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Impact Measurements on a Large Model of a Representative Landplane Fuselage on Water

By

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IMPACT MEASUREMENTS ON A LARGE MODEL OF A REPRESENTATIVE LANDPLANE FUSELAGE ON WATER

by

J.E. Allen, B.Sc. (Eng.), A.F.R.Ae.S.

SUMMARY

An experimental investigation has been made into (i) splash-up, (ii) impact pressures, and (iii) impact forces occurring during controlled alightings on smooth water of a representative landplane fuselage of elliptical cross-section in the Hull Launching Tank.

The width of the actual wetted surface of the cylinder was found to be $\sqrt{2}$ times the width which would be wetted for immersion to the same draught without splash-up. Pressure distributions are presented in the form of data for several landings over a range of initial attitudes and at flight path angles down to 1.5°.

The acceleration results are of limited usefulness due to imperfections in the apparatus.

Photographs are included of the external spray formation.

Results are not generally applicable to design cases for ditching until a rational theory of impact of fuselage shapes be made available.

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1. INTRODUCTION

The work described in this report is part of a limited research programme jointly undertaken by the R.A.E. end the M.A.E.E., directed towards a clarification of the hydrodynamic and structural problems involved in the improvement of landplane ditching characteristics. A comprehensive programme was given by Smith in 1946 (Reference 1) for discussion by the Aeronautical Research Council but only certain aspects of this were actively pursued and these have now ceased. A broad survey of present problems of design for good ditching characteristics and tho limitations of existing data and theory is available (References 3 and 4). The experiments described in this report have been made on a quarter-scale representative landplane in the M.A.E.E. Controlled Hull Launching Tank, to provide information on water impact pressures and accelerations occurring during the initial stages of an alighting on smooth water. The tests were originally planned in 1944 to investigate a series of afterbody forms end wing positrons to establish the optimum combination for good overall ditching characteristics, mainly for military aircraft. At the end of the war, when there wore no longer any operational requirements justifying considerable research effort, the programme was severely curtailed and only ono form has been tested, which is generally representative of clean modern high-speed bombers and civil transport aircraft. Parallel tests which have been made by tho R.A.E. on a smaller dynamically similar model in tho free launching tank have shown that the form tested does give good ditching behaviour.

The ultimate object of the research of which this report is part is to relate impact pressures and accelerations to the initial alighting conditions and to the geometrical shape and mass distribution of the ditching body for design use and also for formulating design requirements.

A serious weakness in the present knowledge is the lack of en established theory of oblique impact of cylindrical bodies on a free surface. Because of this the results arc at present somewhat limited in application, end hence only model results, without intorprotation, are presented.

Four series of tests were made, the scope of which is given in Table I end paragraph 3.4, the tests being made during the periods Docembcr 1948, March 1949 and January-February 1950.

2. EXPERIMENTAL AND THEORETICAL KNOWLEDGE OF LANDPLANE IMPACTS

In this section a brief review is made of current knowledge of the initial impact of landplanes on the water, comprising previous measurements in the Hull Launching Tank and a little theoretical work. A more extensive review of landplane ditching is available in a monograph (Reference 4) giving also full scale operational experience, which is not dealt with hero.

'2.1 Experimental Data

Apart from some early free drop tests on a full scale Hudson aircraft (Reference 5) which demonstrated the vulnerability of local portions of tho under-surface to collapse under water impact pressure and some limited small free model tests on a Mosquito (Reference 6)

/which

which indicated that impact pressures could be very high. British data is confined to the Hull Launching Tank Tests on York (Ref. 7) and Tudor (Ref. 8) models. These were made on large models of one-third and one-quarter scale respectively and represent as closely as possible the dynamic conditions of one or two landings only. In particular the tests were designed to show the difference in the nature of the impact resulting from a high speed, flaps up approach, and a low speed, flaps down approach. Values of the pressures, their duration and extent over the body were measured and, by a simple theory, the results were applied to full scale conditions. The two experiments covered broadly the same scope, an important difference being that the York had a flat under-surface and the Tudor was of circular cross-section. The approximate pressure distribution showed an expected reduction in both maximum and mean pressure by the use of a circular section. The peak pressures in both were high and generally confined to small areas, but sufficient in the York, with flat bottom, to cause extensive local structural failure. The magnitude at a given alighting speed depended on attitude and the angle of descent. The range of these two latter major variables was insufficiently explored to enable quantitative relations to be derived directly from the results. The general conclusion was that the order of pressures likely to be reached in ditching was such that in military aircraft the extra weight of local strengthening of the structure could be tolerated to cope with alightings made up to angles of descent of 5°, but for civil aircraft, where the weight increase could not be accepted to the same extent, reasonable ditchings could only be expected with a very low angle of descent, i.e. $1^{\circ} - 2^{\circ}$ and in calm water (Ref. 3). This conclusion made it imparative to explore the lowest range of angles of descent possible, which was not done in the previous tests. Because of structural limitations in the tank apparatus it is difficult to obtain reliable results for angles of descent below $2\frac{1}{2}^{\circ}$, and impossible to obtain results at all below $1\frac{1}{2}^{\circ}$.

There is also some experimental evidence from one recorded test ditching of a full scale Liberator (Ref. 9) made in America.

2.2. <u>Theory.</u>

While there is no adequate theory available which deals with the impact of landplanes on water, it is reasonable to believe that rhen such theory does become available it will require similar assumptions to be made as are made in theories relating to the impact of seaplane hulls on water, and also that the fuselage can be considered as a simple cylinder.

These assumptions are then :-

(i) A constant forward velocity during impact;

(ii) No angular rotation during the impact;

(iii) Smooth water;

(iv) The aircraft weight is balanced by air lift, i.e. the vertical acceleration prior to first impact is zero;

(v) The body is rigid;

(vi) The pressures are negligible over the after half of the nominal netted area.

In performing model tests it is necessary then to make the test conditions correspond to those assumed in the relevant theories and conditions (i) - (v) above are conformed mith as far as possible in the Hull Launching Tank tests.

/The

The assumption in (vi) is important as it assumes that the flow can be represented as breaking away behind the maximum section, which can then be represented as a step. This simplified assumption in fact implies that no suction forces are present.

Suction forces do, in fact, occur and arise mainly from the water flow round the curved after fuselage and any spray blisters which do not break away from the forward portion.

It is believed that suction forces will be more sensitive to scale effect than the impact forces, because cavitation, surface tension and the condition of the model surface nill all affect the nature of the flow. Experiments made at R.A.E. on the planing of long cylinders include a useful theoretical discussion of this (Ref. 10). In terms of the general ditching problem, a knowledge of the physical nature of these suction forces is important, as small model tests have shown that suction forces can play a large part in determining whether a ditching is good (Ref. 11) or bad (Ref. 12).

Important as are the impact forces in the evolution of a satisfactory theory embracing model and full scale conditions, they are less significant than the pressures, as it is the latter which determine the likelihood of local structural failure and hence the deterioration of an otherwise good ditching performance. In the good ditching shape under investigation the possibility of the total impact forces alone playing a major part in the structural break-up is small. Unfortunately the question of the impact pressures on a typical fuselage is again a difficult one and there is no theoretical background yet available to deal nith the problem.

Experimentally, a serious difficulty is that the finite-sized diaphragms of the pressure pick-ups do not give a true indication of the peak pressure but only a mean value integrated over the extent of the diaphragm. Although the diaphragms are fairly small (1" diameter, i.e. 1/24 fuselage beam) the measured pressures are likely to differ sufficiently from the theoretical peak pressures to give significant errors in calculating the effect of the peak pressure wave on a built up fuselage structure. This "area factor" (Ref. 13) is calculable for the seaplane wedge case in terms of a theoretical pressure distribution derived from the associated mass concept, and recent Hull Launching Tank tests have confirmed that this approach is reasonably accurate (Ref. 14). There is, unfortunately, no corresponding theory available from which to calculate the corresponding factor for the landplane case.

3. EXPERIMENTAL TECHNIQUE

3.1 Model and Launching Apparatus

The model shown in Figure 1 is built of wood in three sections; a short nose, a main central portion of uniform elliptic cross-section and an upswept tapering after part of varying elliptical cross-section. Pressure and accelerometer pick-ups are shown in Figure 1 and dimensions are given in Table II. Figure 2 is a photograph of the model mounted on the carriage launching mechanism.

The model is attached to the swinging linkage of the carriage by a cross-shaft passing through the central portion and built into wing stubs corresponding to a mid-wing position. The model can pivot in pitch about this shaft, freely if desired, but in these tests with a large damping restraint applied by fraction discs and cables. Prior to dropping, the attitude (pitch) can be adjusted to any one of a range of six values by a pin and coxcomb attachment. On release, this

/fixing

fixing drops out and the model pitches in response to the hydrodynamic forces and the damping restraint. Yawing and rolling are prevented by the linkage, which permits freedom in heave. The diagrammatic sketch of the linkage system, Figure 3, shows how the model is counterbalanced at water level. This ensures a constant vertical velocity at contact with the water, thus giving approximately the equivalent in full scale of a landing made at constant angle of descent, with wing lift equal to the aircraft weight. The vertical velocity at impact is varied by releasing the linkage from different heights and the horizontal velocity is the sum of the carriage speed and a smaller component resulting from the swinging motion of the model. Horizontal velocity of the carriage is obtained by winding it up a sloping track and releasing it to roll freely under gravity. A maximum speed of about 33 ft./sec. can be obtained in such 'forward runs'. 'Static drops' are made by releasing the swinging system with the carriage at rat. For further information on the tank mechanism and structure reference should be made to earlier reports. (Refs. 15, 16 and 17).

3.2. Instrumentation and Calibration.

3.2.1. Recording Equipment.

Electronic recording equipment was used similar to that already employed for model hull impact tests. (Ref. 14) The following were mounted on the carriage :- a 16-channel, Model "F", Miller oscillograph, a 15-channel carrier amplifier, Type C-2, with its associated power unit and carrier oscillator, Model C.P.15, and their 12-volt accumulators. Basically similar equipment is fully described by Bennett, Richards and Voss (Ref.17). The installation is shown in Figure 4 and a typical record in Fig.5.

3.2.2. Pressure Piclc-ups.

The construction of these instruments is sham in Figure 6. Strain gauges are used to measure the bending strains in a duralumin cantilever caused by the movement of a one inch diameter German silver diaphragm of approximately 0,003" thickness.

The unclamped natural frequency of vibration of the diaphragm and cantilever system was found to be approximately 4.00 c.p.s. The damping coefficient varied from 0.05 to 0.15 of critical, being dependent on the netted area of the diaphragm.

The response of the pick-up to pressure waves of relatively high frequency was such that the output was too great by 5% for an impressed frequency of 100 c.p.s. falling to an increase of 2% at 80 c.p.s. Above 100 c.p.s. the overshoot became greater, but the error was partially compensated by the reduction of amplifier gain with increase of frequency due to the attenuation of the low pass filter and the falling response of the galvanometers,

The effects of phase distortion and relative displacement along the time axis of initial peak pressures were neglected. For example, assuming a pressure variation of 100 c.p.s., the relative displacement in time is 0.2 milliseconds.

The pressure pick-ups were calibrated individually with an oil-filled dead-weight tester before and after each series of tests. The pressure/deflection curves were fairly linear and the short-term stability, i.e. day to day, was good.

3.2.3. Accelerometer Pick-ups.

The two accelerometer pick-ups were of Miller (Ref.17)

/variable

variable inductance type, range ± 12g. The accelerometers were mounted on a stout clamp fitted to the hull cross-shaft and before and after each test series the accelerometers were calibrated on a tilting table. With the oil damping adjusted to the optimum value of' 0.65 critical, the pick-up gives a linear response within ± 5% over the frequency range 0-1.00 c.p.s. However, it was not always possible to maintain this desirable damping characteristic as microscopic oil leaks in the instruments led to a gradual reduction in damping.

3.2.4. Draught and Attitude Pick-ups.

The draught and attitude pick-ups were a development of the earlier devices whereby the rotation of the beam or hull was converted to a small linear movement by means of a constant lift cam (Ref. 16). This linear movement was used to deflect a beryllium copper cantilever, the bending strains in which were measured by strain gauges. The attitude trace was calibrated against the hull angle measured by inclinometer. The draught trace was calibrated by allowing the model to rest on a ramp, previously calibrated by an optical method to give true vertical height above the water surface.

3.2.5. Horizontal Velocity.

A measure of the horizontal distance travelled was obtained by causing a micro-switch to be operated once per revolution of a carriage wheel, the switch being in a galvanometer circuit giving a pulse on the record for each revolution. Since these 'costs were completed it has been found that there is possible wheel slip after the carriage leaves the sloping track. Accordingly, quoted horizontal velocities may be in error by the order of ± 2%.

3.2.6. Timing.

The Miller recorder is fitted with a 60 c.p.s. oscillator controlled by a tuning Pork. The amplified output from the oscillator drives a synchronous motor which turns an occulting disc at 300 r.p.m. The disc has 20 slots, the tenth and twentieth being wider than the remainder. The record is thus marked with transverse lines at 1/100 sec. intervals with heavier lines every 1/10 sec. (Figure 5) The accuracy of the timing system was estimated to be better then 0.1%.

3.3. Test Procedure.

Prior to each test the amplifier channels were set to values corresponding to the height and attitude settings as found from the calibrations, while the carriage was on the horizontal track before being towed up the ramp. As the carriage experiences a normal acceleration of between 2g and 3g when it runs from the ramp to the level portion of the track, it was decided to rely rather on the proved linearity of the amplifiers than on the absence of zero drift between the time of release at the top of the ramp and the time of impact.

The recorder was operated by a switch closed by the fall of the swinging linkage to give sufficient recording paper for the latter stage of the drop and the complete impact (approximately 2-3 seconds).

The calibrations referred to separately in paragraph 3.2 were made before and after each series of tests and were separated in time by not more than two days.

3.4 Range of Investigation.

The scope of the four series of tests which were made is /indicated

indicated in Table I.

Accelerometer records obtained in the preliminary tests were unsatisfactory because of severe oscillations imposed on the model by vibration of the carriage on its rubber wheels. For the remainder of the earlier tests of 1948-49 pressures only were measured. Since the recorder could not accommodate all the available pick-ups at once, the pressure distribution was explored in different nays during the tests as results became available. In the later tests of Series 3 and 4 when steel wheels had been fitted to reduce the unwanted carriage vibrations, accelerometers were again fitted and, although the records require further improvement, some analysis has been possible. Details of the vibrations in the accelerometer records are given elsewhere, in paragraph 4.3.

4. ANALYSIS.

4.1. Draught

The calibrated draught measurement gives the vertical displacement of the main pitch axis of the model, which is slightly above the model's C. of G. when at zero attitude. The draught quoted in the results is the change of pitch axis height above still water level, zero draught corresponding to the initial contact of the fuselage with the water surface. It should be noted that this definition of draught is not identical with the depth of immersion of the lowest point of the fuselage,. because the latter includes the effect of pitch change during the impact, which can be appreciable at the higher attitudes and lowest speeds tested.

This definition corresponds very closely to the change of vertical height of the C. of G. and, since angular rotations are all small in forward runs because of the high damping in pitch, this definition is thought to be adequate for the type of landings represented. A definition of draught differing from that used for seaplanes with steps is necessary for the landplane fuselage, although the present one may not be the best for theoretical analysis.

4.1.1. Calculation of the Time of First Impact.

The point on the fuselage centre line making the first contact with the water surface depends on the touchdown attitude τ_o. From this measured angle and the fuselage geometry the first contact point is calculated. The time of water impact on the pick-up diaphragm next ahead of this point is found from the record and an allowance made for the time required for draught to increase (at τ_o) to the value for this diaphragm, the model falling at a known rate of descent, i.e. V_{Vo}.

4.2. Velocities.

The relationship between the velocity components used in the results is illustrated in Figure 7. To the horizontal carriage velocity derived from the time interval between wheel contacts is added the component of velocity due to the swing of the model. The vertical velocity of the pitch axis is derived by differentiating the draught - time curve and the horizontal component of swing from the vertical velocity and the calibrated angle to the horizontal of the swinging links. The velocity components quoted refer to the model's C. of G.

4.3. Accelerations.

Results have been obtained from the accelerometers mounted

/on

on the pitch axis parallel and normal to the fuselage datum, i.e. A_T, A_N. Typical records for a static drop and a forward run are shown in Figures 8 and 9. The relatively severe oscillation in the record imposed by the structural vibrations of the carriage and model linkage have been analysed into three main components, enabling a more accurate value of the accelerations resulting from the hydrodynamic forces to be obtained. The smoothed values only of the accelerations are plotted in Figure 10. They are probably accurate to ± 5% at maximum value but the acceleration build-up immediately after impact is quite unreliable because of the very severe structural oscillation which is set up concurrently.

4.4. Equivalent Mass of the Linkage System.

The normal acceleration gives a measure of the total water reaction provided the correct inertia of the swinging system is known. It is convenient to express the total inertia as an equivalent mass at the hull, which includes the main swinging beam, the parallel motion linkage and the balance weight, and is in fact about seven times the fuselage weight alone. Two estimates have been obtained for the equivalent mass, firstly, one calculated from the design drawings and assuming normal specific weights for material as given in the specification and, secondly, from an experiment made on the apparatus itself. The mean experimental result was found to be 470 lb. and the calculated value was 550 lb.

4.5. Splash-up.

The calculation of splash-up factors from the pressure records is described fully in Appendix I.

5. RESULTS.

5.1. Time His tories.

A Summary of essential data is given for all series of tests in Table III. This includes initial velocity and angles of descent and attitude and maximum draught, etc. Some typical time histories of velocity, acceleration, draught, attitude and pressures from the fourth series of tests are in Figures 11 - 21. Figures 22 - 26 give time histories for tie first series but no accelerations were measured here,

5.2. Pressures.

An alternative presentation of the pressure distribution for runs in Figures 22 - 26 is shown in Figures 22A - 26A.+ Here separate pressure diagrams are drawn or the profile of the model for definite instants during the impact, thereby showing the relative extent of mean and peak pressures, and the rate of travel of the latter. Because of the increase of deadrise away from the centro line, these values are very local, as is shown by the contour plan of pressures given in Figures 27 and 28. This form of presentation, although useful, has not been used for all results because of the limited number of diaphragms, necessitating hazardous extrapolation which does not justify the excessive labour required to draw them up. It has been necessary to assume a splash-up factor in drawing in the edge of the wetted areas and this is unlikely to be accurate in tho aft portions where the spray sheets are clinging to the doubly curved sides. Inaccurate as it is, the figure clearly shows the small area of peak pressure and the general order of pressures in the more important force carrying regions.

/5.3. Spray.

+ See note at end of text.

5.3. Spray Formation.

The external photographs, Figures 29 and 30, taken from ahead and behind during forward runs, show the extent to which (i) the spray from the mid-section strikes the undersurface of' the wing root, contributing no doubt to the upward forces, (ii) the displaced water clings to the curved sides of the rear section and some of the water fails to detach from the undersurface near the centre line.

5.4. Splash-up

The values of side splash factors, $\frac{C}{C_o}$, are given in Table IV.

6. GENERAL REMARKS

The results obtained are presented with no formal discussion or conclusions as there is no relevant theory available sith which to make comparisons.

Of the assumptions referred to in Section 2.2, numbers (i) tc (v) are conformed to closely in the experimental set-up, but examination of the pressure results presented shows that assumption (vi) is not justifiable as both considerable pressures and suctions occuraft of the parallel portion of the fuselage. This Will make the development of a complete theory rather complex, while a theory based on a pure cylinder would be a considerable advance but could only be applied to a very limited part of the results without empirical corrections.

Note :- The pressures in figures 22A, 23A, 24A, 25A, 26A and 31 are plotted in such a manner that the normal to the centreline at any point intersects the pressure plot at a distance proportional to the pressure at that point, on the scale indicated in each diagram.

/List of Symbols

LET OF SYMBOLS

		Units
τ	Fuselage datum angle to horizontal	degs.
a	Draught	ft.
t	Time	sec.
V	Linear velocity	ft./sec.
A	Linear acceleration	ft./sec.^{2}
X, Y, Z	Fuselage surface co-ordinates referred to a datum at the bottom end of the cylindrical centre body. (see Figure 1).	ft.
M	Equivalent mass of moving linkage system	slugs
μ	Associated mass factor	
C	Wetted width at any section of fuselage	ft.
C_o	Width of fuselage intersected by the undisturbed water surface	ft.
θ	Angle of non-vertical swinging link members to horizontal	degs.
γ	Angle of descent of fuselage on still water	degs,
P	Maximum pressure	lb./sq.in.
p	Mean pressure	lb./sq.in.
4	Local deadrise angle	degs.

SUBSCRIPTS

N	Normal to fuselage datum
T	Tangential or parallel to fuselage datum
H	Horizontal
V	Vertical
0	At initial contact of fuselage with mater surface
D	Refers to position of pressure pick-up.

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/APPENDIX I

APPENDIX I

CALCULATION OF SPLASH-UP

The following quantities (shown diagrammatically in Figure 32) are needed to calculate the splash-up factor $\frac{C}{C_0}$:-

(i)	Z_D	- measured perpendicular to the base line.
(ii)	X_D	- measured parallel to the base line with E as origin and positive in a forward direction.
(iii)	τ	- base line datum angle to horizontal, which is known and fixed for each run.
(iv)	B	- initial point of contact of hull with undisturbed water surface. This is calculated from the geometry of the hull and (iii).
(v)	N	- the value of X_D for the pick-up in question, found from Table II.
(vi)	BF = d	- draught, measured from point of contact. The method of obtaining the draught is described in paragraph 3.2.4 of the report.
(vii)	AB and EA	- these are functions of (iii) and the requisite values are obtained from the graph in Figure 32.

From the diagram in Figure 32 it can be seen that:-

$$Z_D = \tan\tau \left\{ \left(AB + d \sec\tau \right) \cot\tau - EA - N \right\}$$

$$= AB + d \sec\tau - \tan\tau \quad (EA + N)$$

The fuselage width intersected by the undisturbed water surface (C_0) is a function of Z_D and is obtained from the graph in Figure 32A. The splash is calculated by considering the instant at which any pick-up is at the wetted edge, the width (C) for the pick-up under consideration being found from Table II.

/Table I

TABLE I

SCOPE OF TESTS

Test Series	Date	Approx. V_H (ft./sec.)	Pressure Pick-up Positions	Range of τ_0	Range of γ_0	Remarks
1	Dec. 1948	33-34 Static drops made.	1, 3, 6, 9, 10, 12 14, 7, 8, 11	$2.5^\circ - 4.7^\circ$	$1.7^\circ - 5.9^\circ$	4 rubber wheels. Accelerometer results unsatisfactory.
2	March 1949	33-35	1, 15, 3, 4, 6, 9, 10 16, 14, 13, 7 18	$2.5^\circ - 10^\circ$	$1.8^\circ - 6.1^\circ$	Rubber wheels. NC accelerometers fitted. Extra pressure pick-up 18 fitted. Splash-up investigated.
3	Jan. 1950	Static drops only.	No pick-ups			Test runs using two accelerometers only. Two steel wheels fitted to the carriage.
4	Feb. 1950	24-32 & static drops.	1, 15, 3, 4, 6, 9, 1 16, 14, 13, 7	$-0.5^\circ - 11^\circ$	$4^\circ - 11.2^\circ$	Accelerometers fitted. All four carriage wheels of steel. Carriage speed limited by braking considerations. External spray photographs.

/Table II

TABLE II

MODEL DATA

Total length	20 ft. 0 in.
Maximum beam	2 ft. 0 in.
Length of parallel mid section	6 ft. 0 in.
Length of parallel nose section	4 ft. 0 in.
Elliptical cross-sections :-	
Major semi-axis (vertical)	1 ft. 3.60 in.
Minor semi-axis (horizontal)	1 ft. 0 in.
Weight	265 lb.
C. of G. position	Slightly beneath pitch axis
Scale	$\frac{1}{4}$
Equivalent full scale weight, corresponding to a 1/12 scale model tested at R.A.E.	63,000 lb.

PRESSURE PICK-UP DATA

No.	X	Y	Z	ϕ	C_o
1 15 3 4	5.0 3.667 1.833 - 0.333	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
9 10 12	- 4.333 - 6.25 - 8.32	0 0 0	0.24 0.503 0.892	0 0 0	0 0 0
14 17 8 11	1.833 - 0.333 - 2.333 - 6.415	0.336 0.336 0.329 0.314 0.244	0.08 0.08 0.15 0.313 0.578	25° 25° 25° 25° 25°	0.672 0.672 0.658 0.628 0.488
18	- 0.267	0.709	0.385	$51\frac{1}{2}°$	1.418
16 6	3.667 - 2.333	0.336 0	0.08 0.07	25° 0	0.672 0

/TABLE III

TABLE III

SUMMARY OF IMPORTANT RESULTS - ALL TESTS

Series	Av. V_H (f.p.s.)	V_{H_o} (f.p.s.)	τ_o (degs.)	γ_o (degs)	V_{V_o} (f.p.s.)	Maximum Draught (ft.)	at time (secs)	Max. Accn. (g)	Time to Max. Accn. (secs)	Change of τ (degs.)	Remarks
1	32.6	53.2	2.5	1.1	0.6	0.22	0.57		–		Four rubber wheels on carriage. Acceleration results &satisfactory.
	33.0	33.5	2.5	2.4	1.5	0.44	0.53		–		
	33.4	33.7	4.7	2.4	1.4	0.47	0.53		–		
	32.7	33.0	4.7	5.6	3.4	0.76	0.40		–		
	32.5	32.7	4.7	5.9	3.4	0.76	0.52				
2	32.6	33.2	10.0	5.	2.9	1.03	0.61	–			No accelerometers fitted. Splash-up investigated.
	33.1	33.3	5.1	6.	3.6	0.86	0.46	–			
	33.4	33.5	5.3	5.	3.2	0.83	0.50	–			
	33.5	33.9	5.1	4.	2.7	0.75	0.50	–			
	33.5	34.0	10.0	3.	2.0	0.85	0.70	–			
	33.5	34.8	5.3	3.	2.2	0.67	0.53	–			
	33.7	34.0	5.1	3.	2.0	0.63	0.54	–			
	33.7	34.1	2.7	3.	2.2	0.49	0.46	–			
	34.0	34.3	7.4	2.	1.7	0.6	0.63	–		–	
	33.2	33.2	7.4	2.	1.3	0.57	0.65	–			
	33.5	33.8	2.7	3.	2.0	0.58	0.56	–			
	33.9	34.0	5.1	2.	1.6	0.61	0.59	–			
	34.4	34.8	5.1	1.	1.2	0.57	0.73	–			
	34.0	34.0	2.5	2.	1.4	0.50	0.58	–			
	33.4	33.6	2.7	1.	1.1	0.43	0.65	–			
	0		0.3		3.7	0.77	0.46	–			Vertical drop.
	0		5.1		3.3	1.0	0.56	–			Vertical drop.
3			0		2.7	0.57	0.44	.22	0.44	0	Vertical drops, 30 pressure pick-ups, two steel wheels fitted to carriage.
			0		3.4	0.88	0.51	.27	0.42	0	
			0		3.1	0.64	0.46	.24	0.43	0	
			0		2.3	0.45	0.43	.19	0.41	0	
			0		1.9	0.43	0.46	.18	0.39	0	
	–		0		1.4	0.34	0.50	.12	0.43	0	
	–		1.8		1.3	0.24	0.56	.09	0.53	0.1	
	–		1.5		2.2	0.38	0.53	.17	0.41	0.1	
	–		1.2		3.0	0.60	0.49	.26	0.40	0.3	
	–		1.5		3.7	0.69	0.48	.29	0.42	1.2	
	–		1.5		4.0	0.79	0.46	.32	0.32	1.5	
	–		4.6		4.2	0.76	0.53	.31	1.29	2.3	
	–		7.1		4.1	0.66	0.58	.31	0.38	4.1	
	–		9.6		3.4	0.50	0.62	.29	0.41	5.2	
	–		0.1		3.1	0.66	0.62	.34	0.44	0.1	
	–		0.1		4.2	0.84	0.45	.33	0.44	0	
					3.9	1.03	0.51	.31	0.44	0	Draught suspect
4			0.2		3.8	0.75	0.43	.34	0.38	0	Vertical drops. Further drops with τ_o from 0.2° to 11.9° had a very high change of τ. Forward runs.
			0.2		3.2	0.67	0.49	.31	0.36	0	
			0.3		3.3	3.67	0.45	.32	0.36	0	
			0.2		4.1	3.81	0.48	.36	0.44	0	
			0.1		4.5	3.81	0.40	.41	0.12	0	
			0.1		2.9	0.67	0.55	.25	0.35	0	
	28.0	8.0	9.0	5.9	2.9	1.04	0.54	.23	0.53	0.3	
	27.6	8.7	11.0	5.0	2.5	1.11	0.66	.29	0.61	0.9	
	30.3	1.8	4.7	5.2	2.9	0.74	0.41	.22	0.39	0.2	
	30.1	1.2	2.4	5.5	3.0	3.70	0.44	.26	0.40	0.3	
	30.5	1.6	0.3	5.8	3.2	0.65	0.35	.26	0.32	1.4	
	30.6	a.3	4.7	4.8	2.6	3.71	0.47	.19	0.28	0	
	30.7	1.3	6.7	4.1	2.2	0.68	0.53	.27	0.37	0.2	
	31.3	2.4	2.6	4.3	2.4	0.70	0.45	.23	0.15	0.2	
	24.7	5.6	0.1	5.8	2.6	5.56	0.58	.26	0.36	0	
	25.9	7.1	4.4	9.7	4.6	1.03	0.37	.39	0.30	0.4	
	25.2	6.9	0.6	1.2	5.3	0.71	0.32	.42	0.24	1.9	

