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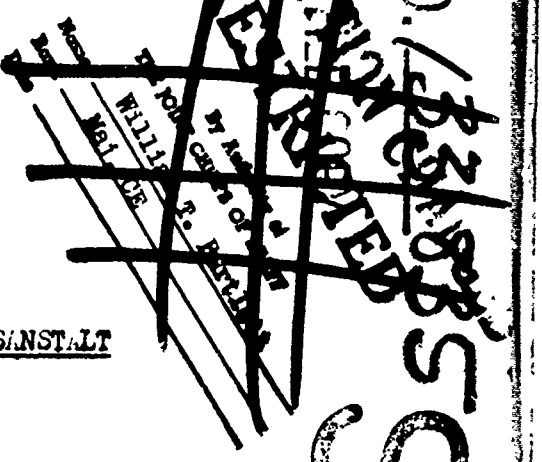

TECHNICAL REPORT No. 494-45

RESEARCH AT THE HAMBURGISCHE SCHIFFBAU VERSUCHSANSTALT

RELATING TO PRESSURE ACTUATED MINES

OCTOBER 1945

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TECHNICAL REPORT No. 494-45

RESEARCH AT THE HAMBURGISCHE SCHIFFBAU VERSUCHSANSTALT RELATING TO PRESSURE ACTUATED MINES

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SUMMARY

Because of the present interest in pressure actuated mines in the United States and the United Kingdom, this report has been prepared in detail and includes all of the experimental data and test methods available at the time the information was obtained. Except for general comments on the methods employed at the Hamburgische Schiffbau Versuchsanstalt and the errors inherent in these methods, no attempt has been made to analyse the data for purposes of utilization in an actual development program.

The results of pressure filed measurements of devices for ship protection are presented in detail. A series of wedges, keels and an airfoil secured to the hull of a 1/30 scale model of the cruiser "Lutzow" were tested for effectiveness in breaking up the ship's pressure field. This work was done at the Hamburgische Schiffbau Versuchsanstalt with a manometric system which is also described.

A subsidiary laboratory, the Forschungstelle für Stabilität und Schwingungen, was assigned the problem of originating and developing sweeps for the mine, but succeeded only in developing an inductance type micro-pressure gage before the war came to an end. This instrument and the methods of sweeping proposed for test at this laboratory are described.

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RESEARCH AT THE HAMBURGISCHE SCHIFFBAU VERSUCHSANSTALT RELATING TO PRESSURE ACTUATED MINES

Introduction

On 5 June 1944, a conference was held in Berlin to initiate a model basin research program leading to the development of suitable countermeasures for pressure actuated mines. Present were representatives of the Oberkommando der Kriegsmarine[1], by whom the meeting was called; the Sperr Versuchs Kommando[2]; the Hamburgische Schiffbau Versuchsanstalt[3]; and the Preussische-Versuchsanstalt für Wasser-,Erd-, und Schiffbau.

The reason for this meeting was revealed to an engineer of HSVA by a member of SVK although it was not announced to the general assembly. This reason was given as an inducement for HSVA, a non-governmental organization, to contract for the project, since that plant was already overloaded with work for the Luftwaffe which evidently had no effective coordination with the Kriegsmarine on the assignment of projects to individual laboratories. This reason is related exactly as told to the HSVA representative and no attempts have been made to check the details of the sequence of events for intelligence purposes. In May 1944, mines requiring pressure signals for actuation were dropped from aircraft off the coast of Holland. A few of these mines, however, were blown inland and landed on the beaches. When these mines were recovered by German personnel, it was found that the actuating mechanism had been removed, presumably by members of the Dutch underground. As a result, it was feared that the mechanism would fall into the hands of the Allied Powers and subsequently be used in operations against the Germans. Up to this time, no serious attempts had been made by the German Navy to develop countermeasures, although some full scale work on the problem had been initiated by the SVK

1. OKM - The German Naval High Command or Navy Department.

2. SVK - Organization for the full-scale development of mines and countermeasures. The work of this group on pressure actuated mines, as well as other types of German mines, is reported in another report of the U.S. Naval Technical Mission in Europe.

Introduction (Cont'd)

3. HSVA - The model basin in Hamburg. The material for this report was obtained from the reports and personnel of HSVA and FSS (Foot note 5).

4. FVMES- The model basin in Berlin.

5. FSS - Laboratory for studies of ship rolling and stability.

6. Ing. Werner Hinterthan was the engineer in charge of this phase of the work at HSVA.

7. This work was to be carried out by Dr. Ing. Karl von Steinen, director of the FSS.

8. Dr. von Steinen, however, did observe a full-scale test of a hydrofoil installed on an M-boat for breaking up its signature. The results of this installation are covered by the minesweeping group of U.S. Naval Technical Mission in Europe.

9. This model was the only suitable model available after the HSVA was partially burned out in July 1943.

As a consequence of this indication that the mechanism had been compromised, it was decided not only to extend the full-scale work of SVK[2], but also to institute a research program at the Hamburgische Schiffbau Versuchsanstalt and its subsidiary laboratory, the Forschungstelle für Stabilität und Schwingungen[5]. The work at HSVA was concerned exclusively with the investigation of methods for individual ship protection[6]. This consisted of determining the characteristics of various devices secured to the ship's hull for breaking up the ship's signature. The FSS was assigned the problem of originating and testing sweeping methods[7]. As far as can be determined, both groups worked independently, and neither group was informed of the progress being made by the SVK[8].

The pressure measurements for ship protection devices were made at the HSVA with a manometric system. The FSS concentrated on the development of an inductance type micropressure gage and, consequently, had made very little progress on sweeping methods when the war ended.

Introduction (Cont'd)

Due to the urgency of the problem and the lack of personnel, no theoretical work was done and no systematic tests were made to determine the laws governing the variables.

The FSS had outlined an extended program of experimentation on suggested methods of sweeping. Although no conclusive tests were made, these suggestions are reviewed in this report. The pressure measurements made by the HSVA are fully described herein. Although power requirements for the various ship protection schemes were also determined, these records have been removed by a team from the Admiralty Experimental works, Haslar, U.K., and were not immediately available for this report.

The tests of ship protection devices were all conducted on a 1/30 scale model of the cruiser "LÜTZOW"9. The specifications for appendages suitable for ship protection called for a device which would supply a positive pressure hump in the signature of this ship. The negative pressures on either side of this hump were not to exceed 7 second in duration at speeds above 20 knots. The maximum depth of water in which the positive hump was required was specified at 50 meters full scale. No limits were set on the maximum permissible power losses accompanying the resistance of these appendages.

For the sweeping devices, the FSS was given specifications which called for the production of a negative pressure field in which could be inscribed a rectuangular signal having a negative pressure change of 20 mm of water and a time out period of 8 seconds. No specifications were given on the depth of water in which this signal was to occur. However, the tests were to be made in water depths corresponding to 10, 20 and 30 meters of water. No details of the operation of the mine mechanism were furnished the personnel of either the HSVA or the FSS.

In order that the tests made at HSVA be of use in the development programs now underway in the United States, all data that are believed to be applicable are presented. Although the HSVA program was directed exclusively toward ship protection, the data may be useful in the determination of the practicability of sweeping a pressure actuated mine by "tricking" with a positive pressure pulse. As a result, the tests of the airfoil employed for breaking up the ship'd signature with a positive pressure hump are presented in complete detail while sufficient data for analysis purposes are presented for other devices.

PART I

METHODS AND INSTRUMENTATION FOR PRESSURE FIELD MEASUREMENTS

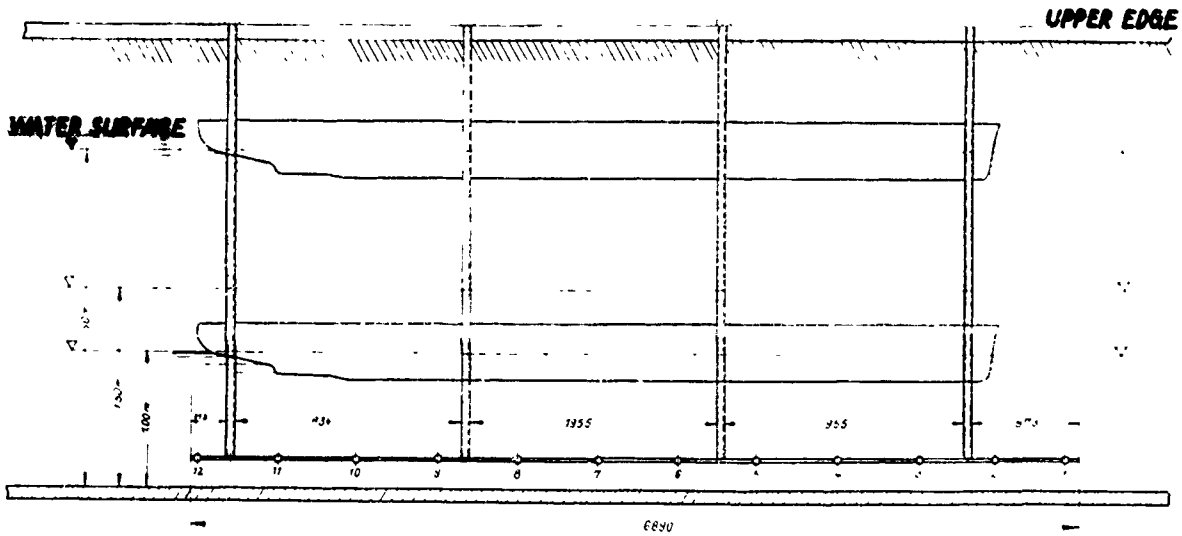
The Manometric System at HSVA[10]

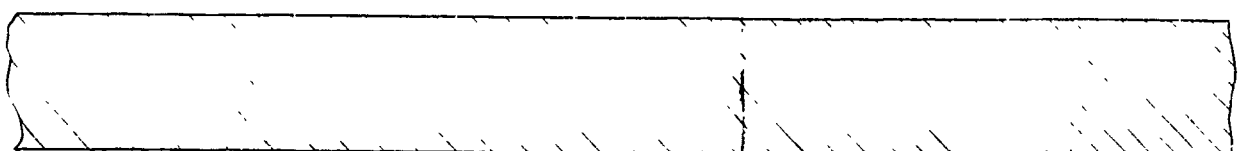
The pressure changes under the hull of a ship model were measured by taking the difference between the static pressures at points under the hull and the static pressure in the free stream. The test arrangements for this system are shown on Figures 1 and 2. Figure 1 is an early scheme for determing the keel signature only. Figure 2 shows a later alteration for measuring athwartships fields. A long tube, 24mm in diameter and 6.89 meters long, was suspended from the V-shaped (and later, trapezoidal) frame with the centerline 95 cm. below the water surface and 5cm. above the shallow water bottom. Piezometer holes, 2mm in diameter, were located at 12 positions along this tube, as shown in Figure 1. At each station, 4 holes were symmetrically located on the circumference of the tube on radii which made angles of 30 degrees with the horizontal centerline of the tube cross-section. The 4 holes at each station were then connected to a common manometer tube. Although earlier tests were made with 4 holes on the horizontal and vertical centerlines of the tube, it was found that the flow near the bottom holes were greatly affected by the unevenness of the shallow water bottom which had been badly warped due to bomb damage and submergence while not in use for long periods. The reference pressure was taken from the static side of a "Prandtl" tube placed in the free stream well away from the model.

The piezometer holes were connected to an inclined manometer by means of small tubes threaded through the struts of the supporting frame. Water was drawn up into the manometer to a predetermined level with an evacuating pump, and then colored with potassium permanganate[11] to provide good contrast when photographing the manometer board. An example of photographs of the manometer board taken during an actual test is shown in Figure 3. From enlarged photographs of this type, readings were taken to the nearest 0.2mm. However, the actual accuracy of the tests was taken to be about $\pm$ 2mm since this value represents the maximum surface level changes resulting from a seiche set in the movement of a model.

10. The pressure gage under development at the FSS is described in the Appendix

TEST ARRANGEMENT





FIGURE

MANOMETRIC ARR
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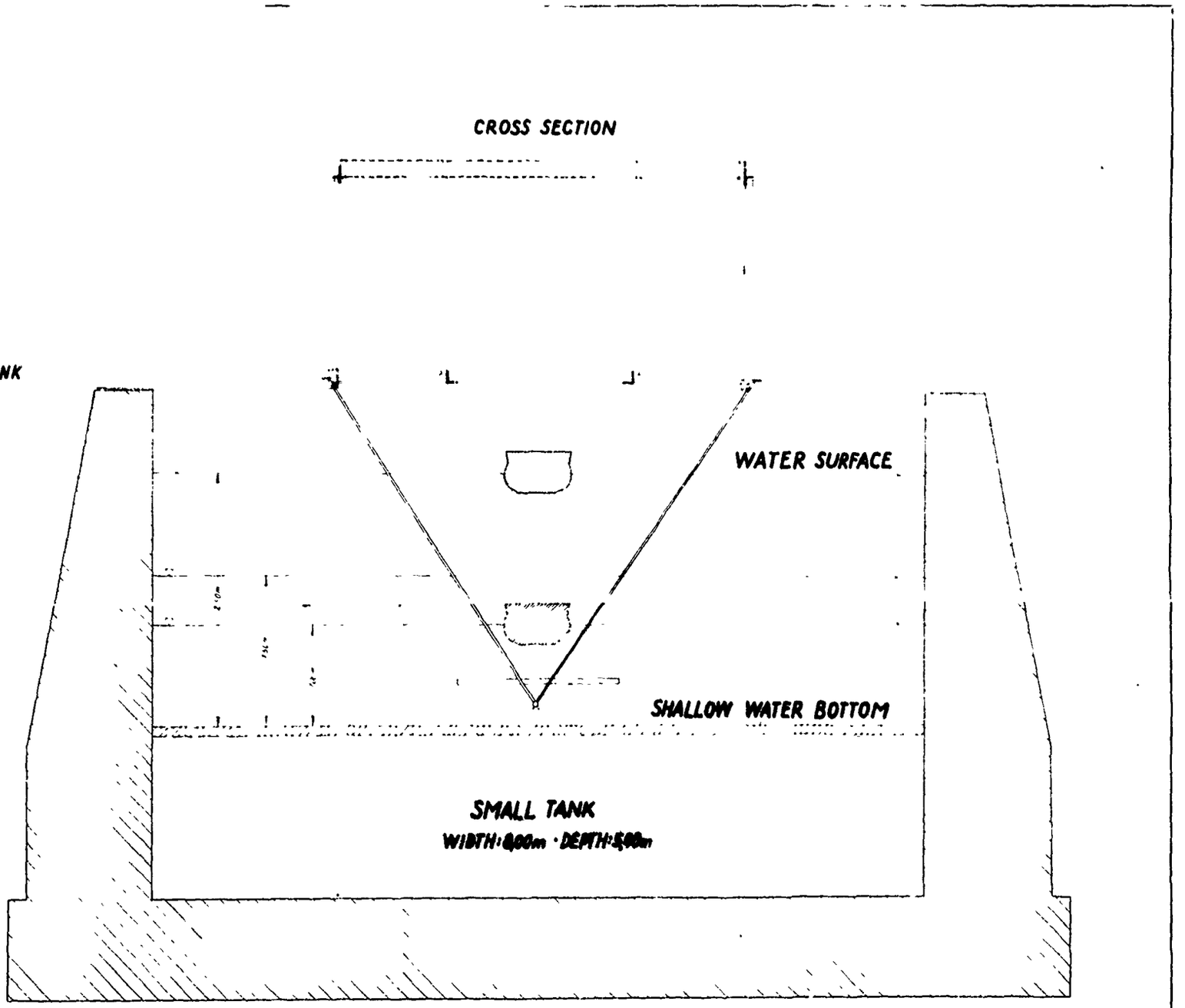
SHIP - M



URE 1.
ARRANGEMENT FOR
SIGNATURES OF
- MODELS

The Manometric System at HSVA (Cont'd)

11. Although the water column in each tube was continuous to the basin water, the dilution of the potassium permanganate at the piezometer holes was not sufficient to affect the color intensity.

