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TABLES AND GRAPHS OF THE THEORETICAL PEAK PRESSURES, ENERGIES, AND IMPULSES OF SHOCK WAVES FROM EXPLOSIVE SOURCES IN SEA WATER

by

Stuart R. Brinkley, Jr., and John G. Kirkwood
Cornell University

NDRC Report No. A-342
OSRD Report No. 5649

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NDRC Report No. A-342
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Submitted by

John G. Kirkwood
Cornell University

Approved on October 4, 1945
for submission to the Committee

E. Bright Wilson, Jr., Chief
Division 2
Effects of Impact and Explosion

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Preface

The work described in this report is pertinent to War Department Project OD-03 and to Navy Department Project NO-224. This work was carried out and reported by Cornell University as part of its performance under Contract OEMsr-121.

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TABLES AND GRAPHS OF THE THEORETICAL PEAK PRESSURES, ENERGIES, AND IMPULSES OF SHOCK WAVES FROM EXPLOSIVE SOURCES IN SEA WATER

Abstract

A theory of the propagation of shock waves from explosive sources was presented in NDRC Report A-318 (OSRD-4814).[1] In that report, a pair of ordinary differential equations for peak pressure and shock-wave energy as functions of the distance from the source were formulated from the equations of hydrodynamics by imposing a similarity restraint on the shape of the energy-time curve of the shock wave. Two-parameter families of peak pressure-distance curves are obtained by the solution of these propagation equations. The parameters are conveniently chosen as the initial values of the pressure and shock-wave energy.

In the present report, tables and graphs of the two-parameter families of curves for shock waves from explosive sources in sea water are presented. A method is outlined for the determination of the parameters from experimental values of the peak pressure and impulse over a limited range of distances from the source.

I. DESCRIPTION OF THE TABLES AND GRAPHS OF THE PROPERTIES OF SHOCK WAVES FROM EXPLOSIVE SOURCES IN WATER

1. Introduction

A theory of propagation of shock waves from explosive sources has been described in an earlier report.[1] A pair of ordinary differential equations for peak pressure and shock-wave energy as functions of distance from the source were obtained from the equations of hydrodynamics and the Hugoniot relations by imposing a similarity restraint on the shape of the energy-time curve and by utilizing the second law of thermodynamics to determine, at an arbitrary distance, the distribution of the initial energy input from the explosive between energy available for further propagation and dissipated energy residual in the fluid already traversed by the shock wave. The theory

[1] Theory of the propagation of shock waves from explosive sources in air and water, by J. G. Kirkwood and S. R. Brinkley, Jr., NDRC Report A-318 (OSRD-4814).

takes proper account of the finite entropy increment in the fluid resulting from the passage of the shock wave and permits the use of the exact Hugoniot curve for the fluid.

The basic equations of the theory are

$$\left.\begin{aligned} \frac{dp}{dR} + \frac{p}{R}\, n(p) &= -\frac{R^2 p^4}{K} F(p), \\ \frac{dK}{dR} &= -p^3 R^2 f(p), \end{aligned}\right\} \quad (1)$$

where

$$f(p) = \frac{12\gamma^3}{\gamma + 1} \frac{h}{c_o^2 p^3},$$

$$F(p) = \frac{12G}{p} \frac{\gamma}{\gamma + 1} \left(\frac{c_o}{U}\right)^2 \frac{1}{2(1 + g) - G},$$

$$n(p) = \frac{4\rho_o/\rho + 2(1 - \rho_o/\rho)G}{2(1 + g) - G},$$

$$G = 1 - \left(\frac{\rho_o U}{\rho c}\right)^2,$$

$$g = 1 - \frac{p}{U} \frac{dU}{dp},$$

and p is the excess peak pressure measured in units of a characteristic pressure B, at a distance Ra_o from the center of a spherical charge of explosive of radius a_o. B is the characteristic pressure of the Tait equation of state,

$$p = B[(\rho/\rho_o)^{\gamma} - 1] \quad (2)$$

and γ is the exponent of ρ/ρ_o in the Tait equation. The quantities ρ and ρ_o are the densities of the water at distances R and infinity, respectively; c and c_o denote the sound velocity in water at densities ρ and ρ_o, respectively; U is the velocity of the shock front; h is the specific enthalpy increment of an element of fluid, traversed by a shock wave of peak pressure p, after return to pressure p_o along its new adiabatic. The variable K is related to the shock-wave energy ε per gram of the initial explosive charge by

$$\varepsilon = \frac{\gamma + 1}{4\gamma^2} \frac{B}{\rho_e} K, \tag{3}$$

where ρ_e is the density of loading of the explosive. The positive impulse is given by

$$I = p\theta B, \tag{4}$$

where

$$-\frac{a_o}{\theta} = \frac{U}{R} \left\{ \frac{2}{G} + \left[\left(\frac{1 + g}{G} \right) \frac{\rho}{\rho_o} + \left(1 - \frac{\rho}{\rho_o} \right) \right] \frac{R}{p} \frac{dp}{dR} \right\}.$$

Tables of the functions defined in Eqs. (1) and (4) are presented in an appendix.

2. Description of the tables and graphs

The two-parameter family of peak pressure-distance curves and the family of shock-wave energy-distance curves for selected values of the constants of integration were obtained by numerical integration of Eqs. (1), employing the methods of Part III of the previous report.[1] Each member of the two families is characterized by a value of p_1, the excess peak pressure at the initial instant of time measured in kilobars and by a value of Q_1, related to the initial shock-wave energy by

$$Q_1 = \frac{4\gamma^2}{\gamma + 1} \frac{\rho_e \varepsilon_1}{B p_1}. \tag{5}$$

The family of peak pressure-distance curves is presented in tabular form in Table I. In this and following tables, a reduced distance variable equal to $R(\rho_e/W)^{1/3}$ is employed, where R is expressed in feet, ρ_e in grams per cubic centimeter, and W in pounds. In order to facilitate interpolation with respect to distance, the entries of the table are of the function $10^{-3}Rp(\rho_e/W)^{1/3}$ with p expressed in pounds per square inch.[2/]

Portions of the peak pressure-distance curves for moderately large distances are presented in a series of graphs, Figs. 1 to 6. Each graph gives a family of peak pressure-distance curves for a fixed value of the parameter Q_1, plotted as $\log Rp(\rho_e/W)^{1/3}$ versus $\log R(\rho_e/W)^{1/3}$. These graphs are designed to aid in the determination of the parameters from an experimental peak pressure-distance curve in a manner to be described in the following.