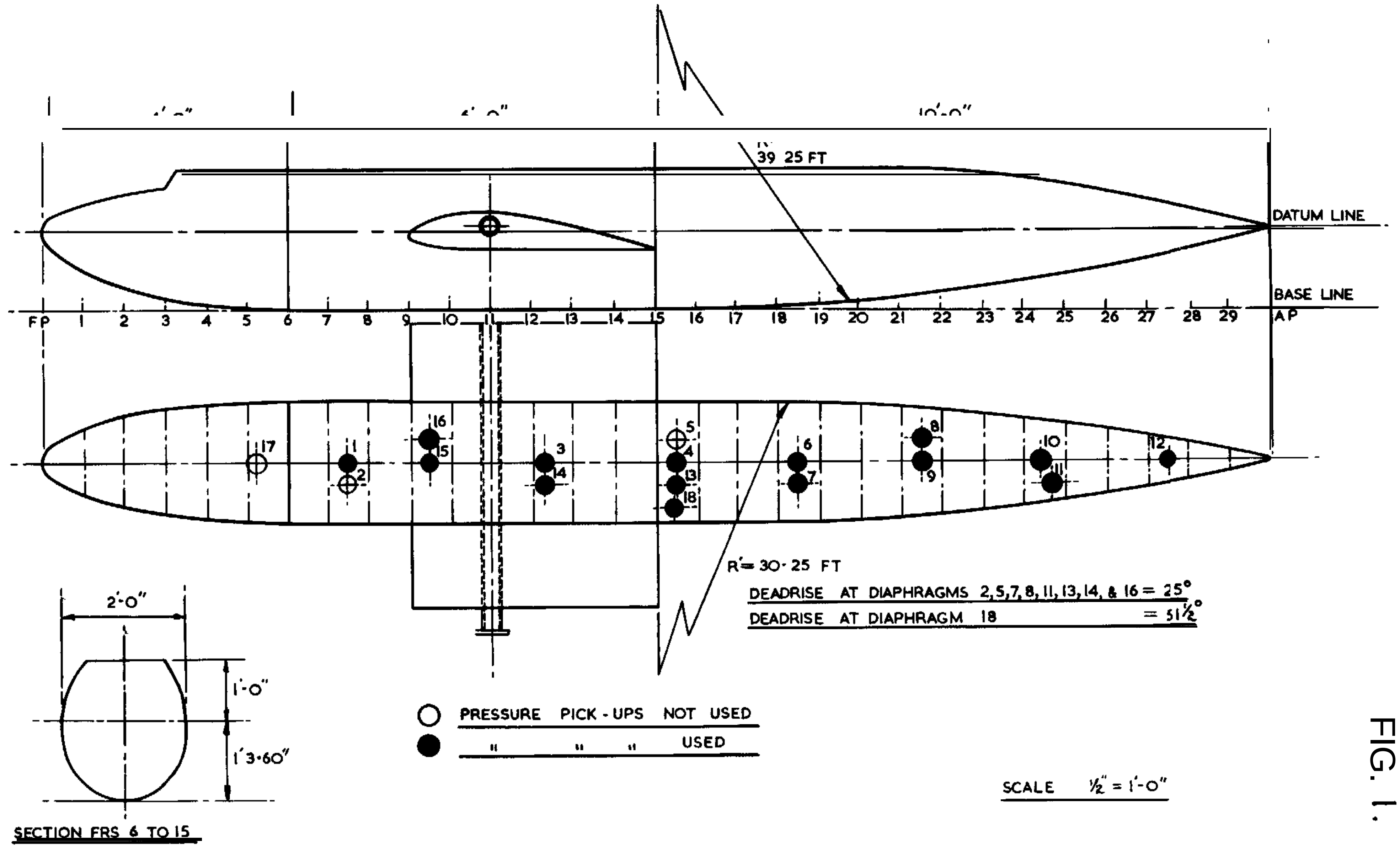
/Table IV

TABLE IV

RESULTS OF SPLASH-UP CALCULATIONS

FORWARD RUNS

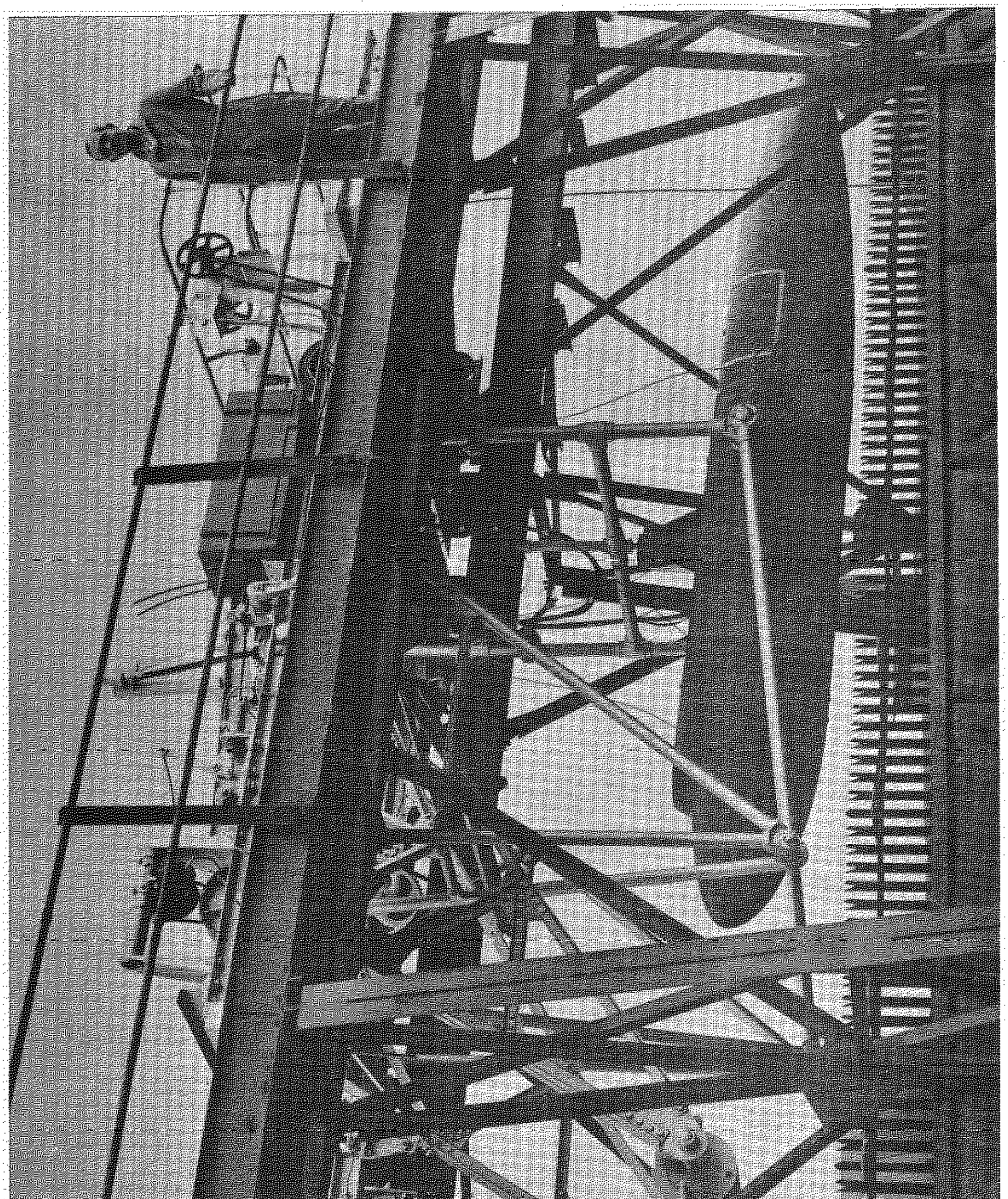
τ_o Deg.	γ_o Deg.	Side-Splash C/C_o Diaphragms 4 & 13 $X_D = -0.33$ ft.	Diaphragms 3 & 14 $X_D = 1.83$ ft.	Diaphragms 15 & 16 $X_D = 3.67$ ft.
	1.10		1.40	
	2.60		1.35	
	2.40		1.40	
	5.90		1.49	
	6.00		1.39	
5.10	6.10	1.39	1.38	1.11
5.10	3.40	1.22	1.24	1.45
2.65	3.68	1.31	1.68	1.73
7.40	2.78	1.68	1.22	
7.40	2.35	1.73	1.13	
2.67	3.40	1.25	1.73	1.51
5.10	2.70	1.31	1.73	1.68
5.10	1.93	1.64	1.08	
2.50	2.35	1.24	1.42	1.05
2.70	1.85		1.68	1.22
Mean Value		1.42	1.42	1.39
Complete Mean			1.41	



GENERAL ARRANGEMENT OF STAFFORD MODEL SHOWING PRESSURE PICK-UPS.

FIG. 1.

FIG. 2



PHOTOGRAPH OF MODEL ON CARRIAGE.

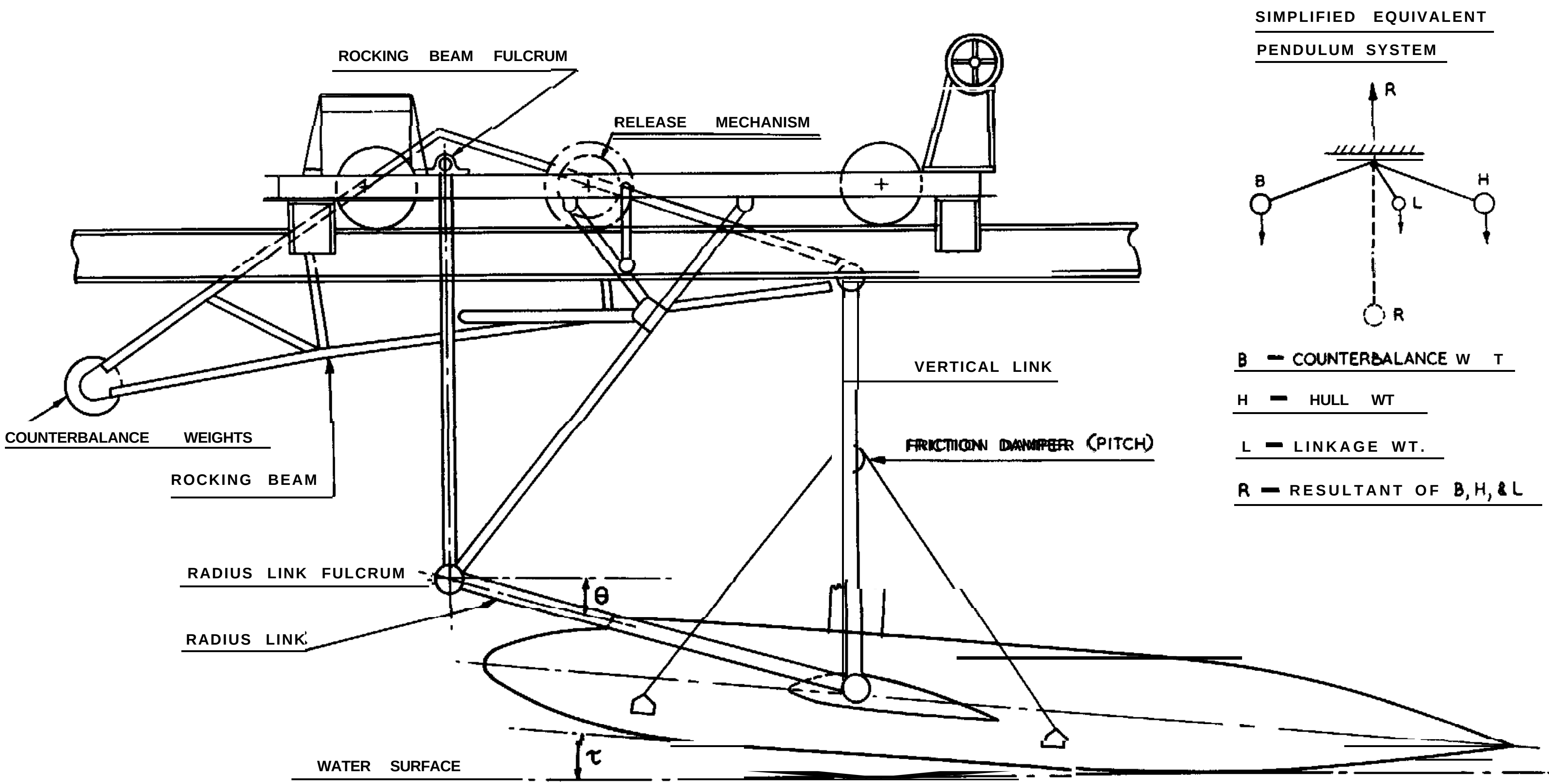
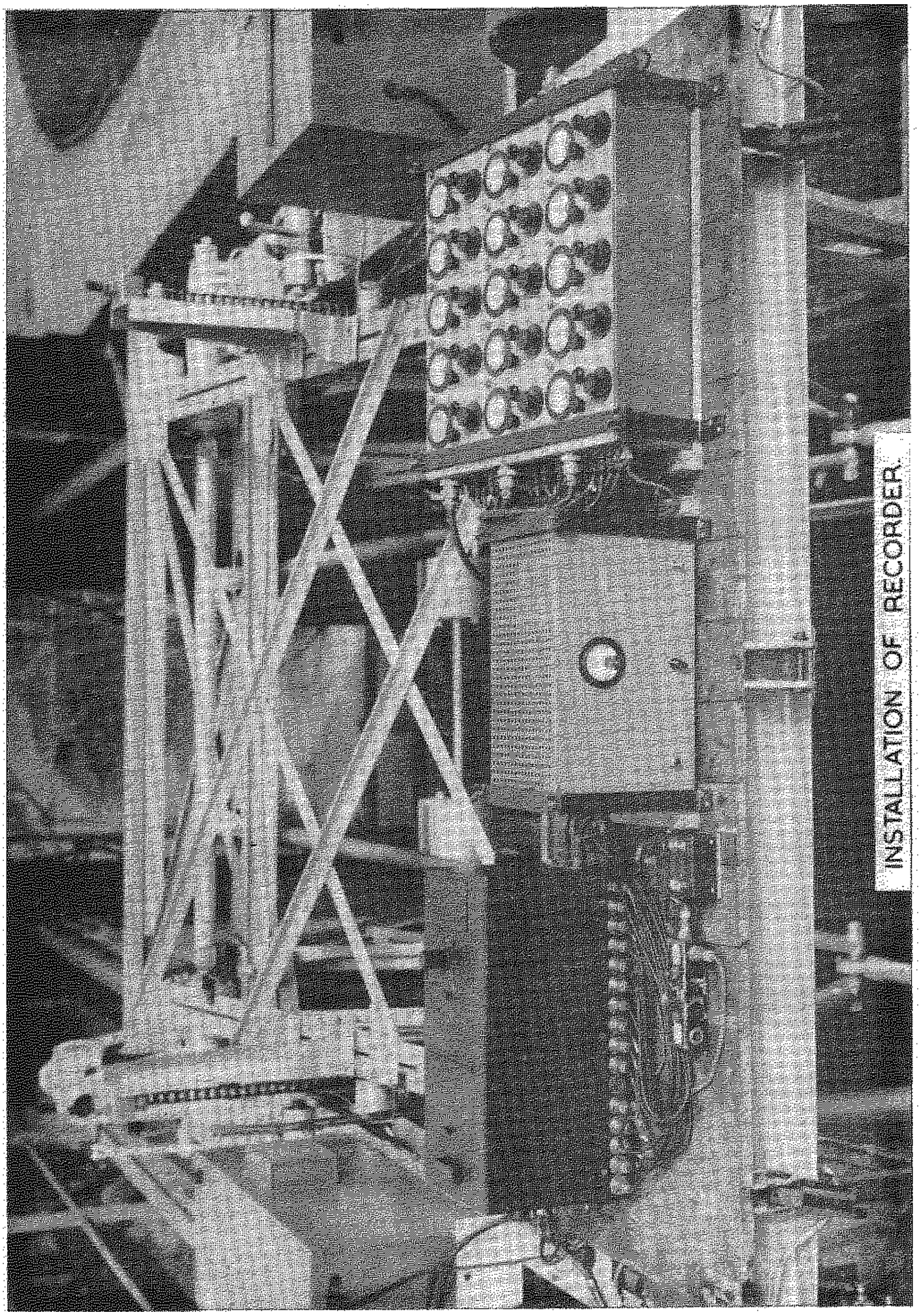


FIG 3

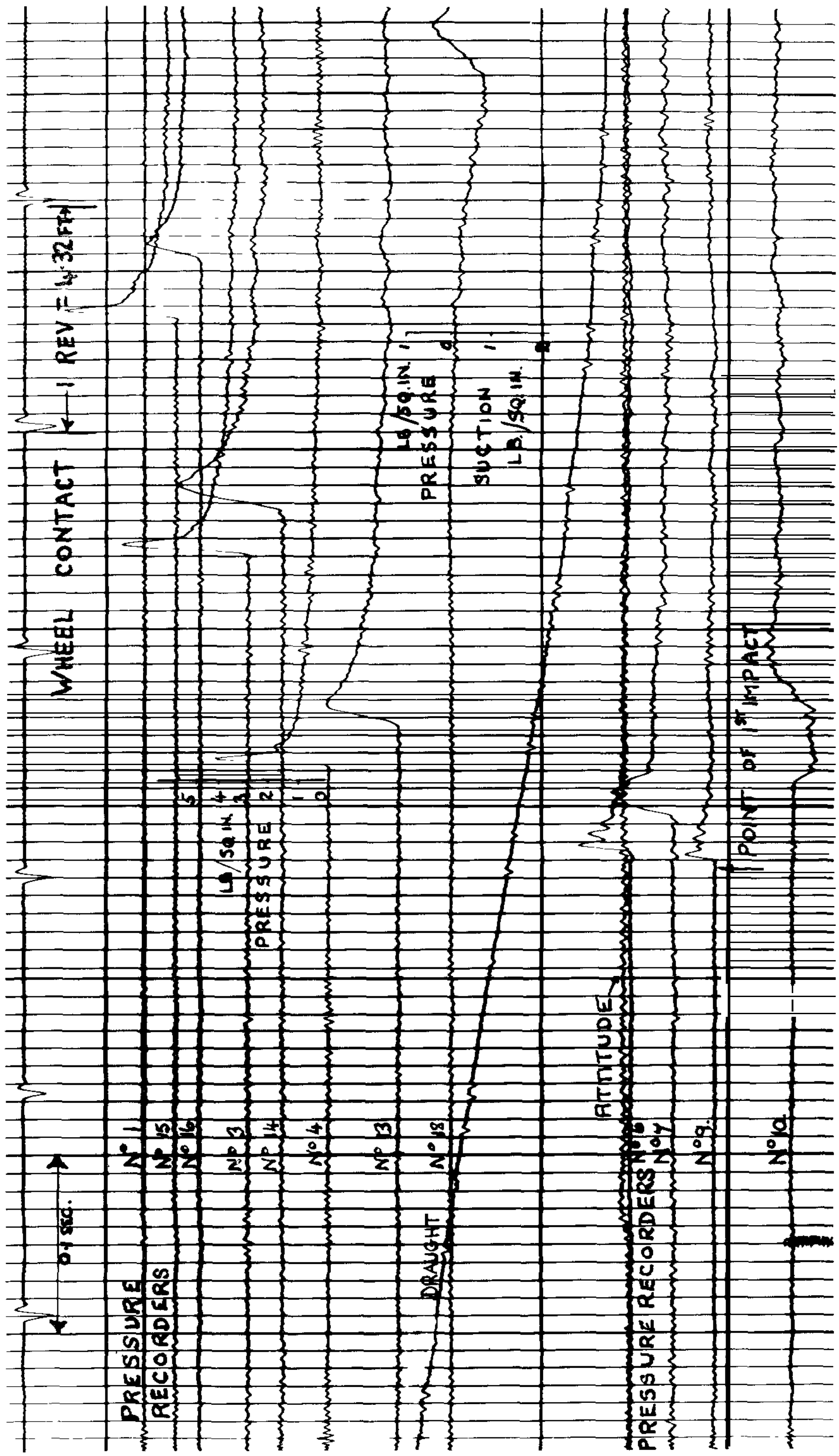
DIAGRAMMATIC SKETCH OF LINKAGE SYSTEM.

FIG. 4.



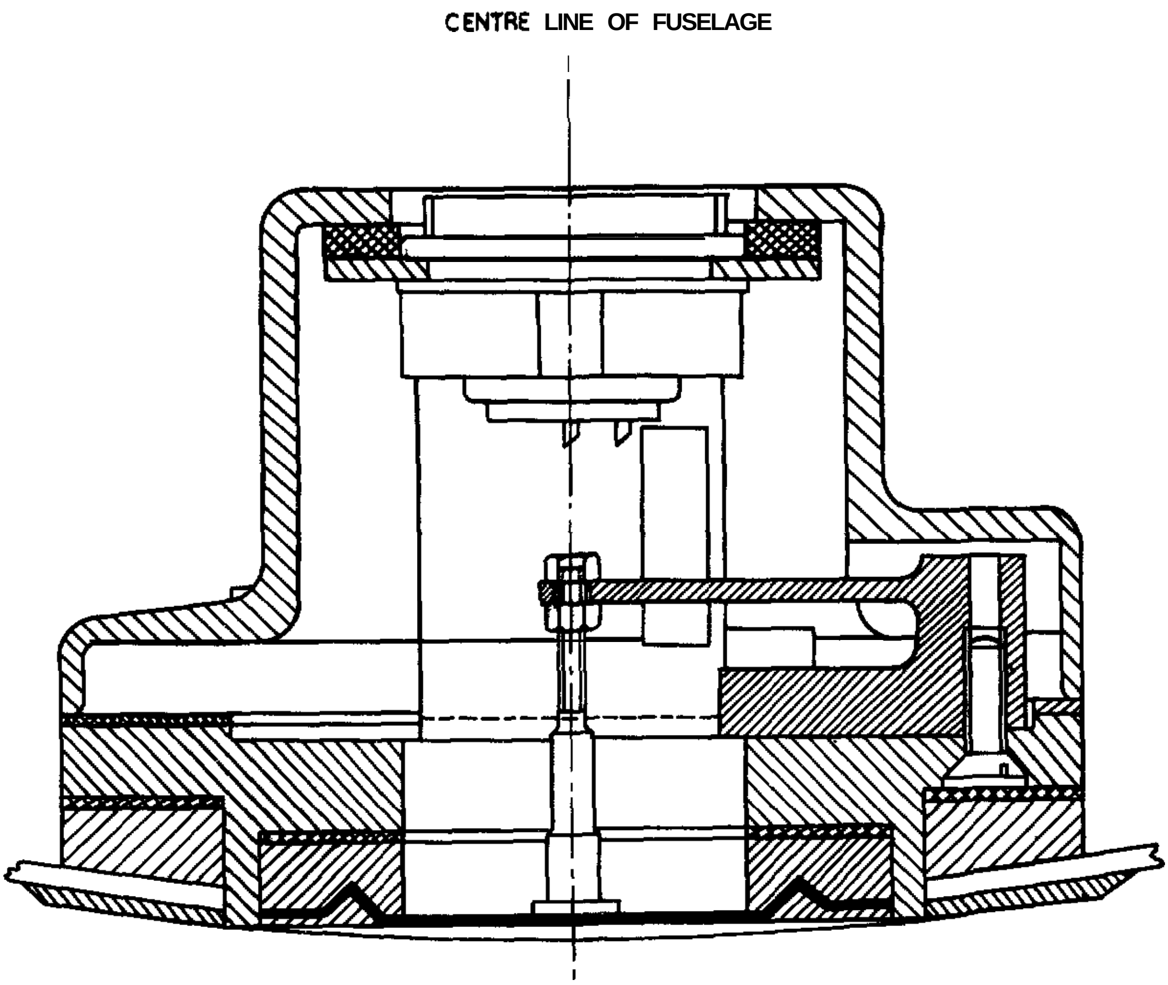
INSTALLATION OF RECORDER.

FIG. 5.

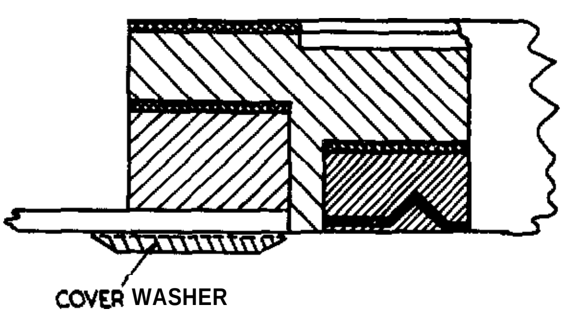


TYPICAL PRESSURE RECORD (INITIAL ANGLE OF DESCENT 3 4°, INITIAL ATTITUDE 5 1°)

FIG. 6.



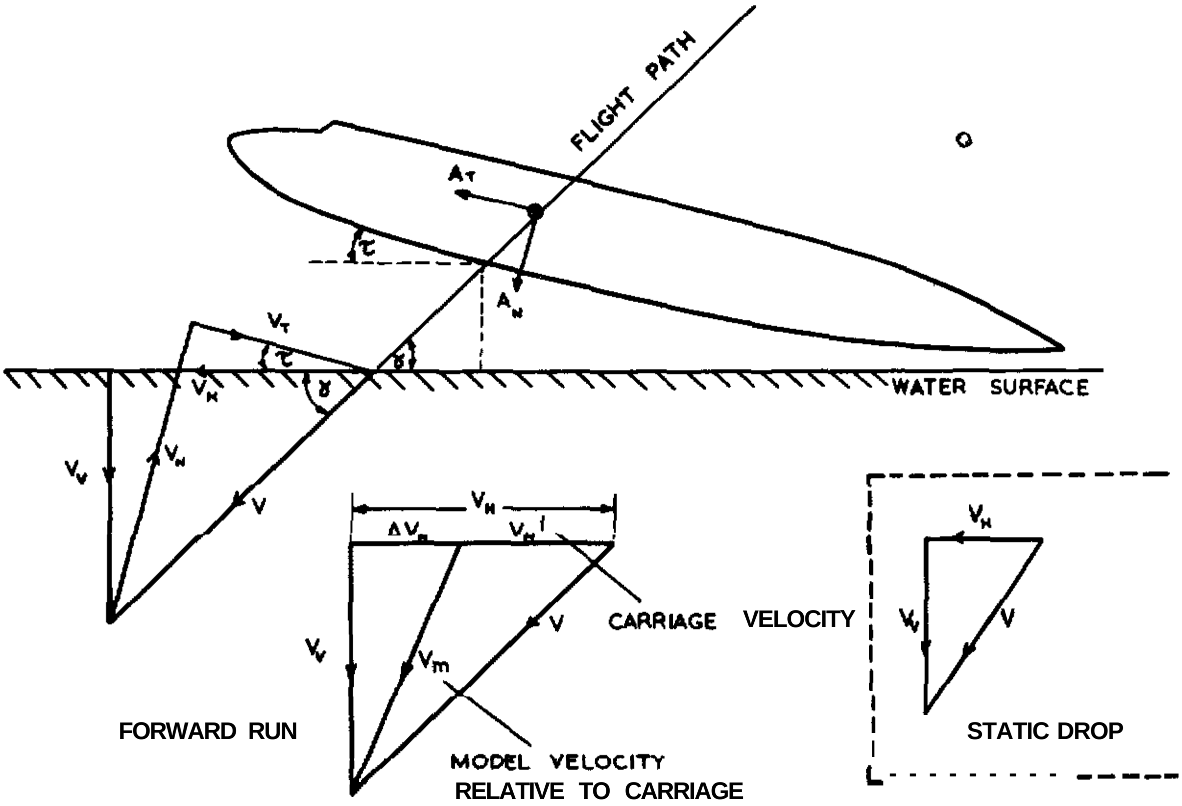
TRANSVERSE SECTION THROUGH FUSELAGE AND PRESSURE PICK-UP



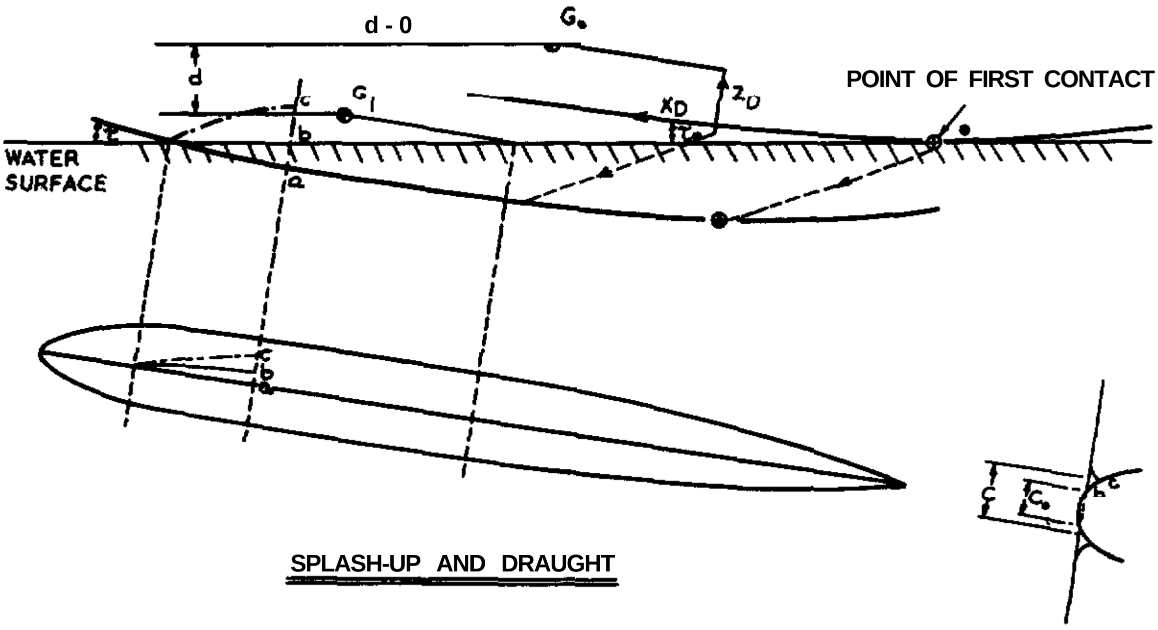
PART LONGITUDINAL SECTION THROUGH FUSELAGE AND PRESSURE PICK -UP

PRESSURE PICK-UP.