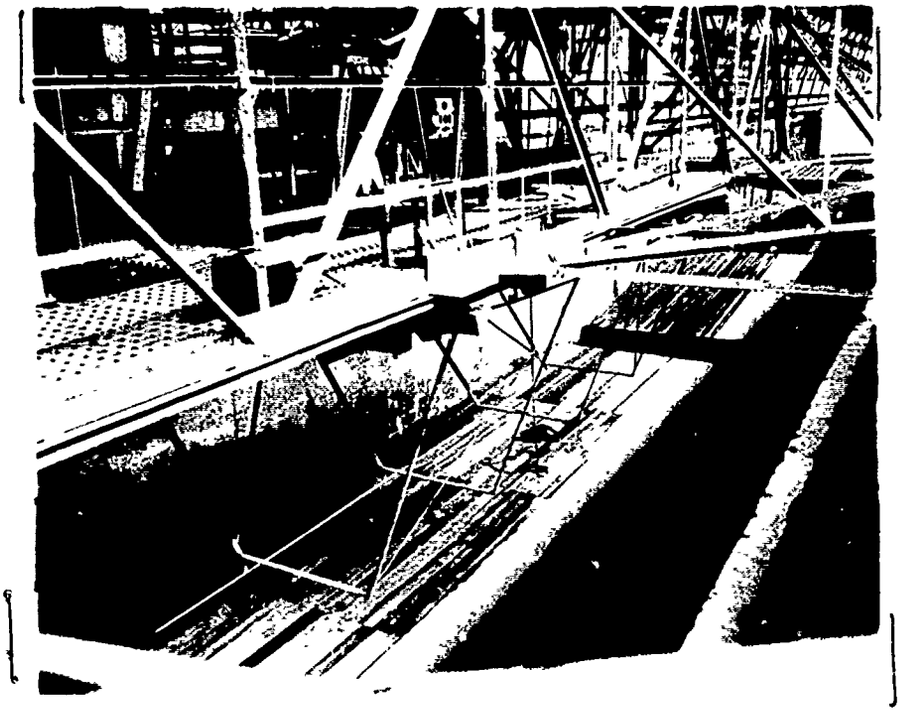


Figure 2

The piezometer tube and frame installed under the carriage at H.S.V.A. The tube is displaced to the left of the centerline for athwartships pressure field measurements. Part of the shallow water bottom is shown beneath the carriage.

The Manometric System at HSVA[10] (Cont'd)

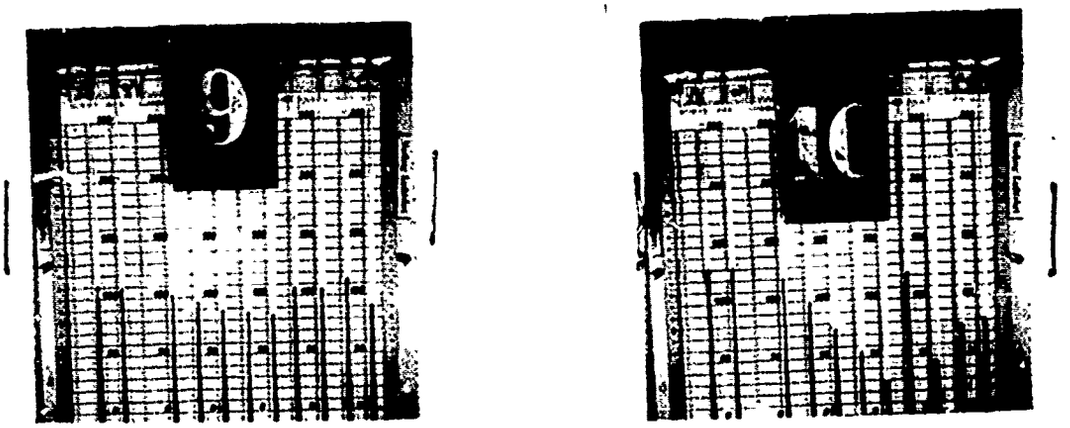


Figure 3

Typical manometer board photographs taken during an actual test. The fourth tube from the right is the reference free steam pressure.

In order to avoid the influence of seiches on the calibration of the manometric system, the calibration tests were always made at the start of a day's testing before any models were placed in the water. The only available calibration of the system is given in Table I, and the values are plotted on Figure 4.

TABLE I

Calibration of Manometric Pressure Measuring System (mm of water)

Water Depth (Meters)	Speed (Knots)	Piezometer Number (See Figure 1) 1	2	3	4	6	7	9	10	11	12
5.06	20	-7.8	-0.6	-1.4	-0.2	-1.1	-1.1	-1.1	-1.1	0	-9.8
5.06	30	-6.4	-1.8	-3.7	-3.0	-2.1	-2.4	-1.5	-1.5	0	-13.9
1.00	20	-7.8	-0.6	-0.3	-0.3	-0.3	-1.2	-1.5	-3.4	-0.8	-11.5
1.00	30	-7.1	0	-2.9	-2.7	-2.4	-1.6	-0.8	-3.5	-0.5	-21.6

Notes: 1. Speed is given for the full scale ship. All other values are for the model conditions.

2. For convenience in the conversion of data for purposes of analysis, the actual values , where available, as well as the plotted curves, are given throughout this report.

These values were, of course, subtracted from the readings taken during an actual test to obtain the influence of the model alone. All values subsequently given in this report have been corrected for this calibration, but the corresponding full scale values have not been determined[12].

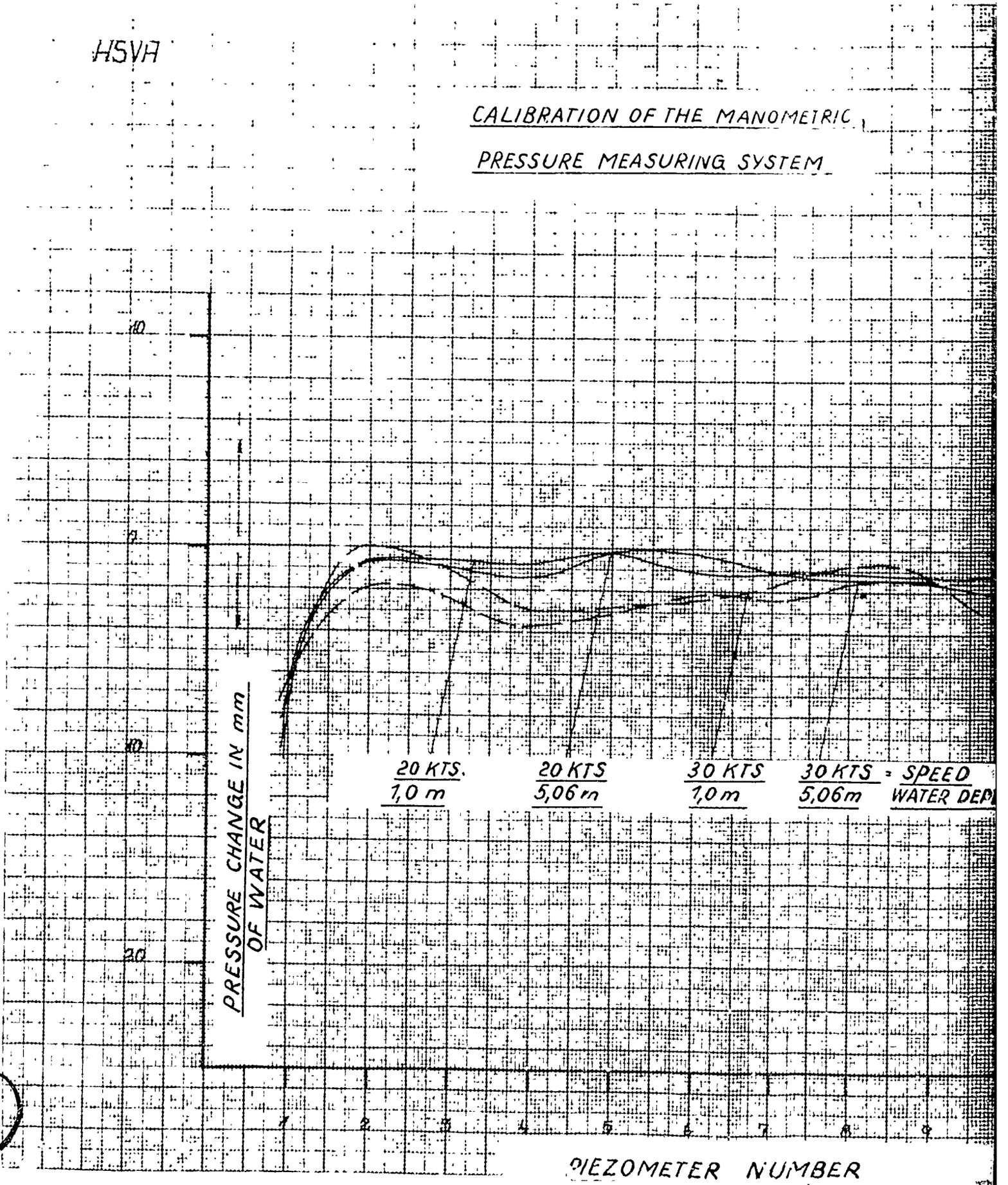
Procedure In Testing a Model at HSVA

The method of installing the model of the "LÜTZOW" is shown on Figures 1 and 5. For keel signatures, which constitute the greater number of tests made, the piezometer tube was under the centerline of the ship. A few tests were conducted to obtain athwartships signatures with the arrangement shown in Figure 2. The model was placed with the stem directly above piezometer number 2 and the stern above number 12. For intermediate test spots, the model was displaced fore or aft with respect to the piezometer tube.

12. Comments on the methods used at HSVA are given at the end of Par. 2.

HSVA

CALIBRATION OF THE MANOMETRIC PRESSURE MEASURING SYSTEM

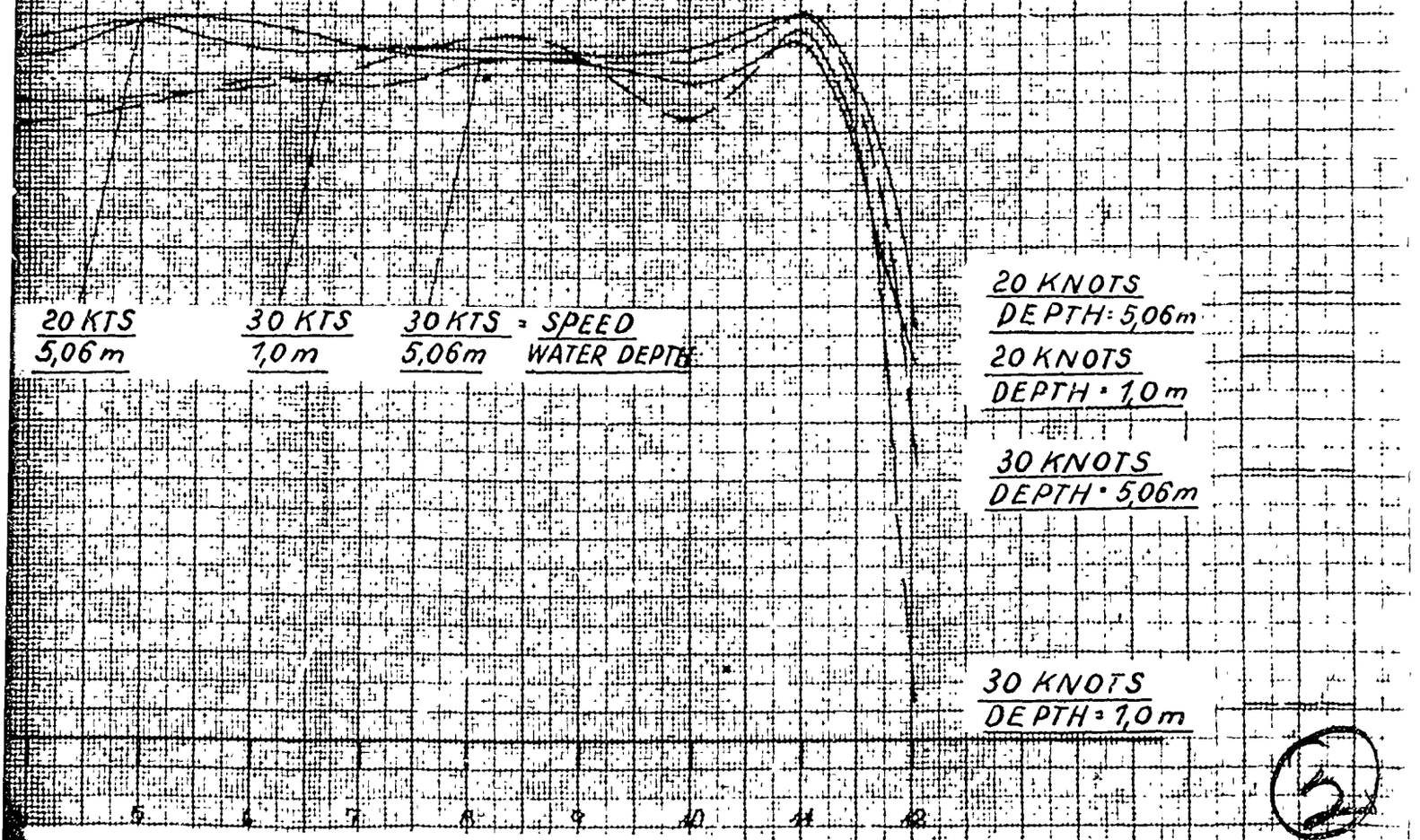


(1)

BRATION OF THE MANOMETRIC

SURE MEASURING SYSTEM

FIGURE 4



Procedure In Testing Model at HSVA (Cont'd)

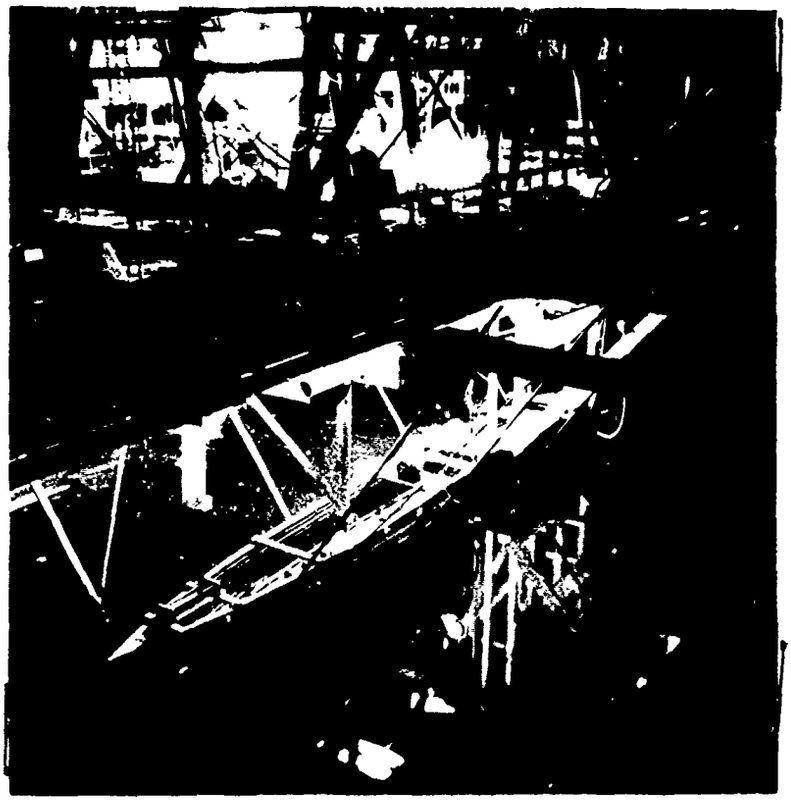


Figure 5

The 1/30 scale model of the "Lutzow" is shown installed within the manometric frame for measurement of keel signatures.