The family of shock-wave energy-distance curves is tabulated in Table II, the entries of which are $\rho_e \mathcal{E}$ with the reduced distance defined in the foregoing as argument. The units of $\mathcal{E}$ are calories per gram of explosive.

The family of positive impulse-distance curves was constructed with the aid of Eqs. (3), and it is tabulated in Table III. Here, the function $10^3 RI(\rho_e/W)^{2/3}$ is listed with the reduced distance as argument. The units of I are pound-second per square inch.

3. Determination of the initial parameters from experimental data

The graphs, Figs. 1 to 6, are designed to aid in the determination of the parameters of those members of the families of peak-pressure curves that give the best fit to a particular set of experimental data. For this purpose, the experimental data may be plotted to the correct scale on tracing cloth and compared with the theoretical values by superimposing the tracing on the published graphs. Unless the data are of high accuracy, this procedure will not lead to a unique determination of the parameters but to the selection of several pairs of values of the parameters between which a choice could not easily be made by visual methods. The method of least squares may then be used to narrow the choice of parameters. One computes the mean of the squares of the weighted deviations of the individual experimental values of the peak pres-

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[2/] Note that in the tables p is expressed in pounds per square inch, while in the equations p was a dimensionless quantity expressed in units of B.

sure and positive impulse from the theoretical values given by the curves selected by visual matching, employing the reciprocal of the root mean square deviations of the experimental points at a given distance from their mean as the weight factor at that distance. One then selects the parameter set yielding the smallest value of this quantity.[3/]

II. TABLES AND GRAPHS OF THE PEAK PRESSURE, ENERGY, AND IMPULSE OF SHOCK WAVES FROM EXPLOSIVE SOURCES IN SEA WATER

Symbols and Units

Symbol	Unit	Definition
R	ft	Distance from the center of spherical charge of explosive.
ρ_e	gm/cm^3	Density of explosive.
W	lb	Weight of charge of explosive.
p	lb/in^2	Excess peak pressure of shock wave.
p_1	kilobars	Initial excess peak pressure.
Q_1	---	Initial value of reduced energy variable.
ε	cal/gm	Shock-wave energy.
I	$lb\text{-}sec/in^2$	Impulse of shock wave.

Note: The first tabulated value of the distance argument $(\rho_e/W)^{1/3} = 0.156$, corresponds to the surface of the sphere of intact explosive.

3/ See E. T. Whittaker and G. Robinson, The calculus of observations, 3rd (Blackie and Son, 1940), pp. 182, 221.

Table I. The peak pressure.

Q_1	p_1 \ $R(\rho_e/W)^{1/3}$	0.156	0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0	10	15
		$10^{-3}Rp\,(\rho_e/W)^{1/3}$												
25	25	56.7	50.9	42.4	33.3	28.7	25.0	21.8	20.1	18.2	16.4	15.4	14.6	13.3
	30	68.0	60.6	49.6	37.9	32.1	27.5	23.7	21.6	19.4	17.4	16.3	15.4	14.6
	35	79.4	70.2	56.5	42.3	35.3	29.7	25.3	22.9	20.4	18.2	17.1	16.0	15.1
	40	90.7	79.8	63.4	46.5	38.2	31.8	26.7	24.1	21.4	18.9	17.7	16.6	15.6
	45	102	89.4	70.2	50.5	40.9	33.6	28.0	25.1	22.2	19.5	18.2	17.1	16.1
	50	113	98.8	76.8	54.4	43.5	35.4	29.2	26.1	22.9	20.1	18.8	17.6	16.5
30	25	56.7	51.3	43.4	34.8	30.3	26.6	23.3	21.5	19.5	17.6	16.6	15.8	15.0
	30	68.0	61.2	50.9	39.8	34.1	29.4	25.5	23.3	21.0	18.8	17.7	16.7	15.8
	35	79.4	70.9	58.2	44.6	37.6	32.0	27.3	24.8	22.2	19.7	18.5	17.4	16.4
	40	90.7	80.7	65.4	49.2	40.9	34.3	29.0	26.2	23.2	20.6	19.2	18.1	17.0
	45	102	90.4	72.5	53.6	44.0	36.5	30.5	27.4	24.2	21.3	19.9	18.6	17.5
	50	113	100	79.5	58.0	46.9	38.5	31.9	28.5	25.0	22.0	20.4	19.2	18.0
35	25	56.7	51.7	44.2	35.9	31.6	27.9	24.6	22.8	20.7	18.8	17.7	16.8	15.9
	30	68.0	61.6	51.9	41.3	35.7	31.0	27.0	24.7	22.3	20.0	18.8	17.8	16.8
	35	79.4	71.5	59.4	46.4	39.5	33.8	29.1	26.5	23.7	21.1	19.8	18.6	17.6
	40	90.7	81.3	66.9	51.4	43.2	36.5	31.0	28.0	24.9	22.0	20.6	19.4	18.2
	45	102	91.1	74.3	56.2	46.6	38.9	32.7	29.4	26.0	22.9	21.3	20.0	18.8
	50	113	101	81.5	60.8	49.8	41.2	34.3	30.7	26.9	23.6	22.0	20.6	19.3
40	25	56.7	51.9	44.8	36.9	32.6	29.0	25.7	23.9	21.8	19.7	18.7	17.7	16.8
	30	68.0	61.9	52.6	42.5	37.0	32.4	28.3	26.0	23.5	21.1	19.9	18.8	17.8
	35	79.4	71.8	60.4	47.9	41.1	35.4	30.6	27.9	25.0	22.3	20.9	19.7	18.6
	40	90.7	81.7	68.0	53.2	45.0	38.3	32.7	29.6	26.4	23.4	21.8	20.6	19.3
	45	102	91.7	75.7	58.2	48.7	41.0	34.6	31.2	27.6	24.3	22.7	21.3	20.0
	50	113	102	83.2	63.1	52.3	43.5	36.3	32.6	28.6	25.1	23.4	21.9	20.5
45	25	56.7	52.1	45.2	37.6	33.5	29.9	26.7	24.8	22.7	20.6	19.5	18.6	17.6
	30	68.0	62.1	53.2	43.5	38.1	33.5	29.4	27.1	24.6	22.1	20.9	19.7	18.7
	35	79.4	72.1	61.1	49.1	42.5	36.8	31.9	29.2	26.2	23.4	22.0	20.8	19.6
	40	90.7	82.1	69.0	54.6	46.6	39.9	34.2	31.1	27.7	24.6	23.0	21.6	20.4
	45	102	92.1	76.7	59.9	50.6	42.8	36.3	32.8	29.0	25.6	23.9	22.4	21.1
	50	113	102	84.4	65.0	54.4	45.6	38.2	34.3	30.2	26.5	24.7	23.1	21.7
50	25	56.7	52.2	45.6	38.3	34.3	30.7	27.5	25.6	23.5	21.4	20.3	19.3	18.3
	30	68.0	62.3	53.7	44.3	39.1	34.5	30.4	28.1	25.5	23.0	21.8	20.6	19.5
	35	79.4	72.3	61.8	50.2	43.6	38.1	33.1	30.4	27.3	24.4	23.0	21.7	20.5
	40	90.7	82.4	69.8	55.8	48.0	41.3	35.6	32.4	28.9	25.7	24.0	22.6	21.3
	45	102	92.4	77.7	61.4	52.2	44.4	37.8	34.2	30.3	26.8	25.0	23.5	22.1
	50	112	102	85.4	66.7	56.2	47.4	39.9	35.9	31.6	27.8	25.9	24.2	22.7