FIG. 7.



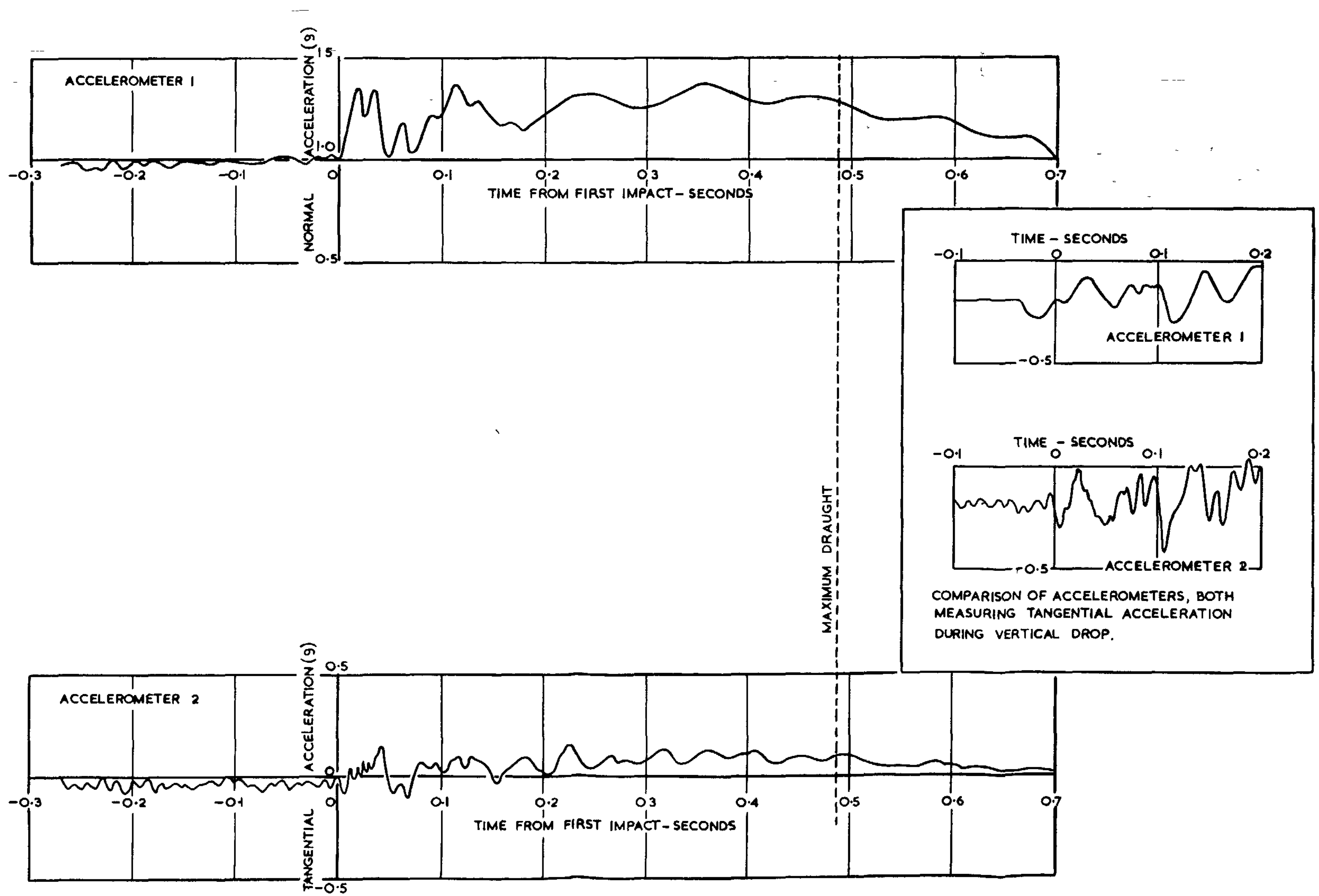
VELOCITY DIAGRAMS



SPLASH-UP AND DRAUGHT

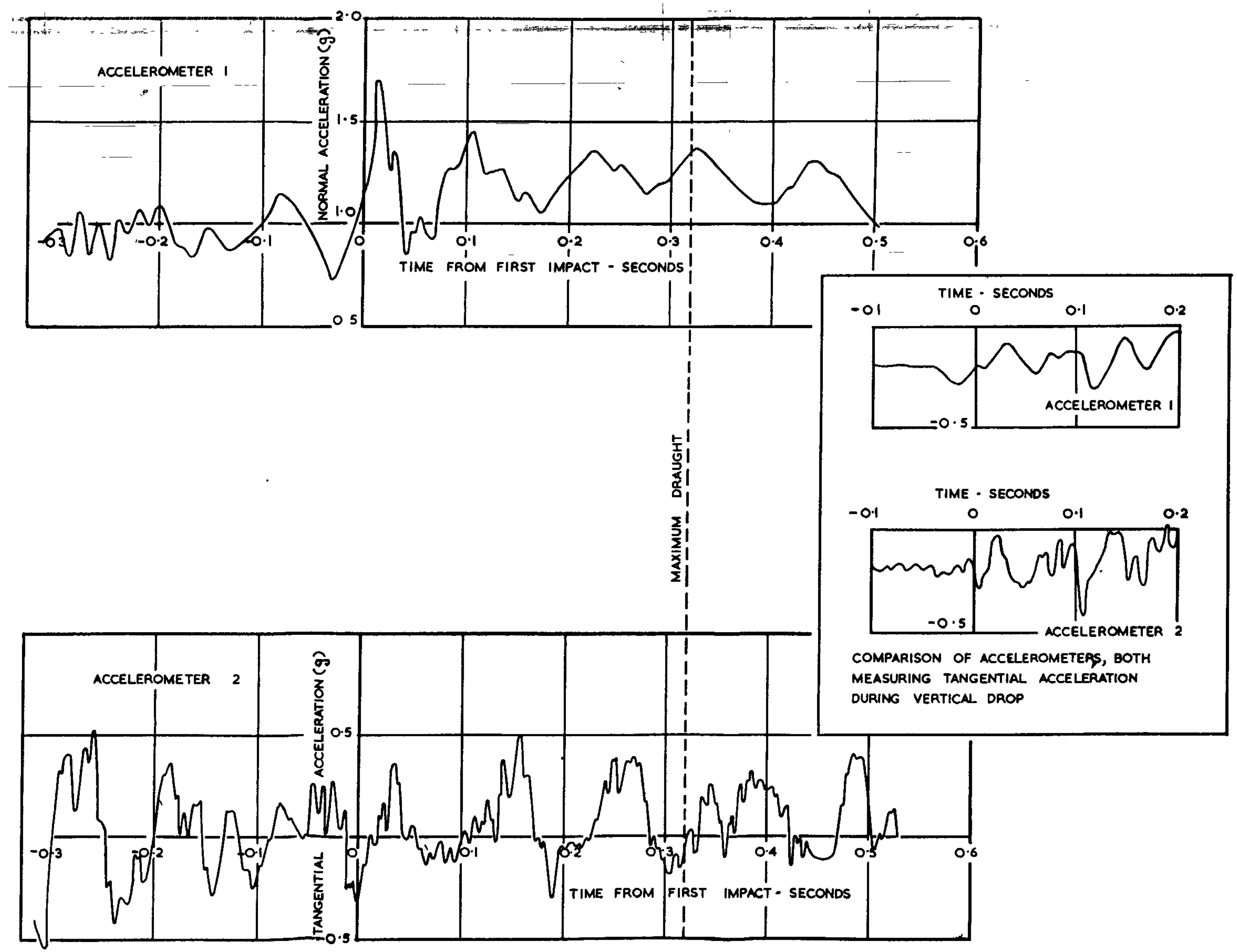
HULL GEOMETRY AND VELOCITY DIAGRAMS.

FIG. 8.

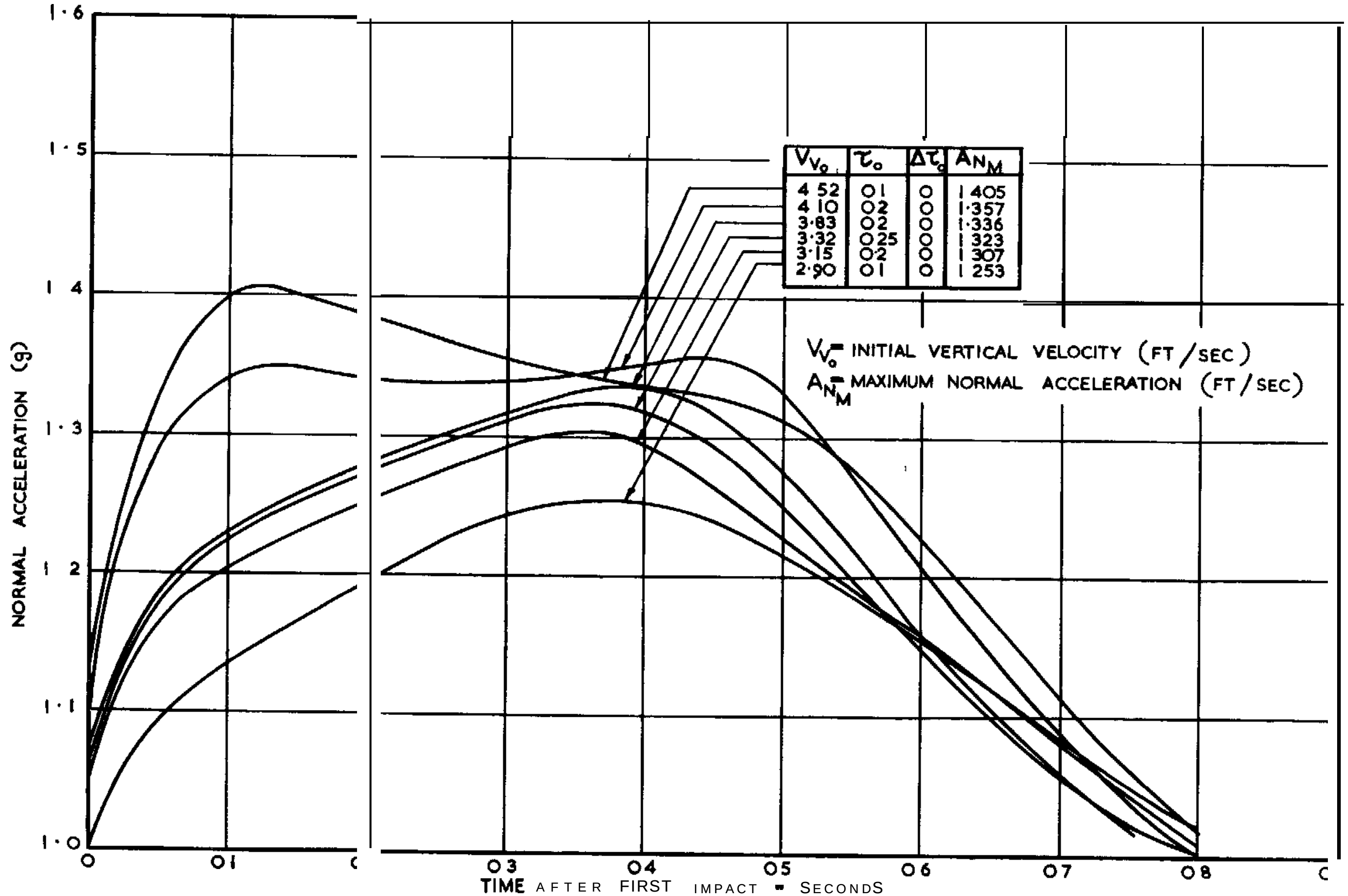


TYPICAL ACCELEROMETER RECORDS — VERTICAL DROP.

FIG. 9.



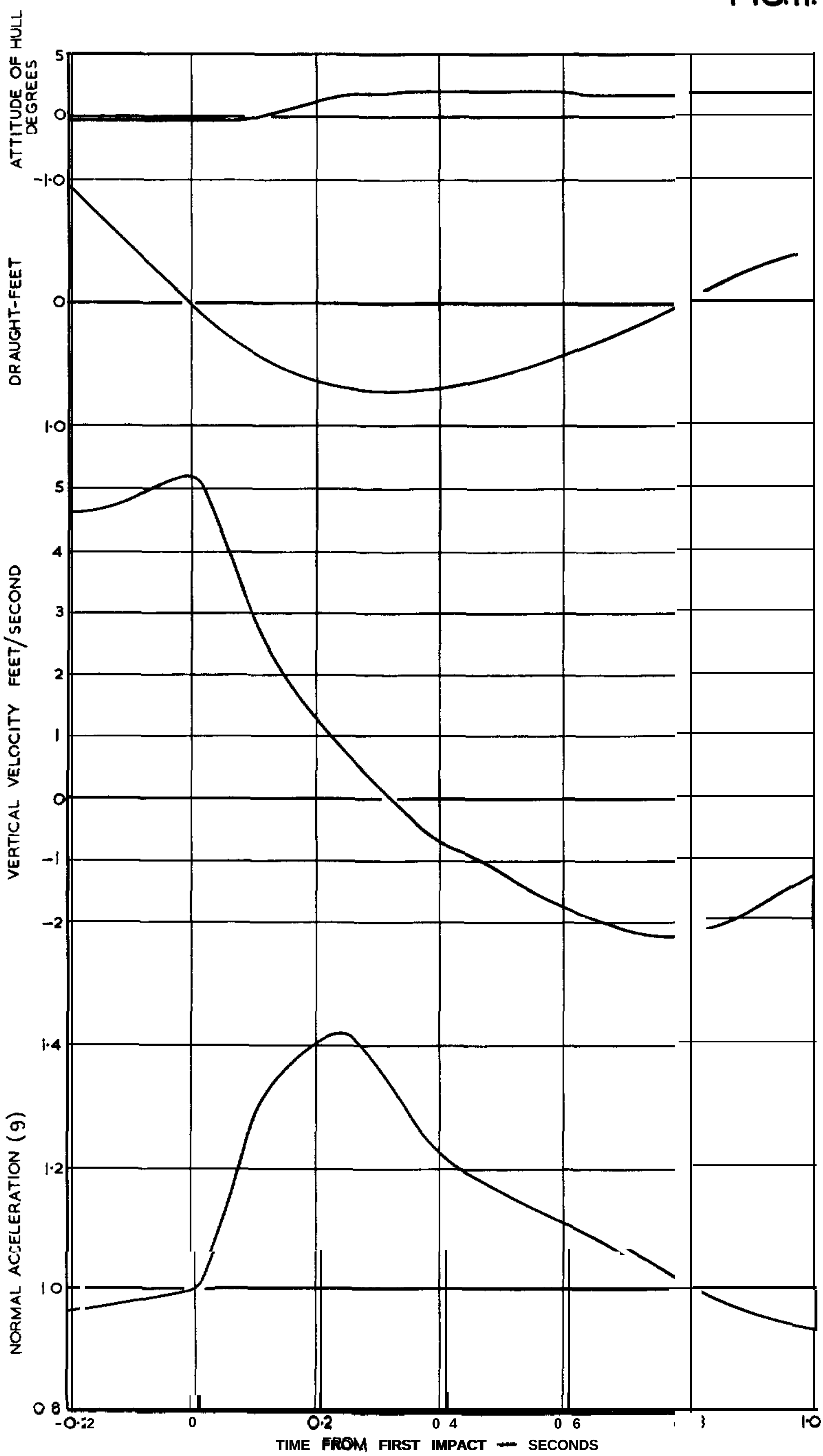
TYPICAL ACCELEROMETER RECORDS - FORWARD RUN.



TYPICAL SMOOTHED ACCELERATIONS, VERTICAL DROPS.

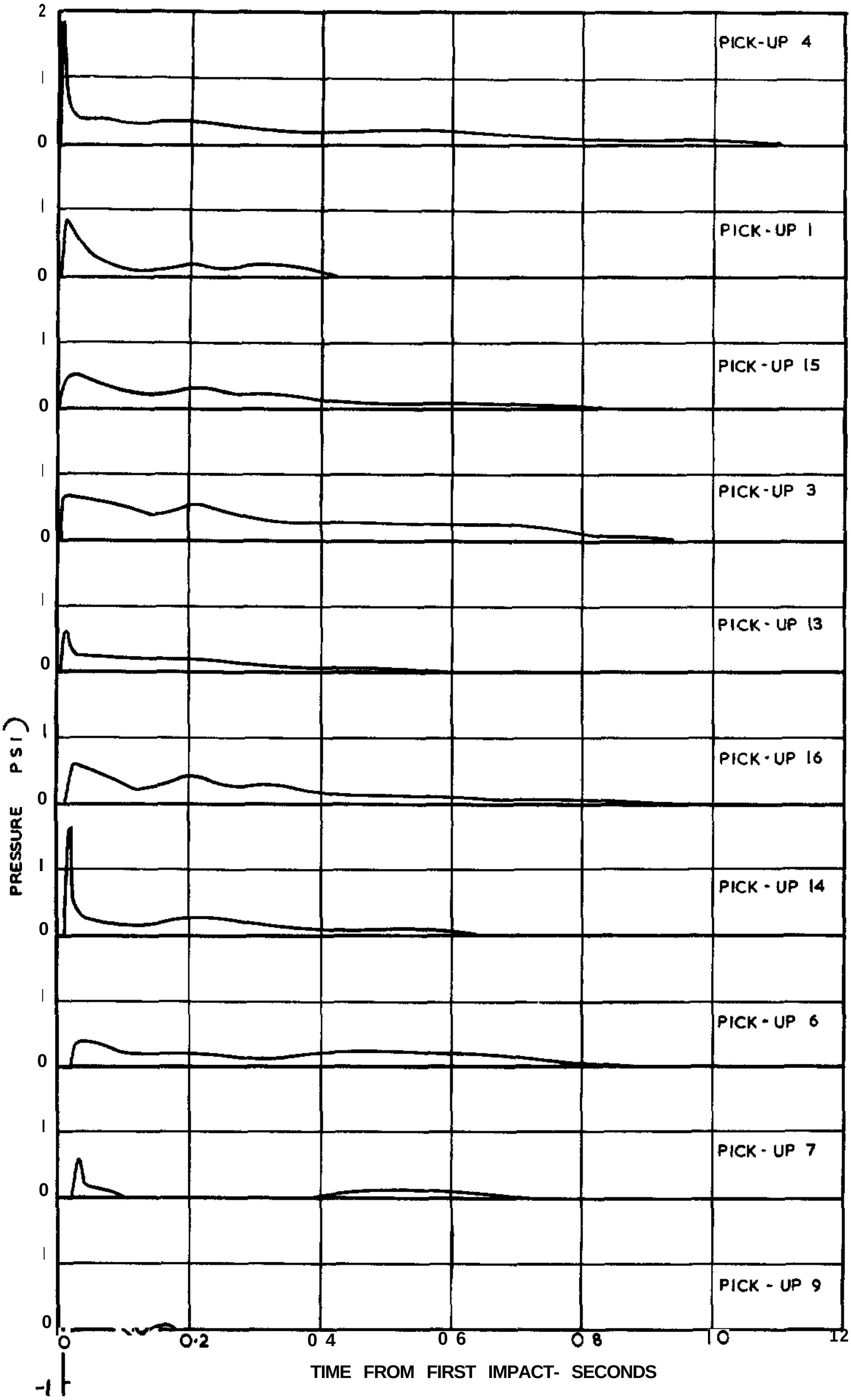
FIG. 10.

FIG.11.



TIME HISTORY OF FORWARD RUN. $\tau_0 = -0{\cdot}3^\circ$, $\gamma_0 = 11{\cdot}2^\circ$, $V_{H_0} = 26{\cdot}9$ FT/SEC.

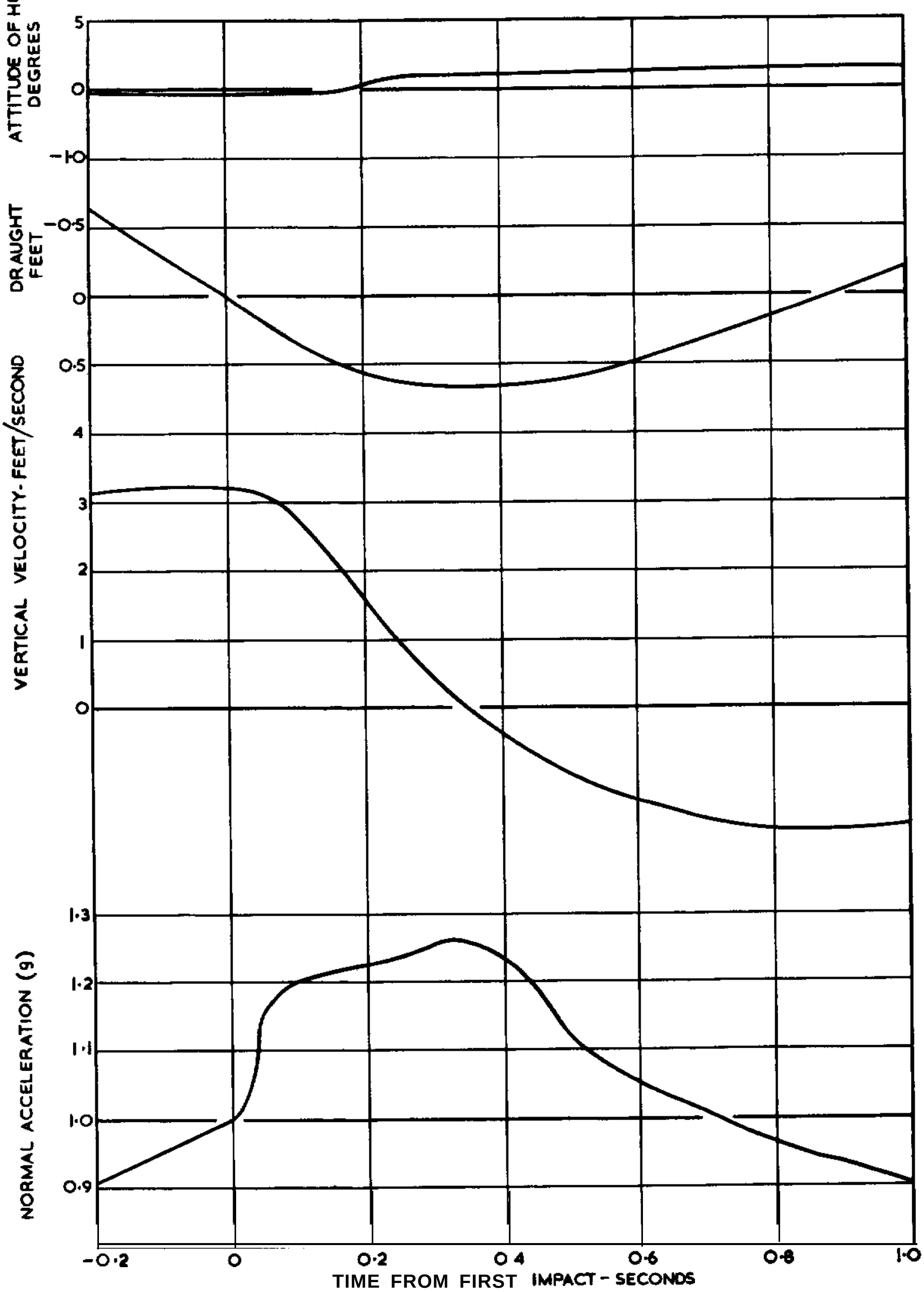
FIG. 11A.



TIME HISTORY OF PRESSURES FOR FIG. 11

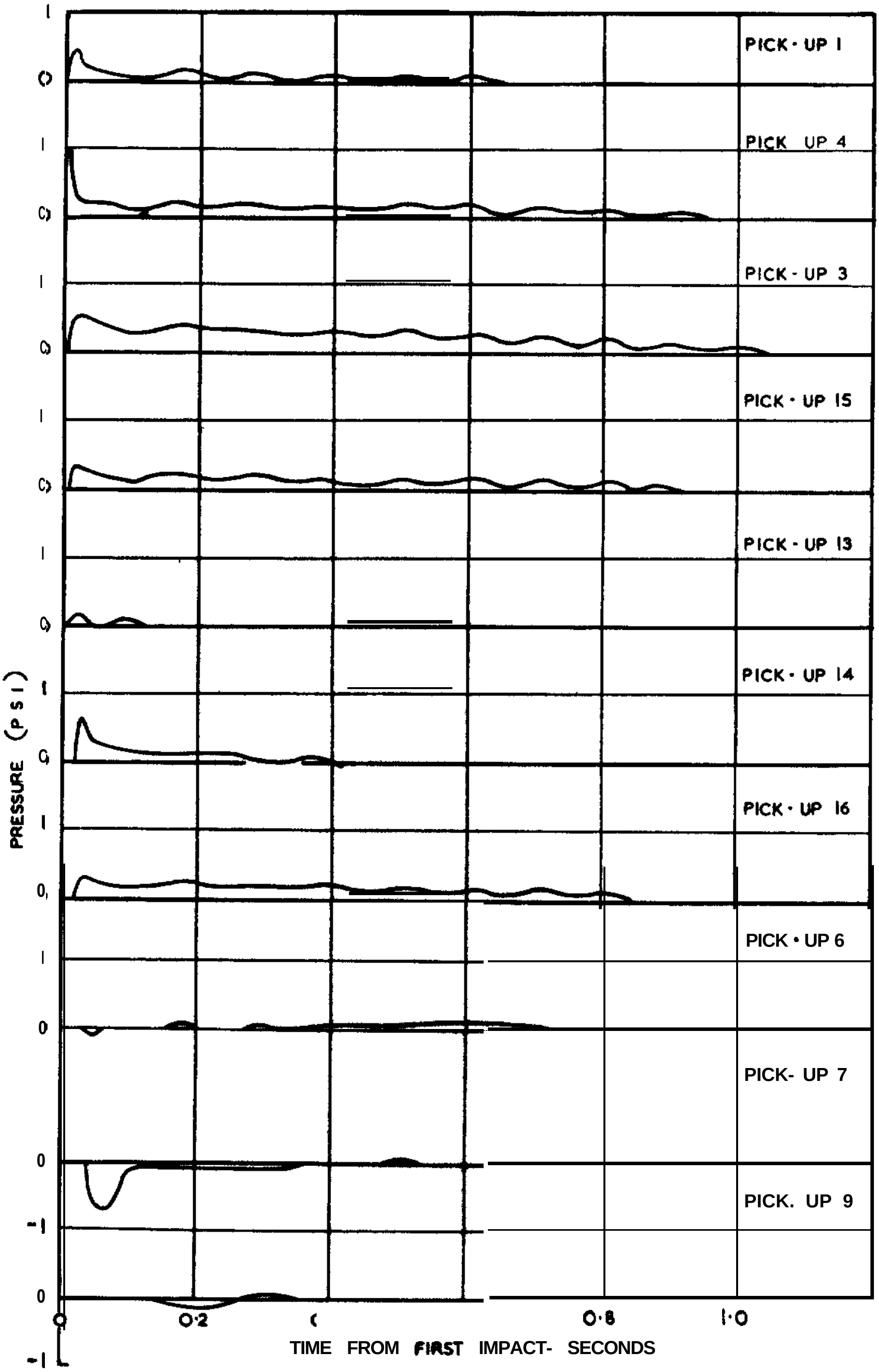
$\tau_o = -0 \cdot 3°$, $\gamma_o = 11 \cdot 2°$, $V_{H_o} = 26 \cdot 9$ FT/SEC

FIG.12.



