C.P. No. 340
(17,895)
A.R.C. Technical Report

C.P. No. 340
(17,895)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL

CURRENT PAPERS

Full Scale Measurement of Impact Loads on a Large Flying Boat (Sunderland Mk. 5) Part III - Data for Impacts on Main Step

By

R. Parker, B.Sc.

LONDON : HER MAJESTY'S STATIONERY OFFICE

1957

SIX SHILLINGS NET

C.P. No. 340

Report No. F/Res/259

August 1954

MARINE AIRCRAFT EXPERIMENTAL ESTABLISHMENT, FELIXSTOWE, SUFFOLK

FULL SCALE MEASUREMENT OF IMPACT LOADS ON A LARGE FLYING BOAT (SUNDERLAND MK. 5)

PART III - DATA FOR IMPACTS ON MAIN STEP

by

R. Parker, B.Sc.

S U M M A R Y

The results of a series of full-scale impact tests on the hull of a Sunderland Mk.5 flying boat at an all up weight of 50,000 lb. were compared with an appropriate theory and discussed generally in a previous report. As discrepancies between this data and the theory were shown and explanation of this has not been forthcoming, this report presents complete time histories of a number of the actual measurements to permit comparison with other theories when such become available and application by empirical methods where appropriate.

/LIST OF CONTENTS

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

A full investigation was carried out some time ago on forebody landing impacts of a Sunderland Mk.5 flying boat, as part of a general investigation on seaplane landing impacts. This first series of tests was confined to calm water only, and almost entirely to cases where the afterbody was not wetted during the initial impact. The results of these tests were compared with the most recent relevant theory (Ref.1) and the comparison was reported in Reference 2.

Discrepancies between the measured and calculated acceleration/time curves were found, in particular the measured times to maximum acceleration were about twice those predicted by theory. As no explanation of this discrepancy has been found a selection of the measured data is given in this report for two purposes viz.

(a) to permit comparison with other theories or further investigation of the apparent errors in that at present available and

(b) to permit its use by empirical methods and comparisons with current design strength requirements for seaplanes.

2. AIRCRAFT

The aircraft employed was a standard Sunderland Mk.5 flying boat with four Pratt and Whitney Twin Wasp engines. The general arrangement drawing of the aircraft is given in Figure 1 and a lines plan in Figure 2.

One possible explanation of the discrepancies between measured and calculated results is associated with the flexibility of the aircraft structure, particularly the wings. To permit investigation of this Figure 1 includes a general indication of the major concentrations of mass in the aircraft as it was loaded for the tests.

3. INSTRUMENTATION

The apparatus is discussed in Reference 3 in considerable detail and only a brief survey is given below.

3.1. Total force

Total force was measured by means of an arrangement of accelerometers whose outputs were combined in the correct proportions to give a true representation of the acceleration of the aircraft's C.G.

3.2. Pressures

Pressures on the planing bottom were measured by means of flush diaphragm pressure pick-ups.

3.3. Attitude and roll

Aircraft attitude (keel angle) and angle of roll were measured by means of an Anschutz gyroscope.

3.4. Vertical and horizontal velocities and draught

The aircraft position at any instant was recorded by means of a high speed camera mounted on an accurately aligned tripod at a suitable shore position.

Analysis of this photographic record enables calculation to be made of vertical and horizontal velocity, draft and keel angle.

The latter is a duplication of the keel angle measurement by the gyroscope, and forms a convenient check on the accuracy achieved by the two methods.

3.5. Recording

All measurements under Items 3.1, 3.2 and 3.3 were recorded on two 16-channel galvo-camera recorders, the attitude and roll being obtained by electrical signals directly from the gyroscope which were fed straight to the galvanometers, while the accelerometers and pressure pick-ups work in conjunction with two 15-channel amplifier units.

A system producing a timing mark simultaneously on both the shore camera film and the recorder records is used to give accurate synchronisation.

3.6. Accuracy

The accuracy achieved in the various measurements has been assessed in Reference 3, and is as follows.

Attitude	$\pm$ 0.5°
Draught	$\pm$ 0.2 ft.
Vertical Velocity	$\pm$ 1 ft./sec.
Foreward Velocity	$\pm$ 2 ft./sec.
Time	$\pm$ 0.1% (Synchronisation $\pm$ 0.01 sec.)
Acceleration	$\pm$ 0.1g.
Pressures	$\pm$ 5% (The minimum time of pressure build of which can be recorded = 0.01 sec.).

4. RANGE OF TESTS AND PILOT TECHNIQUE

The primary objective of the tests was to obtain landing impacts which fulfilled the conditions assumed in available theoretical analyses. Future theoretical work will almost certainly include the cases covered, though may permit relaxation of some of the requirements, which are assumed as follows:-

(a) zero vertical acceleration prior to touchdown,
(b) zero drift at touchdown,
(c) zero angle of roll throughout the impact,
(d) zero angular velocity in pitch, and
(e) the main step only to be immersed.

The piloting technique to achieve these conditions is described in Reference 2 and the runs given in this report have been selected to conform, as closely as possible, to these requirements with the exception of two runs in which the landing attitude is high and the afterbody plays a considerable part in the first part of the impact.

The angle between the forebody keel line and a line from the main step to the rear step point is approximately 9° so impacts with an attitude at touch down greater than this will involve some afterbody effect.

Where the attitude is lower than this throughout the whole impact (as in most of the runs given here) the afterbody is in the trough behind the main step and its only likely effect is the possibility of suctions occuring due to imperfect ventilation.

/A later

A later series of tests has been completed in which the pressures on the afterbody were measured in landings covering a large range of attitudes and the results are recorded in Reference 4.

All tests were made at one weight and C.G. position, i.e. 50,000 lb. all-up weight with C.G. 3 ft. forward of the main step point measured parallel to hull datum. All landings were done in the normal landing configuration, i.e. 2/3 flap and in good weather conditions with winds of, on an average, 3-4 knots giving a relatively calm water surface with the roughest condition consisting of wavelets not more than 6 in. high.

5. RESULTS

The results are given in Figures 4 to 15, and comprise time histories of keel attitude, draught, vertical velocity, C.G. acceleration and pressures at a number of individual points on the forebody. The positions of these points are given in Figure 3, and relevant dimensions in Table II.

Reference 2 gives results from 23 impacts and uses data from these. The twelve impacts of which data is given in this report are selected from these and cover as wide a range of the various parameters as possible and include only runs where the data is fairly complete. (The main difficulty was poor serviceability of pressure pick-ups).

The numbers given to the various runs are the same as those used in Reference 2 so reference from one report to the other may be made readily.

It will be noted on some of the draught plots that more than one curve is given, this is done where inconsistencies occur which cannot be explained. The results of three methods of obtaining draught are used in all cases and where only one curve is given, satisfactory consistency was achieved. Where more than one, the degree of accuracy which can be assumed is apparent. Methods used for obtaining draught are:

(a) direct measurement from the camera record,
(b) double integration of the vertical acceleration record, and
(c) by geometrical methods from the positions of pick-ups near to the keel as each enters the undisturbed water surface.

The accuracy given in Section 3.6 relates to the camera method and this is felt to be generally reliable.

The double integration of draught from camera records requires a means of establishing the initial vertical velocity or the time of maximum draught, i.e. the time of zero vertical velocity. Where this method is used, one or other of these must be obtained from the camera record.

The geometrical method, using first contact of each pick-up is subject to slight error due to the splash-up but, as only pick-ups near the keel are used, this is small as splash-up forward is negligible. It will also be noted that the records show the vertical acceleration at the instant of touch-down to differ from zero by amounts up to 0.1g - generally in an upward sense, i.e. the lift is slightly greater than the weight of the aircraft.

The wing lift will also vary slightly during an impact due to change in the flight path angle and, where it is appreciable, changes in attitude both of which alter the wing angle of attack.

To permit estimation of the magnitude of this effect the lift of the aircraft in the condition used was measured and the C_L curves obtained are given in Figure 16. It should be noted that these curves are the results of tests done at an altitude of several hundred feet and application without allowance for ground effects may incur a slight error.

/Results

Results for level flight and glides are given as some tests were done with a little engine power on but in general the "glide" curve will give the most accurate representation.

6. <u>GENERAL DISCUSSION</u>

It is not proposed in this report to examine the results in detail, as the purpose is merely to make the data available for use, either to assist in the establishment of empirical relationships or as a check and guide in the development of basic theories.

The geometry of the Sunderland hull is typical of a low beam loading seaplane and is such that the chines are very rarely immersed during initial landing impact.

The accuracy of the results presented is not as high as might be desired but is felt to be quite good for full scale work of this type. The assessments in para 3.6. are maximum values and much of the data is within closer limits than these.

/ <u>LIST OF REFERENCES</u>

LIST OF REFERENCES

No.	Author/s)	Title
1	R.J. Monaghan P.R. Crewe	Formulae for estimating the forces in Seaplane - Water impacts without rotation or chine immersion. R. & M. 2804. January, 1949.
2	J.A. Hamilton	Full Scale Measurements of Impact Loads on a large Flying Boat. (Sunderland Mk.5). Part II - Results for Impact on Main Step. C.P. No. 205. February, 1951.
3	J.W. McIvor	Full Scale Measurements of Impact Loads on a Large Flying Boat. Part I. C.P. No. 182. March, 1950.
4	R. Parker	Full Scale Measurements of Impact Loads on a Large Flying Boat. (Sunderland Mk.5). Part IV - Data for Impacts on rear step. C.P. No. 341. August, 1954.

/ TABLE I

TABLE I

Sunderland Mark 5
Data

Hull

Beam (max)	ft.	9.79
Length (F.P. to Rear Step)	ft.	62.12
Length: Beam Ratio		6.35
Forebody Length (F.P. to Main Step Keel)	ft.	32.94
Afterbody Length (Main Step Keel to Aft step)	ft.	29.18
Keel-Chine Deadrise at Main Step		26°
Step Plan Included Angle		132°
Forebody Keel - Hull Datum Angle		3°
Heel - Heel Angle		9° 17'
Forebody Keel - Afterbody Keel Angle		7° 29'
Main Step Fairing Ratio		6:1

Wings

Area (gross)	sq.ft.	1687
Span	ft.	112.8
Incidence to Hull Datum		6° 9'
Section		Gottingen 436 modified

Flaps

Type		Gouge
Area	sq.ft.	286

Tailplane

Area (including elevators)	sq.ft.	205
Elevator area (including tabs)	sq.ft.	84.5
Elevator movement		16° 30' up and down

Engines

4 Pratt Whitney Twin Wasp R.1830-90B giving 1200 B.H.P. at 2,700 r.p.m. and + 9 lb/sq.in. boost for sea level take-off.

Loading

At A.U.Wt. 50,000 lb

C.G. "Normal" is 3.02 ft. forward of main step at keel parallel to hull datum line.

/TABLE II

TABLE II

Details of Individual Pressure Pick-up Positions

Pick-up No.	l (in)	b (in)	c (in)	θ_L
1	206.2	9.3	11.5	31°
2	175.4	9.9	11.7	31°
3	144.7	10.7	12.6	30.5°
4	122.6	6.8	8.0	31°
5	122.6	16.5	19.3	29°
6	122.6	27.0	31.2	27°
7	122.6	37.9	43.2	23°
8	93.1	7.0	8.3	31°
9	70.3	7.3	8.7	31°
10	70.3	17.7	20.6	28°
11	70.3	28.3	32.5	26°
12	70.3	39.0	44.4	24°
13	70.3	52.1	56.3	18°
14	49.1	7.4	8.8	31°
15	33.8	7.6	8.9	31°
16	33.8	18.2	21.1	29°
17	33.8	28.8	33.1	27°
18	33.8	39.7	45.0	24°
19	33.8	50.2	56.3	19°
20	13.7	7.6	9.0	31°

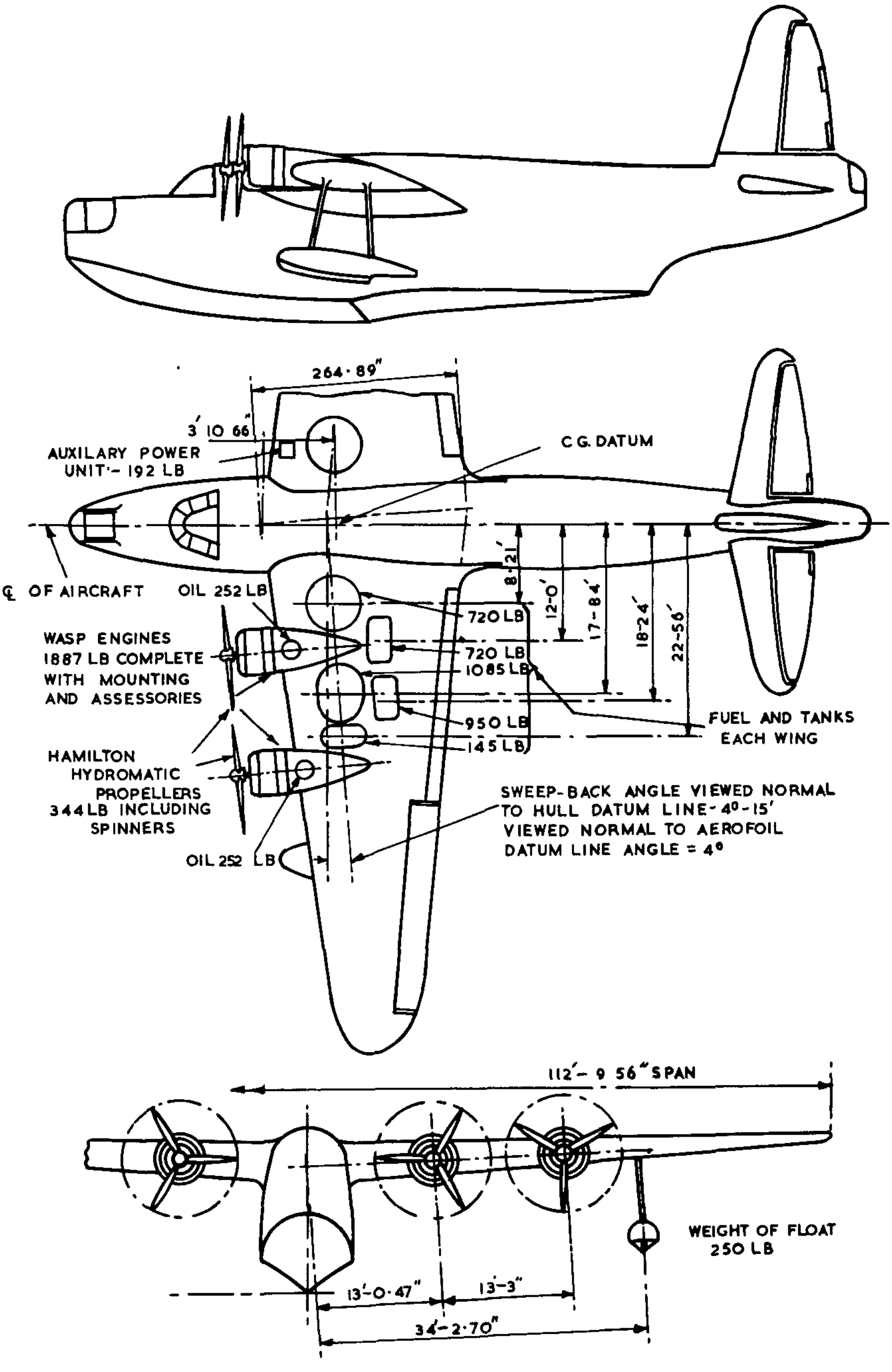
l   Distance forward of step and parallel to keel datum