For all tests, the model was self-propelled at the desired corresponding speed. In the first series, attempts were made to measure the power requirements simultaneously with the pressure change measurements. However, it was found that the fore and aft movements of the model relative to the towing carriage during the adjustment of propeller revolutions caused a fluctuation in the pressure measurements leading to errors. As a result, the actual tests of power and of pressure were carried out independently. In every case, how-

Procedure In Testing a Model at HSVA (Cont'd)

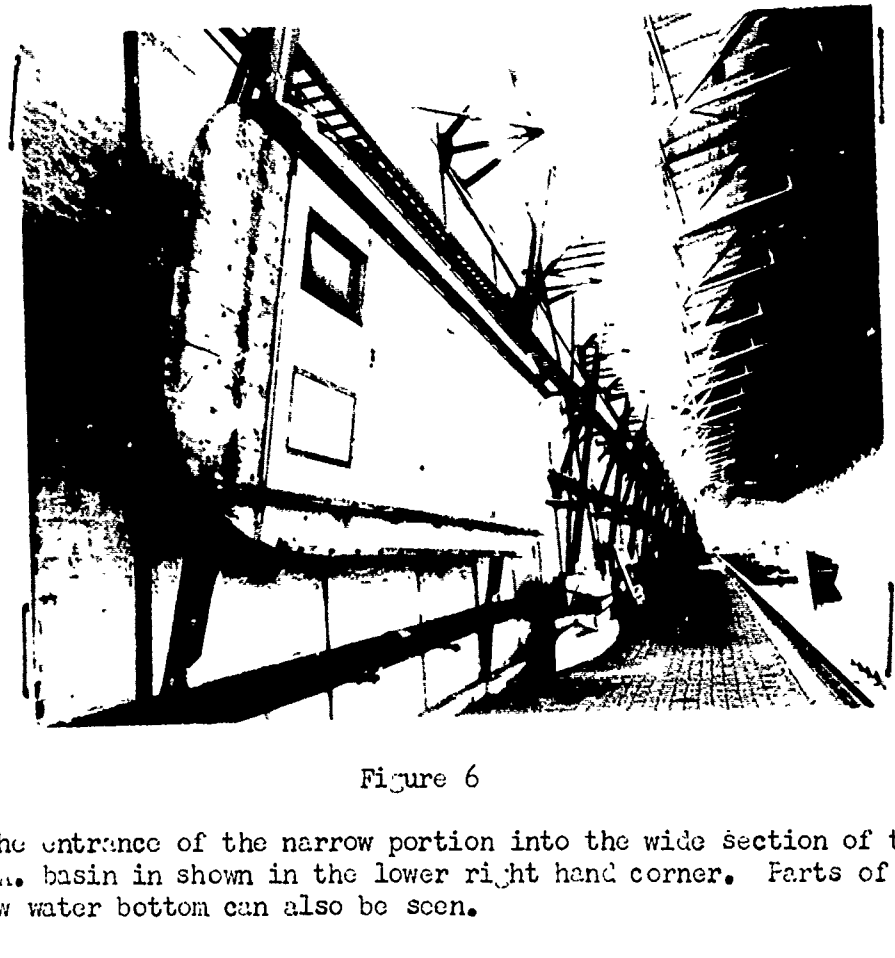


Figure 6

The entrance of the narrow portion into the wide section of the H.S.V.A. basin in shown in the lower right hand corner. Parts of the shallow water bottom can also be seen.

Procedure In Testing a Model at HSVA. (Cont'd)

Figure 7

The large carriage of H.S.V.A. is shown standing over the narrow section of the basin. The outer set of rails continues along the entire length of the wide basin.

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PART II

TESTS OF APPENDAGES ON A 1/30 SCALE MODEL OF THE "LÜTZOW" FOR SHIP PROTECTION AGAINST PRESSURE ACTUATED MINES

Preliminary Tests of the Model Alone

Before any tests were made to determine the influence of devices secured to the ship's hull, tests were made to "calibrate" the model for keep signatures as a reference for the subsequent experiments. The dimensions of the model were as follows: Length (water line), 6.067 meters; Beam, 0.689 meters; and Draft, 0.1923 meters. The results of these tests are shown in Table 2 and have been plotted on Figure 8.

TABLE 2

Keel Signatures of a 1/30 Scale Model of the Lützow (mm of water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	-	+4.0	-2.2	-4.4	-4.8	-4.9	-4.3	-1.5	0	+0.5
30	5.06	-1.5	+3.3	-2.9	-10.0	-17.5	-18.6	-16.3	-10.9	+0.7	+2.5
20	1.00	+9.0	+4.4	-5.2	-8.3	-9.9	-10.4	-9.7	-1.3	+1.3	+5.2
30	1.00	+4.2	+11.6	+12.0	-6.4	-32.0	-54.0	-68.6	-69.0	+60.6	-43.9

Appurtenances Tested for Breaking Up the Ship's Signature

Three types of appendages were tested for effect on the ship's signature. The first two types of devices, a series of wedges and a series of plate arrangements, were dependant on displacement effect to produce a positive hump in the negative pressure signal. The third method made use of an airfoil which produced a positive hump by transfer of lift to the bottom of the channel, or to the point at which the measurement was being made.

The several wedge arrangements are shown on Figure 9, wedge numbers 3-6. A series of six single wedges fixed to the model above piezometer hole number 7 at construction frame 10 were first tested.

Appurtenances Tested for Breaking Up the Ship's Signature (Cont'd)

These wedges extended the entire width of the model, 380mm. The length of each wedge was 180mm. A seventh wedge arrangement utilized two wedges in tandem, Figure 9, number 13.

The keel arrangements, Figure 9, numbers 9-11, were a series of plates perpendicular to the hull and with various openings between them at the leading and trailing edges. These plates had a height of 52mm and a length of 1.0 meter. Another type of keel arrangement, designate "plows", Figure 9, numbers 14 and 15, utilized plates inclined to the ship's hull.

The airfoil tested, Figure 10, was the Göttingen profile no. 620. The model was made of teakwood with the following overall dimensions: span, 1670mm: chord, 316.6mm. The airfoil was tested in two positions: at the midships section, frame 10, and again piezometer no. 5, 1440mm forward of frame 10. Tests were made with the airfoil at distances of 167, 250, and 333mm. below the hull of the model. The foil was supported by three struts, two forward and one aft, arranged to facilitate changes of the angle of attack. In general, tests were made at angles of attack of 0-, 4-, and 6- degrees.

For the experiments with the wedge and plate arrangements, only centerline signatures were obtained. Tests with the airfoil included one series of athwartships pressure signatures.

Results of the Pressure Measurements

1. Wedge arrangements

(a) Single wedge

The test arrangement and the reference to the pertinent table of results and the corresponding plots of these data are summarized in Table 3.

HSVA

KEEL SIGNATURES OF THE MODEL WITHOUT APPENDAGES

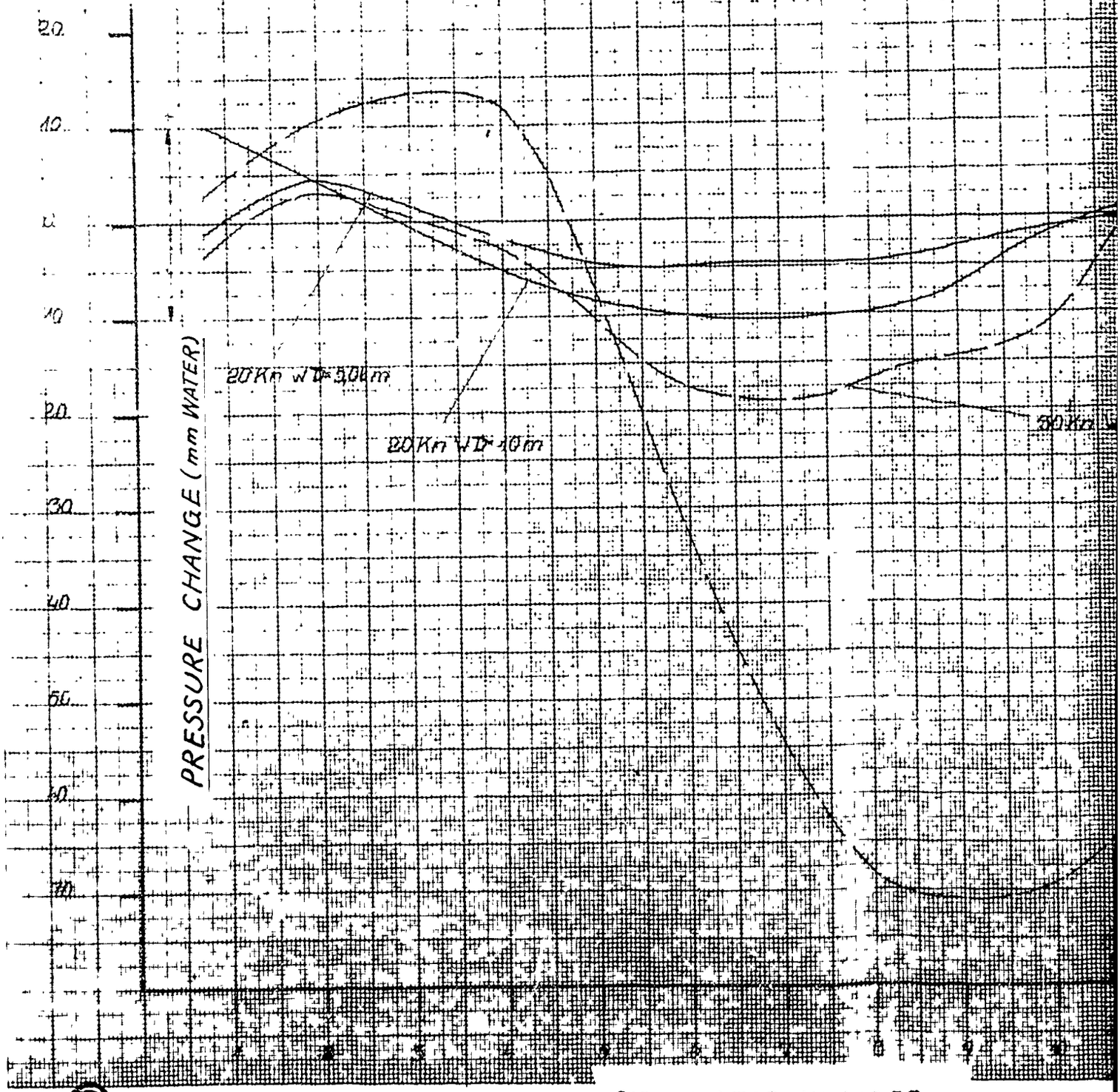

FIGURE 8

L SIGNATURES OF THE MODEL

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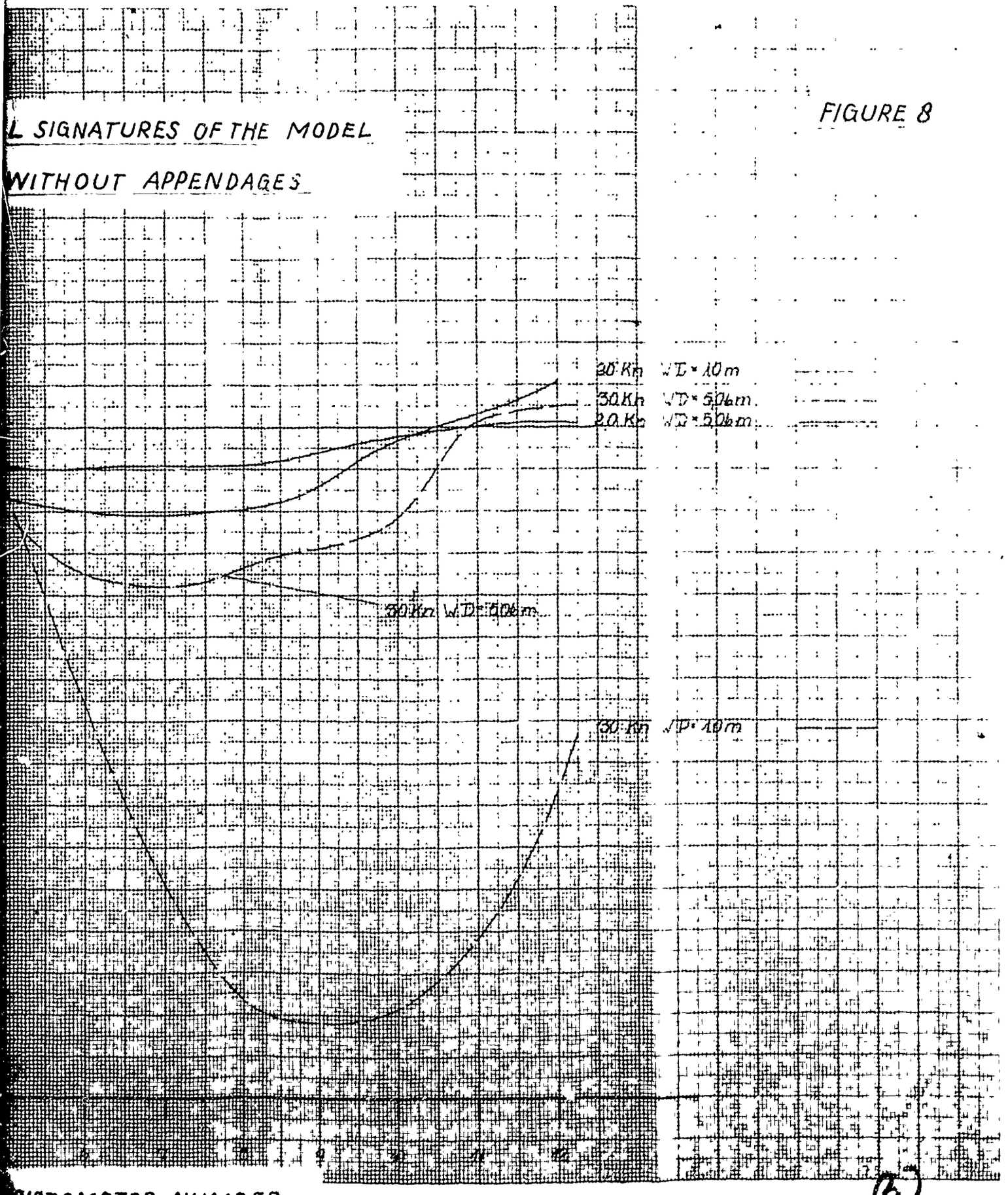

