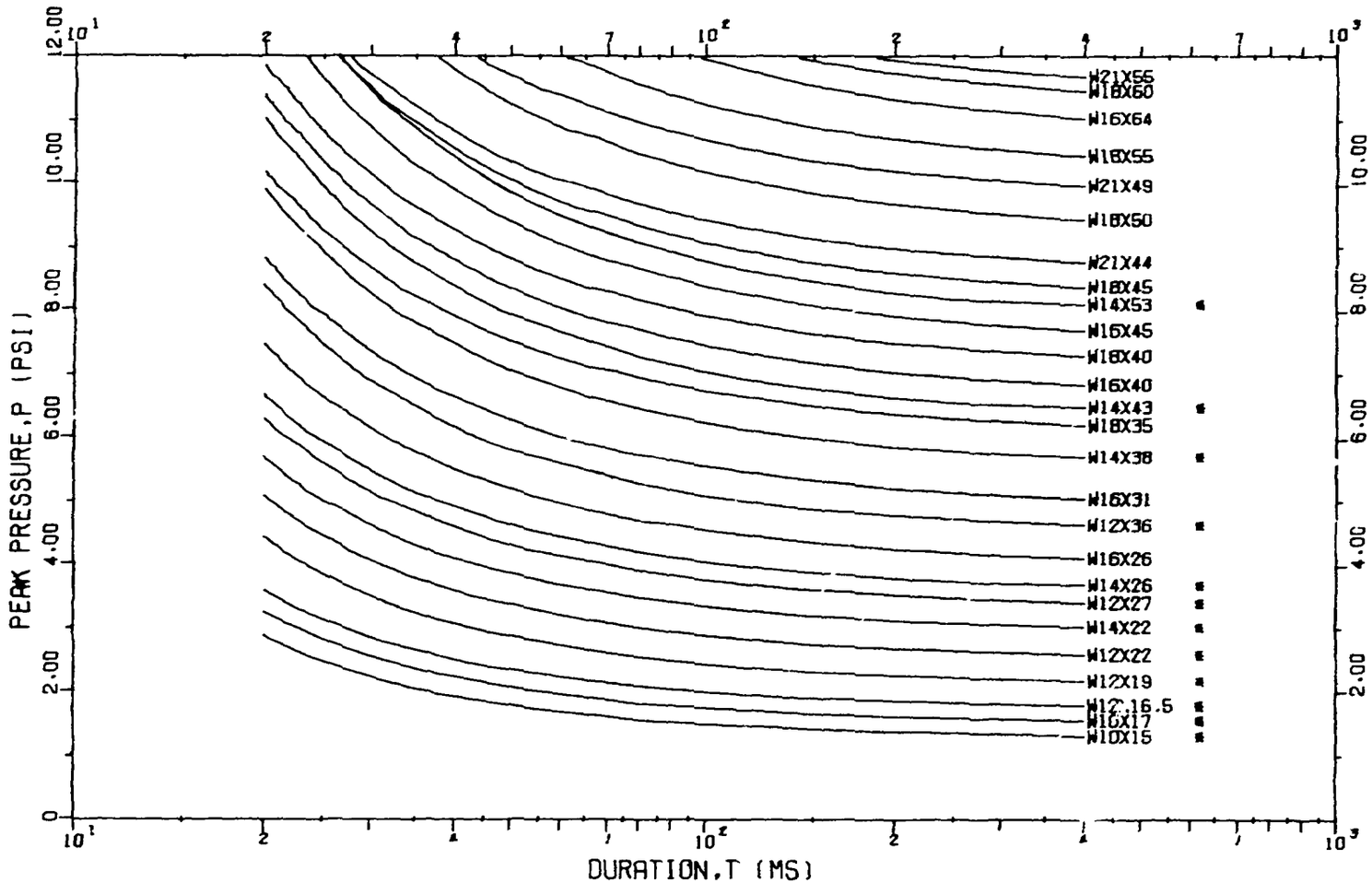


FIGURE 105

REUSABLE BEAM,SPAN=25 FT,SPACING=5 FT, FIXED ENDS

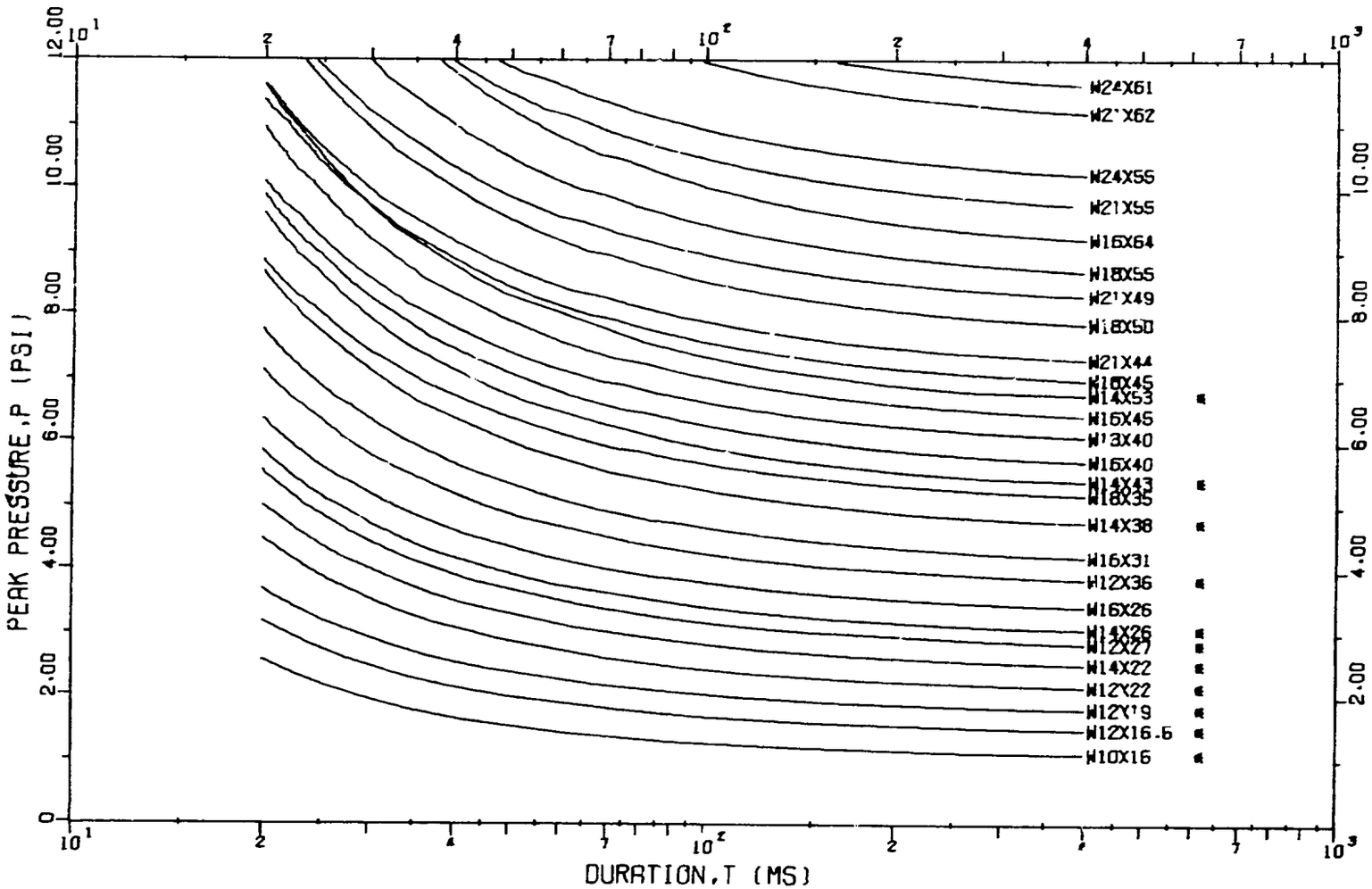


FIGURE 194

REUSABLE BEAM,SPAN=25 FT,SPACING=6 FT, FIXED ENDS

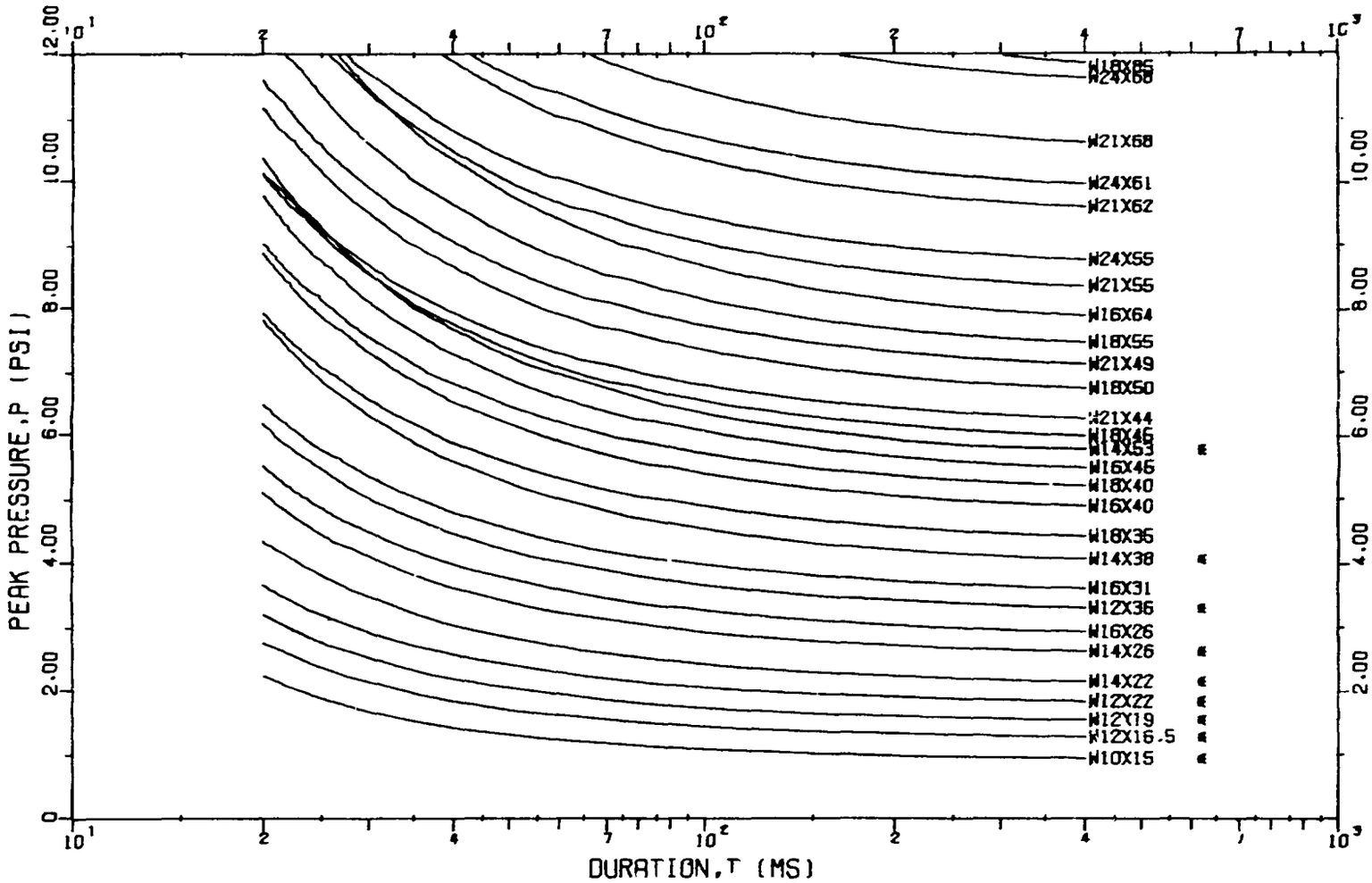


FIGURE 195

REUSABLE BEAM,SPAN=25 FT,SPACING=7 FT, FIXED ENDS

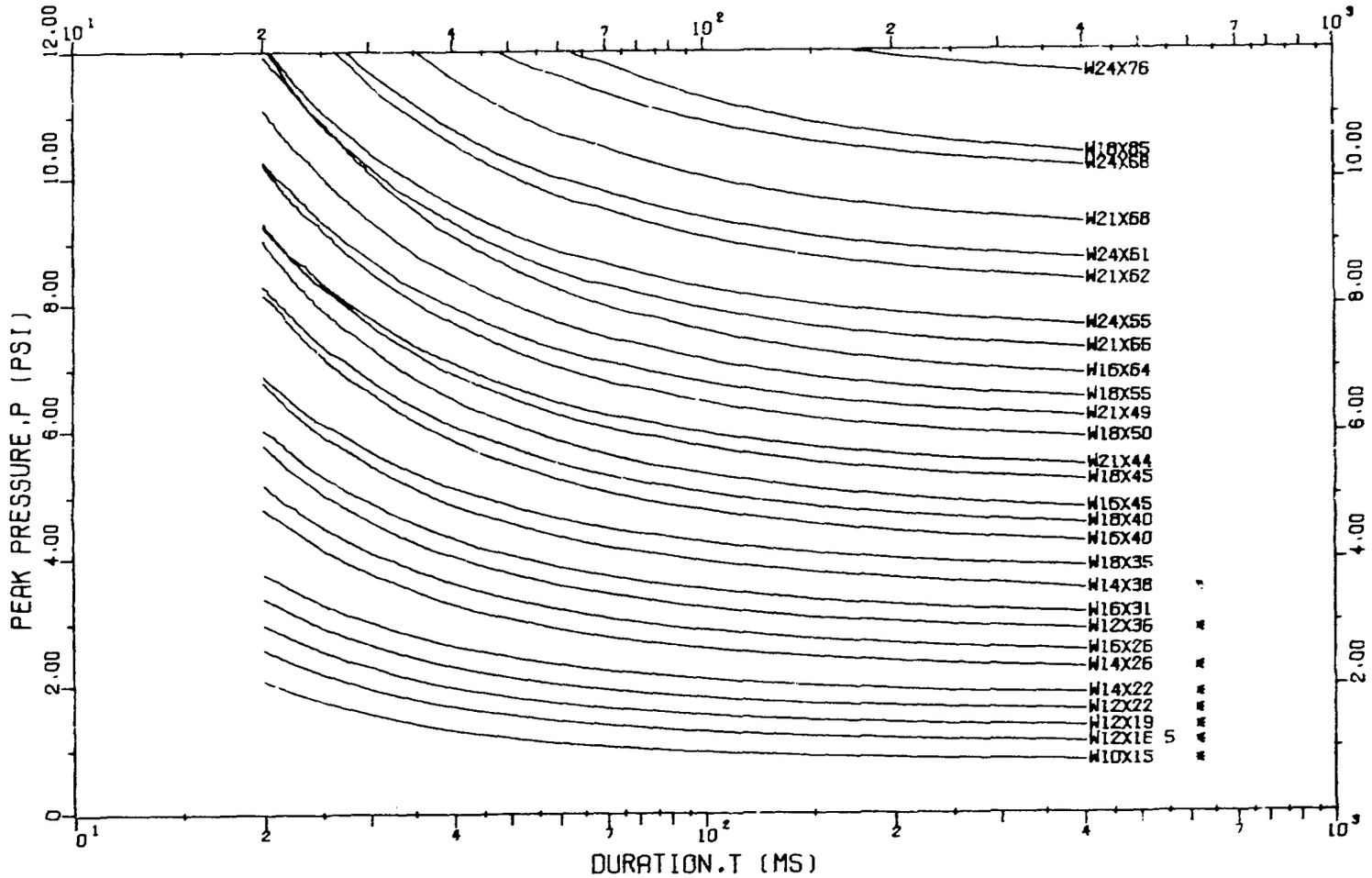


FIGURE 196

REUSABLE BEAM.SPAN=25 FT.SPACING=8 FT. FIXED ENDS

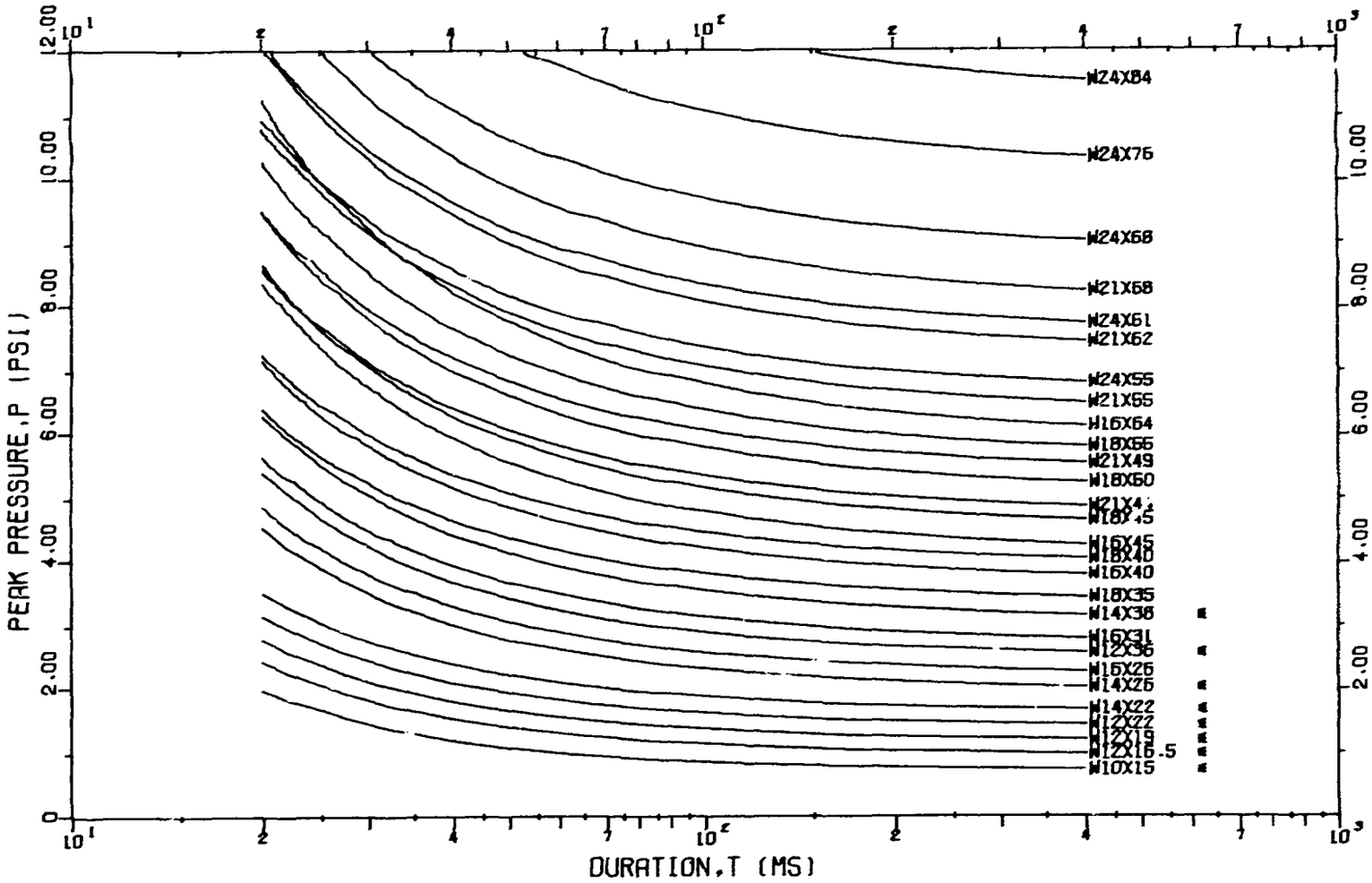


FIGURE 197

REUSABLE BEAM,SPAN=25 FT,SPACING=9 FT, FIXED ENDS

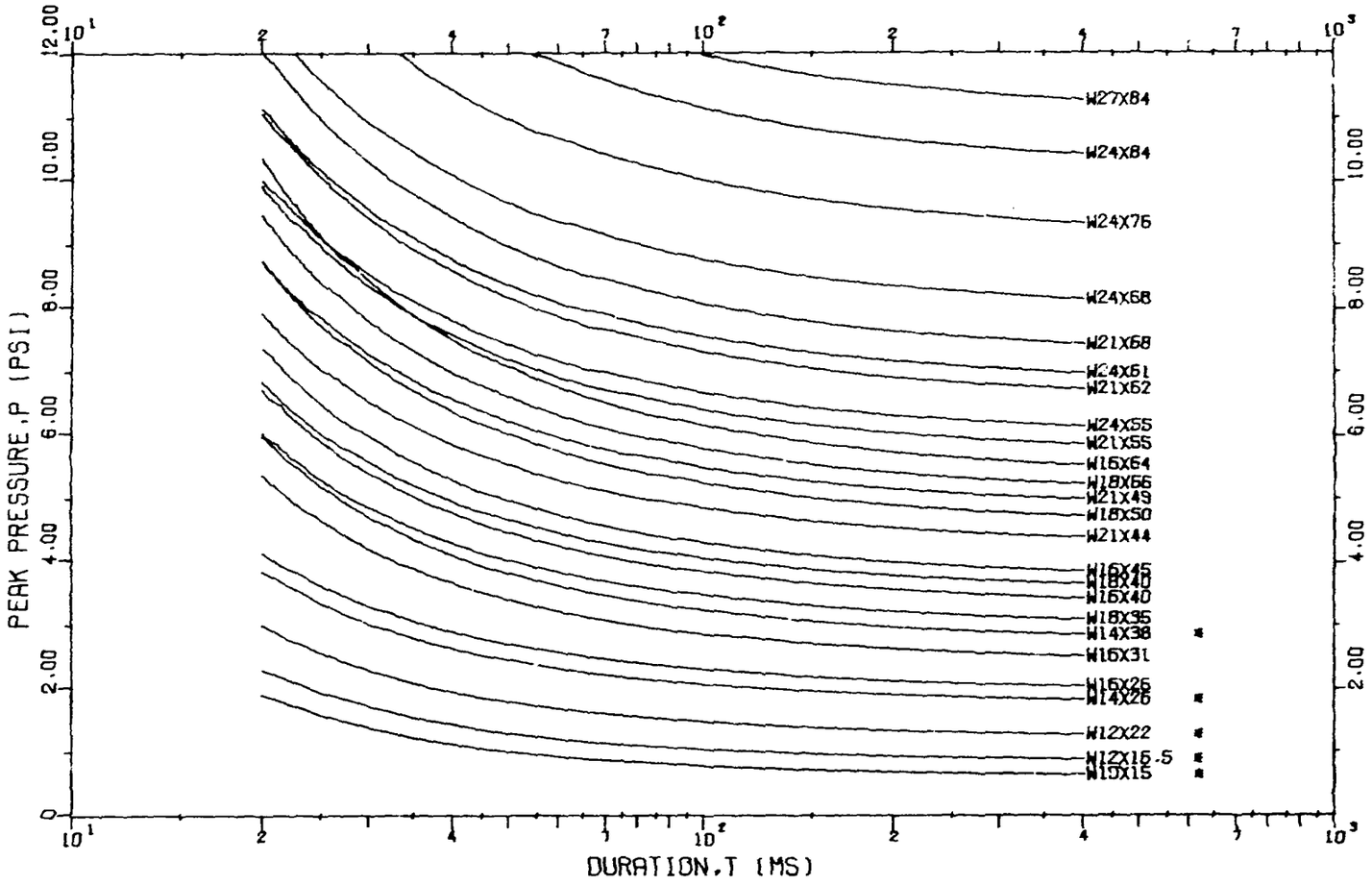


FIGURE 198

REUSABLE BEAM.SPAN= 25 FT.SPACING= 10FT. FIXED ENDS

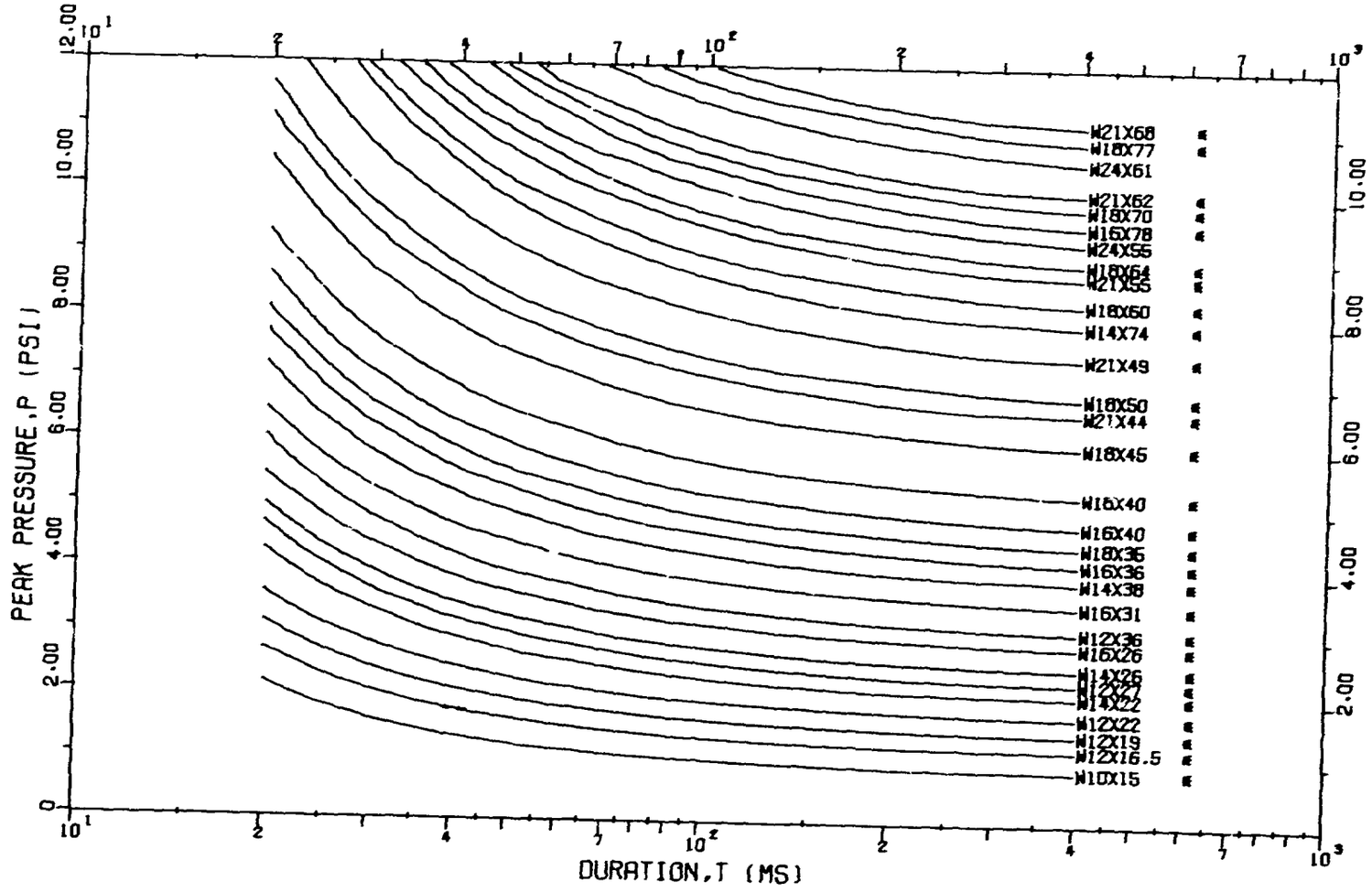


FIGURE 199

REUSABLE BEAM,SPAN=25 FT,SPACING=5 FT, SIMPLE-FIXED

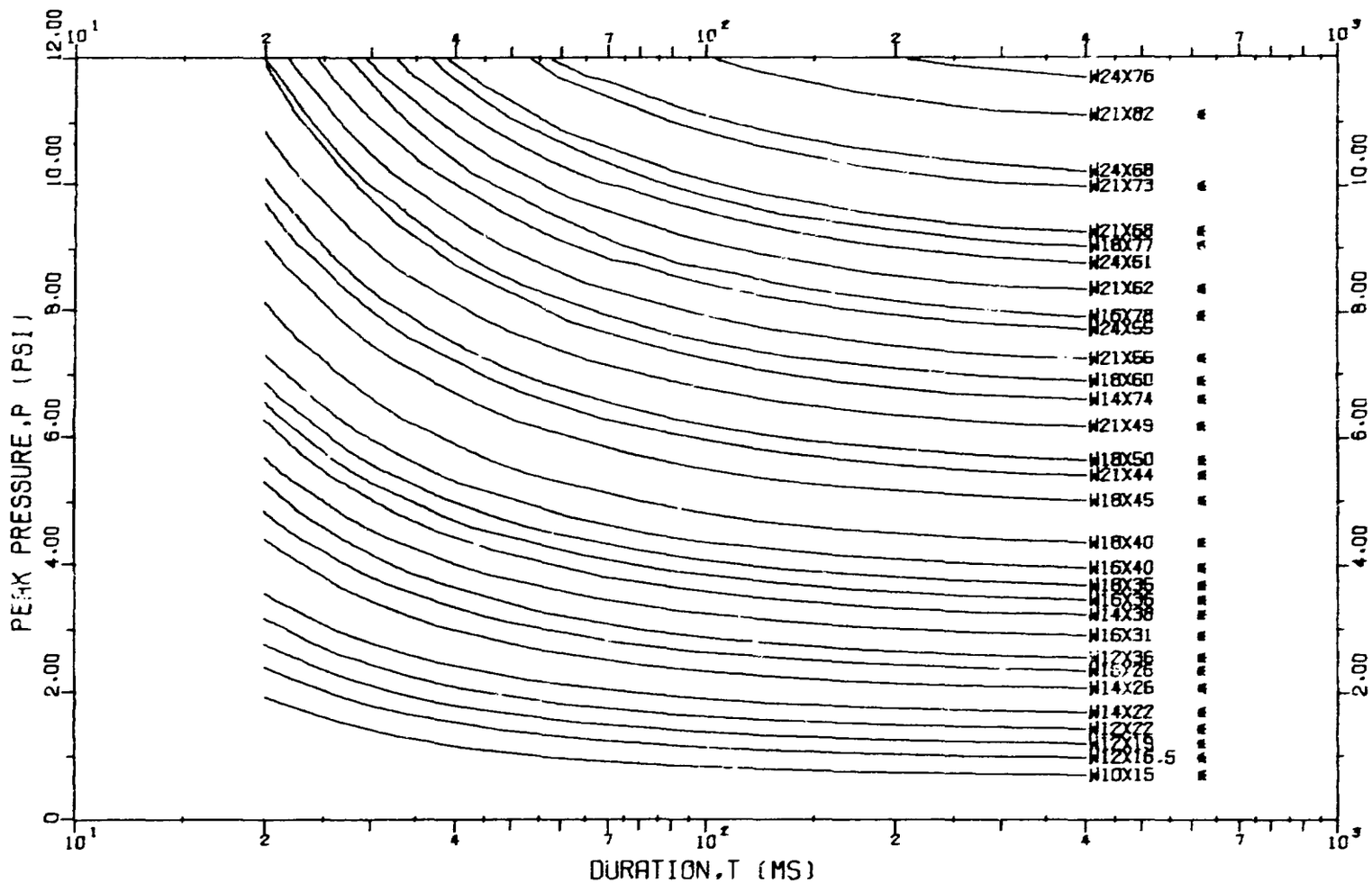


FIGURE 200

REUSABLE BEAM,SPAN=25 FT,SPACING=6 FT, SIMPLE-FIXED

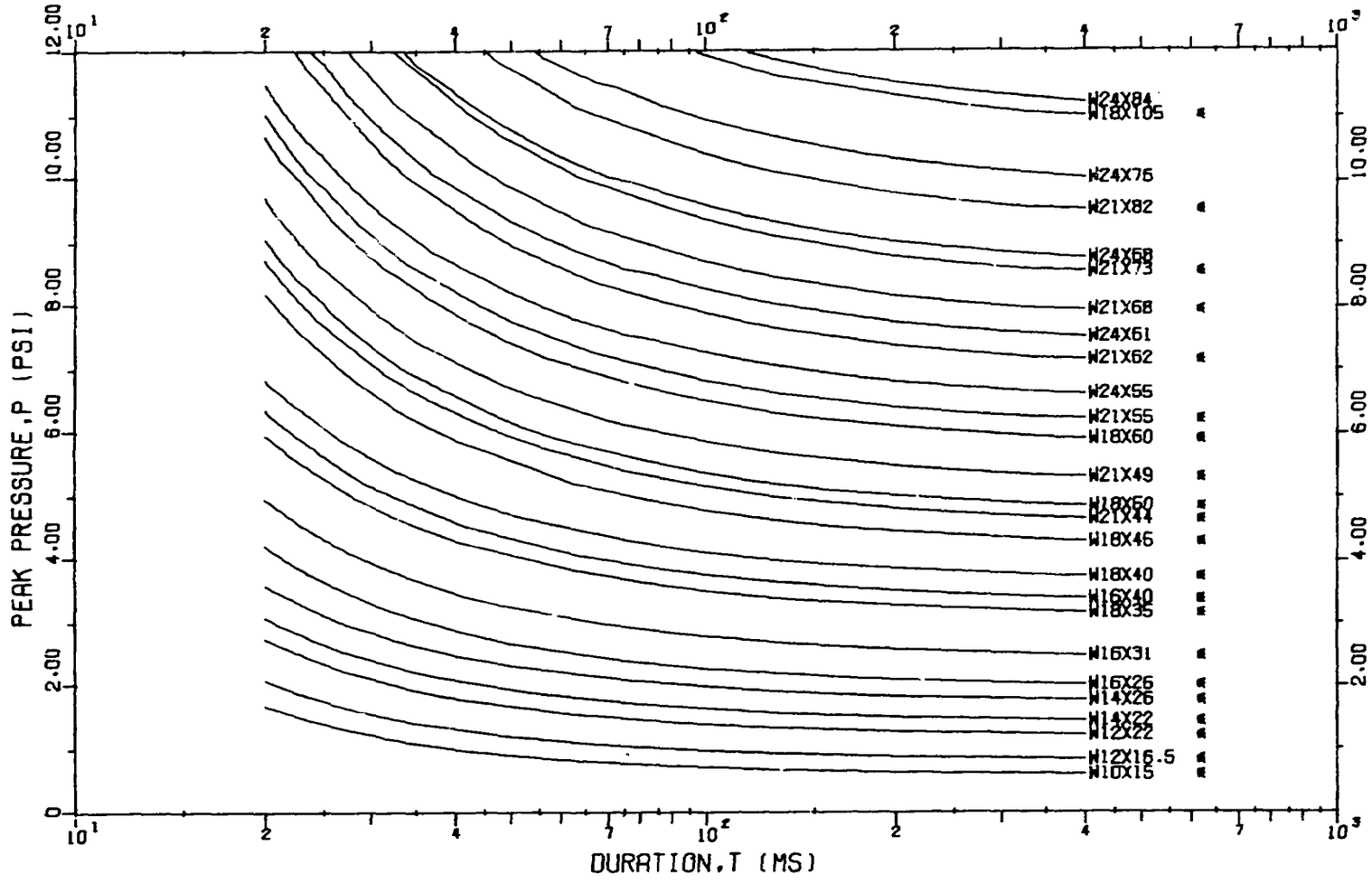


FIGURE 201

REUSABLE BEAM,SPAN=25 FT,SPACING=7 FT, SIMPLE-FIXED

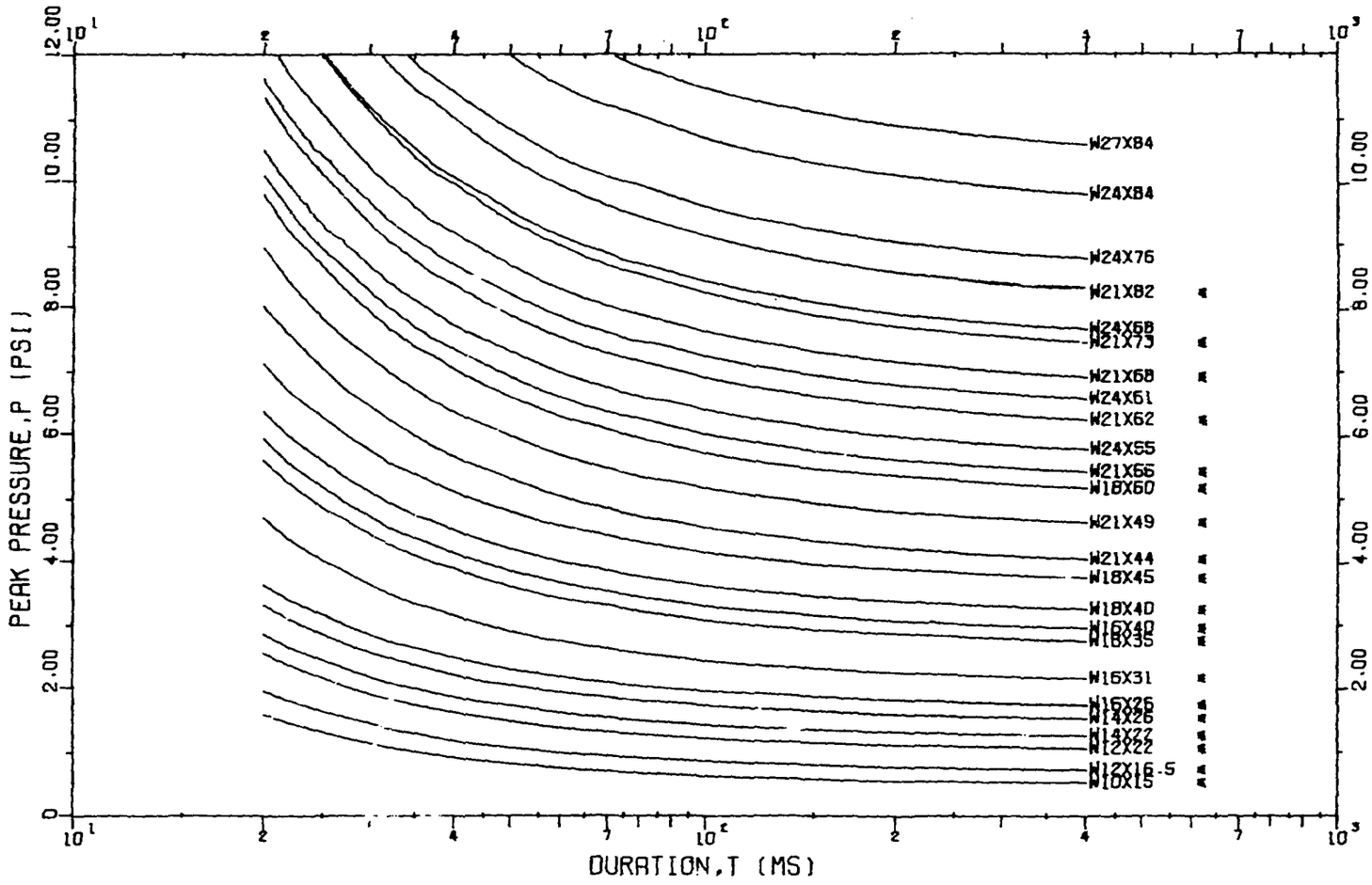


FIGURE 202

REUSABLE BEAM.SPAN=25 FT.SPACING=8 FT. SIMPLE-FIXED

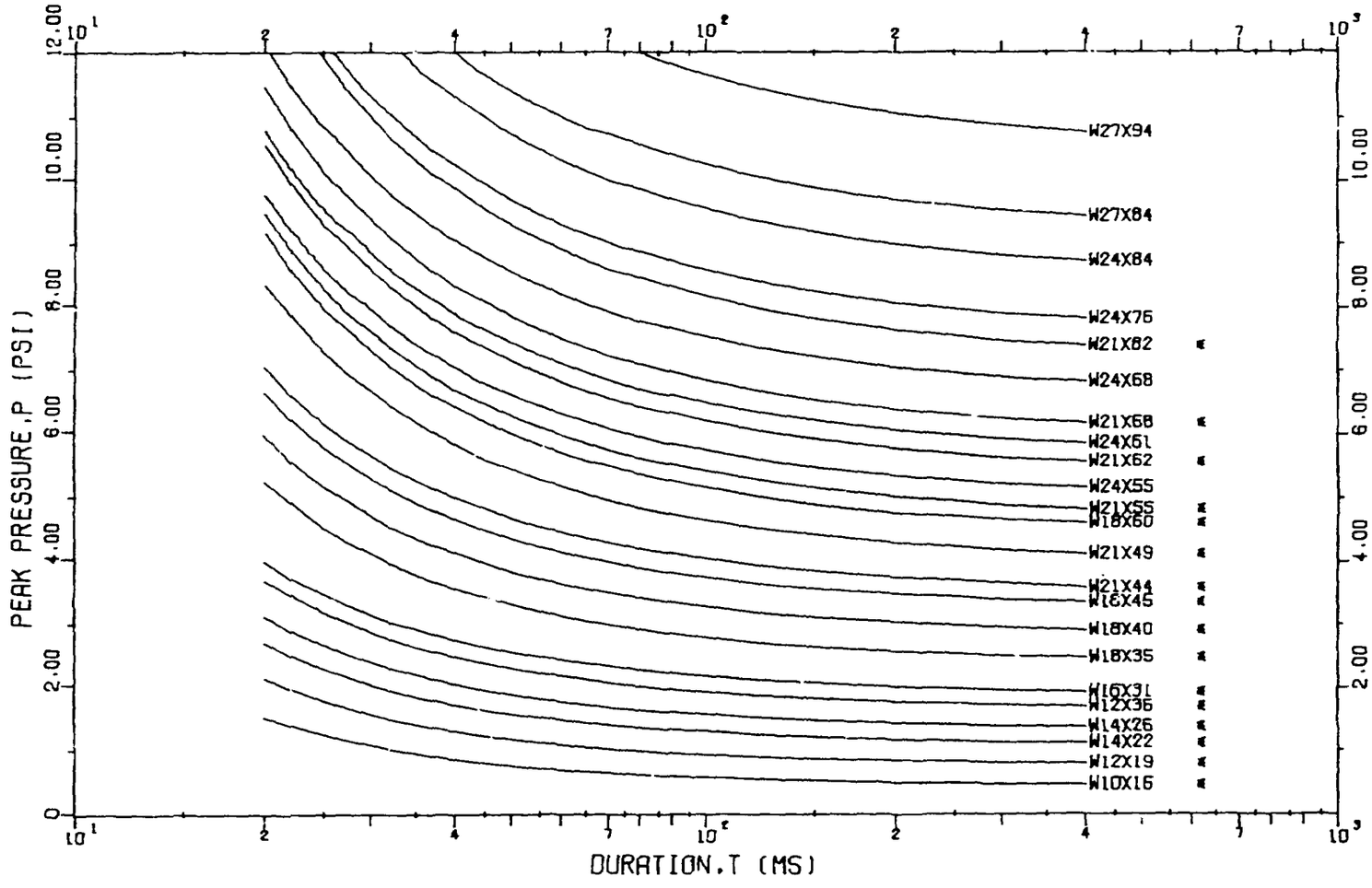


FIGURE 203

REUSABLE BEAM.SPAN= 25 FT.SPACING= 9 FT. SIMPLE-FIXED

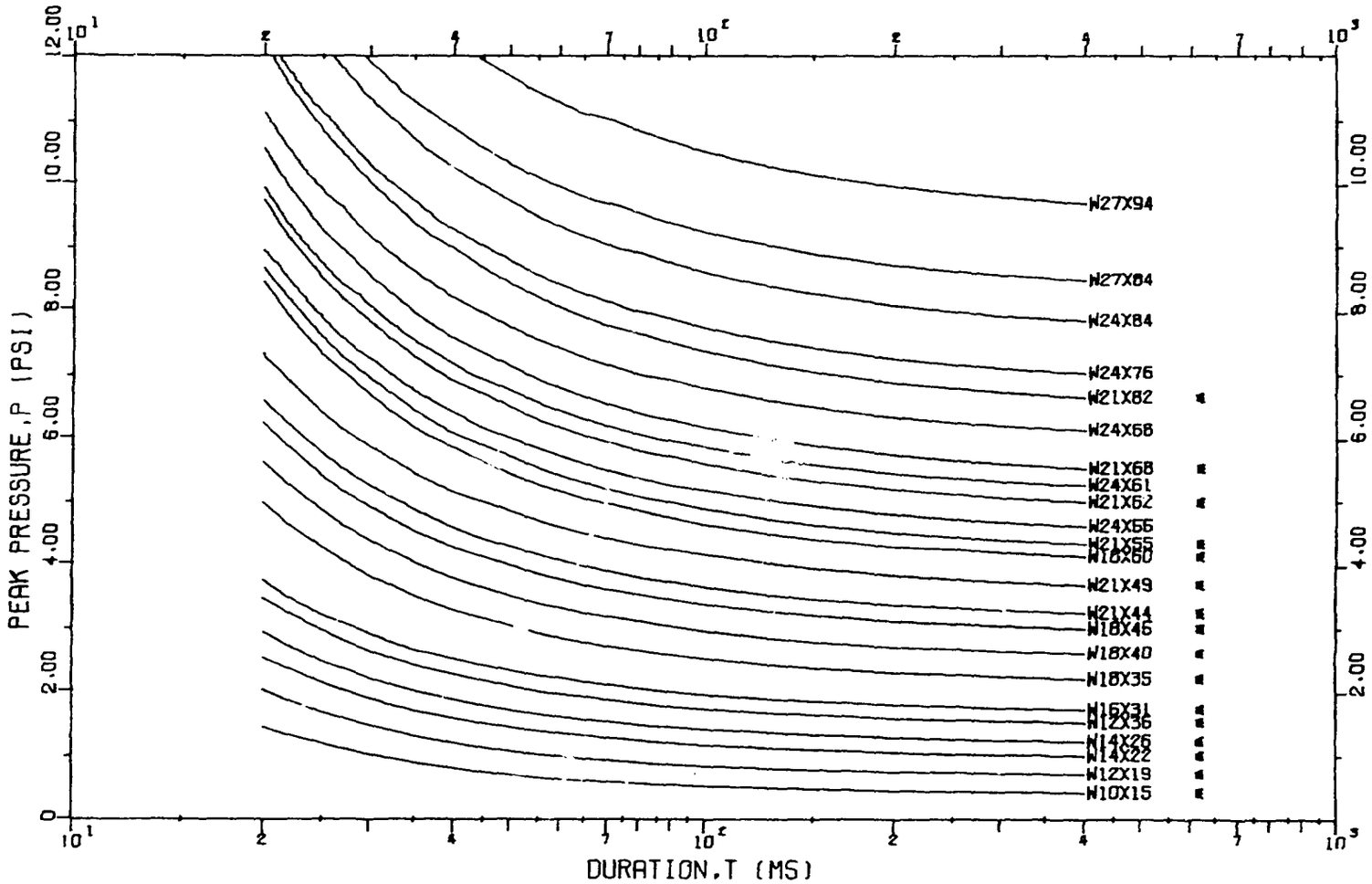


FIGURE 204

REUSABLE BEAM,SPAN=25 FT,SPACING=10FT, SIMPLE-FIXED

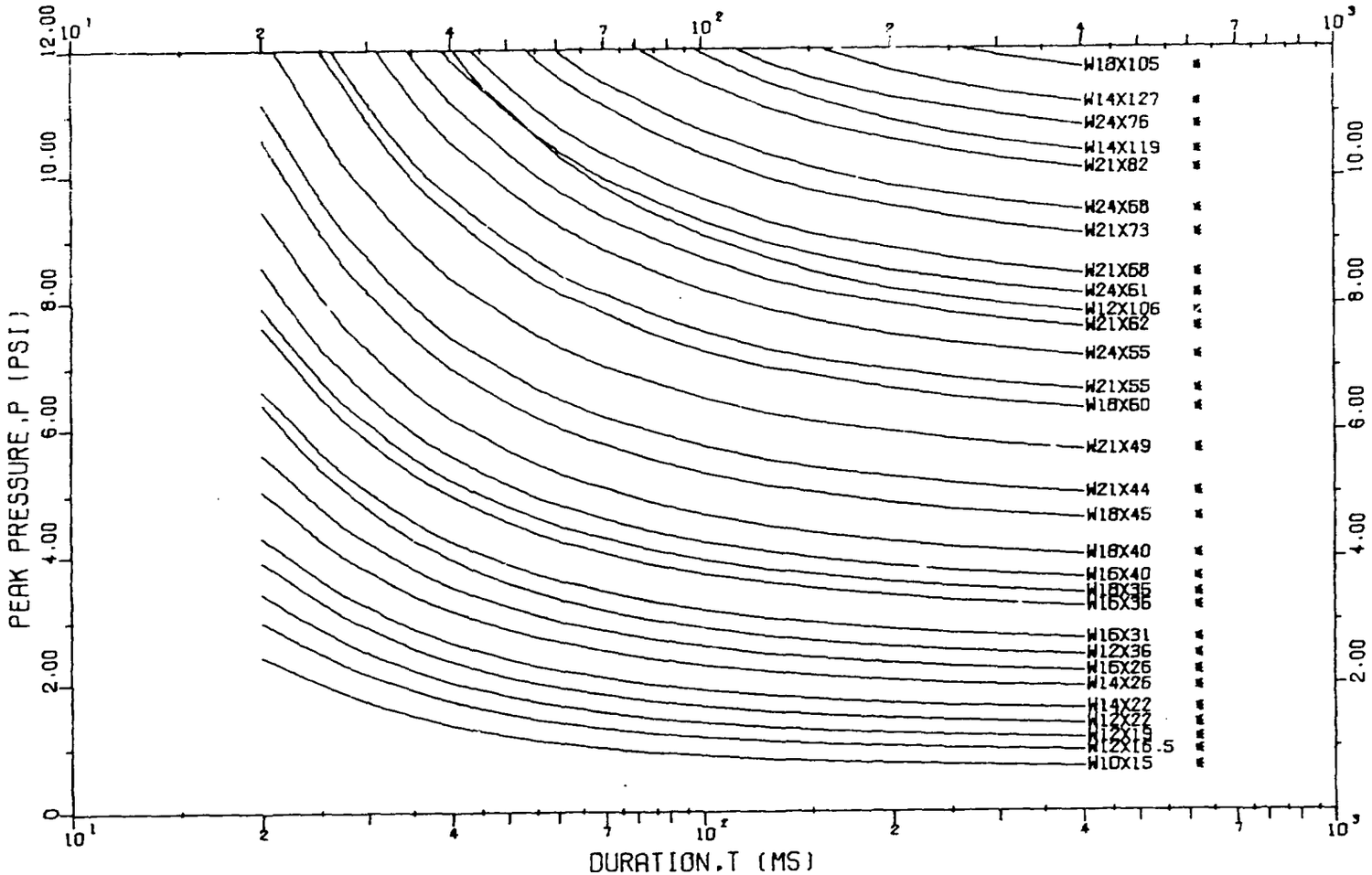


FIGURE 205

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=5 FT. SIMPLY-SUPPORTED

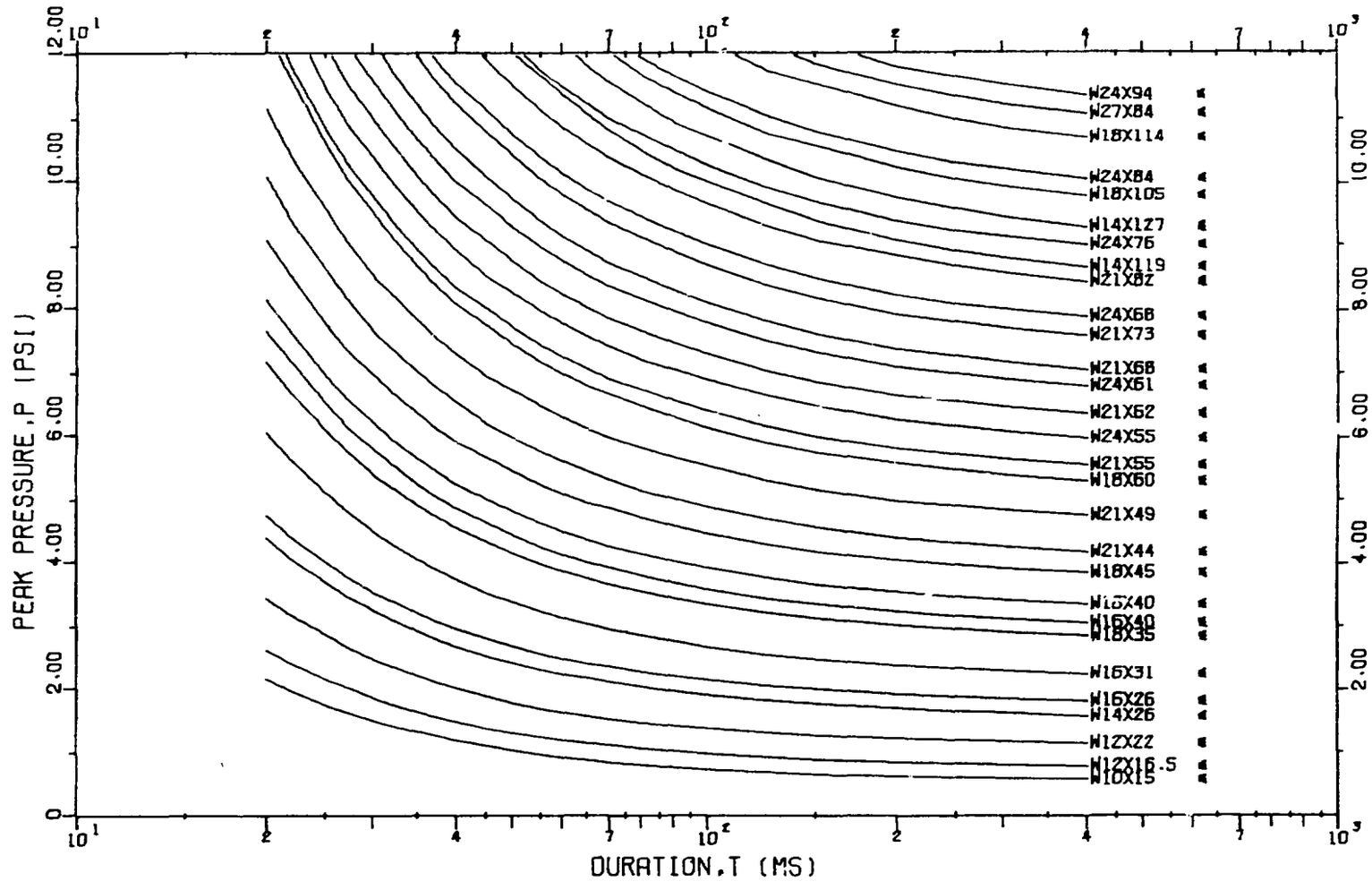


FIGURE 206

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=6 FT, SIMPLY-SUPPORTED

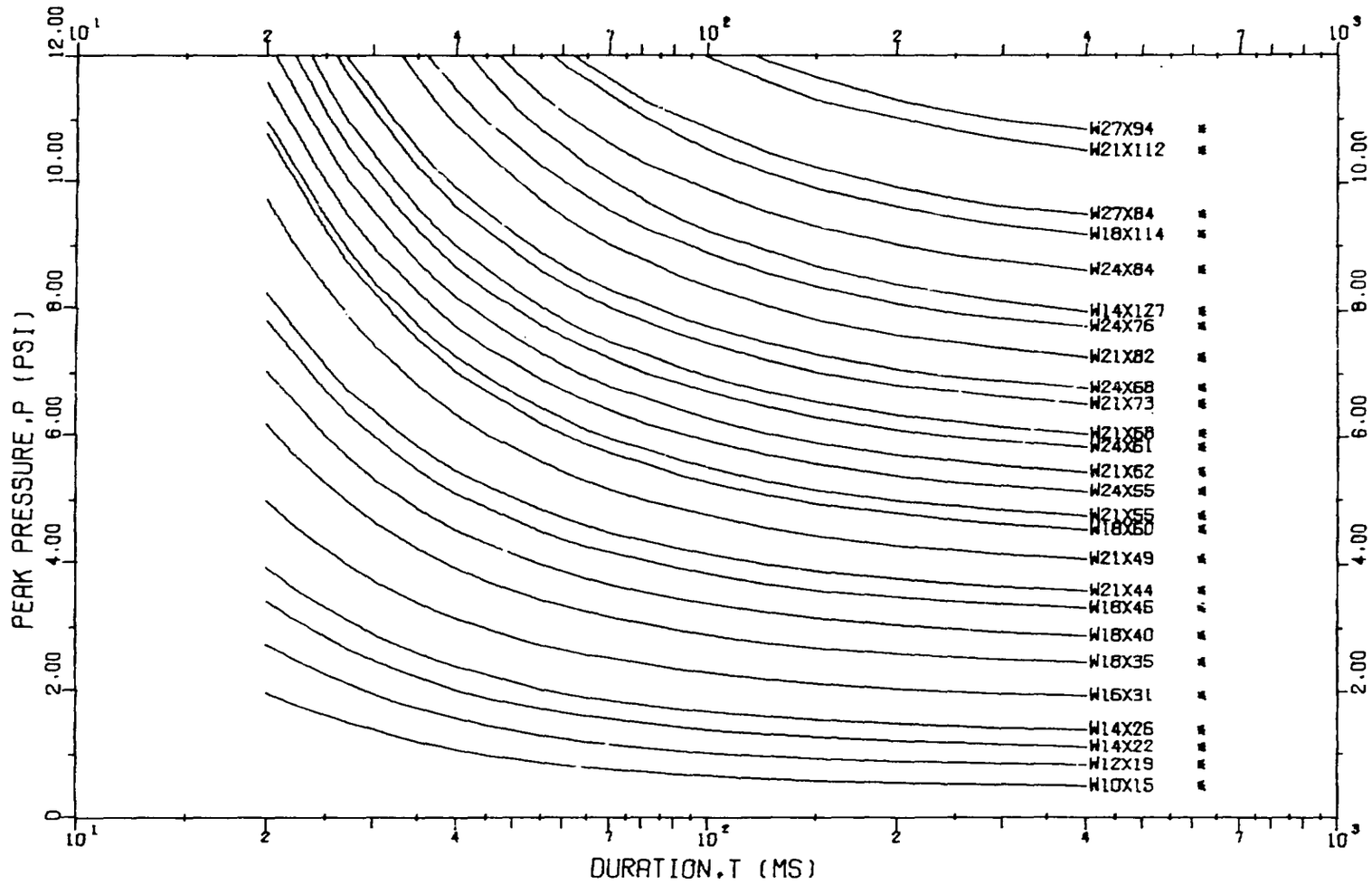


FIGURE 207

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=7 FT. SIMPLY-SUPPORTED

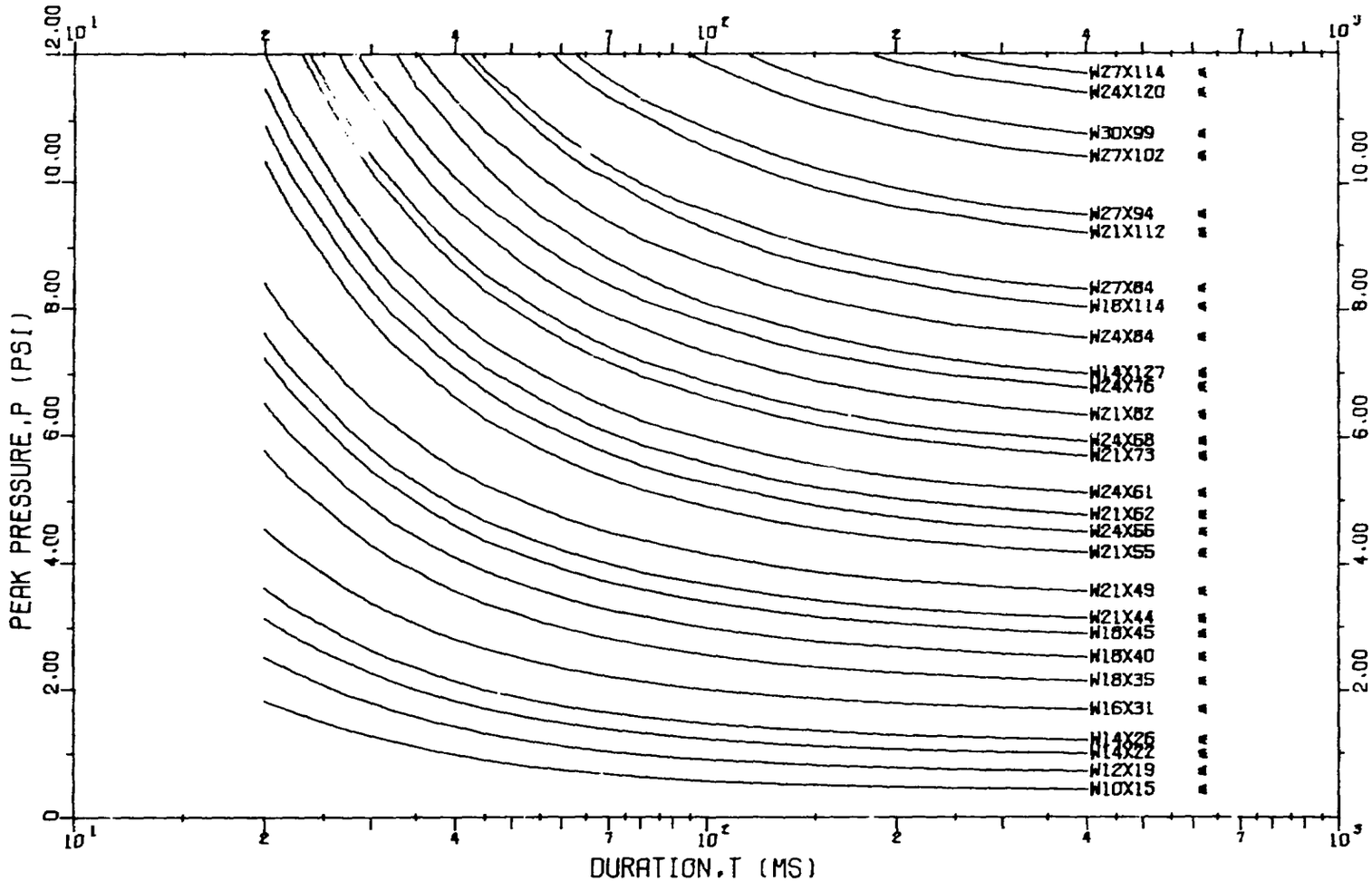


FIGURE 208

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=8 FT. SIMPLY-SUPPORTED

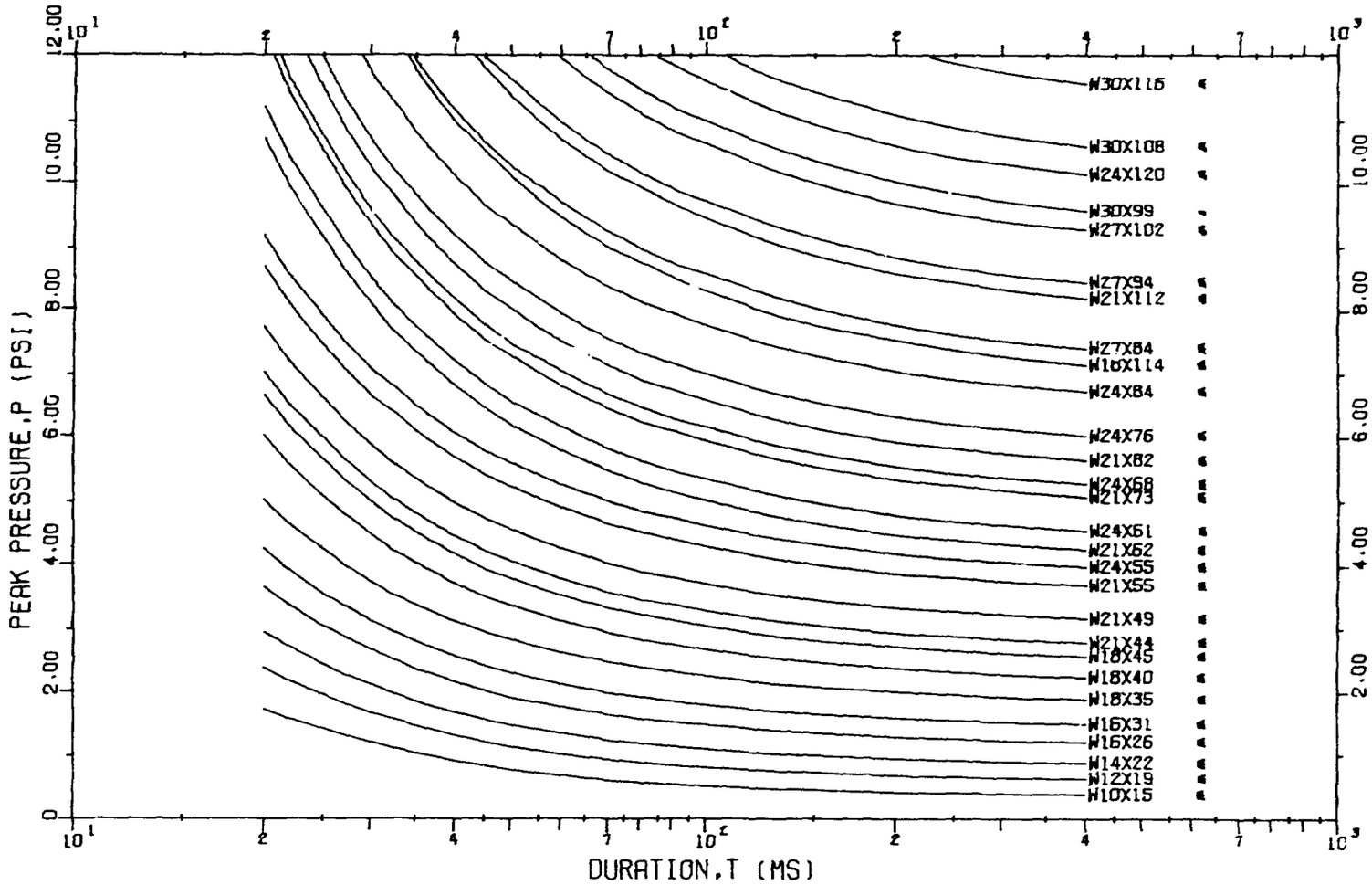


FIGURE 209

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=9 FT. SIMPLY-SUPPORTED

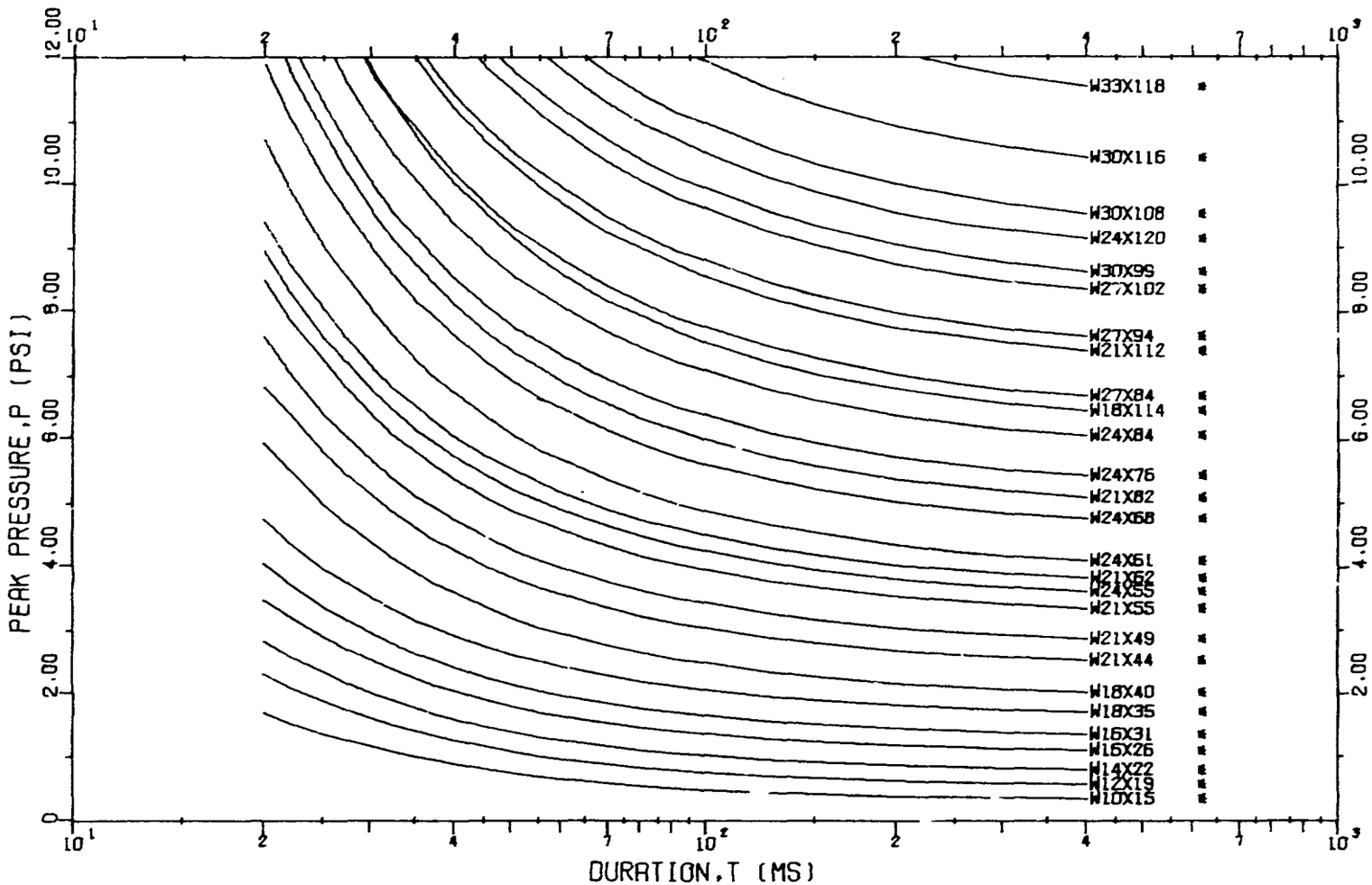


FIGURE 210

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING= 10 FT. SIMPLY-SUPPORTED