Table II. The shock-wave energy.

Q_1	$R(\rho_e/W)^{1/3}$ / P_1	$\rho_e\mathcal{E}$ 0.156	0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0	10	15
25	25	595	573	531	471	436	405	373	355	334	313	302	291	281
	30	714	685	628	549	502	460	422	399	374	349	336	323	312
	35	833	795	723	623	564	512	466	440	410	381	366	352	338
	40	952	906	818	696	624	562	508	477	443	410	393	378	364
	45	1070	1020	911	766	681	609	547	512	474	438	419	403	387
	50	1190	1130	1000	835	737	655	584	546	504	465	444	426	409
30	25	714	692	648	585	545	507	471	450	424	398	384	371	358
	30	857	827	768	683	630	581	535	508	476	445	428	412	397
	35	999	962	887	778	711	650	594	561	524	487	468	450	433
	40	1140	1100	1000	872	790	716	649	611	568	527	505	485	466
	45	1290	1230	1120	962	865	779	702	658	610	564	539	518	497
	50	1430	1370	1240	1050	937	838	751	702	648	598	572	548	526
35	25	833	811	766	700	657	615	573	548	518	487	470	454	439
	30	1000	970	910	820	762	706	652	620	583	545	525	506	488
	35	1170	1130	1050	936	862	792	726	688	643	599	575	554	533
	40	1330	1290	1190	1050	960	876	797	751	700	649	622	598	575
	45	1500	1450	1330	1160	1050	954	863	811	752	695	666	639	614
	50	1670	1600	1470	1270	1140	1030	925	867	801	738	706	677	650
40	25	952	930	884	815	769	723	677	648	614	578	558	540	522
	30	1140	1110	1050	957	895	834	773	737	694	650	626	604	583
	35	1330	1290	1220	1100	1020	938	864	819	767	715	687	662	638
	40	1520	1420	1380	1230	1130	1040	950	897	836	776	745	716	689
	45	1710	1660	1540	1370	1250	1140	1030	969	900	833	798	766	736
	50	1900	1840	1700	1500	1360	1230	1110	1040	961	886	848	813	780
45	25	1070	1050	1000	931	382	833	783	751	713	672	650	629	609
	30	1290	1260	1190	1100	1030	963	896	856	807	757	730	705	680
	35	1500	1460	1380	1250	1170	1090	1000	954	896	836	804	775	746
	40	1710	1670	1570	1420	1310	1210	1110	1050	978	908	872	839	807
	45	1930	1870	1760	1570	1440	1320	1200	1130	1050	976	935	898	863
	50	2140	2080	1940	1720	1570	1430	1300	1220	1130	1040	995	954	916
50	25	1190	1170	1120	1040	997	945	390	356	814	769	743	721	698
	30	1430	1400	1330	1230	1170	1090	1020	978	924	868	837	809	781
	35	1670	1630	1550	1420	1330	1240	1150	1090	1030	960	923	890	858
	40	1900	1860	1760	1600	1490	1380	1270	1200	1120	1040	1000	965	928
	45	2140	2090	1970	1780	1640	1510	1380	1300	1210	1120	1080	1040	995
	50	2380	2320	2180	1950	1790	1640	1490	1400	1300	1200	1150	1100	1060

Table III. The impulse.