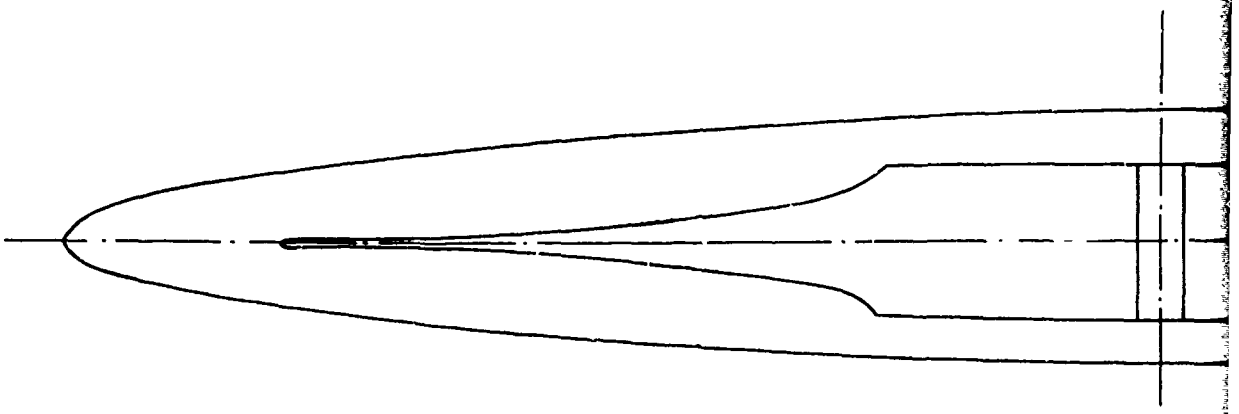

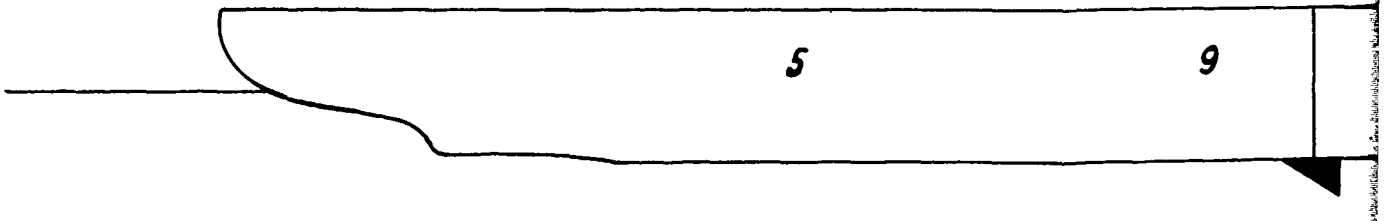
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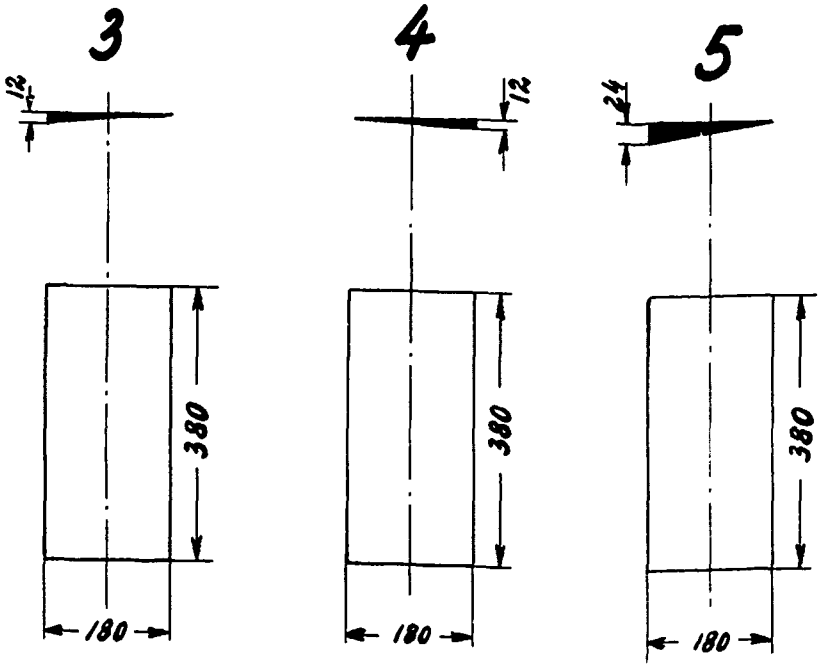
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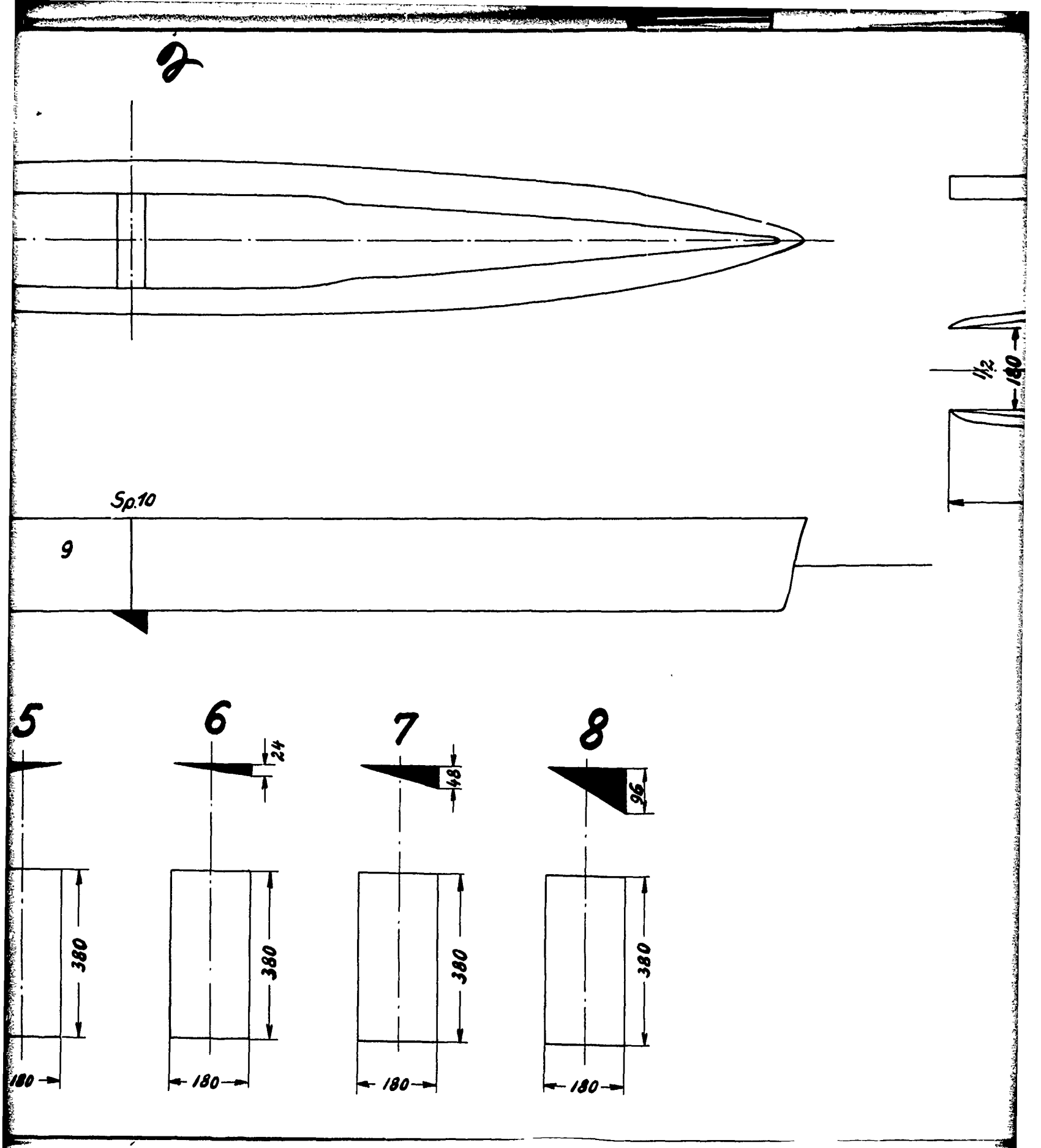
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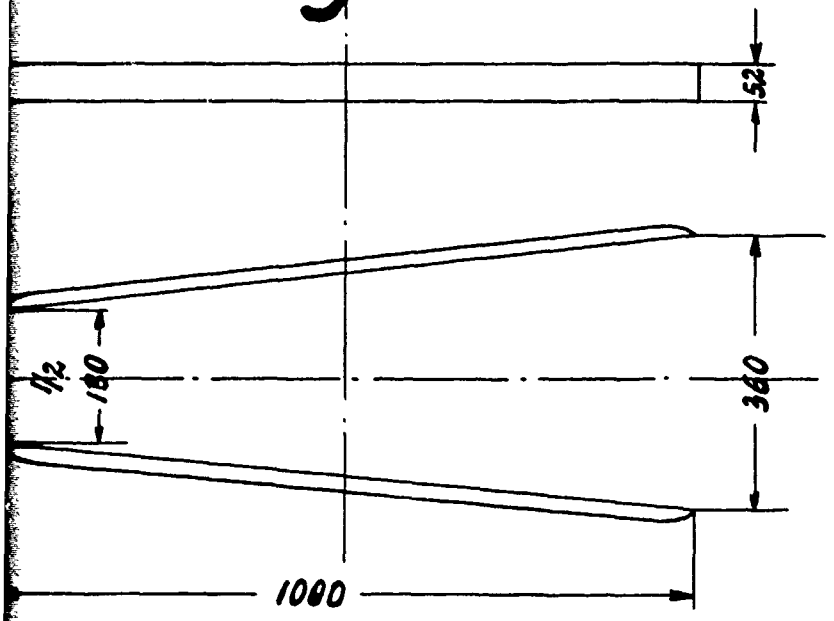

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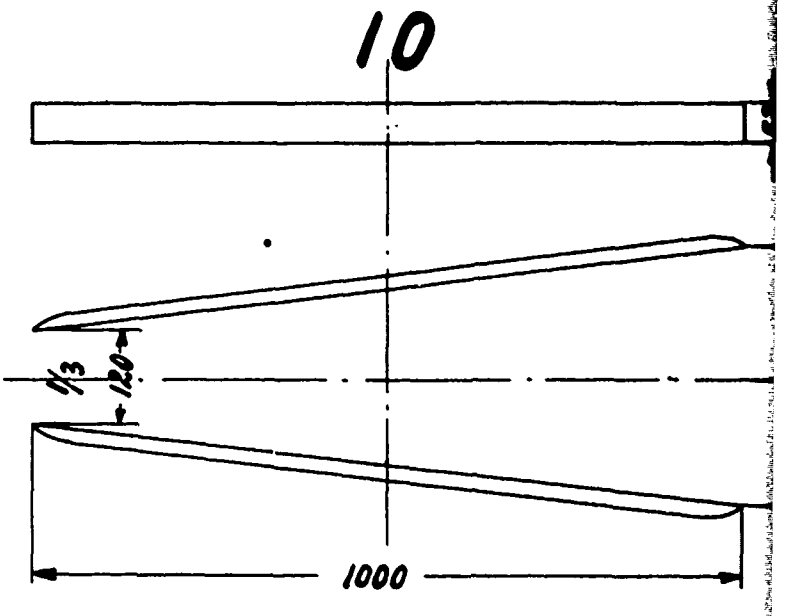

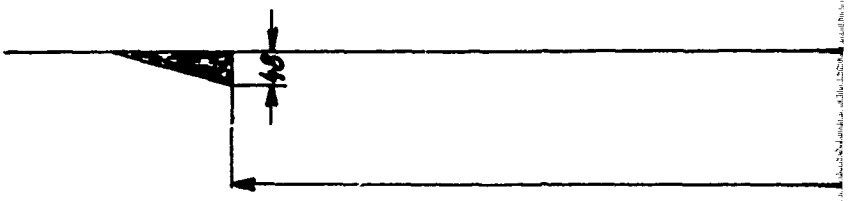

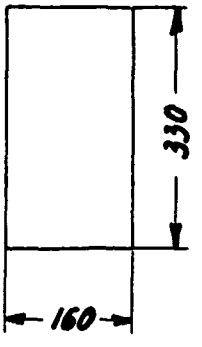

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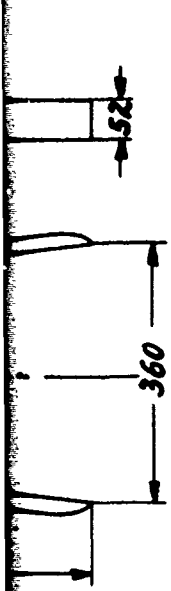

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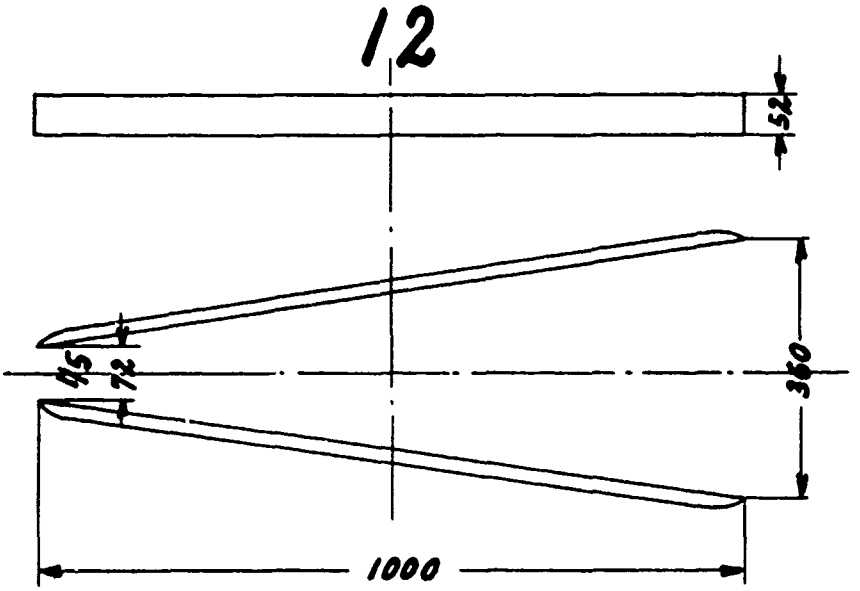

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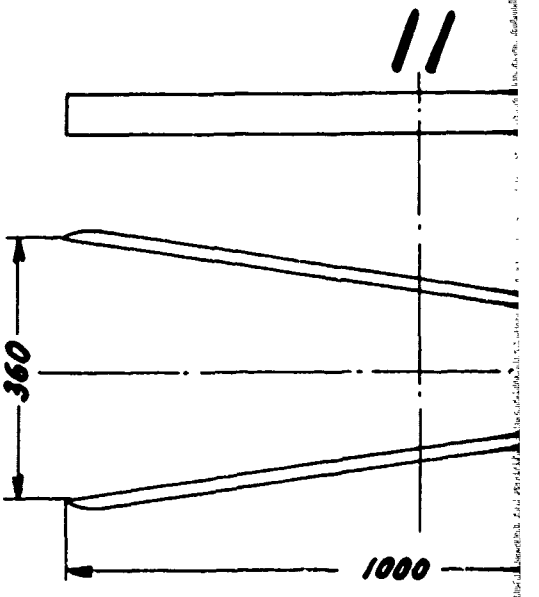