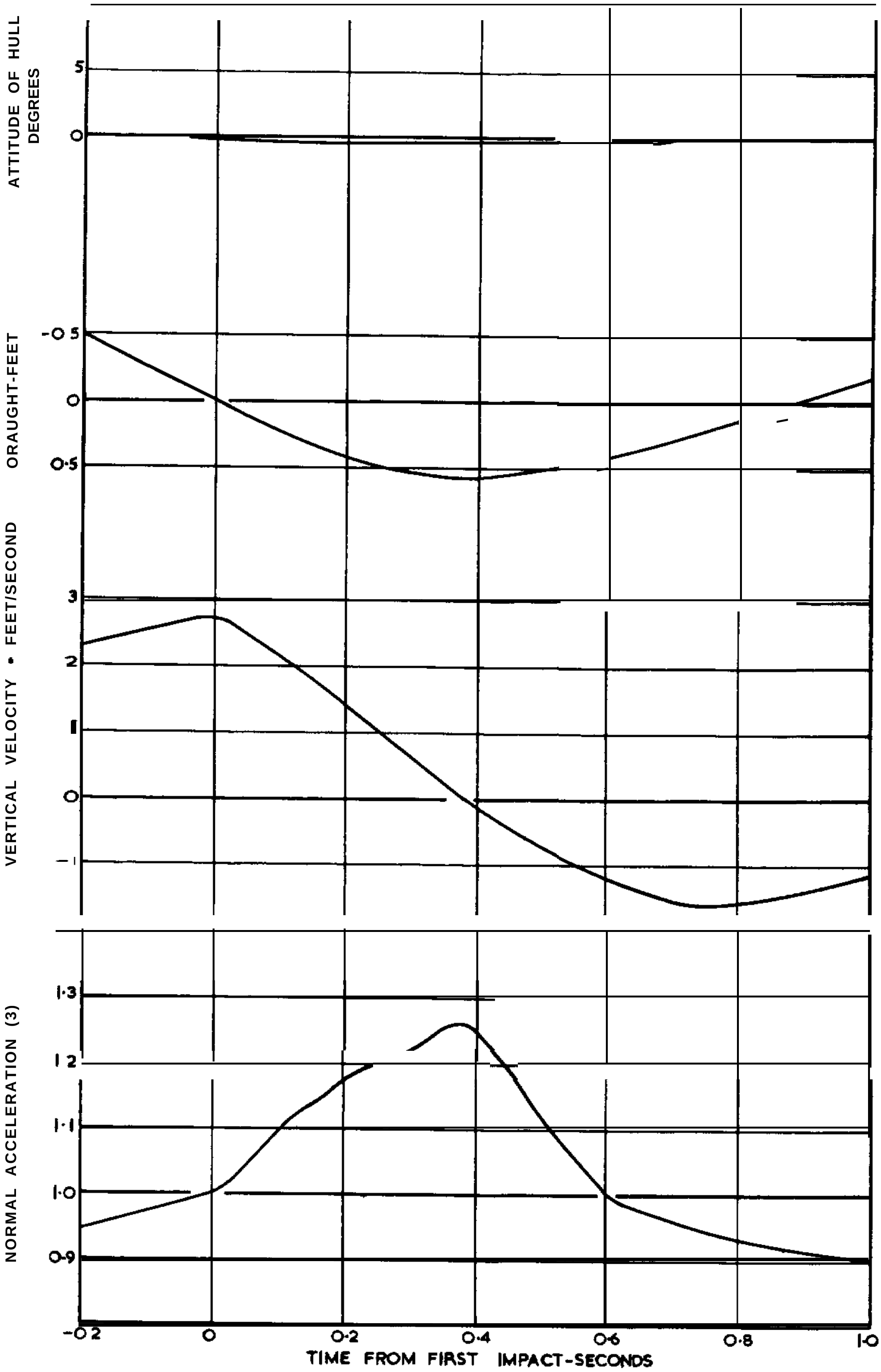
TIME HISTORY OF FORWARD RUN. $\tau_0 = -0{\cdot}3°$, $\gamma_0 = 5{\cdot}8°$, $V_{H_0} = 31{\cdot}6$ FT/SEC.

FIG. 12A.



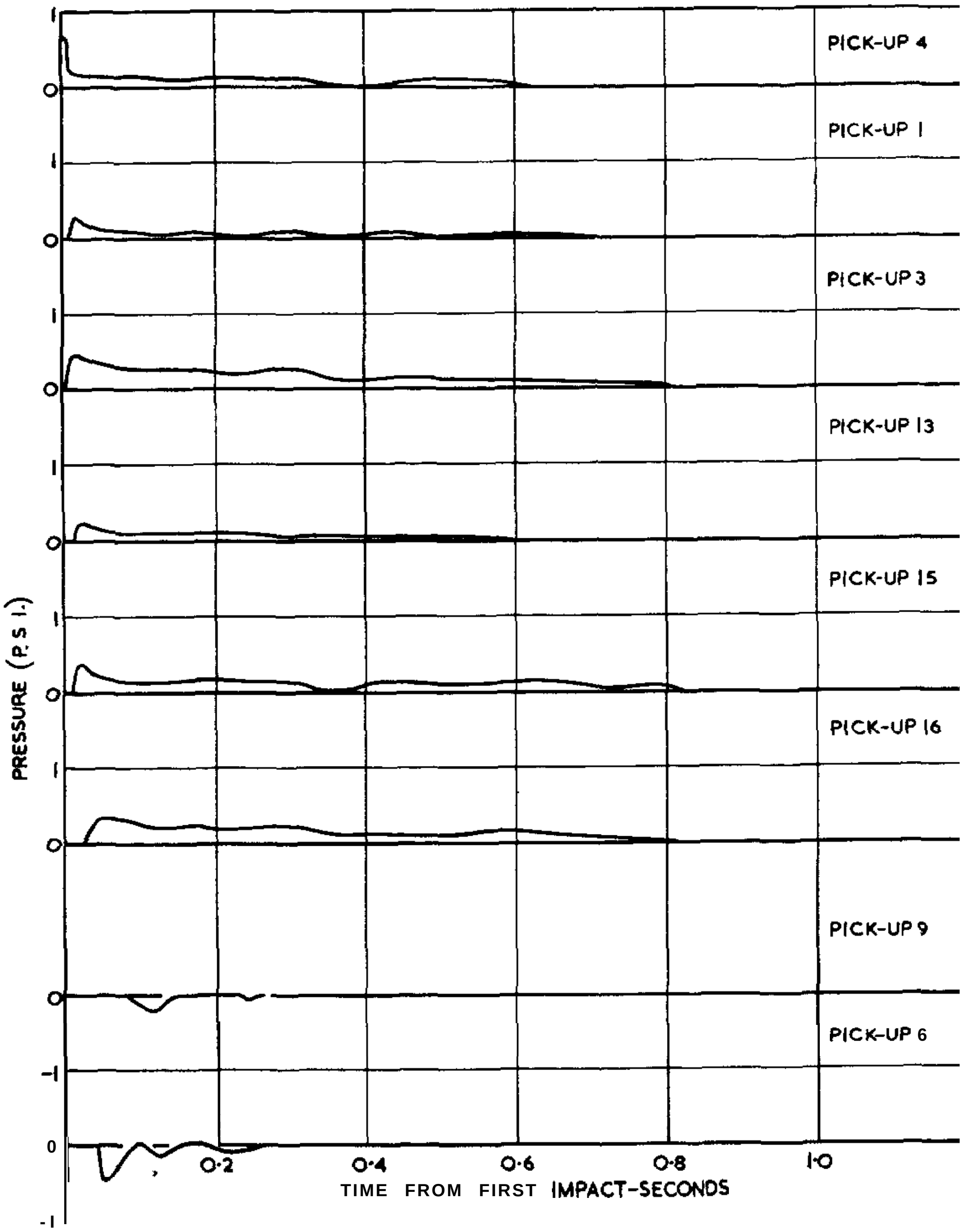
TIME HISTORY OF PRESSURES FOR FIG.12
$\tau_0 = 0\cdot 3^\circ$, $\gamma_0 = 5\cdot 8^\circ$, $V_{H_0} = 31\cdot 6$ FT./SEC

FIG.13.



TIME HISTORY OF FORWARD RUN. $\tau_0 = -0{\cdot}1°$, $\gamma_0 = 5{\cdot}8°$, $V_{H_0} = 25{\cdot}6$ FT/SEC.

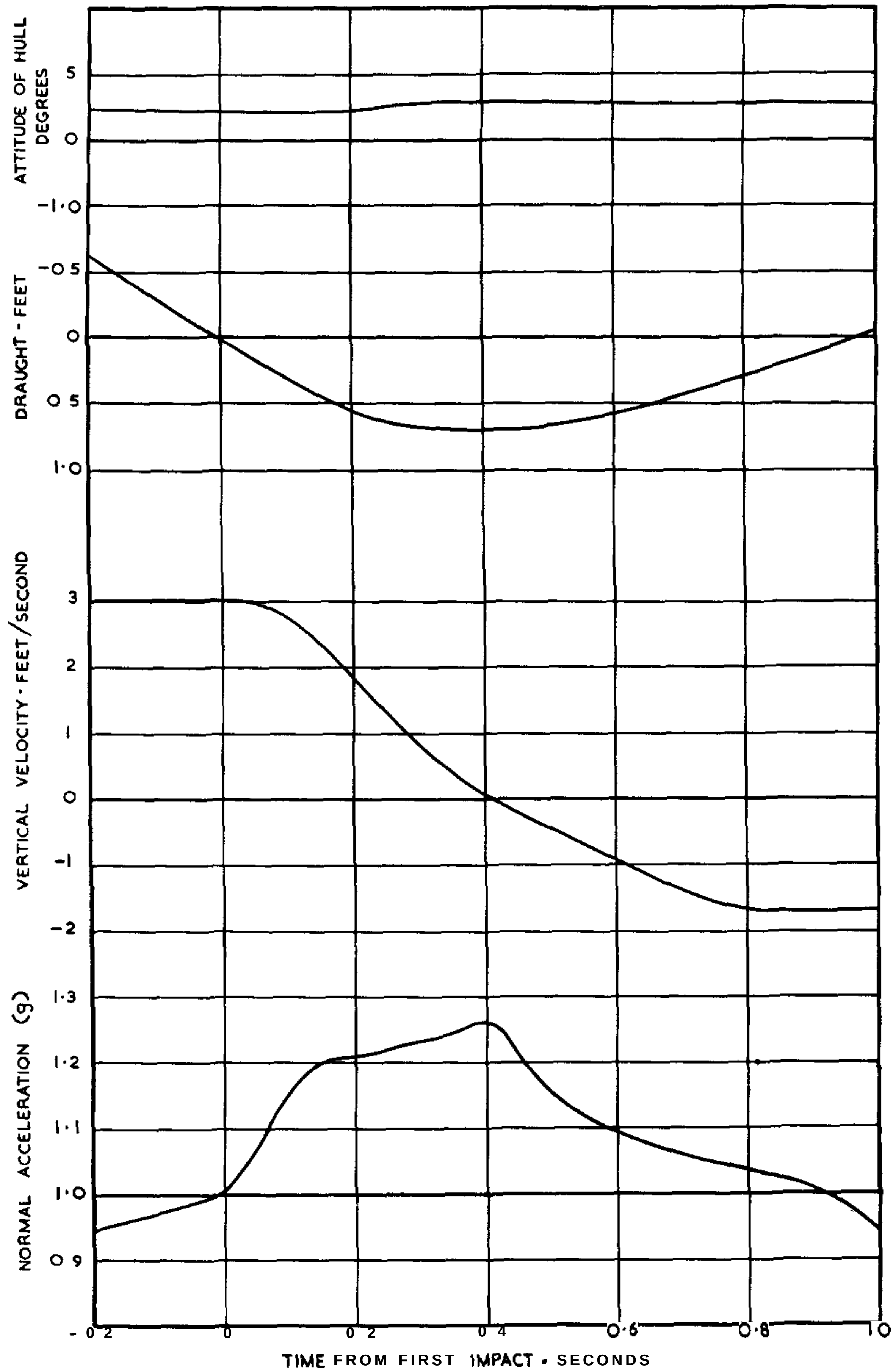
FIG.13A.



TIME HISTORY OF PRESSURES FOR FIG. 13.

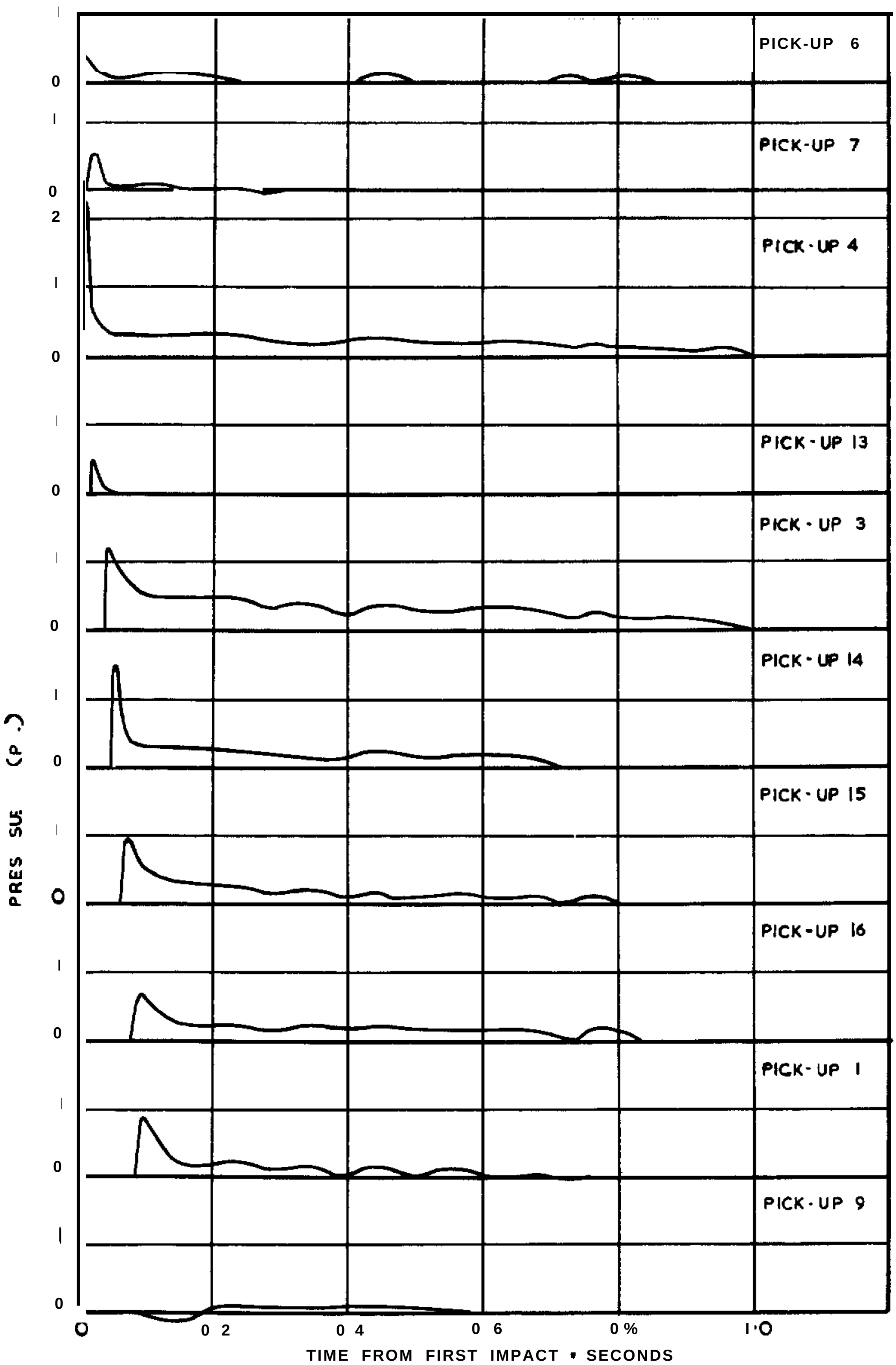
$\tau_0 = -0 \cdot 1^\circ$, $\gamma_0 = 5 \cdot 8^\circ$, $V_{H_0} = 25{\cdot}6$ FT./SEC.

FIG. 14.



TIME HISTORY OF FORWARD RUN, $\tau = 2{\cdot}4^\circ$, $\gamma_0 = 5{\cdot}5^\circ$, $V_{H_0} = 31{\cdot}2$ FT/SEC.

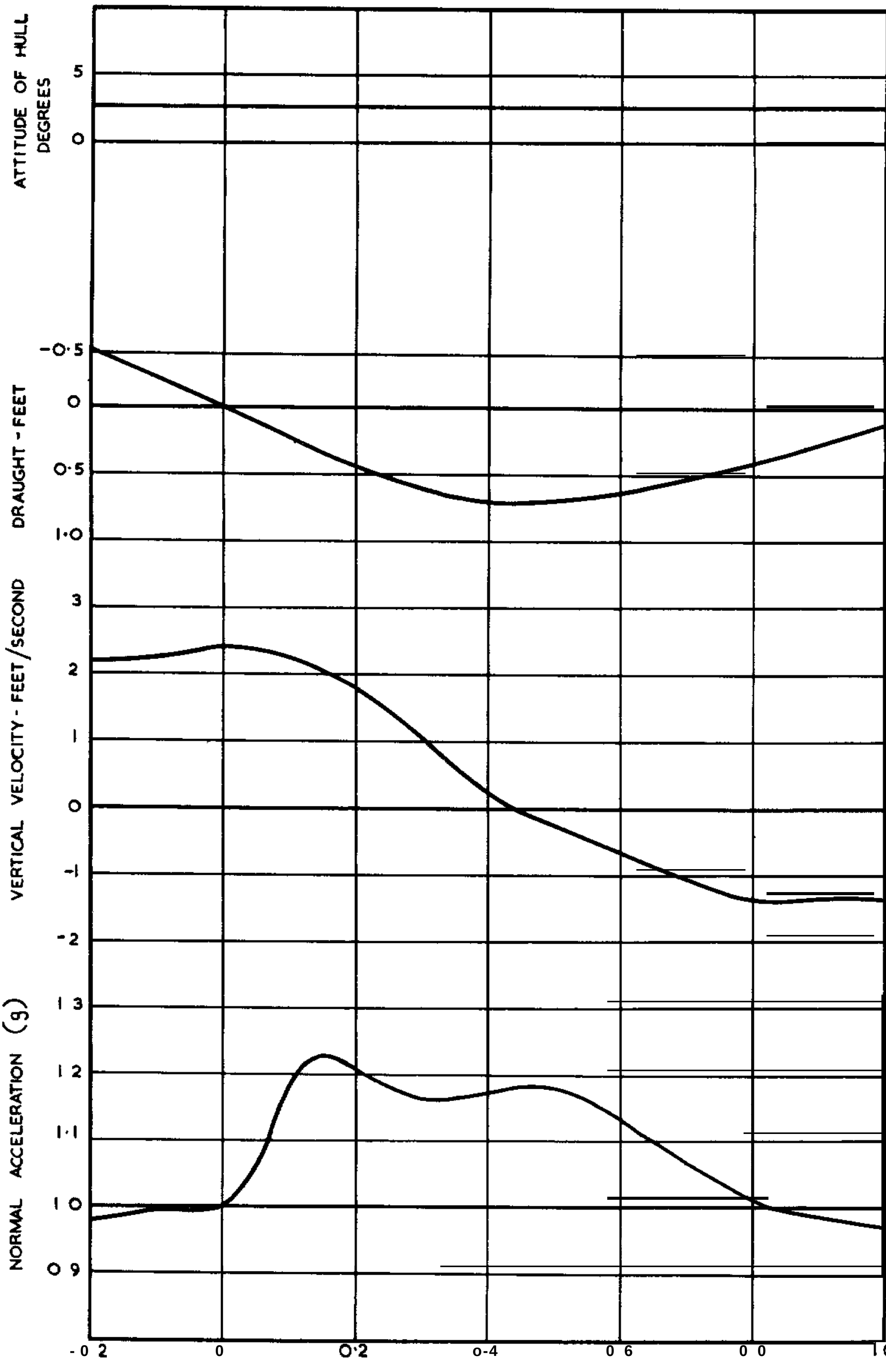
FIG. 14 A.



TIME HISTORY OF PRESSURES FOR FIG.14

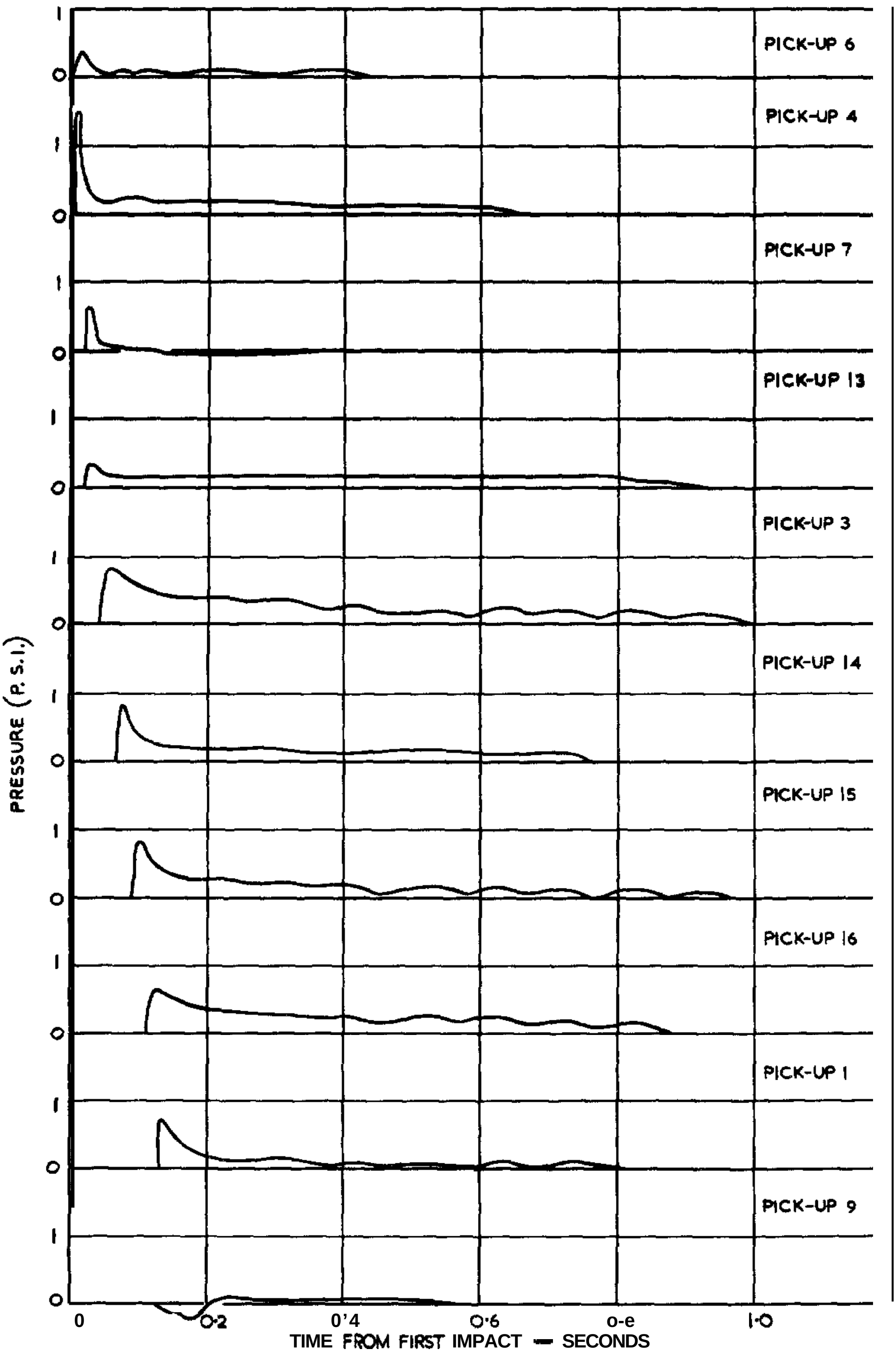
$\tau_0 = 2{\cdot}4^\circ$, $\gamma_0 = 5{\cdot}5^\circ$, $V_{H_0} = 31{\cdot}2$ FT./SEC

FIG.15.



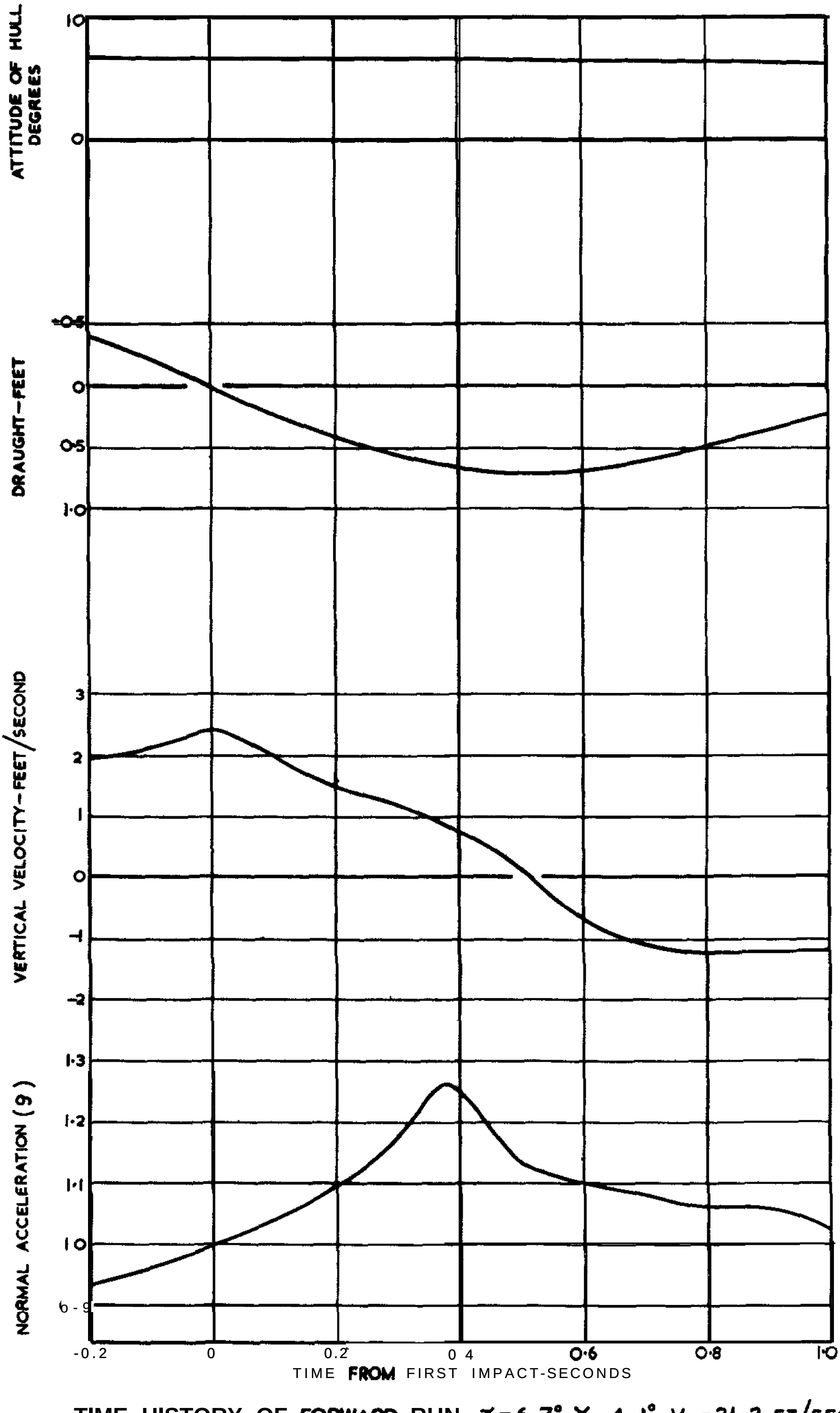
TIME HISTORY OF FORWARD RUN $\tau_0 = 2 \cdot 6^\circ$, $\gamma_0 = 4\ 3^\circ$, $V_{H_0} = 32 \cdot 4$ FT/SEC.

FIG.15A.



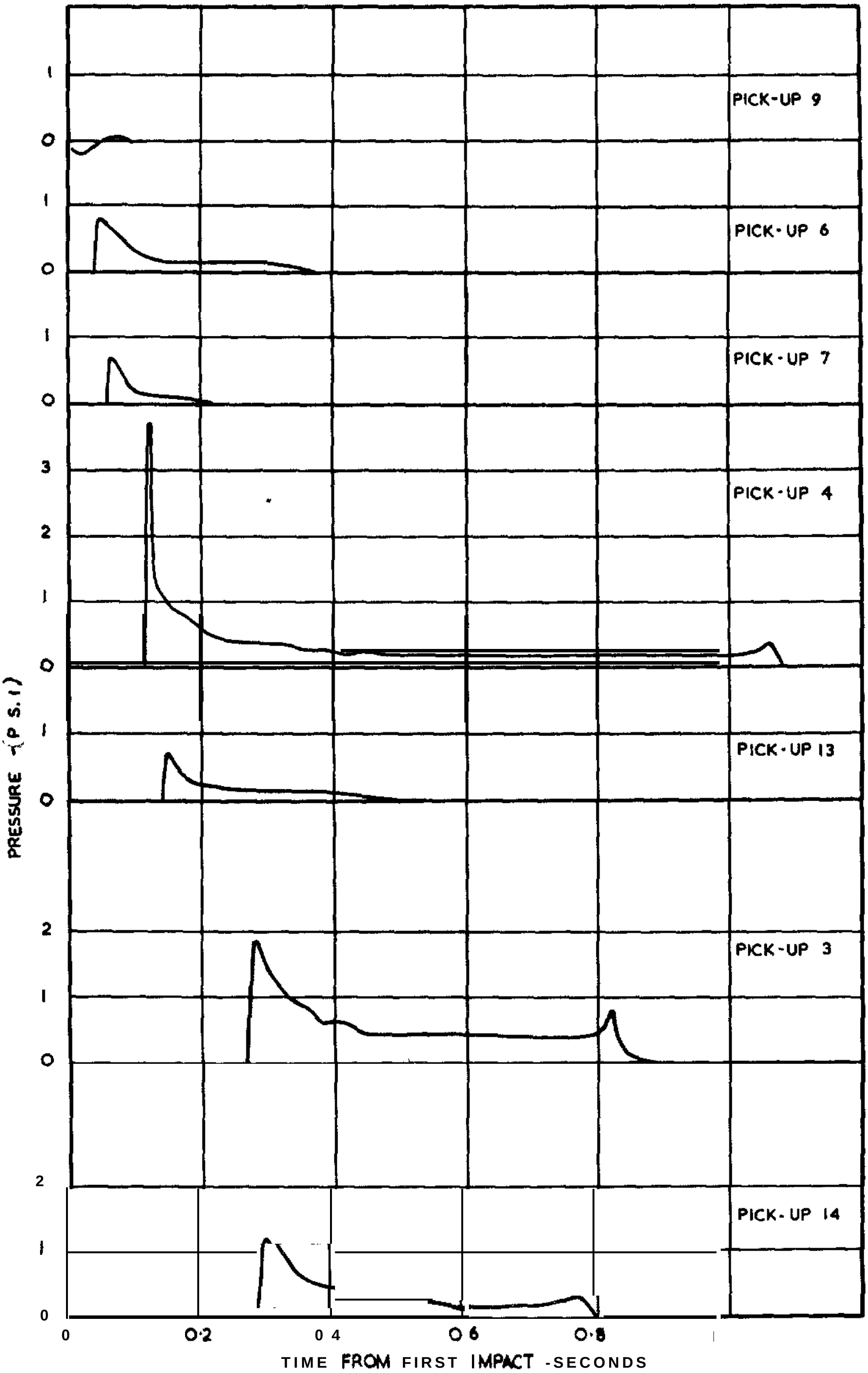
TIME HISTORY OF PRESSURES FOR FIG. 15.
$\tau_o = 2{\cdot}6°$, $\gamma_o = 4{\cdot}3°$, $V_{H_o} = 32{\cdot}4$ FT./SEC.