Q_1	$R(\rho_e/W)^{1/3}$ / P_1	$10^3 RI(\rho_e/W)^{2/3}$												
		0.156	0.2	0.3	0.5	0.7	1.0	1.5	2.0	3.0	5.0	7.0	10	15
25	25	206	242	279	321	378	433	480	505	540	576	596	614	633
	30	223	257	301	326	392	449	501	529	566	606	627	647	667
	35	240	273	333	338	405	463	519	551	590	632	656	674	698
	40	241	287	344	351	414	480	535	569	611	655	680	701	723
	45	248	300	355	364	422	488	550	586	630	676	703	726	748
	50	257	315	369	379	429	499	565	602	648	696	723	748	772
30	25	222	265	315	363	434	498	557	589	632	676	700	722	744
	30	241	284	350	373	451	518	582	619	664	710	737	761	784
	35	260	300	376	389	465	536	603	643	691	740	770	794	819
	40	261	317	383	407	475	552	624	664	716	769	800	826	852
	45	270	332	403	424	484	564	642	686	738	794	826	854	881
	50	280	348	419	442	490	576	657	705	759	817	849	879	908
35	25	235	284	347	399	488	564	633	673	723	774	803	829	854
	30	256	304	386	417	507	585	660	705	758	813	844	872	900
	35	276	323	413	438	522	606	686	732	788	847	881	912	940
	40	278	342	424	459	532	621	708	759	818	879	915	946	977
	45	288	359	445	480	540	636	728	784	840	908	946	979	1010
	50	298	377	462	504	543	650	746	802	865	934	973	1010	1040
40	25	246	301	375	436	537	623	673	752	810	869	903	932	962
	30	268	322	417	459	559	649	735	787	849	913	950	981	1010
	35	290	343	446	483	574	670	765	821	884	953	991	1020	1060
	40	292	364	459	509	587	690	790	851	915	988	1030	1060	1100
	45	302	382	483	534	591	705	812	874	944	1020	1060	1100	1140
	50	314	402	500	562	596	720	833	897	970	1050	1090	1130	1180
45	25	256	315	400	471	584	682	774	830	895	963	1000	1040	1070
	30	278	338	445	498	608	711	811	869	938	1010	1050	1090	1120
	35	301	360	475	526	625	733	842	907	976	1060	1100	1140	1180
	40	304	383	492	556	636	754	870	938	1010	1090	1140	1180	1220
	45	315	403	517	586	638	772	895	964	1040	1130	1180	1220	1270
	50	327	423	535	617	651	790	916	988	1070	1160	1210	1260	1300
50	25	263	327	423	504	630	739	842	907	980	1060	1100	1140	1170
	30	287	352	471	534	654	770	883	951	1030	1110	1160	1200	1240
	35	312	375	501	567	673	795	917	988	1070	1160	1210	1250	1290
	40	314	399	522	599	682	817	946	1020	1110	1200	1250	1300	1350
	45	326	421	548	634	687	837	974	1050	1140	1240	1290	1340	1390
	50	339	442	566	669	705	856	998	1080	1180	1280	1330	1380	1430

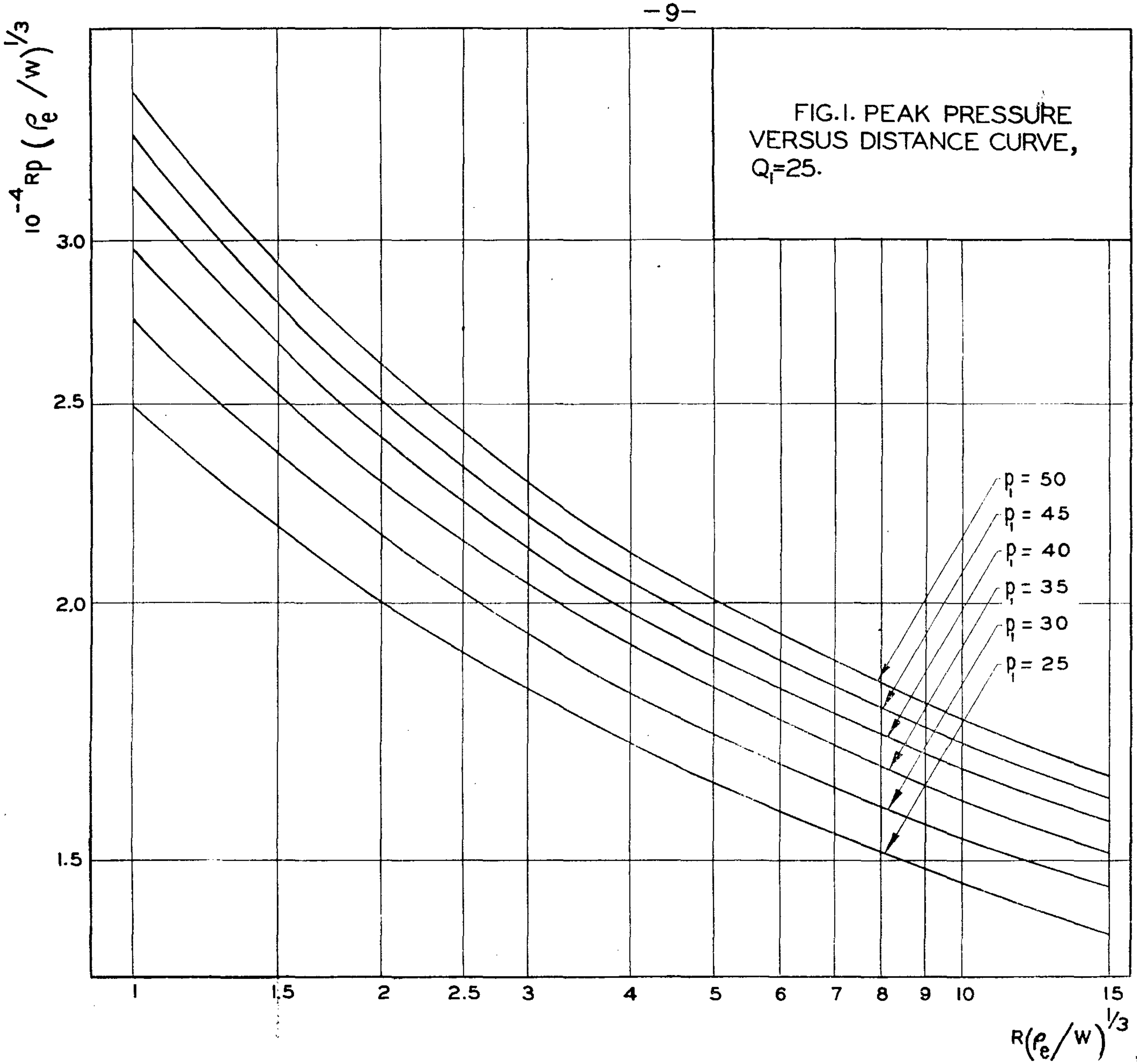

FIG. 1. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 25$.