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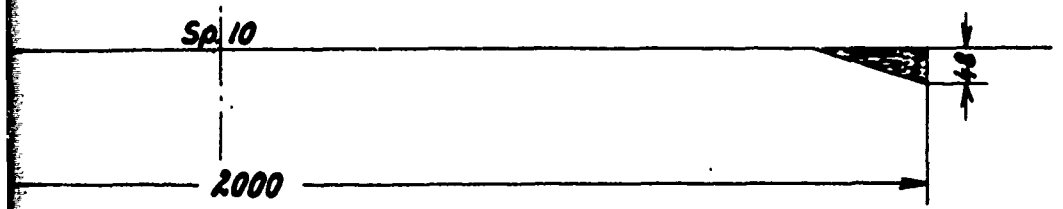

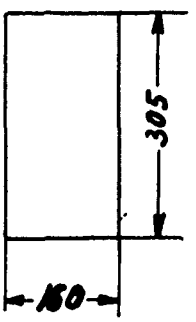

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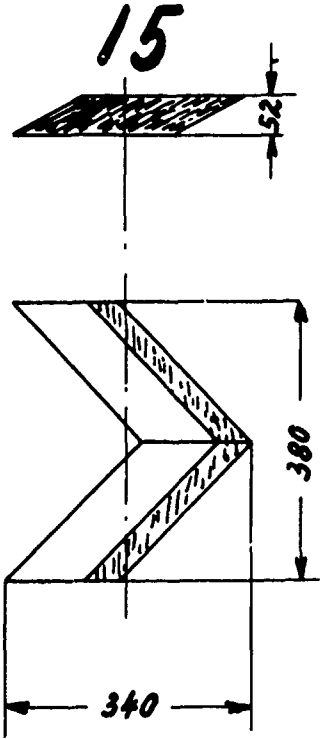

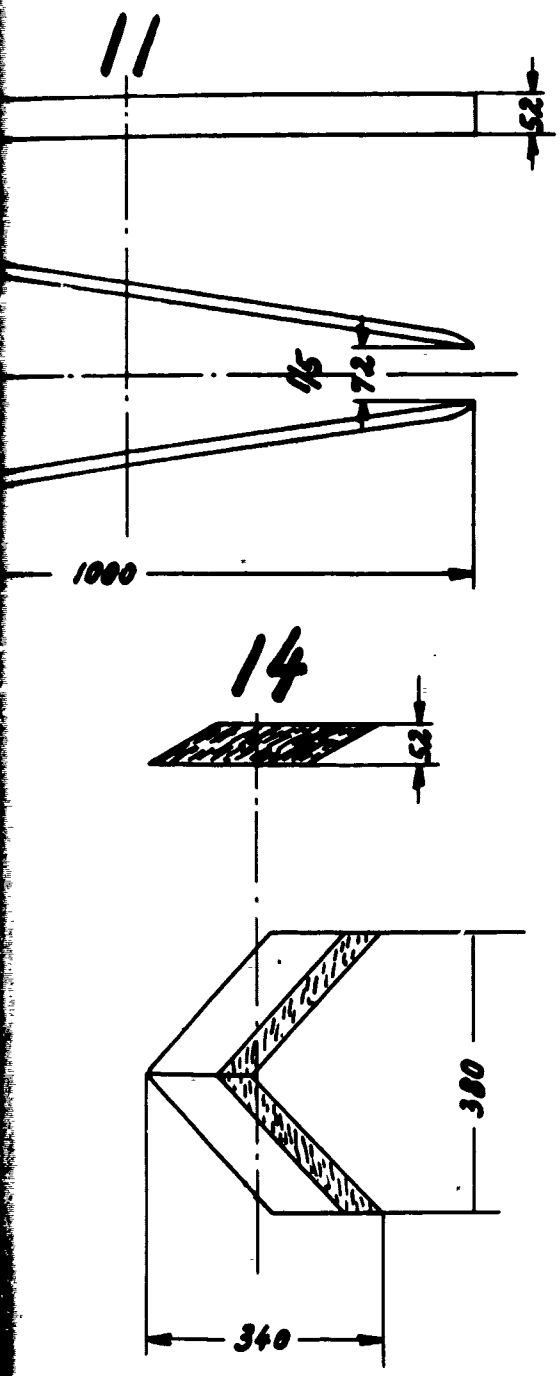

FIGURE 9

SKETCH OF THE WEDGES AND KEEL ARRANGEMENTS TESTED FOR EFFECT ON SHIP'S PRESSURE FIELD

Results of the Pressure Measurements (Cont'd)

TABLE 3

Keel Signatures of the "LUTZOW" with Single Wedges Fixed to the Hull

Wedge No.	Altitude of the triangle forming the wedge (mm)	Position of the altitude of the wedge	Reference table of pressure values	Reference curves
3	12	aft	4	Figure 11
4	12	forward	5	Figure 12
5	24	aft	6	Figure 13
6	24	forward	7	Figure 14
7	48	forward	8	Figure 15
8	96	forward	9	Figure 16

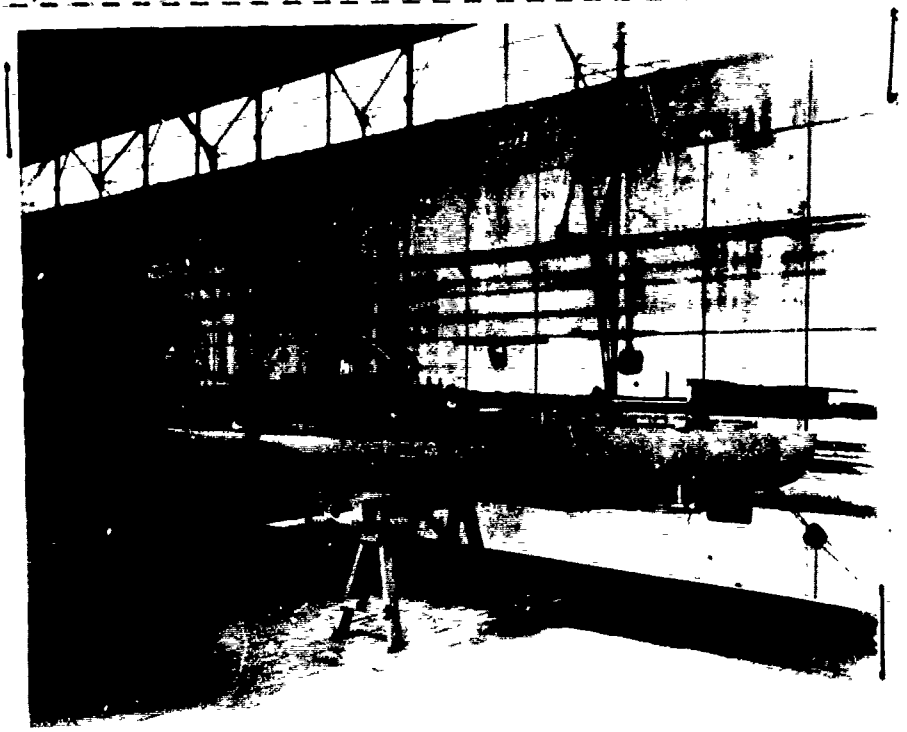

Figure 10

Model of the "Lutzow" with the airfoil tested for breaking up the ship's pressure field.

TABLE 4

Keel Signatures of the "LUTZOW" with Wedge Number 3 (mm. of water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+11.1	+4.3	-2.0	-4.7	-4.4	-4.4	-4.9	-1.9	0	+1.4
30	5.06	+1.1	+3.4	-2.3	-7.3	-14.6	-17.4	-15.6	-10.4	+0.8	+2.6
20	1.0	+9.0	+4.4	-4.9	-8.3	-9.8	-10.4	-9.6	-2.7	+2.2	+5.77
30	1.0	+3.5	+11.6	+12.5	-6.7	-31.6	-53.9	-67.9	-69.0	-60.5	-43.5

TABLE 5

Keel Signatures of the "LUTZOW" with Wedge Number 4 (mm. of water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+8.7	+3.1	-1.9	-4.2	-3.9	-4.2	-4.1	-1.6	0	+1.4
30	5.06	-0.4	+4.4	-1.3	-6.9	-15.2	-17.0	-15.2	-9.0	+1.4	+2.4
20	1.0	+9.1	+4.5	-4.7	-8.3	-10.3	-11.1	-9.6	-1.6	+0.7	+5.2
30	1.0	+4.0	+11.6	+14.0	-4.0	-13.9	-33.5	-53.0	-59.3	-47.9	-38.2

TABLE 6

Keel Signatures of the "LUTZOW" with Wedge Number 5 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+8.8	+6.7	-3.8	-6.9	-5.7	-5.6	-5.3	+0.5	-0.3	+0.1
30	5.06	-3.0	+4.1	-1.0	-7.9	-16.2	-20.8	-21.0	-1.5	+2.5	+3.0
20	1.0	+7.8	+3.7	-6.0	-9.0	-10.8	-11.5	-9.8	-2.0	+1.3	+5.8
30	1.0	-1.0	+11.0	+15.6	+4.0	-15.0	-38.8	-60.0	-64.5	-55.0	-49.0

TABLE 7

Keel Signature of the "LUTZOW" with Wedge Number 6 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+9.3	+4.6	-1.2	-3.0	-3.0	-4.1	-4.4	-1.1	+0.9	+1.7
30	5.06	-2.5	+3.3	+0.2	-6.0	-14.2	-17.1	-16.7	-1.8	+0.7	+1.0
20	.0	+10.4	+4.5	+5.4	-9.0	-11.3	-11.9	-10.8	-1.5	+2.4	+5.6
30	.0	-4.5	+9.5	-13.6	+5.6	-13.9	-35.0	-46.4	-44.5	-40.5	-29.5

TABLE 8

Keel Signatures of the "LUTZOW" with Wedge Number 7 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	4	5	6	7	8	10	11	12
20	5.06	+12.1	+4.3	-2.0	-4.8	-4.4	-4.4	-4.9	+1.4	-0.6	+1.4
30	5.06	+1.8	+3.3	-2.3	-7.3	-14.6	-17.7	-18.2	-8.0	-0.6	-1.4
20	1.0	+9.7	+4.6	-5.3	-9.1	-11.5	-14.5	-12.6	-1.5	+2.4	+5.6
30	1.0	+2.0	+8.5	+8.5	+2.5	-3.5	-11.3	-36.0	-37.5	-31.2	-24.0

TABLE 9

Keel Signatures of the "LUTZOW" with Wedge Number 8 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+3.3	-0.6	-3.3	-4.2	-5.0	-6.0	-6.6	-0.6	+1.5	+3.0
30	5.06	-1.2	+3.3	-1.4	-3.8	-5.4	-10.0	-8.5	0	+2.1	+2.8
20	1.0	+6.2	+2.6	-5.0	-9.0	-12.5	-19.2	-20.3	-6.5	-2.5	+3.4

Keel Signatures of the "LUTZOW" with Double Wedge Arrangement (mm of wate

Speed (knots)	Water depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+11.1	+4.3	-2.1	-4.7	-4.3	-3.0	-3.0	+0.5	+2.6	+4.0
30	5.06	+1.2	+4.2	0	-8.9	-20.2	-23.6	-24.4	-7.8	-4.6	-3.1
20	1.0	+10.4	+4.5	-5.4	-9.0	-11.3	-11.9	-10.9	-4.2	-0.6	+2.0
30	1.0	-2.0	+8.2	+13.3	+5.7	-13.8	-35.0	-46.5	-44.5	-40.5	-30.0

TABLE 11

Keel Signatures of the "LUTZOW" with Perpendicular Plates

Plate set number	Opening forward (mm)	Opening aft (mm)	Reference table of pressure values	Reference curves
9	360	180	12	Figure 18
10	360	120	13	Figure 19
11	72	360	14	Figure 20
12	360	72	15	Figure 21

TABLE 12

Keel Signatures of the "LUTZOW" with Plate Set No. 9 (mm. of water)

Speed (knots)	Water depth meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+9.2	+4.1	-2.2	-4.6	-4.5	-4.8	-4.2	-1.4	0	+0.6
30	5.06	-1.2	+5.2	-2.2	-6.3	-15.5	-17.7	-18.9	-2.6	+1.5	+2.6
20	1.0	+6.6	+5.2	-4.5	-11.7	-13.1	-13.2	-12.3	-1.4	+2.2	+5.6
30	1.0	+1.0	+10.0	+15.0	+3.2	-18.5	-26.0	-39.0	-36.5	-33.2	-27.6

TABLE 13

Keel Signatures of the "LUTZOW" with Plate Set No. 10 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number									
		1	2	3	4	6	7	8	10	11	12
20	5.06	+9.2	+4.1	-2.2	-4.6	-4.5	-4.8	-4.2	-1.4	0	+0.6
30	5.06	-5.6	+4.8	+1.5	-3.7	-13.5	-16.6	-17.6	-5.0	+1.4	+2.4
20	1.0	+4.5	+3.2	-7.7	-10.9	-12.6	-12.9	-10.8	-5.0	-0.4	+4.0
30	1.0	+5.8	+10.0	+14.0	-1.2	-17.5	-31.6	-41.0	-29.0	-26.3	-19.0

TABLE 14

Keel Signatures of the "LUTZOW" with Plate Set No. 11 (mm. of Water)

Speed (knots)	Water depth (meters)	Piezometer Number									
		1	2	3	4	6	7	8	10	11	12
20	5.06	+9.2	+4.1	-2.2	-4.6	-4.5	-4.8	-4.2	-1.4	0	+0.6
30	5.06	-5.6	+4.8	+1.5	-3.7	-13.5	-16.6	-17.6	-5.0	+1.4	+2.4
20	1.0	+4.5	+3.2	-7.7	-10.9	+12.6	-12.9	-10.8	-5.0	-0.4	+4.0
30	1.0	+5.8	10.0	+14.0	+1.2	-17.5	-31.6	-41.0	-29.0	-26.3	-19.0

TABLE 15

Keel Signatures of the "LUTZOW" with Plate Set No. 12 (mm. of Water

Speed (knots)	Water depth (meters)	Piezometer Number									
		1	2	3	4	6	7	8	10	11	12
20	5.06	+8.7	+3.1	-2.8	-5.7	-5.0	-5.8	-6.3	-2.3	-0.6	0
30	5.06	+1.6	+4.4	+0.6	-5.0	-17.9	-17.8	-17.3	-1.6	+1.3	+2.0
20	1.0	+4.5	+3.2	-7.7	-10.9	-12.6	-12.9	-10.8	-5.0	-0.4	+4.0
30	1.0	+2.0	+8.5	+12.0	-2.5	-19.0	-39.0	-36.8	-27.5	-34.0	-27.5

Results of the Pressure Measurements (Cont'd)

The only wedge that showed a significant influence on the signature was number 9. However, the power requirements became so high that tests at 30 knots in the shallow depth were not considered practicable. It can easily be seen that the power requirements would be excessive due to the increase in resistance in shallow water in combination with the resistance of flat plate area of the wedge perpendicular to the stream.

(b) Double Wedge Arrangement

Two wedges with a height of 48 mm were installed on the model with the altitude of the triangles forward. These wedges were placed 1.0 meter forward and aft of the midships section, frame 10, making a total spacing of 2.0 meters. The forward wedge was 330mm in beam and 180mm long, while the after one was 305mm in beam and 160mm long. The results of the tests with this arrangement are summarized in Table 10 and plotted on Figure 17.