FIG. 16.



TIME HISTORY OF FORWARD RUN. $\tau_0 = 6{\cdot}7°$, $\gamma_0 = 4{\cdot}1°$, $V_H = 31{\cdot}3$ FT/SEC.

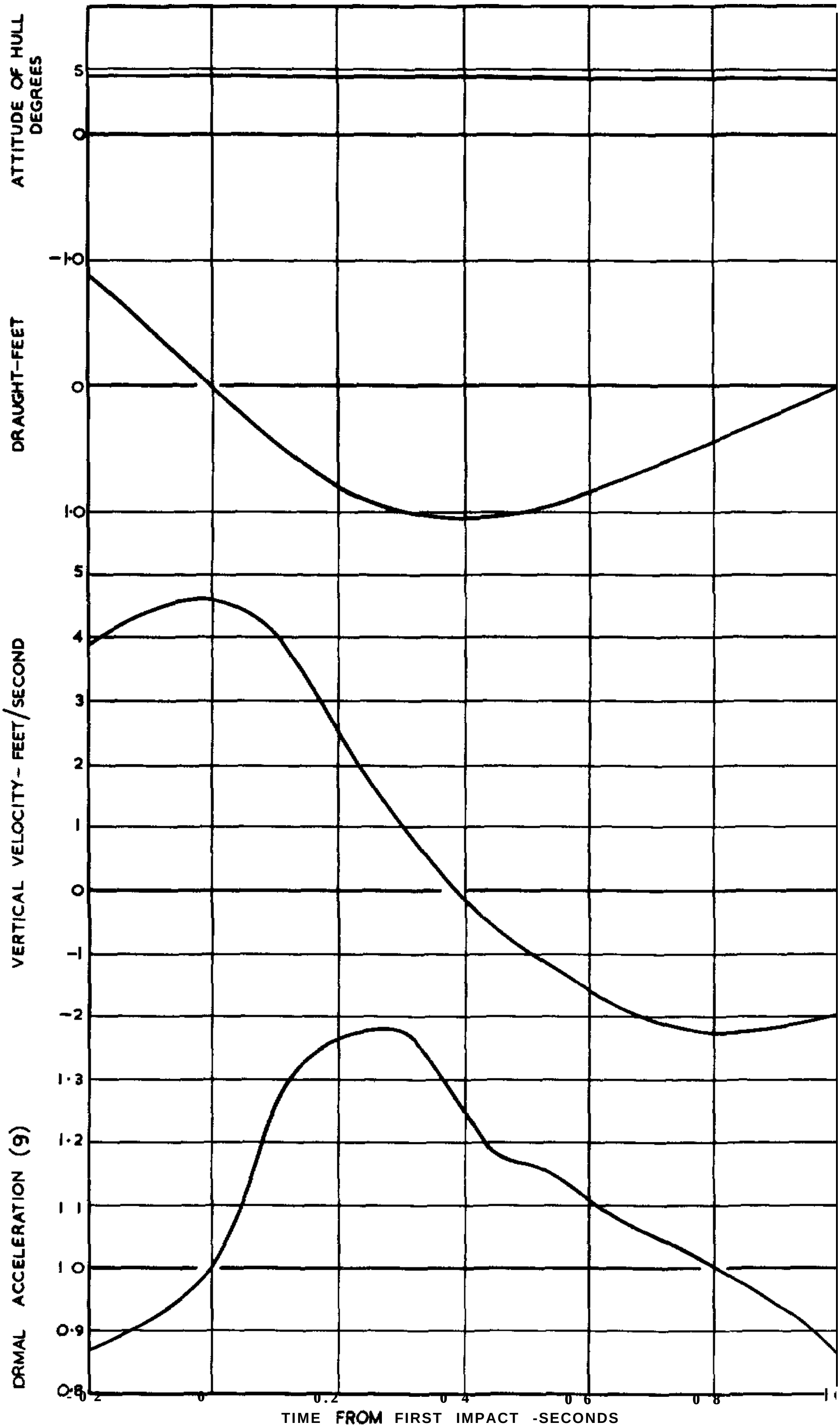
FIG. 16A.



TIME HISTORY OF PRESSURES FOR FIG. 16.

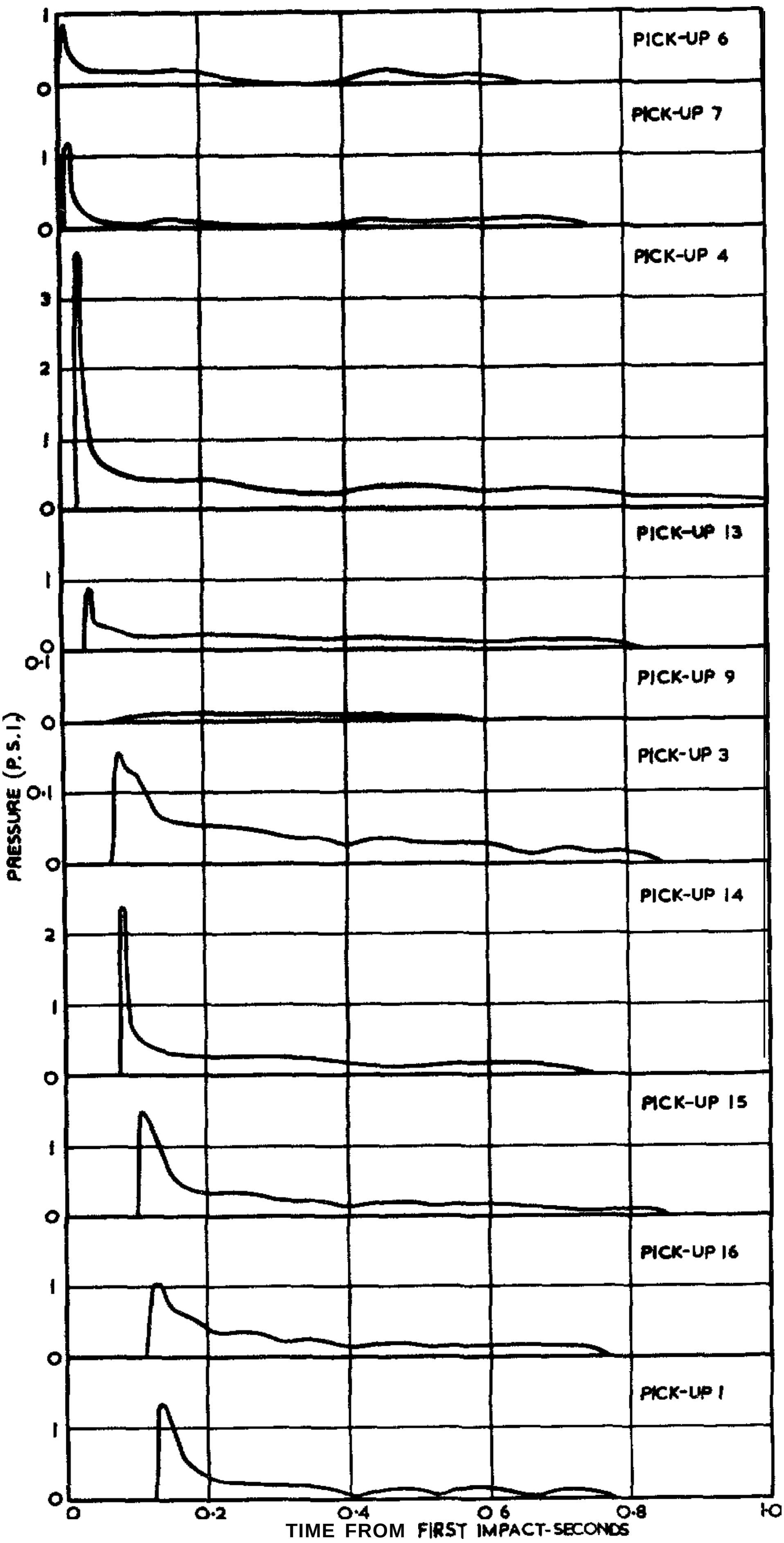
$\tau_o = 6\cdot7^\circ$, $\gamma_o = 4\cdot1^\circ$, $V_{H_o} = 31\cdot3$ FT/SEC.

FIG. 17.



TIME HISTORY OF FORWARD RUN. $\tau_0 = 4\cdot4°$, $\gamma_0 = 9\cdot7°$, $V_{H_0} = 27\cdot1$ FT/SEC.

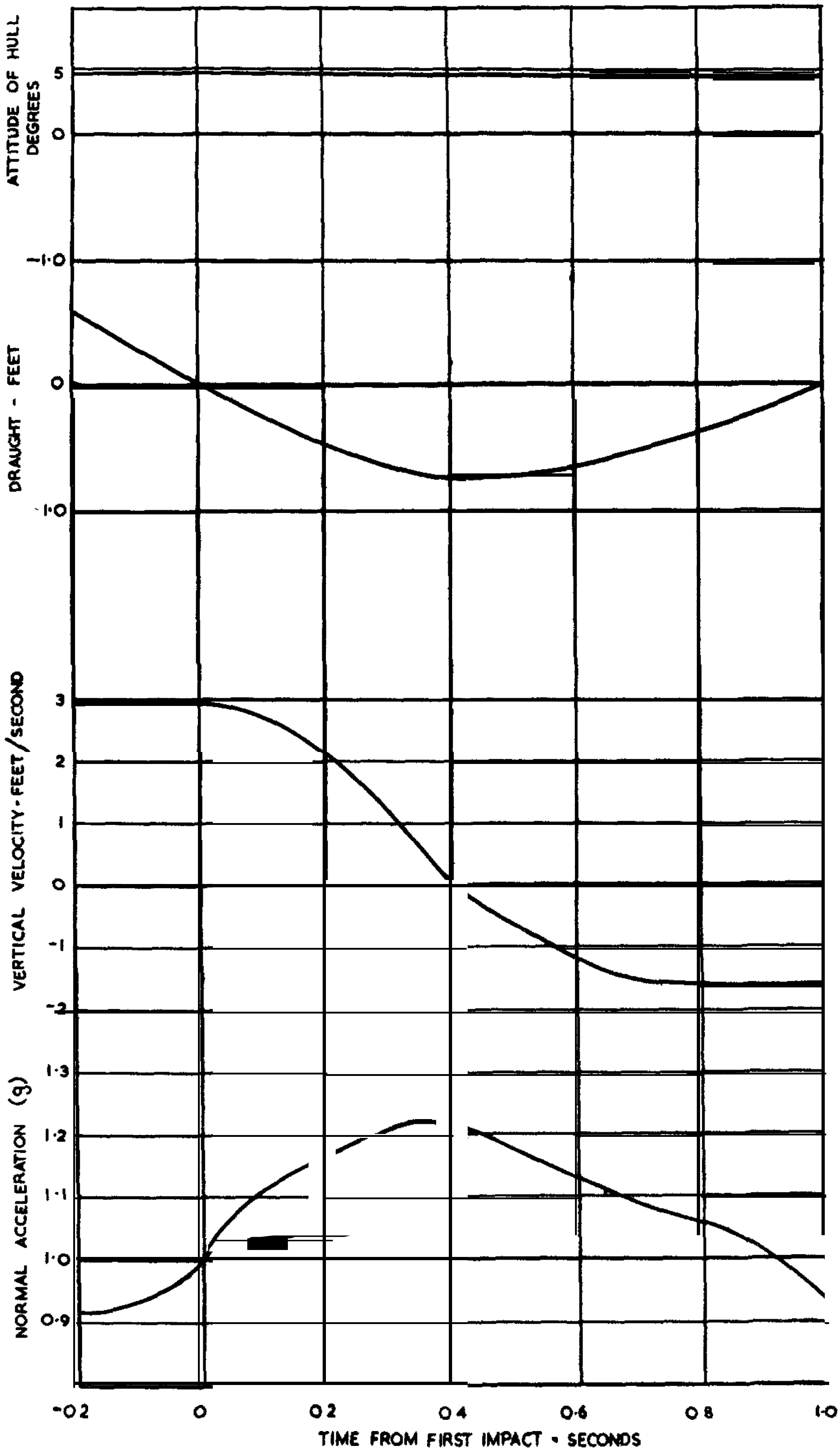
FIG.17A.



TIME HISTORY OF PRESSURES FOR FIG.17.

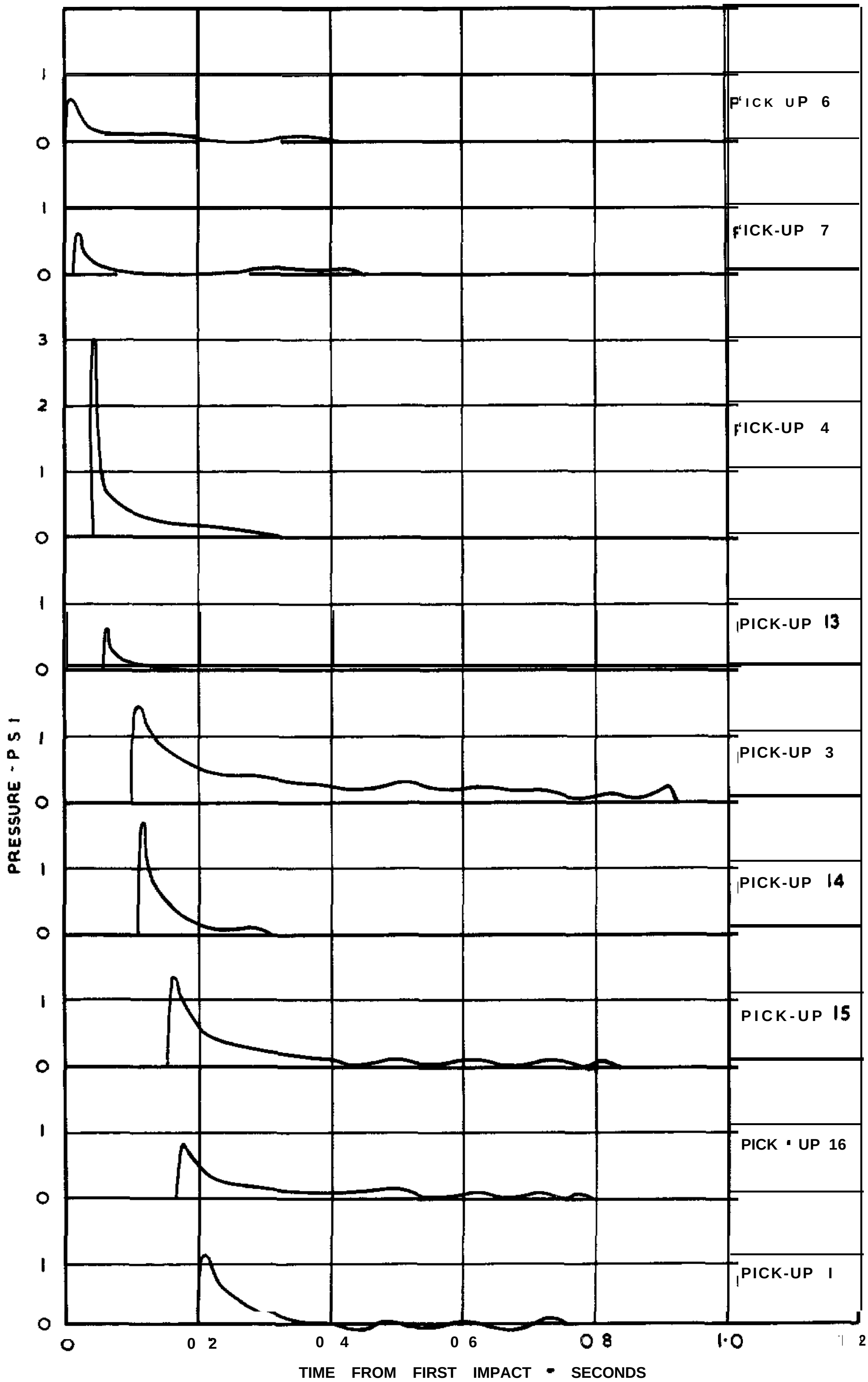
$\tau_o = 4{\cdot}4°$; $\gamma_o = 9{\cdot}7°$; V_H = 27·1 FT/SEC.

FIG. 18.



TIME HISTORY OF FORWARD RUN. $\tau_0 = 4\cdot7^\circ$, $\gamma_0 = 5\cdot2^\circ$, $V_{H_0} = 31\cdot8$ FT/SEC.

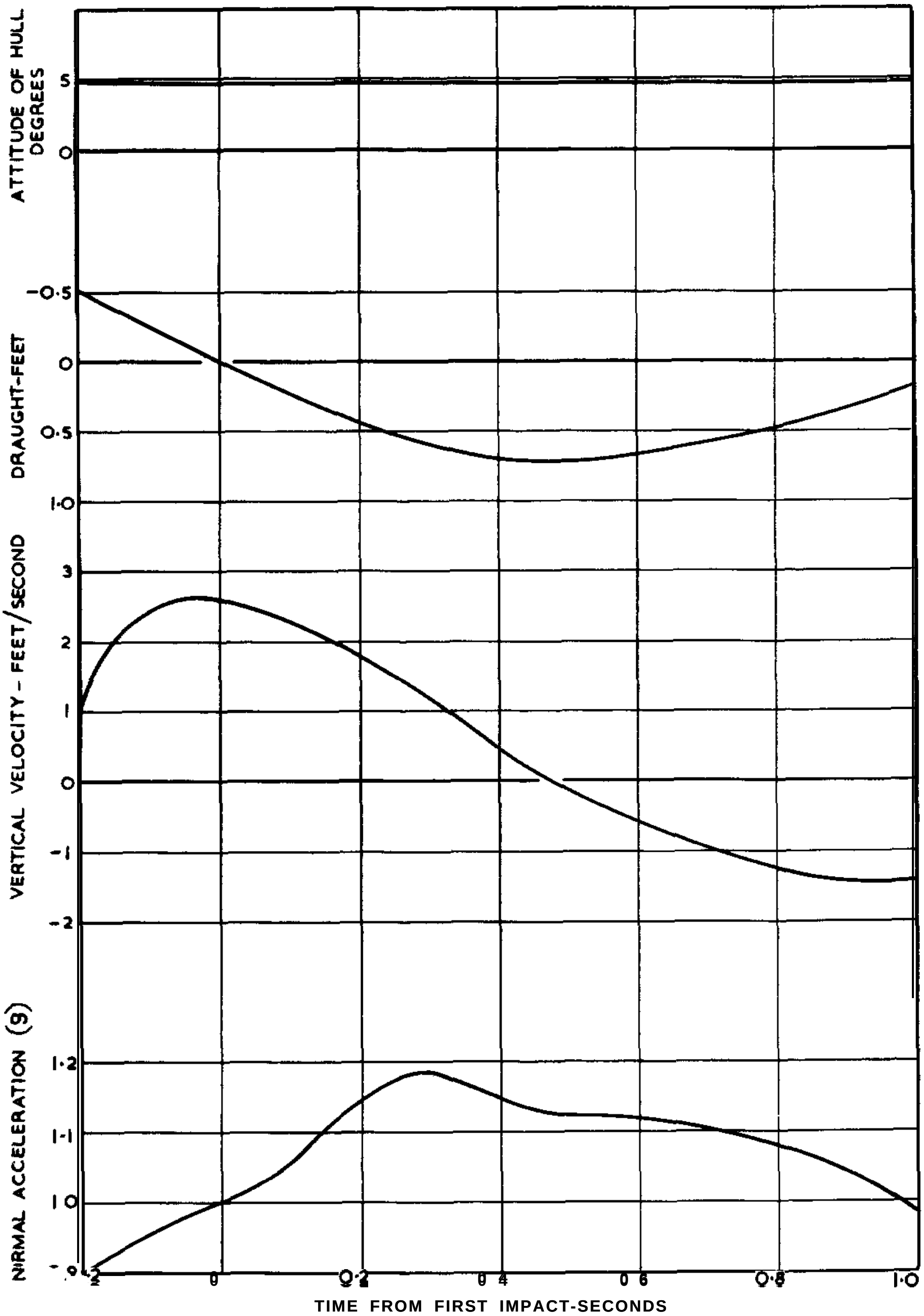
FIG. 18A.



TIME HISTORY OF PRESSURES FOR FIG. 18.

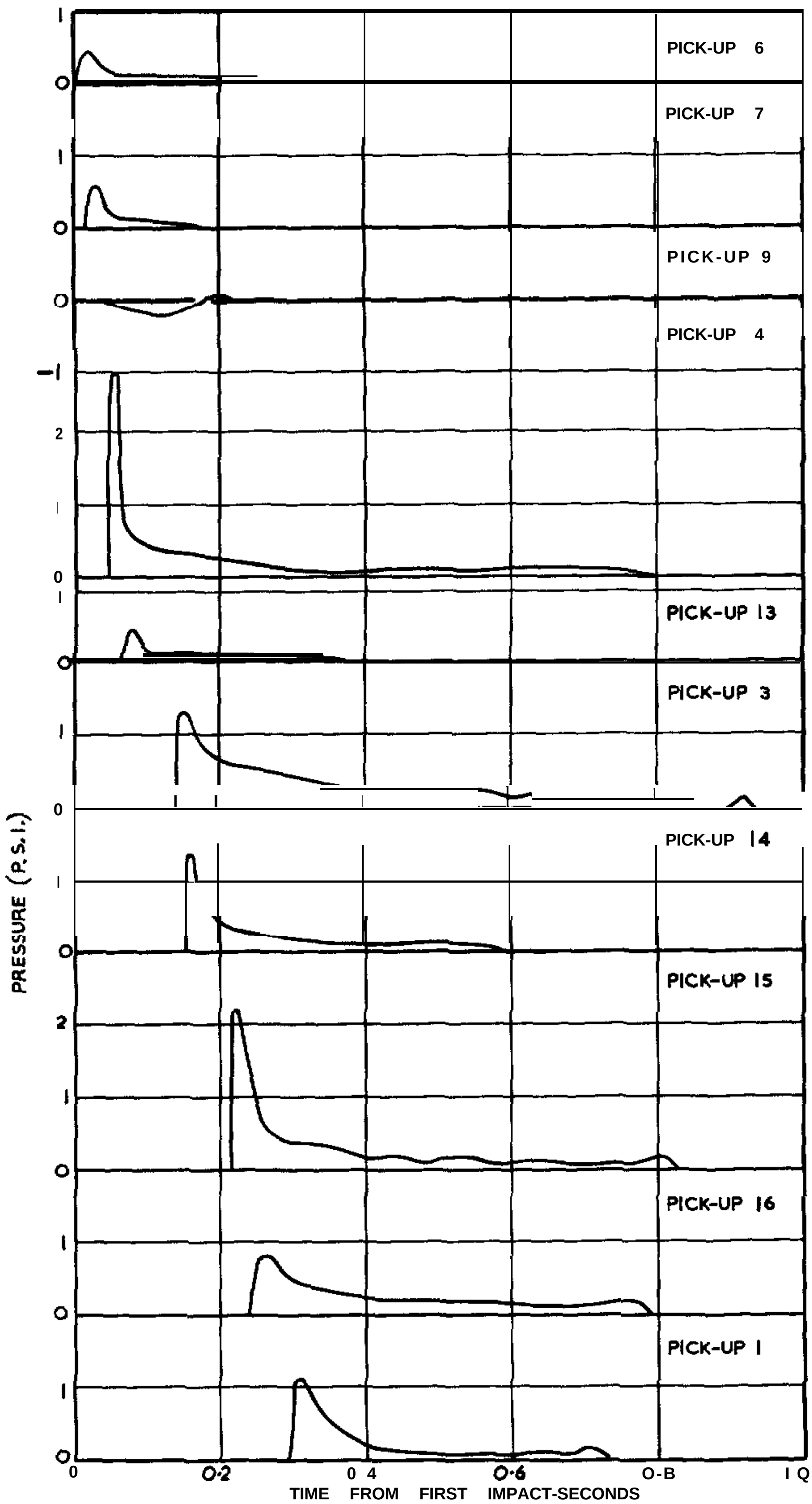
$\tau_0 = 4{\cdot}7^\circ$, $\gamma_0 = 5{\cdot}2^\circ$, $V_{H_0} = 31{\cdot}8$ FT./SEC

FIG. 19.



TIME HISTORY OF FORWARD RUN. $\tau_0 = 4\cdot7^\circ$, $\gamma_0 = 4\cdot8^\circ$, $V_{H_0} = 31\cdot3$ FT/SEC.

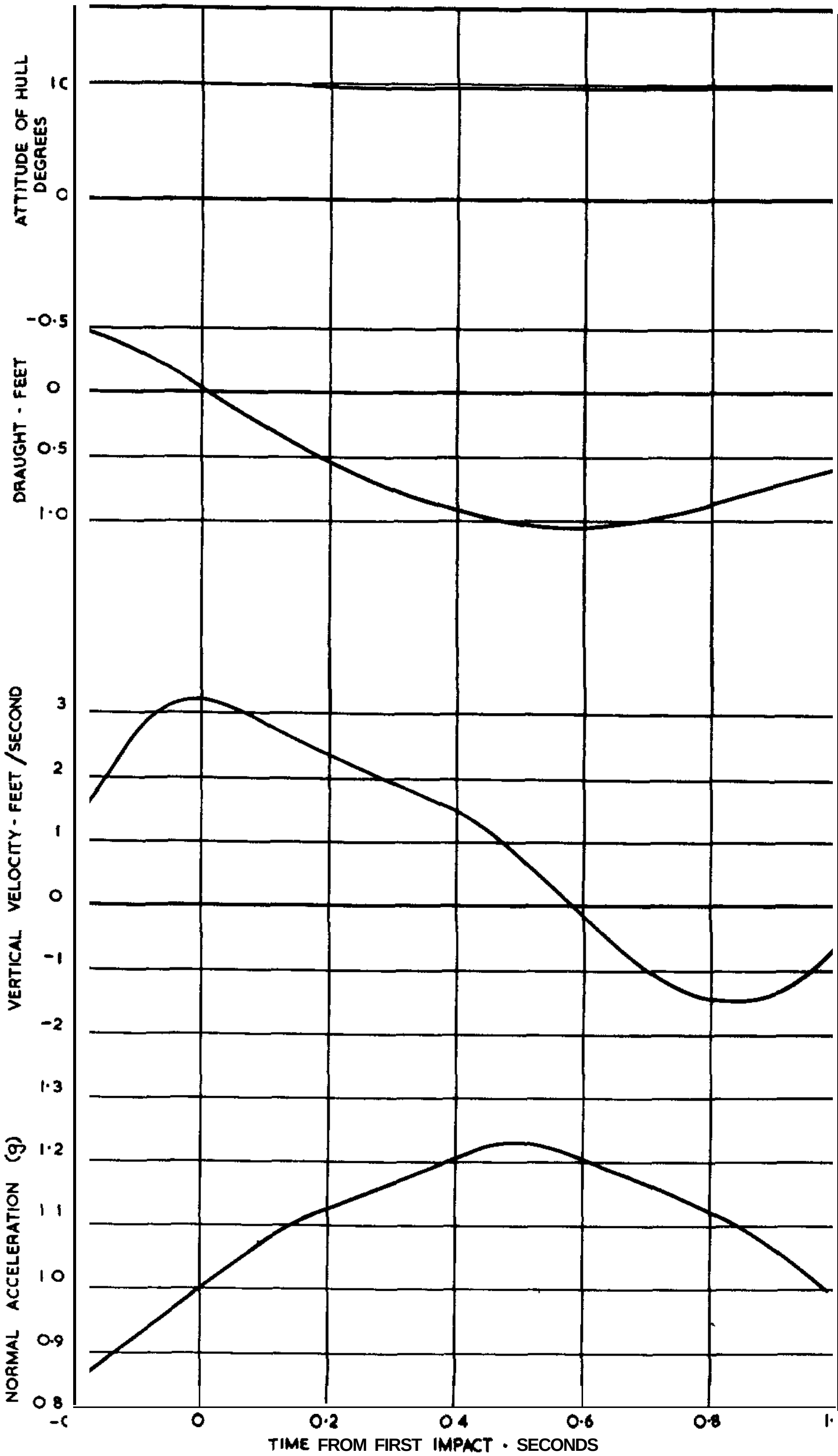
FIG. 19A.



TIME HISTORY OF PRESSURES FOR FIG.19.