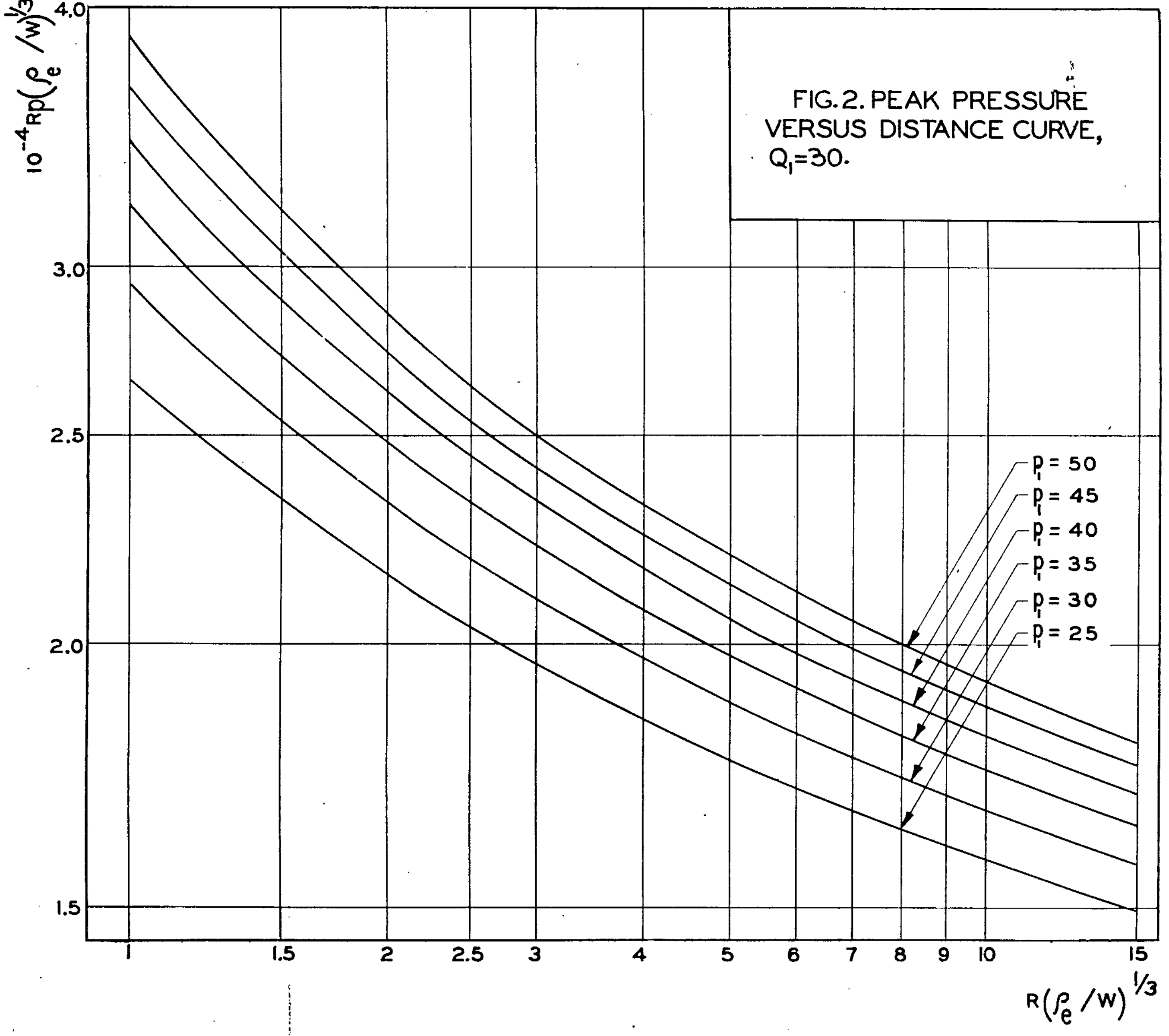

FIG. 2. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 30$.