b   Horizontal distance from keel to pressure pick-up

c   Distance from keel to pick-up along keel chine line

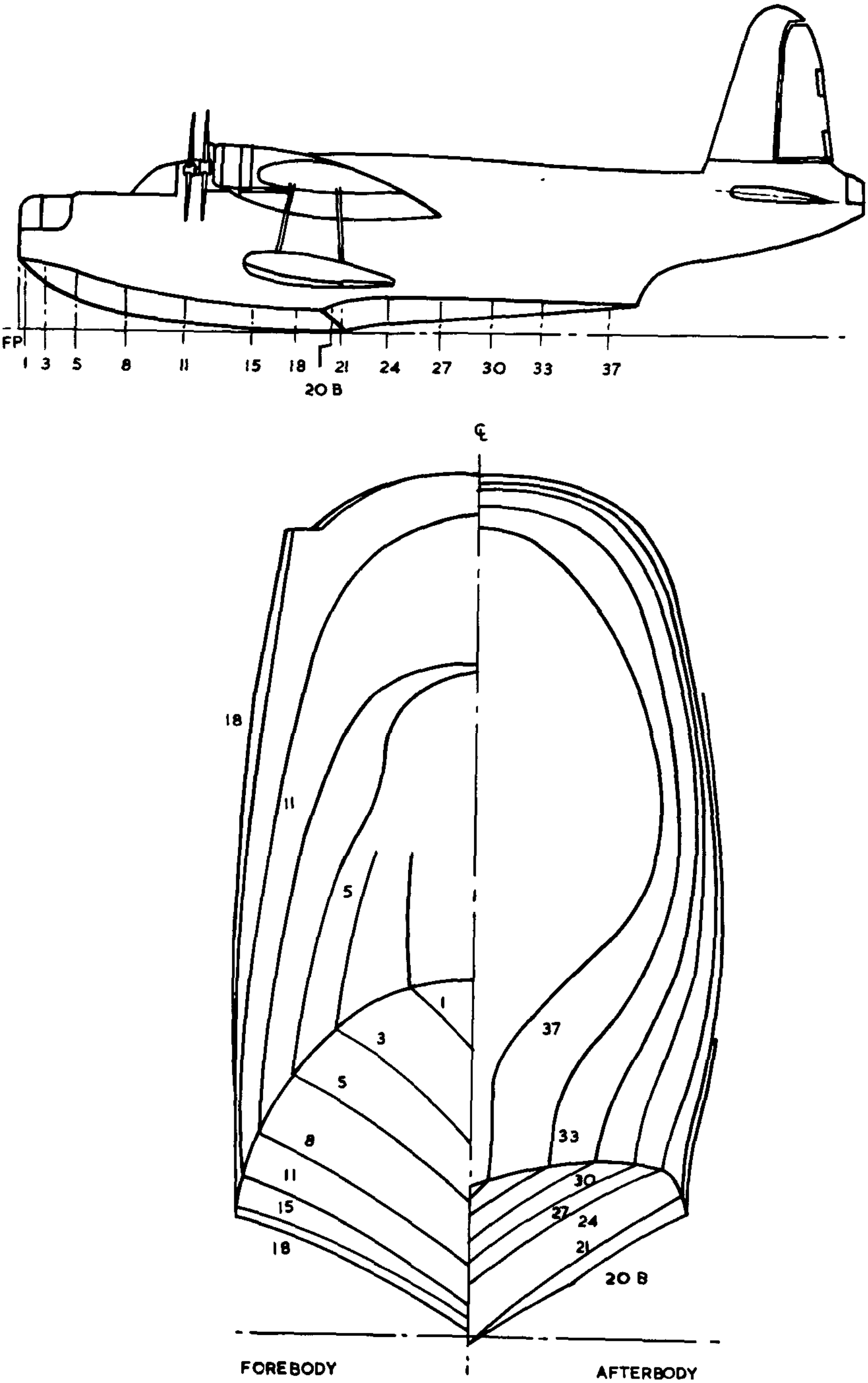
θ_L Local deadrise

FIG. 1.



SUNDERLAND MK. V FLYING BOAT
GENERAL ARRANGEMENT AND POSITIONS OF MASSES IN WINGS

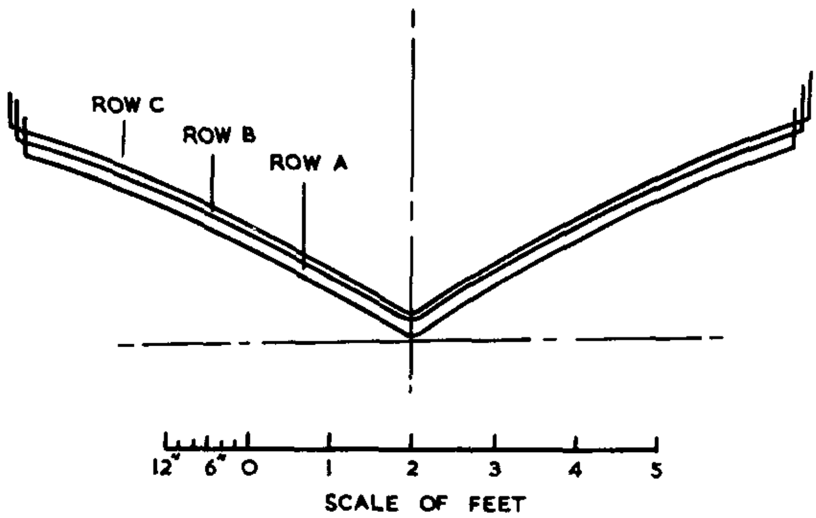
FIG. 2.



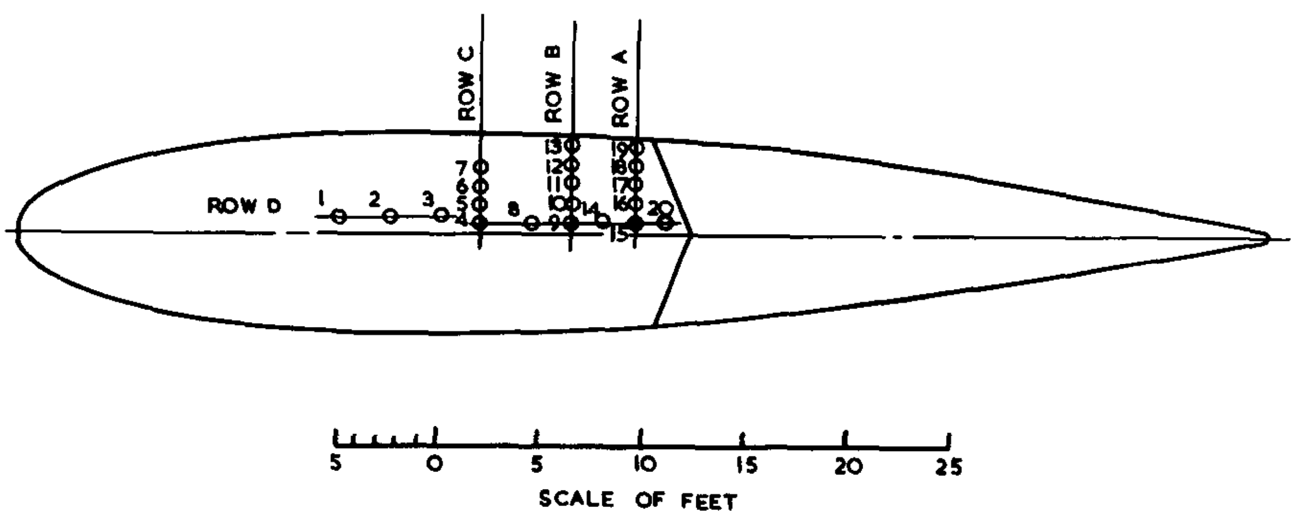
SUNDERLAND MK. V HULL LINES

FIG. 3.