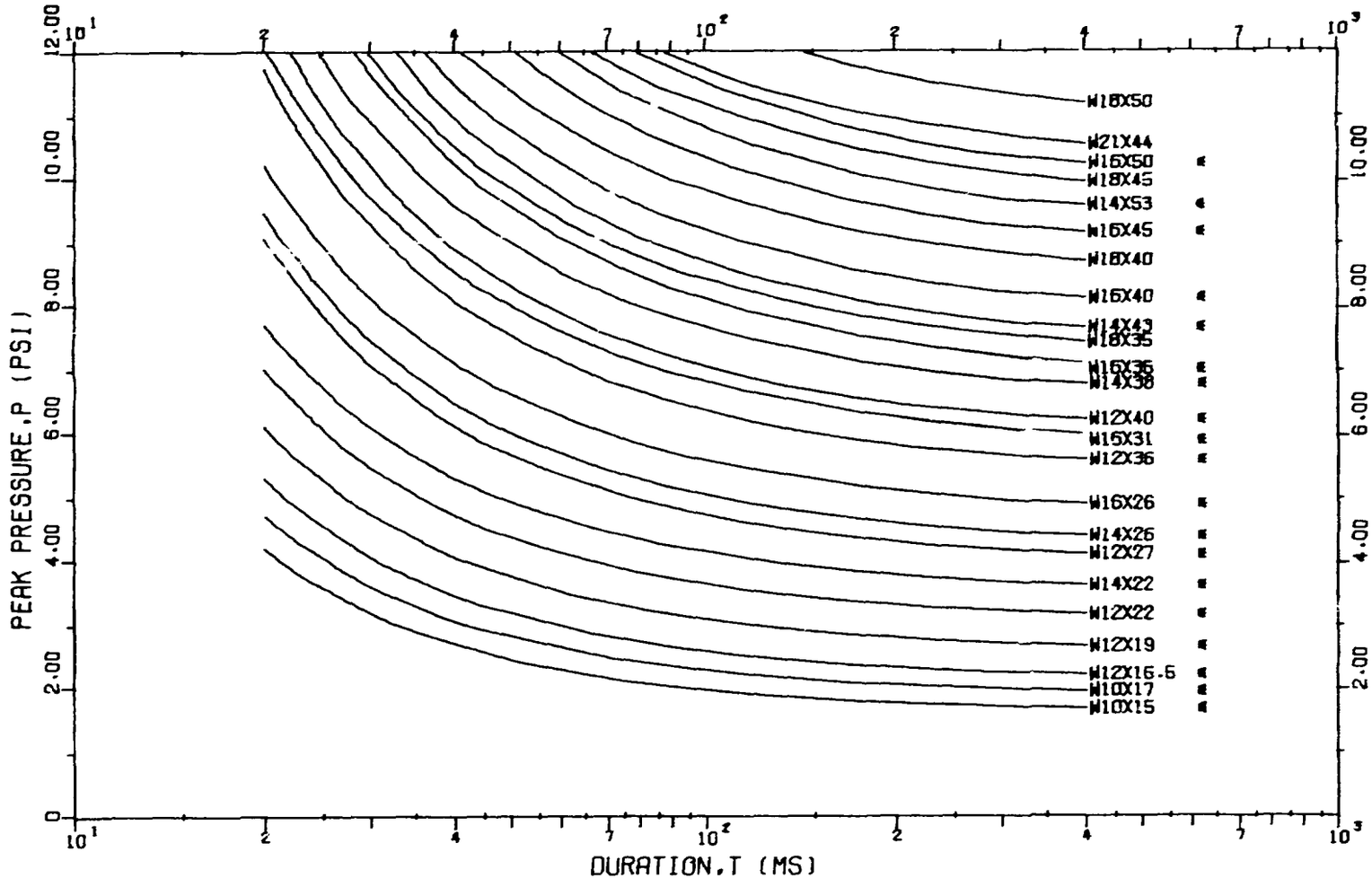


FIGURE 211

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=5 FT, FIXED ENDS

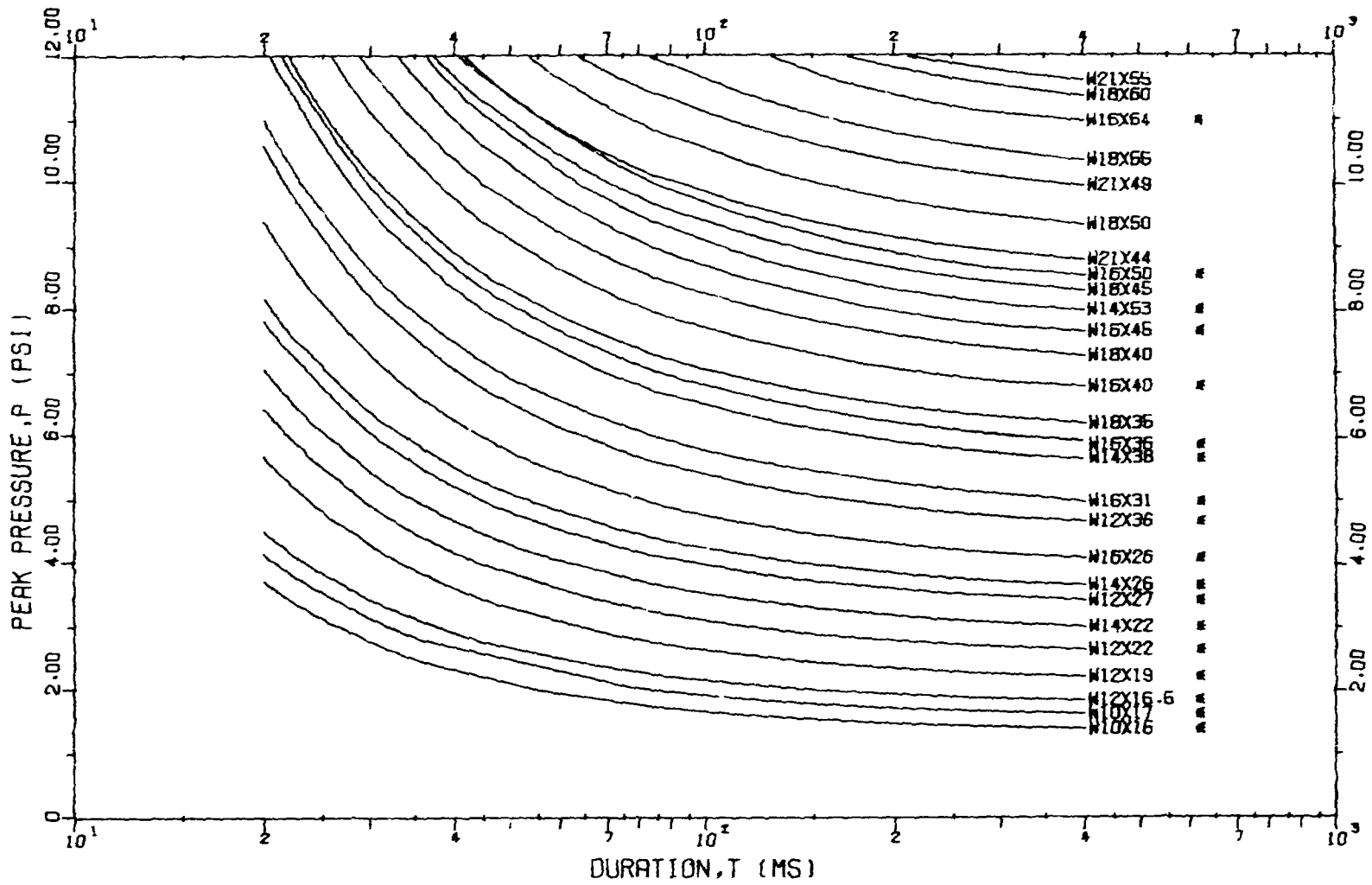


FIGURE 212

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=6 FT, FIXED ENDS

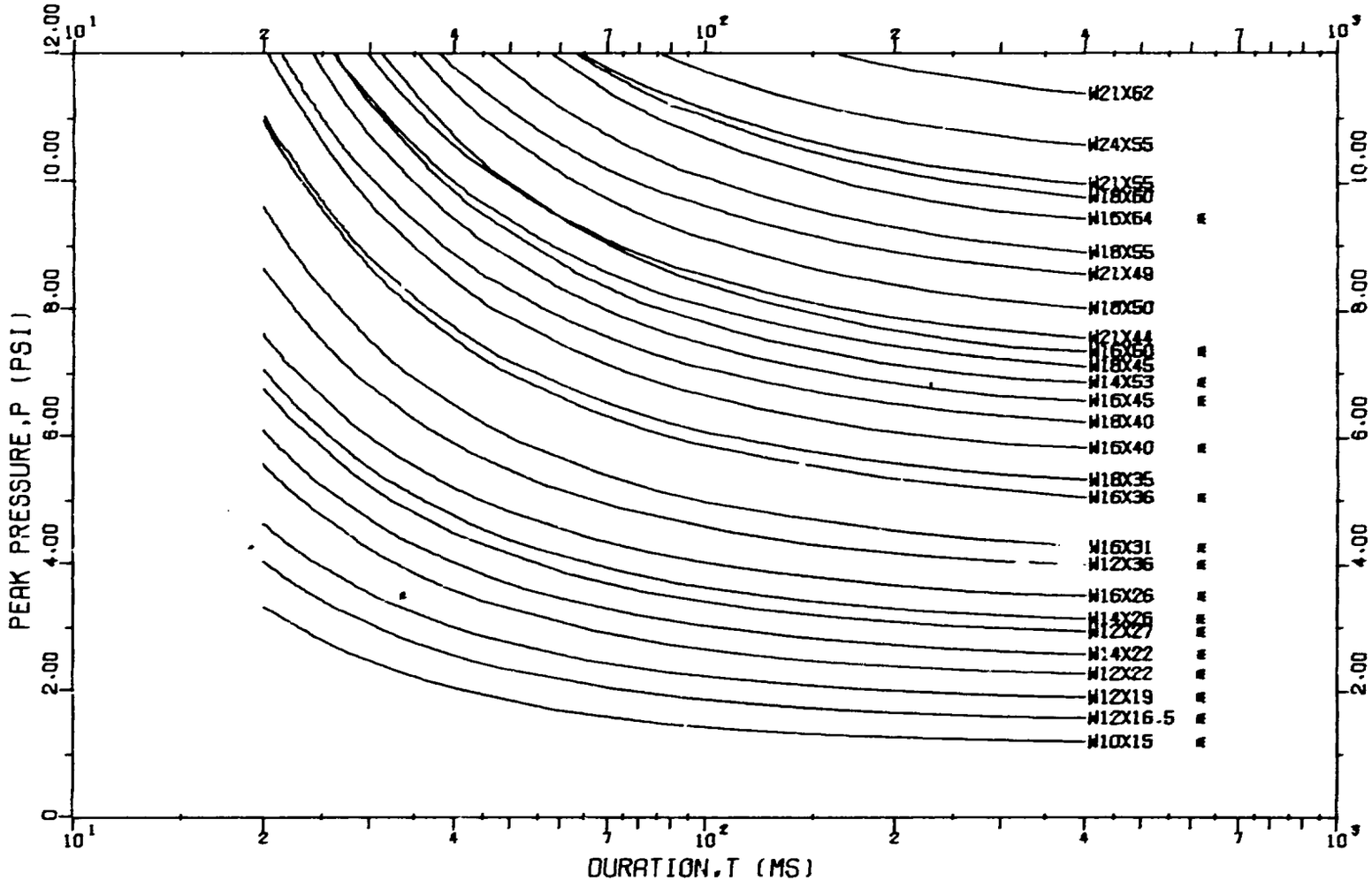


FIGURE 213

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=7 FT, FIXED ENDS

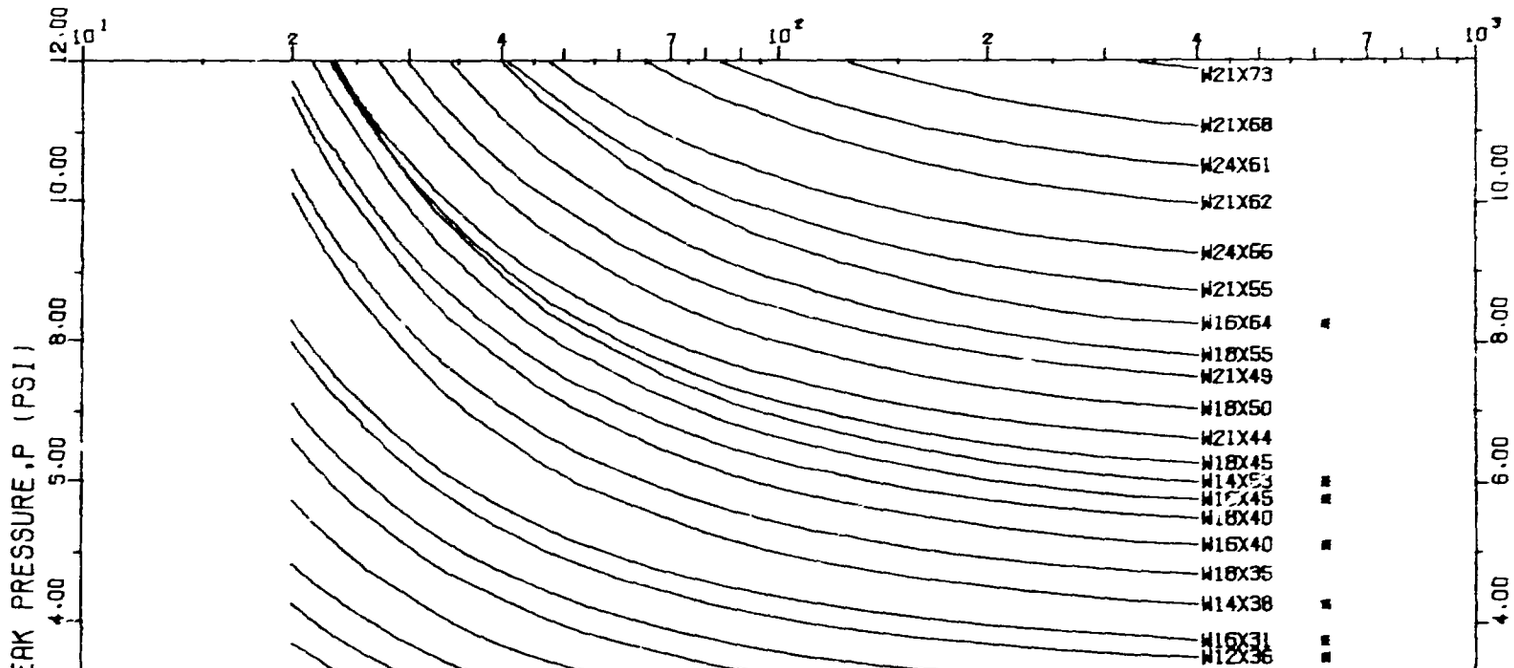


FIGURE 214

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=8 FT, FIXED ENDS

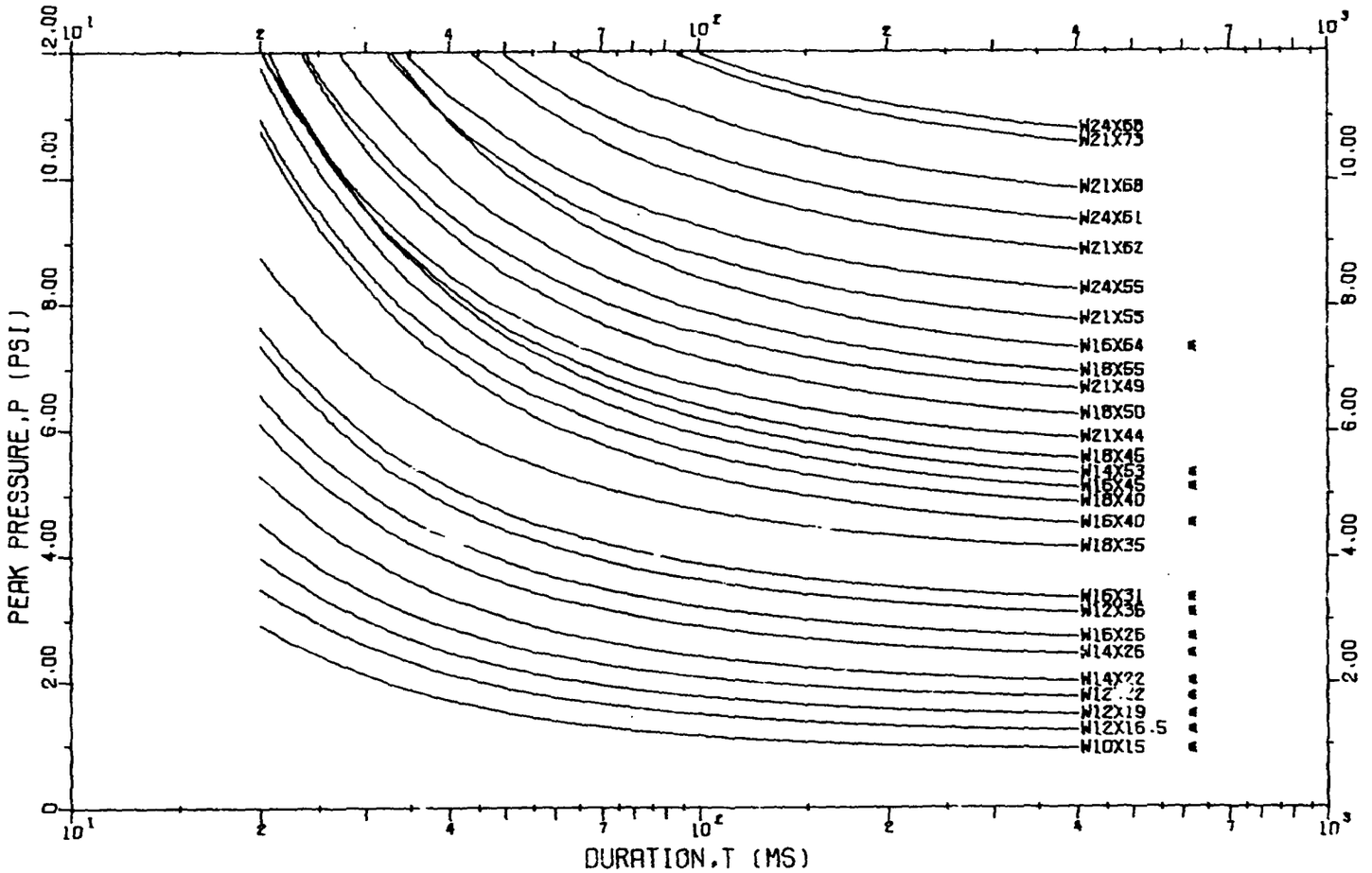


FIGURE 215

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=9 FT, FIXED ENDS

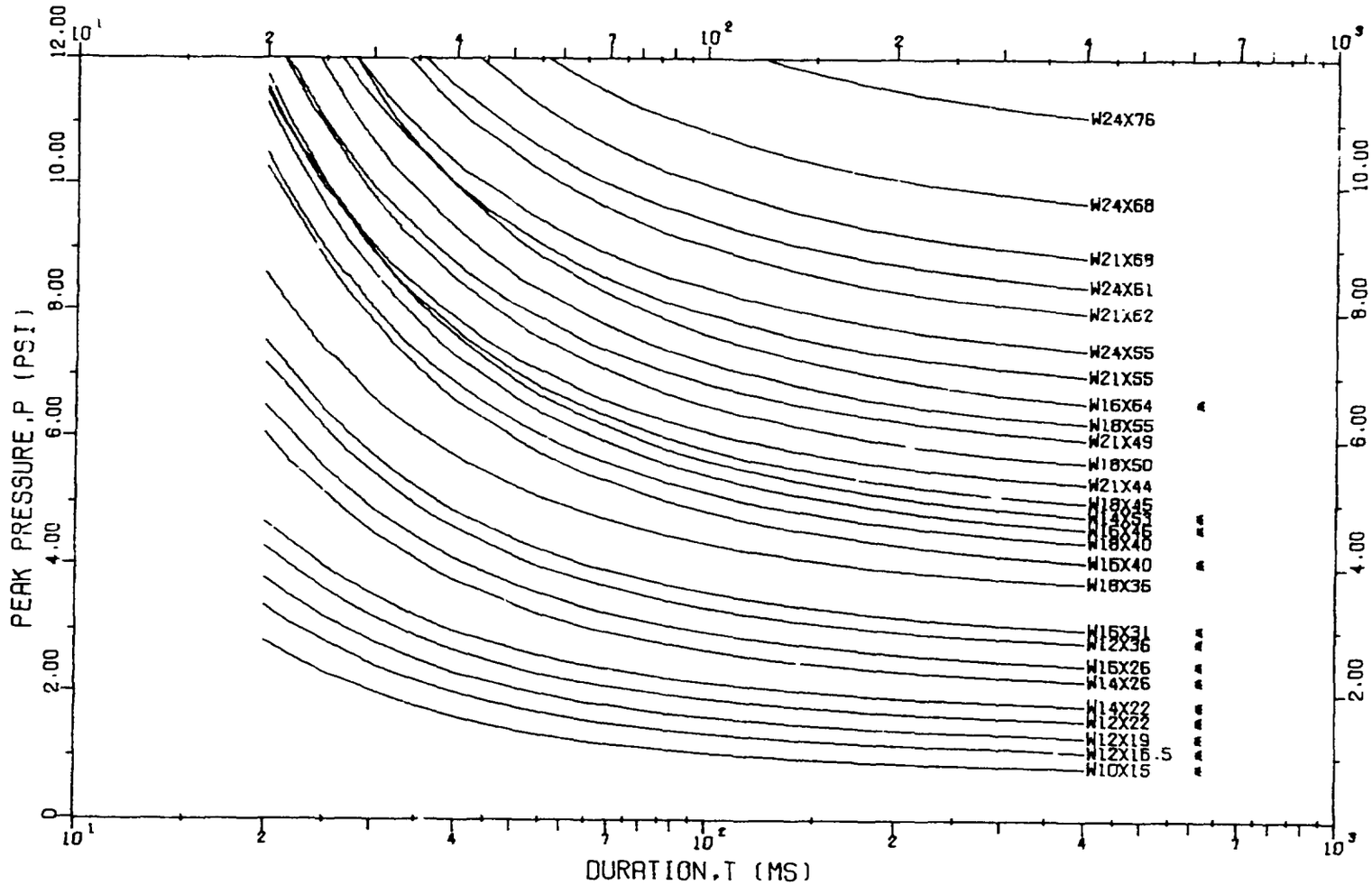


FIGURE 2:6

NON-REUSABLE BEAM.SPAN= 25 FT.SPACING= 10 FT. FIXED ENDS

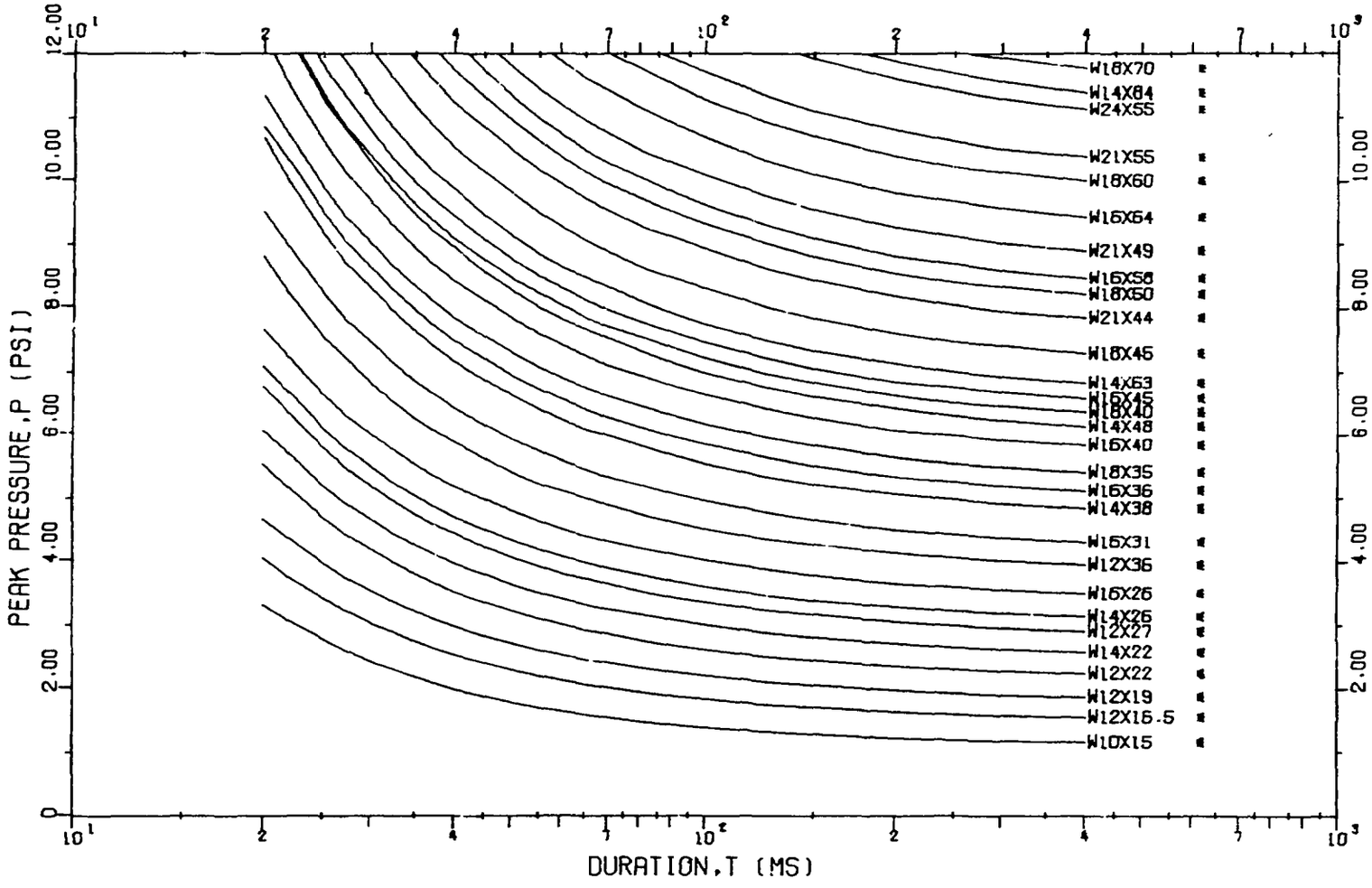


FIGURE 217

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=5 FT, SIMPLE-FIXED

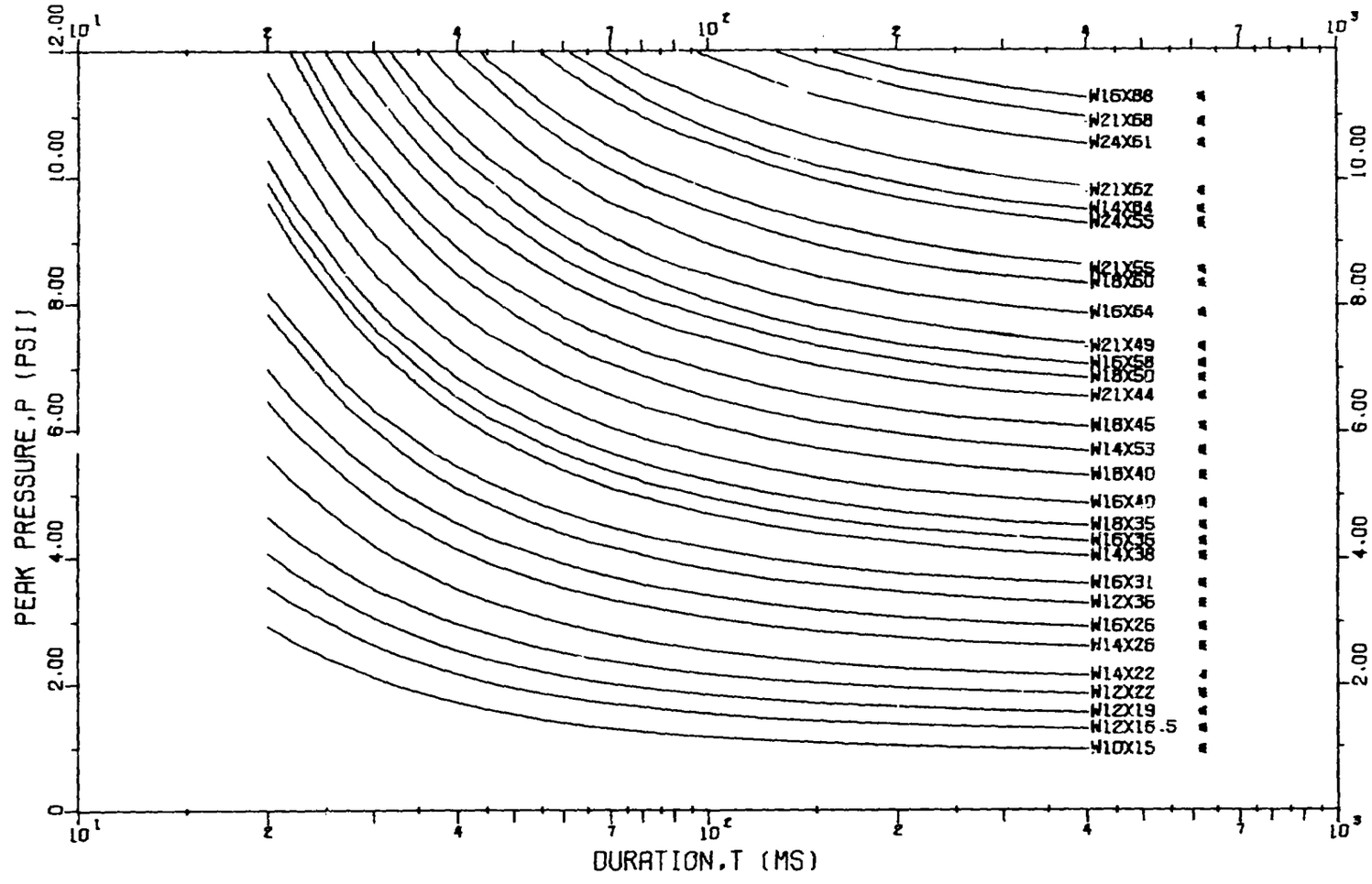


FIGURE 218

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=6 FT. SIMPLE-FIXED

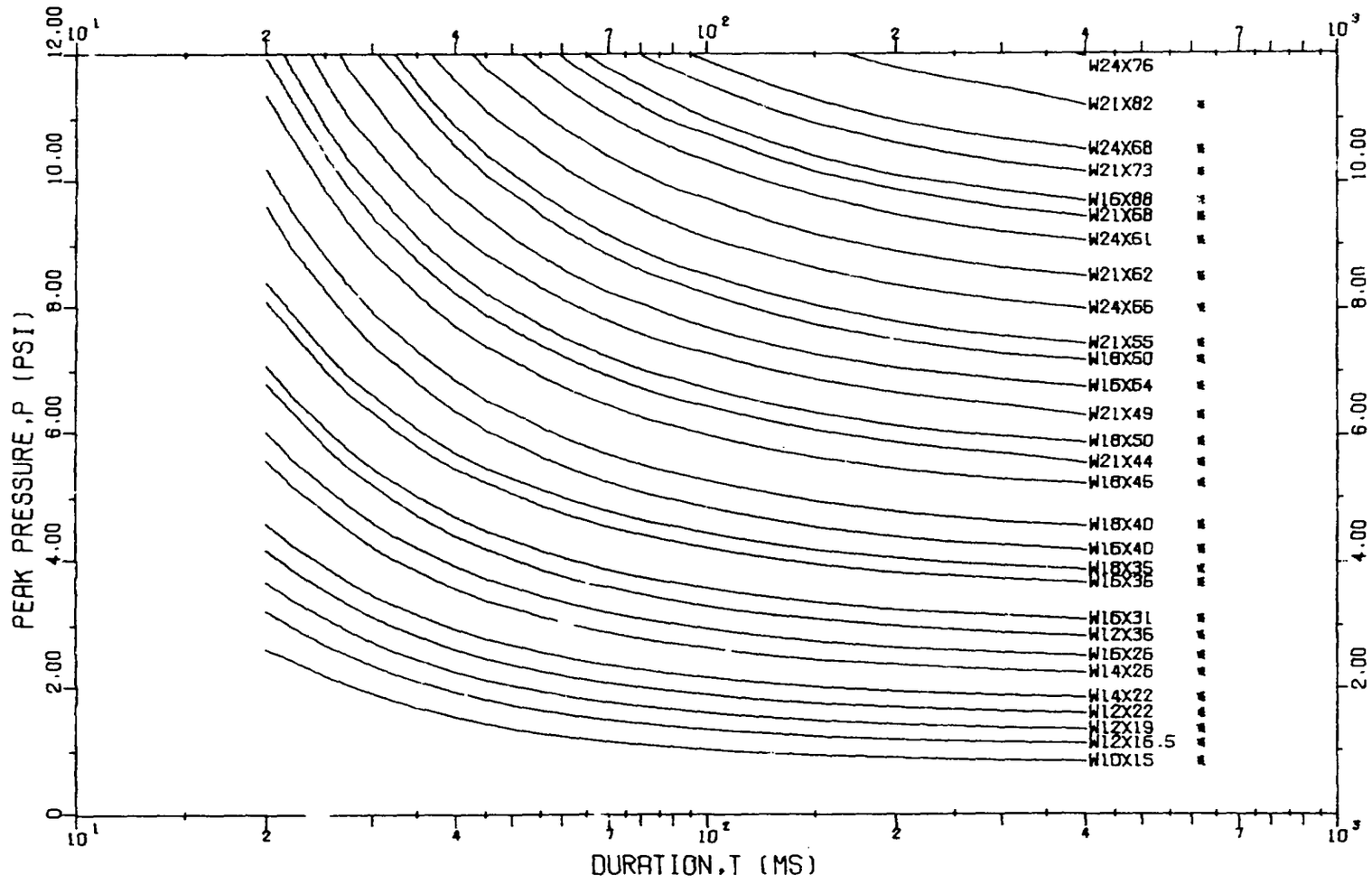


FIGURE 219

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=7 FT, SIMPLE-FIXED

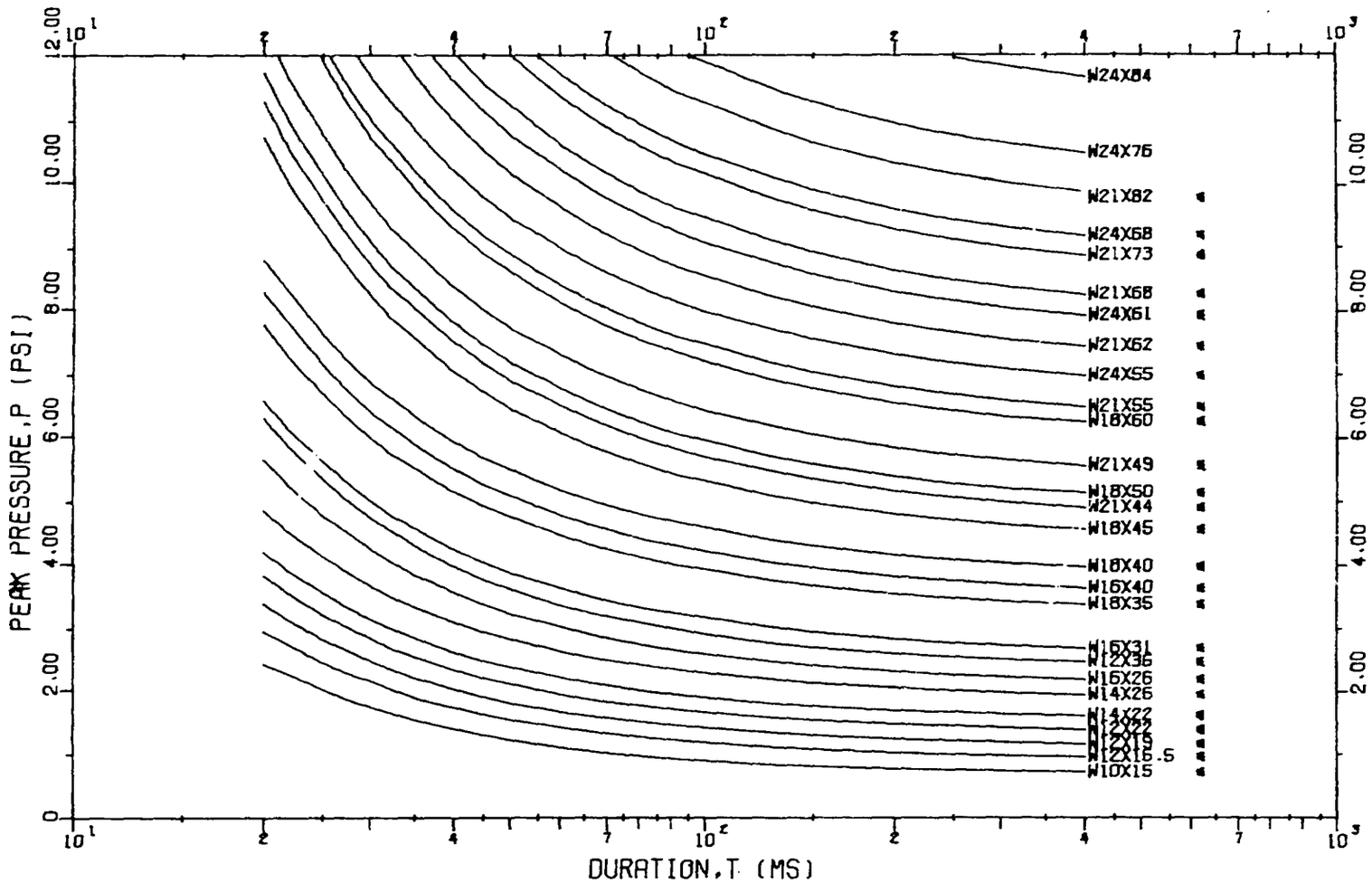


FIGURE 220

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=8 FT. SIMPLE-FIXED