2. Keel or Plate Arrangements

(a) Plates Perpendicular to the Ship's Hull

The test arrangements and the references to pertinent table of results and the corresponding plots of these data are summarized in Table 11 and Figure 9.

(b) Inclined Plate or "Plow" Arrangements

The arrangements described in the foregoing were thought to deflect the flow to the sides with a resultant loss in efficiency. In order to obtain a component of flow toward the bottom of the channel, the intersecting plates shown on Figure 9, numbers 15 and 16, were tested. The arrangements were 52mm high with an opening of 380mm. The plates were inclined at angles of 30 degrees and intersected at 90 degrees.

The results of these tests are summarized in Tables 16 and 17 and the data plotted on Figures 22 and 23.

TABLE 16

Keel Signatures of the "LUTZOW" with "Plow" No. 14 (mm. of water)

Speed (knots)	Water Depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+9.2	+4.1	-2.2	-4.6	-4.5	-4.8	-4.2	-1.4	0	+0.6
30	5.06	+1.2	+5.2	+2.3	-10.0	-13.4	-13.2	-14.0	-11.0	+0.9	+2.5
20	1.0	+6.5	+5.3	-4.5	-11.5	-12.5	-12.3	-11.1	-2.3	-1.6	+5.5
30	1.0	+3.0	+7.0	+12.5	+1.0	-10.8	-32.5	-40.5	-42.5	-39.0	-31.3

TABLE 17

Keel Signatures of the "LUTZOW" with "Plow" No. 15 (mm. of water)

Speed (knots)	Water Depth (meters)	Piezometer Number 1	2	3	4	6	7	8	10	11	12
20	5.06	+8.7	+7.5	-4.0	-6.0	-5.7	-5.6	-5.3	+0.5	-0.3	0
30	5.06	+4.0	+6.8	+3.6	-1.9	-14.3	-18.2	-16.2	-1.4	+2.6	+3.0
20	1.0	+7.8	+3.8	-6.8	-9.2	-10.8	-11.5	-9.8	-2.0	+0.6	+4.6
30	1.0	+5.7	+10.0	+15.5	-4.5	-27.0	-24.5	-16.5	-40.5	-38.0	-10.5

For the purposes of comparison, the results for all appendages tested have been plotted from additional data on Figures 24 through 29. Figures 24 through 27 show the results at constant speeds and depths for all the devices. None of the devices tested showed the desired result of a positive pressure hump in the negative part of the signatures. On Figures 28 and 29 are plotted additional data for wedges no. 4 and 7 respectively. These two latter series of tests were evidently the only attempt at a systematic examination of the effect of speed on the signature.

3. Tests of the Lifting Airfoil

(a) Keel Signatures for Airfoil Under Midships Section

The results of the keel signature measurements with the airfoil at the midships section are given in Table 18. The trim of the model during a run, as well as the initial trim, is also tabulated where these data were available. The changes in draft measured at the midships section are also given.

TABLE 18

KEEL SIGNATURES OF THE LÜTZOW WITH AIRFOIL UNDER THE

RUN Nº	MODEL SPEED KNOTS	WATER DEPTH METERS	DISTANCE OF AIRFOIL BELOW HULL BOTTOM mm	ANGLE OF ATTACK OF AIR FOIL DEGREES	TRIM		CHANGE IN DRAFT mm	P	
					INITIAL DEGREES	UNDERWAY DEGREES		1	2
1	1.87	5.06	167	0	0	+ 18'		+ 8.0	+ 2.2
2	2.50	〃	〃	0	0	+ 3'		+ 5.2	+ 4.0
3	1.87	〃	〃	4	0	+ 3'		+ 3.6	+ 1.9
4	2.50	〃	〃	4	0	+ 4'		+ 5.6	+ 0.2
5	1.88	〃	250	4	-1	+ 8'		- 0.6	+ 2.2
6	2.50	〃	〃	4	-1	+ 18'	- 14	+ 4.6	0
7	1.86	〃	〃	6	-1	+ 8'	- 17	+ 2.4	+ 5.2
8	2.49	〃	〃	6	-1	+ 19'	- 17	+ 7.0	+ 3.0
9	1.92	〃	333	0	-1	+ 5'	- 22	+ 2.7	+ 2.1
10	2.46	〃	〃	0	-1	+ 9'		+ 7.0	+ 2.0
11	1.88	〃	〃	4	—	+ 4'		- 1.2	+ 1.8
12	2.50	〃	〃	4	-1	+ 12'	- 11	+ 4.0	- 1.3
13	1.83	〃	〃	6	-1	+ 6'	- 11	- 3.0	- 0.5
14	2.45	〃	〃	6	-1	+ 13'	- 20	+ 6.0	+ 1.0
15	1.87	1.0	167	0	0	+ 18'		- 0.8	+ 4.9
16	2.50	〃	〃	0	0	+ 27'		- 5.8	+ 9.0
17	1.87	〃	〃	4	0	+ 7'		+ 0.2	+ 5.0
18	2.50	〃	〃	4	0	+ 45'		+ 11.7	+ 9.3
19	1.90	〃	250	4	-1	+ 13'	- 13	- 4.1	+ 2.2
20	2.51	〃	〃	4	-1	+ 1° 3'	- 4	+ 12.1	+ 7.2
21	1.88	〃	〃	6	-1	+ 8'	- 17	- 4.0	+ 2.8
22	2.54	〃	〃	6	-1	+ 19'	- 22	+ 12.2	+ 7.8
23	1.96	〃	333	0	-1	+ 10'		- 1.2	+ 5.6
24	2.52	〃	〃	0	-1	+ 35'	- 5	+ 12.3	+ 5.8
25	1.89	〃	〃	4	—	+ 10'		- 6.1	+ 6.8
26	2.51	〃	〃	4	-1	+ 50'	- 2	+ 12.6	+ 7.6
27	1.88	〃	〃	6	-1	+ 11'	- 12	- 6.2	+ 2.6
28	2.49	〃	〃	6	-1	+ 44'	- 9	+ 8.7	+ 4.6

TABLE 18

TZOW WITH AIRFOIL UNDER THE MIDSHIPS SECTION.

TRIM		CHANGE IN DRAFT mm	PRESSURES CHANGE mm OF WATER PIEZOMETER Nº										REFERENCE CURVES
AL ES	UNDERWAY DEGREES		1	2	4	5	6	7	8	10	11	12	
	+ 18'		+ 8.0	+ 2.2	- 2.3	- 3.6	- 3.2	- 4.0	- 7.0	- 1.4	+ 1.0	- 3.7	FIGURE 30
	+ 3'		+ 5.2	+ 4.0	+ 1.8	- 4.0	- 7.5	- 9.8	- 14.6	0	+ 4.2	- 4.8	FIGURE 31
	+ 3'		+ 3.6	+ 1.9	- 1.5	- 2.7	- 3.6	- 3.7	- 7.3	- 1.1	+ 1.7	- 1.3	FIGURE 30
	+ 4'		+ 5.6	+ 0.2	+ 0.8	- 5.5	- 7.9	- 8.4	- 15.3	- 0.3	+ 1.1	- 2.8	FIGURE 31
	+ 8'		- 0.6	+ 2.2	+ 2.0	+ 0.6	- 0.8	+ 0.4	+ 4.7	+ 3.8	+ 1.7	- 6.0	FIGURE 30
	+ 18'	- 14	+ 4.6	0	- 3.2	+ 5.2	- 16.3	- 3.0	- 19.6	- 0.2	+ 4.6	+ 1.4	FIGURE 31
	+ 8'	- 17	+ 2.4	+ 5.2	+ 3.1	+ 0.6	- 0.8	0	+ 3.0	+ 1.0	+ 1.2	+ 1.5	FIGURE 30
	+ 19'	- 17	+ 7.0	+ 3.0	+ 3.8	+ 1.0	- 16.0	+ 0.8	- 15.4	+ 2.8	+ 6.8	+ 1.4	FIGURE 32
	+ 5'	- 22	+ 2.7	+ 2.1	0	- 2.1	- 3.3	- 3.3	- 2.6	- 0.9	+ 0.4	+ 1.6	FIGURE 30
	+ 9'		+ 7.0	+ 2.0	- 9.8	- 4.6	- 11.6	- 9.6	- 7.6	- 2.6	+ 2.5	+ 1.4	FIGURE 31
	+ 4'		- 1.2	+ 1.8	+ 1.4	- 0.2	- 1.6	- 0.8	+ 7.0	+ 5.4	+ 3.8	- 5.6	FIGURE 30
	+ 12'	- 11	+ 4.0	- 1.3	- 3.8	+ 2.8	+ 12.8	- 0.3	- 19.4	- 1.4	+ 3.4	+ 0.2	FIGURE 31
	+ 6'	- 11	- 3.0	- 0.5	- 0.6	- 1.7	- 3.4	- 2.6	+ 2.0	- 3.2	- 1.4	- 2.2	FIGURE 30
	+ 13'	- 20	+ 6.0	+ 1.0	+ 3.4	- 3.0	- 13.0	- 1.4	- 10.4	0	+ 3.6	+ 1.4	FIGURE 32
	+ 18'		- 0.8	+ 4.9	- 3.8	- 6.2	- 7.6	- 6.1	- 11.0	0	- 2.5	+ 3.4	FIGURE 33
	+ 27'		- 5.8	+ 9.0	- 6.0	- 16.6	- 31.0	- 42.1	- 60.0	- 26.7	- 13.3	- 3.4	FIGURE 34
	+ 7'		+ 0.2	+ 5.0	- 2.8	- 6.3	- 5.9	- 2.8	- 11.4	- 7.1	- 3.0	+ 2.6	FIGURE 33
	+ 45'		+ 11.7	+ 9.3	- 0.8	- 14.8	- 68.0	- 41.7	- 58.7	- 34.7	- 18.7	- 4.7	FIGURE 35
	+ 13'	- 13	- 4.1	+ 2.2	- 1.8	- 3.3	- 13.2	- 2.8	- 10.9	- 5.7	- 6.1	+ 1.9	FIGURE 33
	+ 1° 3'	- 4	+ 12.1	+ 7.2	+ 4.8	- 9.9	- 67.4	- 20.6	- 59.1	- 35.9	- 17.5	0	FIGURE 35
	+ 8'	- 17	- 4.0	+ 2.8	- 0.5	- 0.1	+ 1.8	+ 2.4	- 7.4	- 3.8	- 4.4	+ 5.0	FIGURE 33
	+ 19'	- 22	+ 12.2	+ 7.8	- 6.3	+ 0.4	- 62.9	- 10.1	- 50.6	- 32.1	- 16.2	- 0.9	FIGURE 36
	+ 10'		- 1.2	+ 5.6	0	- 2.4	- 4.0	- 4.8	- 7.2	0	0	- 2.8	FIGURE 33
	+ 35'	- 5	+ 12.3	+ 5.8	- 1.8	- 11.5	- 50.0	- 33.4	- 43.8	- 29.0	- 18.1	+ 4.1	FIGURE 34
	+ 10'		- 6.1	+ 6.8	- 3.9	- 4.4	- 13.1	- 2.5	- 11.1	- 5.8	- 6.0	+ 1.8	FIGURE 33
	+ 50'	- 2	+ 12.6	+ 7.6	- 6.0	- 4.3	- 53.6	- 18.5	- 43.8	- 29.3	- 14.1	+ 1.8	FIGURE 35
	+ 11'	- 12	- 6.2	+ 2.6	- 3.2	- 5.8	- 11.0	+ 2.6	- 8.4	- 3.0	- 4.0	+ 2.6	FIGURE 33
	+ 44'	- 9	+ 8.7	+ 4.6	+ 2.1	- 5.2	- 50.3	- 12.2	- 41.1	- 23.8	- 11.2	+ 0.8	FIGURE 36

3. Tests of the Lifting Airfoil (Cont'd)

Perhaps the most significant result shown by these data is that the ship model actually increased in draft for the majority of the cases despite the lift developed by the airfoil. The actual values of change in draft should be examined with caution, however, since the values show comparable changes for deep and shallow water, and this result is believed to be inconsistent. This conclusion was concurred in by the test engineer who admitted that the model, on visual observation, showed a greater change in draft in the shallow water tests than in deep water, and, as a result, expressed doubt in his own data.

An initial trim by the bow was used in most cases. This was found to be necessary since the combination of increase in draft and trim by the stern during a run caused the model to take water over the stern.

(b) Keel Signature for Airfoil 1440mm Forward of Midships Section

The results of the keel signature measurements with the airfoil positioned 1440mm ahead of the midships section are summaried in Table 19.

A comparison of the data of Table 18 with the results shown in Table 19 indicate that the after position of the airfoil is the more satisfactory. With the airfoil at the midships section, a more satisfactory signature was obtained with a smaller influence on the trim and change in draft.

(c) Athwartships Signature of the Model With Airfoil at Midships Section

One series of tests was made to obtain an estimate of the extent of the pressure field. The model was displaced laterally with respect to the piezometer tube with a distance of 1170mm between the centerline of the model and piezometer tube. This placed the piezometer tube 325mm beyond the tip of the airfoil. Tests were made for the model without the airfoil and with the combinations for which the angles of attack of the airfoil were 4- and 6- degrees. These results are summaried in Table 20.

A comparison of the centerline and athwarships signature of the model in a constant depth of water with different angles of attack and speed is shown in Figure 49.

Comments and Conclusions

There are two sources of error in the measurements derived at HSVA which are perhaps more significant than the usual errors resulting from reading small difference on manometers such as averaging oscillating water columns and displacement of the model with respect to the piezometer openings. These errors are:

(a) The "interference" between the supporting frame for the piezometer tube and the model.

(b) The influence of the channel cross-section on the pressure field of the model itself.

Although the piezometer tubes were all calibrated in place before a model was tested, the resulting flow when in combination with a model may be sufficiently altered so that the difference between the total pressures and the calibration pressures may not represent the true pressure field of the model alone. In most cases, the influence of the frame will cause slightly lower pressures, due to the construction of the flow cross-section, than would be obtained if there were no members in the vicinity of the model. This error is probably small compared with the errors introduced by the influence of the basin cross-section, however.

The cross-section of the HSVA tank, compared with the cross-section of the model tested, Figure 1, is such that the tests in shallow-water were actually conducted in a "restricted" channel. The restriction of the section, in which the flow about the model occurs, results in relatively higher velocities at the model than would exist if the model were towed in a channel of very much larger cross-section. As a result, the velocities for the model are greater than the corresponding velocities for the full-scale ship in un-restricted waters with correspondingly higher pressure changes[13] for the model than for the prototype.