PLANING BOTTOM CONTOURS

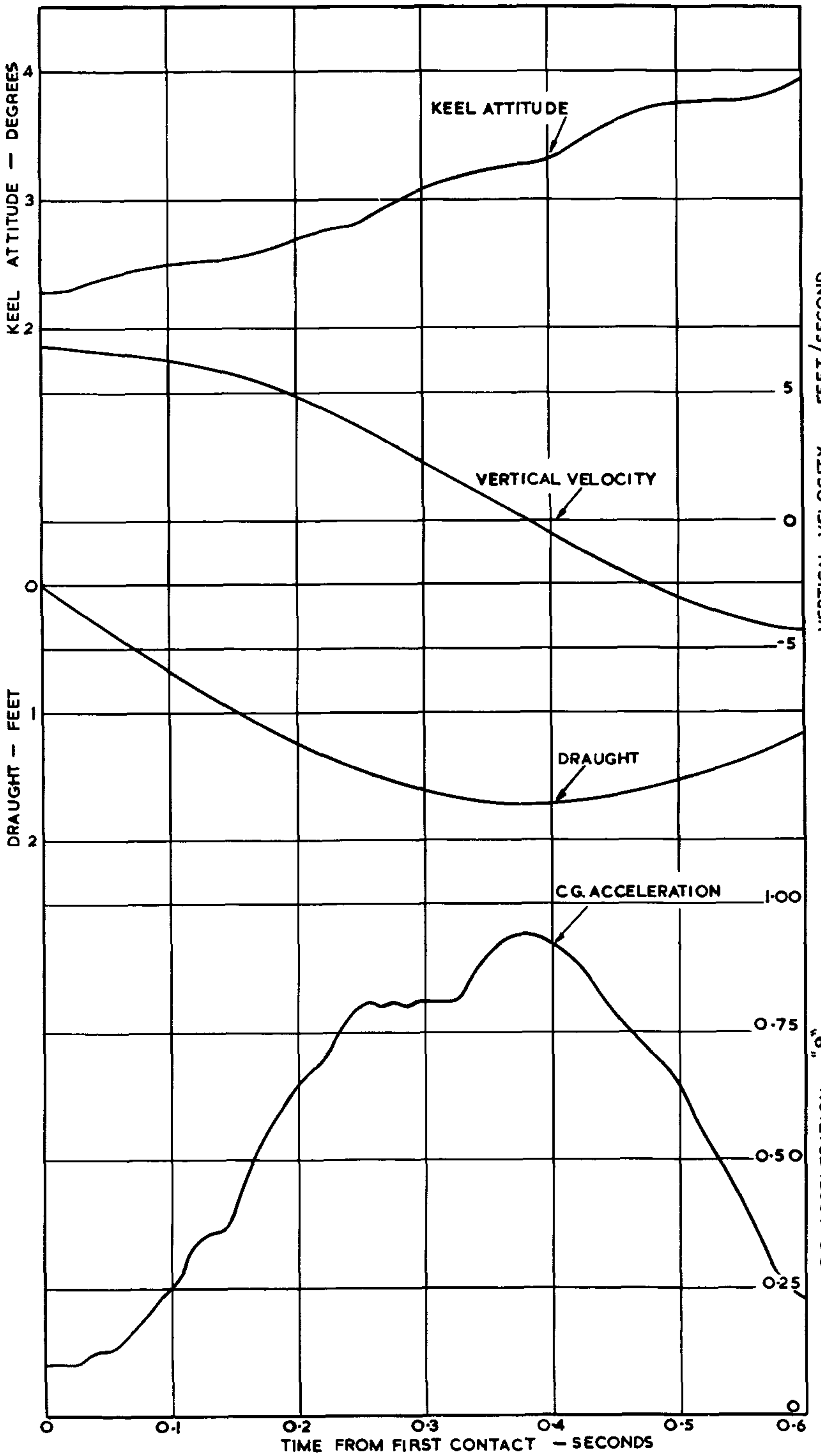


FOR ADDITIONAL DETAILS OF PICK UP POSITIONS SEE TABLE II



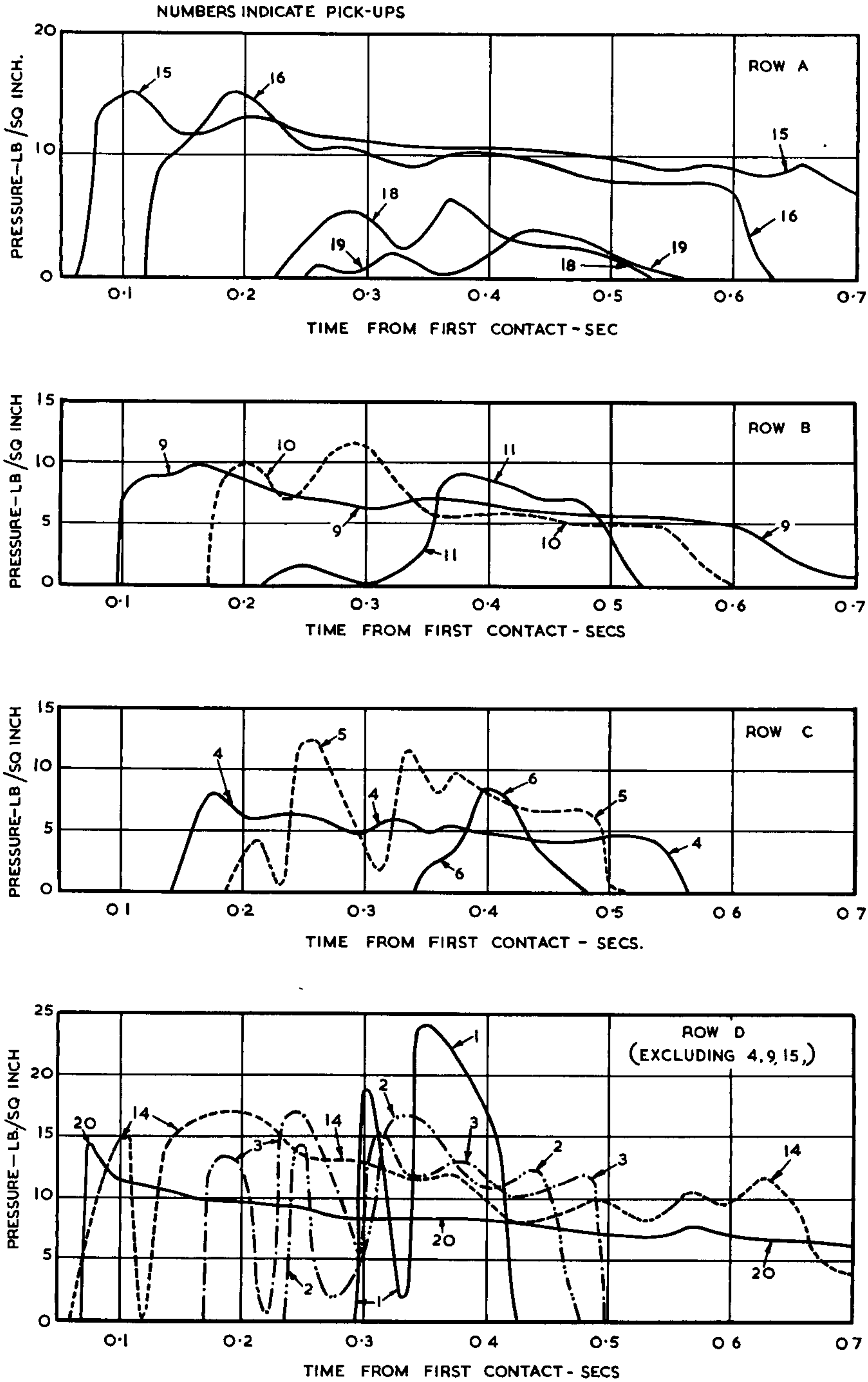
PRESSURE PICK UP POSITIONS

FIG. 4.



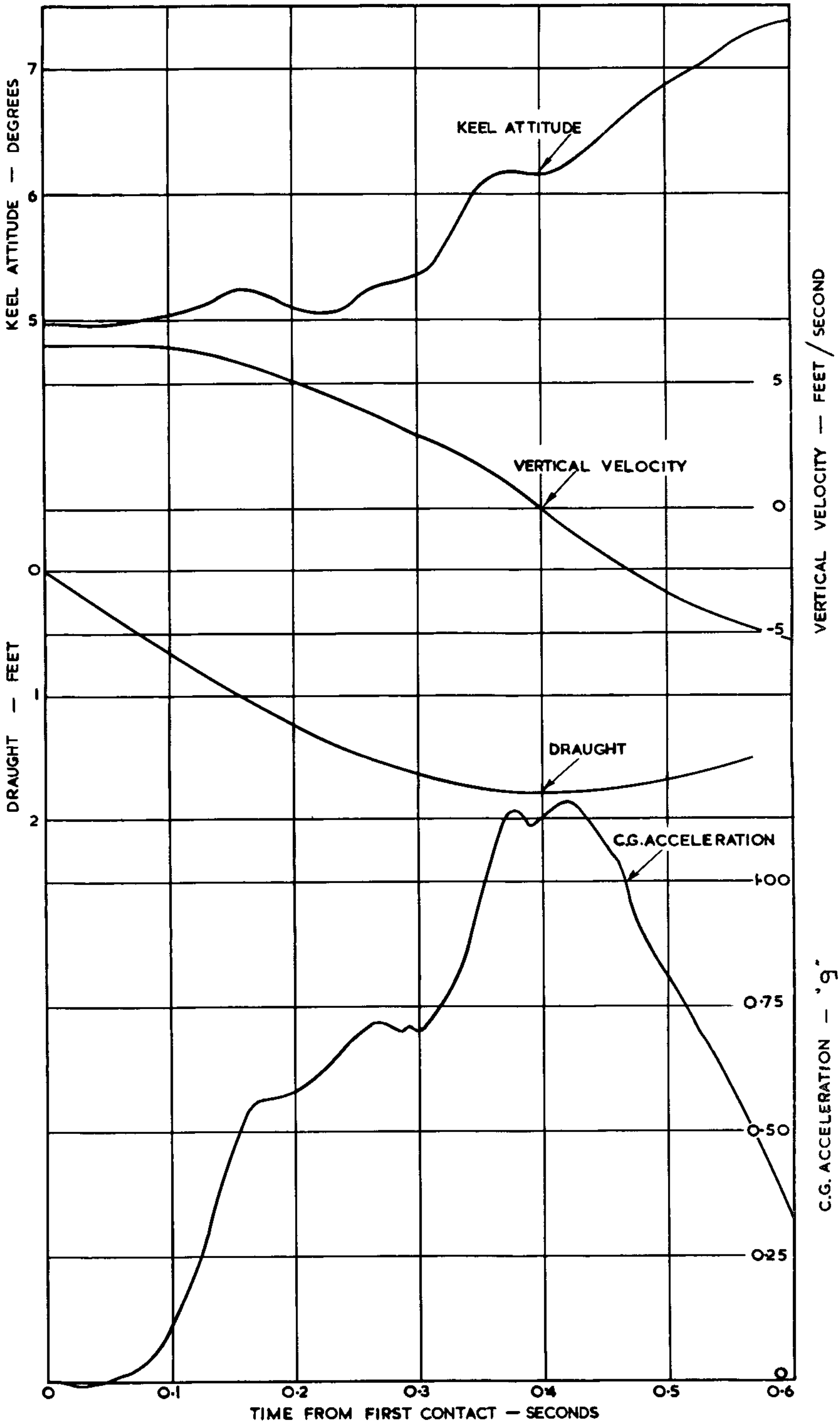
TOTAL IMPACT RESULTS. RUN 1. IMPACT 1. V_H = 148 F.P.S.

FIG. 4 A.



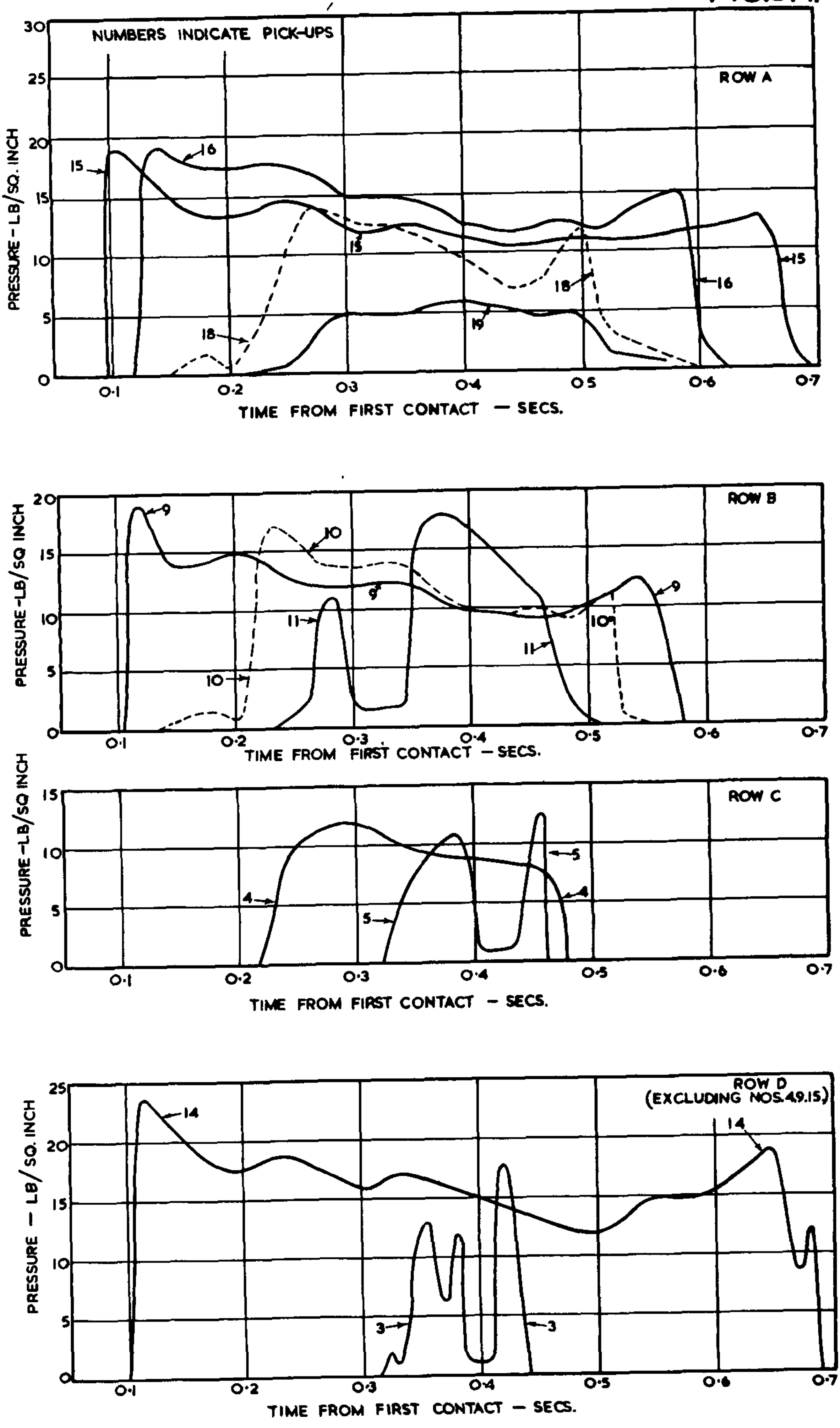
PRESSURE RESULTS FOR RUN I IMPACT I.

FIG. 5.



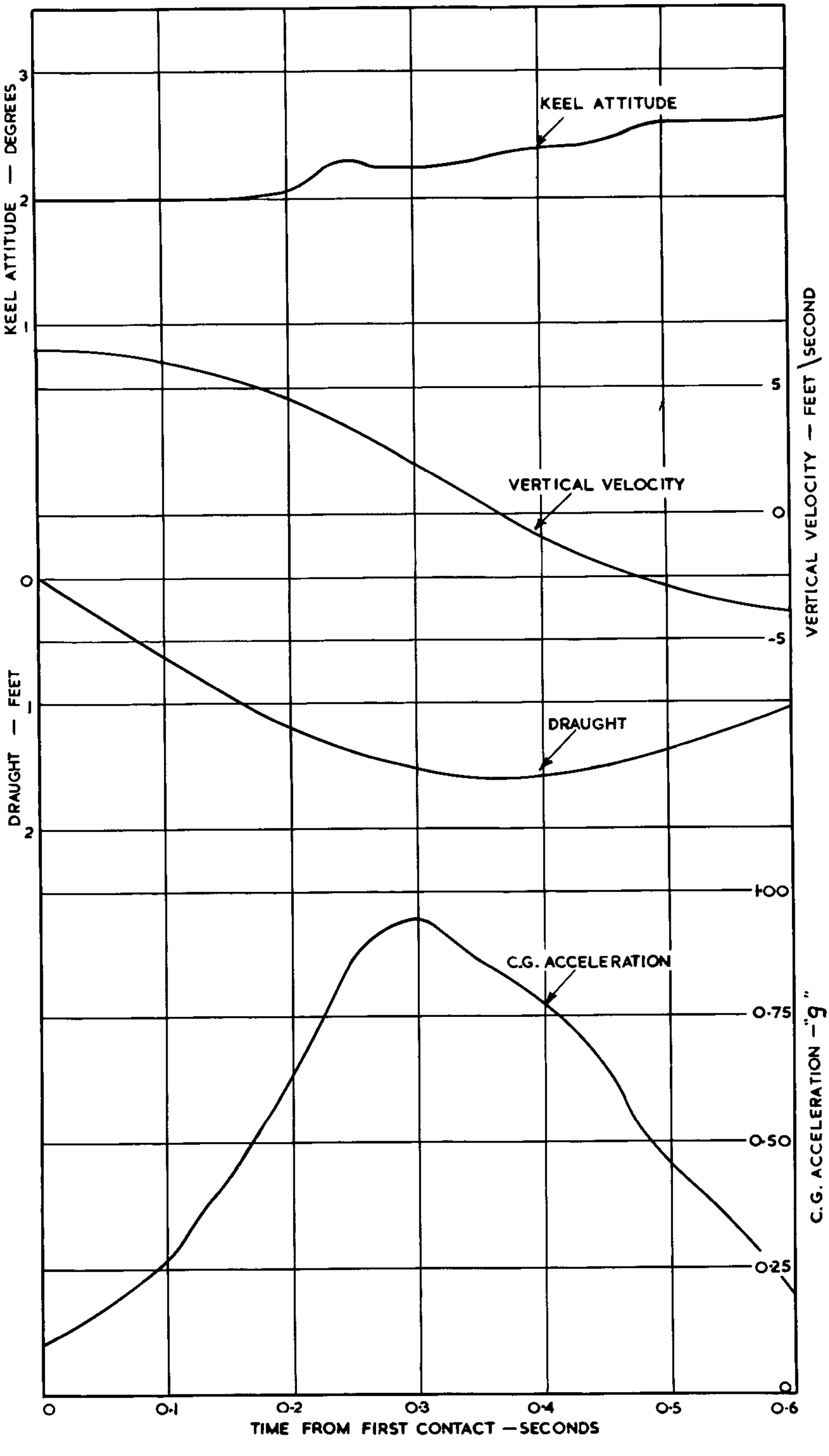
TOTAL IMPACT RESULTS. RUN 2. IMPACT 1. V_H = 138 F.P.S

FIG.5A.