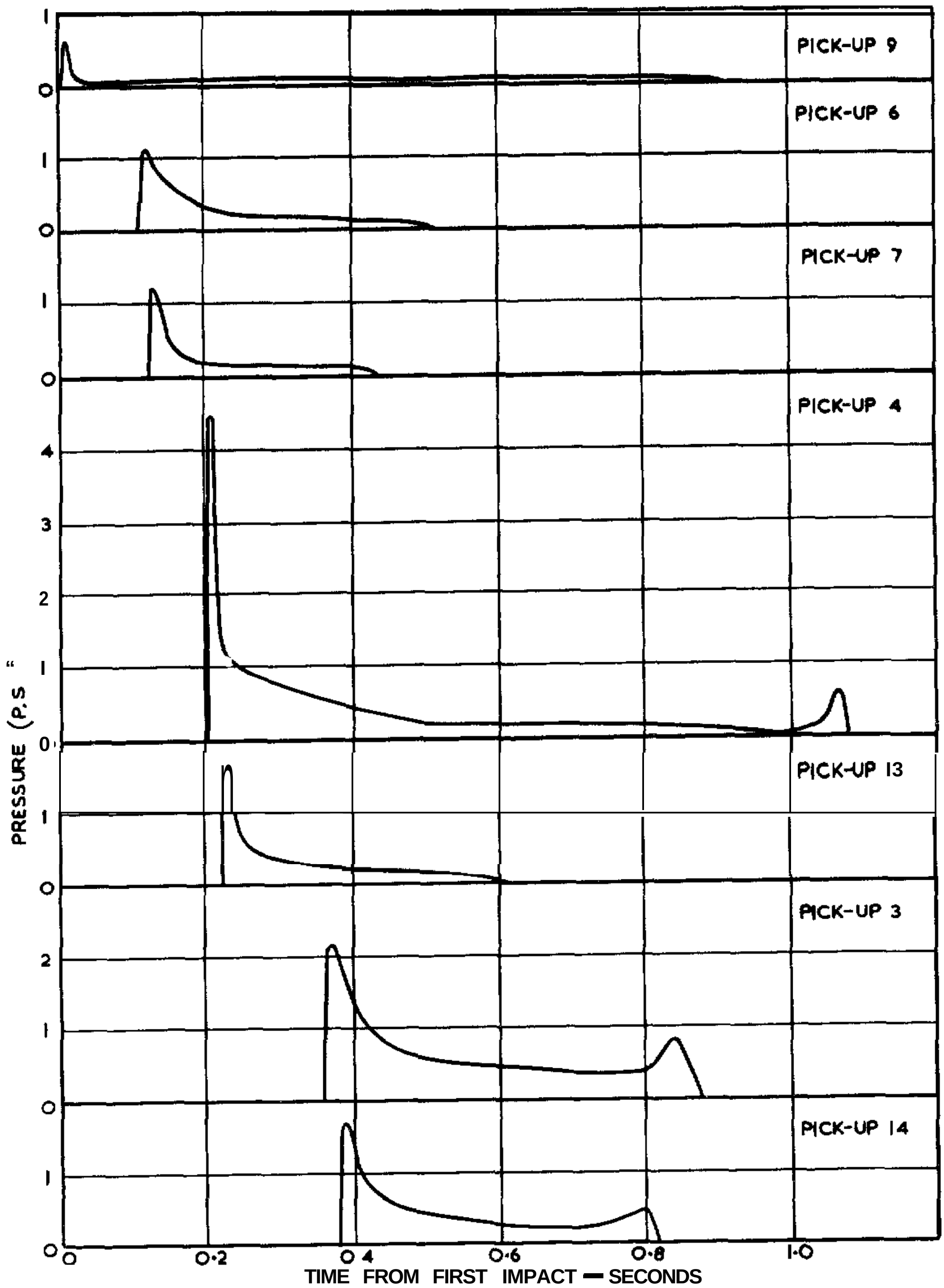
$\tau_o = 4\cdot7°;\ \gamma_o = 4\cdot8°;\ V_{H_o} = 31\cdot3$ FT/SEC.

FIG. 20.



TIME HISTORY OF FORWARD RUN. $\tau_0 = 9\cdot0^\circ$, $\gamma_0 = 5\cdot9^\circ$, $V_{H_0} = 28\cdot0$ FT/SEC.

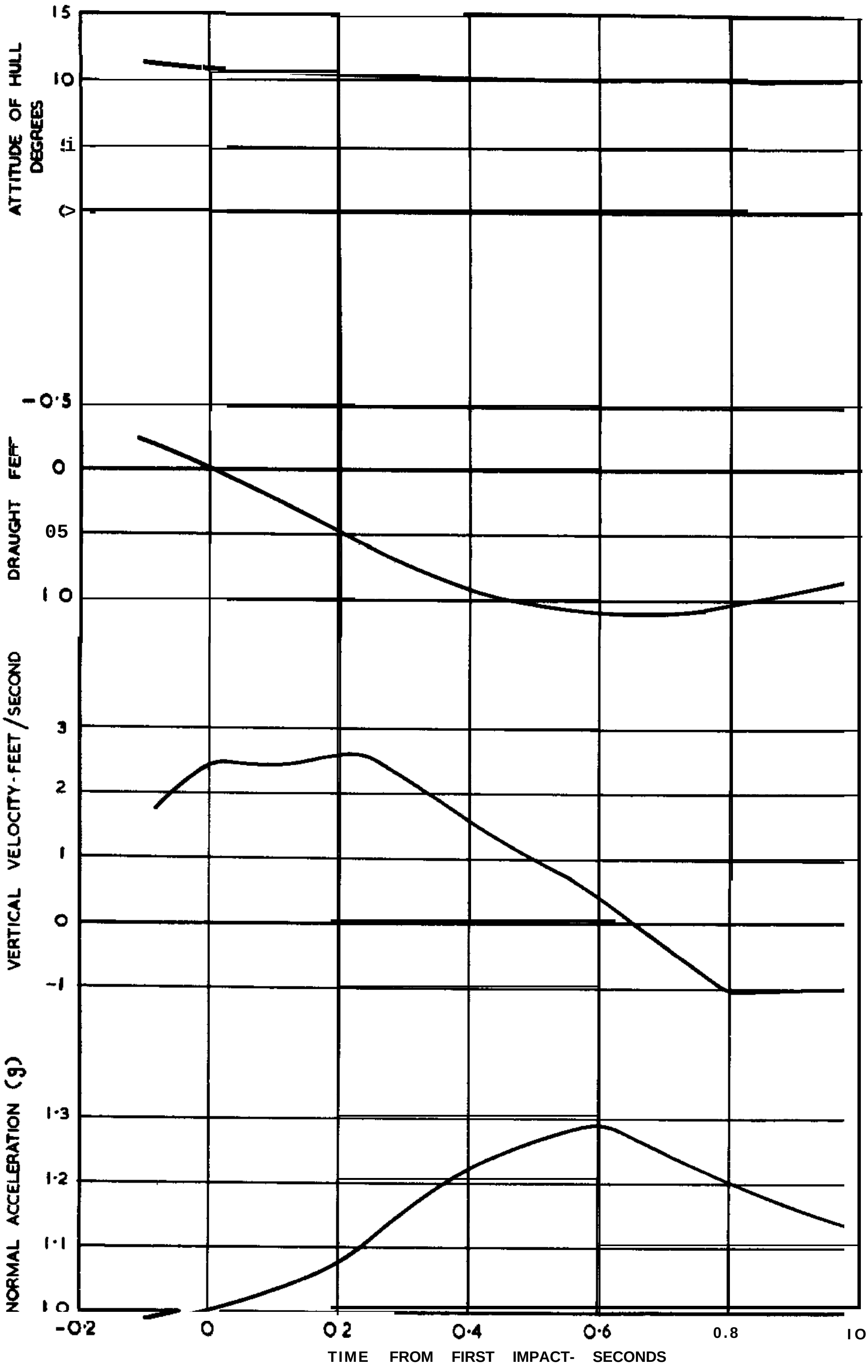
FIG. 20A.



TIME HISTORY OF PRESSURES FOR FIG. 20.

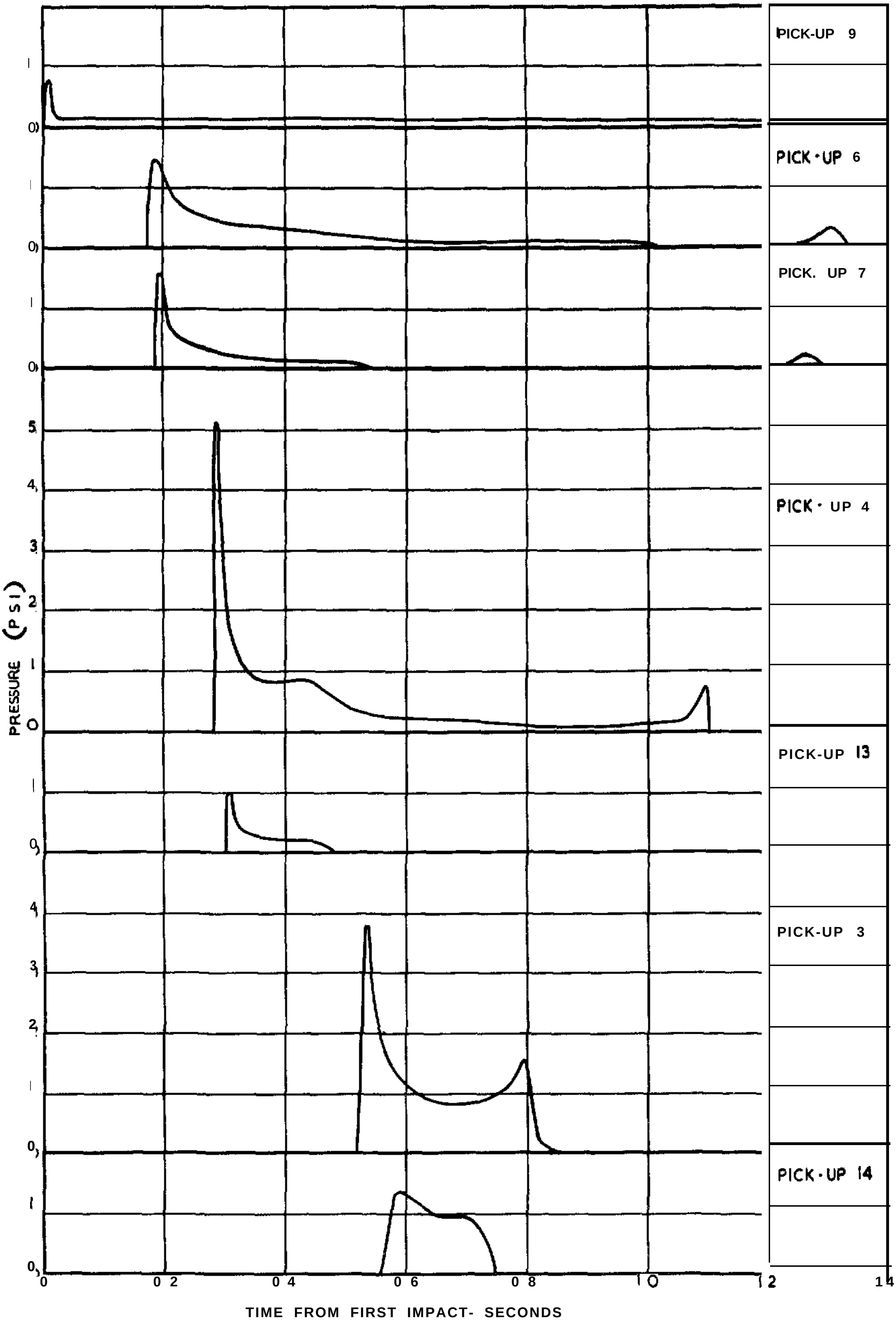
$\tau_o = 9\cdot0°;\ \gamma_o = 5\cdot9°;\ V_{H_o} = 28\cdot0$ FT/SEC.

FIG. 21.



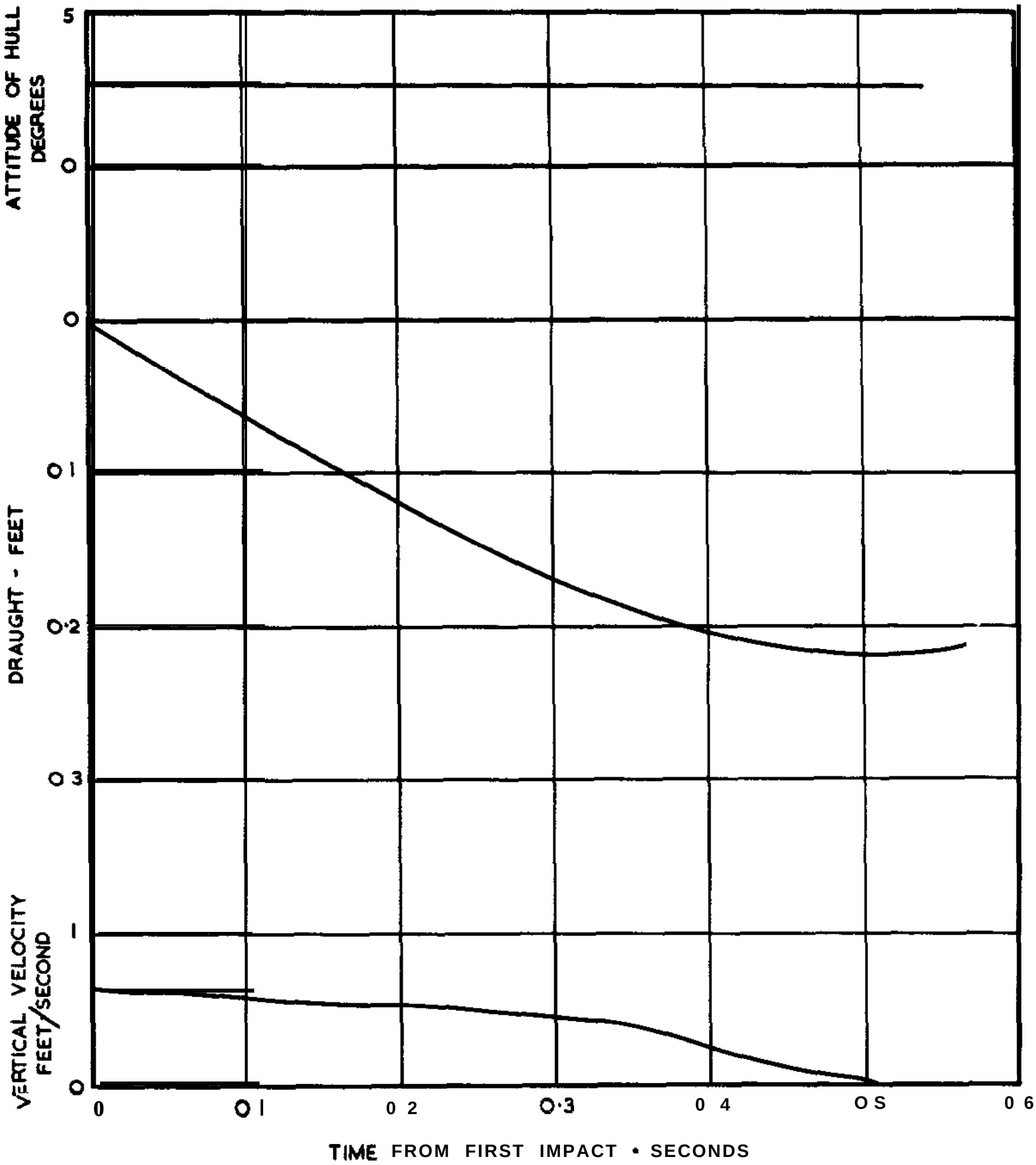
TIME HISTORY OF FORWARD RUN $\tau_0 = 11 \cdot 0^\circ$, $\gamma_0 = 5 \cdot 0^\circ$, $V_{H_0} = 28 \cdot 7$ FT/SEC.

FIG. 21A.



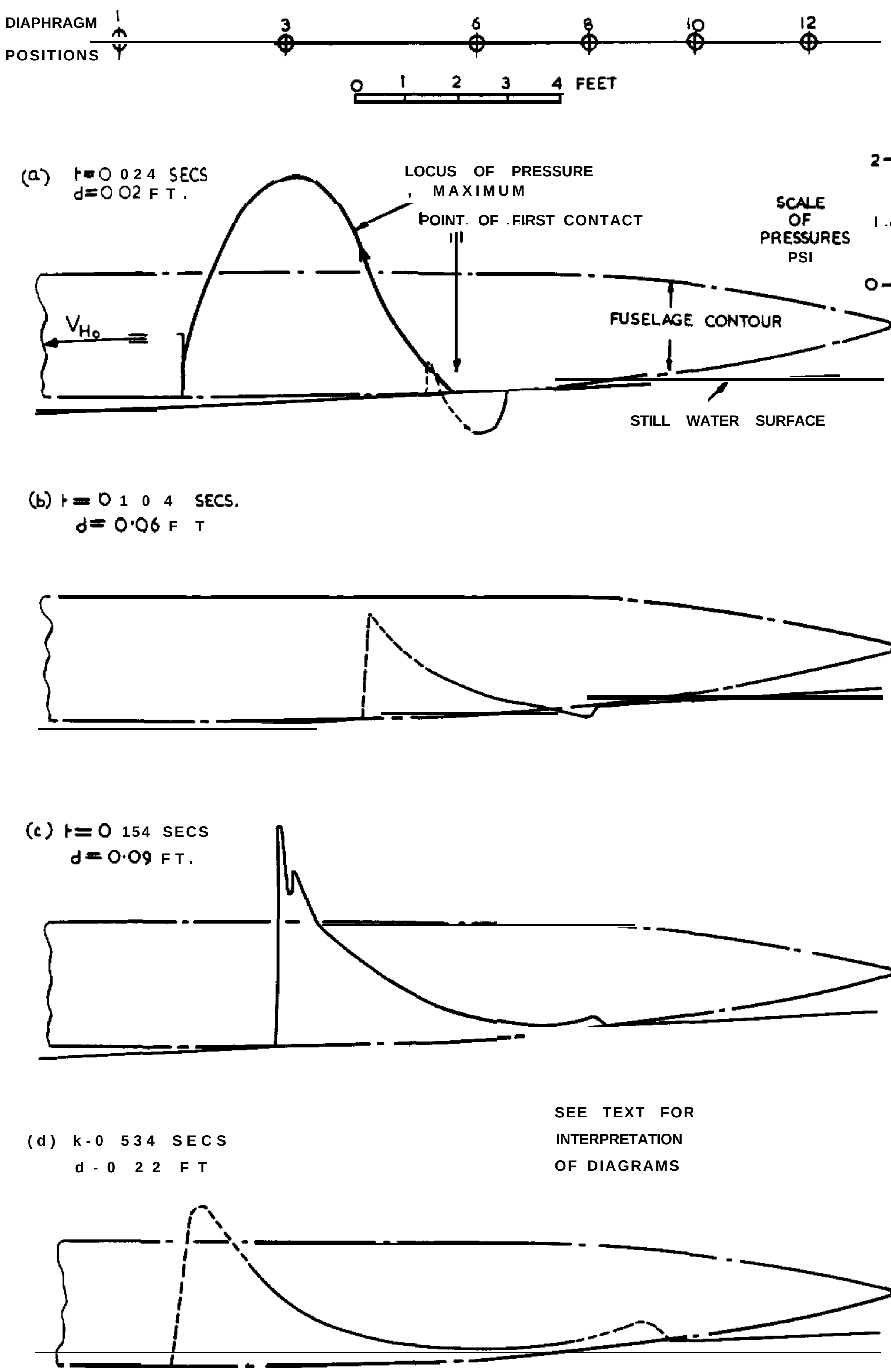
TIME HISTORY OF PRESSURES FOR FIG 21. $\tau_0 = 11{\cdot}0^\circ, \gamma_0 = 5{\cdot}0^\circ, V_{H_0} = 28.7$ FT/SEC.

FIG. 22.



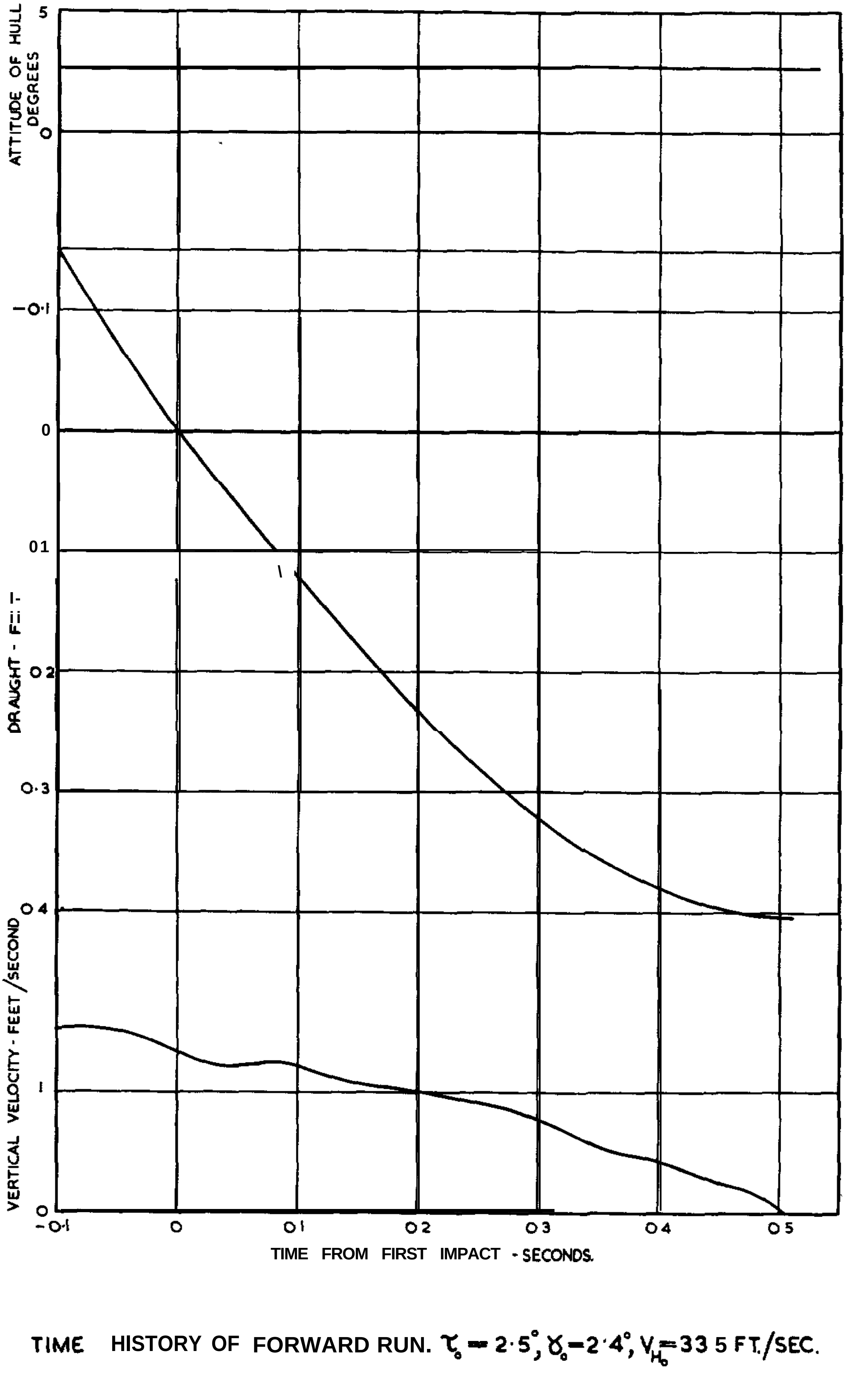
TIME HISTORY OF FORWARD RUN. $\tau_0 = 2 \cdot 5^\circ$, $\gamma_0 = 1 \cdot 1^\circ$, $V_{H_0} = 33 \cdot 2$ FT/SEC.

FIG. 22A.



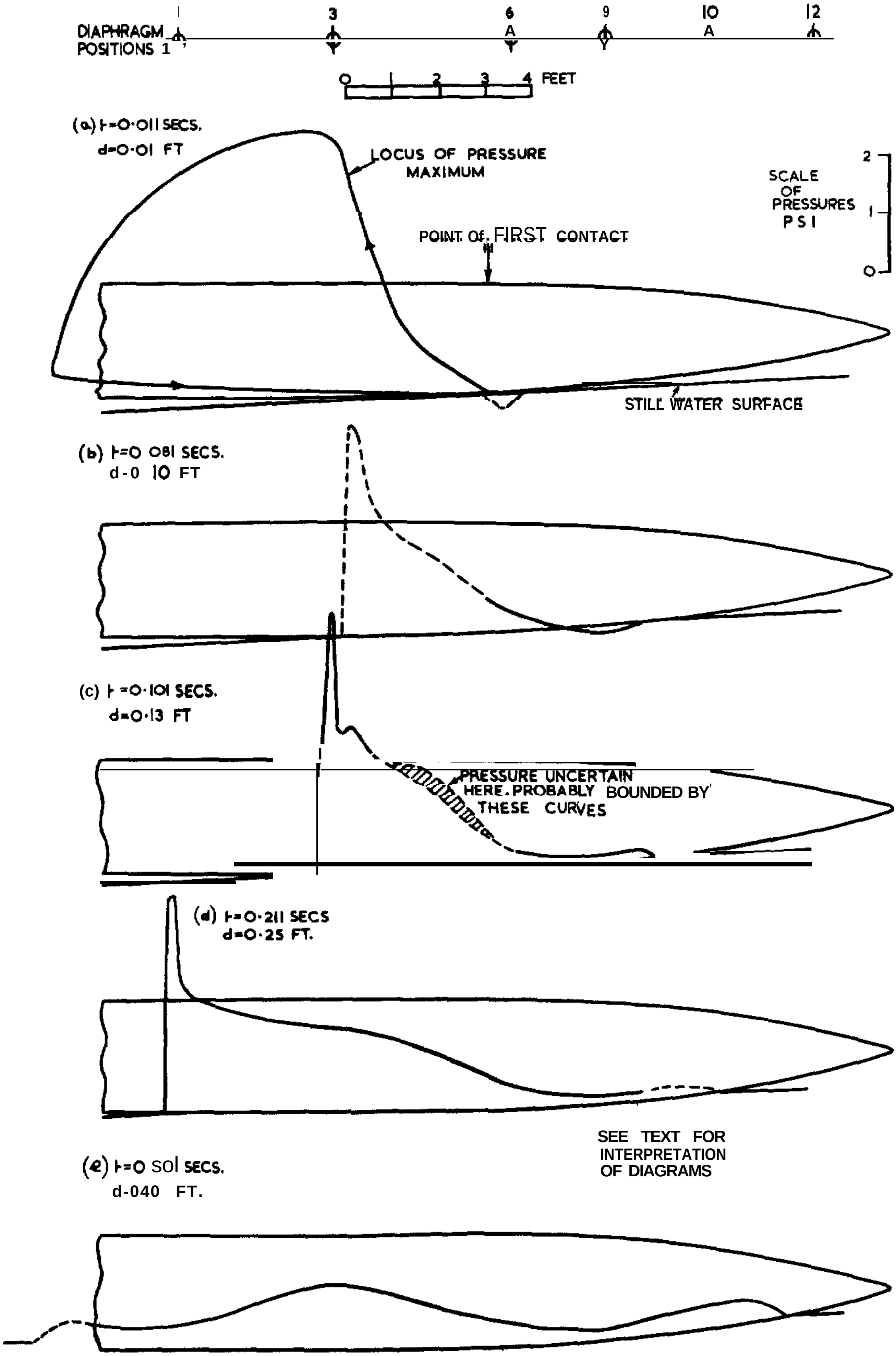
CENTRE LINE PRESSURE DISTRIBUTIONS $\tau_0 = 2{\cdot}5^\circ, \gamma_0 = 1{\cdot}1^\circ, V_{H_0} = 33{\cdot}2$ FT/SEC.

FIG. 23.



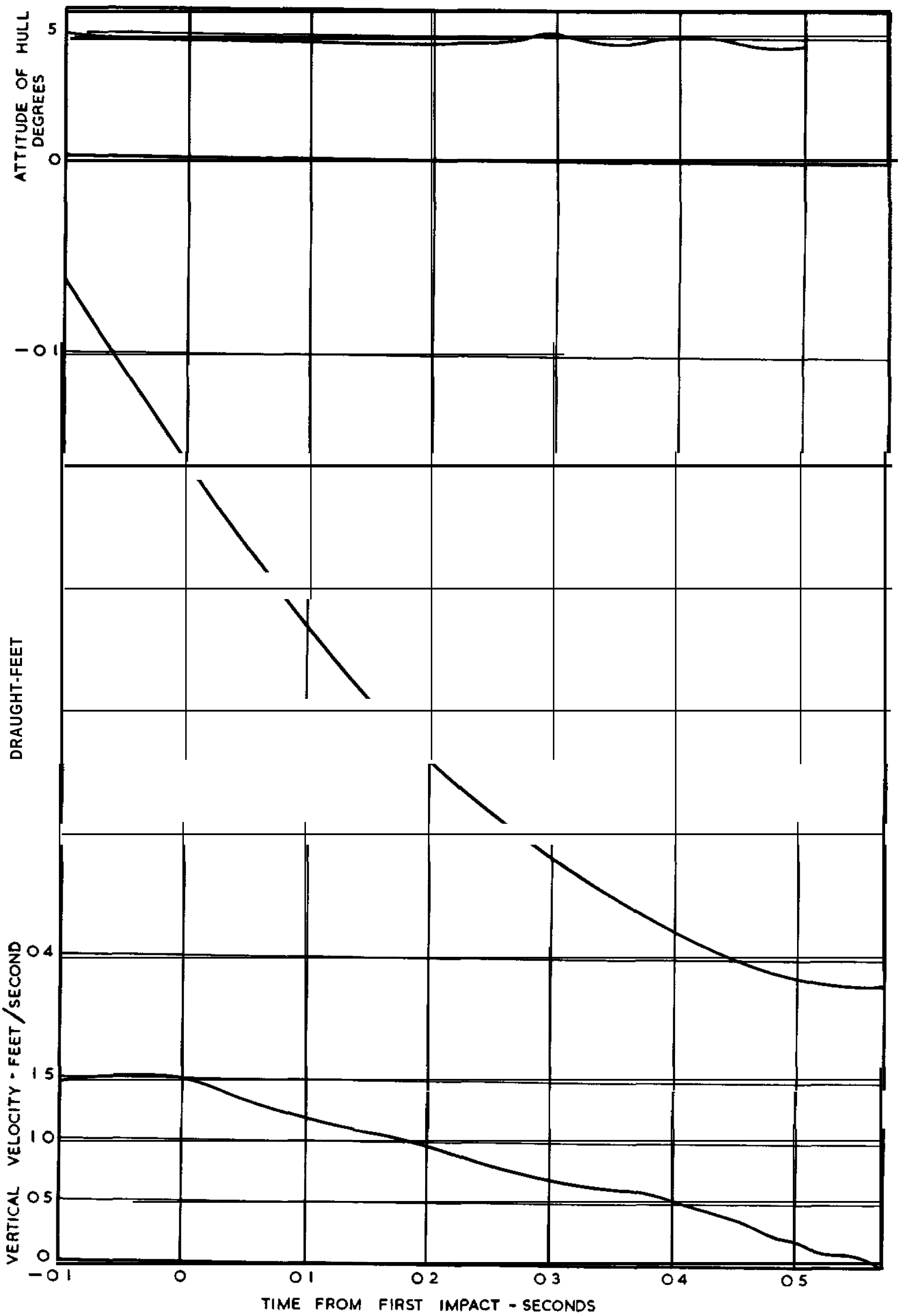
TIME HISTORY OF FORWARD RUN. $\tau_o = 2{\cdot}5^\circ$, $\gamma_o = 2{\cdot}4^\circ$, $V_{H_o} = 33{\cdot}5$ FT./SEC.