The results obtained in the deep portion of the basin during a single run do not represent the actual values that would result in the vicinity of a wall (or bottom). A consideration of the velocities near a wall, based on the method of images, shows that the velocities at a wall in a given position are considerably higher than they would be at the same point with the wall displaced from this point. As a result, it is assumed that the deep water tests were intended mainly

TABLE: 19

KEEL SIGNATURES OF THE LÜTZOW WITH AIRFOIL 1140

RUN No:	MODEL SPEED	WATER DEPTH	DISTANCE OF AIRFOIL BELOW HULL BOTTOM	ANGLE OF ATTACK OF AIRFOIL	TRIM DEGREES		CHANGE IN DRAFT		
	KNOTS	METERS	mm	DEGREES	INITIAL	UNDERWAY	mm	1	2
29	1.87	5.06	167	0	0°	+ 29'	-2	- 0.5	+ 1.8
30	2.49			0		+ 38'	+2	+ 0.5	+ 2.1
31	1.87			4		+ 48'	-7	+ 0.5	+ 1.6
32	2.48			4		+ 1° 14'	-11	+ 7.3	+ 2.2
33	1.86			6		+ 55'	-11	- 3.0	- 0.8
34	2.45			6		+ 1° 31'	-16	+ 7.8	+ 3.1
35	1.85		250	0		+ 22'	+1	- 6.2	- 1.8
36	2.45			0		+ 30'	+7	+ 2.5	- 3.6
37	1.85			4		+ 44'	-6	- 1.2	+ 1.3
38	2.49			4		+ 1° 18'	-8	- 10.7	+ 4.6
39	1.90			6		+ 1° 39'	-8	- 1.9	+ 1.4
40	2.53			6		+ 1°	-18	+ 7.2	+ 7.0
41	1.85		333	0		+ 28'	+1	- 1.9	+ 0.7
42	2.50			0		+ 45'	-2	+ 3.5	+ 4.8
43	1.86			4		+ 55'	-10	- 1.8	+ 0.5
44	2.49			4		+ 1° 32'	-18	+ 10.2	+ 6.4
45	1.89			6		+ 1° 5'	-14	- 2.5	- 0.5
46	2.54			6		+ 1° 57'	-26	+ 8.4	+ 6.1
47	1.89	1.00	167	0		+ 32'	-1	+ 3.9	+ 4.5
48	2.60			0		+ 54'	+14	+ 16.7	- 10.7
49	1.88			4		+ 54'	-6	- 0.6	+ 5.4
50	2.50			4		+ 1° 35'	-2	+ 13.9	+ 8.2
51	1.88			6		+ 1° 3'	-11	- 5.6	- 4.0
52	2.46			6		+ 1° 40'	-6	+ 16.1	+ 10.3
53	1.87		250	0		+ 26'	-1	+ 1.0	+ 4.0
54	2.46			0		+ 43'	+18	+ 15.8	+ 10.0
55	1.89			4		+ 52'	-8	+ 4.4	+ 4.4
56	2.51			4		+ 1° 28'	+13	+ 19.0	+ 11.9
57	1.88			6		+ 1° 8'	-12	- 5.1	+ 3.0
58	2.54			6		+ 2° 14'	-8	+ 19.8	+ 14.0
59	1.87		333	0		+ 32'	0	- 3.2	+ 4.0
60	2.52			0		+ 1° 14'	+9	+ 14.9	+ 9.4
61	1.88			4		+ 1° 4'	-12	- 3.3	+ 5.5
52	2.51			4		+ 2° 5'	-7	+ 13.6	+ 8.1
63	1.87			6		+ 1° 22'	-15	- 1.3	+ 5.5
64	2.50			6		+ 2° 27'	-20	+ 14.5	+ 8.7

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H AIRFOIL 1140 mm FORWARD OF MIDSHIPS SECTION

(2)

ANGE N RAFT	PRESSURE CHANGES (mm OF WATER) PIEZOMETER №												REFERENCE CURVES
m	1	2	3	4	5	6	7	8	9	10	11	12	
-2	- 0.5	+ 1.8		- 1.7	- 4.0	- 4.7	- 3.5	- 9.5		+ 0.5	+ 1.2	+ 1.1	FIGURE 37
+2	+ 0.5	+ 2.1		- 2.8	- 7.2	- 1.4	- 14.6	- 5.8		- 1.4	- 1.0	- 2.4	FIGURE 38
-7	+ 0.5	+ 1.6		- 4.0	- 2.8	- 2.8	- 2.1	- 1.6		- 1.5	0	+ 1.1	FIGURE 37
-11	+ 7.3	+ 2.2		+ 5.9	- 4.3	- 2.4	- 16.4	- 4.9		- 3.1	- 9.3	+ 7.8	FIGURE 38
-11	- 3.0	- 0.8		- 0.9	- 1.2	- 5.1	- 3.7	- 5.7		- 2.1	- 1.2	+ 1.1	FIGURE 37
-16	+ 7.8	+ 3.1		+ 8.3	- 2.7	- 0.2	- 15.6	- 2.2		- 2.2	- 7.2	- 7.6	FIGURE 39
+1	- 6.2	- 1.8		- 4.9	- 6.8	- 7.0	- 6.0	- 6.7		- 4.0	- 1.4	- 2.3	FIGURE 37
+7	+ 2.5	- 3.6		- 1.5	- 5.5	- 1.5	- 12.3	- 6.1		- 2.3	- 2.4	- 2.5	FIGURE 38
-6	- 1.2	+ 1.3		- 4.1	- 7.6	- 3.7	- 3.0	- 3.3		- 0.8	+ 0.3	- 0.7	FIGURE 37
-8	- 10.7	+ 4.6		+ 7.9	- 1.1	- 2.9	- 13.0	- 4.5		- 2.0	- 6.4	- 3.3	FIGURE 38
-8	- 1.9	+ 1.4		+ 3.0	+ 0.3	- 6.2	- 3.9	- 3.2		- 0.1	+ 0.8	+ 2.0	FIGURE 37
-18	+ 7.2	+ 7.0		+ 9.9	+ 0.4	- 0.2	- 15.8	- 3.6		- 2.0	- 7.0	- 7.3	FIGURE 39
+1	- 1.9	+ 0.7		+ 3.5	- 2.8	- 2.8	- 2.8	- 3.1		0	+ 1.8	- 2.4	FIGURE 37
-2	+ 3.5	+ 4.8		+ 4.3	- 3.3	- 3.0	- 13.1	- 5.0		- 0.6	- 0.9	- 2.7	FIGURE 38
-10	- 1.8	+ 0.5		+ 1.6	+ 0.4	- 6.5	- 5.7	- 4.9		- 1.5	+ 0.5	+ 2.0	FIGURE 37
-18	+ 10.2	+ 6.4		+ 11.3	+ 5.1	- 0.5	- 13.3	- 3.2		- 1.8	- 4.2	- 2.5	FIGURE 38
-14	- 2.5	- 0.5		- 1.2	+ 1.3	- 7.3	- 5.2	- 6.3		- 4.2	- 1.1	+ 1.5	FIGURE 37
-26	+ 8.4	+ 6.1		+ 10.5	+ 9.5	- 9.6	- 15.6	- 6.0		- 2.8	- 6.8	- 6.8	FIGURE 39
-1	+ 3.9	+ 4.5		- 2.9	- 11.6	- 15.6	- 11.3	- 10.9		- 4.2	- 2.5	+ 2.7	FIGURE 40
+14	+ 16.7	- 10.7		- 0.9	- 28.2	- 26.1	- 52.6	- 43.3		- 21.4	- 19.1	- 7.9	FIGURE 42
-6	- 0.6	+ 5.4		+ 3.6	- 3.4	- 12.6	- 5.3	- 8.1		- 1.0	+ 0.4	+ 4.9	FIGURE 40
-2	+ 13.9	+ 8.2		+ 7.1	- 15.1	- 33.8	- 54.4	- 42.6		- 22.8	- 24.8	- 12.9	FIGURE 43
-11	- 5.6	- 4.0		+ 3.5	- 2.1	- 13.7	- 6.2	- 9.9		- 3.7	- 1.1	+ 4.1	FIGURE 41
-6	+ 16.1	+ 10.3		+ 10.5	- 12.4	- 26.4	- 52.0	- 42.0		- 19.2	- 16.0	- 8.4	FIGURE 44
-1	+ 1.0	+ 4.0		- 2.4	- 9.9	- 14.1	- 10.2	- 9.6		- 4.0	- 1.6	+ 2.9	FIGURE 40
+18	+ 15.8	+ 10.0		- 0.4	- 23.7	- 30.4	- 47.5	- 34.5		- 14.4	- 10.8	- 3.4	FIGURE 42
-8	+ 4.4	+ 4.4		+ 7.4	- 3.5	- 13.7	- 10.1	- 10.8		- 2.8	- 1.7	+ 1.3	FIGURE 40
+13	+ 19.0	+ 11.9		+ 10.3	+ 0.3	- 29.5	- 48.9	- 42.0		- 20.8	- 17.0	- 8.7	FIGURE 43
-12	- 5.1	+ 3.0		+ 2.0	- 3.9	- 19.5	- 9.1	- 12.2		- 6.1	- 4.5	+ 0.3	FIGURE 41
-8	+ 19.8	+ 14.0		+ 14.1	- 0.7	- 40.1	- 55.9	- 46.9		- 26.8	- 33.9	- 17.0	FIGURE 44
0	- 3.2	+ 4.0		0	- 7.0	- 11.0	- 8.6	- 7.4		- 1.0	+ 1.0	+ 4.2	FIGURE 40
+9	+ 14.9	+ 9.4		+ 4.3	- 13.3	- 37.7	- 50.5	- 46.0		- 25.8	- 22.4	- 12.2	FIGURE 42
-12	- 3.3	+ 5.5		+ 5.2	+ 2.5	- 12.9	- 4.2	- 15.2		- 0.6	- 1.5	+ 5.4	FIGURE 40
-7	+ 13.6	+ 8.1		+ 14.8	+ 4.2	- 33.4	- 46.3	- 40.7		- 18.7	- 14.5	- 6.6	FIGURE 43
-15	- 1.3	+ 5.5		+ 8.3	+ 5.6	- 11.1	- 4.9	- 6.2		- 0.8	+ 1.9	+ 5.8	FIGURE 41
-20	+ 14.5	+ 8.7		+ 17.9	+ 10.5	- 28.2	- 47.2	- 37.1		- 18.1	- 14.3	- 6.9	FIGURE 44

(1)

TABLE: 20

ATHWARTSHIP SIGNATURES OF THE LÜTZOW WITH THE AIRFOIL A

RUN №	MODEL SPEED	WATER DEPTH	DISTANCE OF AIRFOIL BELOW HULL BOTTOM	ANGLE OF ATTACK OF AIRFOIL	PRESSURE CHANG				
					PIEZOMETER				
	KNOTS	METERS	m m	DEGREES	1	2	4	5	6
65	1.89	5.06	250	6	+ 0.3	+ 0.4	- 0.9	- 1.6	- 1.1
66	2.46	〃	250	6	+ 7.0	0	- 2.3	- 3.0	- 5.1
67	1.89	〃	333	4	- 1.3	- 0.1	0	0	- 2.1
68	2.43	〃	333	4	+ 8.0	+ 1.7	- 3.5	- 3.1	- 6.1
69	1.89	〃	333	6	- 3.7	- 0.5	- 1.3	- 3.8	- 1.1
70	2.46	〃	333	6	+ 8.3	- 1.2	- 0.6	- 2.8	- 8.1
71	1.87	1.00	250	6	- 4.7	+ 2.2	+ 4.0	+ 0.7	- 5.1
72	2.53	〃	250	6	+ 8.1	+ 3.2	- 1.2	- 2.3	- 4.1
73	1.89	〃	333	4	- 2.6	+ 3.2	- 2.5	- 9.9	- 6.1
74	2.47	〃	333	4	+14.9	+ 6.7	- 0.6	-11.8	-33.1
75	1.93	〃	333	6	- 1.8	+ 3.1	0	- 6.6	-15.1
76	2.52	〃	333	6	+14.2	+ 6.3	+ 2.0	- 6.7	-44.1
77	1.87	5.06	MODEL WITHOUT AIRFOIL		+12.7	+ 1.1	- 2.8	- 4.7	- 5.1
78	2.50	5.06	〃 〃	〃	+ 9.7	+ 4.5	- 1.8	- 3.7	- 4.1
79	1.87	1.00	〃 〃	〃	+ 4.4	+ 4.4	- 6.0	- 8.0	- 6.1
80	2.52	1.00	〃 〃	〃	+ 5.0	+11.3	+ 2.0	-12.5	-25.1

TABLE: 20

OF THE LÜTZOW WITH THE AIRFOIL AT THE MIDSHIPS SECTION

ANGLE OF ATTACK OF AIRFOIL	PRESSURE CHANGES (mm OF WATER) PIEZOMETER Nº										REFERENCE CURVES
DEGREES	1	2	4	5	6	7	8	10	11	12	
6	+ 0.3	+ 0.4	- 0.9	- 1.6	- 1.1	- 4.7	- 3.6	+ 1.0	- 2.6	+ 0.7	FIGURE 45
6	+ 7.0	0	- 2.3	- 3.0	- 5.4	- 6.5	- 5.5	+ 1.0	- 0.6	+ 0.6	FIGURE 46
4	- 1.3	- 0.1	0	0	- 2.5	- 4.1	- 2.6	- 2.6	- 2.5	0	FIGURE 45
4	+ 8.0	+ 1.7	- 3.5	- 3.1	- 6.4	- 9.8	- 8.5	+ 4.1	+ 6.5	+ 2.3	FIGURE 46
6	- 3.7	- 0.5	- 1.3	- 3.8	- 1.1	- 5.6	- 3.7	+ 1.4	- 0.4	+ 0.6	FIGURE 45
6	+ 8.3	- 1.2	- 0.6	- 2.8	- 8.4	- 8.5	- 8.5	+ 2.1	+ 1.4	+ 2.9	FIGURE 46
6	- 4.7	+ 2.2	+ 4.0	+ 0.7	- 5.0	- 5.4	- 11.8	+ 3.0	- 2.2	+ 2.4	FIGURE 47
6	+ 8.1	+ 3.2	- 1.2	- 2.3	- 4.0	- 2.7	- 2.9	+ 1.2	+ 0.4	- 1.3	FIGURE 48
4	- 2.6	+ 3.2	- 2.5	- 9.9	- 6.5	- 5.0	- 1.0	- 2.6	- 1.0	+ 3.5	FIGURE 47
4	+14.9	+ 6.7	- 0.6	- 11.8	- 33.5	- 27.0	- 33.5	- 10.5	- 0.5	+ 2.5	FIGURE 48
6	- 1.8	+ 3.1	0	- 6.6	- 15.3	- 8.9	- 9.5	+ 3.6	- 2.8	+ 2.0	FIGURE 47
6	+14.2	+ 6.3	+ 2.0	- 6.7	- 44.2	- 30.4	- 43.0	- 21.2	+ 2.2	+ 3.4	FIGURE 48
NT AIRFOIL	+12.7	+ 1.1	- 2.8	- 4.7	- 5.5	- 5.3	- 4.5	- 0.6	+ 0.7	+ 0.4	FIGURE 45
"	+ 9.7	+ 4.5	- 1.8	- 3.7	- 4.3	- 4.9	- 5.0	- 2.0	- 0.8	- 0.6	FIGURE 46
"	+ 4.4	+ 4.4	- 6.0	- 8.0	- 6.9	- 6.8	- 6.4	- 4.3	- 0.4	+ 2.6	FIGURE 47
"	+ 5.0	+ 11.3	+ 2.0	- 12.5	- 25.0	- 39.1	- 32.8	- 11.3	- 7.6	0	FIGURE 48

Comments and Conclusions (Cont'd)

to obtain additional data for comparison purposes, although the HSVA personnel attempted to show that the specifications had been met for both depths of water.