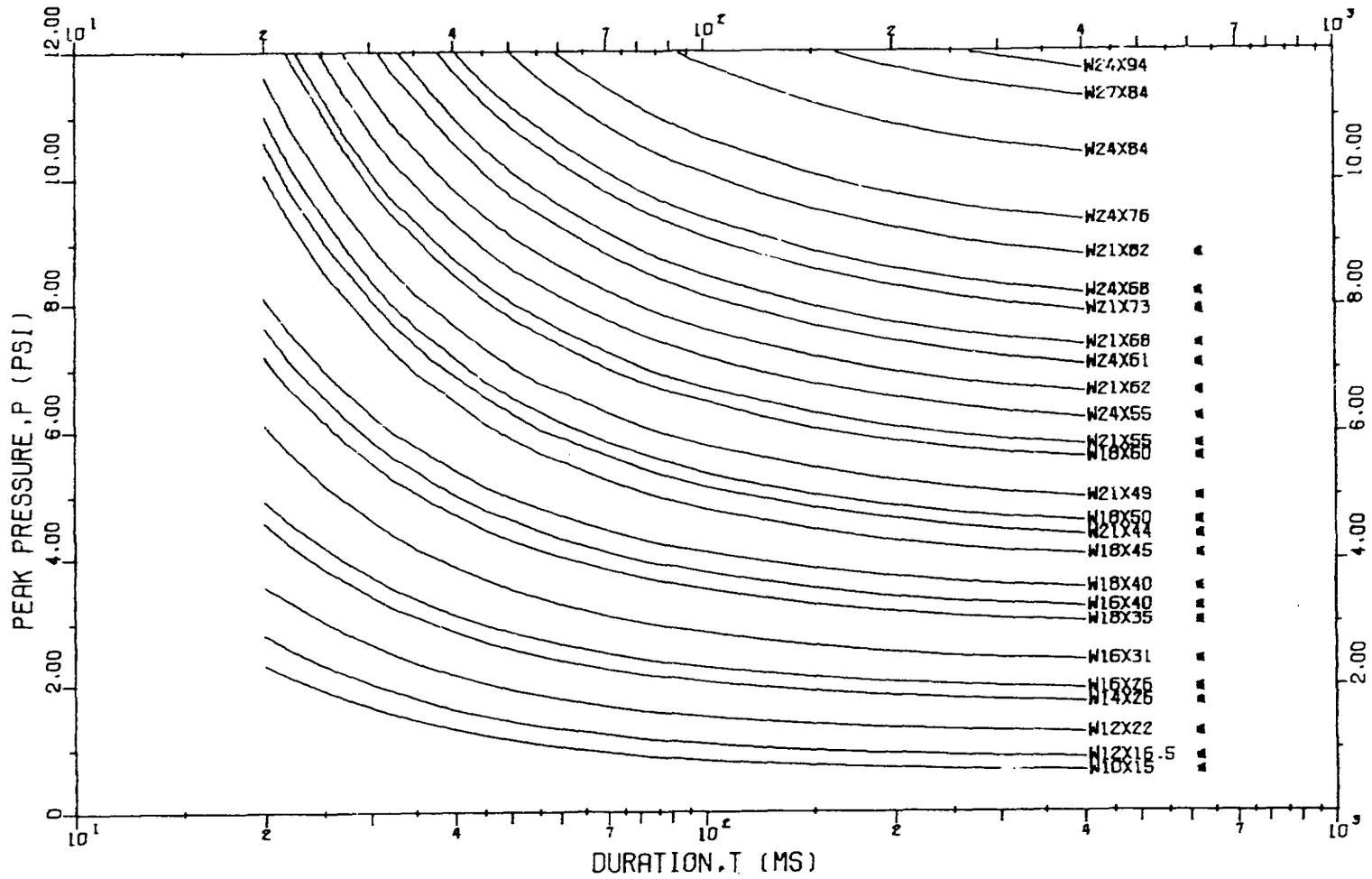


FIGURE 221

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING=9 FT, SIMPLE-FIXED

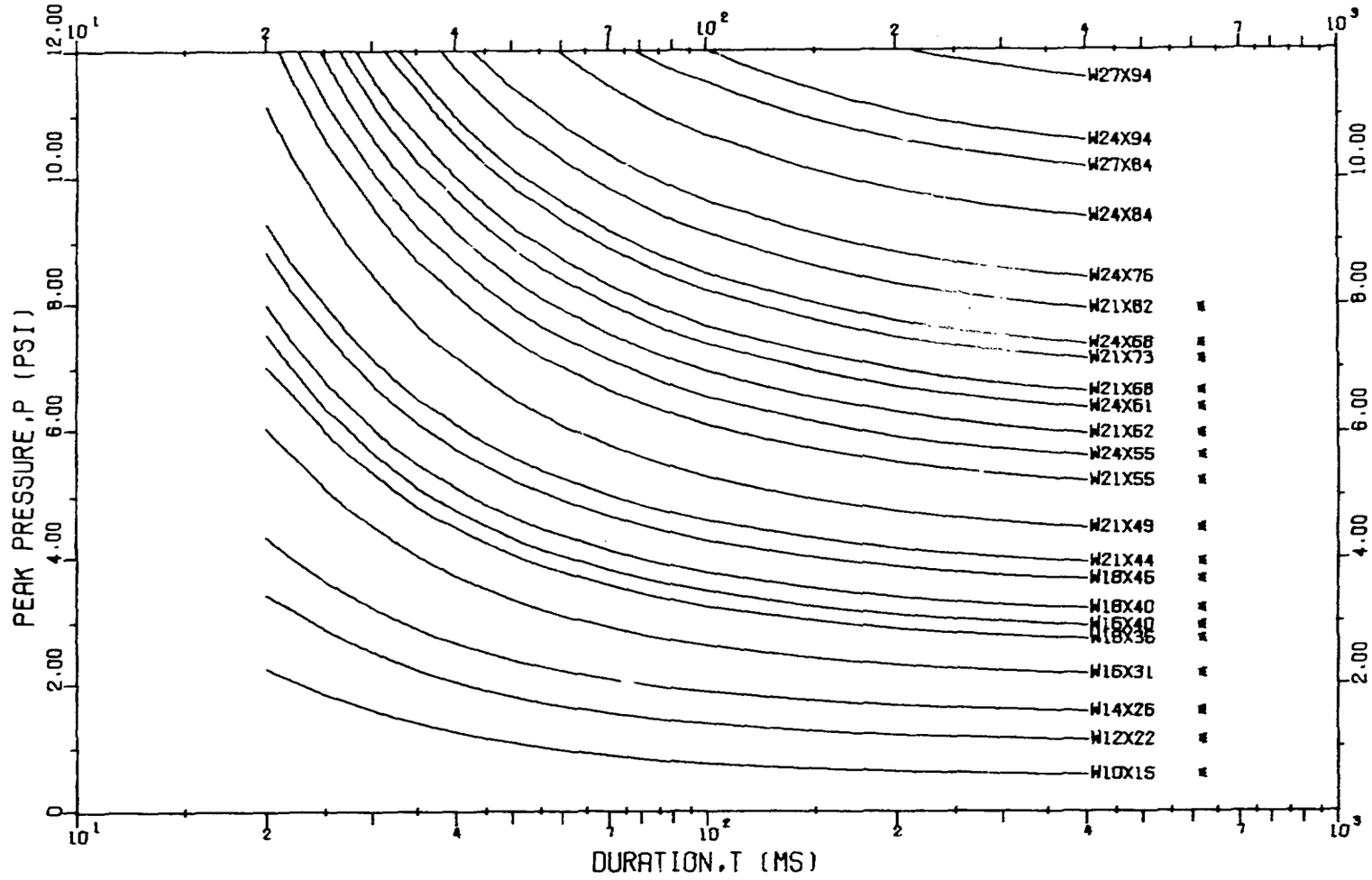


FIGURE 222

NON-REUSABLE BEAM,SPAN= 25 FT,SPACING= 10 FT. SIMPLE-FIXED

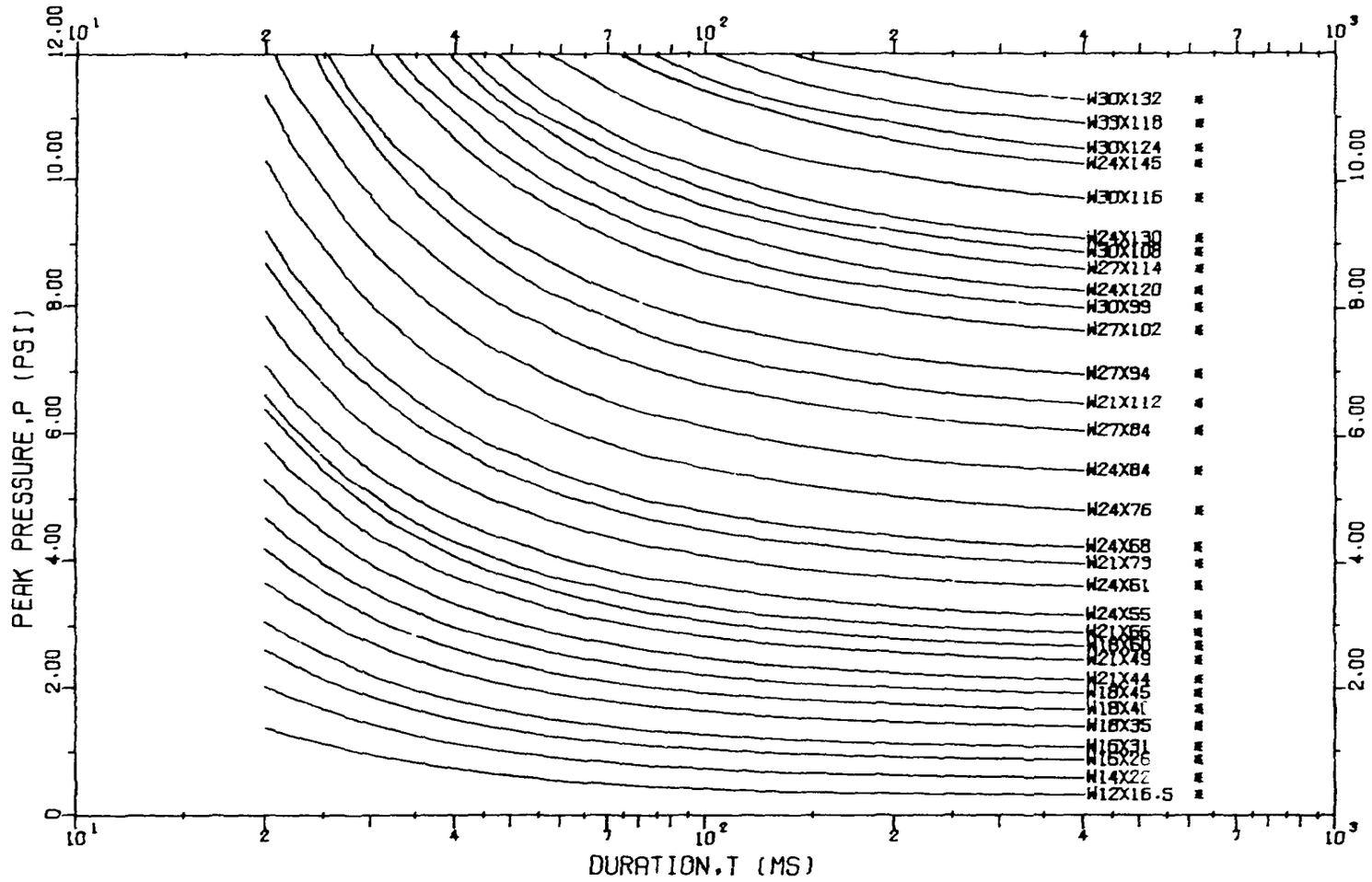


FIGURE 223

REUSABLE BEAM.SPAN= 30 FT.SPACING= 6 FT. SIMPLY-SUPPORTED

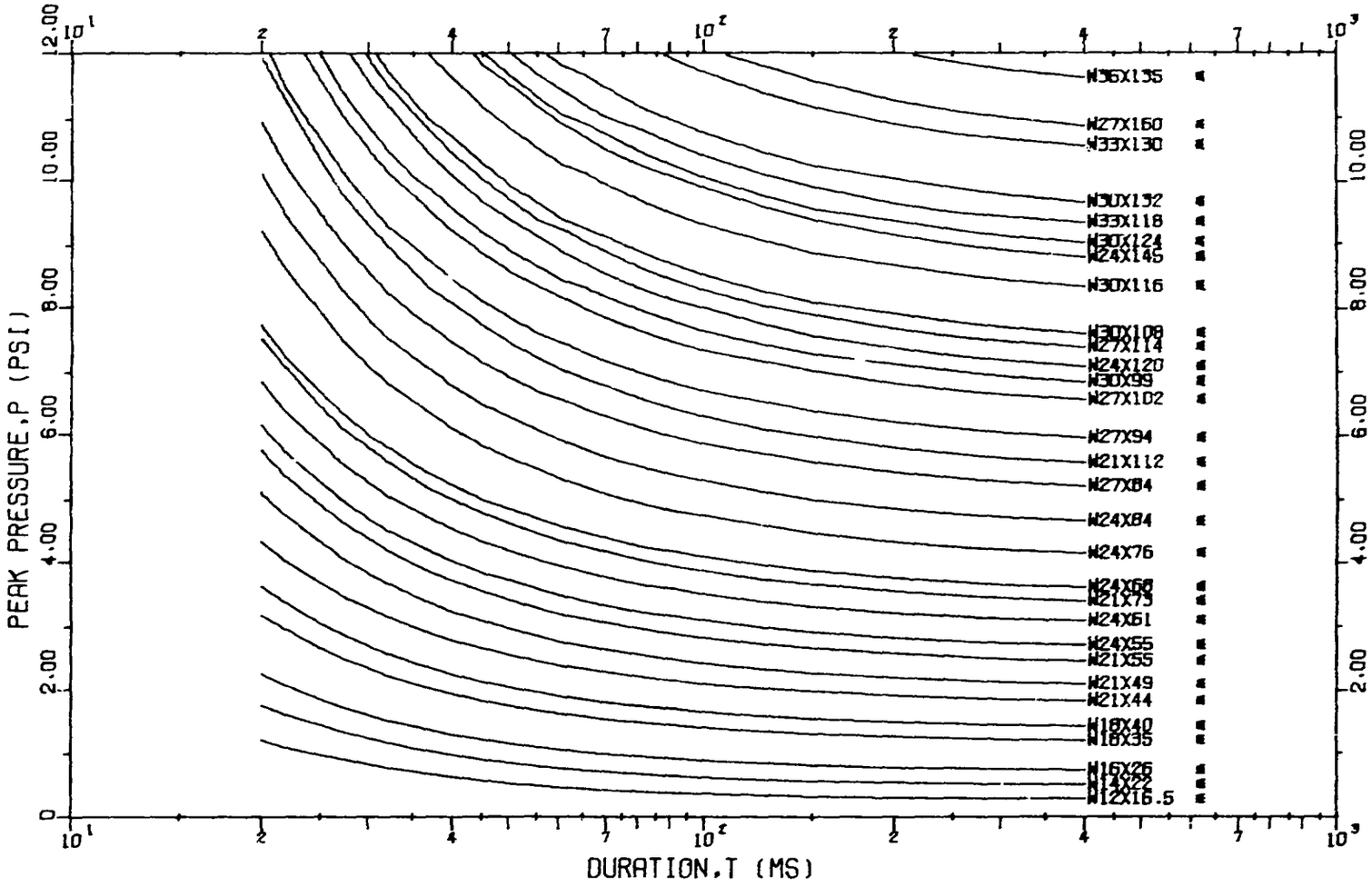


FIGURE 224

REUSABLE BEAM,SPAN=30 FT,SPACING=7 FT, SIMPLY-SUPPORTED

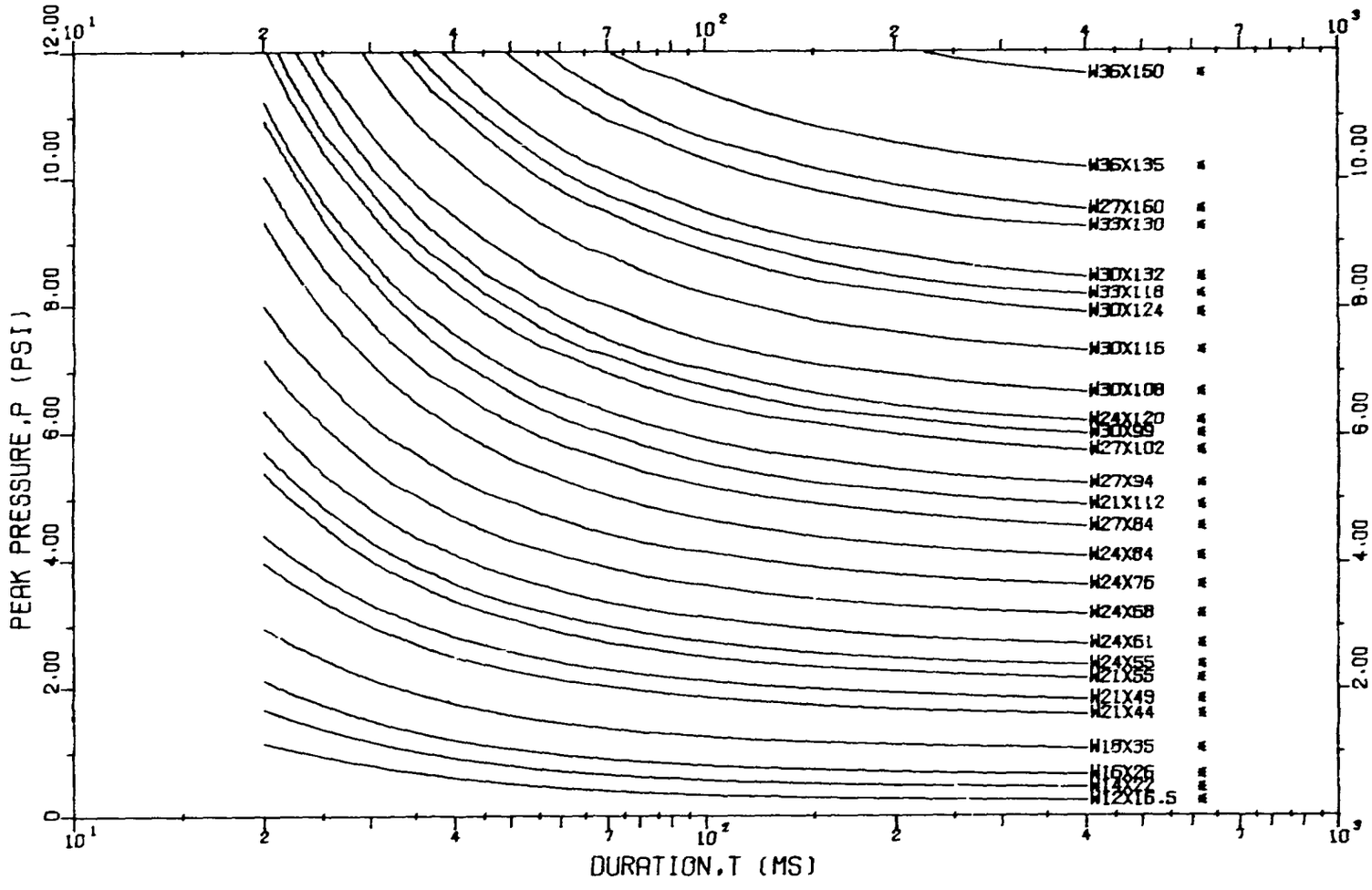


FIGURE 225

REUSABLE BEAM,SPAN=30 FT,SPACING=8 FT, SIMPLY-SUPPORTED

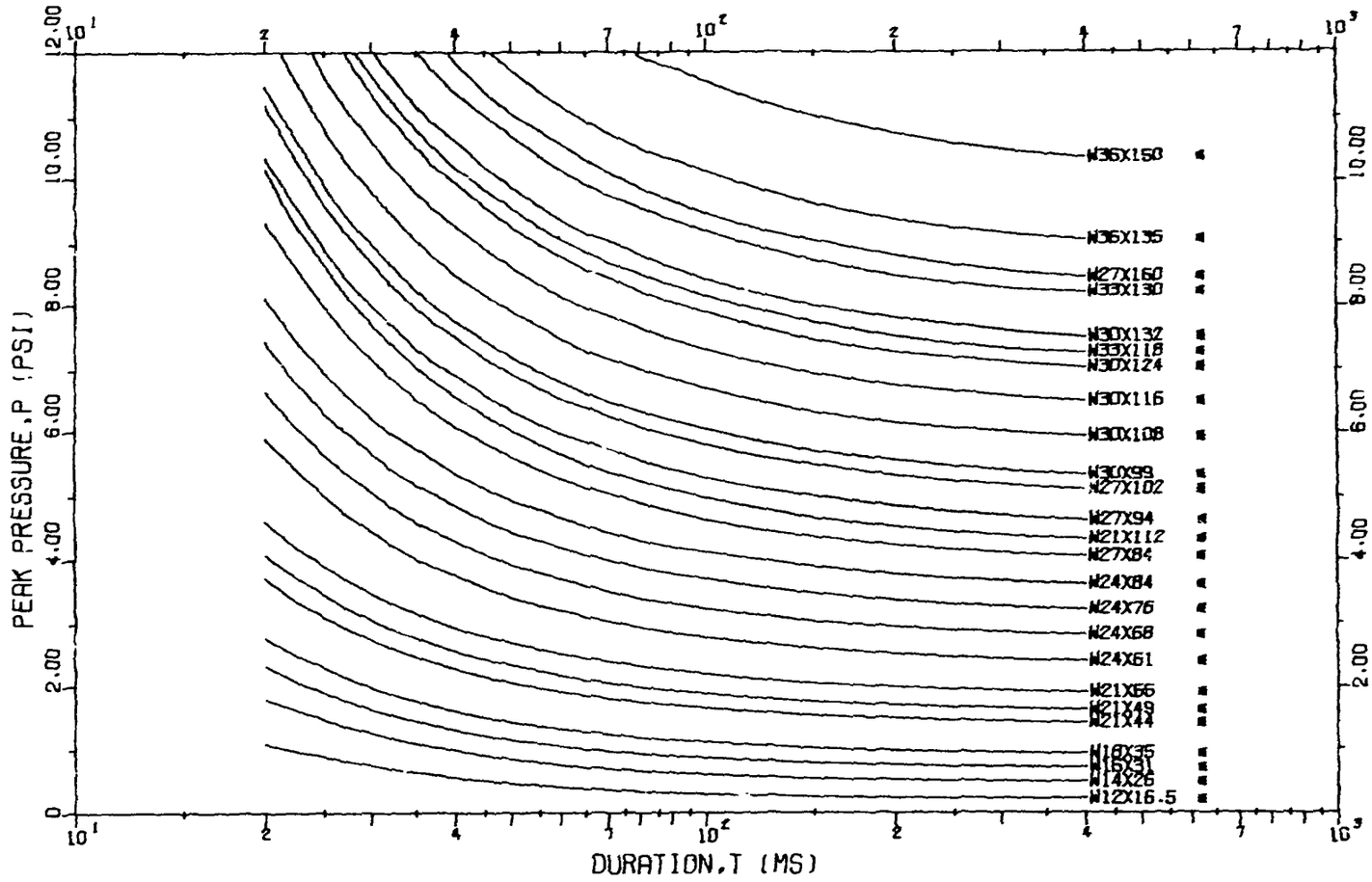


FIGURE 226

REUSABLE BEAM,SPAN=30 FT,SPACING=9 FT, SIMPLY-SUPPORTED

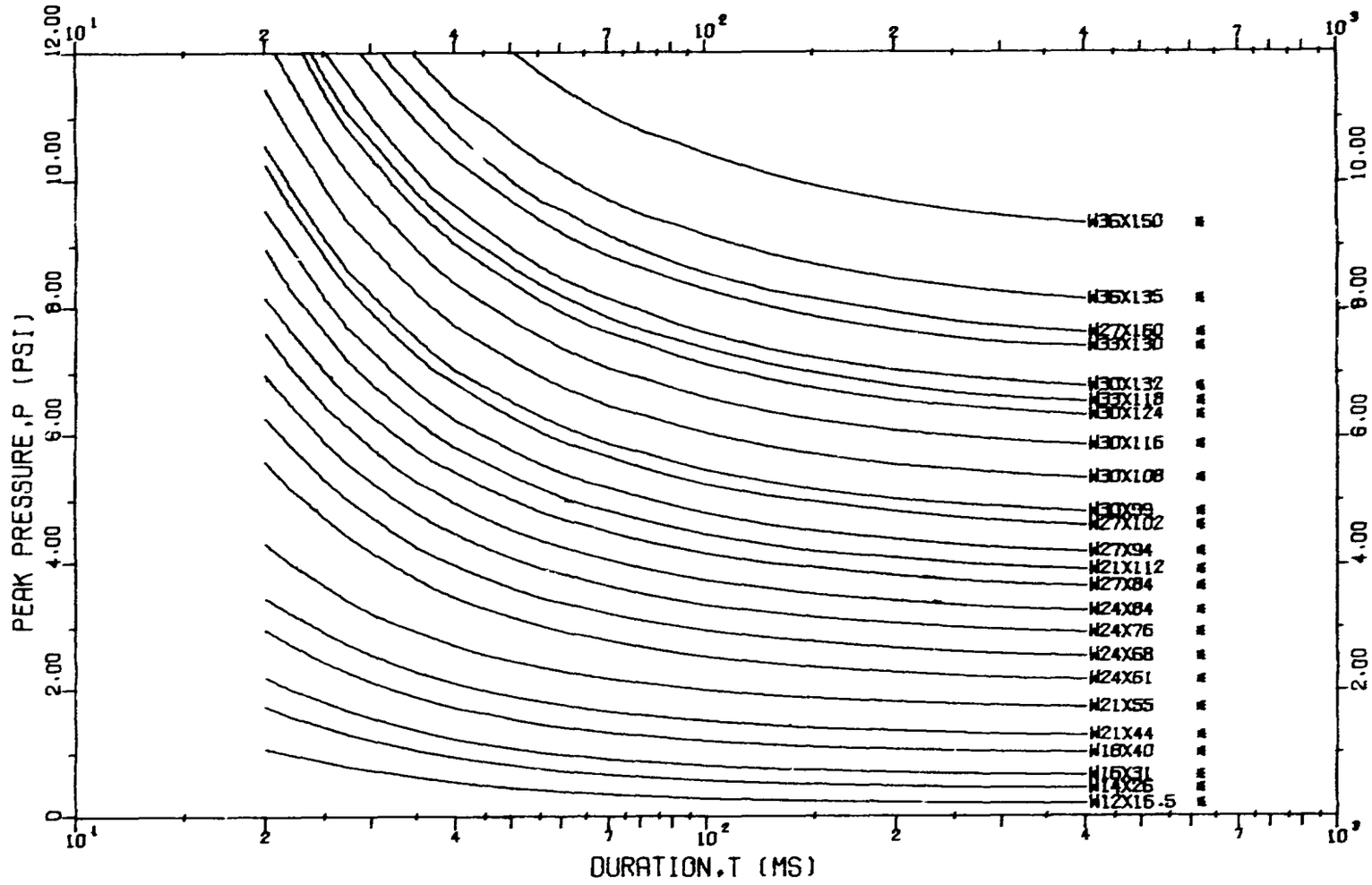


FIGURE 227

REUSABLE BEAM,SPAN=30 FT,SPACING=10FT, SIMPLY-SUPPORTED

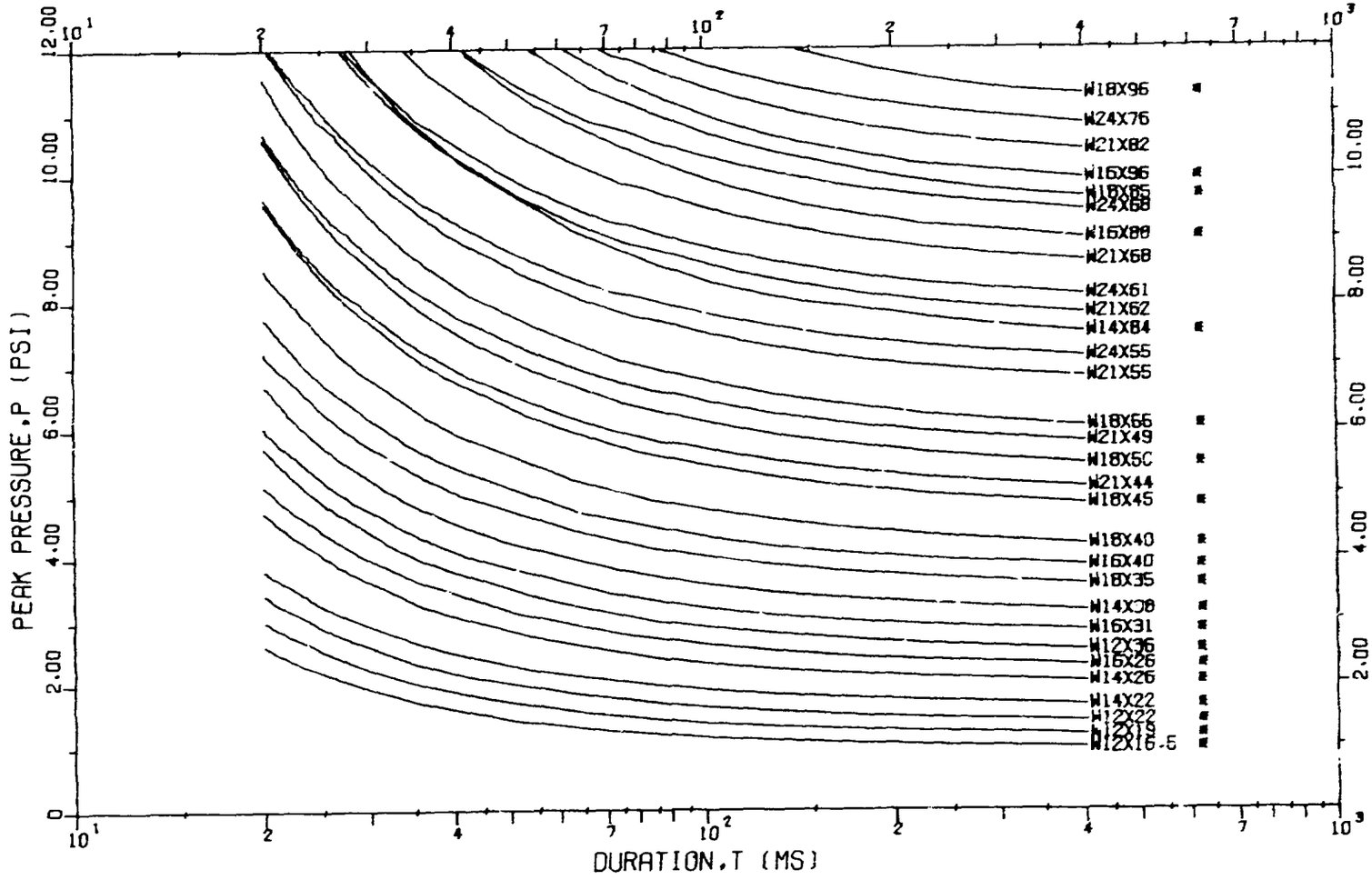


FIGURE 22a

REUSABLE BEAM,SPAN=30 FT,SPACING=6 FT, FIXED ENDS

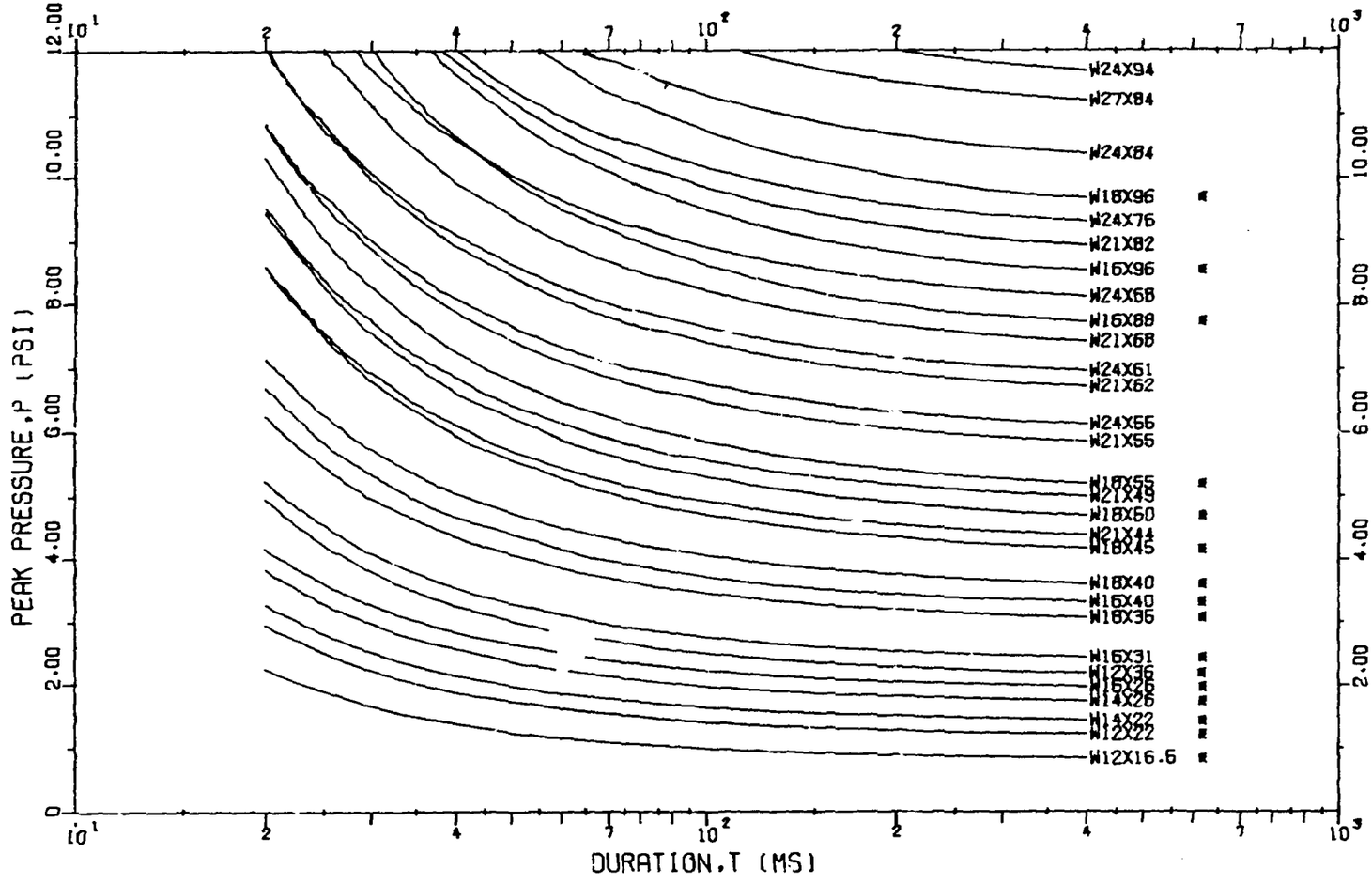


FIGURE 229

REUSABLE BEAM,SPAN=30 FT,SPACING=7 FT, FIXED ENDS

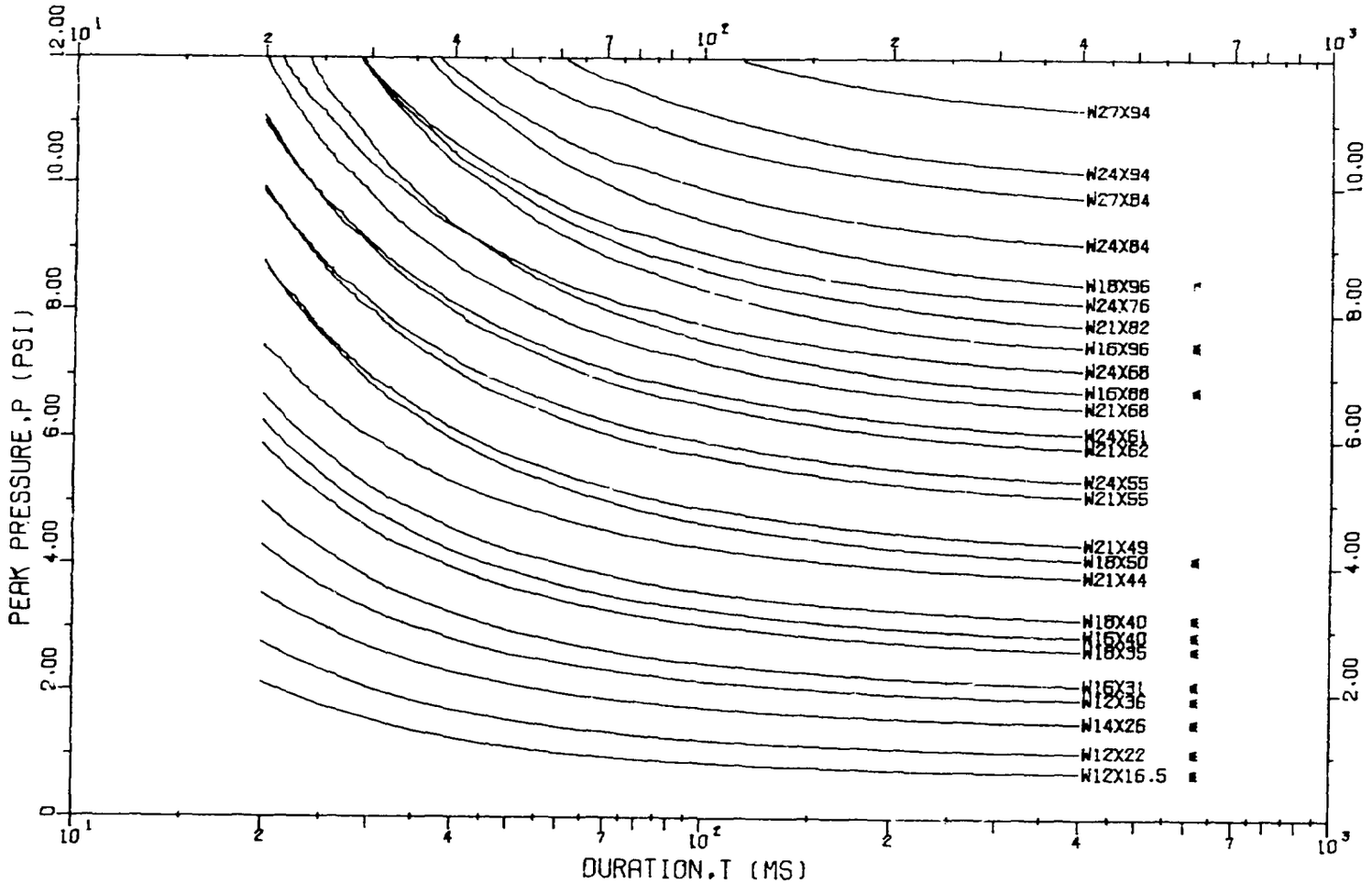


FIGURE 23C

REUSABLE BEAM,SPAN= 30 FT,SPACING= 8 FT, FIXED ENDS

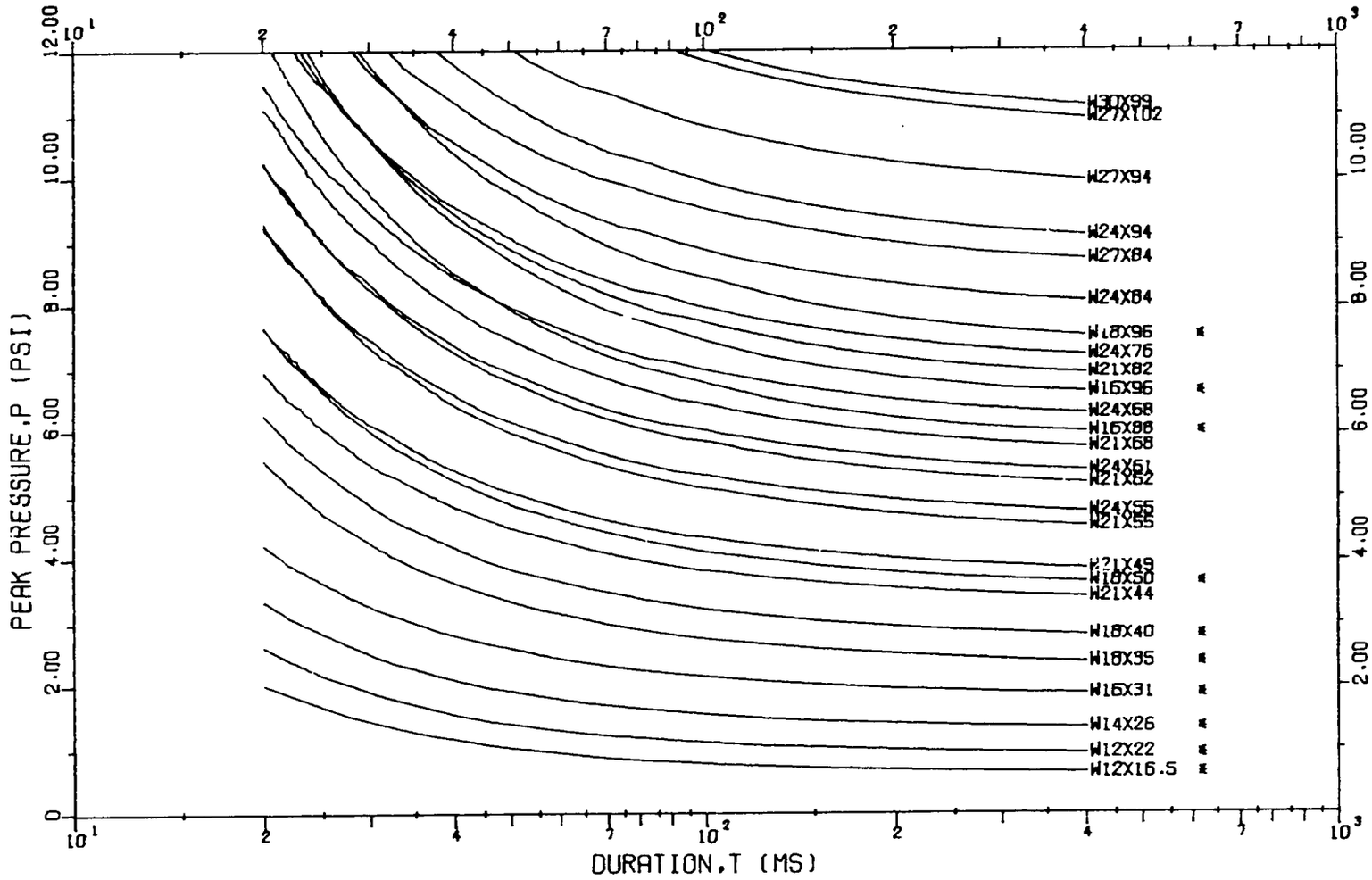


FIGURE 231

REUSABLE BEAM.SPAN= 30 FT.SPACING= 9 FT. FIXED ENDS

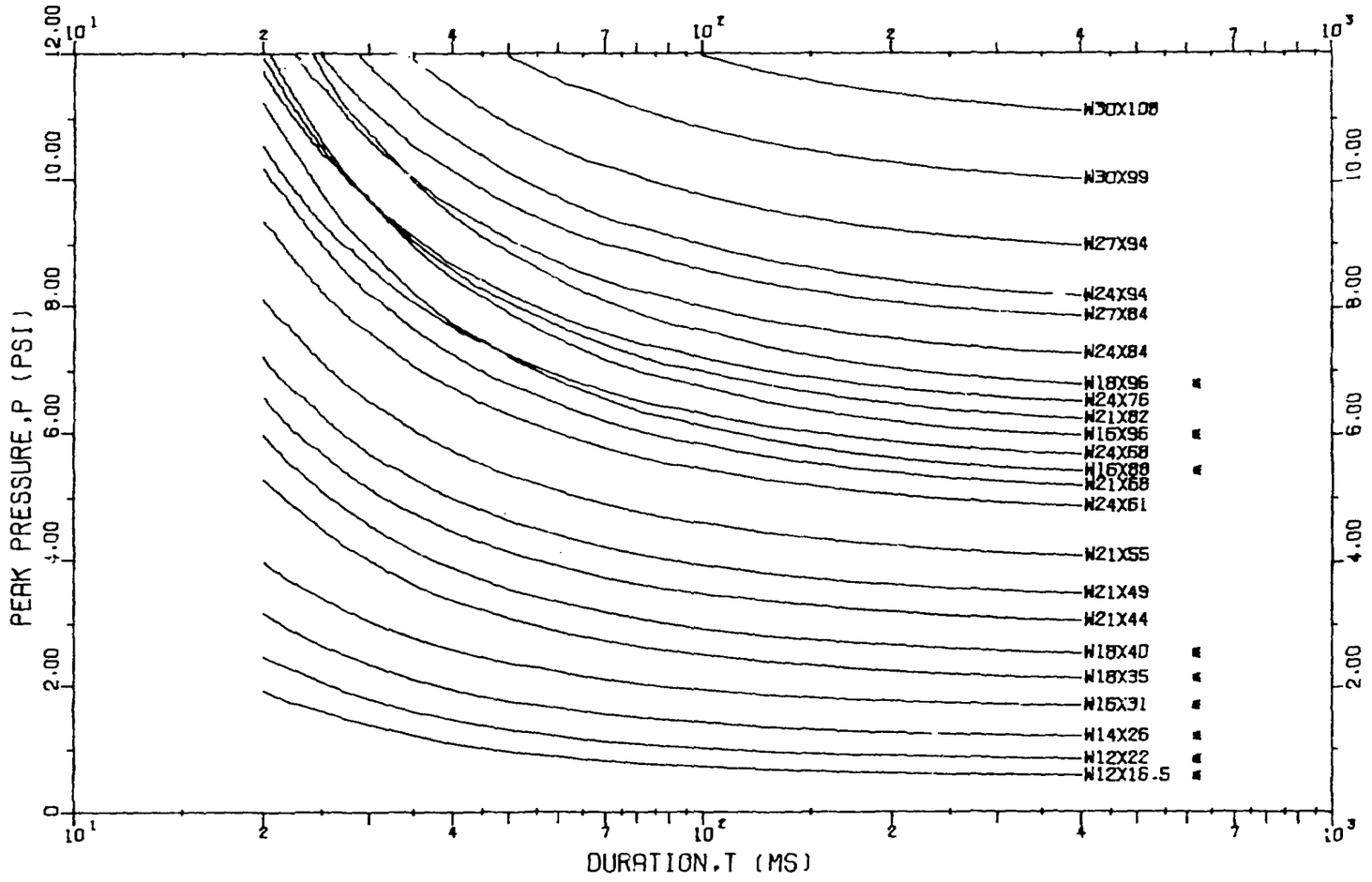


FIGURE 232