FIG. 23A.



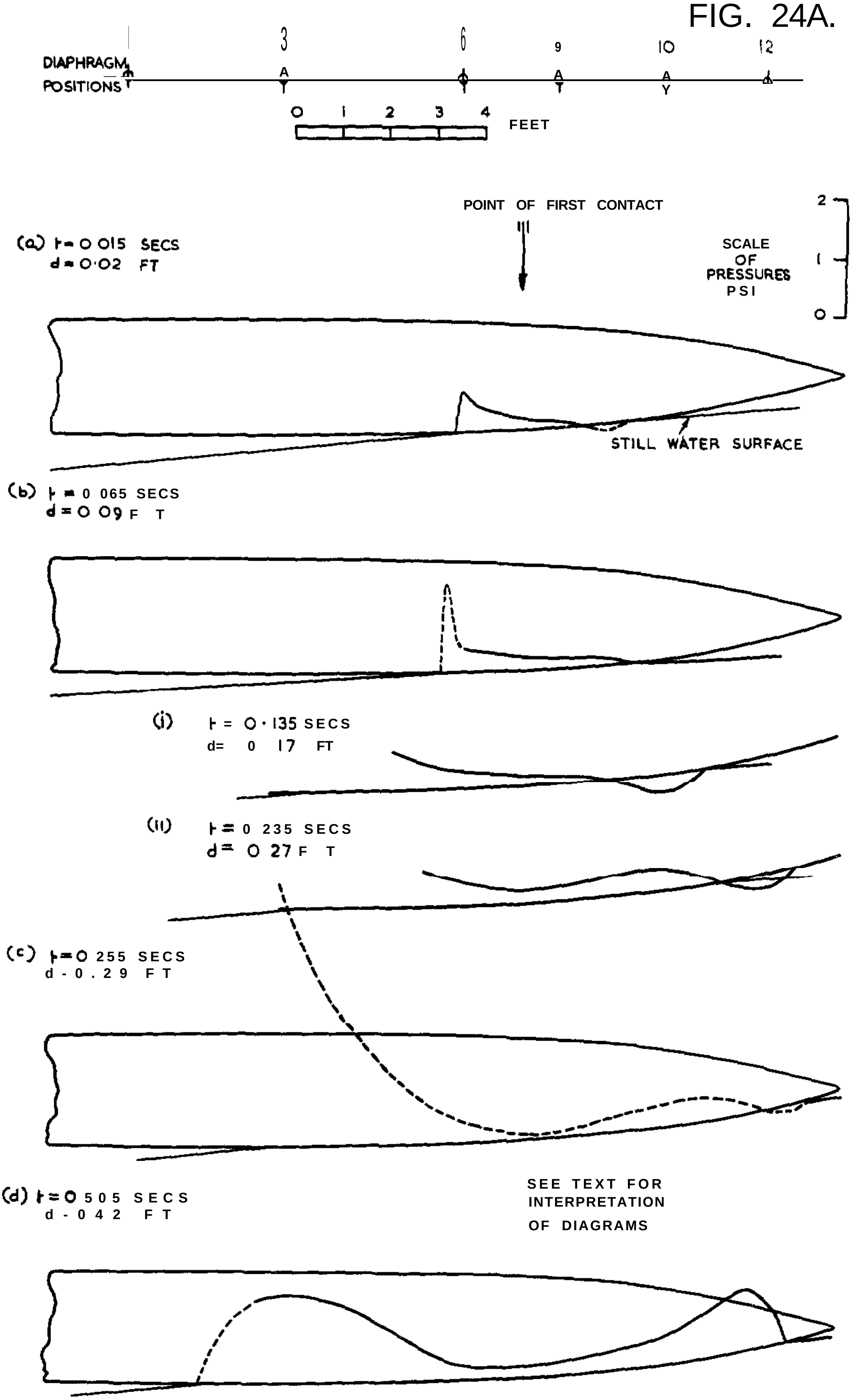
CENTRE LINE PRESSURE DISTRIBUTIONS. $\tau_0 = 2 \cdot 5°$, $\gamma_0 = 2 \cdot 4°$, $V_{H_0} =$ 33-5 FT./SEC.

FIG. 24.



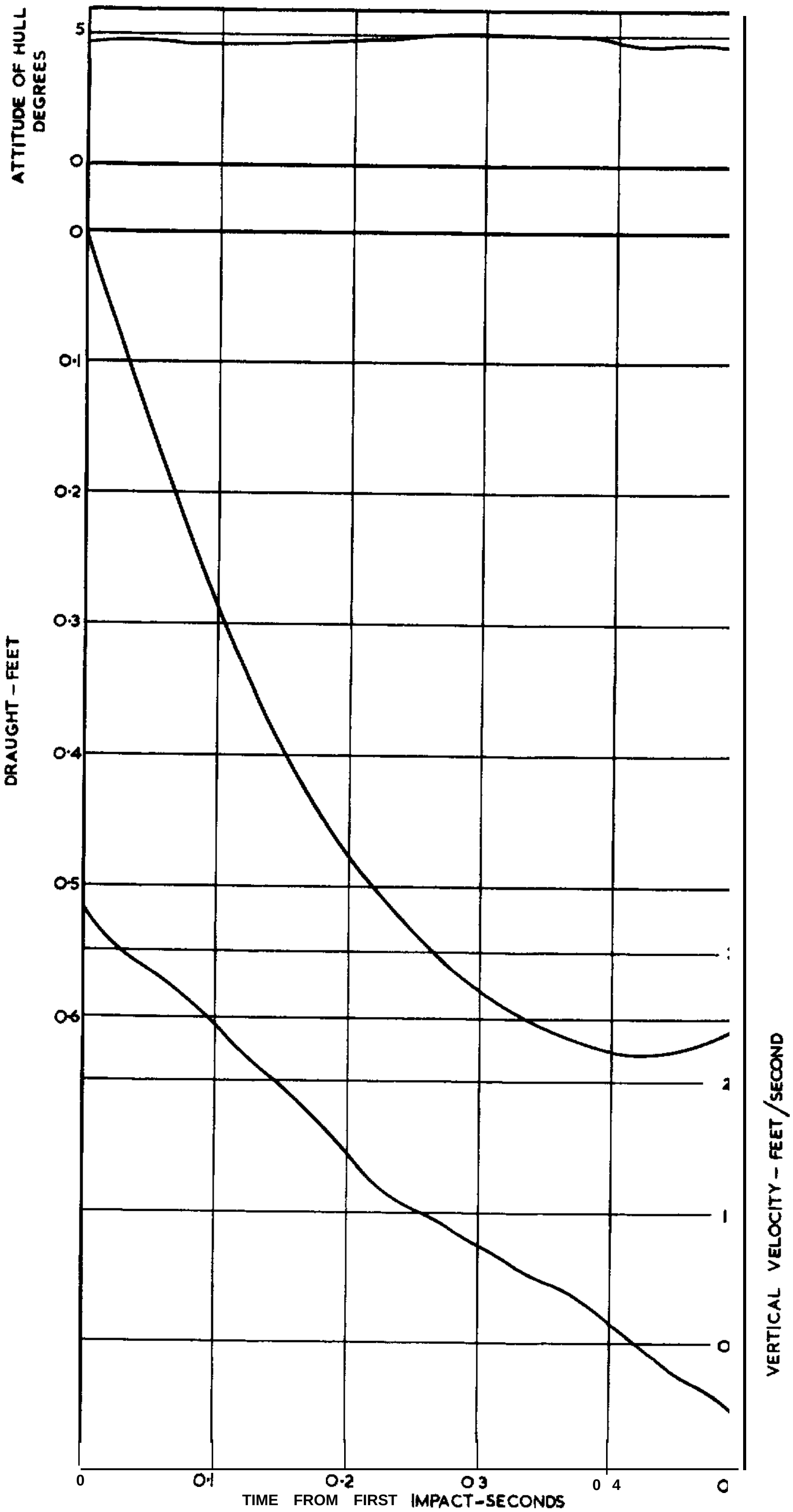
TIME HISTORY OF FORWARD RUN, $\tau_o = 4{\cdot}7^\circ$, $\gamma_o = 2{\cdot}4^\circ$, $V_{H_o} = 33{\cdot}7$ FT./SEC.

FIG. 24A.



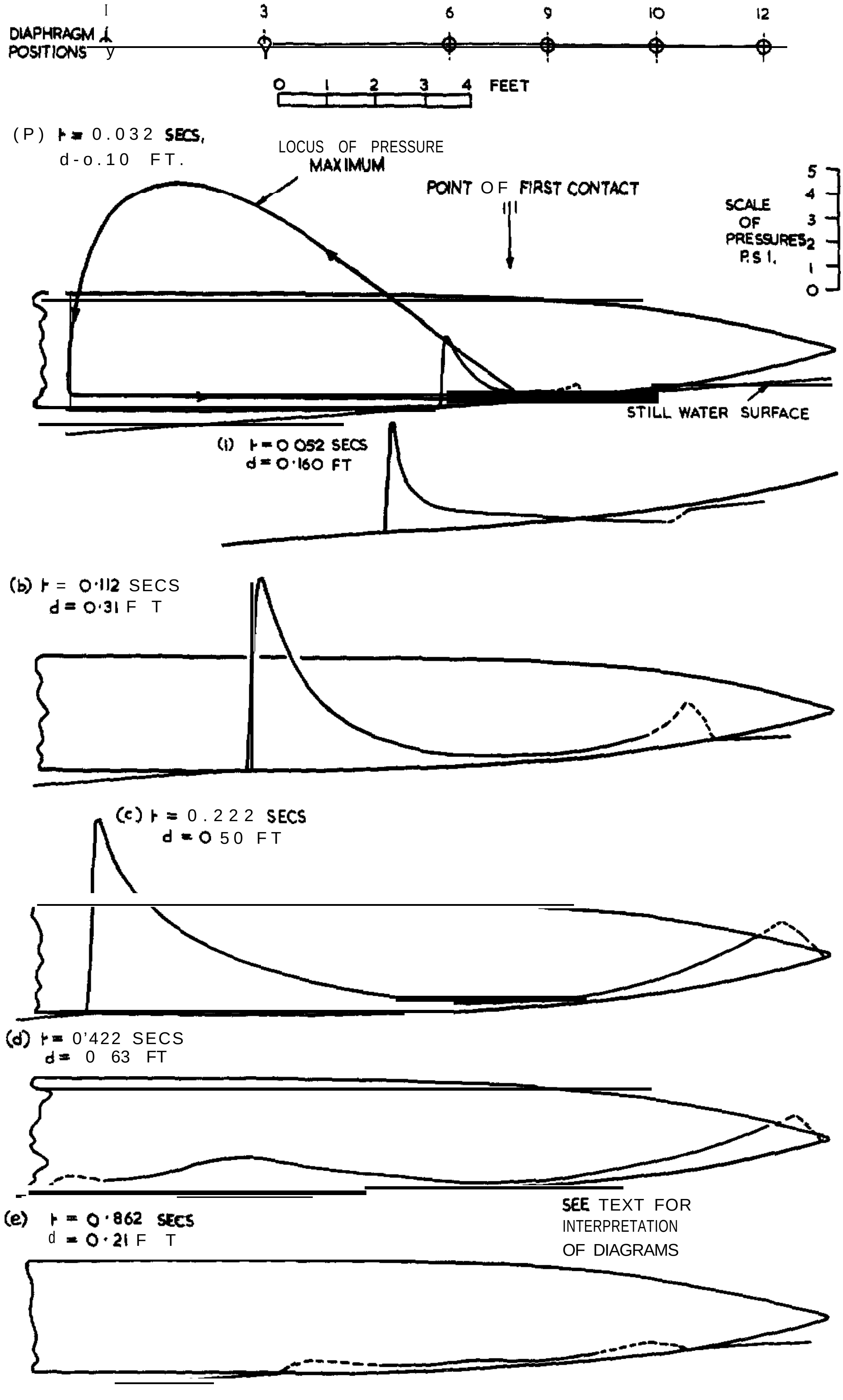
CENTRAL LINE PRESSURE DISTRIBUTIONS. $\tau_o = 4.7$; $\gamma_o = 2{\cdot}4^\circ$, $V_{H_o} = 33\ 7$ FT/SEC.

FIG.25.



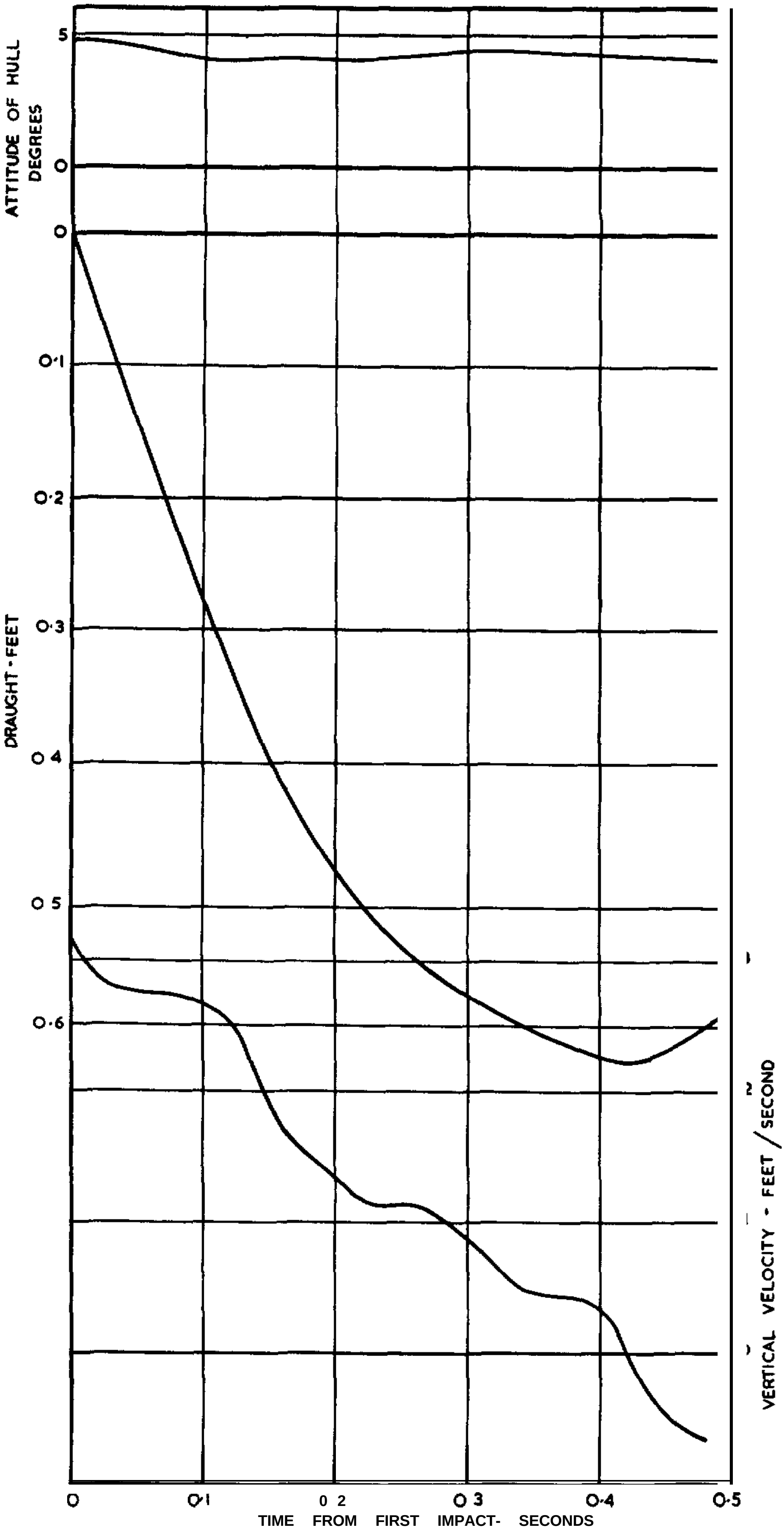
TIME HISTORY OF FORWARD RUN. $\tau_0 = 4{\cdot}7°, \gamma_0 = 5{\cdot}6°, V_{H_0} = 33{\cdot}0$ FT/SEC.

FIG. 25 A.



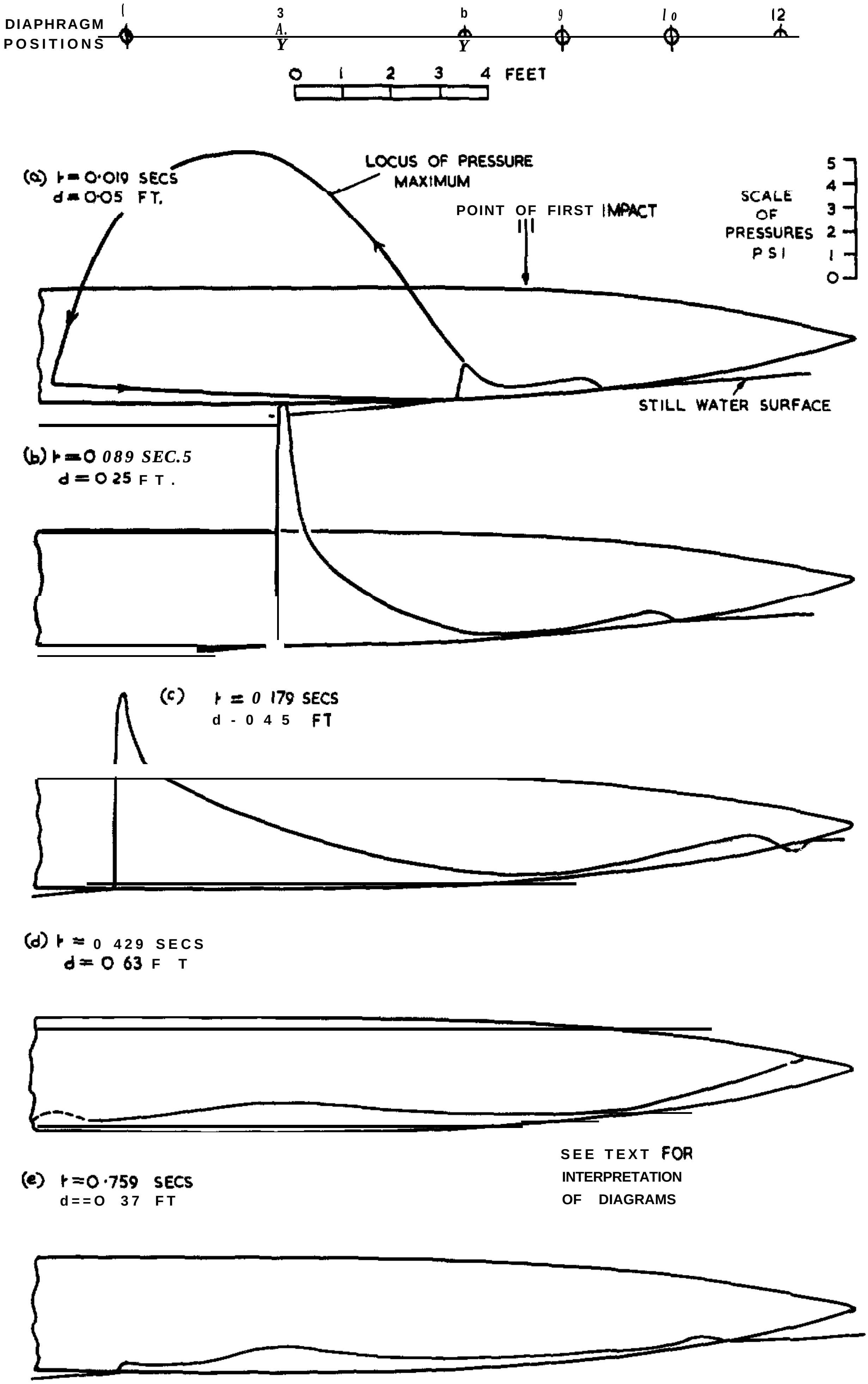
CENTRE LINE PRESSURE DISTRIBUTIONS. $\tau_0 = 4{\cdot}7^\circ$, $\gamma_0 = 5{\cdot}6^\circ$, $V_{H_0} = 33.0$ FT./SEC.

FIG. 26.



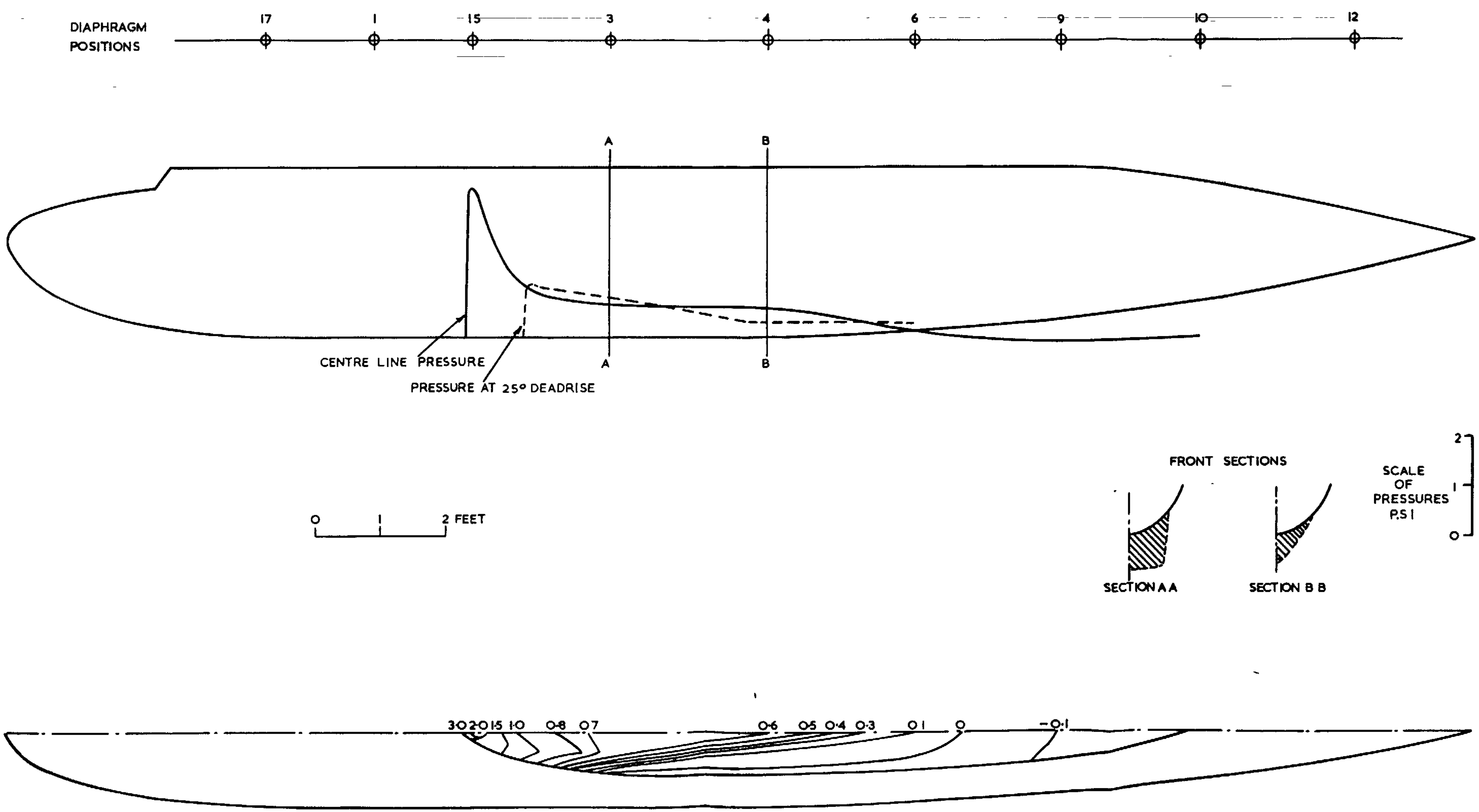
TIME HISTORY OF FORWARD RUN. $\tau_0 = 4{\cdot}7^\circ, \gamma_0 = 5{\cdot}9^\circ, V_{H_0} = 32{\cdot}7$ FT./SEC

FIG. 26A.



CENTRE LINE PRESSURE DISTRIBUTIONS. $\tau_0 = 4{\cdot}7^\circ$, $\gamma_0 = 5{\cdot}9^\circ$, $V_{H_0} = 32{\cdot}7$ FT/SEC

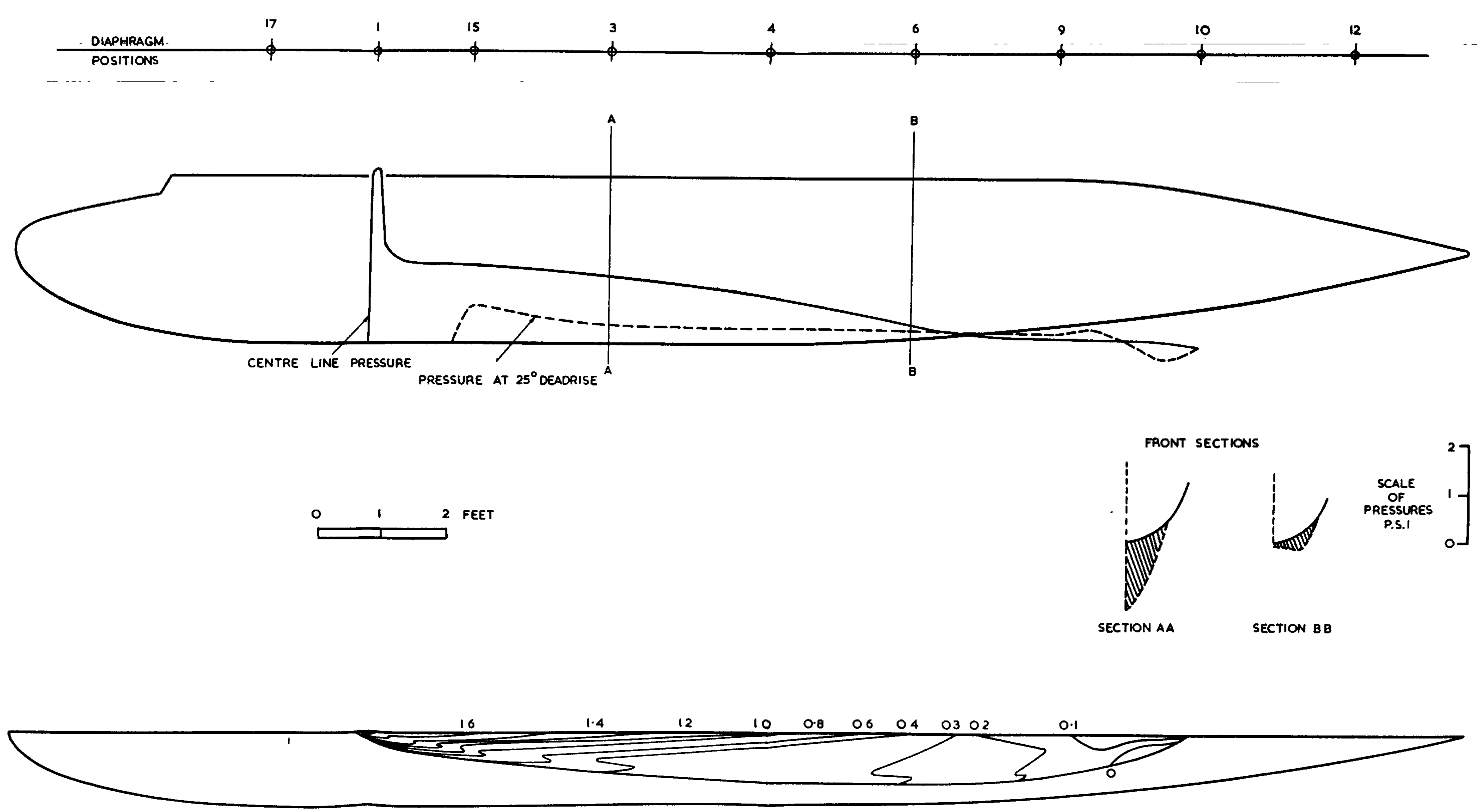
FIG. 27.