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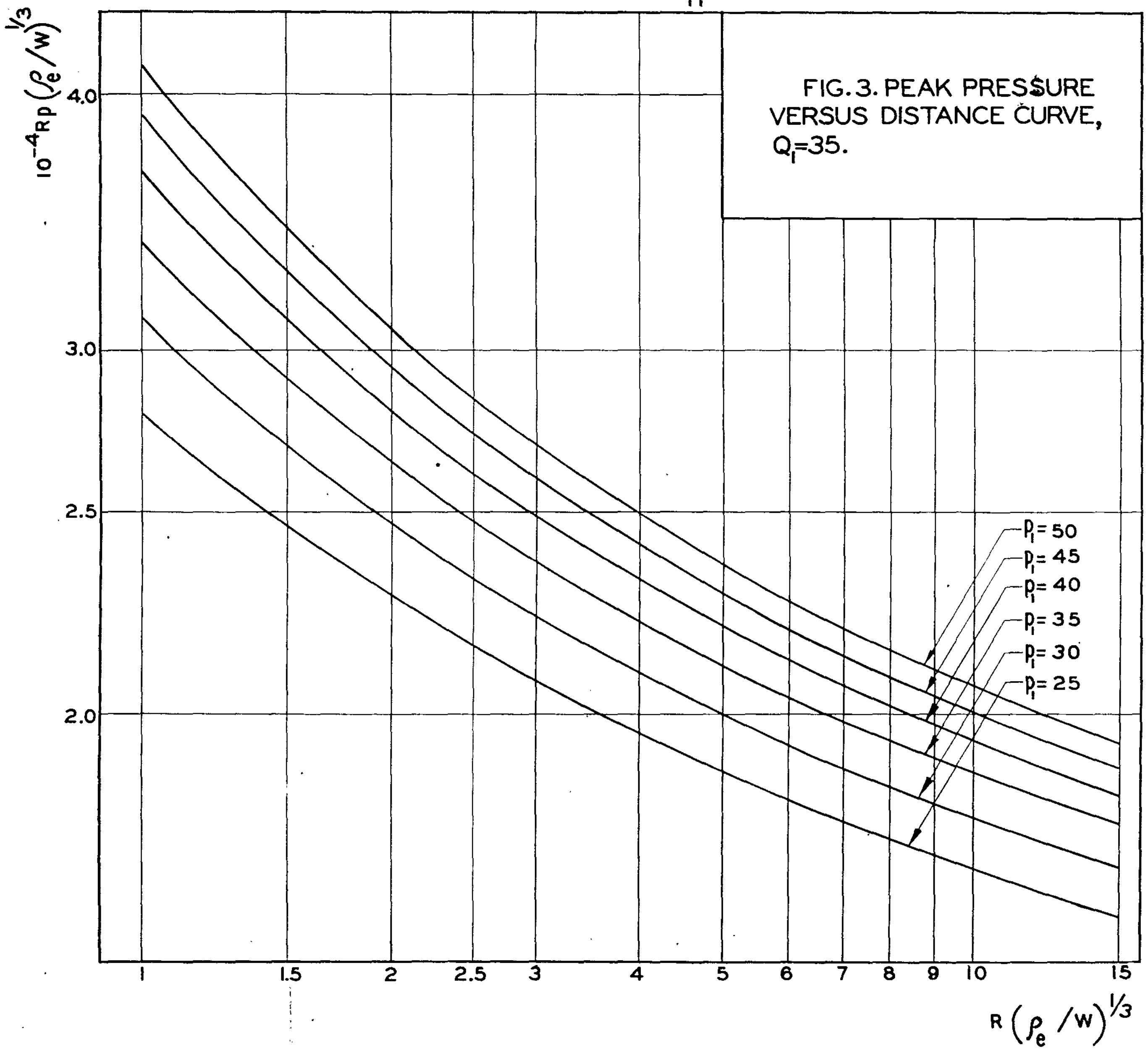
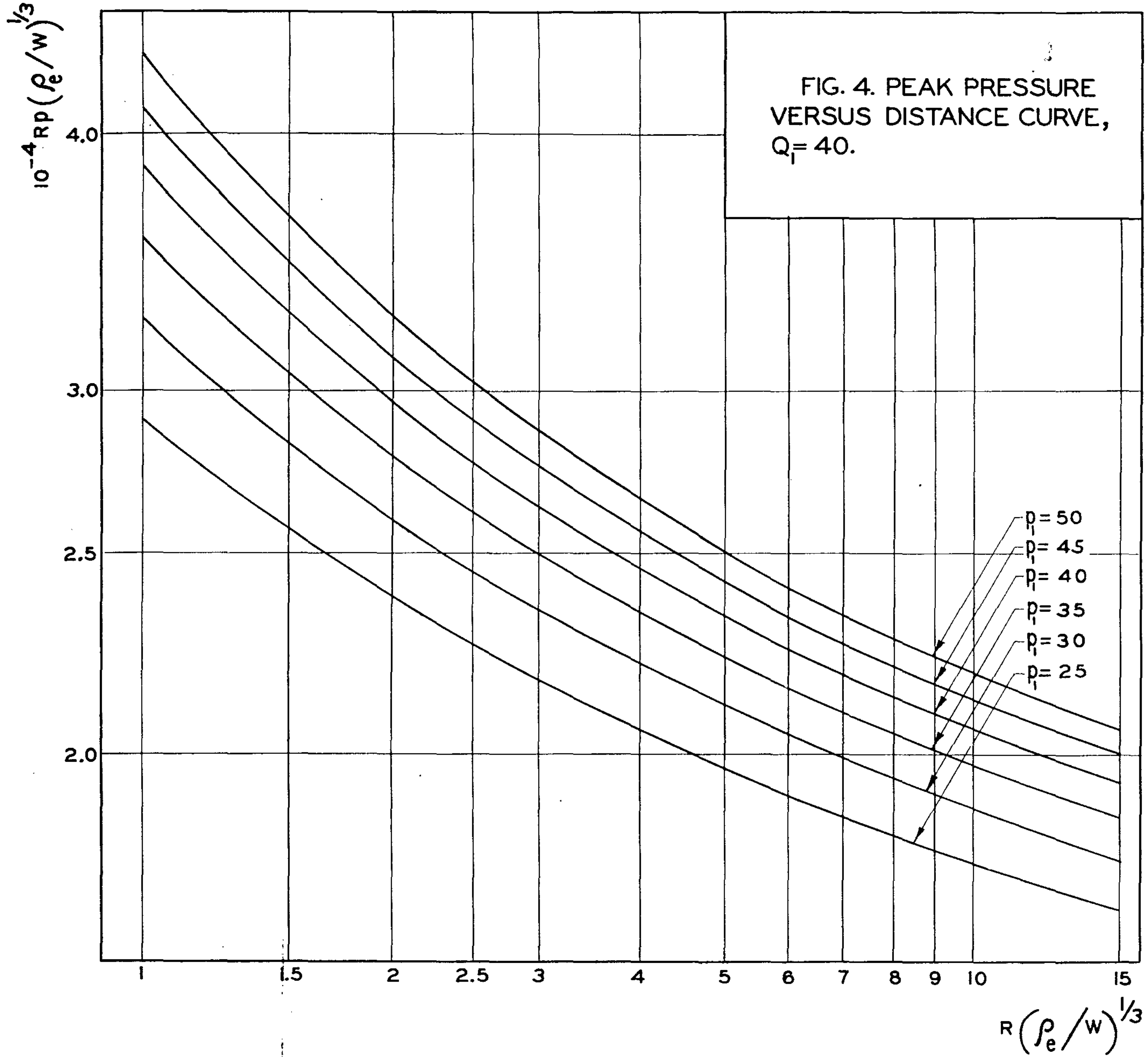


FIG. 3. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 35$.

FIG. 4. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 40$.