REUSABLE BEAM,SPAN=30 FT,SPACING=10FT, FIXED ENDS

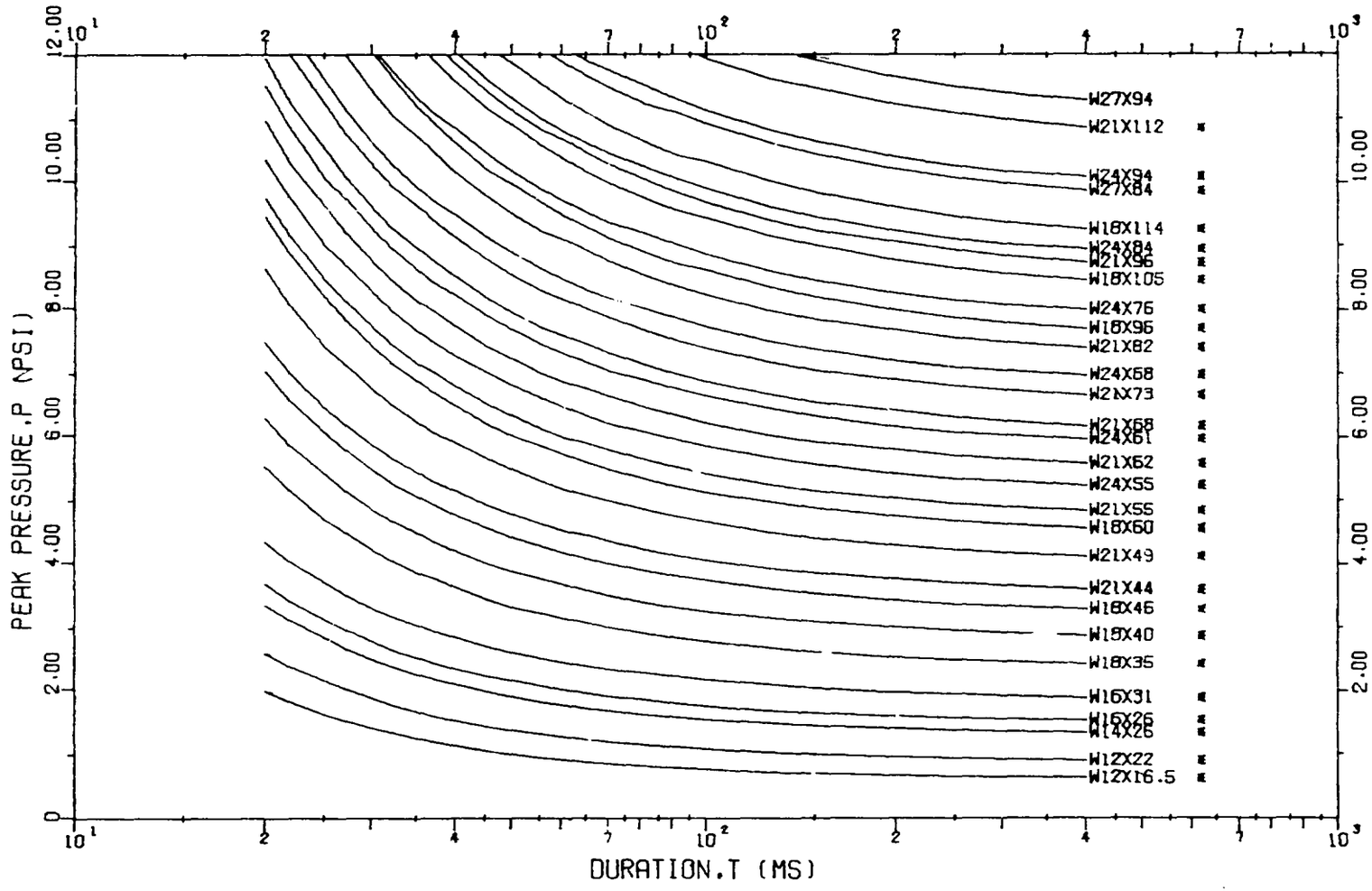


FIGURE 233

REUSABLE BEAM,SPAN= 30 FT,SPACING= 6 FT, SIMPLE-FIXED

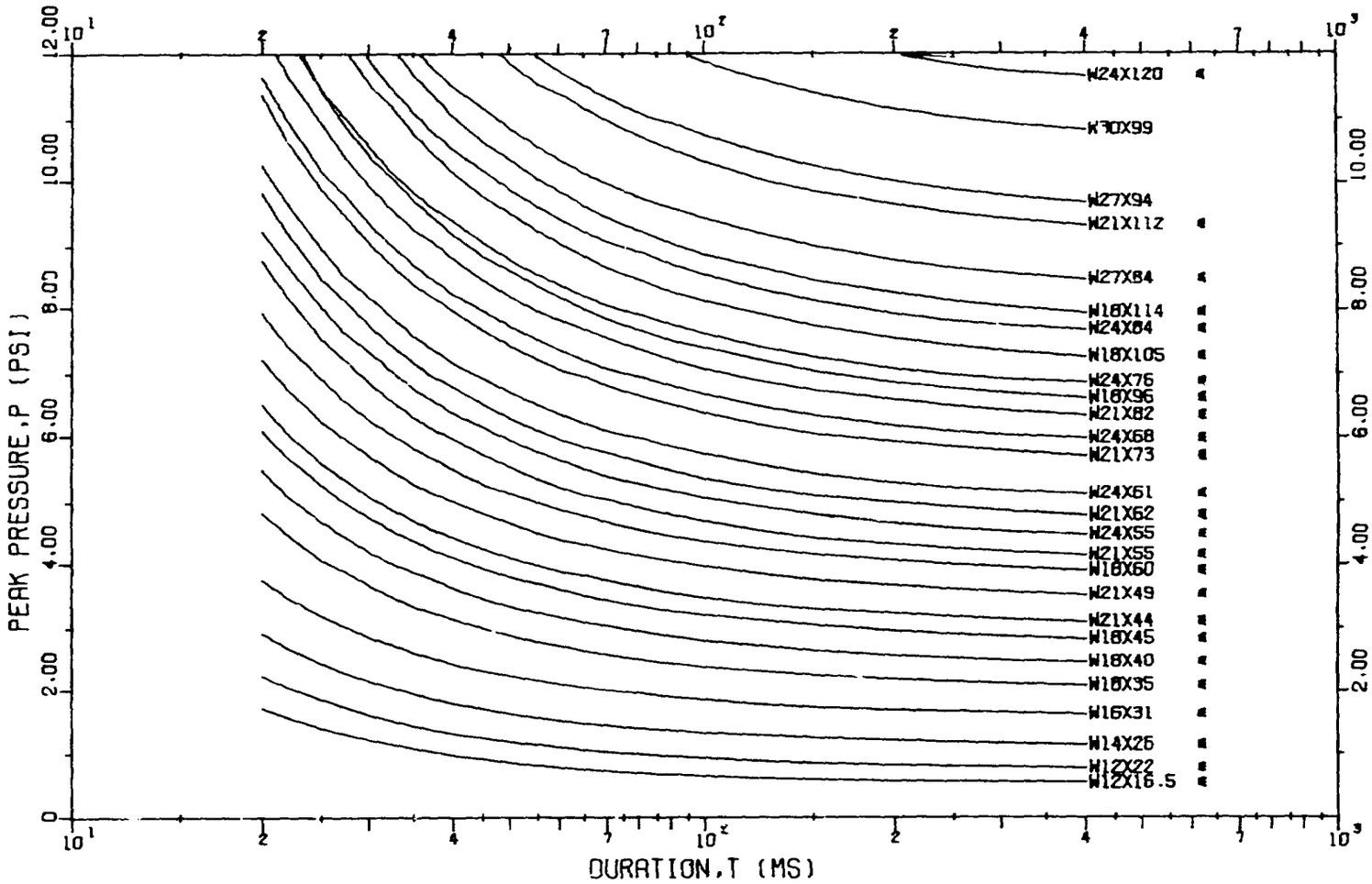


FIGURE 234

REUSABLE BEAM,SPAN= 30 FT,SPACING= 7 FT, SIMPLE-FIXED

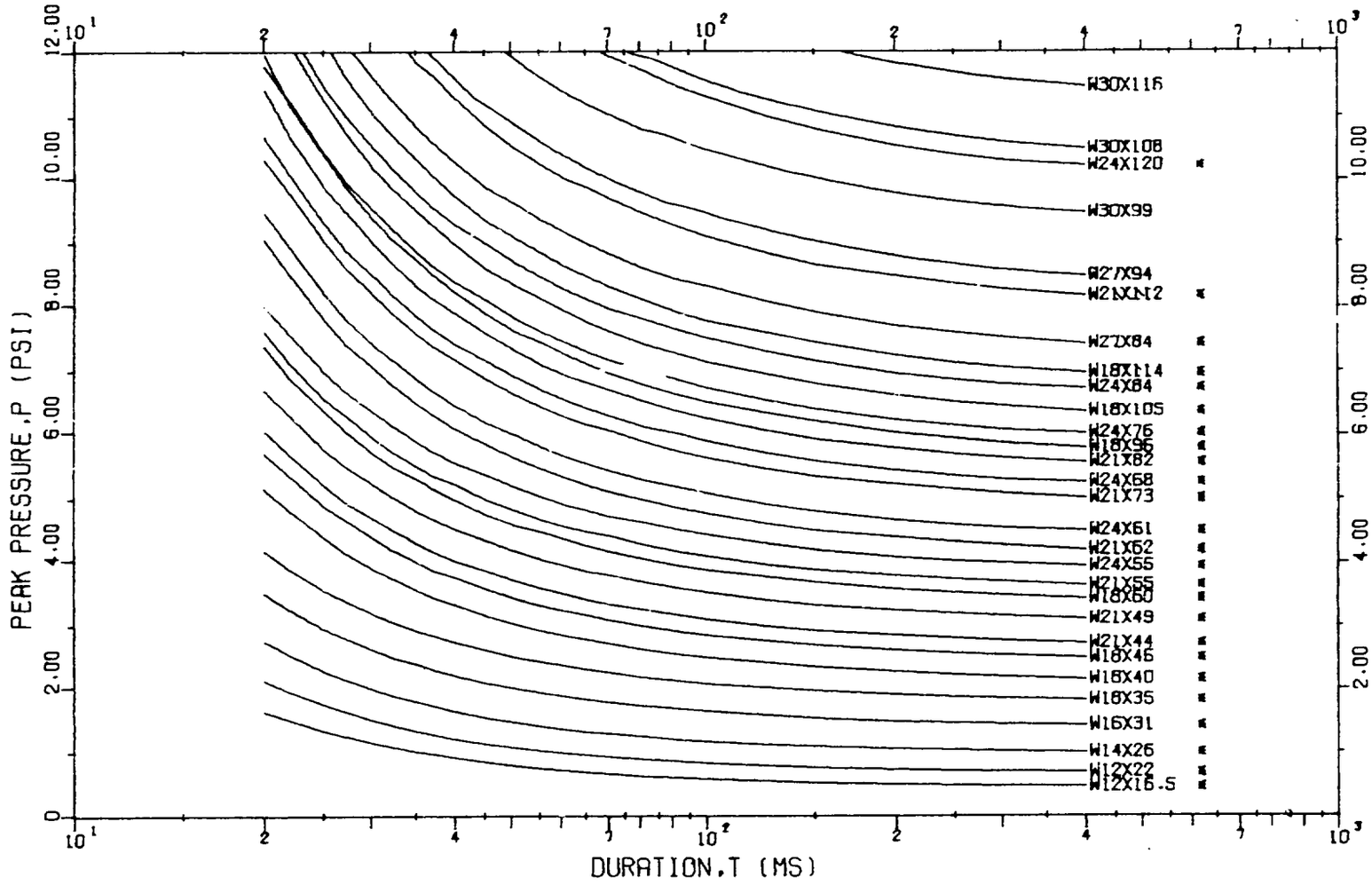


FIGURE 235

REUSABLE BEAM.SPAN=30 FT.SPACING=8 FT. SIMPLE-FIXED

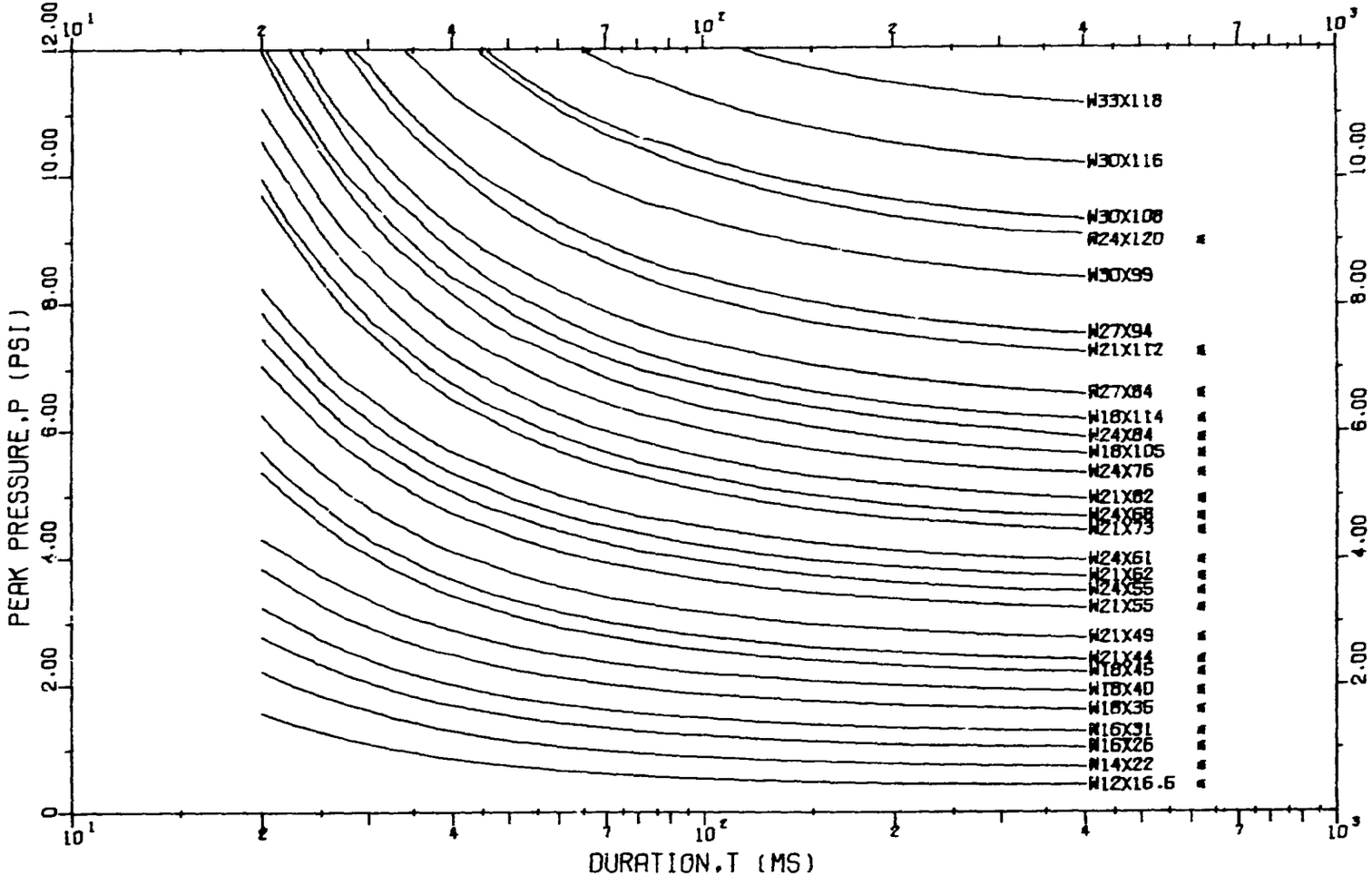


FIGURE 236

REUSABLE BEAM,SPAN=30 FT,SPACING=9 FT, SIMPLE-FIXED

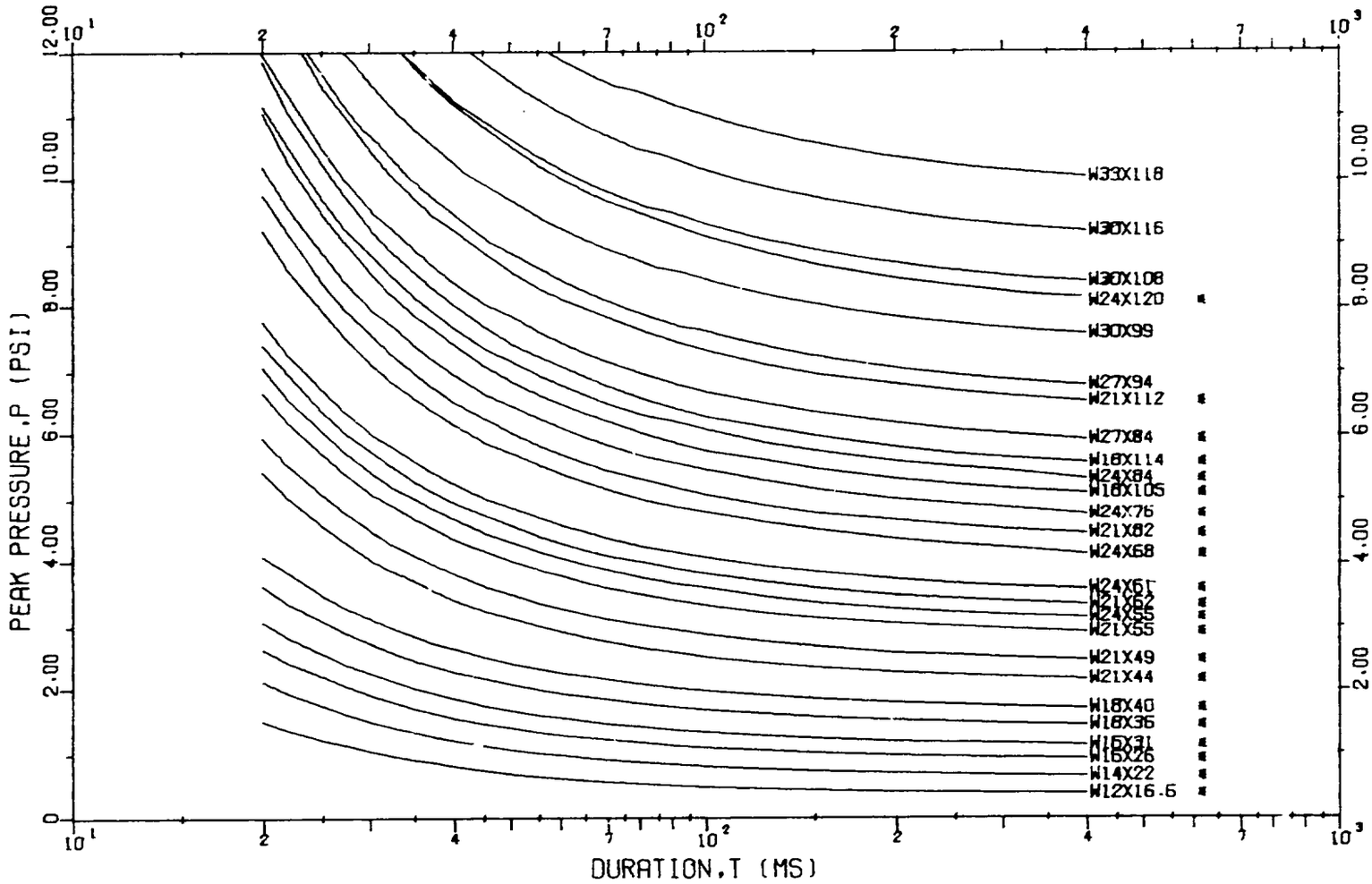


FIGURE 237

REUSABLE BEAM,SPAN= 30 FT,SPACING= 10FT, SIMPLE-FIXED

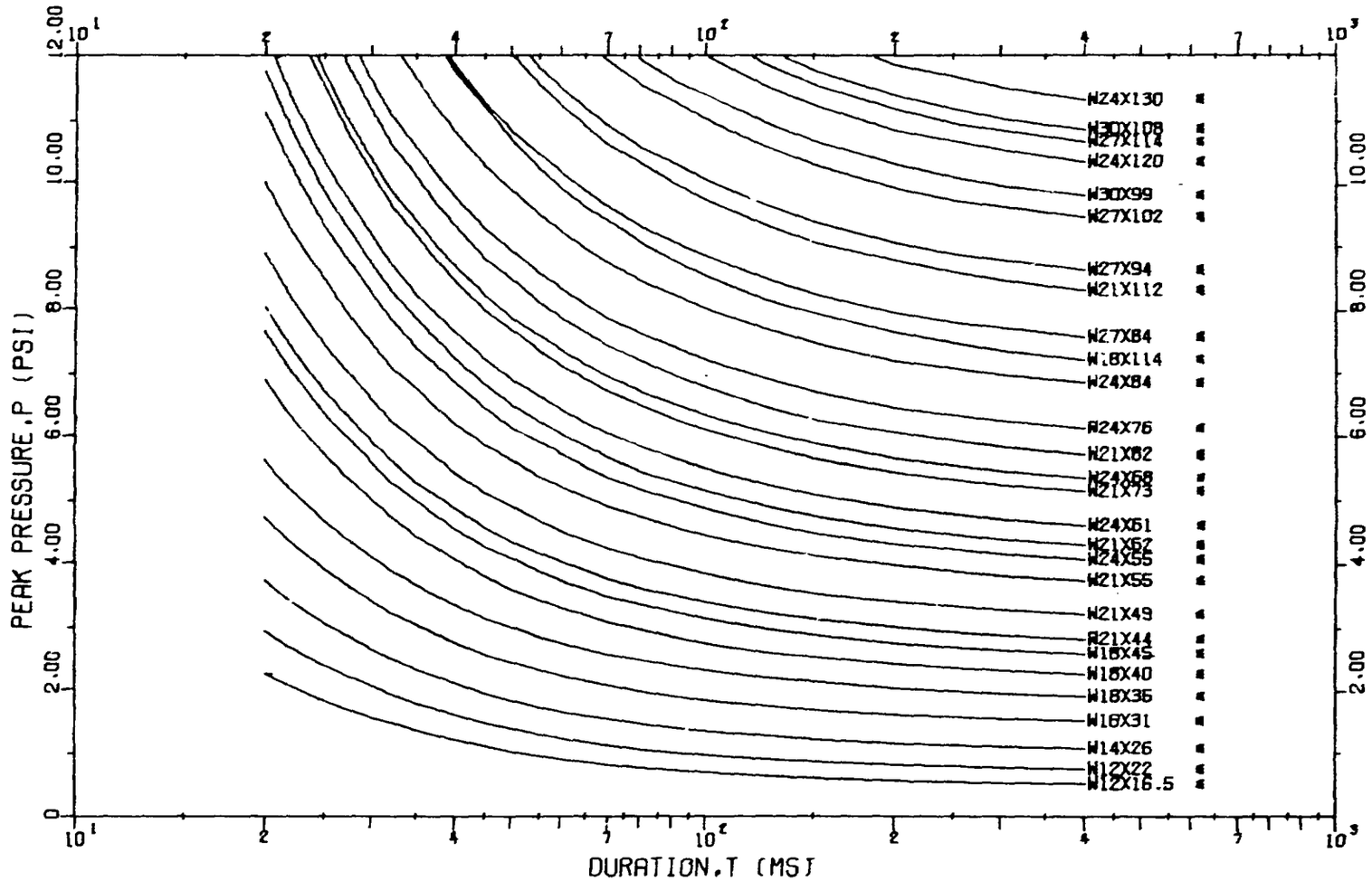


FIGURE 238

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING=6 FT. SIMPLY-SUPPORTED

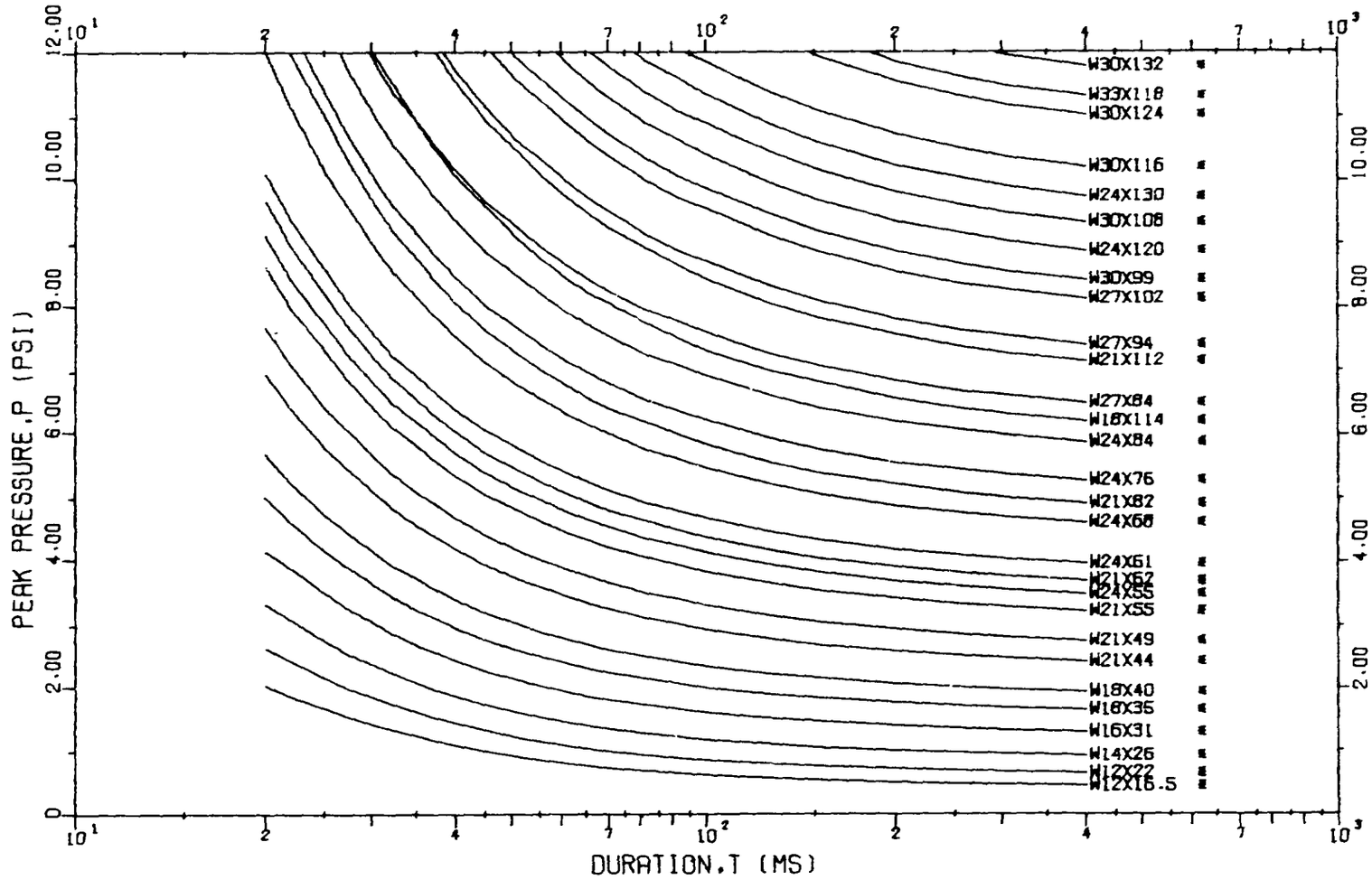


FIGURE 239

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=7 FT. SIMPLY-SUPPORTED

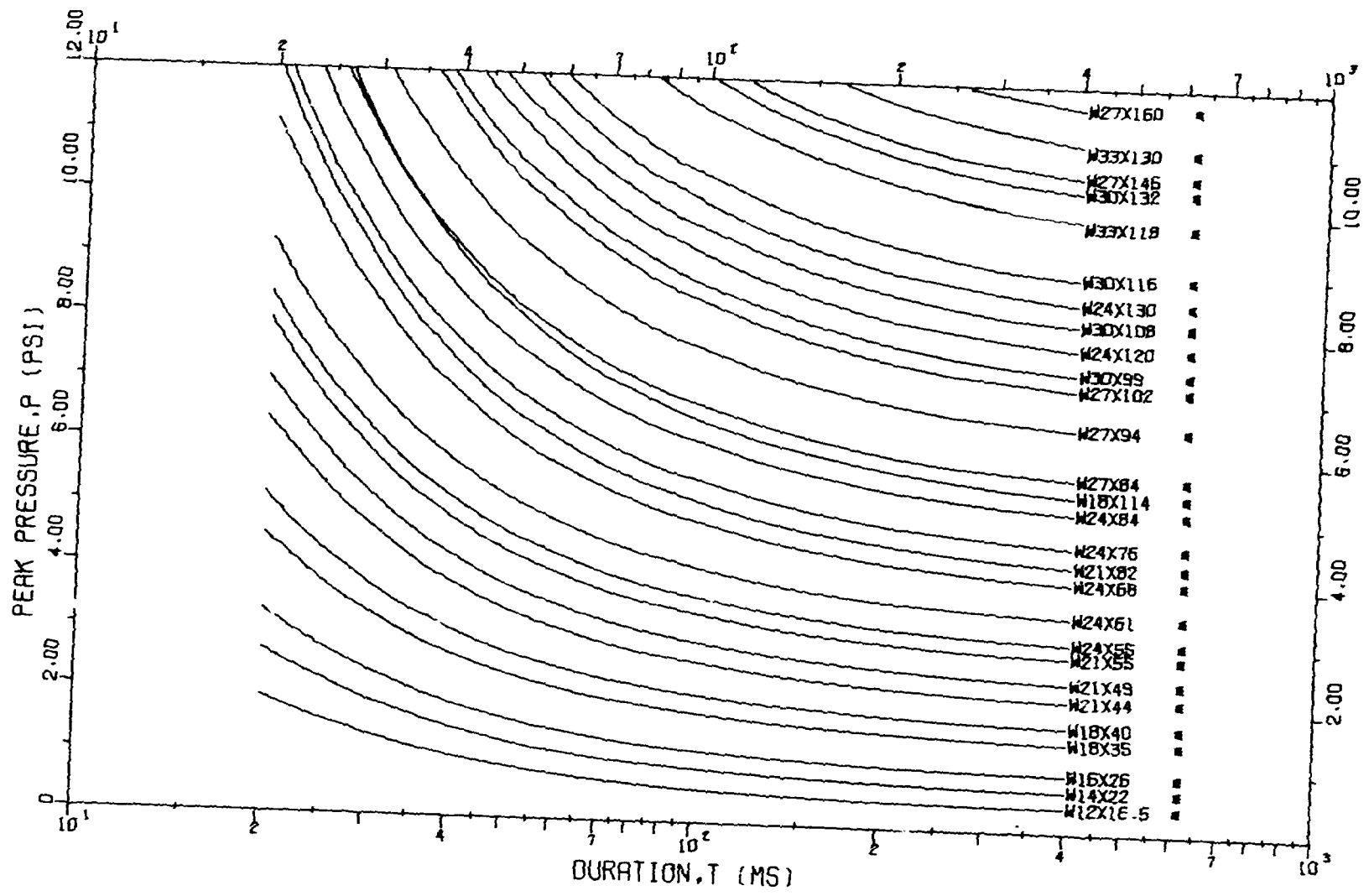


FIGURE 240

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING=8 FT. SIMPLY-SUPPORTED

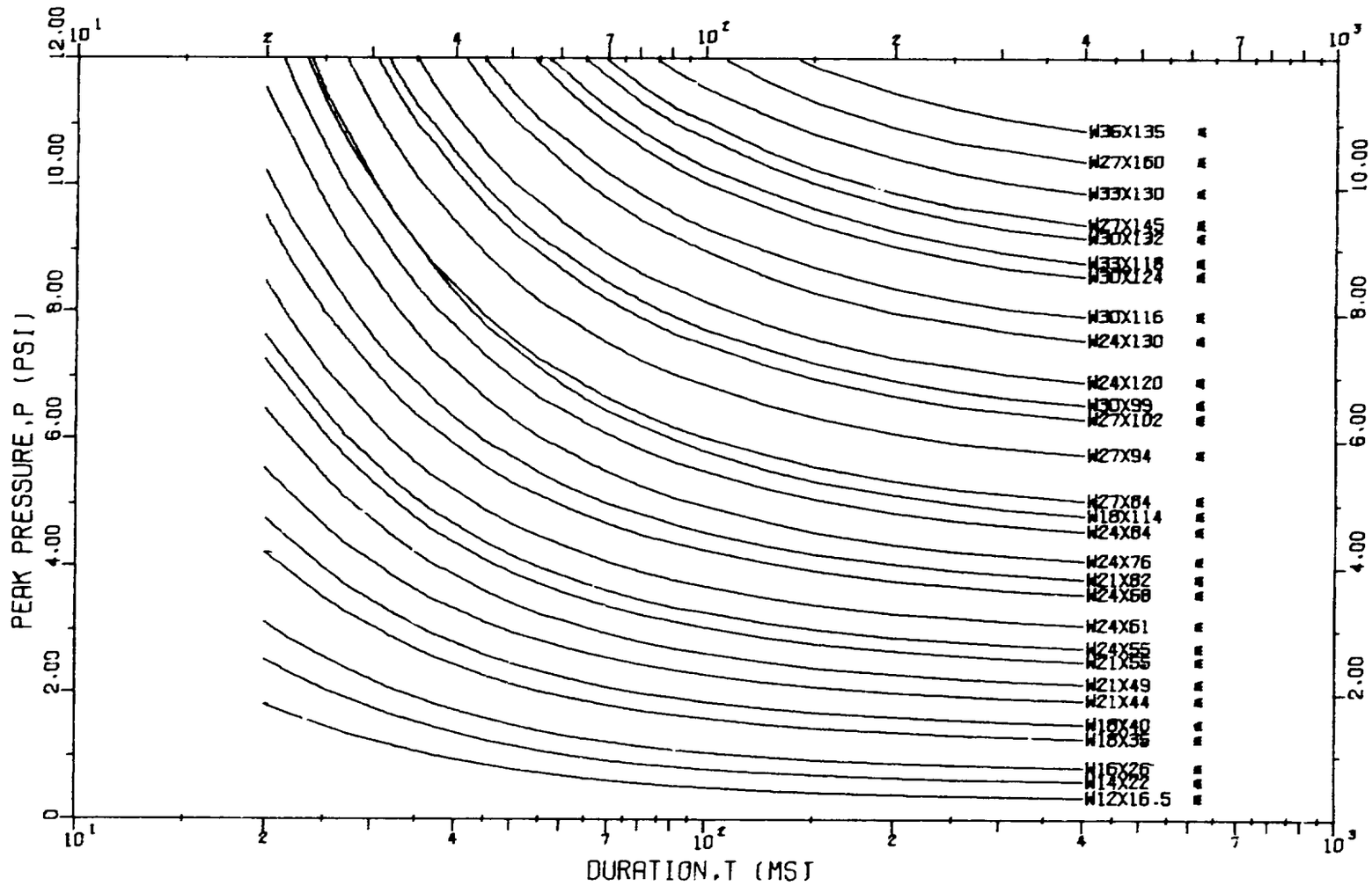


FIGURE 241

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=9 FT, SIMPLY-SUPPORTED

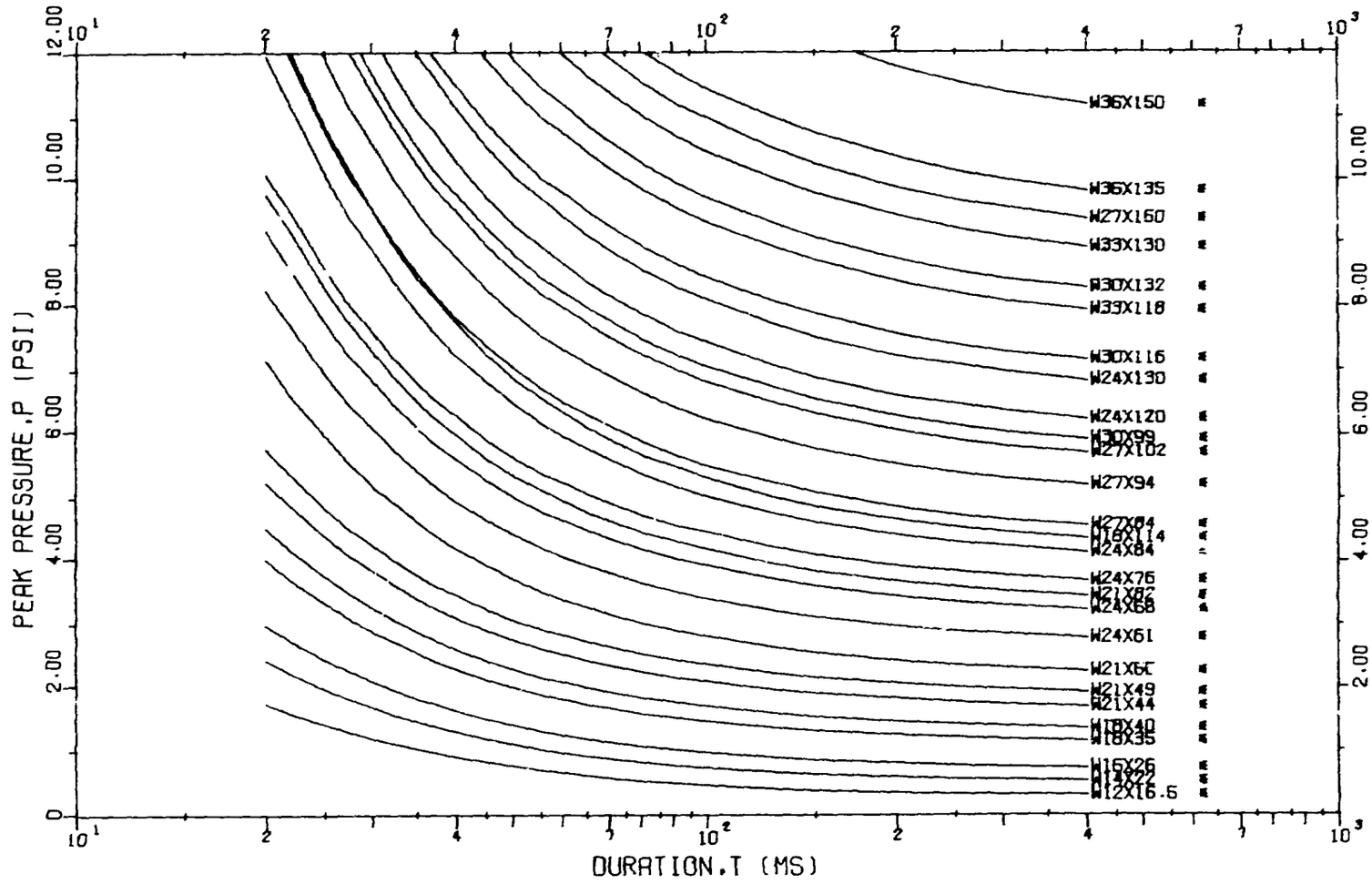


FIGURE 242

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING= 10 FT, SIMPLY-SUPPORTED