TYPICAL PRESSURE CONTOUR DIAGRAMS.

$\tau = 2{\cdot}65^{\circ}$ $d = 0{\cdot}228$ FT. $t = 0{\cdot}107$ SECS.

FIG. 28.

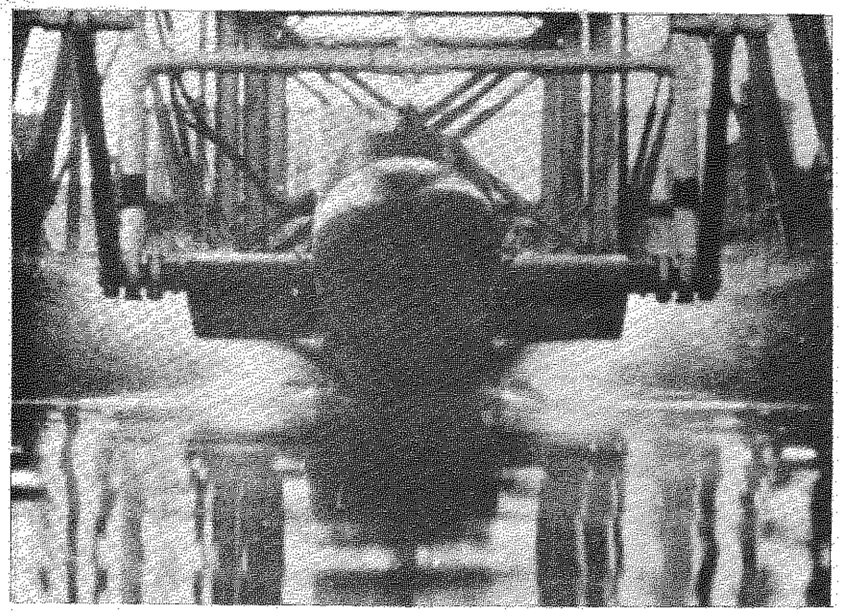


TYPICAL PRESSURE CONTOUR DIAGRAMS

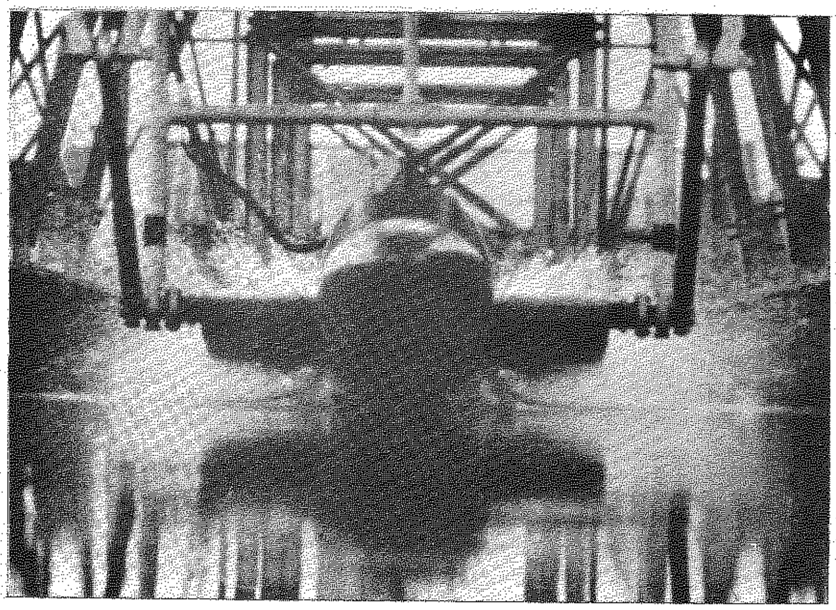
$\tau = 2{\cdot}5°$; $d = 0{\cdot}24$ FT, $t = 0{\cdot}21$ SECS., ($\tau_0 = 2{\cdot}5°$, $\gamma_0 = 2{\cdot}6°$, $V_H = 33{\cdot}0$ F.P.S. $V_V = 1{\cdot}5$ F.P.S.)

NEARLY FULL IMMERSION.

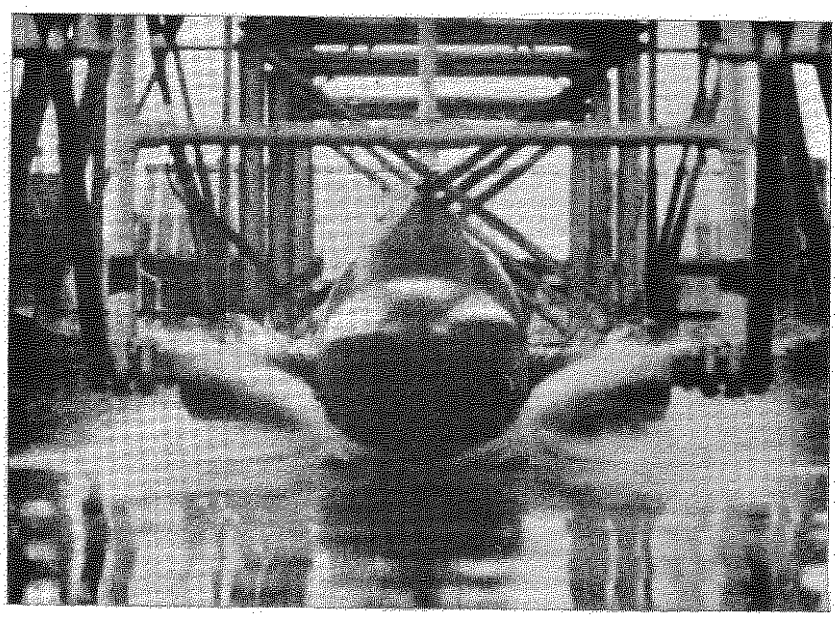
FIG. 29



FIRST CONTACT



DEVELOPMENT OF SPLASH AND REDUCTION OF ATTITUDE

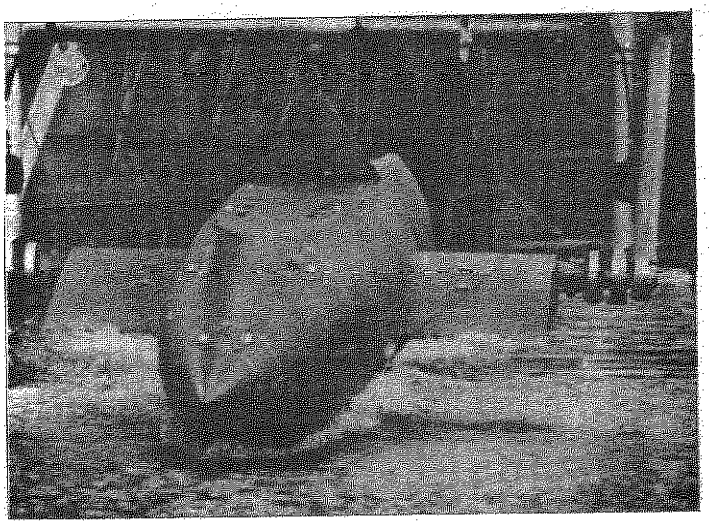


MAXIMUM DRAUGHT

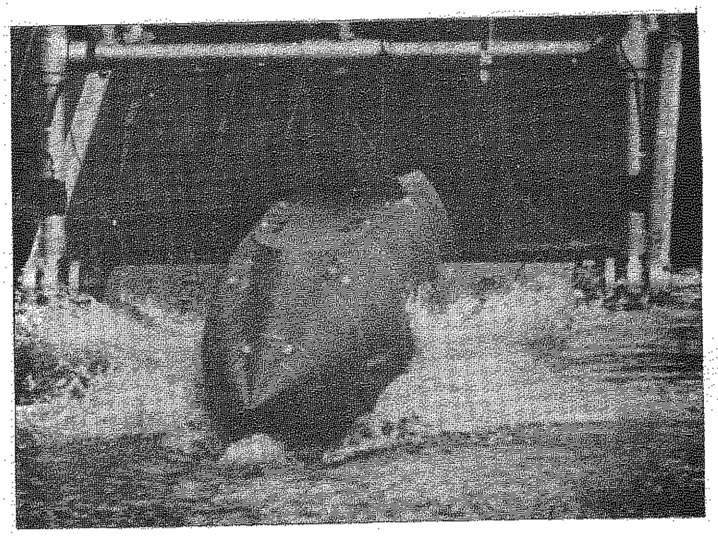
DEVELOPMENT OF SIDE SPLASH IN FORWARD RUN. ($\tau_s \doteq 5^\circ$, $\gamma_s \doteq 3\cdot5^\circ$)

FIG. 30

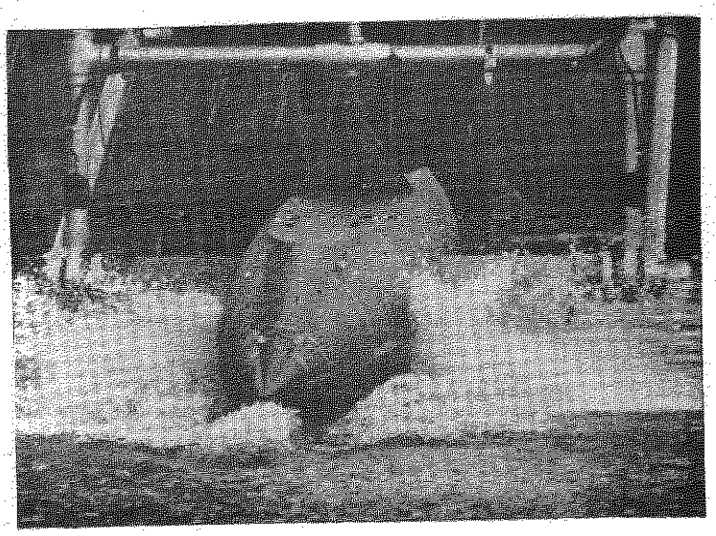
$t = 0.031$ sec.
$d = 0.065$ ft.
$\tau = 2.65°$



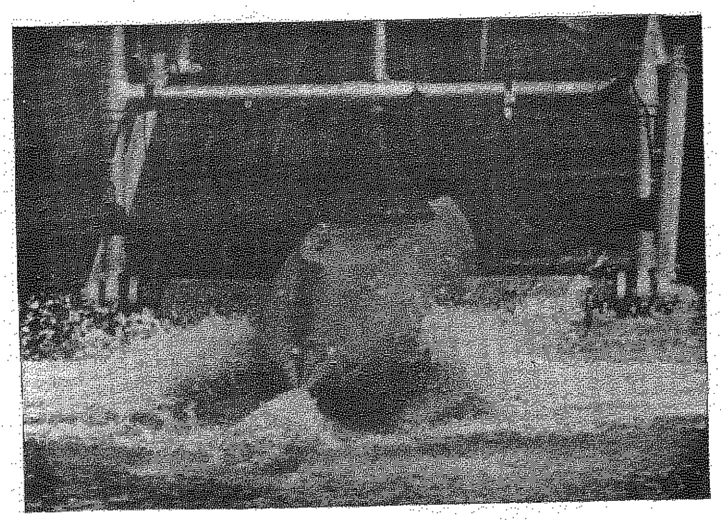
$t = 0{\cdot}067$ sec.
$d = 0{\cdot}145$ ft.
$\tau = 2{\cdot}65°$



$t = 0{\cdot}107$ sec.
$d = 0{\cdot}228$ ft.
$\tau = 2{\cdot}65°$

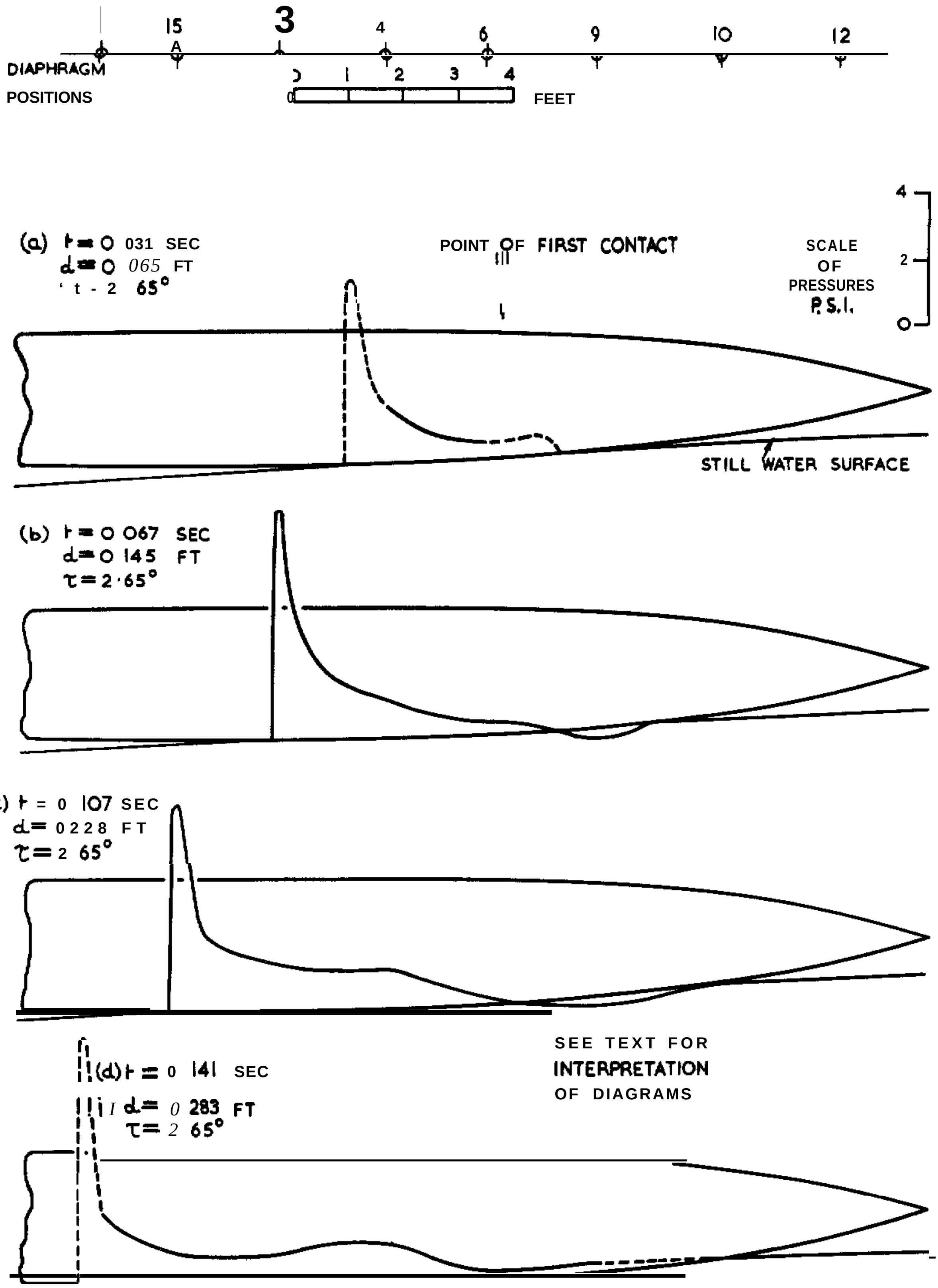


$t = 0{\cdot}141$ sec.
$d = 0{\cdot}283$ ft.
$\tau = 2{\cdot}65°$



SPRAY PHOTOGRAPHS ($V_{H_0} = 34{\cdot}1$ FT/SEC, $\gamma_0 = 3{\cdot}7°$)

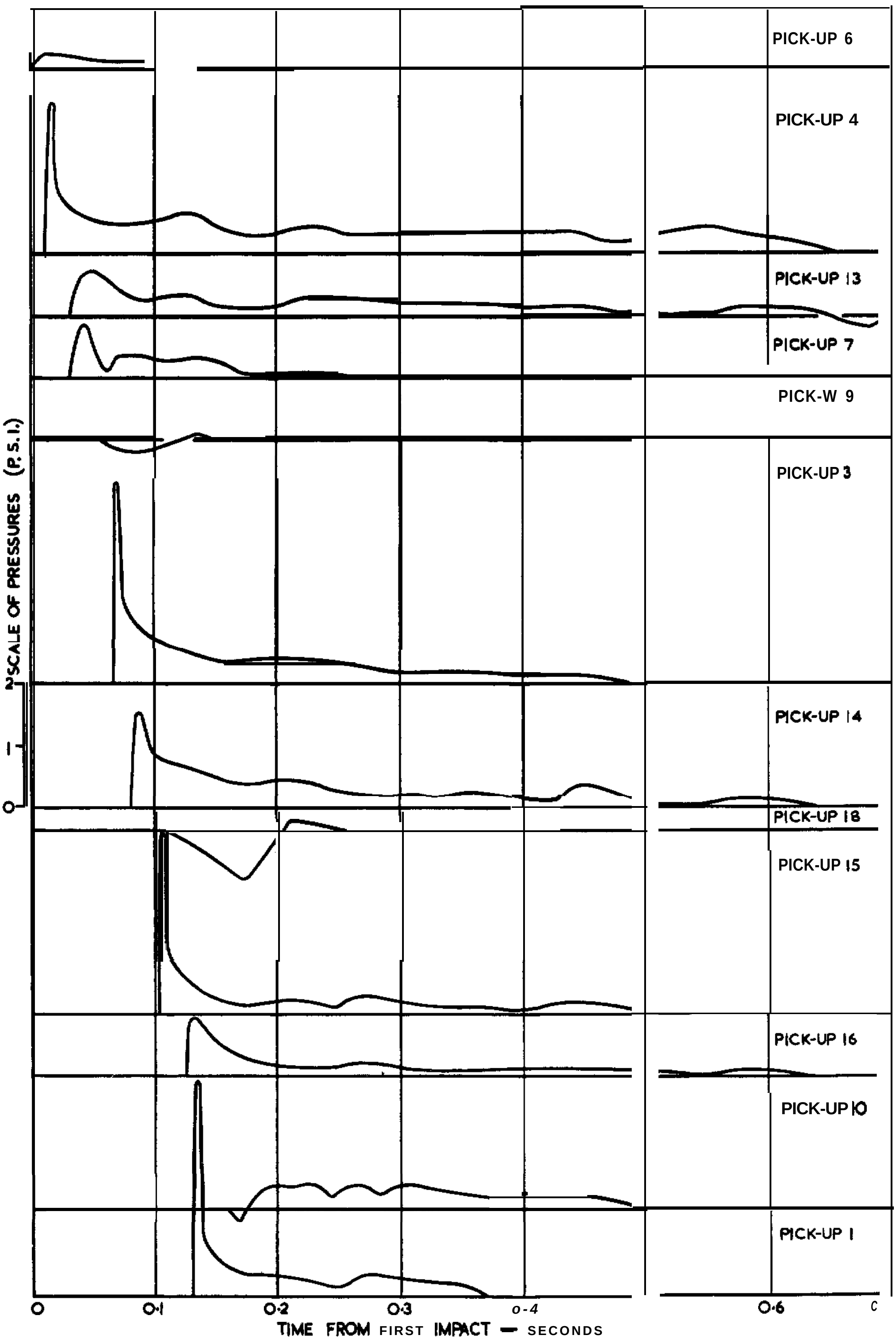
FIG. 31.



CENTRE LINE PRESSURE DISTRIBUTIONS. $\tau_0 = 2{\cdot}65°$, $\gamma_0 = 3{\cdot}7°$, $V_{H_0} = 34{\cdot}1$ FT/SEC.

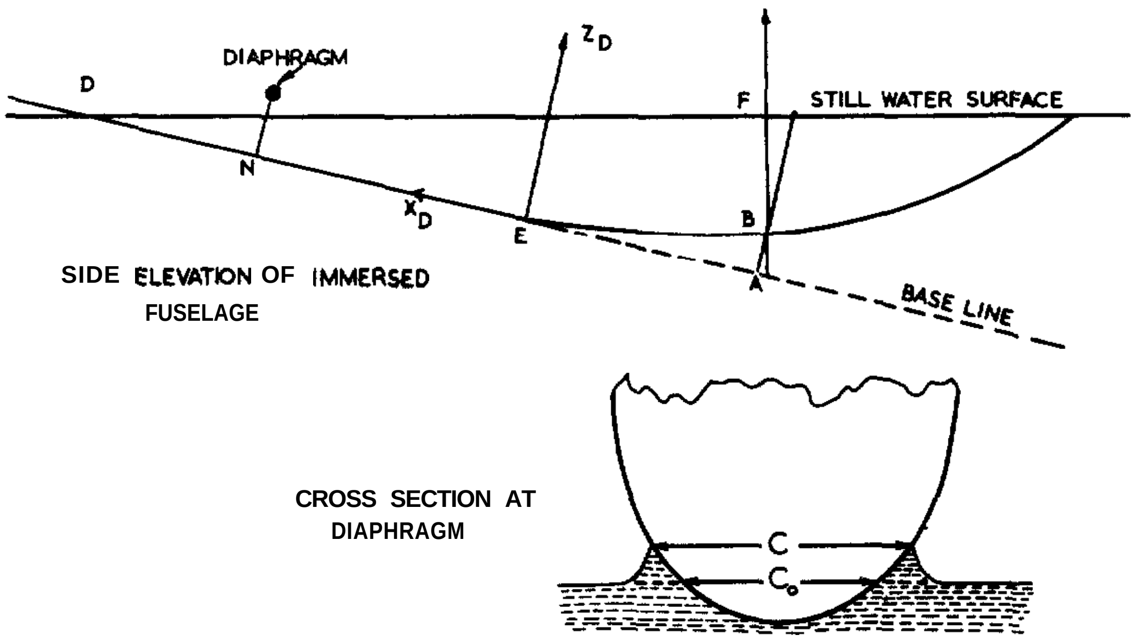
(cf. SPRAY PHOTOGRAPHS IN FIG. 30.)

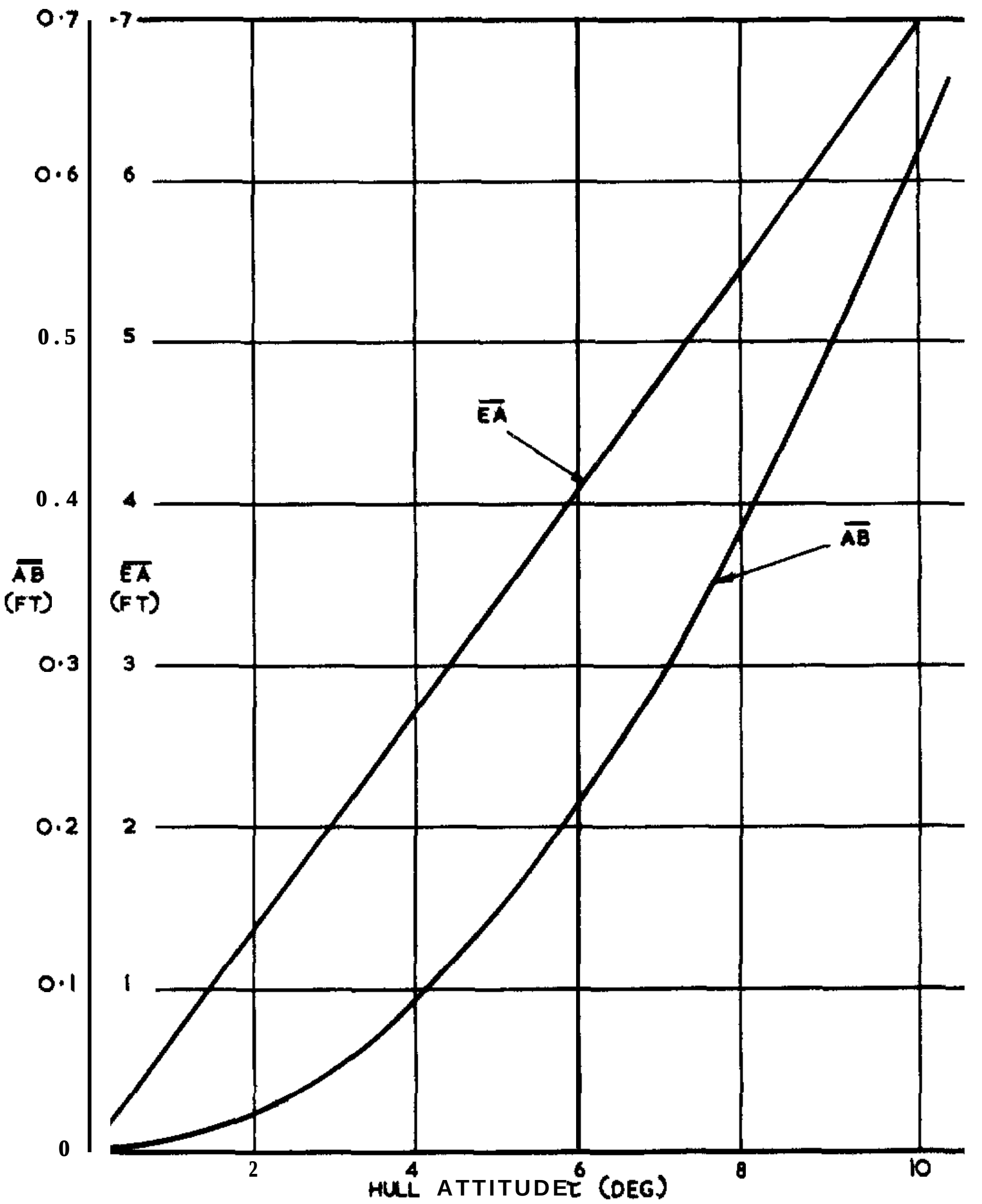
FIG. 31A.



TIME -HISTORY OF PRESSURES FOR FIG. 31.
$\tau_o = 2\cdot65°$, $\gamma_o = 3\cdot7°$; $V_{H_o} = 34\cdot1$ FT/SEC.

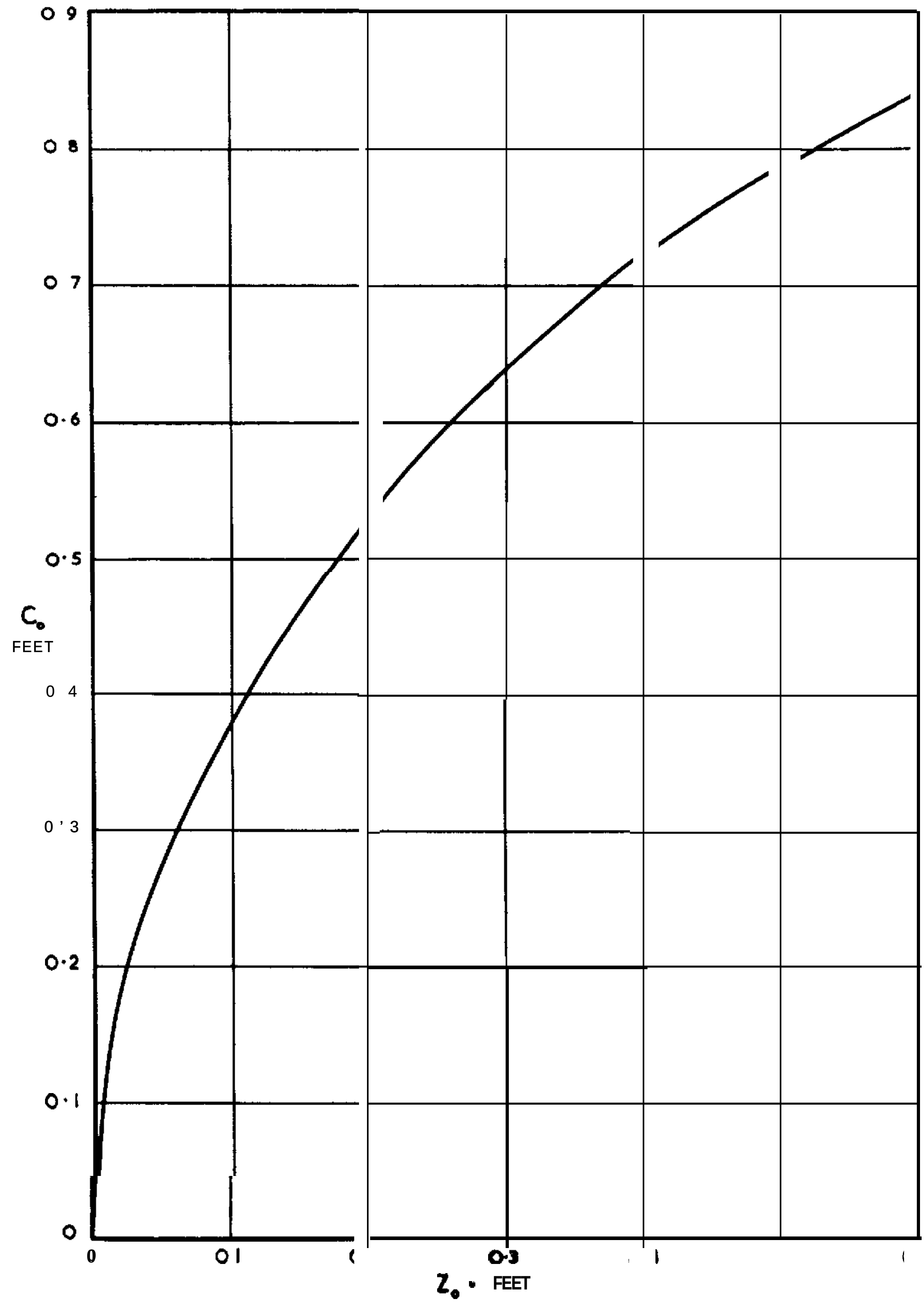
FIG. 32.





CALCULATION ff SPLASH UP APPENDIX I.

FIG.32A.



CALCULATION OF SPLASH UP. (APPENDIX I)

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