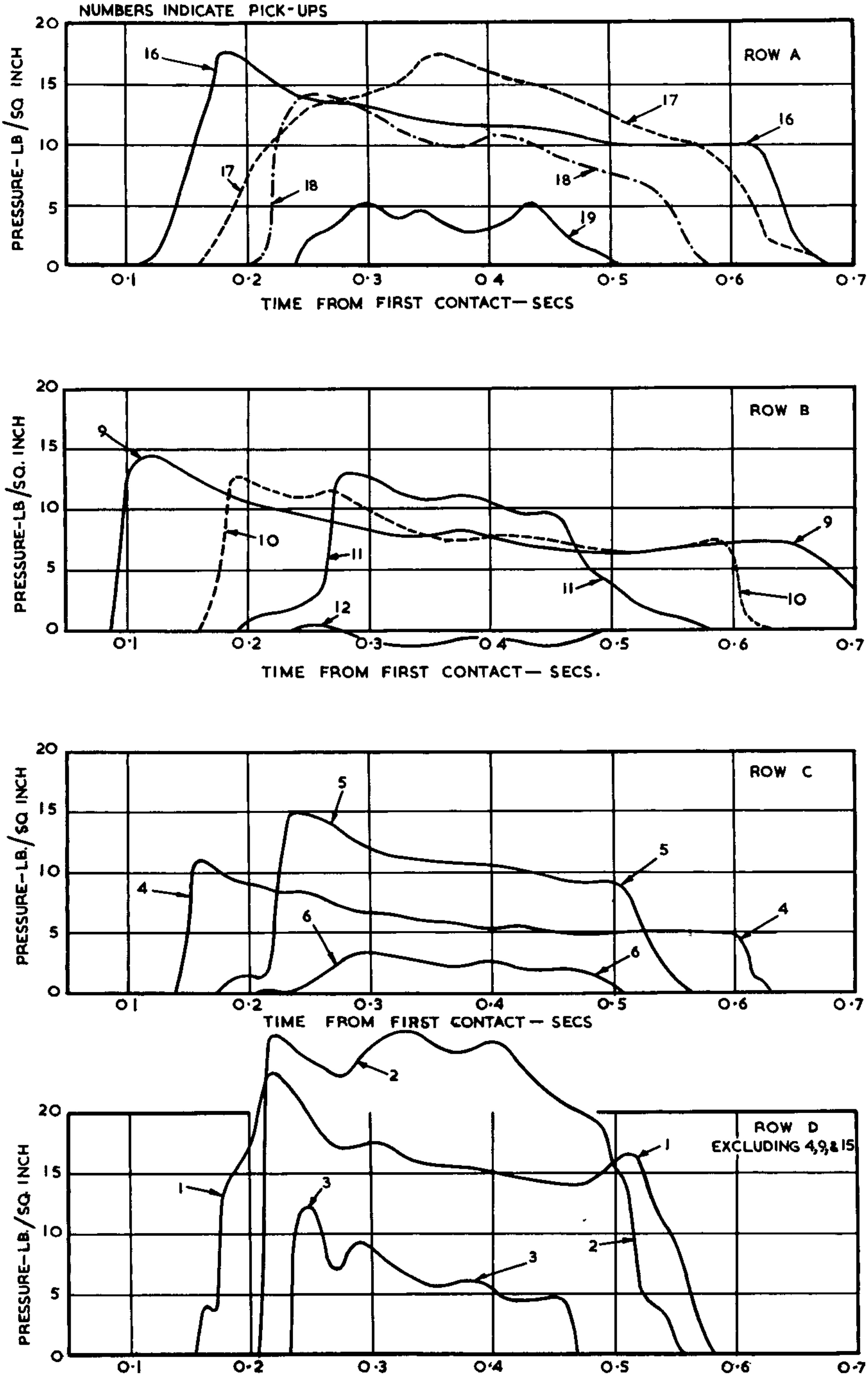
PRESSURE RESULTS FOR RUN 2. IMPACT 1.

FIG. 6.



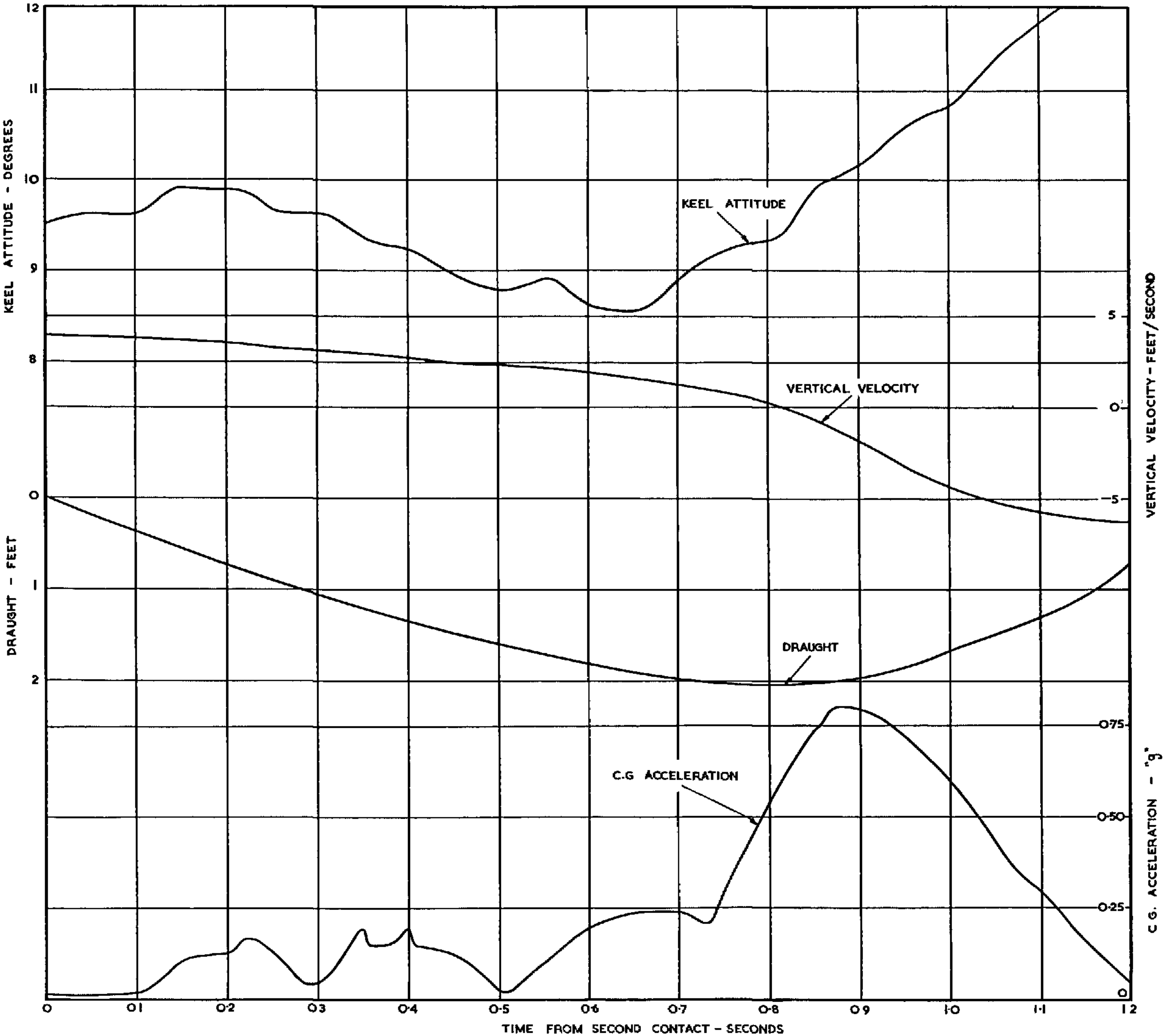
TOTAL IMPACT RESULTS. RUN 4. IMPACT 1 $V_H = 153$ F.P.S

FIG. 6 A.



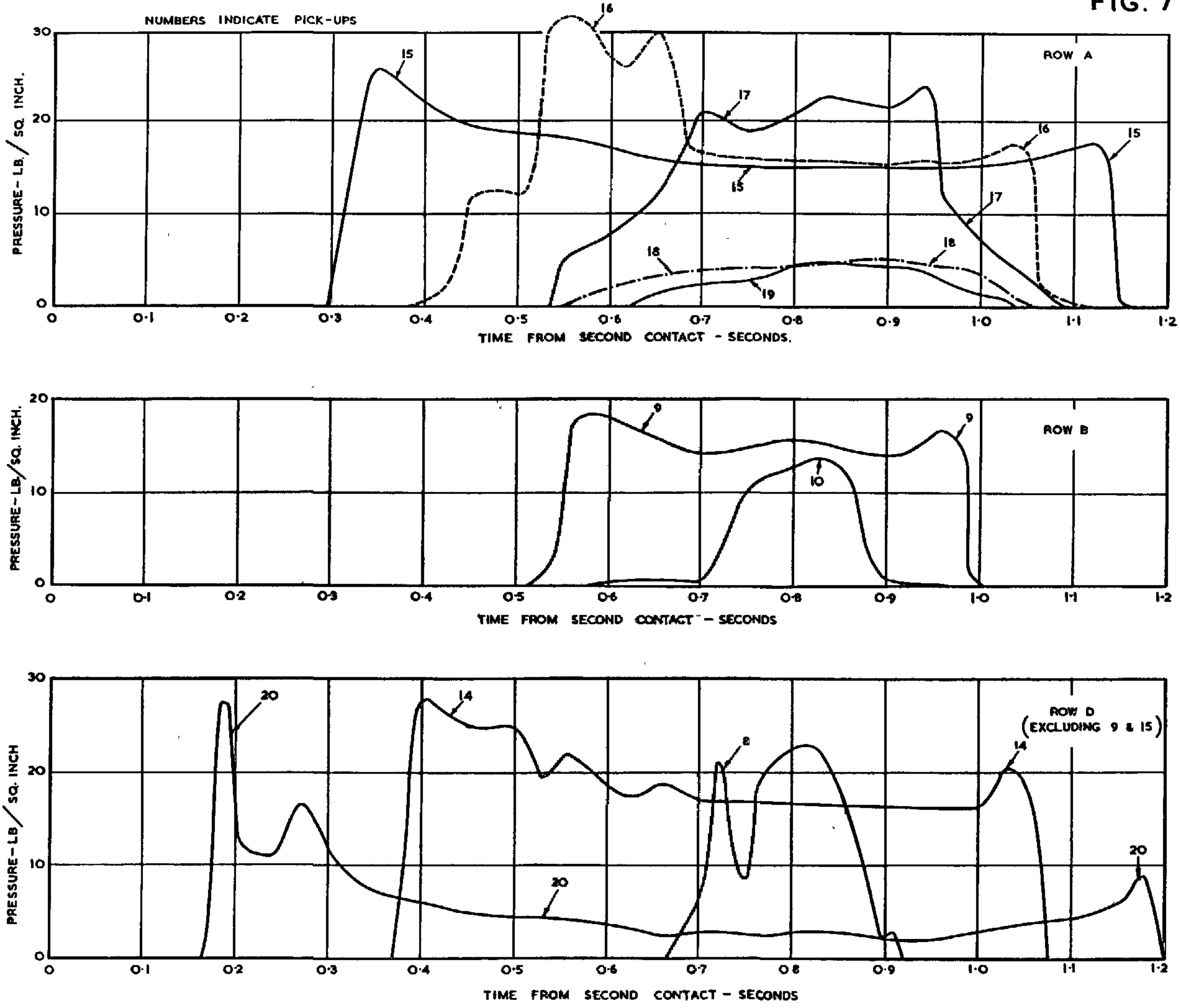
PRESSURE RESULTS FOR RUN 4 IMPACT I.

FIG. 7.



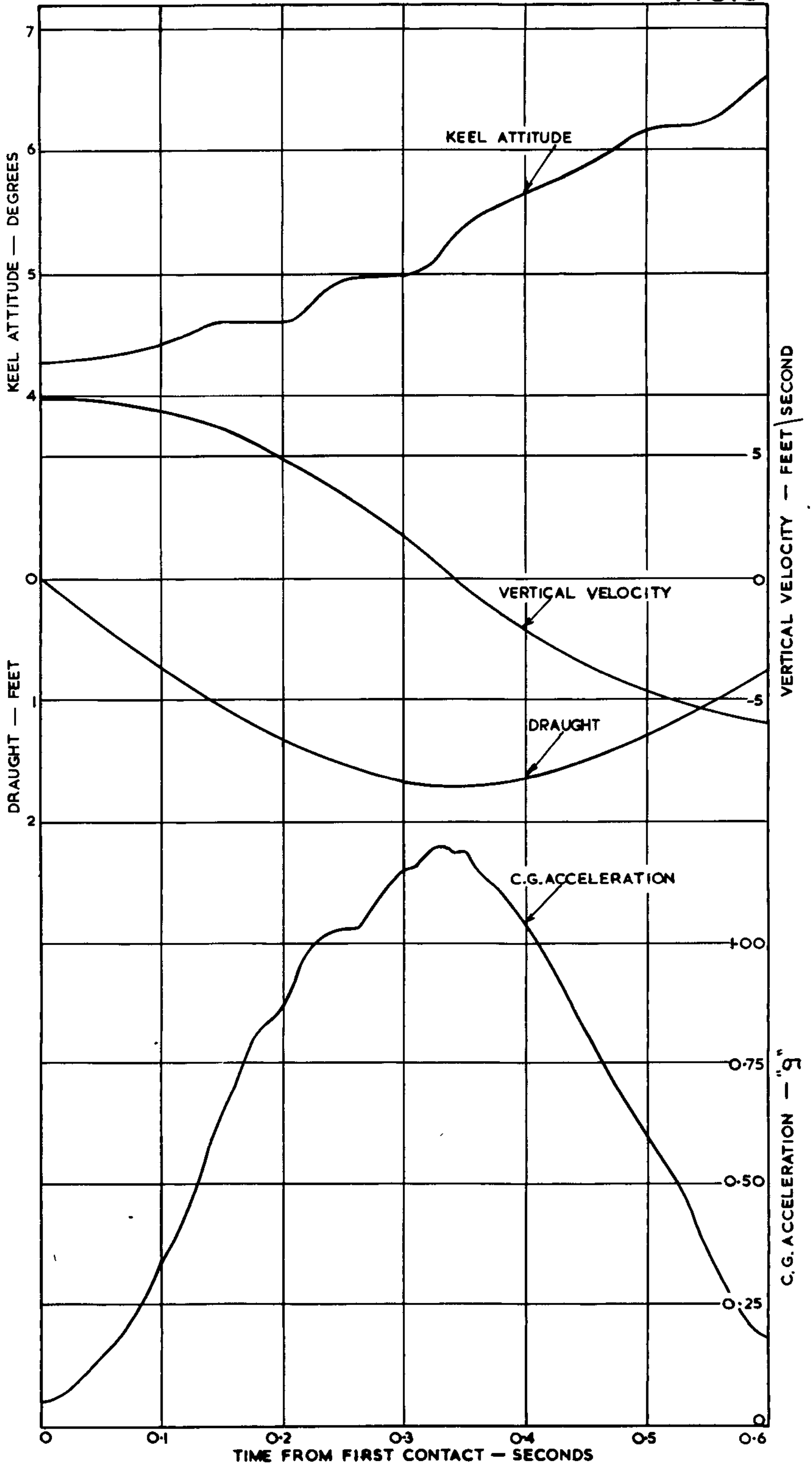
TOTAL IMPACT RESULTS. RUN 10. CONTACT 2. $V_H = 120$ F.P.S.