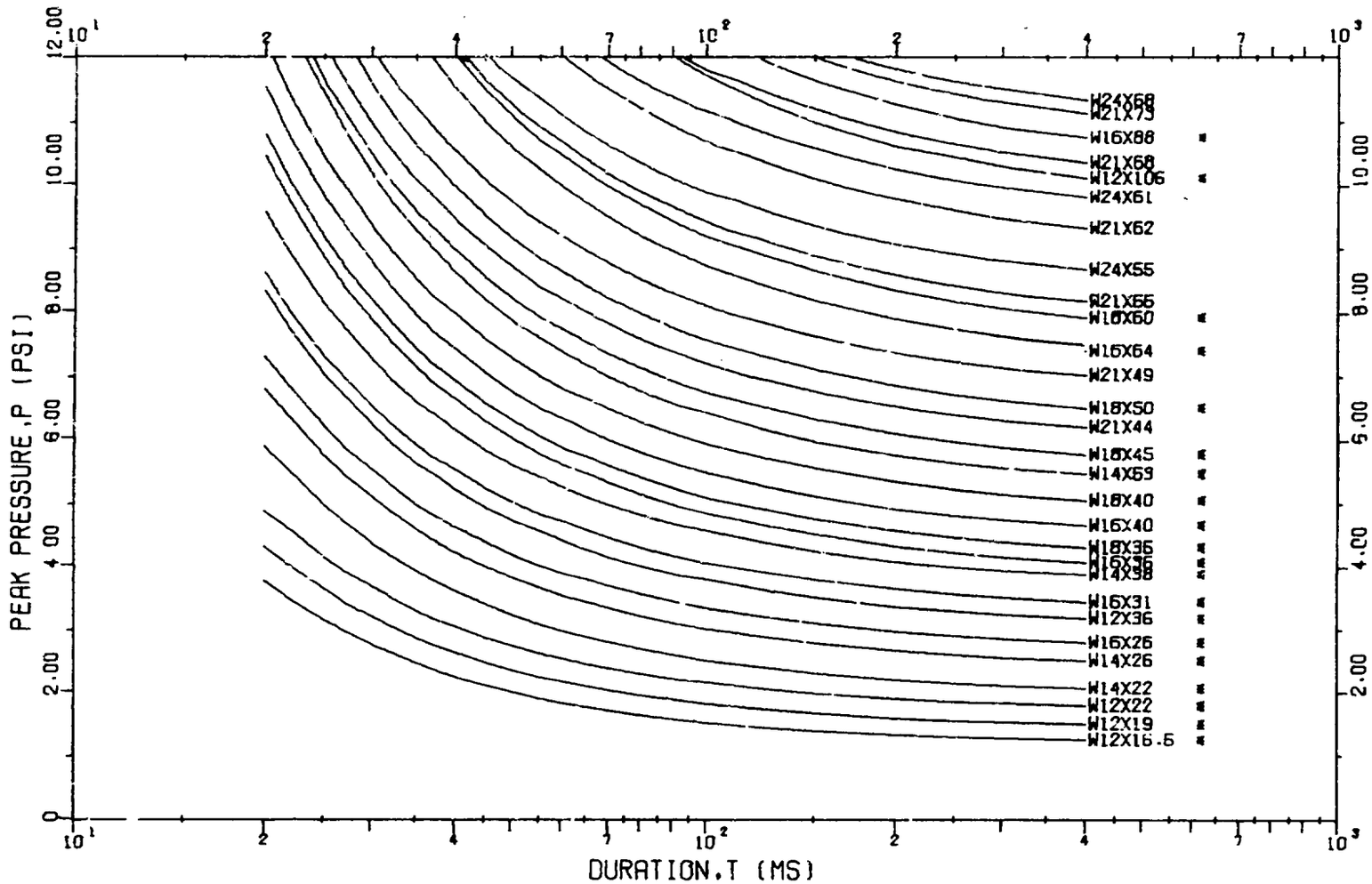


FIGURE 243

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=6 FT. FIXED ENDS

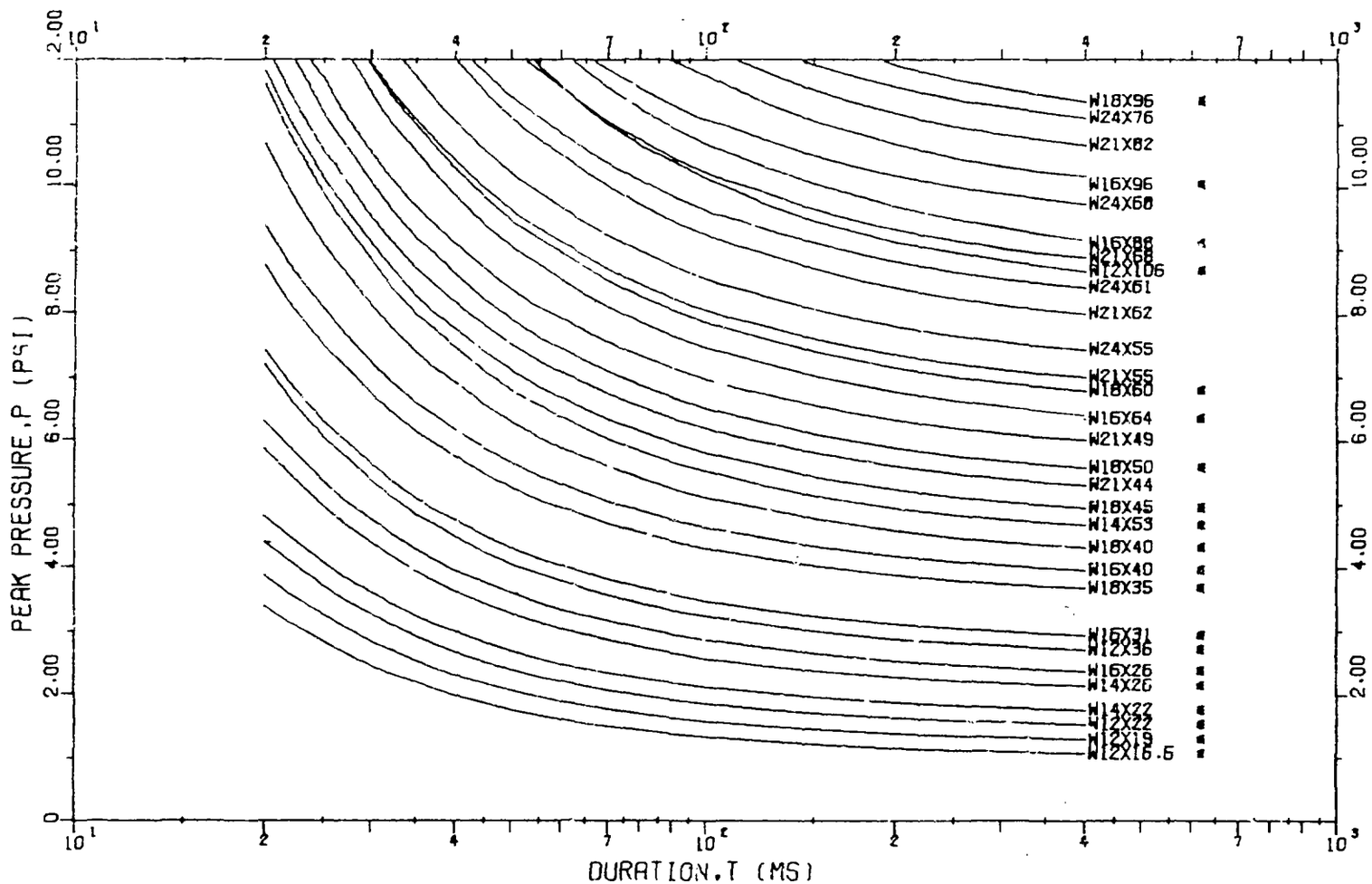


FIGURE 244

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=7 FT. FIXED ENDS

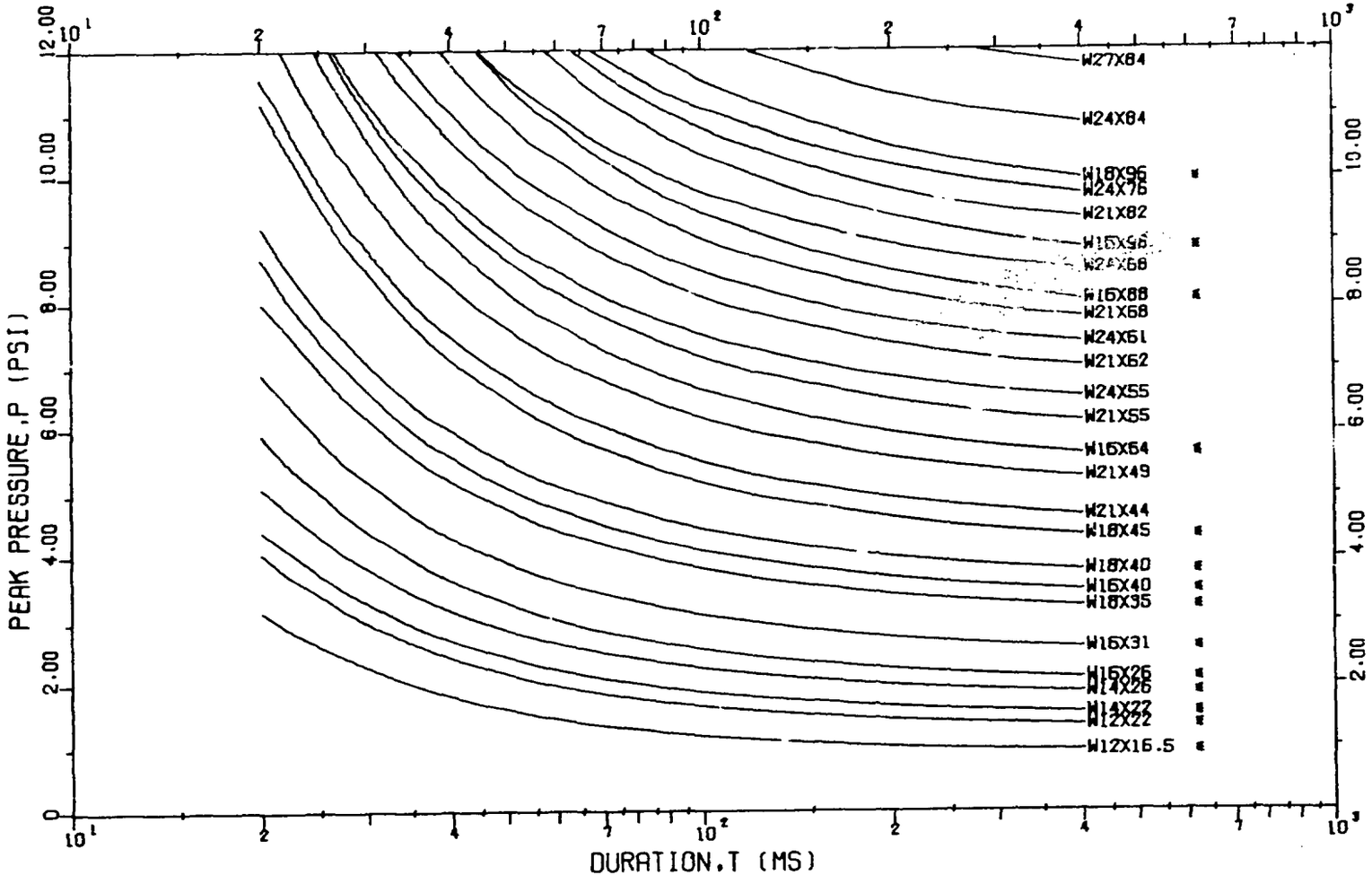


FIGURE 245

NON-REUSABLE BEAM,SPAN= 30 FT.SPACING=8 FT. FIXED ENDS

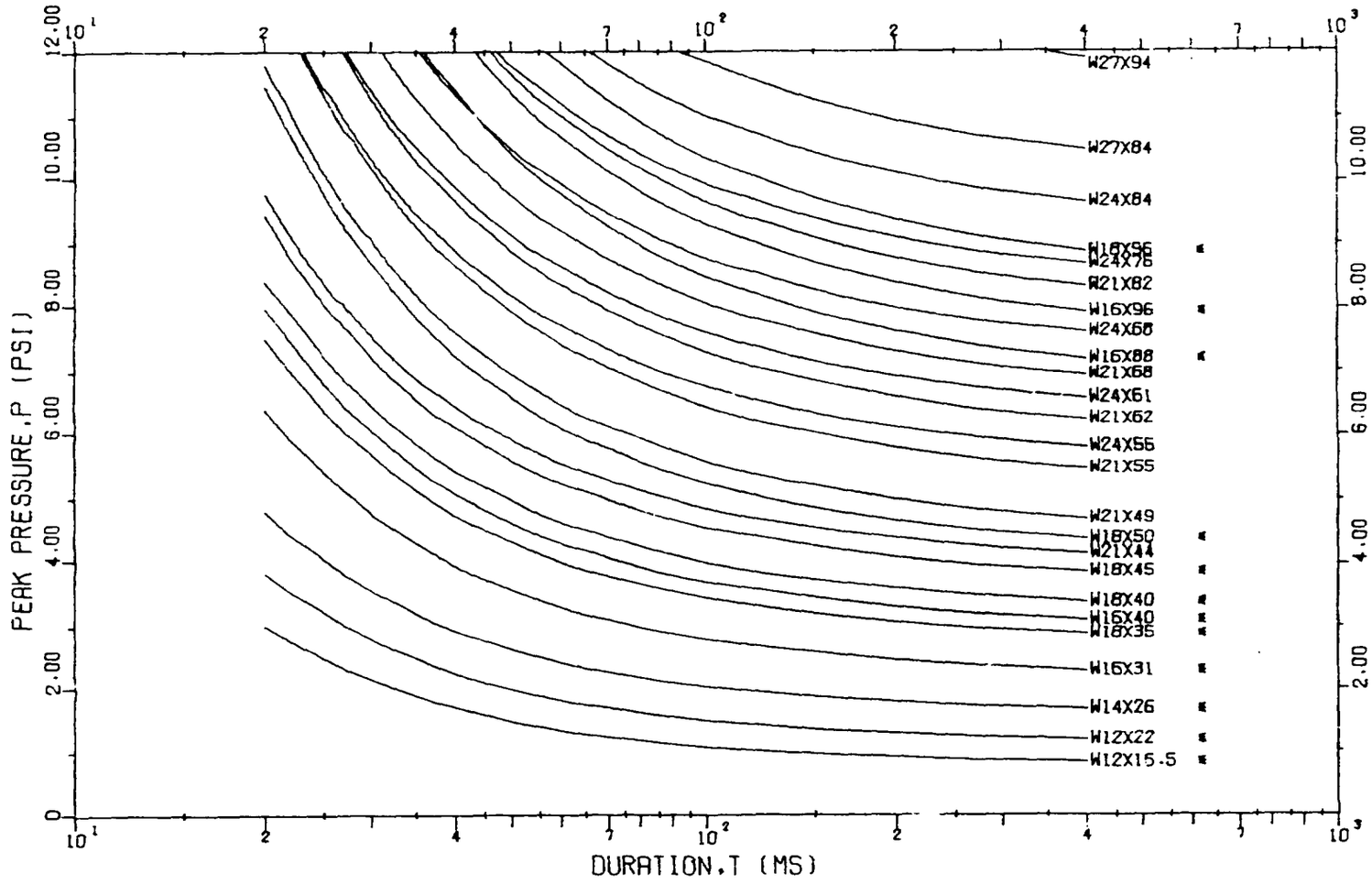


FIGURE 246

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING= 9 FT. FIXED ENDS

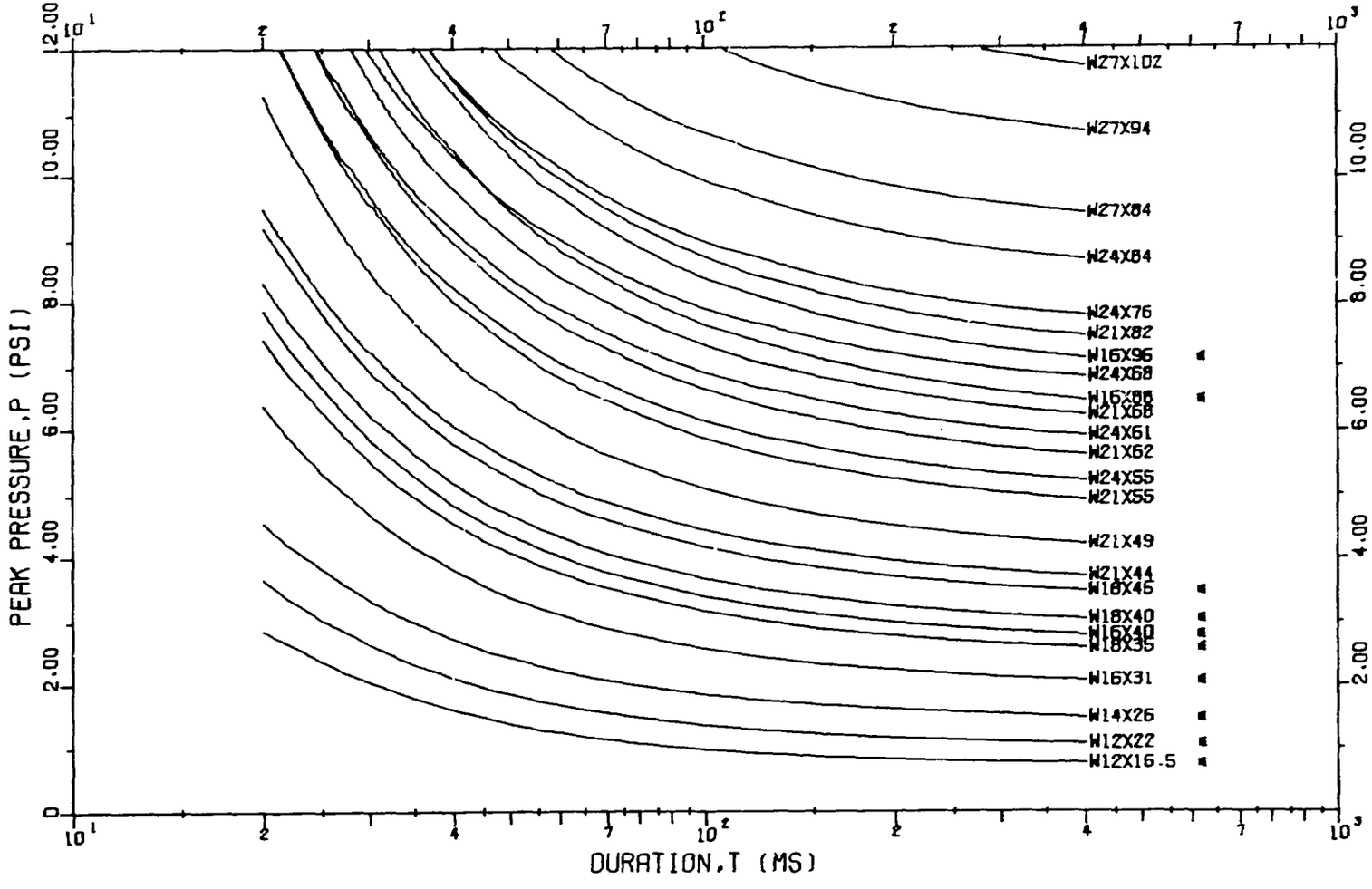


FIGURE 247

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING= 10 FT. FIXED ENDS

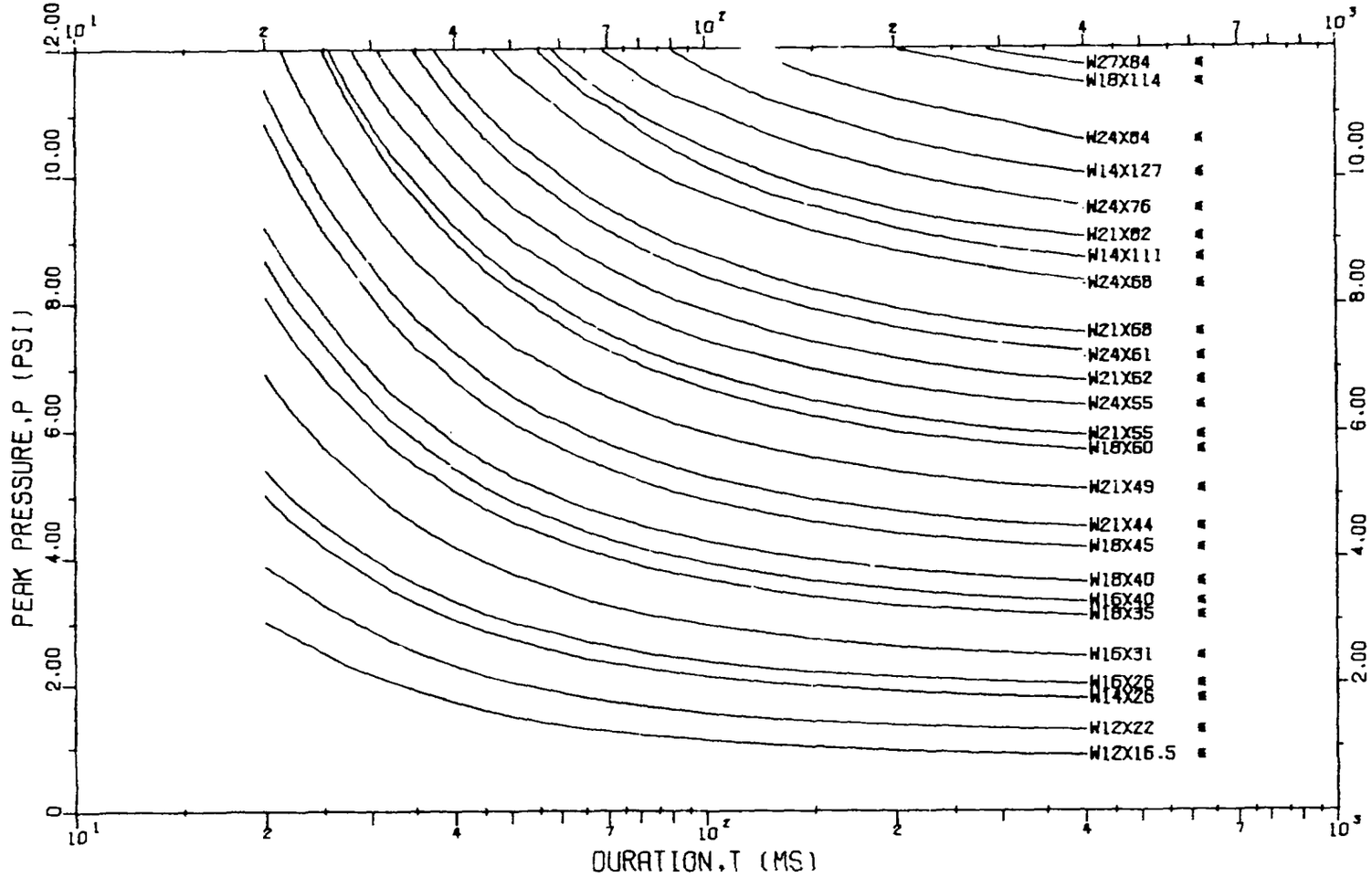


FIGURE 248

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING=6 FT. SIMPLE-FIXED

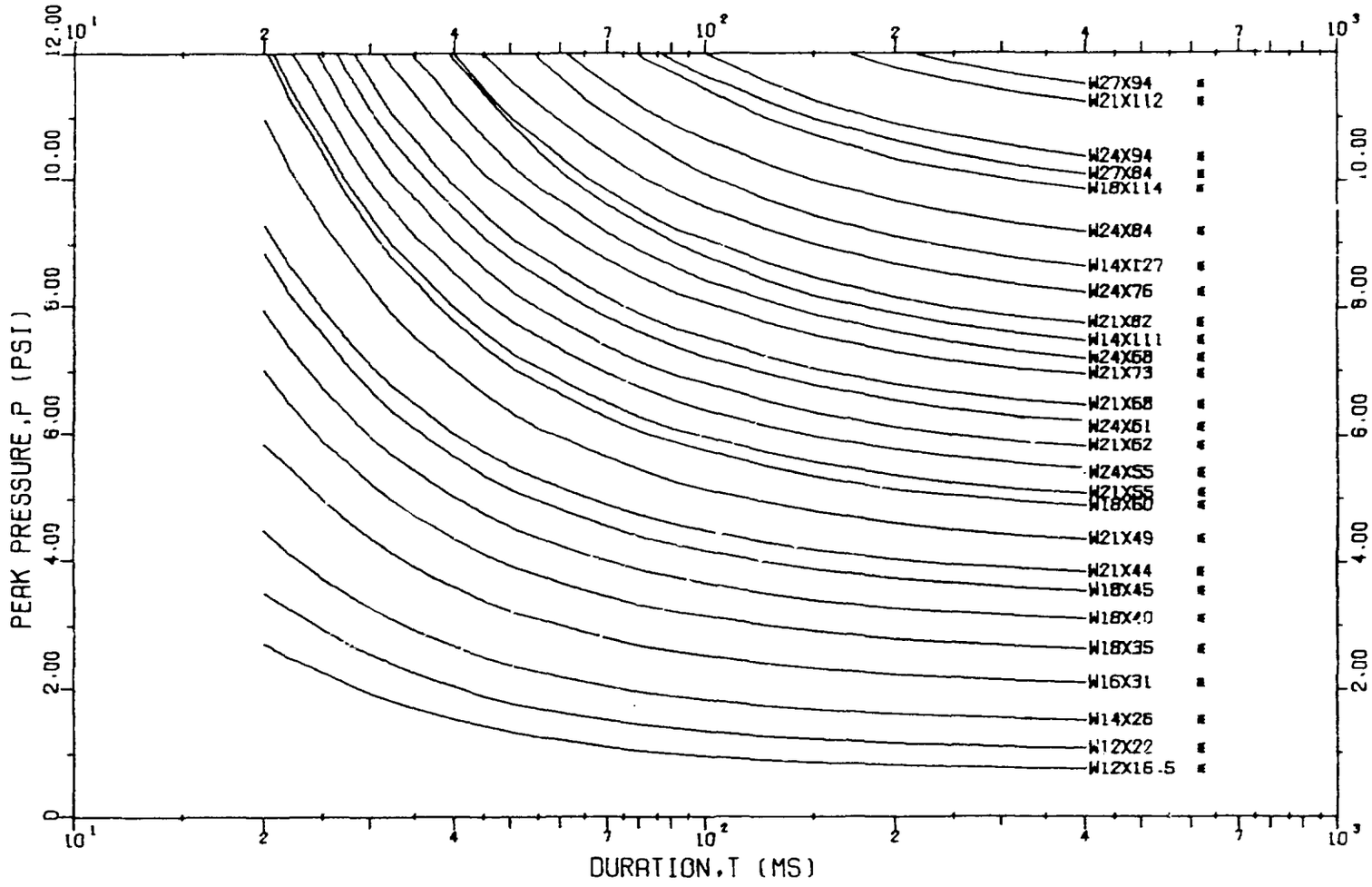


FIGURE 249

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=7 FT, SIMPLE-FIXED

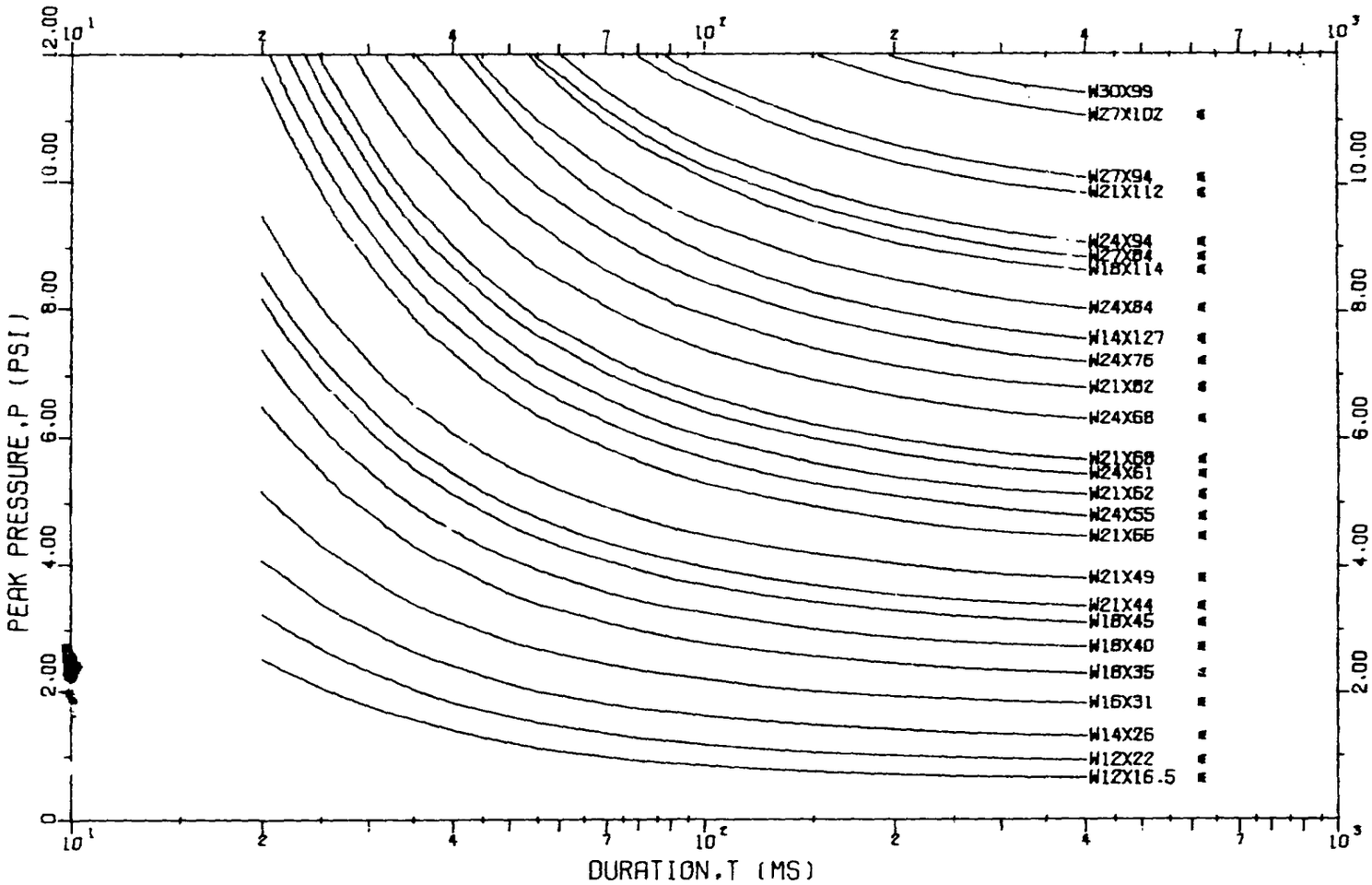


FIGURE 250

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING=8 FT. SIMPLE-FIXED

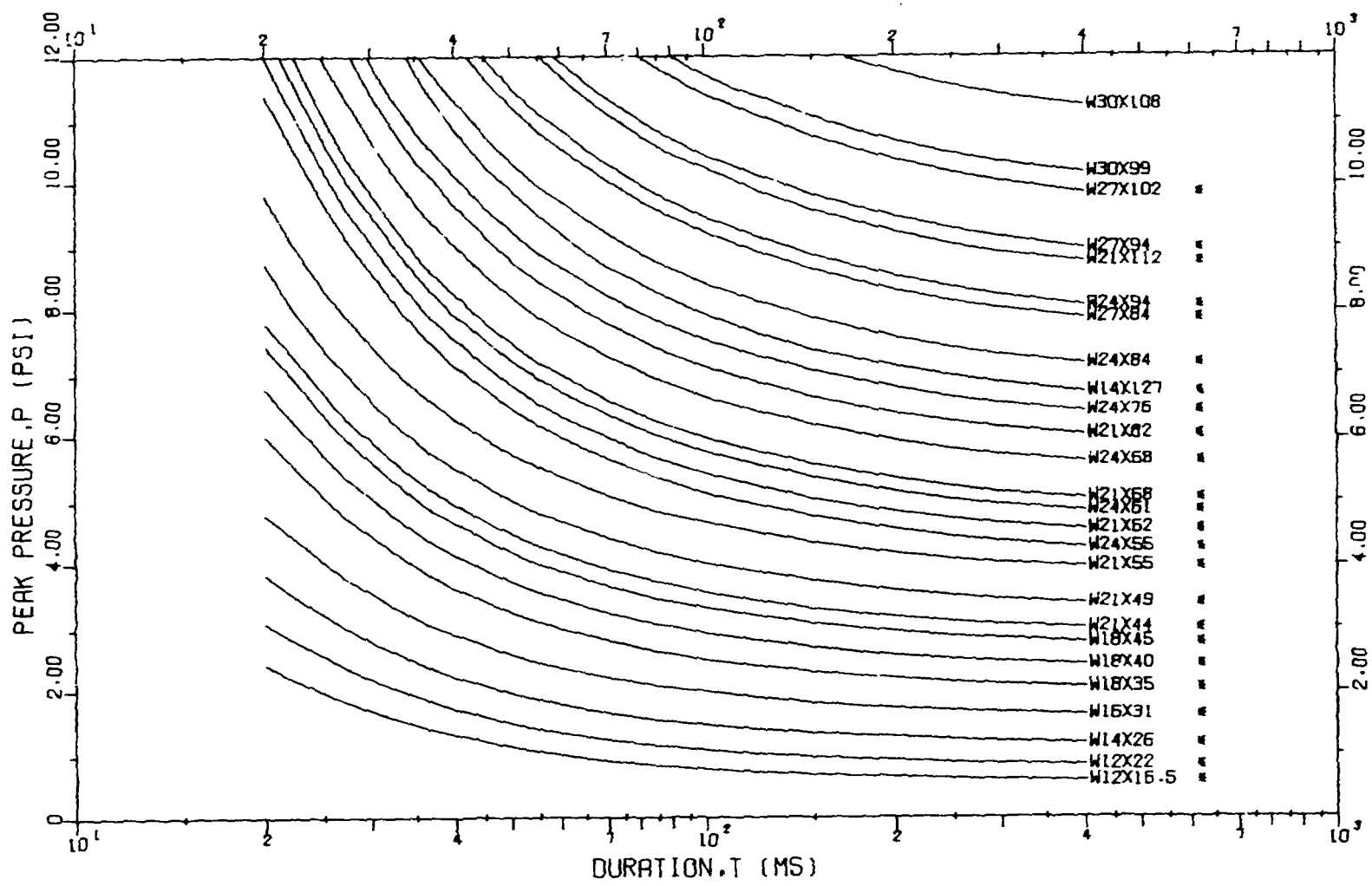


FIGURE 251

NON-REUSABLE BEAM,SPAN= 30 FT,SPACING=9 FT. SIMPLE-FIXED

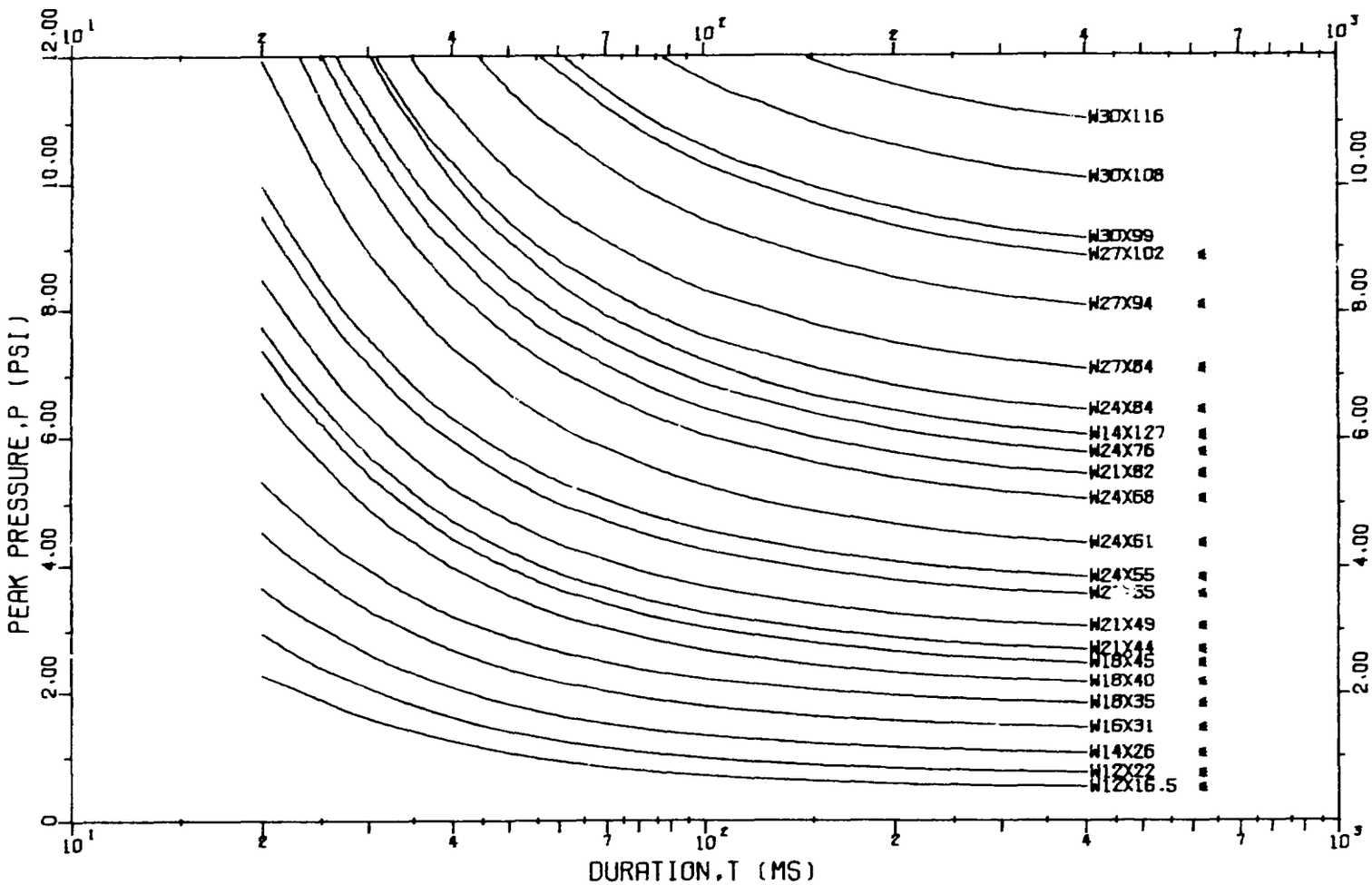


FIGURE 252