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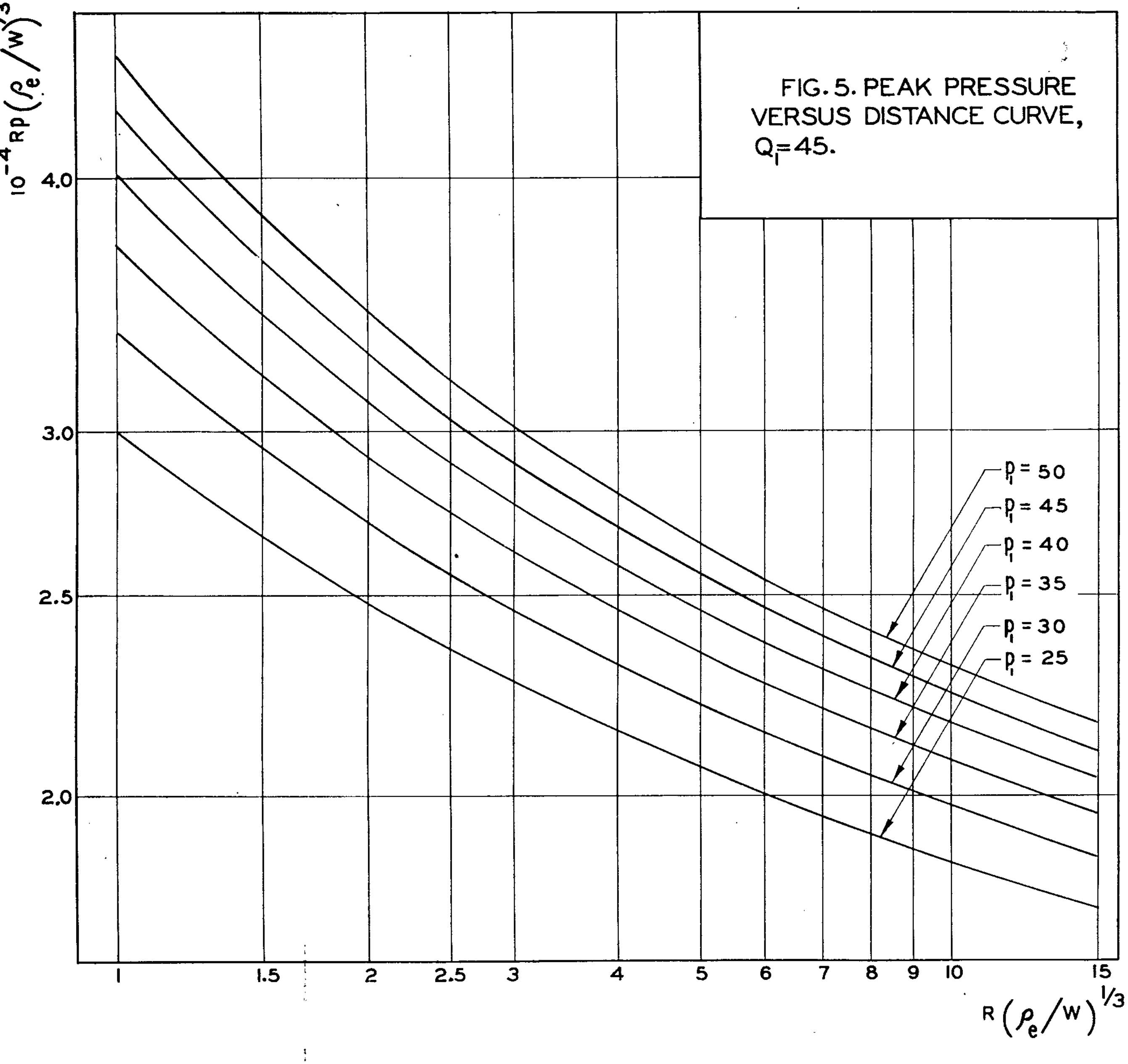

FIG. 5. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 45$.

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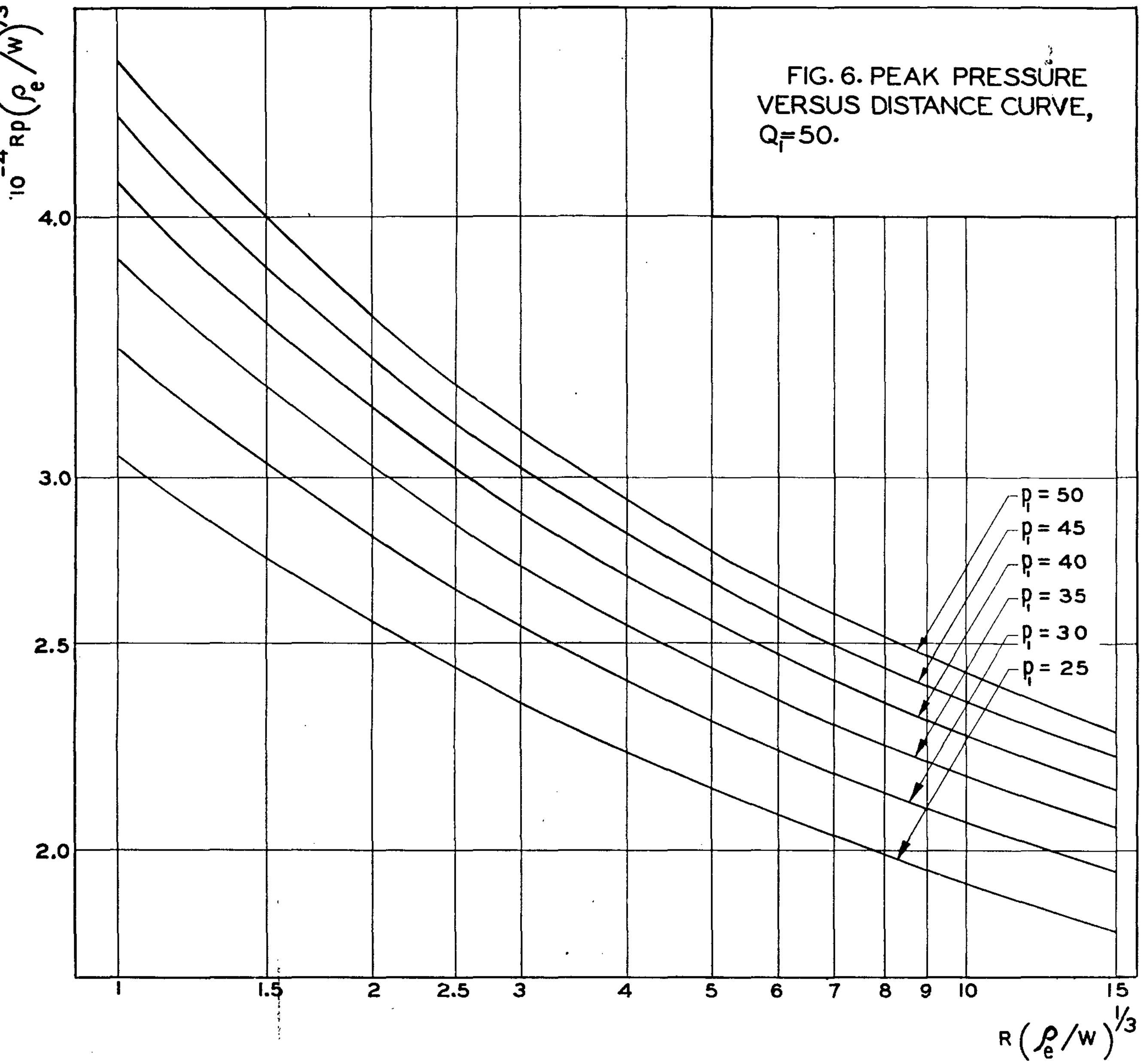