FIG. 7A.



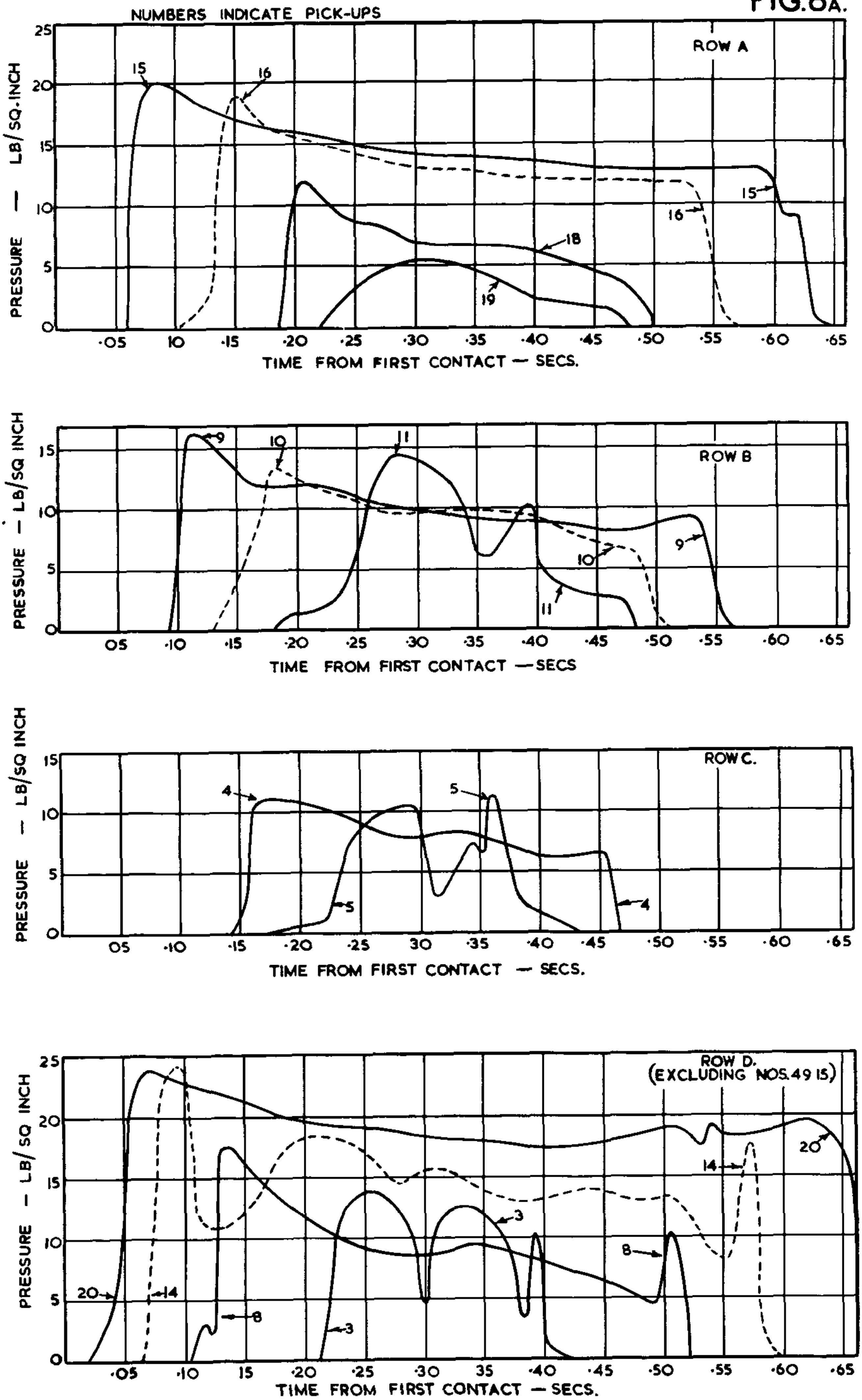
PRESSURE RESULTS FOR RUN 10. IMPACT 2.

FIG. 8.



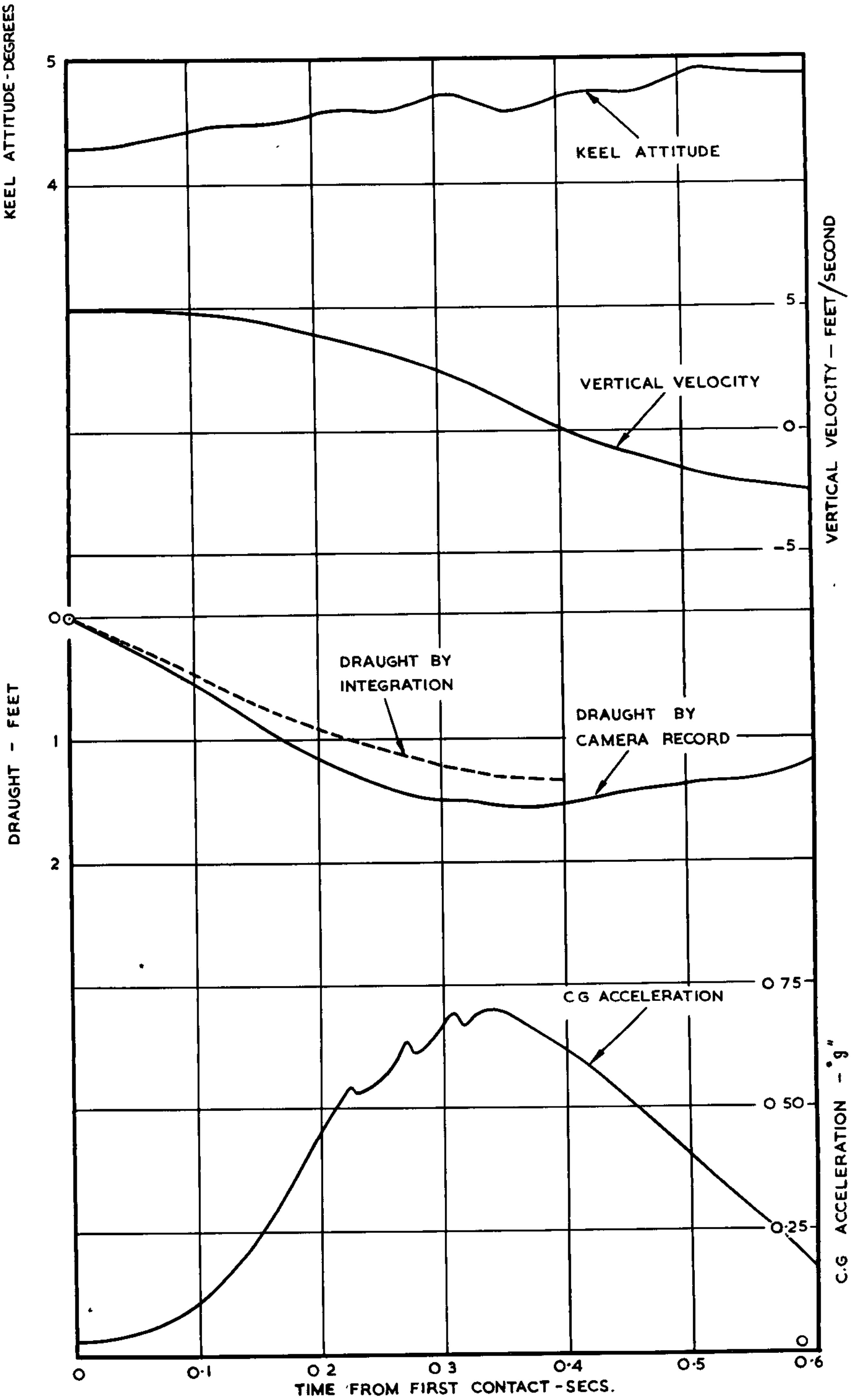
TOTAL IMPACT RESULTS. RUN 12 IMPACT 1 V = 120

FIG.8A.



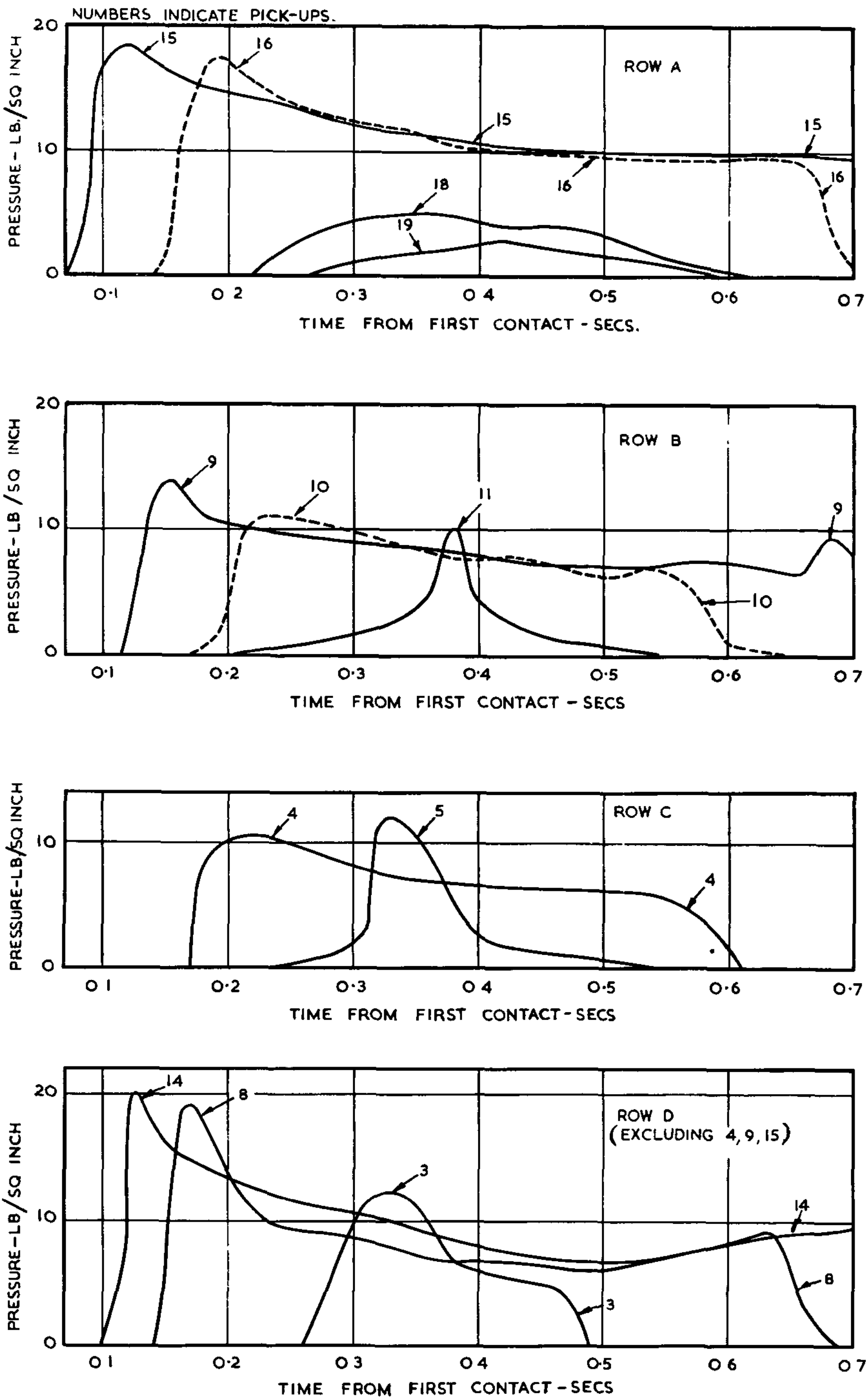
PRESSURE RESULTS FOR RUN 12. IMPACT 1.

FIG. 9.