NON-REUSABLE BEAM.SPAN= 30 FT.SPACING= 10 FT. SIMPLE-FIXED

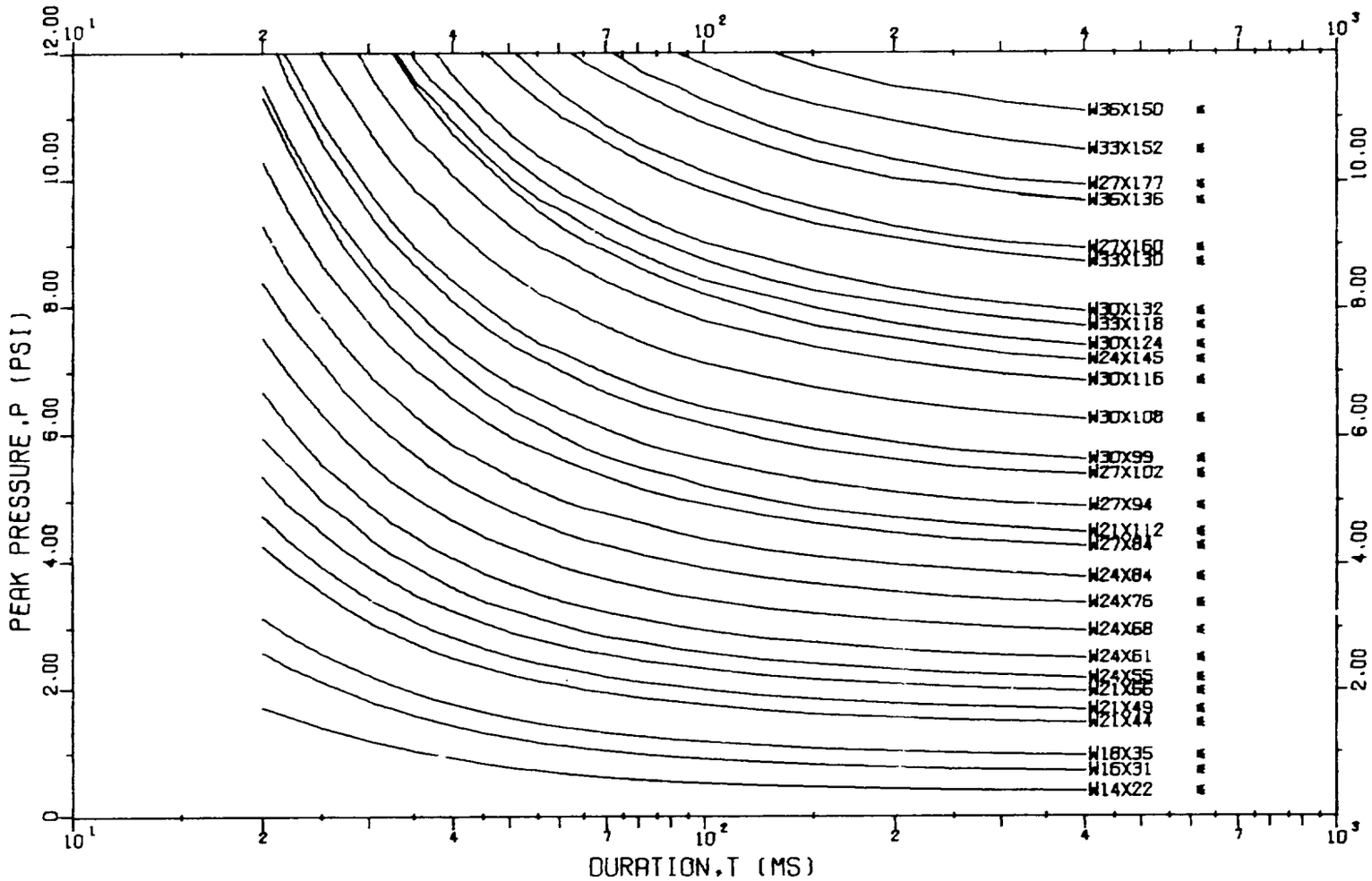


FIGURE 253

REUSABLE BEAM,SPAN= 35 FT,SPACING= 6 FT, SIMPLY-SUPPORTED

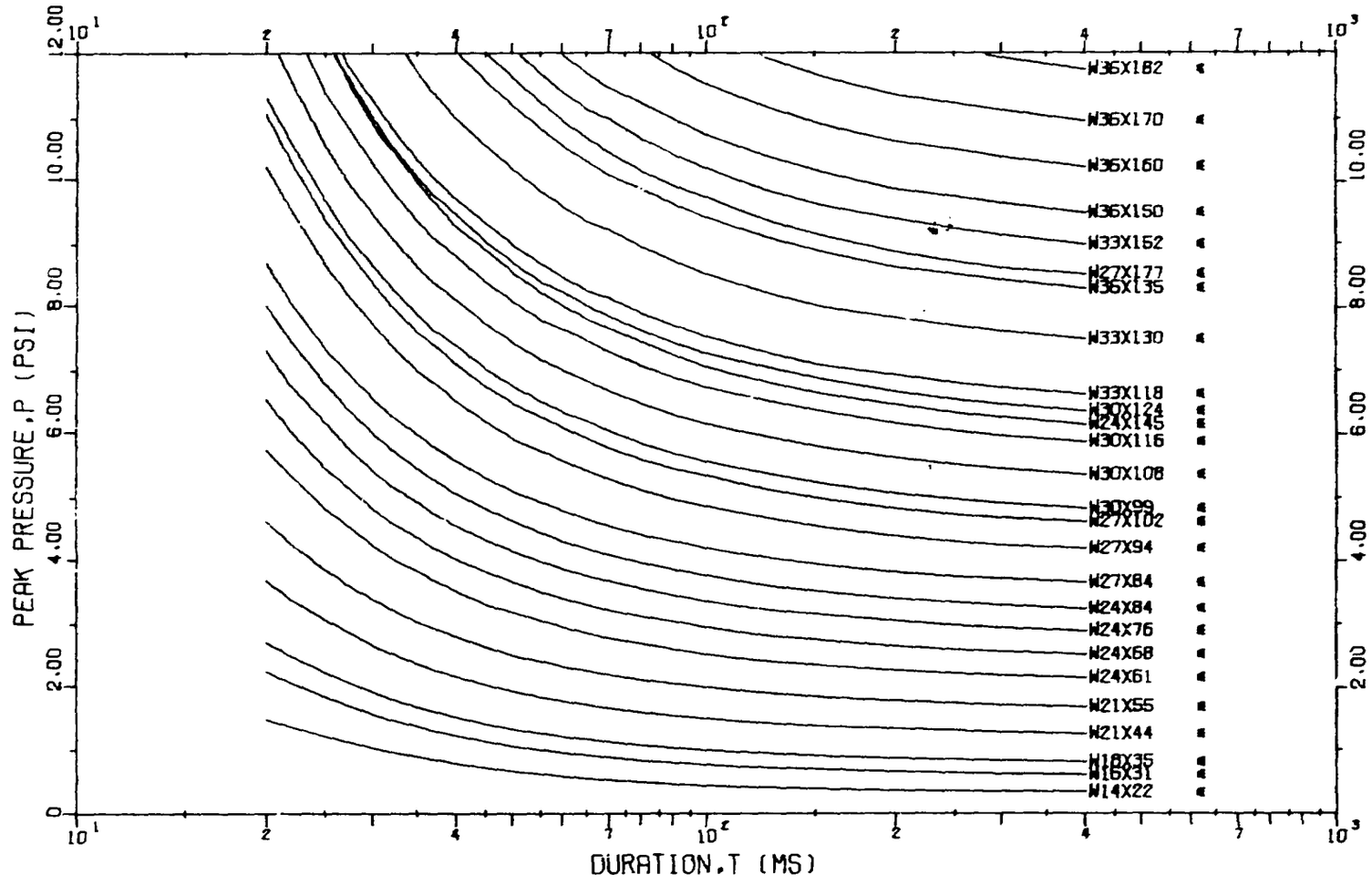


FIGURE 254

REUSABLE BEAM,SPAN= 35 FT,SPACING= 7 FT, SIMPLY-SUPPORTED

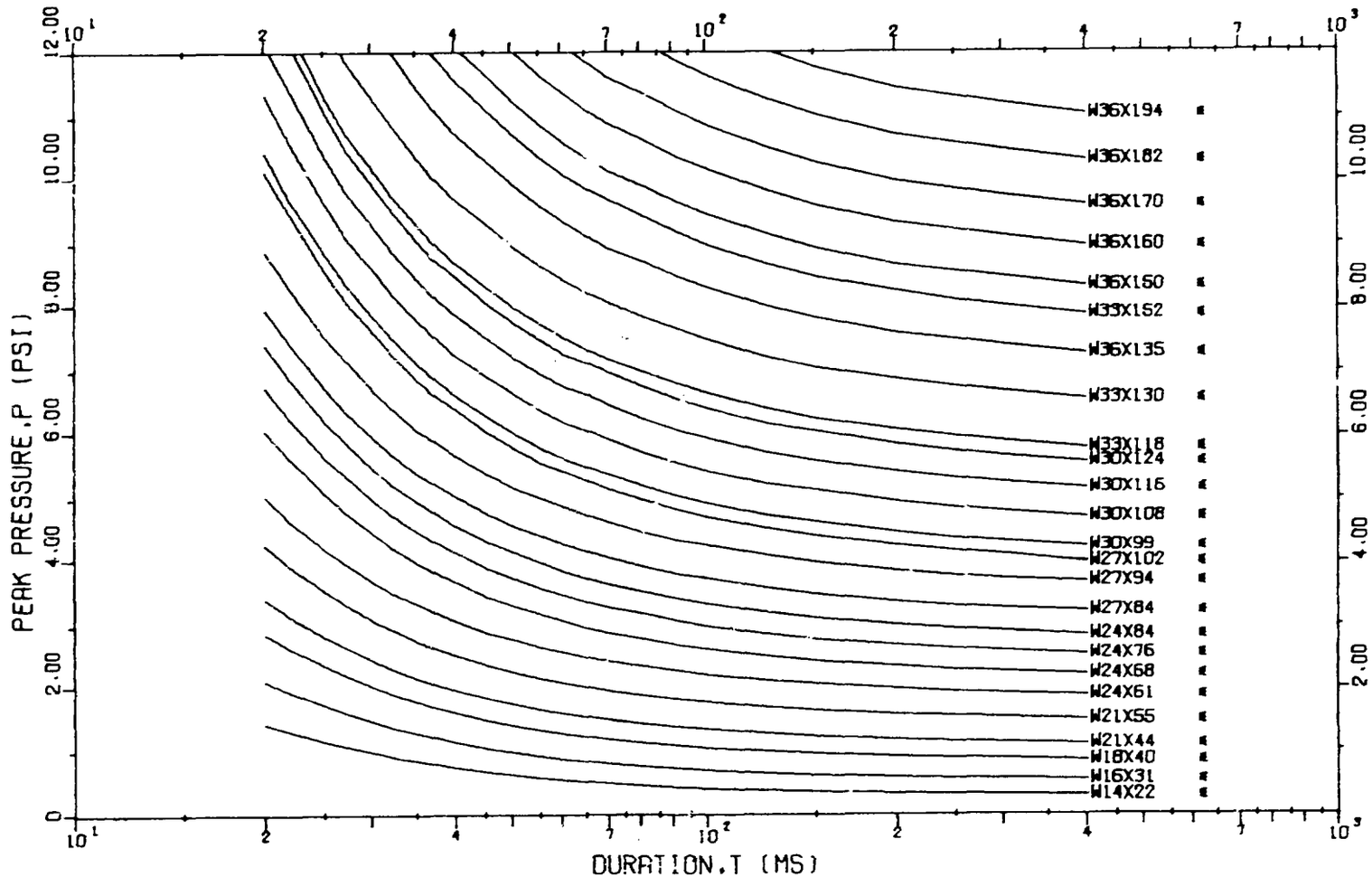


FIGURE 255

REUSABLE BEAM,SPAN= 35 FT,SPACING= 8 FT, SIMPLY-SUPPORTED

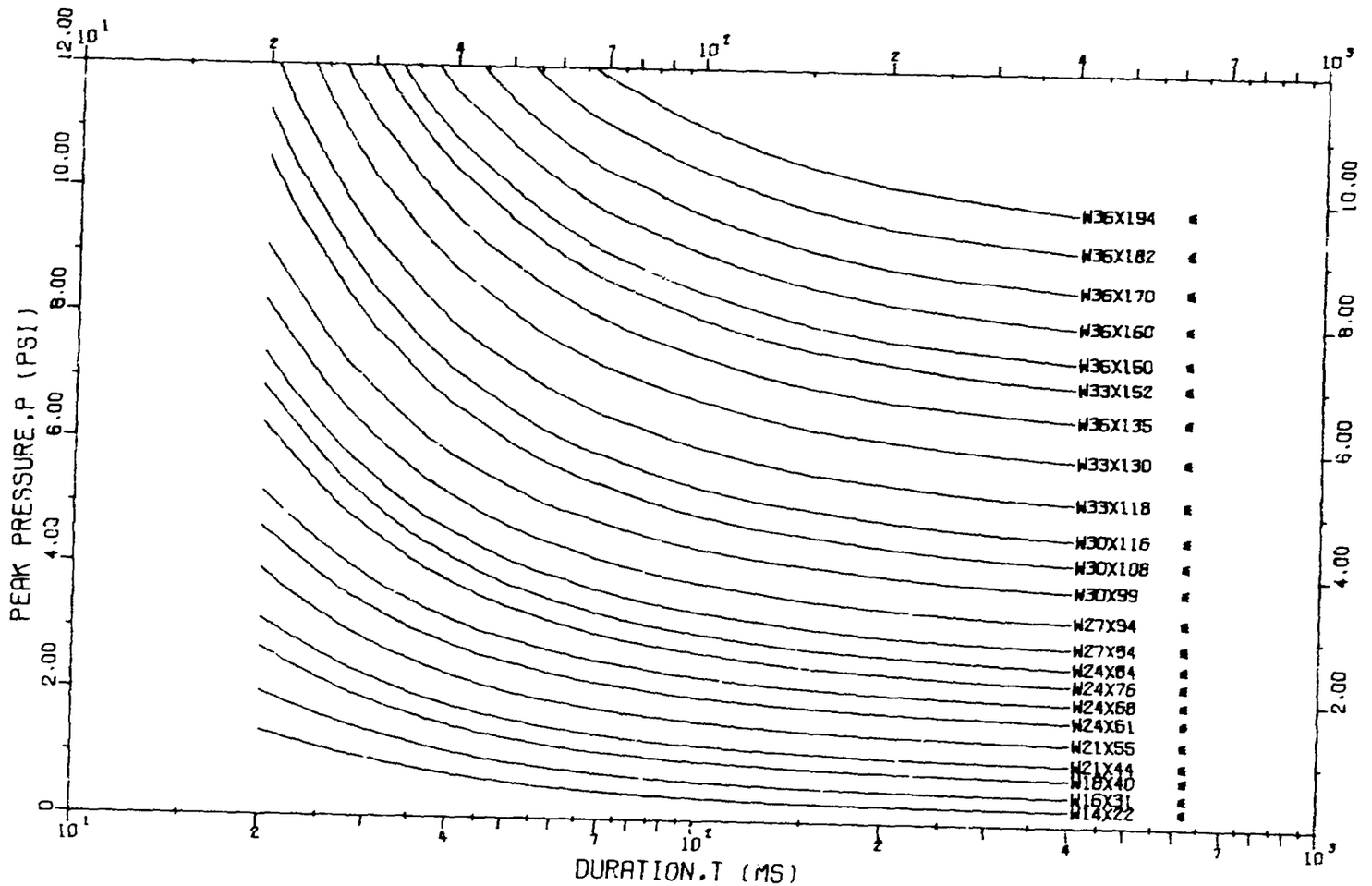


FIGURE 256

REUSABLE BEAM,SPAN= 35 FT,SPACING= 9 FT, SIMPLY-SUPPORTED

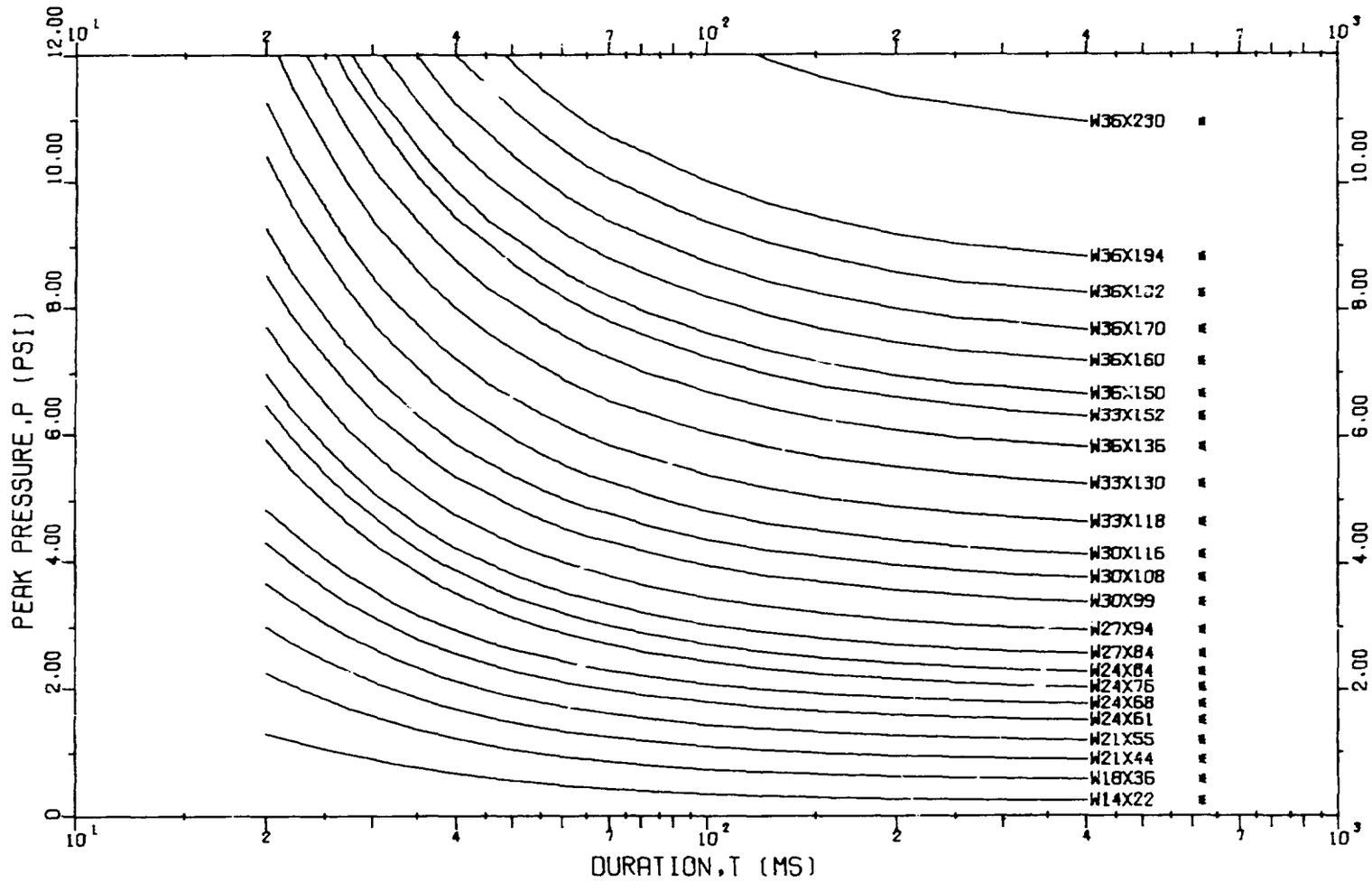


FIGURE 257

REUSABLE BEAM,SPAN= 35 FT,SPACING= 10 FT, SIMPLY-SUPPORTED

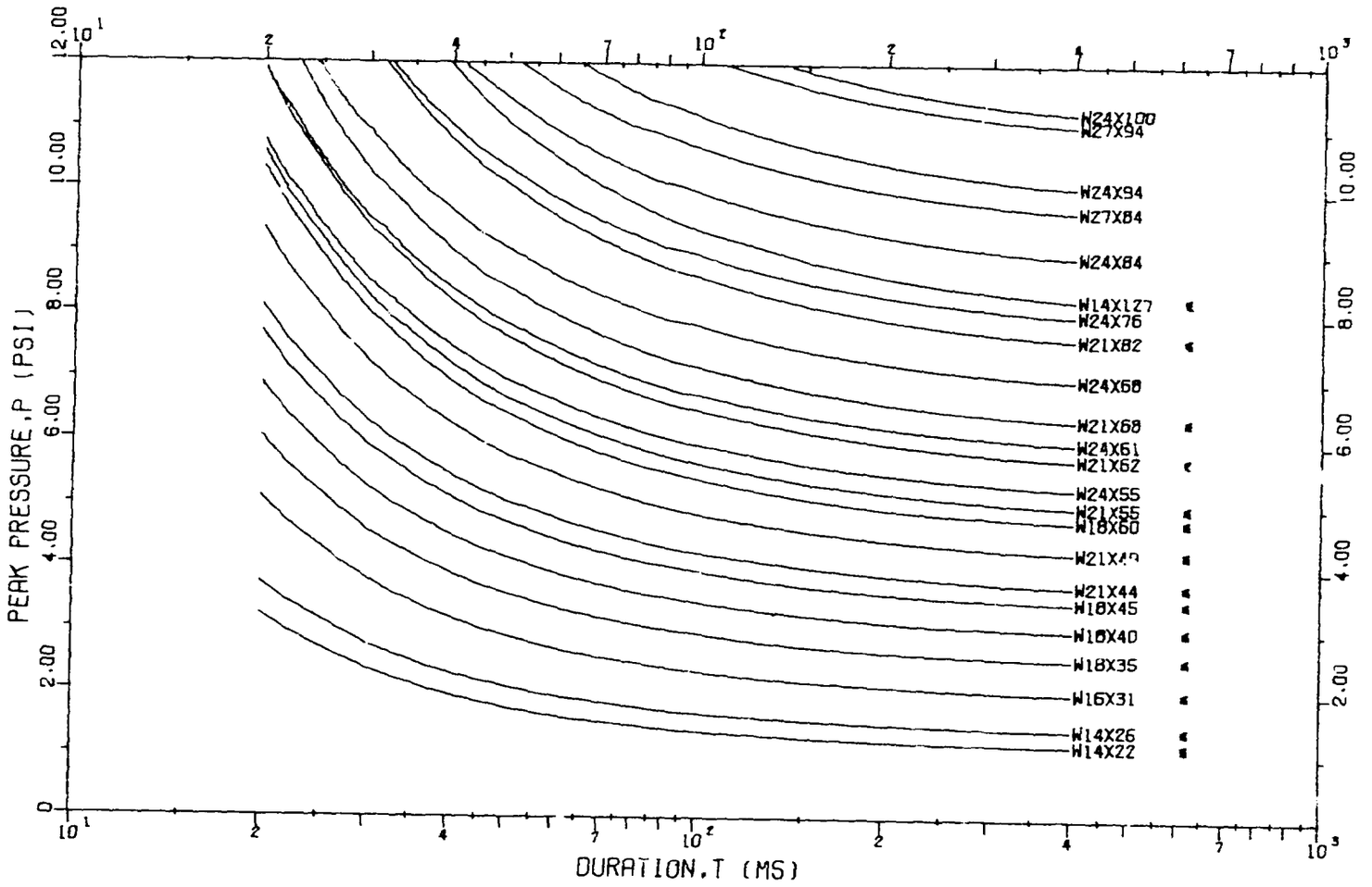


FIGURE 258

REUSABLE BEAM,SPAN= 35 FT.SPACING= 6 FT. FIXED ENDS

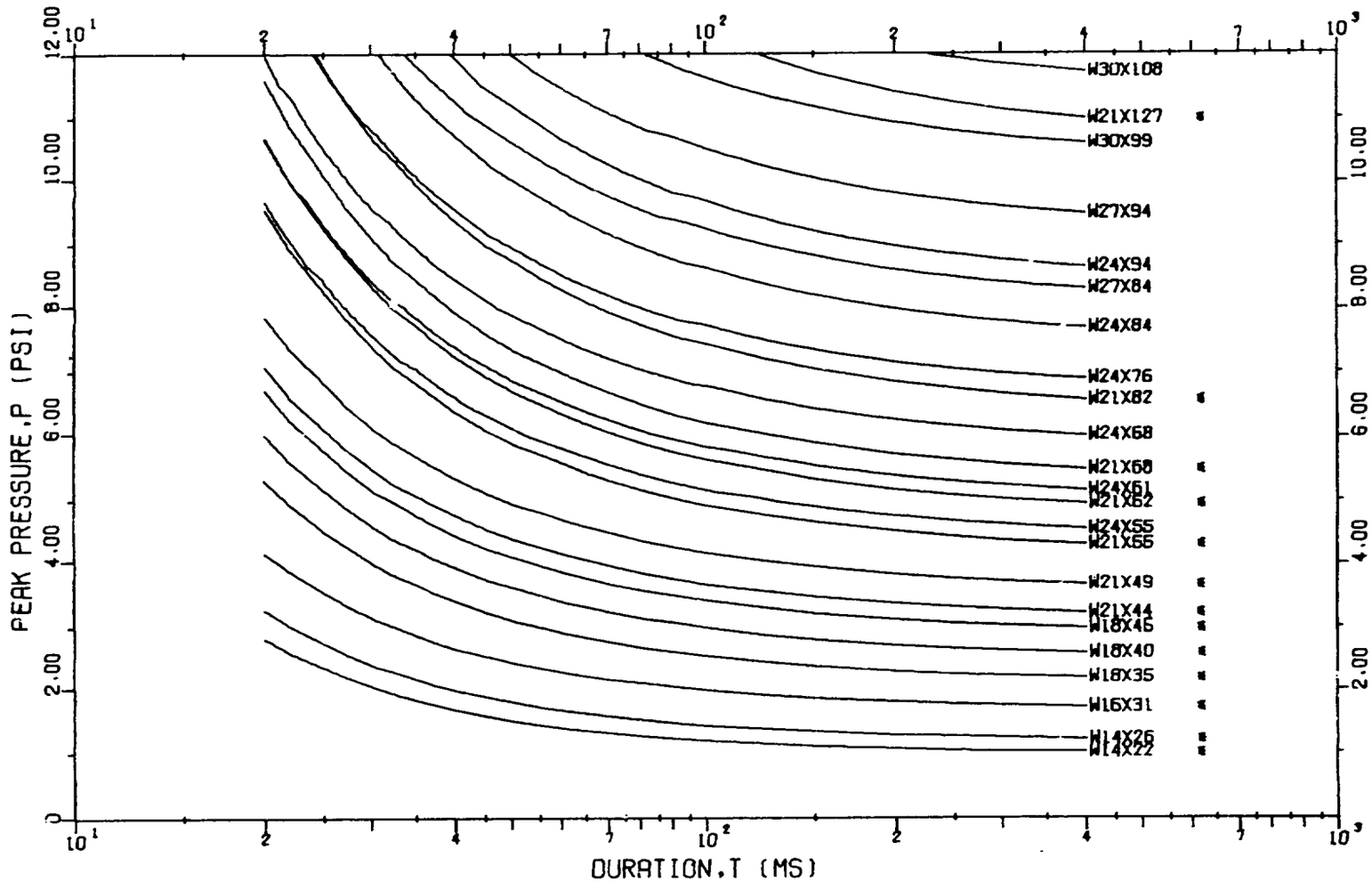


FIGURE 259

REUSABLE BEAM,SPAN= 35 FT,SPACING= 7 FT, FIXED ENDS

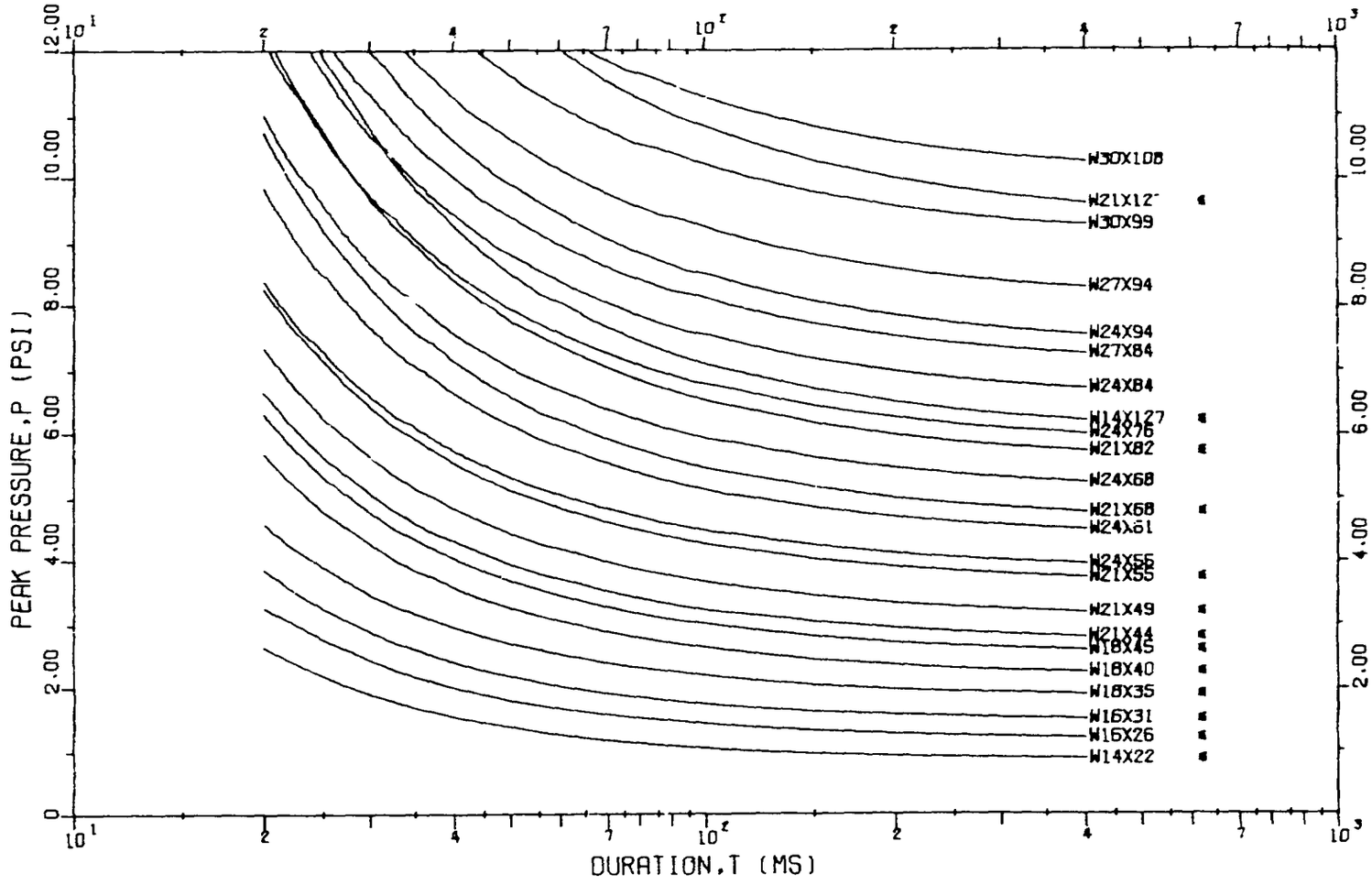


FIGURE 260

REUSABLE BEAM.SPAN=35 FT.SPACING=8 FT. FIXED ENDS

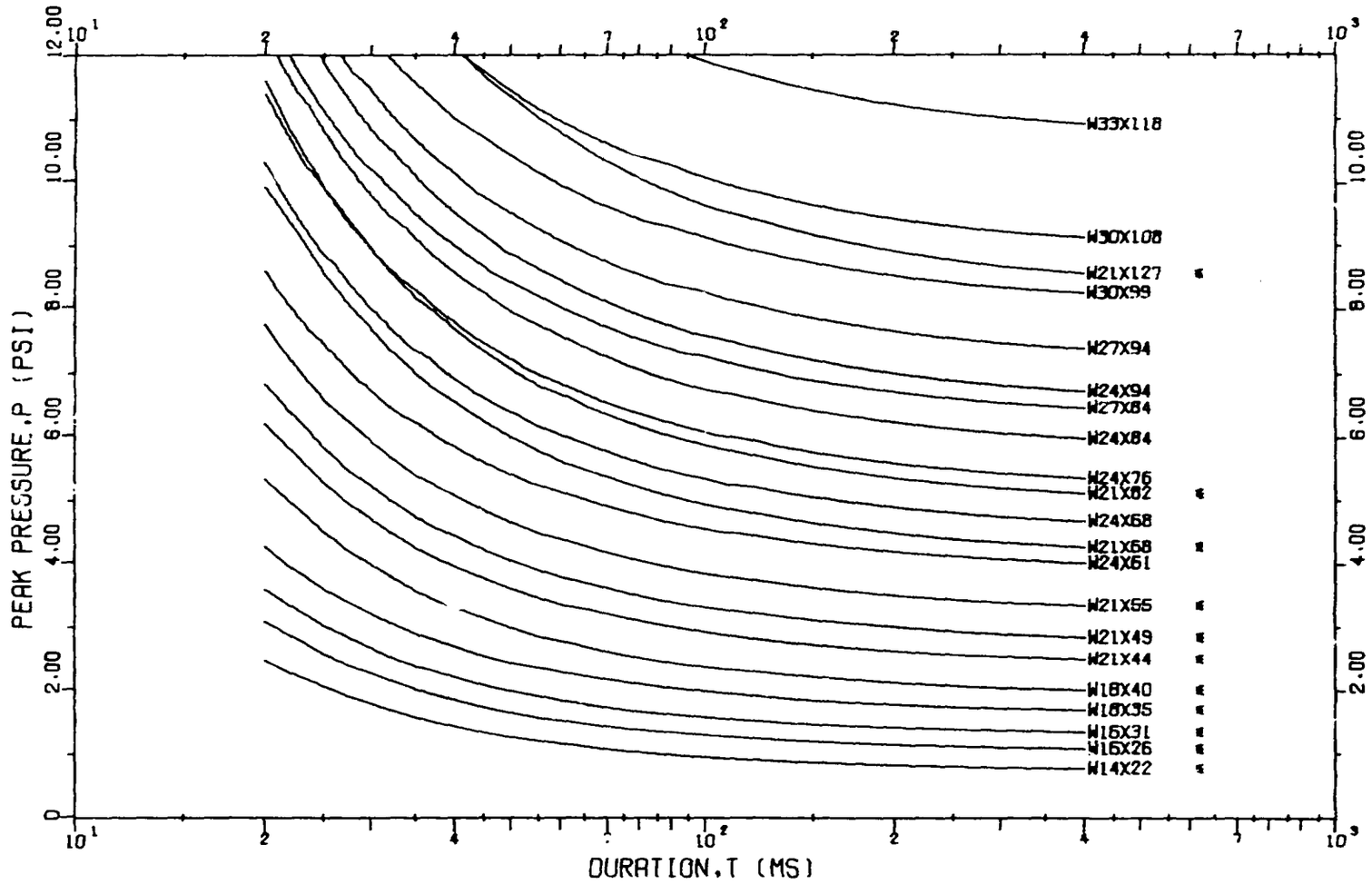


FIGURE 261

REUSABLE BEAM,SPAN= 35 FT,SPACING= 9 FT, FIXED ENDS

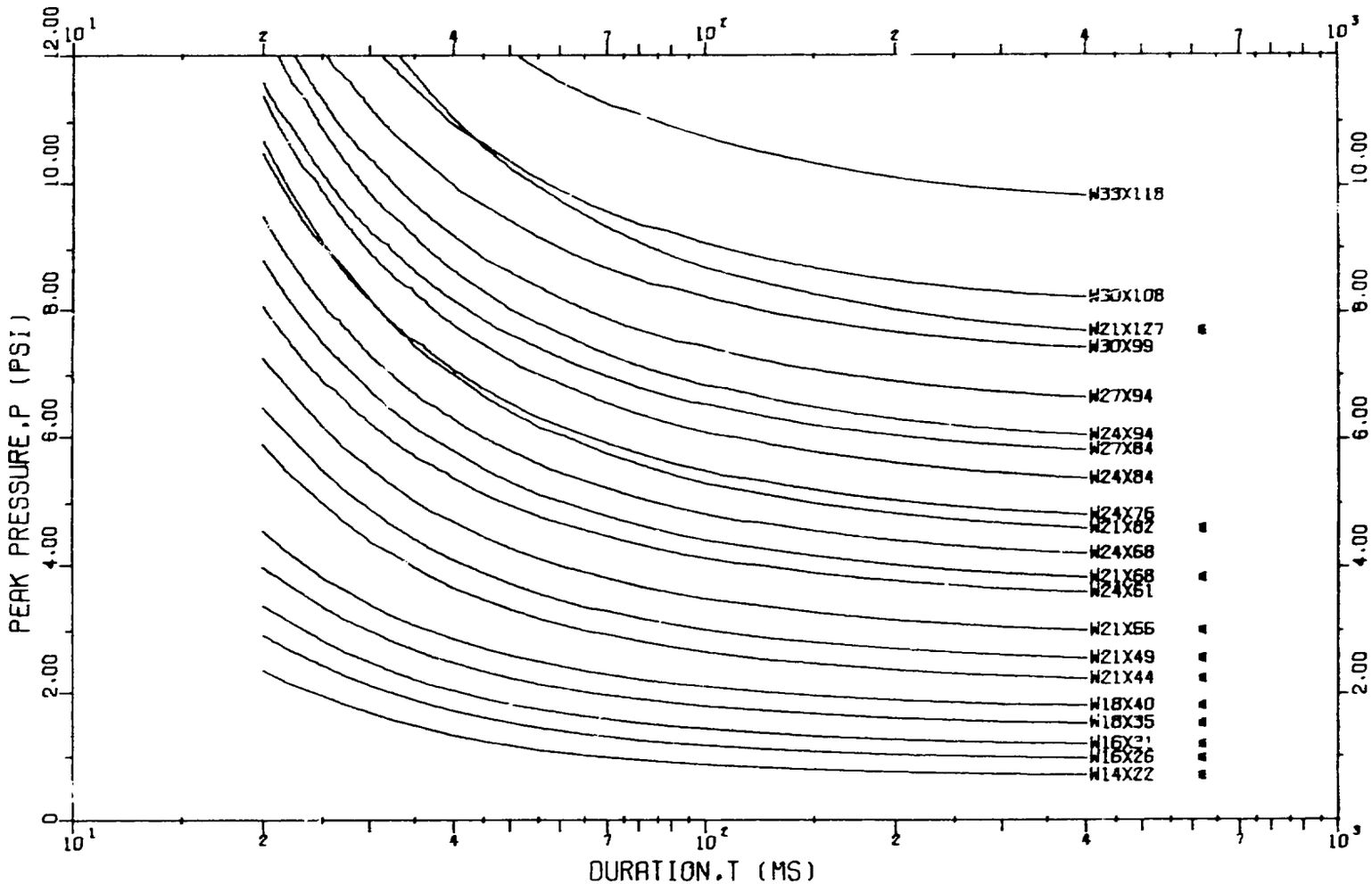


FIGURE 262

REUSABLE BEAM,SPAN= 35 FT,SPACING= 10 FT, FIXED ENDS