FIG. 6. PEAK PRESSURE VERSUS DISTANCE CURVE, $Q_1 = 50$.

APPENDIX

Methods of Numerical Integration

In the present section, methods that are appropriate for the numerical integration of the basic differential equations, Eqs. (1), are described and tables are given of the auxiliary functions required for this integration.

For shock waves in water, it is convenient to employ the following variables:

$$\left.\begin{aligned} X &= \log R, \\ Y &= \log P, \\ Z &= \log Q, \\ Q &= K/Rp, \\ P &= pR. \end{aligned}\right\} \quad (A1)$$

In these variables, Eqs. (1) become

$$\left.\begin{aligned} -\frac{dY}{dX} &= \ell(p) + \frac{P^2}{Q} m(p), \\ \frac{dZ}{dX} &= \ell(p) + \frac{P^2}{Q} \eta(p), \end{aligned}\right\} \quad (A2)$$

where

$$\ell(p) = n(p)-1,$$

$$m(p) = F(p),$$

$$\eta(p) = F(p)-f(p).$$

Tables of the functions $\ell(p)$, $m(p)$, and $\eta(p)$ are presented in Table IV. Table V lists certain auxiliary quantities necessary for the calculation of the impulse by Eq. (4).

A procedure for the numerical integration of Eqs. (A2) has been outlined in an earlier report.[1/] It is suggested that the integration be started with the Runge-Kutta method, and an iterative procedure for continuing the integration is outlined.

Table IV. Functions for the integration of the propagation equation in sea water.

p (Units of B)	ℓ(p)	m(p)	n(p)
0	0	1.5000	0.5000
0.01	0.001495	1.4843	.4950
.02	.002924	1.4670	.4882
.03	.004355	1.4524	.4839
.04	.005725	1.4363	.4778
.05	.007075	1.4207	.4721
.06	.008424	1.4054	.4665
.07	.009774	1.3871	.4600
.08	.01112	1.3759	.4560
.09	.01247	1.3617	.4510
0.1	.01380	1.3479	.4462
.2	.02622	1.2175	.3984
.3	.03745	1.1058	.3576
.4	.04763	1.0095	.3215
.5	.05676	0.9305	.2939
.6	.06581	.8555	.2673
.7	.07388	.7923	.2450
.8	.08156	.7378	.2268
.9	.08867	.6886	.2102
1.0	.09517	.6439	.1945
1.5	.1235	.4793	.1404
2.0	.1416	.3844	.1133
2.5	.1563	.3123	.0889
3.0	.1696	.2524	.0690
3.5	.1815	.2048	.0536
4.0	.1919	.1695	.0428
4.5	.2009	.1465	.0366
5.0	.2085	.1348	.0345
10	.2506	.05140	.01276
15	.2678	.02770	.00694
20	.2848	.01731	.00452
25	.3143	.01242	.00359

Table V. Auxiliary table for blast waves in sea water.

p (Units of B)	U/c_0	g	G	ρ/ρ_0
0.01	1.003	0.9971	0.005654	1.001393
.02	1.006	.9944	.01121	1.002774
.03	1.008	.9917	.01669	1.004142
.04	1.011	.9890	.02211	1.005502
.05	1.014	.9863	.02737	1.006846
.06	1.017	.9838	.03258	1.008180
.07	1.020	.9812	.03773	1.009499
.08	1.023	.9787	.04278	1.01082
.09	1.025	.9762	.04777	1.01213
0.1	1.027	.9737	.05266	1.01342
.2	1.054	.9512	.09779	1.02584
.3	1.072	.9316	.1371	1.03738
.4	1.103	.9147	.1706	1.04818
.5	1.126	.8995	.2011	1.05835
.6	1.148	.8859	.2283	1.06797
.7	1.170	.8738	.2525	1.07705
.8	1.191	.8627	.2748	1.08568
.9	1.211	.8526	.2949	1.09392
1.0	1.231	.8435	.3130	1.1018
1.5	1.321	.8069	.3862	1.1368
2.0	1.407	.7654	.4500	1.1673
2.5	1.486	.7408	.4975	1.1935
3.0	1.555	.7298	.5192	1.2136
3.5	1.619	.7241	.5296	1.2302
4.0	1.682	.7110	.5515	1.2478
4.5	1.742	.6998	.5682	1.2630
5	1.797	.6906	.5799	1.2762
10	2.272	.6381	.6593	1.3720
15	2.462	.6149	.6944	1.4294
20	2.961	.5943	.7142	1.4687
25	3.252	.5638	.7255	1.4945