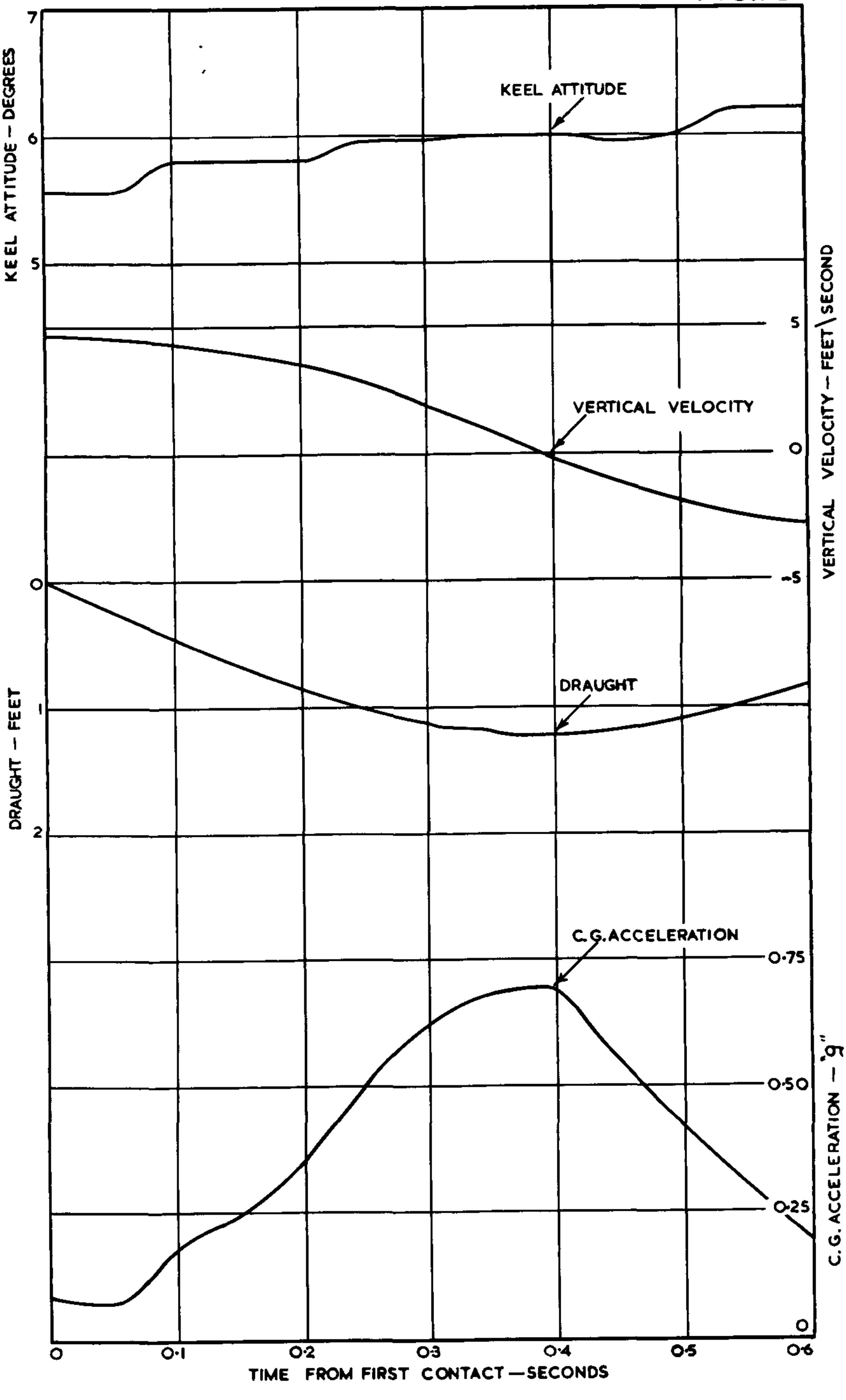
TOTAL IMPACT RESULTS. RUN 14. IMPACT 1. V_H= 128 F.P.S.

FIG. 9 A.



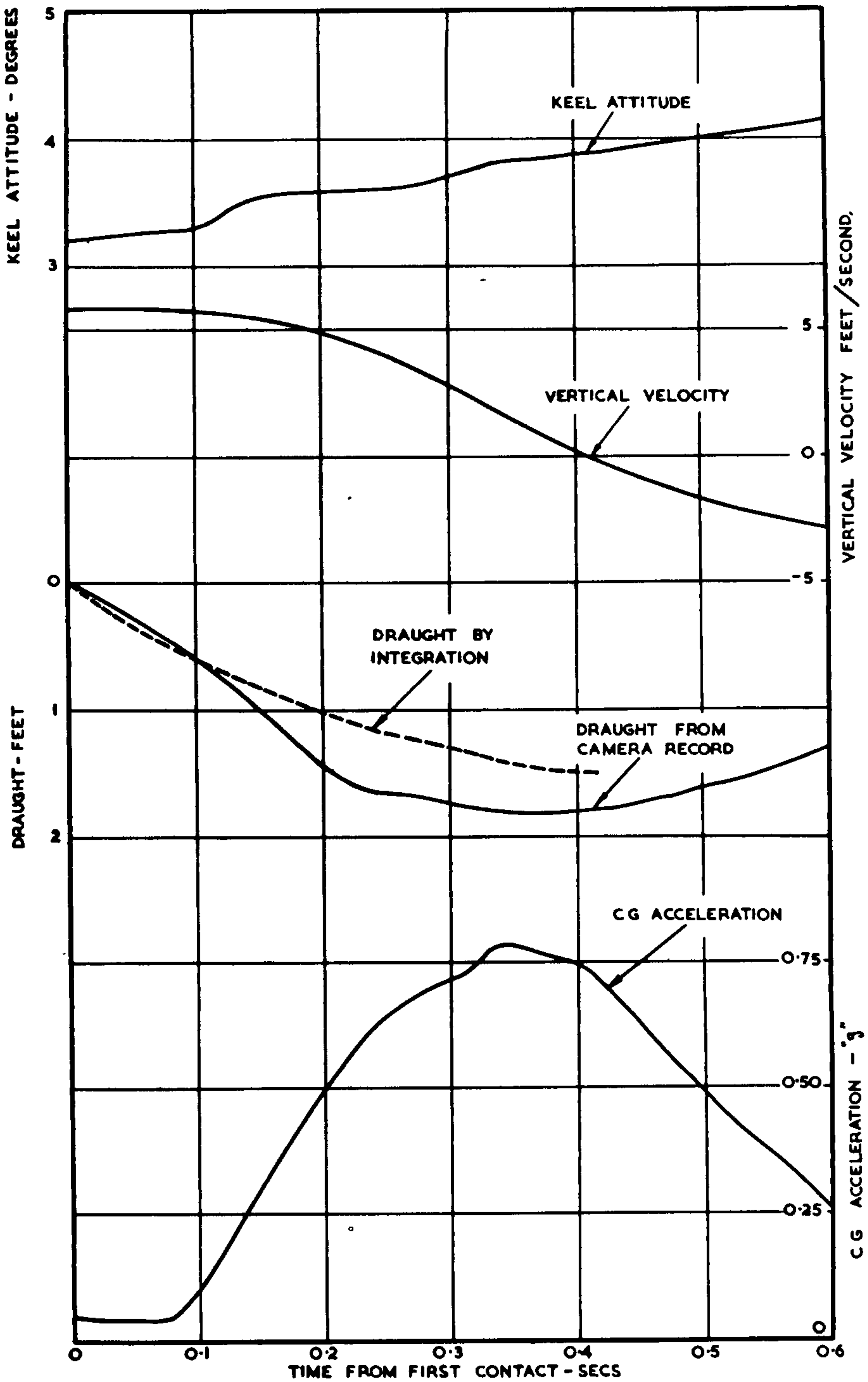
PRESSURE RESULTS FOR RUN 14. IMPACT 1.

FIG.10.



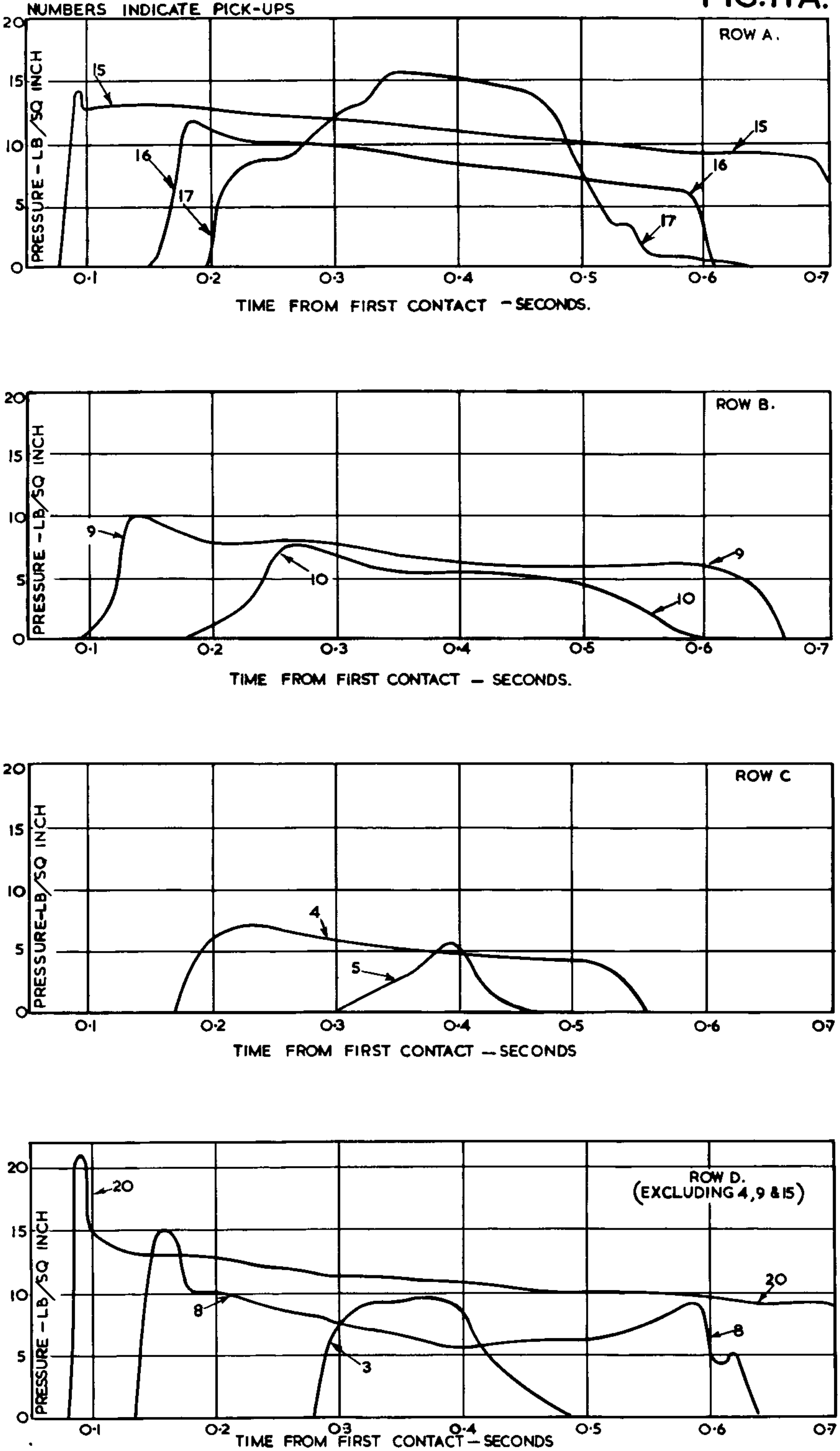
TOTAL IMPACT RESULTS. RUN 15. IMPACT 1. V_H = 146 F.P.S.

FIG. 11.

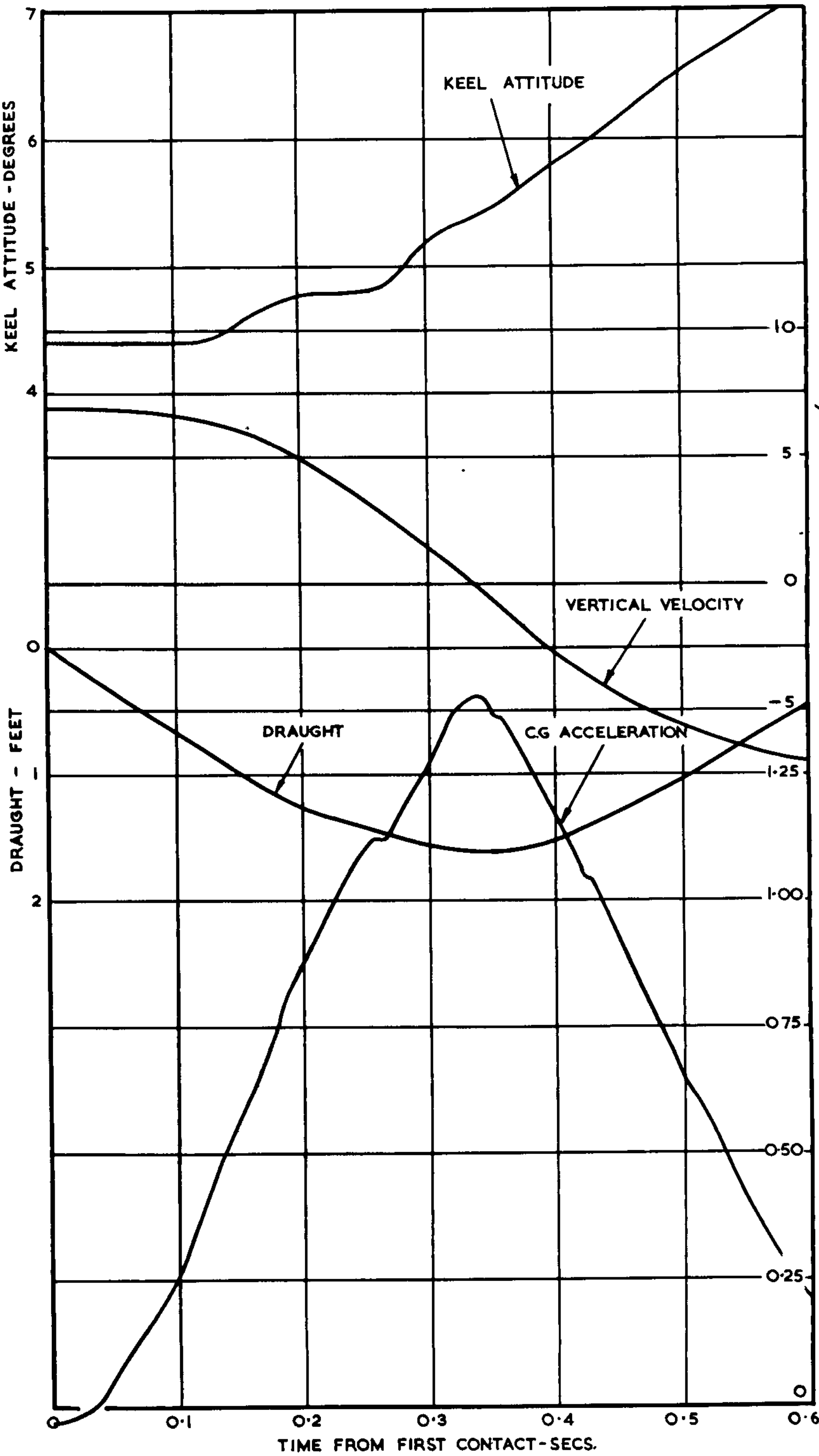


TOTAL IMPACT RESULTS RUN 17 IMPACT I V_H = 159 F.P.S.