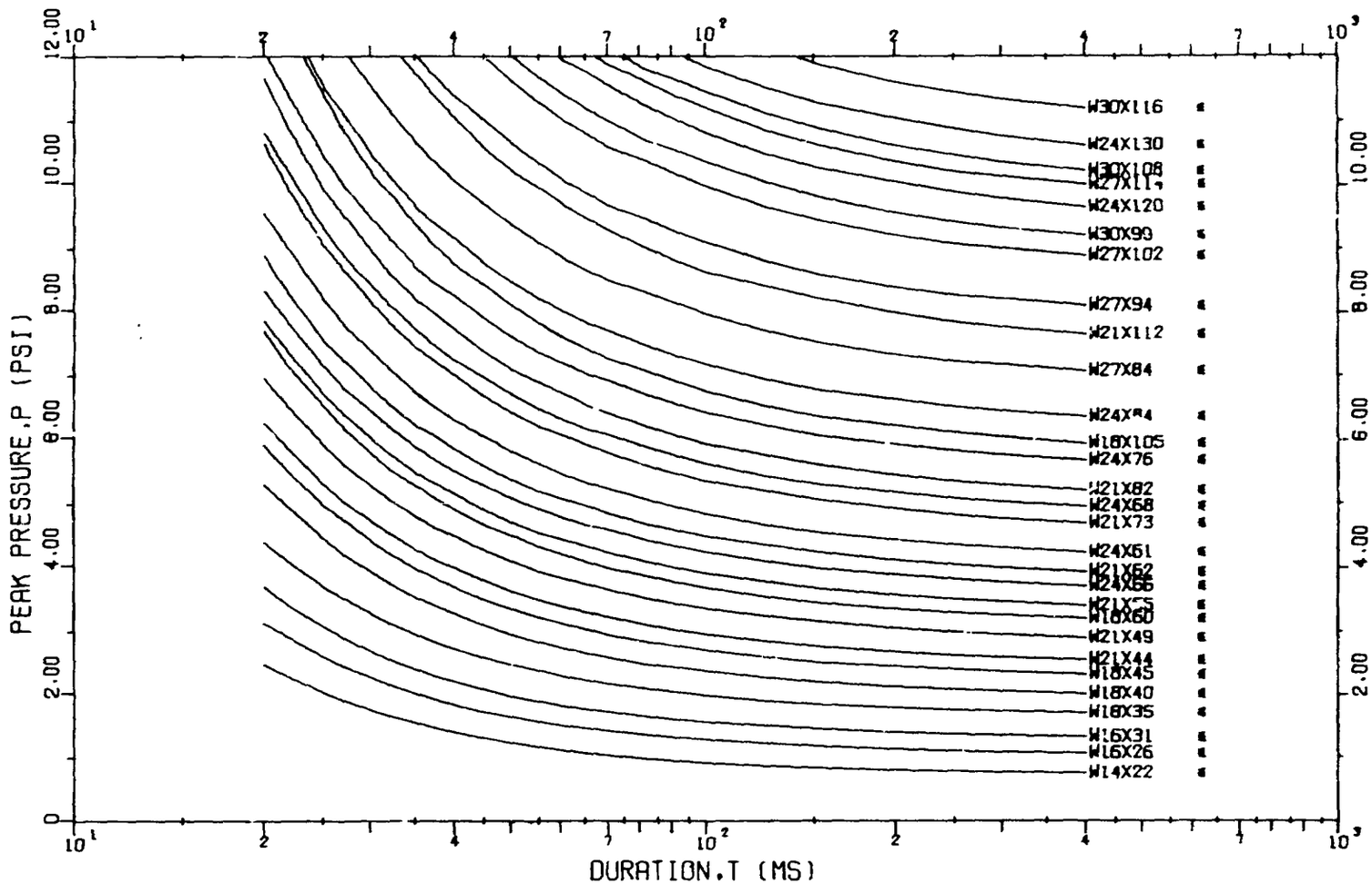


FIGURE 263

REUSABLE BEAM.SPAN= 35 FT.SPACING= 6 FT. SIMPLE-FIXED

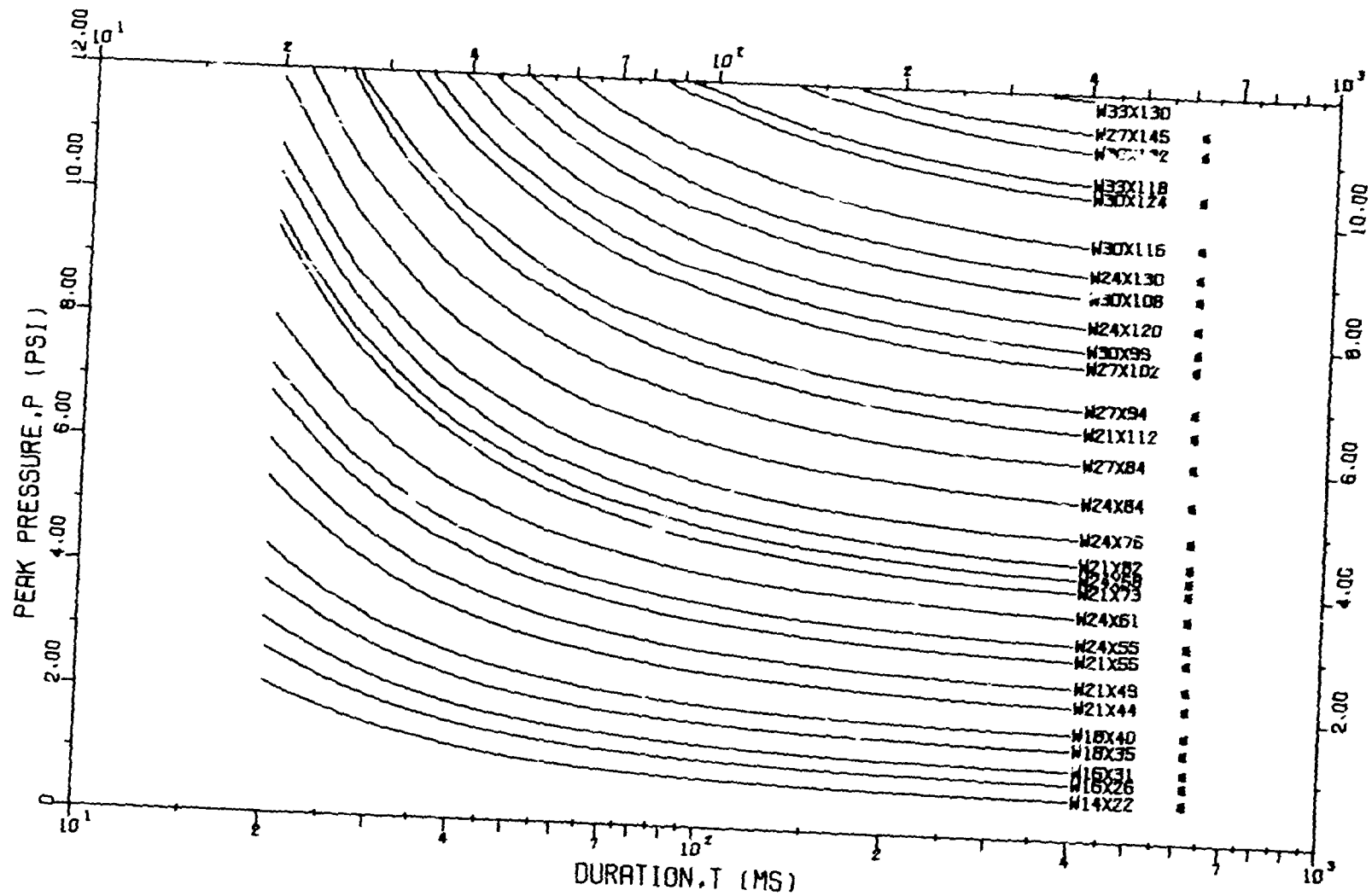


FIGURE 264

REUSABLE BEAM,SPAN= 35 FT,SPACING= 7 FT, SIMPLE-FIXED

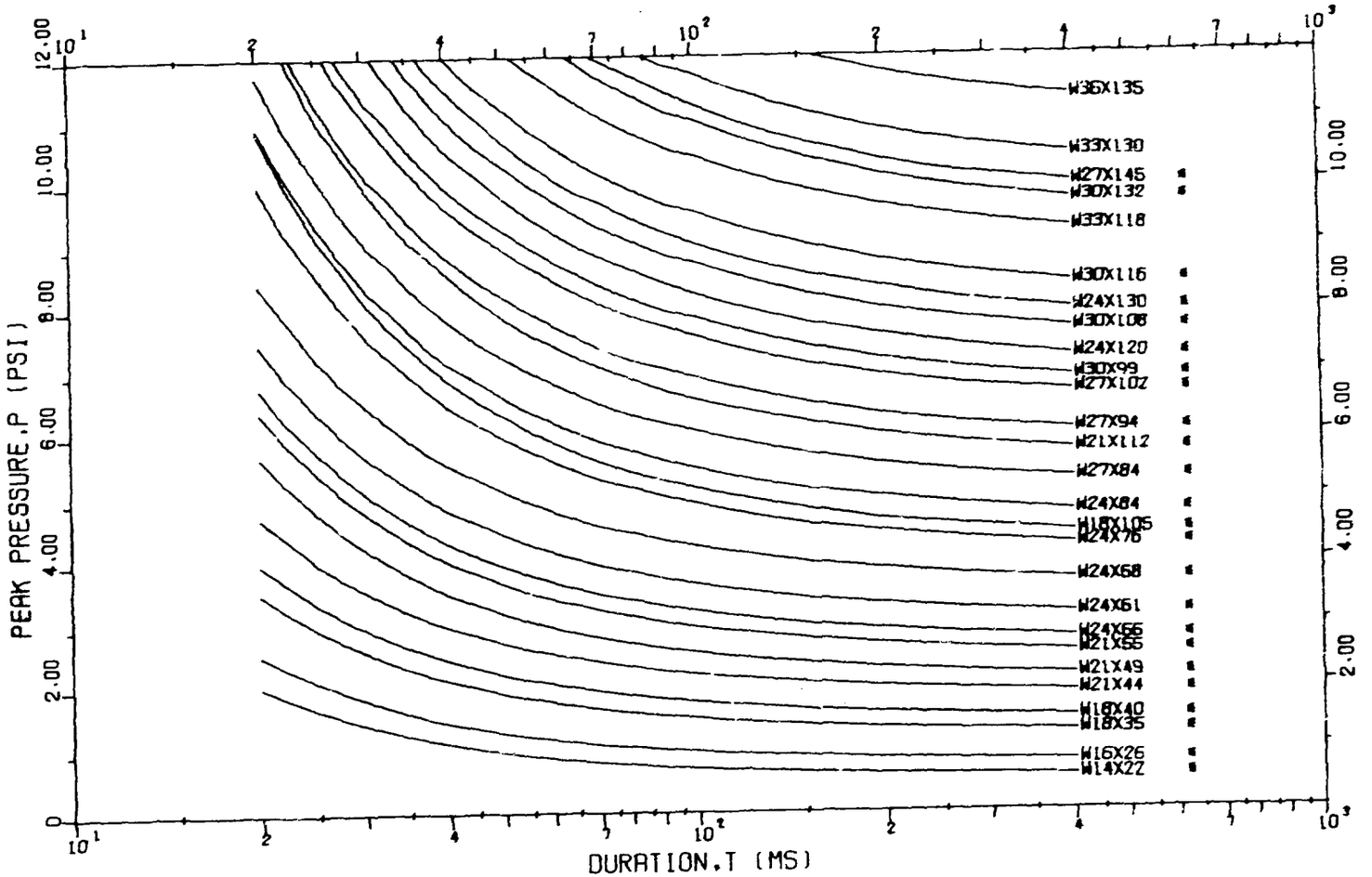


FIGURE 265

REUSABLE BEAM.SPAN= 35 FT.SPACING= 8 FT. SIMPLE-FIXED

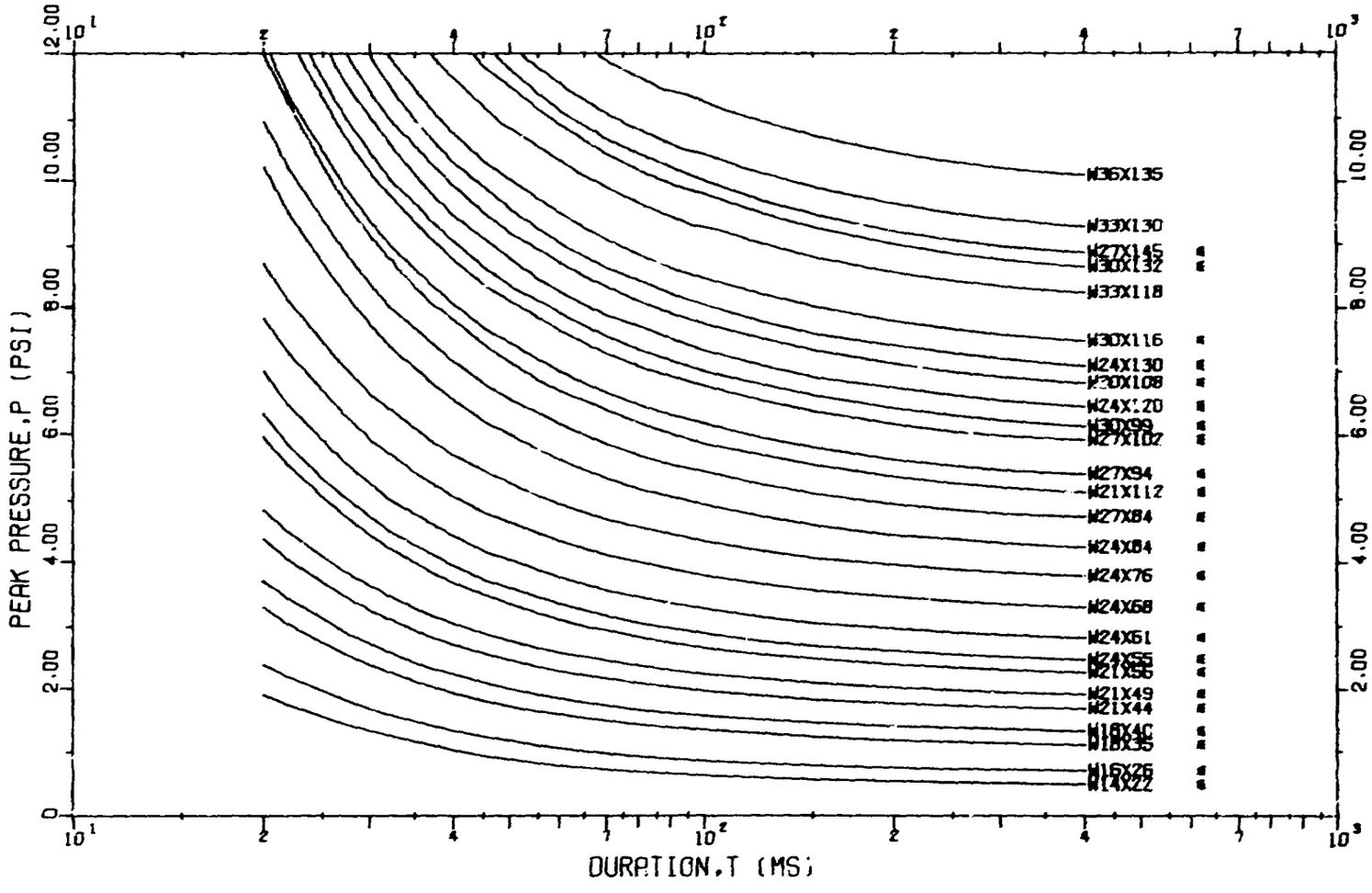


FIGURE 266

REUSABLE BEAM,SPAN= 35 FT,SPACING= 9 FT, SIMPLE-FIXED

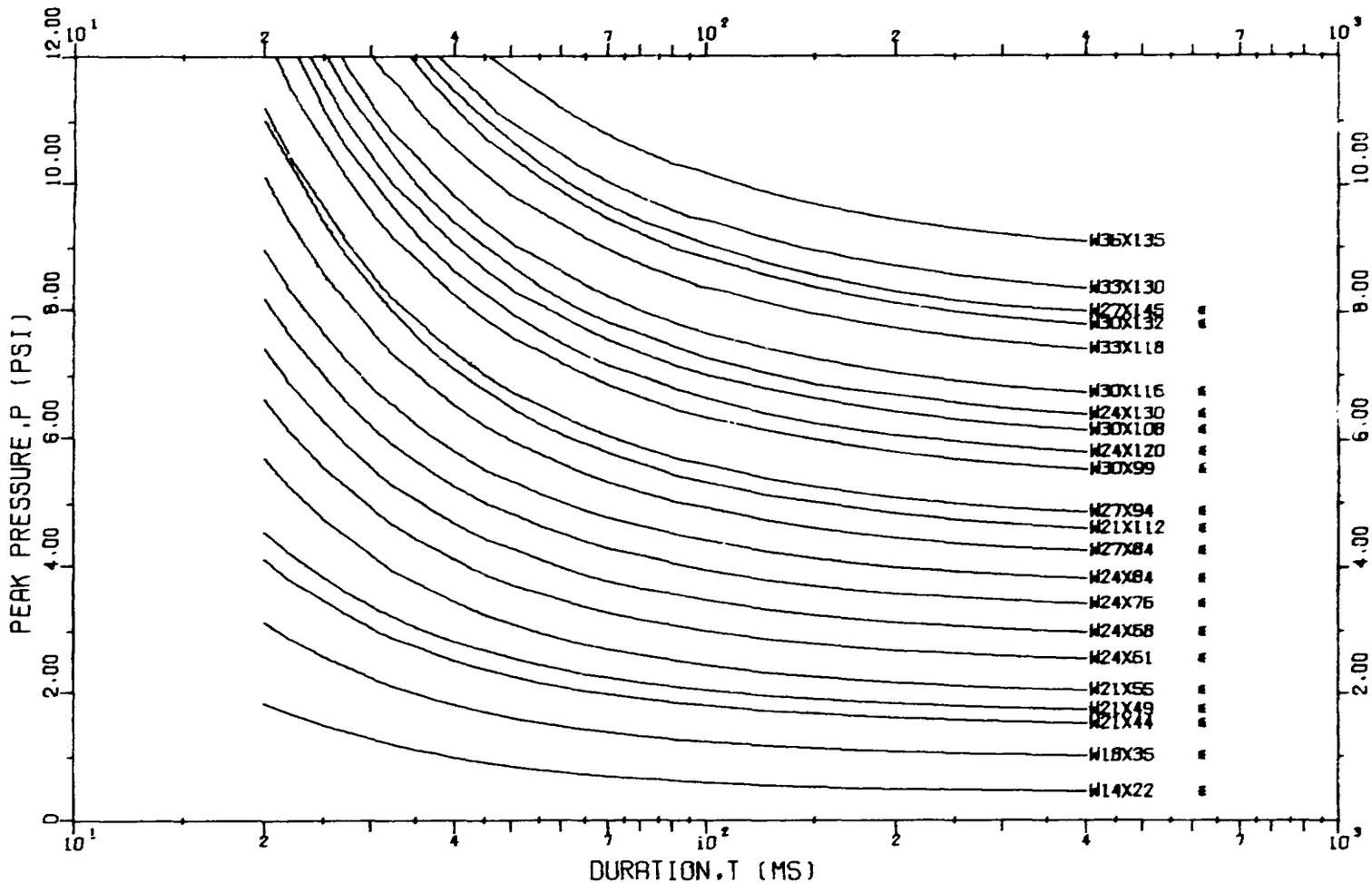


FIGURE 267

REUSABLE BEAM,SPAN= 35 FT,SPACING= 10FT, SIMPLE-FIXED

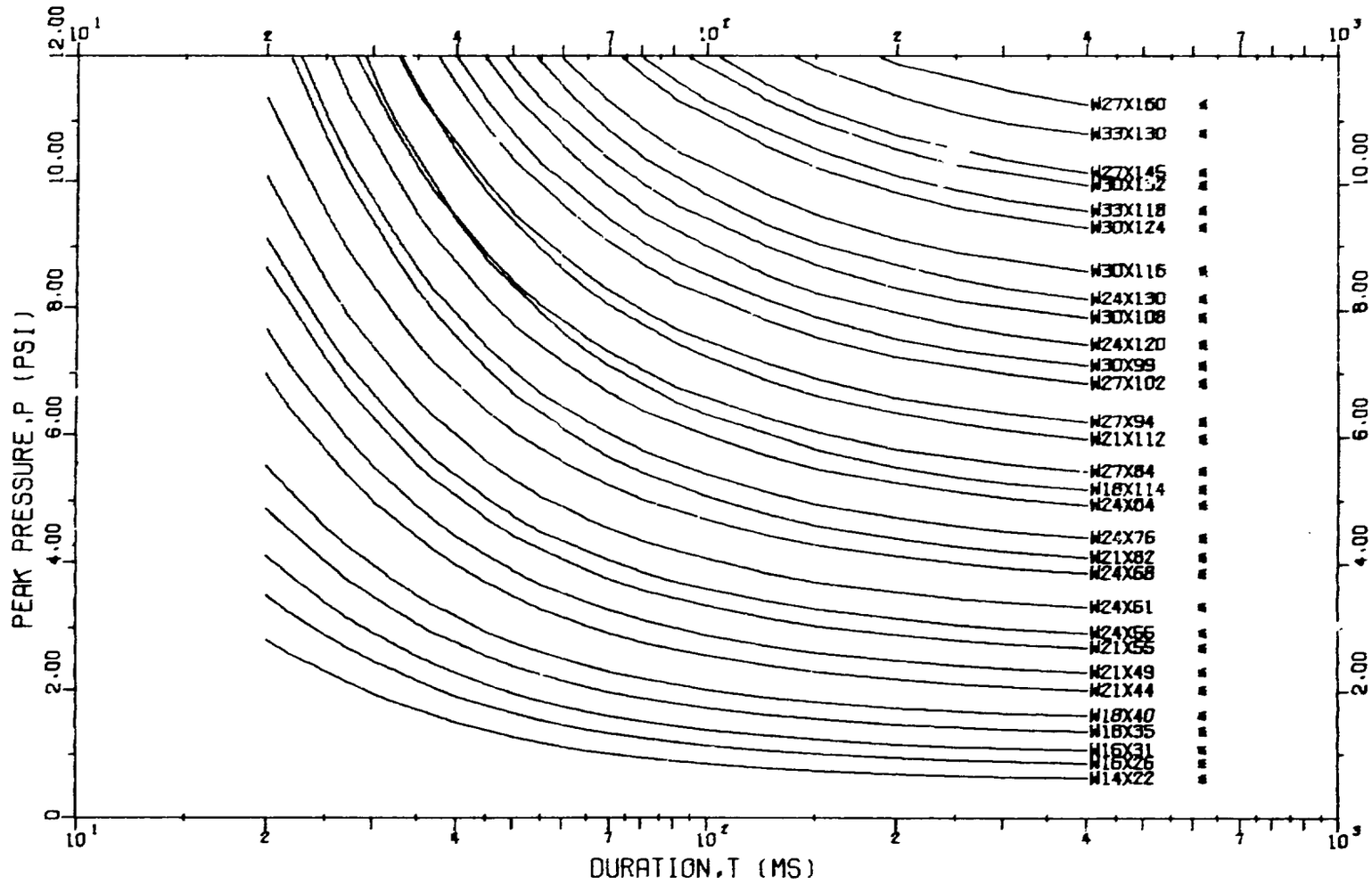


FIGURE 268

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=6 FT, SIMPLY-SUPPORTED

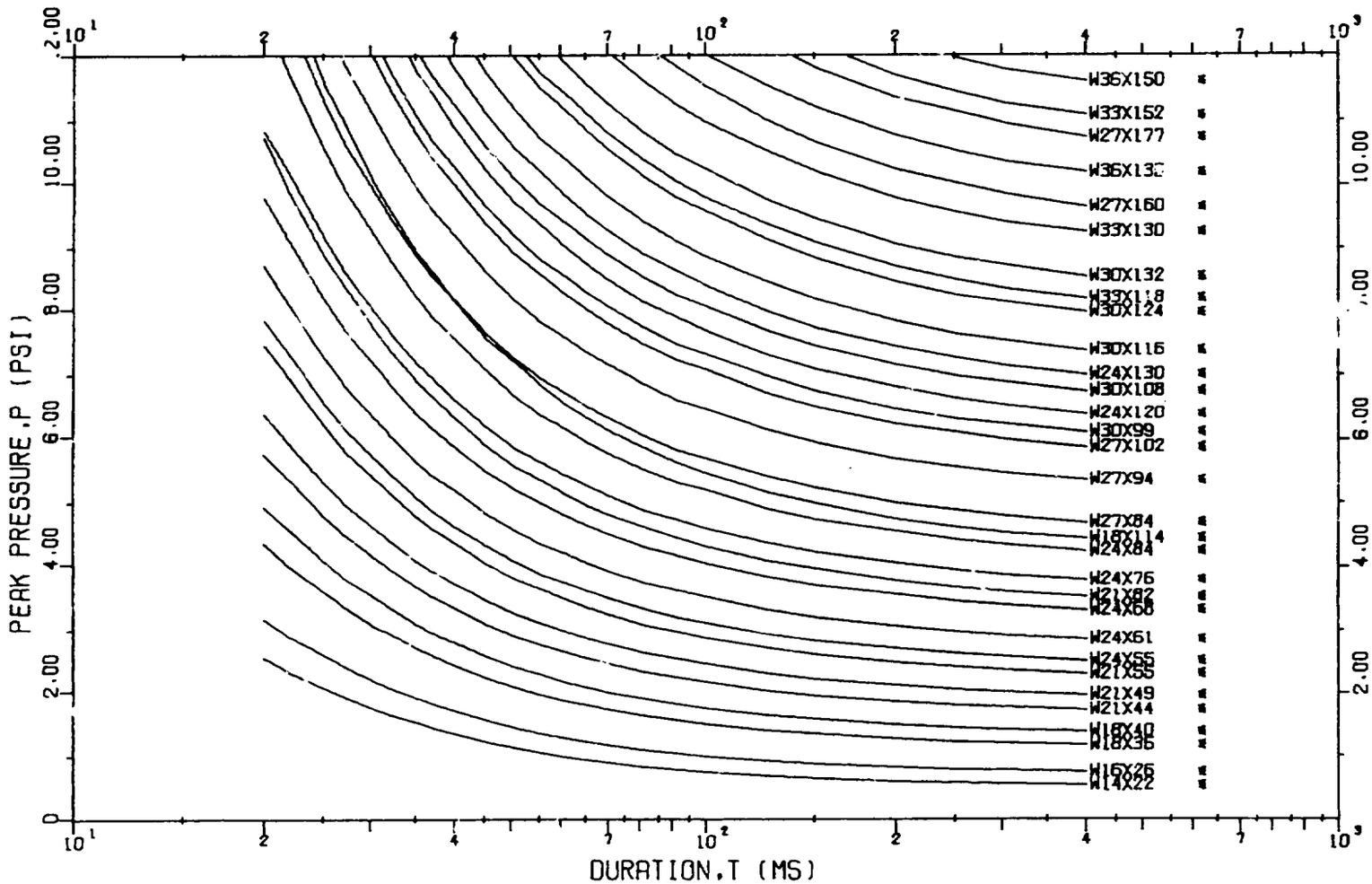


FIGURE 269

NON-REUSABLE BEAM.SPAN= 35 FT.SPACING=7 FT. SIMPLY-SUPPORTED

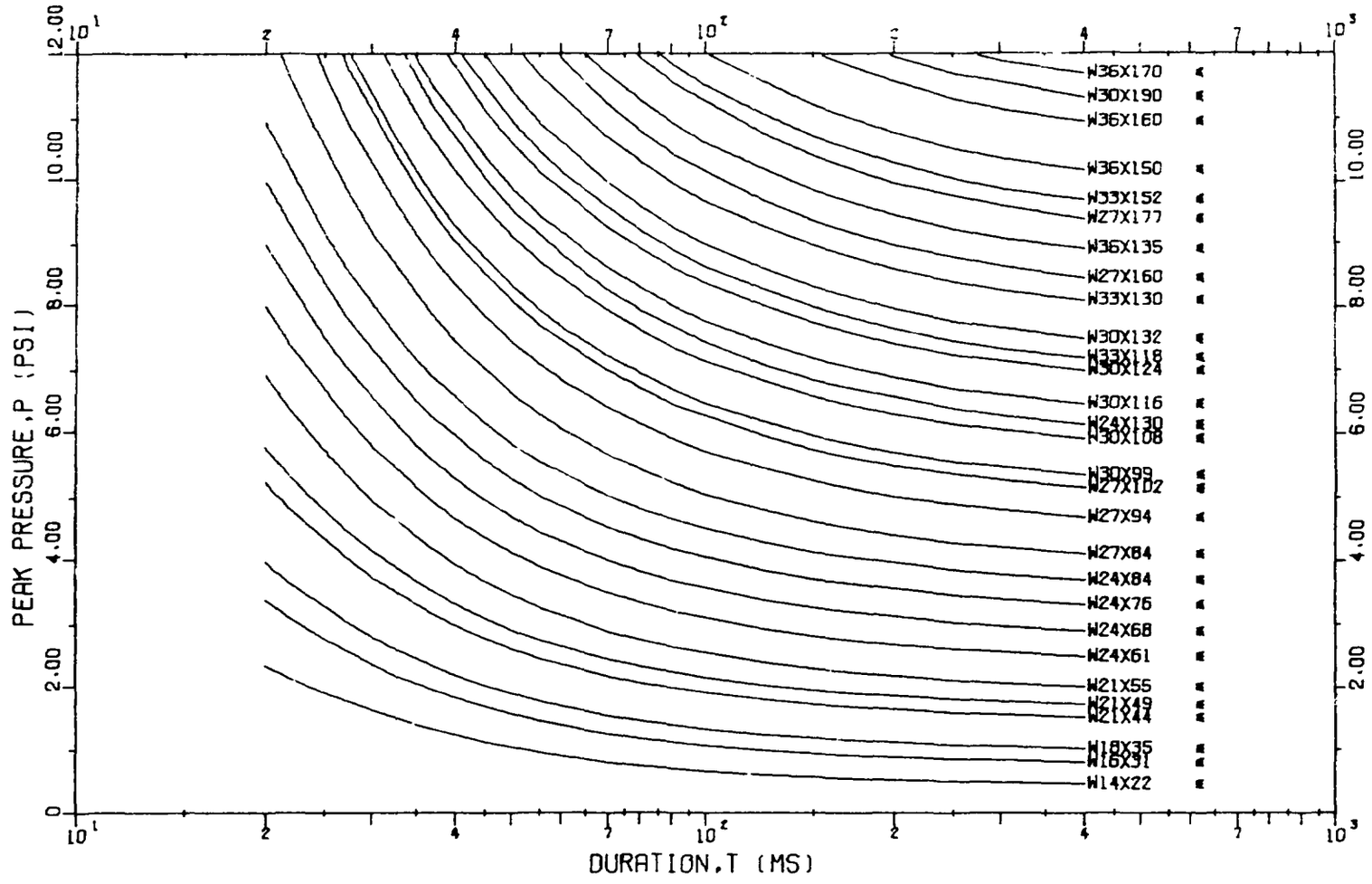


FIGURE 270

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=8 FT, SIMPLY-SUPPORTED

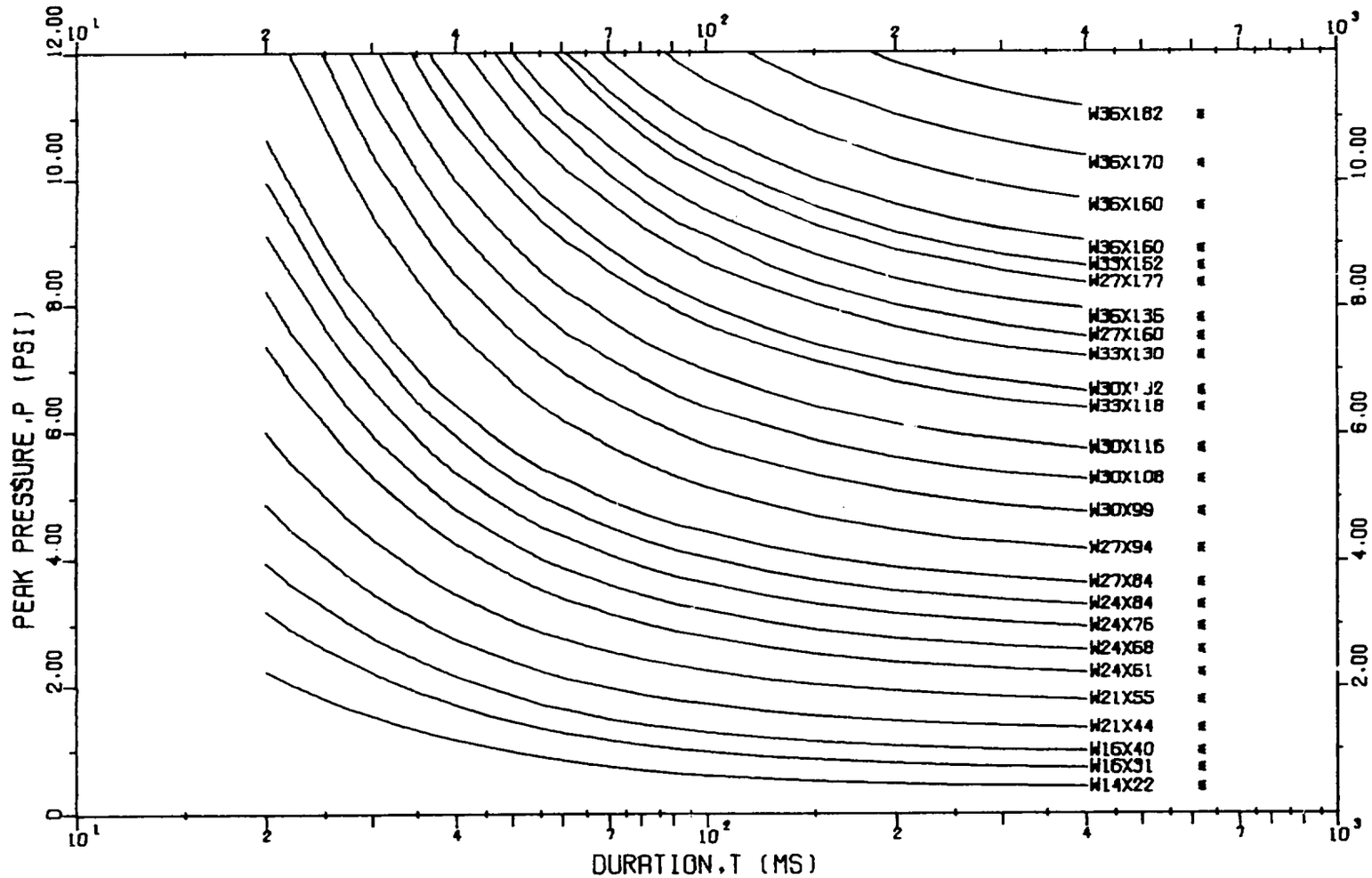


FIGURE 271

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING= 9 FT, SIMPLY-SUPPORTED

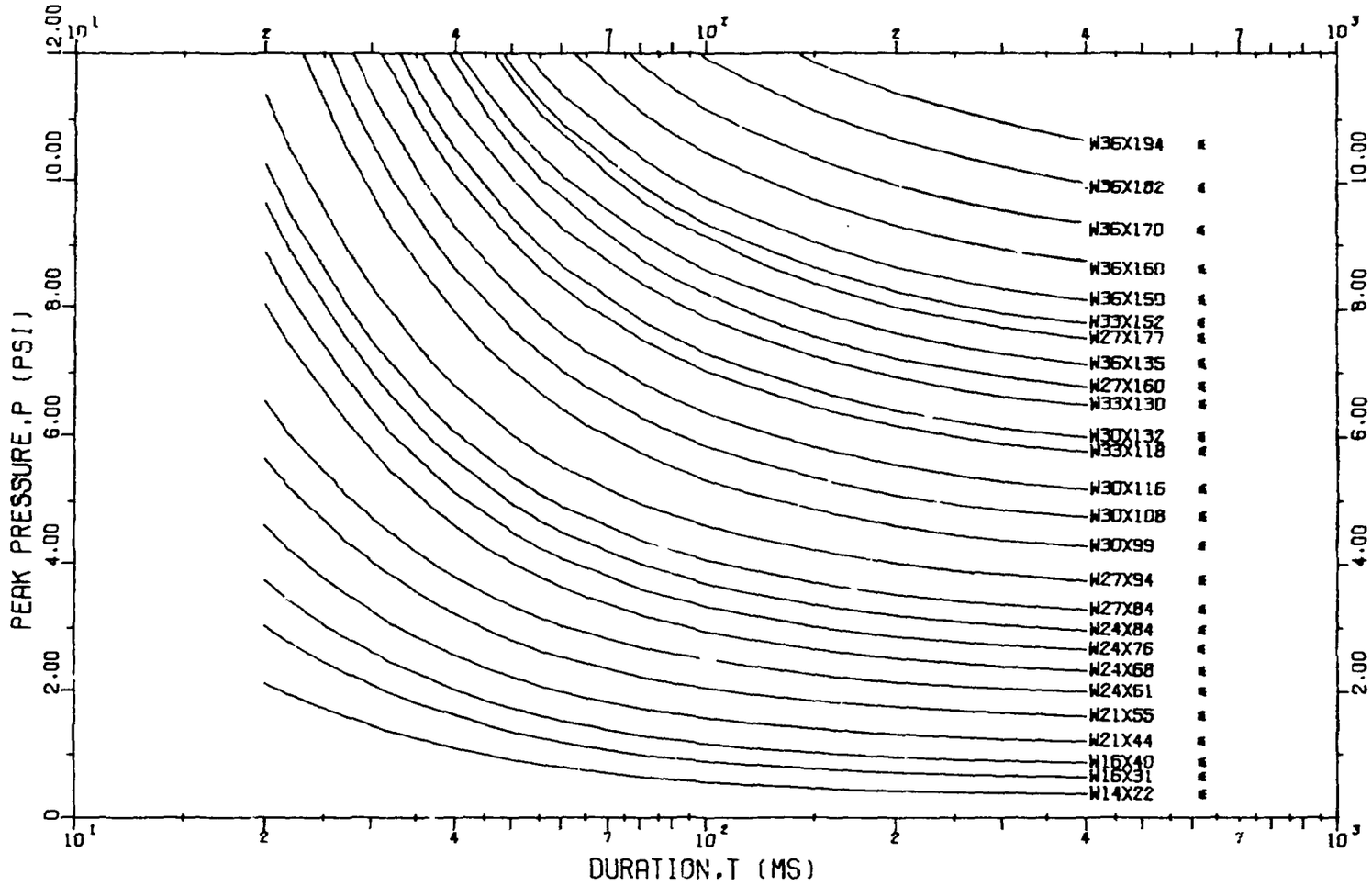


FIGURE 272

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING= 10 FT. SIMPLY-SUPPORTED

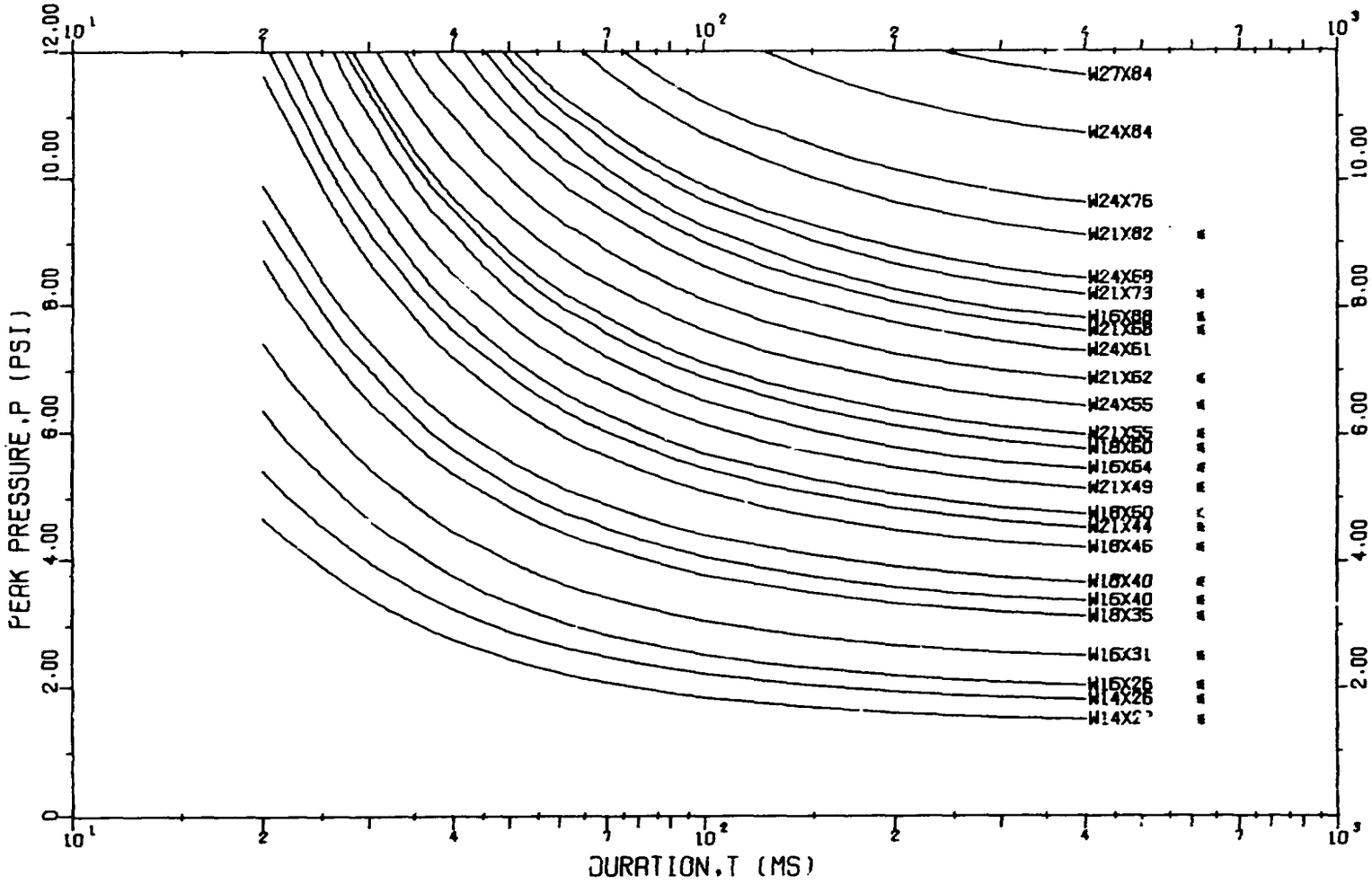


FIGURE 273

NON-REUSABLE BEAM.SPAN= 35 FT.SPACING=6 FT. FIXED ENDS

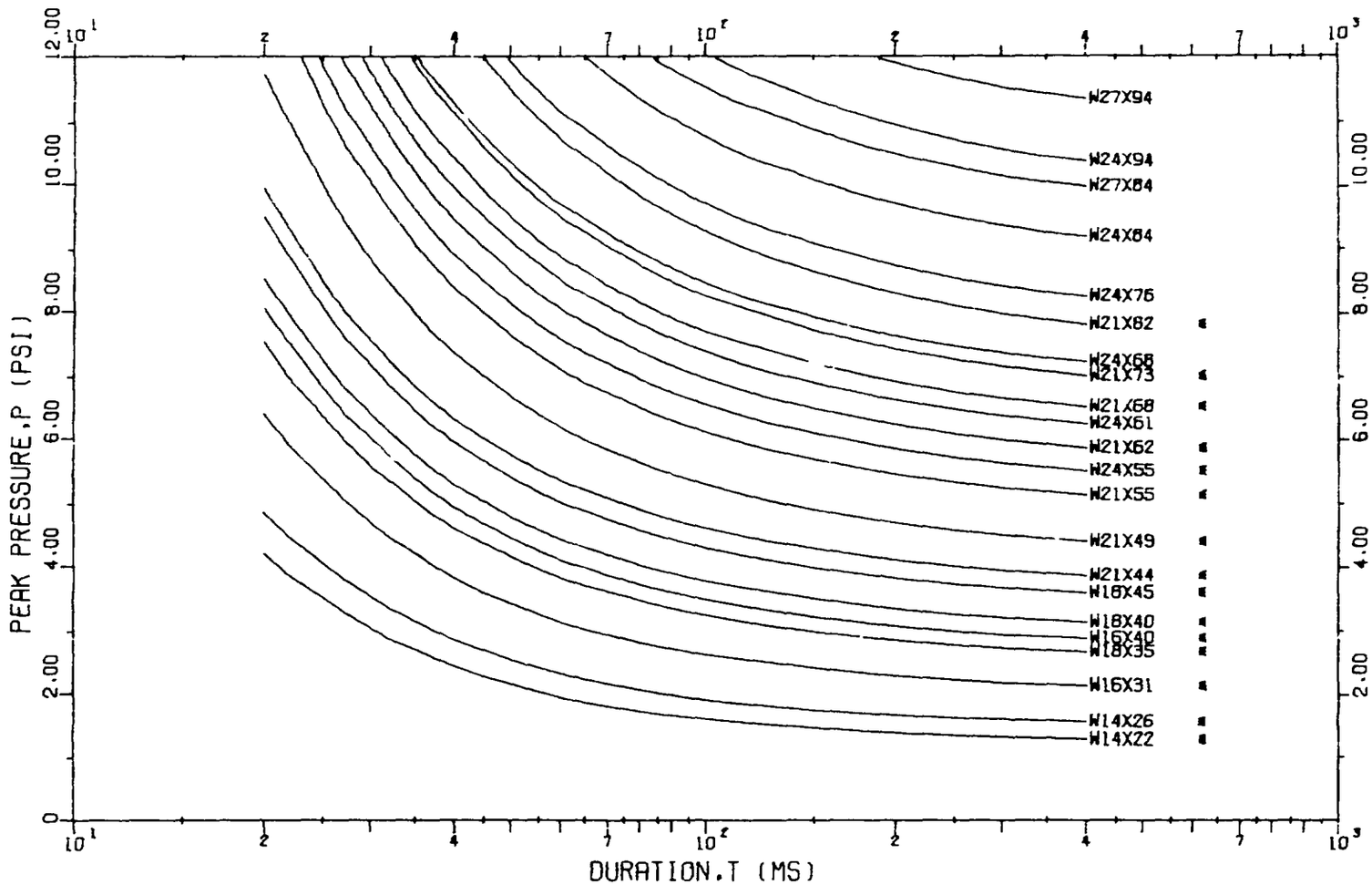


FIGURE 274

NON-REUSABLE BEAM.SPAN= 35 FT.SPACING= 7 FT. FIXED ENDS

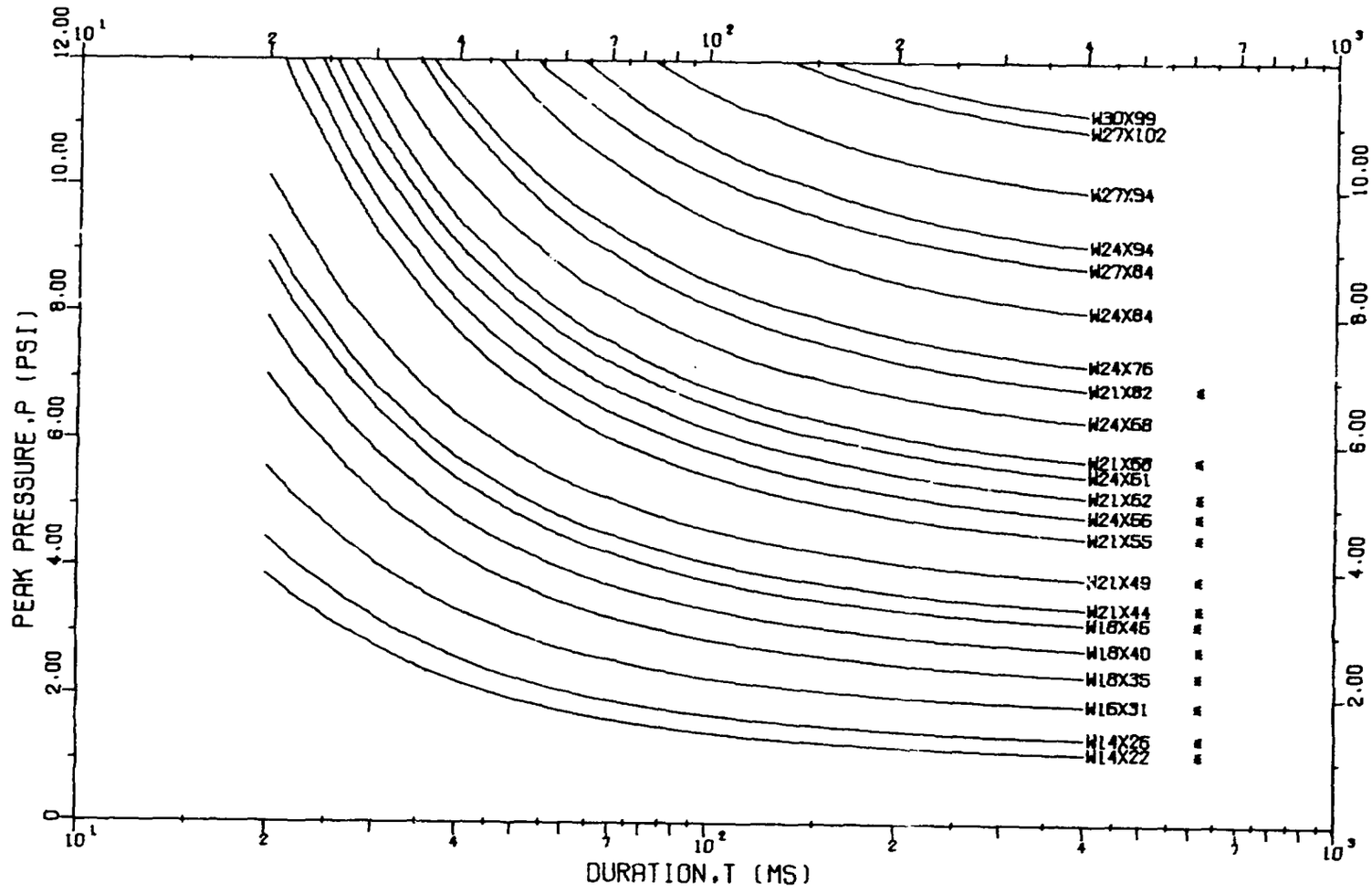


FIGURE 275

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=8 FT, FIXED ENDS

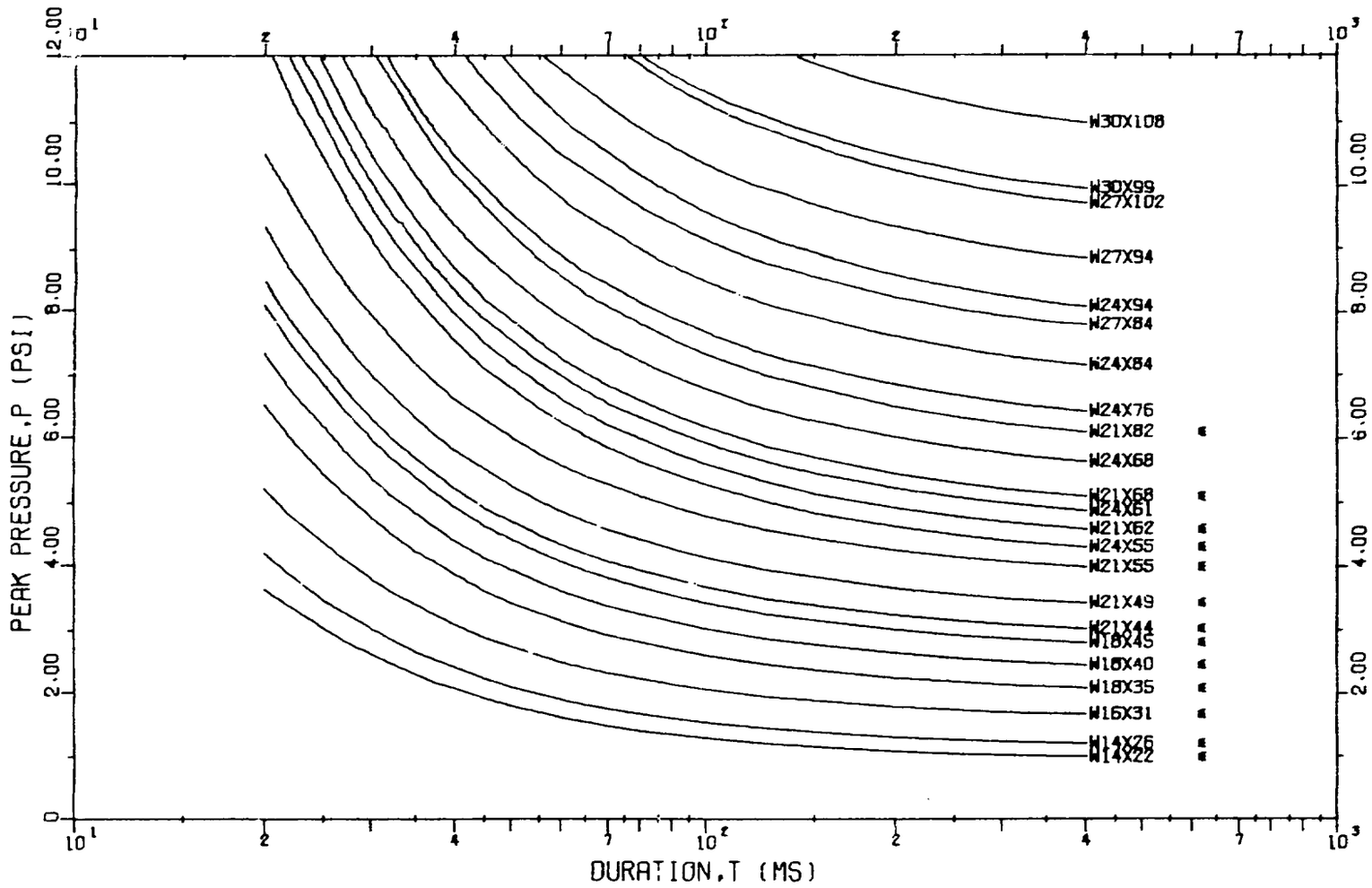


FIGURE 276

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING= 9 FT. FIXED ENDS

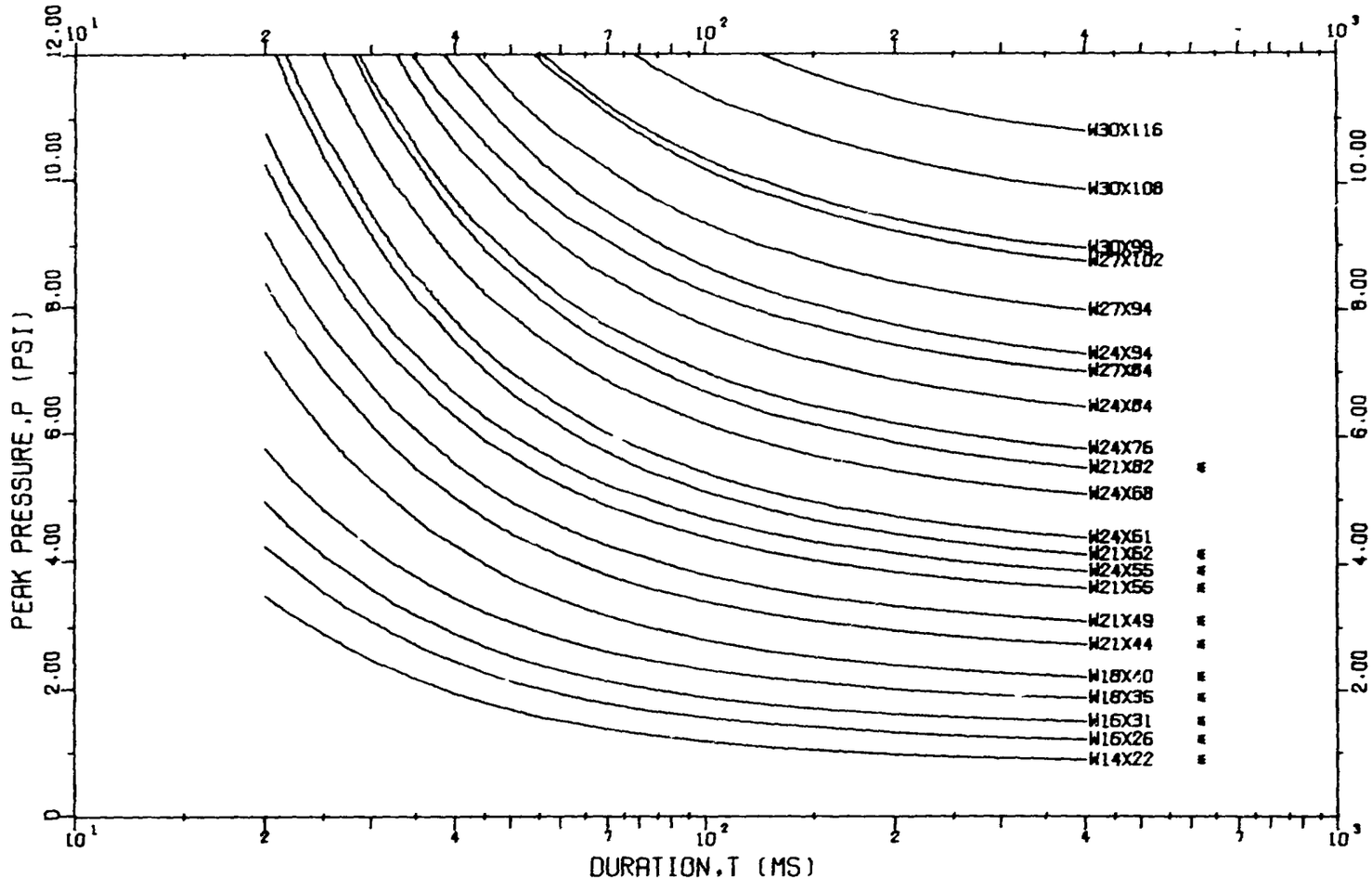


FIGURE 277

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING= 10 FT, FIXED ENDS

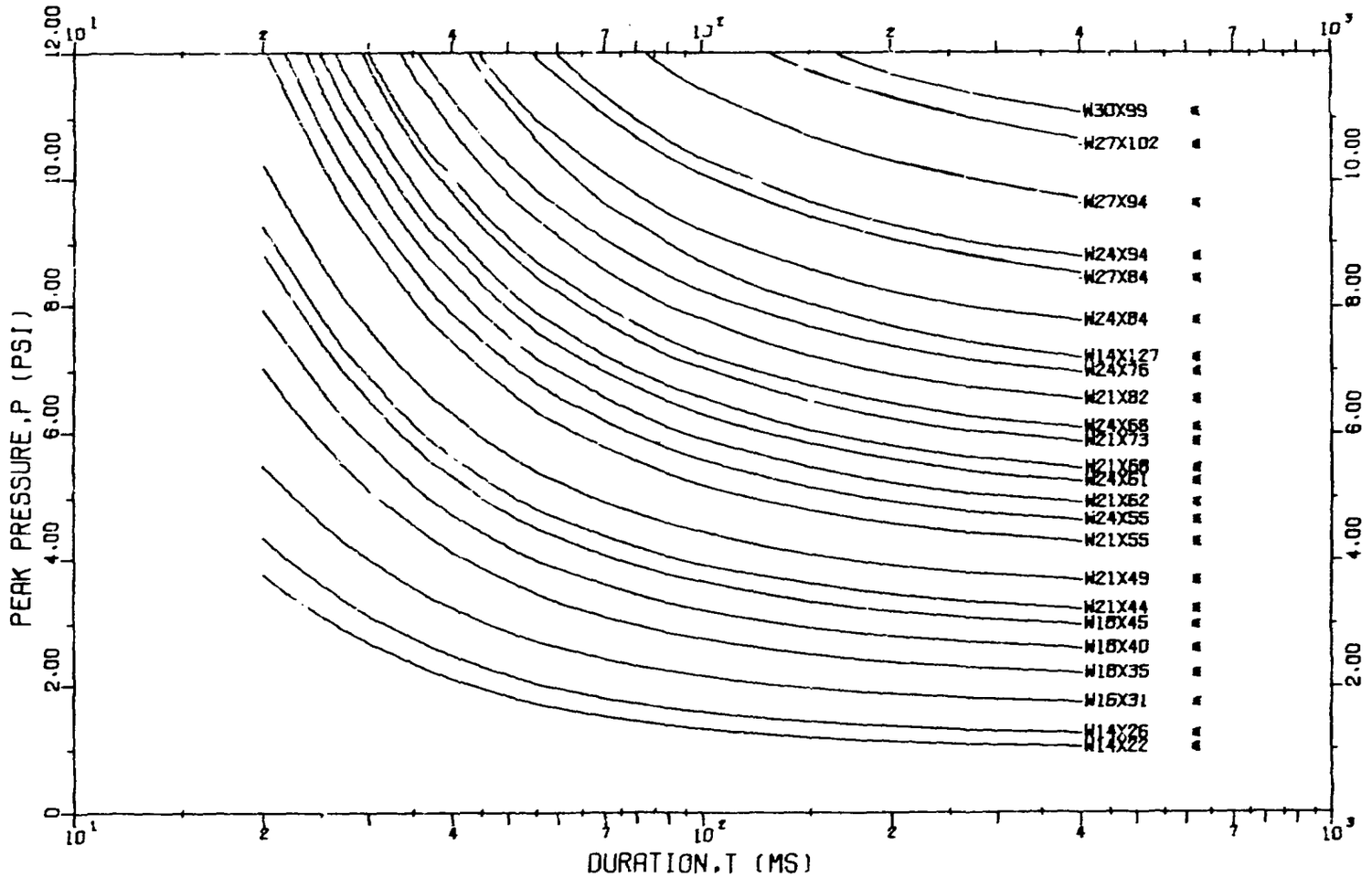


FIGURE 278

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=6 FT, SIMPLE-FIXED

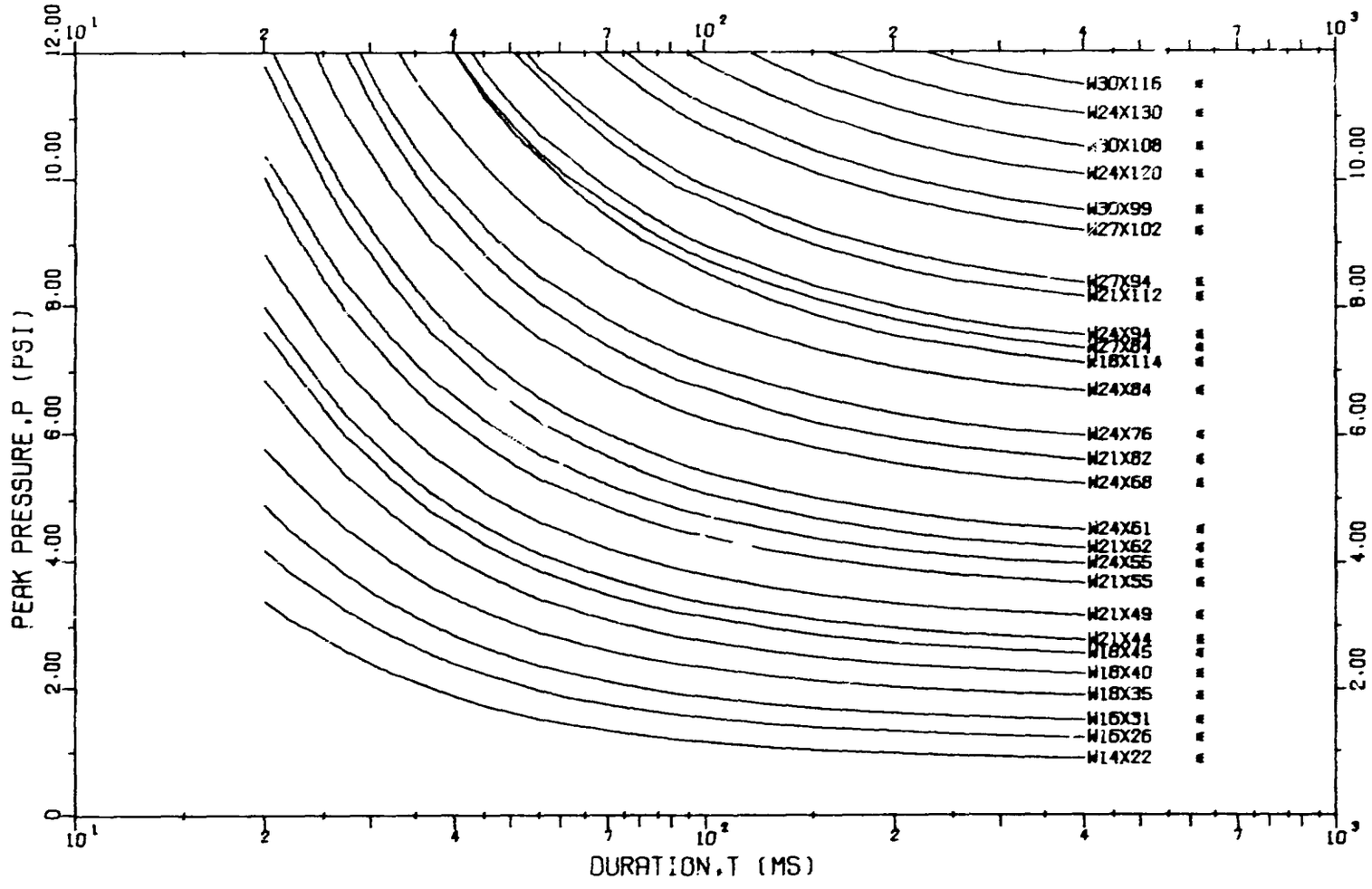


FIGURE 279

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=7 FT. SIMPLE-FIXED

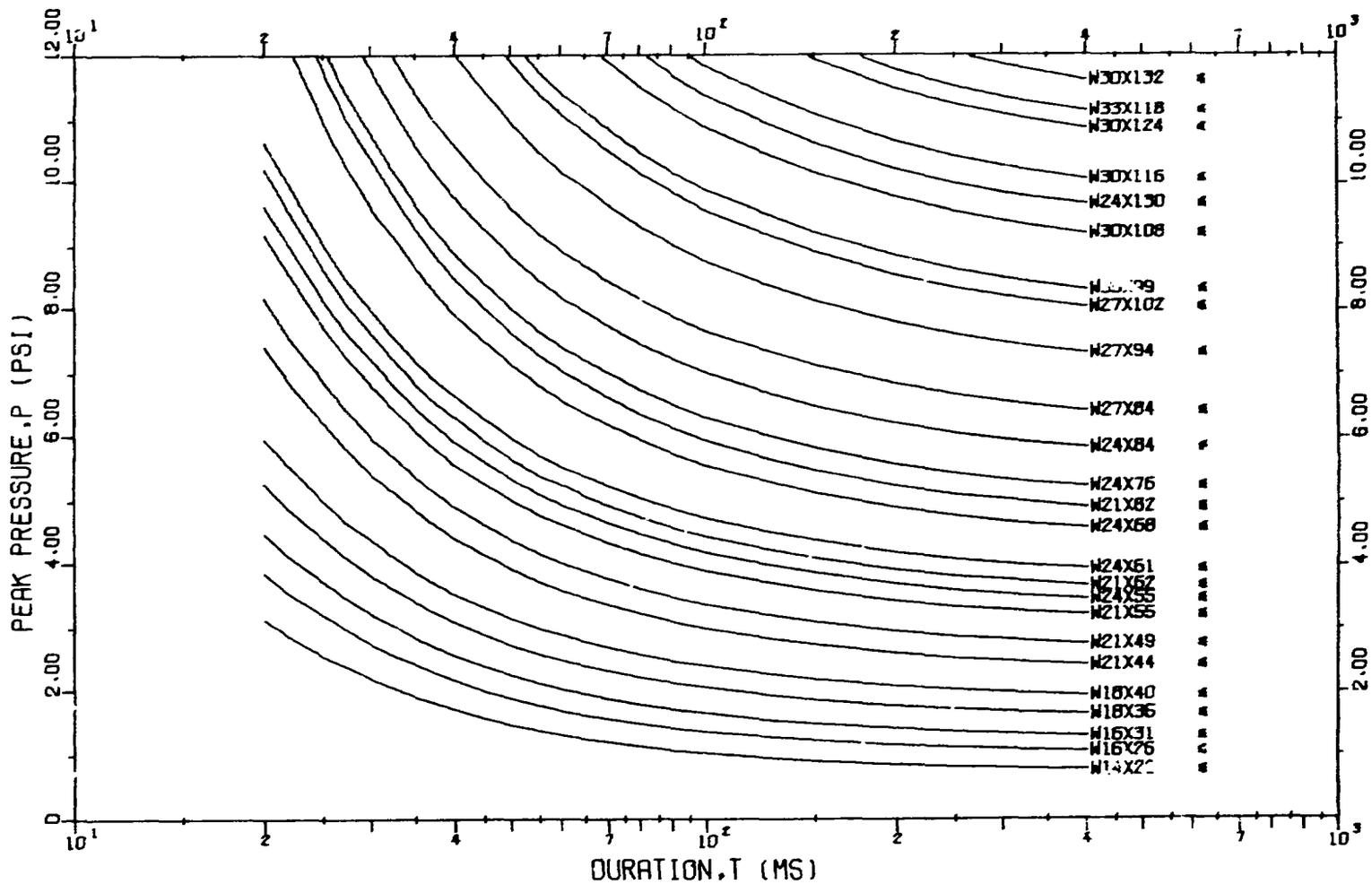


FIGURE 280

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=8 FT, SIMPLE-FIXED

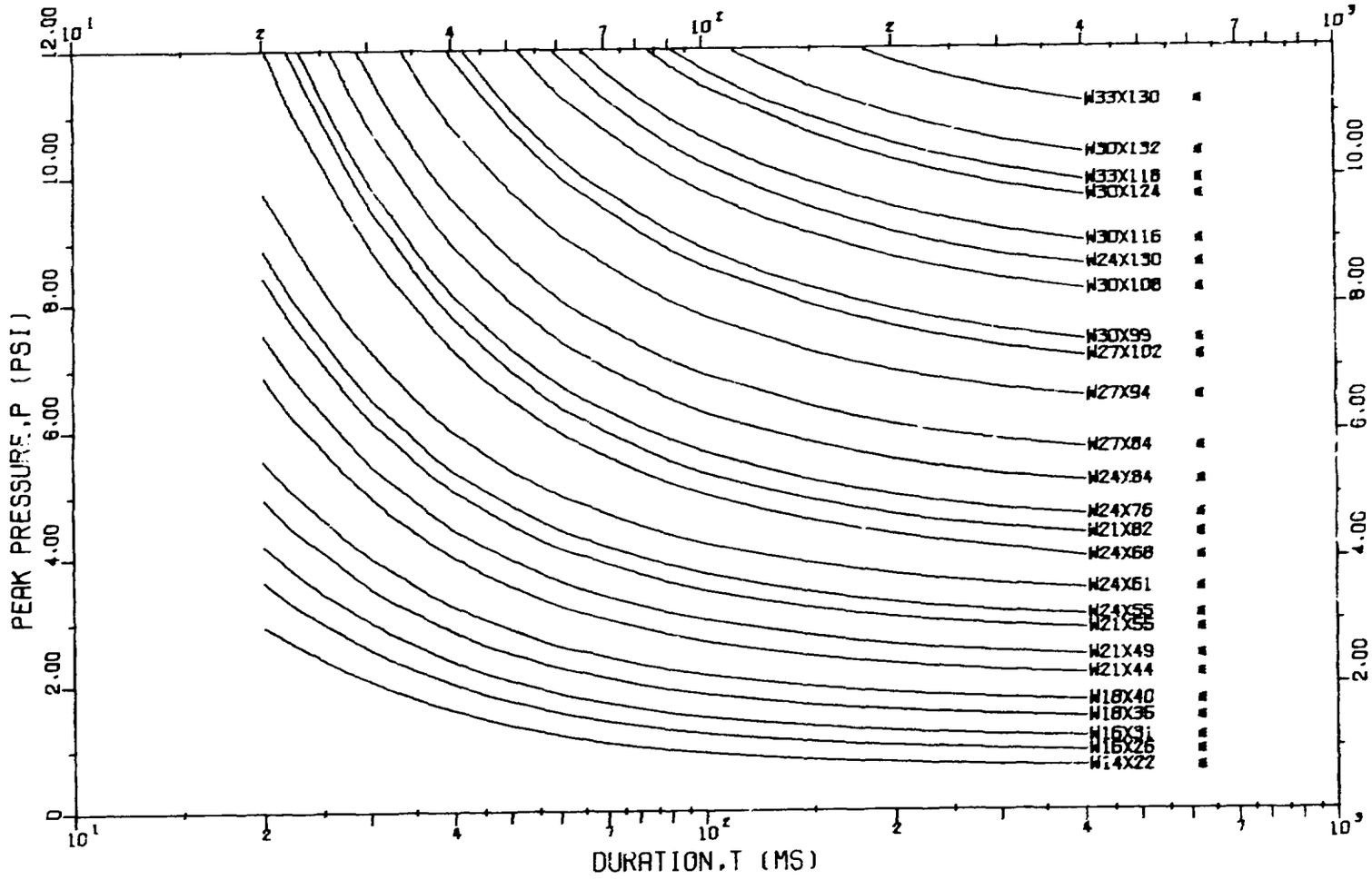


FIGURE 281

NON-REUSABLE BEAM,SPAN= 35 FT,SPACING=9 FT, SIMPLE-FIXED

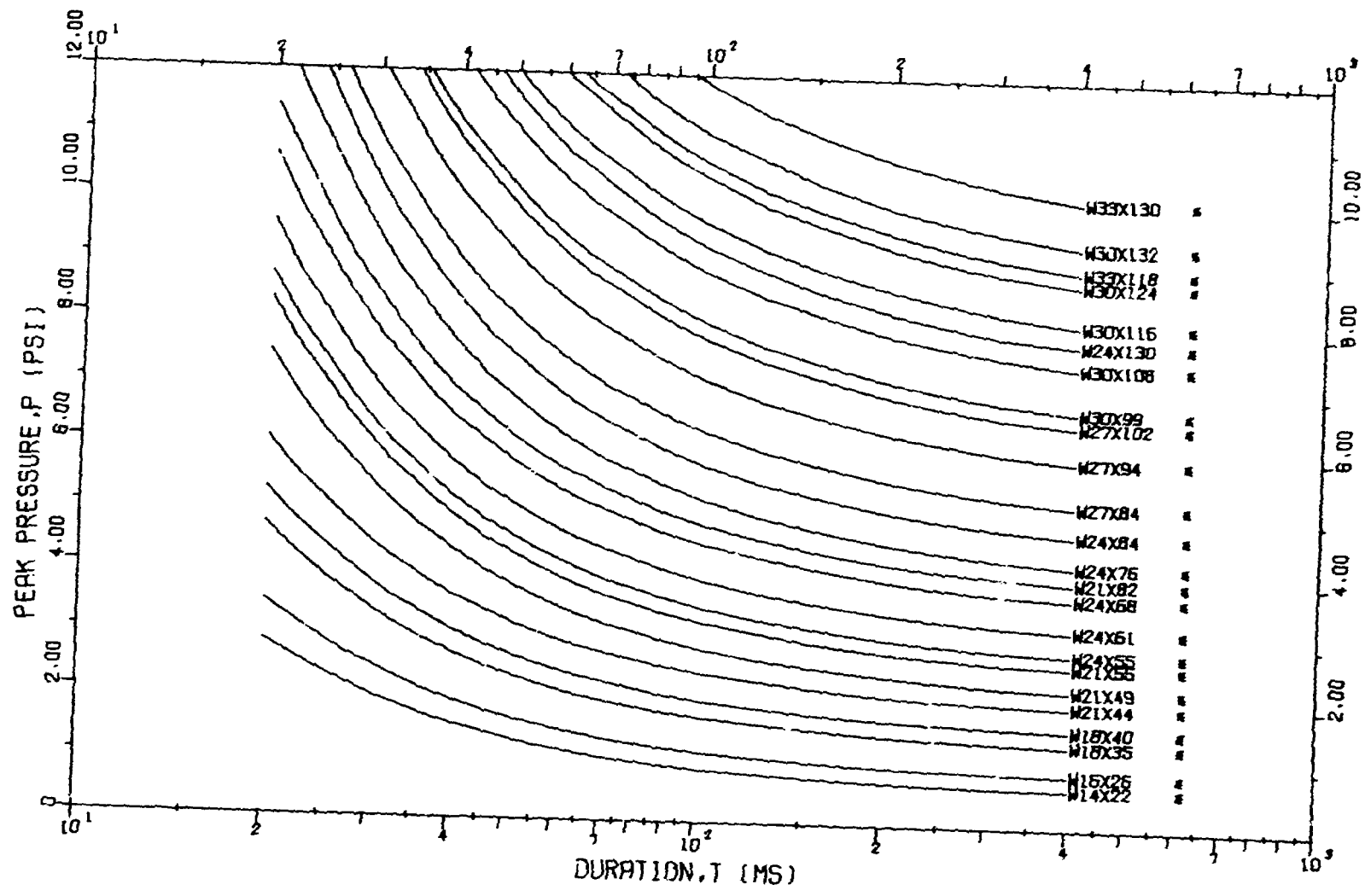


FIGURE 282

NON-REUSABLE BEAM.SPAN= 35 FT.SPACING= 10 FT. SIMPLE-FIXED