FIG. 11A.

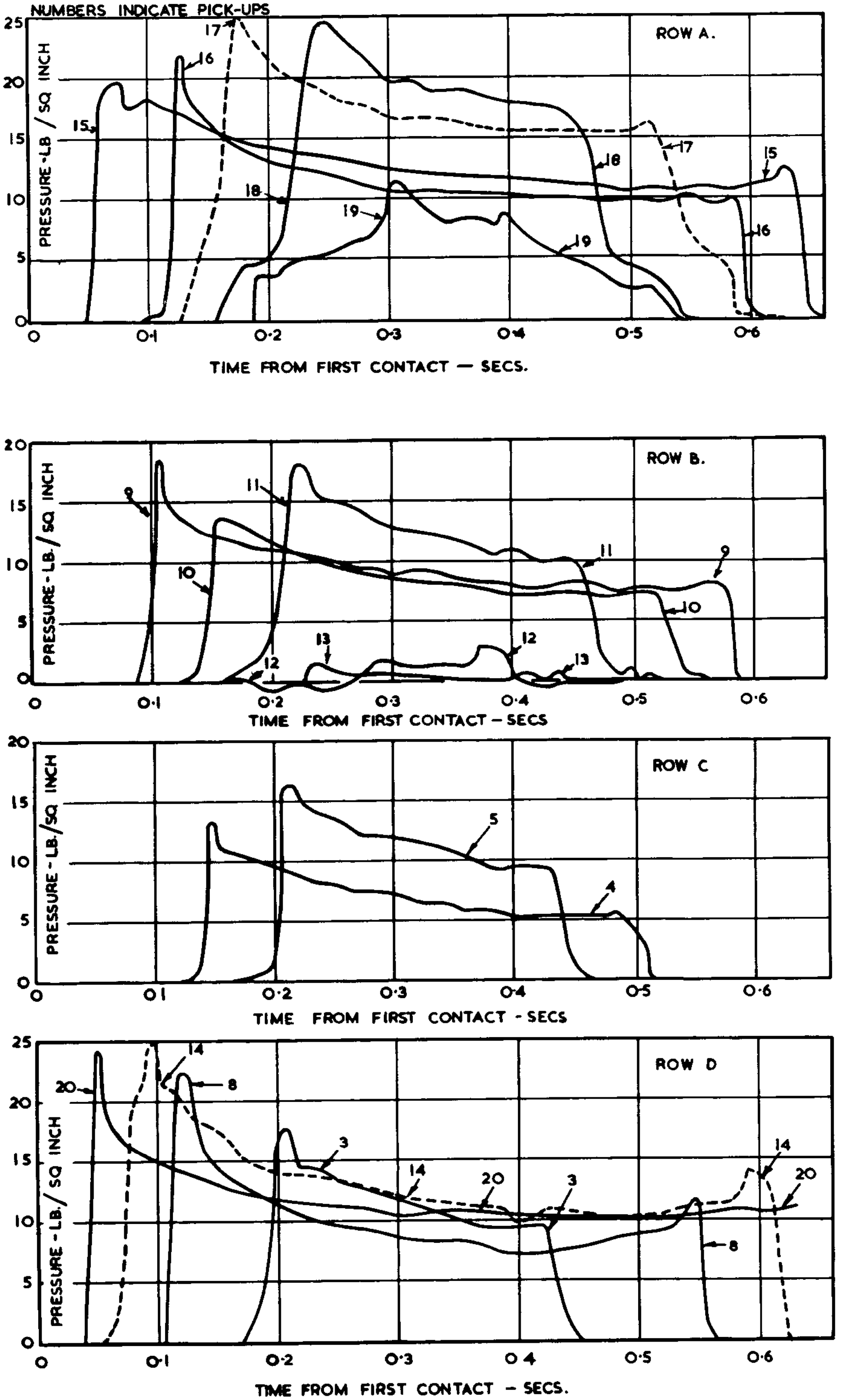


PRESSURE RESULTS FOR RUN 17. IMPACT 1.

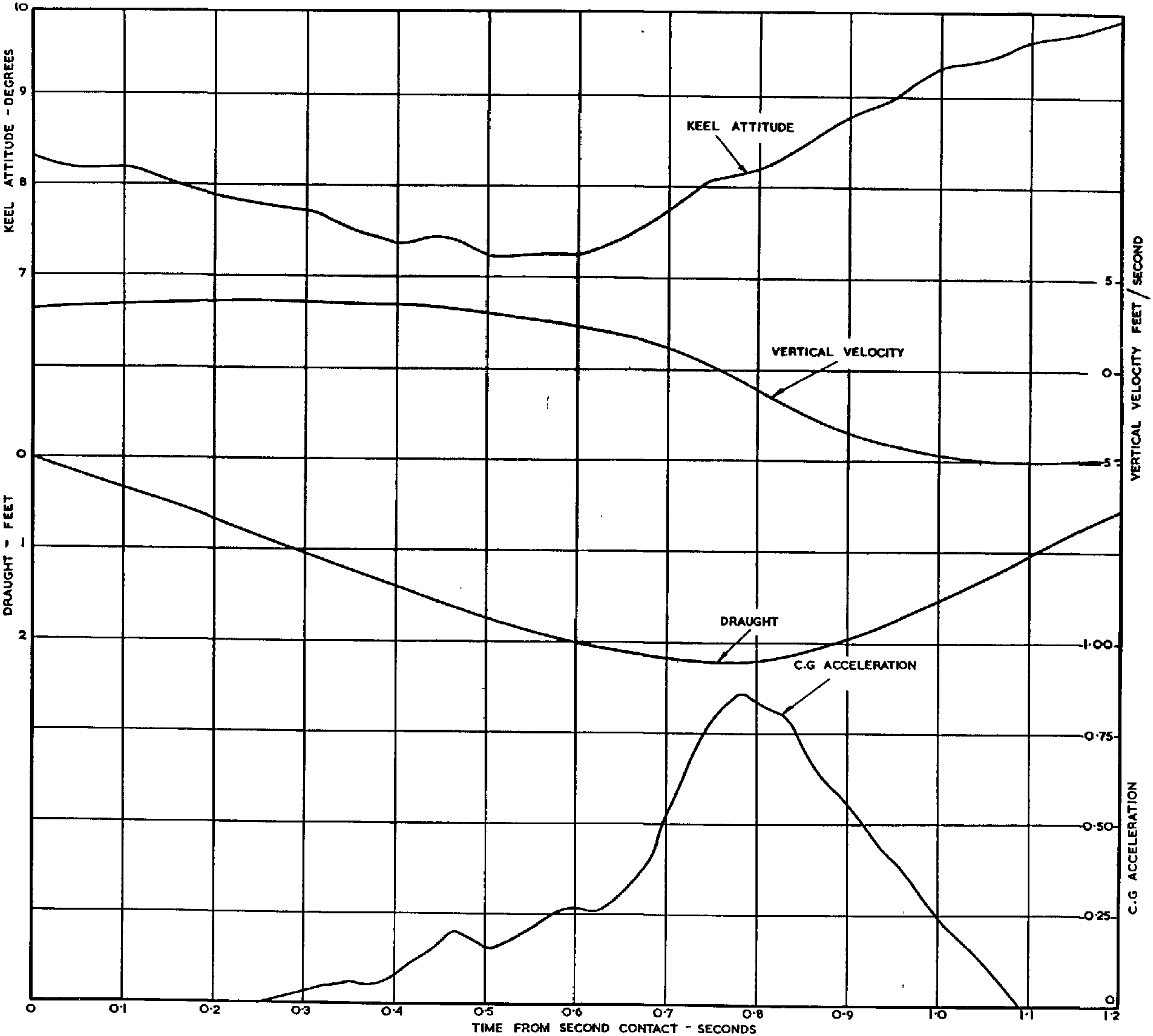


TOTAL IMPACT RESULTS RUN 18 IMPACT 1 $V_H = 134$ F.P.S.

FIG. 12A.

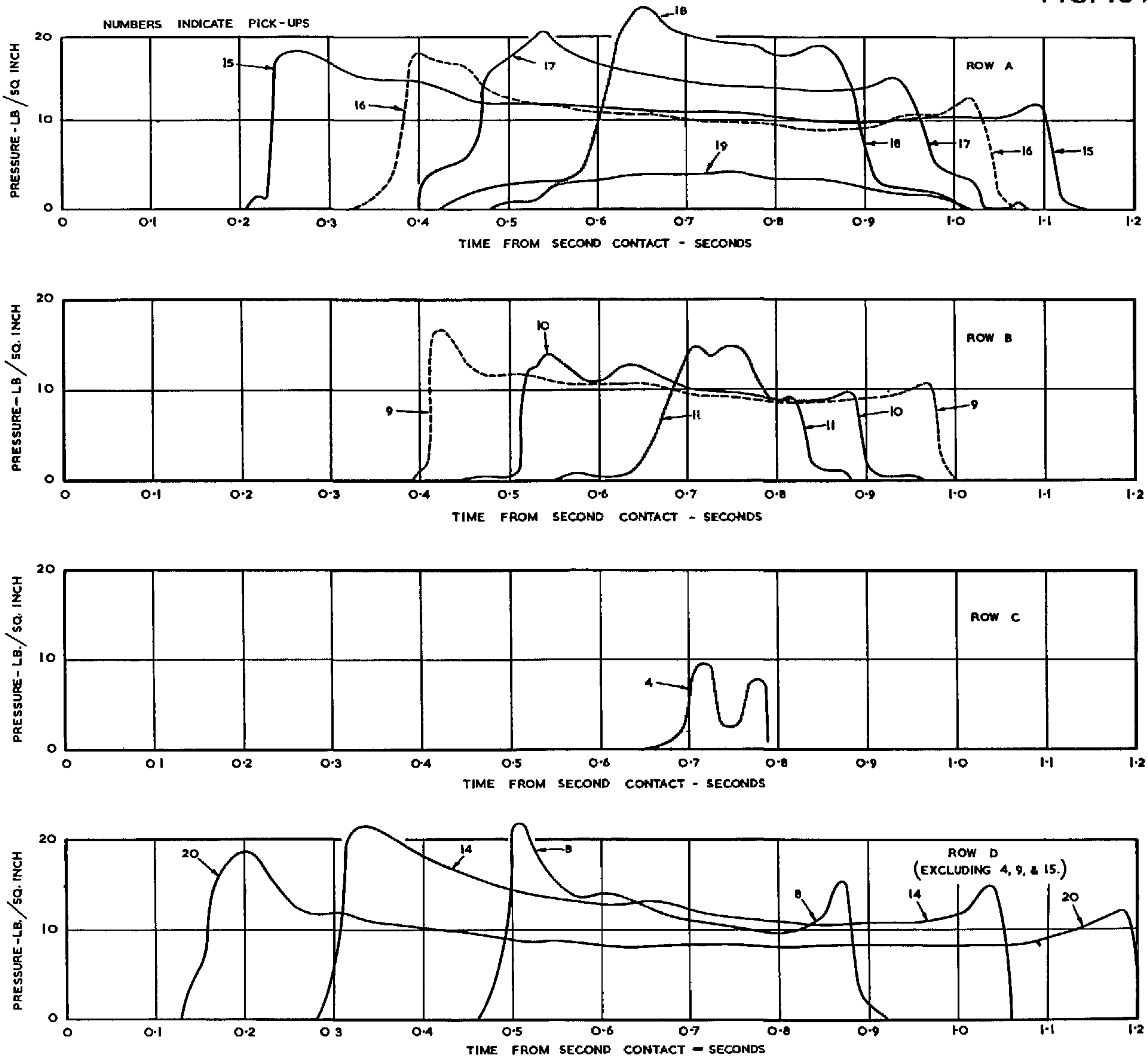


PRESSURE RESULTS FOR RUN 18. IMPACT I



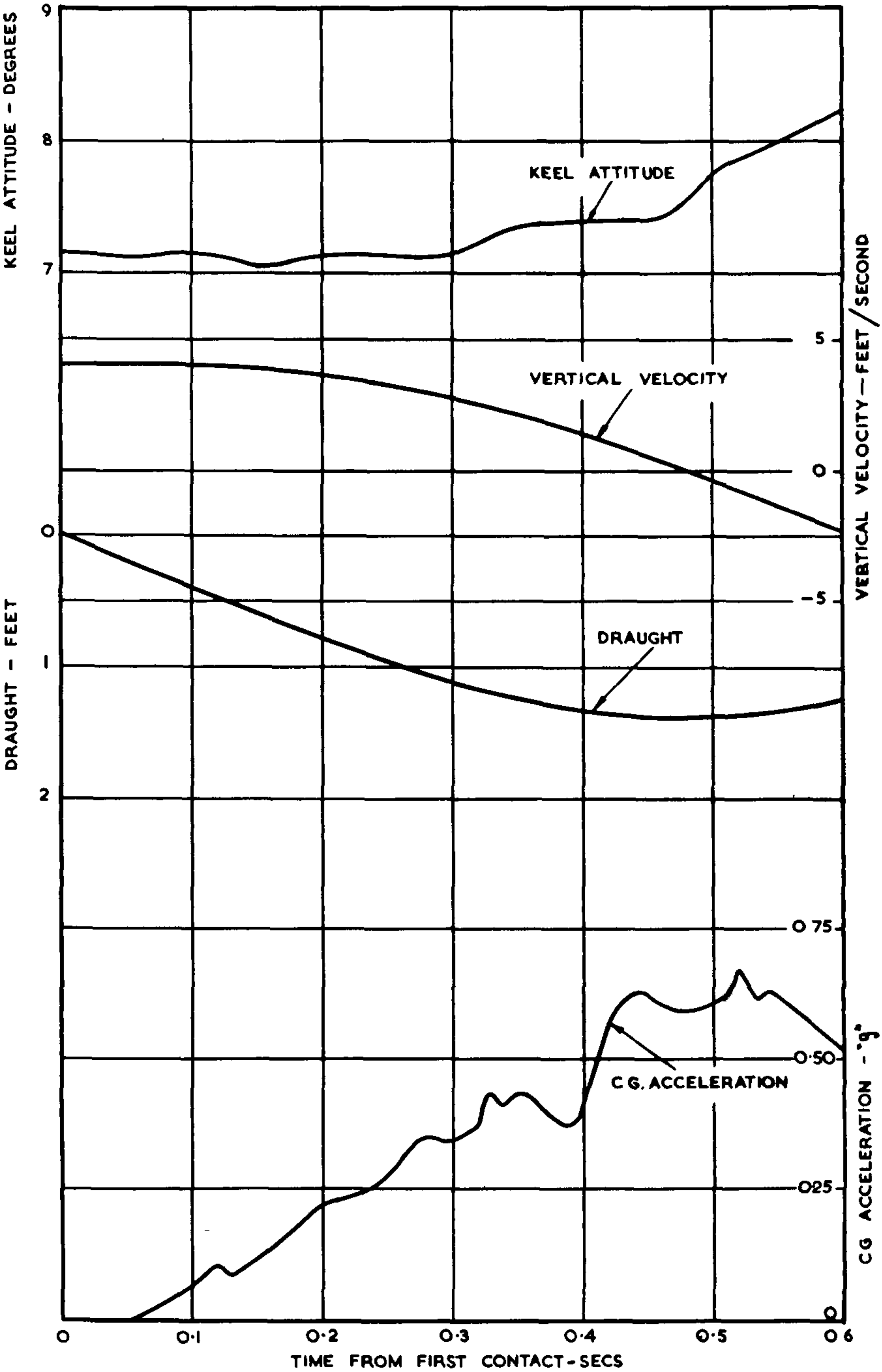
TOTAL IMPACT RESULTS. RUN 20. IMPACT 2. $V_H = 109$ F.P.S.

FIG. 13 A.



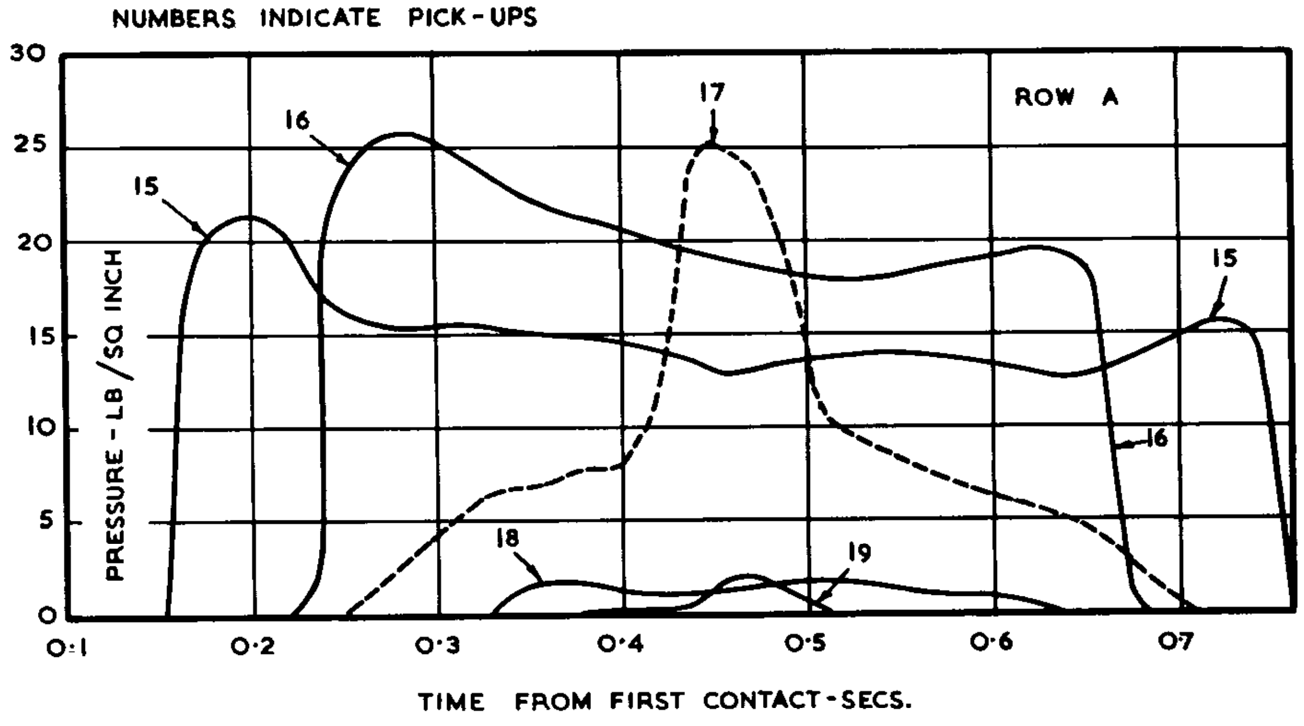
PRESSURE RESULTS FOR RUN 20. IMPACT 2.

FIG. 14.



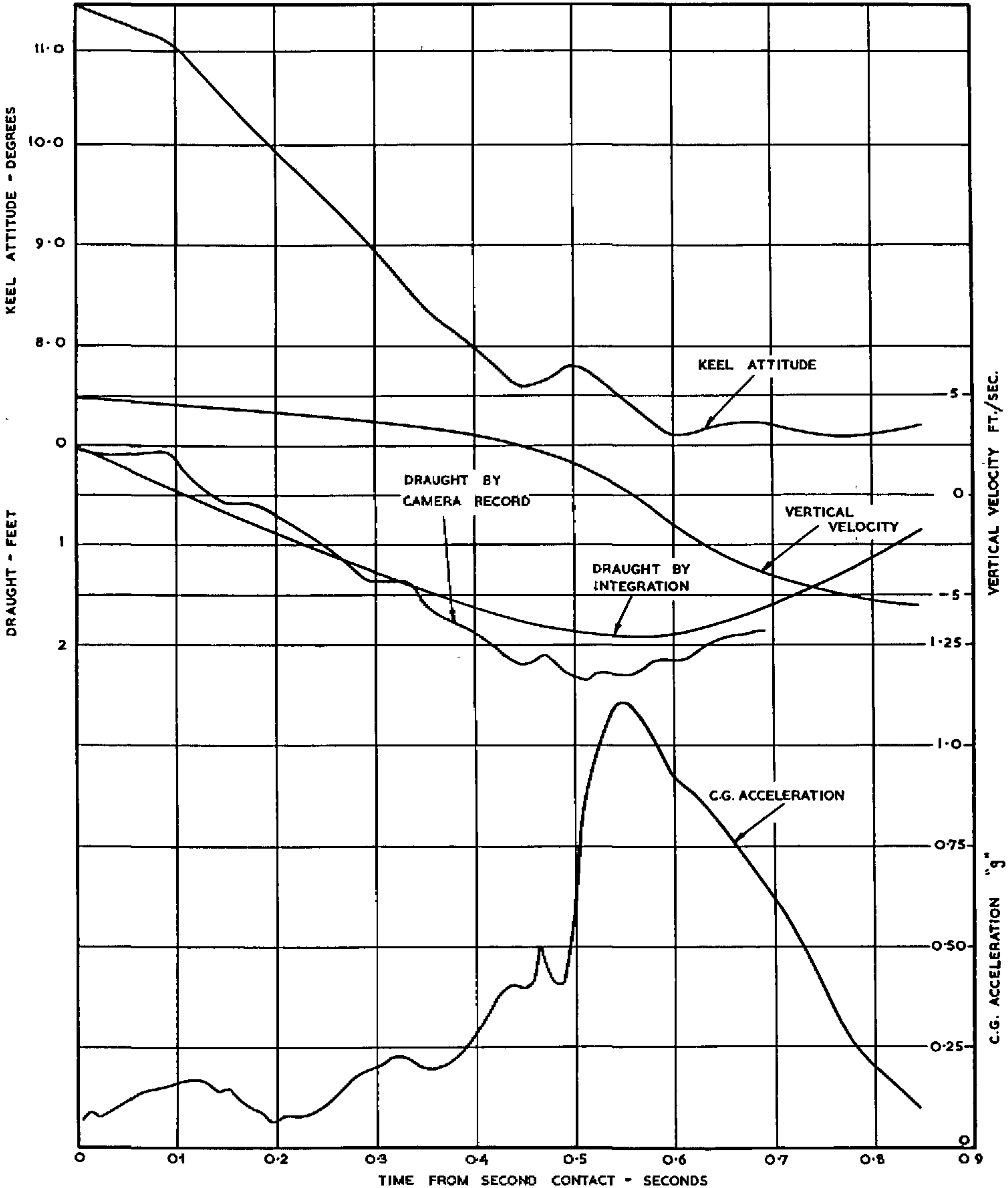
TOTAL IMPACT RESULTS. RUN 23. IMPACT 1. V_H= 134 F.P.S

FIG. 14 A.

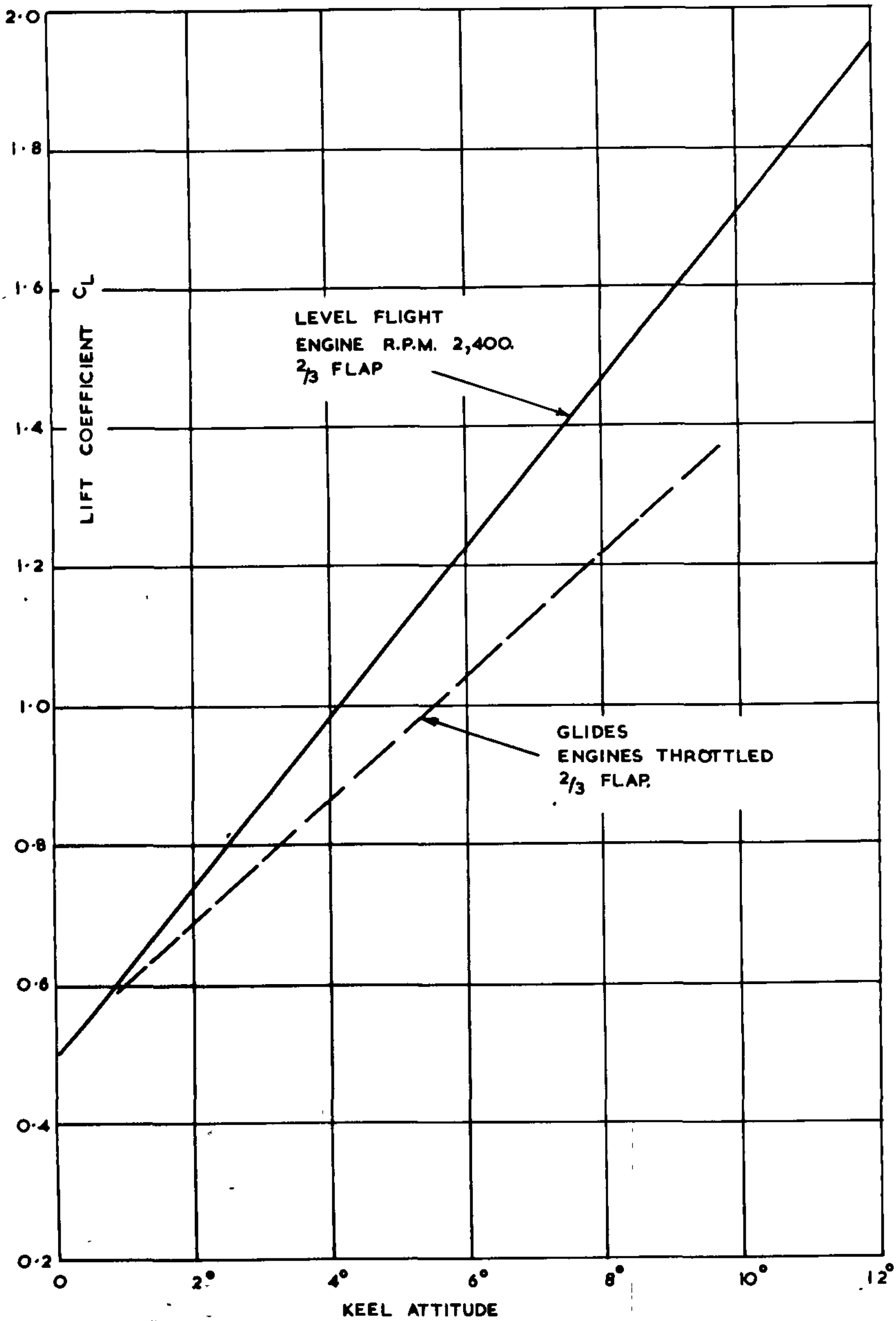


PRESSURE RESULTS FOR RUN 23 IMPACT 1.

FIG. 15.



TOTAL IMPACT RESULTS FOR RUN 19 IMPACT 2 V=116 FPS



LIFT CURVES FOR SUNDERLAND MK V WITH 2/3 FLAP.

D557875/1 R72 300 6/57CL

C.P. No. 340
(17,895)
A.R.C. Technical Report

Printed and published by
HER MAJESTY'S STATIONERY OFFICE
To be purchased from
York House, Kingsway, London W.C.2
423 Oxford Street, London W.1
13A Castle Street, Edinburgh 2
109 St Mary Street, Cardiff
39 King Street, Manchester 2
Tower Lane, Bristol 1
2 Edmund Street, Birmingham 3
80 Chichester Street, Belfast
or through any bookseller
Printed in Great Britain

S.O. Code No. 23-9010-40

C.P. No. 340