With respect to the use of a lifting airfoil for supply a positive pressure signal for "tricking" the Oyster mine, one or two conclusions can be drawn immediately from the data presented in this report. The size of the airfoil used with the Lützow model emphasizes the necessity of obtaining a design of ship hull which will not produce the large negative pressure field of the conventional hull. At the same time, however, the data on changes in draft of the model show that a much higher angle of attack (limited by the stalling angle for the given water depth and the additional power requirements) could have been used before special ballasting of the model would have been necessary to equalize the lift of the airfoil.

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13. This can be seen directly from a consideration of Beroullis equations for the pressure changes along different streamlines with equal initial velocities in a field of constant free stream velocity.

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Notes on Additional Proposals for Ship Protection

Plans were being made at HSVA to test two, and possibly three, additional methods for ship protection against pressure actuated mines at the time the tests described in the foregoing were completed. However, the entire program was still in the preliminary stages, and no work beyond that already described was actually accomplished.

The first scheme to be tested upon completion of the program reported herein was based on the effect produced by appendages secured to the sides of the ship. These were to be flat plate flaps hinged at the midships section so that they would fold into or against the hull when underway in cleared waters. Upon entering a suspected minefield, the flaps were to be swung into the stream at right angles to the longitudinal centerline of the ship. The problems of power, strength and mechanism requirements were realized, but it was proposed that these, as well as the size and draft of the flaps, be determined from the results of the experiments.

Notes on Additional Proposals for Ship Protection (Cont'd)

The second scheme to be proposed to the OKM as a possibility for ship protection involved a redesign of the ship's hull. It was suggested that a rectangular or semi-cylindrical section be removed from the midships section starting from the bottom of the hull with a tentative height of about 1/3 to 1/2 the draft and extending across the entire beam of the ship. The HSVA personnel thought that that would have the desired effect of producing a positive hump in the signature.

Another method was under discussion as to its adaptability for testing on model scale although no actual conclusions were reached. This method was suggested by a Dr. Dischner of Berlin, an underwater accoustics man, who proposed the use of an oscillating flexible sphere, two or three meters in diameter, towed under or near the ship's hull. This sphere was to be filled with water and pulsed with pumps at the proper frequencies. Preliminary calculations indicated that the pumps would require only about 150 horsepower to sufficiently alter the pressure field of a vessel the size of the Lutzow.

Beyond these notes, no further thought was given to the problem by HSVA personnel.

PART III

Methods Proposed at FSS for Sweeping Pressure - Actuated Mines

Since the FSS concentrated on the development of a gage for measuring very small pressure changes under water and did not actually succeed in carrying any part of a program to a systematic testing stage, the methods which were to be tested for sweeping pressure mines will be reviewed only briefly. Although this establishment was to originate and propose methods, some of the schemes were suggested to FSS by other sources. Where these sources are known, they are mentioned in the pertinent sections.

To initiate the program, preliminary tests were made with a cascade of hydrofoils in conjunction with the development of the micropressure gage. The hydrofoils were used to produce a negative pressure signal by testing them as depressors. The FSS had realized that the signature of a single hydrofoil would not be of sufficient duration

Methods Proposed at FSS for Sweeping Pressure - Actuated Mines (Cont'd)

to actuate the mine mechanism. As a result, a cascade of two staggered foils was first used to furnish a basis for further experimentation. The tests made were few in number and were intended primarily for determining the performance of the gage rather than the hydrofoils[14]. The use of hydrofoils for both sweeping and breaking up the ships signature was originally suggested by Dr. A. Betz of Göttingen.

The use of a towed barge for the production of a deep depression wave at the stern was suggested for early testing. It was considered that the negative pressure under the stern wave could be used for sweeping. However, the fact that the pressure field due to the displacement flow about such a barge would be of much more importance than the stem wave seemed to have been completely overlooked by the FSS.

The production of a wave train by a stationary source was also included in the list of proposed methods. However, only one method for producing waves had been seriously considered by Dr. Von Steinen's group. This was to use a barge of required displacement in which a large oscillating mass was to be installed, to produce the required [illegible] changes in draft at the desired frequencies. [illegible] frequencies.

The method whereby overlapping fields from two ships abreast would be used for sweeping a path between the ships was also proposed for test. This idea evidently came from full scale tests made by the SVK on the practicability of using the athwartships portions of a single ship's field which resembles "butterfly" wings.

A final method, proposed by Dr. Von Steinen, was intended to combine in a single sweep the component devices by sweeping either pressure-accoustic or pressure-magnetic combinations. For the pressure look, it was suggested to use a large ring with an airfoil cross-section to produce the negative pressure changes around the circumference. For accoustic combinations, a propellor of proper noise-levels would be installed in the center of the ring. For magnetic combination, coils would be wound about the circumferences. How the device would be towed or how to obtain the required negative pressure time-out periods, proper noise-levels or magnetic fields with a single coil were not included in the proposal.

Methods Proposed at FSS for Sweeping Pressure - Actuated Mines (Cont'd)

The method of "tricking" the mine with positive pressure signals had not occurred to this group.

- -

14. Oscillograph records of these tests are in the possession of the Admiralty Experimental Works, Haslar, U.K.

- -

APPENDIX

The Inductance Type Micro-Pressure Gage at FSS

It is not definitely known where the micro-pressure gage being developed at FSS was originally designed. However, information available indicates that the gage was a joint design of the FSS and the firm Hagenuk, Hansectische Apparatbau-Gesellschaft in Kiel. It appears that Hagenuk designed and built the first unit in cooperation with FSS and that, thereafter, FSS took over the work of development for use in model tests. It was learned that a gage designed on the principle of capacitance changes was originally tried but was too unstable under water and was abandoned in favor of the inductance type.

The micro-pressure gage is shown on Figure 50, and the wiring diagrams for the component parts are shown on Figure 51. The characteristics of the circuit elements are listed in Tables 21, 22, and 23[15]. The pressure gage is constructed with a corrugated diaphragm to which is soldered a small arm supporting a soft iron disk suspended between two coils. The coils are supplied with a frequency of 780 cycles per second. The deflection of the diaphragm due to a change in pressure in the surrounding fluid causes an unbalance of the bridge circuit as the iron disk is deflected near the coils. This unbalance is calibrated against known changes in pressures for use in experiments.

To calibrate the system, the gage is lowered to a predetermined depth and the diaphragm brought to zero position by means of air pressure. The gage is suspended with the air pipe which is clamped to a micrometer arrangement and changes in depth are effected with the micrometer screw. The changes in hydrostatic pressure due to the change in

The Inductance Type Micro-Pressure Gage at FSS (Cont'd)

depth of the gage provides a calibration of the type shown on Figure 52, the only calibration curve available at the time this information was obtained. The minimum measurable pressure change was claimed to be 1mm of water with a maximum measurable frequency of about 10 cycles per second.

The system had not been perfected when work was stopped. Difficulties were encountered with the response and stability of the instrument. It was thought that temperature changes, especially in the air volume backing the diaphragm, were the chief source of instability.

- -

15. To avoid confusion due to translation of the German terms for the circuit elements, the tables have been made up from original lists. The manufacturing firms, where known, have been listed to facilitate identification.

Prepared by:

P. Eisenberg
Ens., USNR

TABLE 21

Resistances for Circuit Diagrams of Figure 51

Symbol	Nomenclature	Characteristics	Firm	Types
W1	Schichtwiderstand	4 M-Ohm, 0.25W	Hagenuck	
W2	do	600 k-Ohm, 0.5W	do	
W3	do	600 Ohm, 0.25W	do	
W4	do	2-M-Ohm, 0.5W	do	
W5	Doppelschicht-drehwiderstand	2 x 10 K-Ohm lin.	do	
W6	Schichtdrehwiderstand	100 Ohm lin	do	
W7	Doppelschicht-drehwiderstand	2 x 10 k-Ohm lin	do	
W8	Schichtdrehwiderstand	500 k - Ohm lin	do	
W9	Schichtwiderstand	600 k Ohm, 0.25W	do	
W10	do	200 k Ohm, 0.25W	do	
W11	do	60 k Ohm, 0.25W	do	
W12	do	20 k Ohm, 0.25W	do	
W13	do	6 k Ohm, 0.25W	do	
W14	do	2 k Ohm, 0.25W	do	
W15	do	600 Ohm, 0.25W	do	
W16	do	200 Ohm, 0.25 W	do	
W17	do	60 Ohm, 0.25W	do	
W18	do	20 Ohm, 0.25W	do	
W19	do	500 Ohm, 0.5W	do	
W20	do	100 k Ohm, 0.5W	do	
W21	do	500 Ohm, 0.5W	do	
W22	do	100 k Ohm, 0.5W	do	
W23	do	5 k Ohm, 2W	do	
W24	do	1 k Ohm, 1W	do	
W25	Drahtwiderstand m. einstellk. Schelle	16 k Ohm, 12W	do	
W26	Drahtwiderstand m. einstellk. Schelle	16 k Ohm, 12W	do	
W27	Drahtwiderstand	30 Ohm, 4W	do	
W28	do	20 Ohm, 4W	do	
W29	do	12.5 Ohm, 4W	do	
W30	Schichtwiderstand	2 K Ohm, 0.5W	do	

CONFIDENTIAL

TABLE 22

Condensors for Circuit Diagram of Figure 51

Symbol	Nomenclature	Characteristics	Firm	Types
C1	Glimmer Kondensator	135 nF ± 1%	Monete	
C2	Glimmer Kondensator	10 nF ±1%	do	
C3				
C4				
C5	Keramik-Kondensator	100 pF/10% 400 v/4		
C6	Papier-Kondensator	10 mF/250V		
C7	Elektrolyt-Kondensator	10 µF/250V	Austria	Ditmar 8772
C8	Elektrolyt-Kondensator	100 µF/30V	do	Ditmar 8735
C9	do do	10 µF/250V	do	do 8772
C10	do do	100 µF/6V	do	do 8705
C11	do do	5 µF/250V	do	do 8771
C12	do do	5 µF/250V	do	do 8771
C13	Glimmer-Kondensator	10 µF± 1%	Monete	
C14	Elektrolyt-Kondensator	100 µF/6V	Austria	Ditmar 8705
C15	Papier-Kondensator	100 nF/250V		
C16	Glimmer-Kondensator	10 nF ±1%	Monete	
C17	Keramik-Kondensator	400 pF/2% 250v/4		
C18	Rohr-Kondensator	1 µF ±10%, 256V		
C19	Glimmer-Kondensator	10 nF ±1%	Monete	
C20	Elektrolyt-Kondensator	25 µF/350V	Austria	Ditmar 8783
C21	Papier-Kondensator	1 nF ±20%, 500V		
C22	Becher-Kondensator	8 µF± 10%, 500V	Siemens	65998
C23	Becher-Kondensator	8 µF ±10%, 500V	do	63998
C24	Elektrolyt-Kondensator	25 µF/ 350 V	Austria	Ditmar 8785

TABLE 23

Elements For Circuit Diagram of Figure 51

Symbol	Nomenclature	Characteristics	Firm	Type
G	Messgleichrichter	1 m A	Siemens	G 1341/1
MS	Drehpulstrommesser	1 m A		
Rö 1	Stahlröhre			EDD 11
Rö 2	do			EF 12
Rö 3	do			EF 12
Rö 4	do			ES 11
S 1	Stufenschalter		Ellinger; Geissler	901/11
S 2	Drehschalter		do	810
Sp 1	Transformator		Hagenuk	ST 294
Sp 2	do		do	ST 295
Sp 3	Drossel		do	ST 308
Sp 4	do		do	ST 308
Sp 5	do		do	ST 325
Sp 6	Messpule		do	ST 324
Sp 7	do		do	ST 324
Sp 8	Transformator		do	ST 231
Sp 9	do		do	ST 230
Sp 10	do		do	ST 233
Sp 11	do		do	ST 232
Sp 12	Drossel		do	ST 80

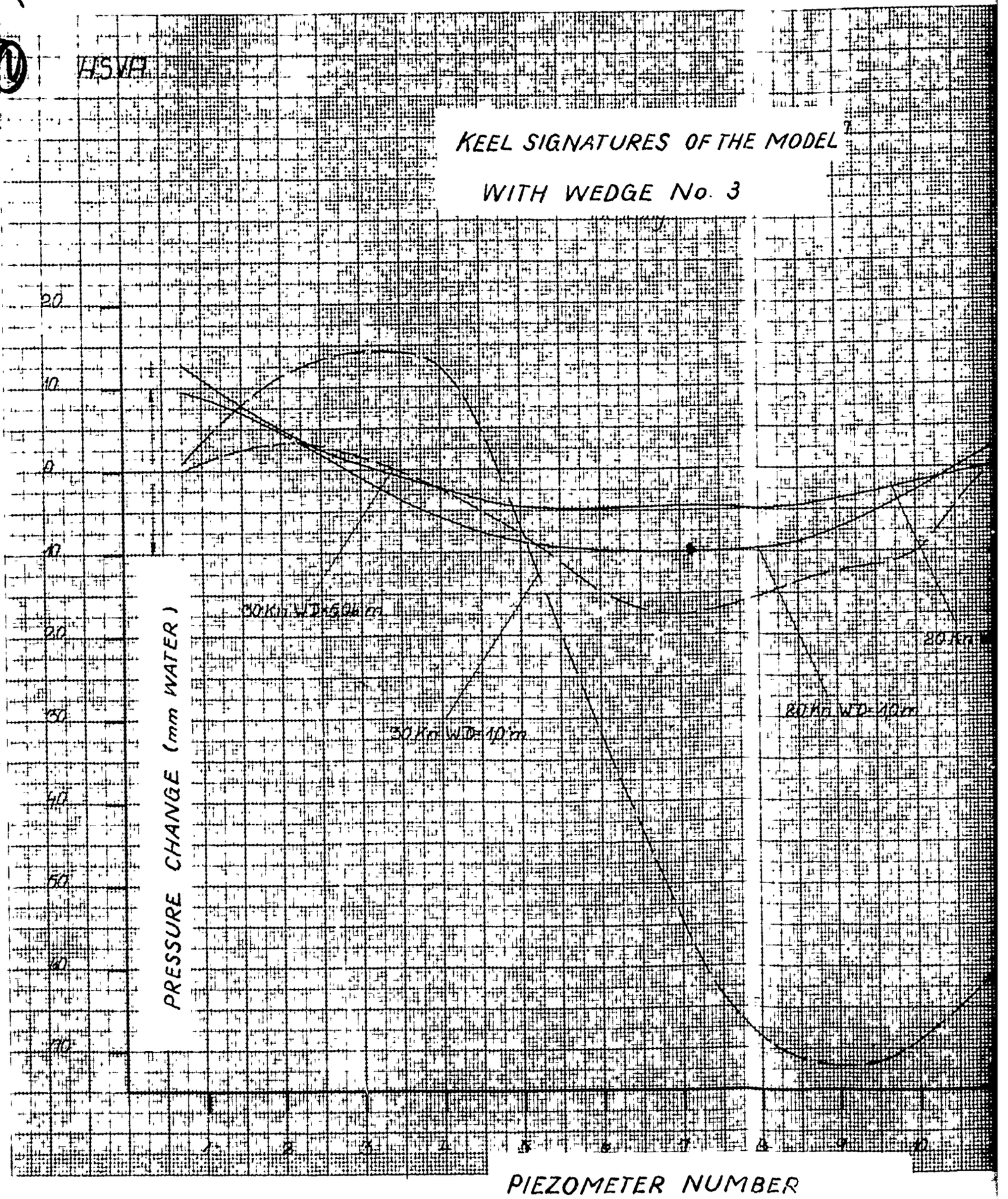
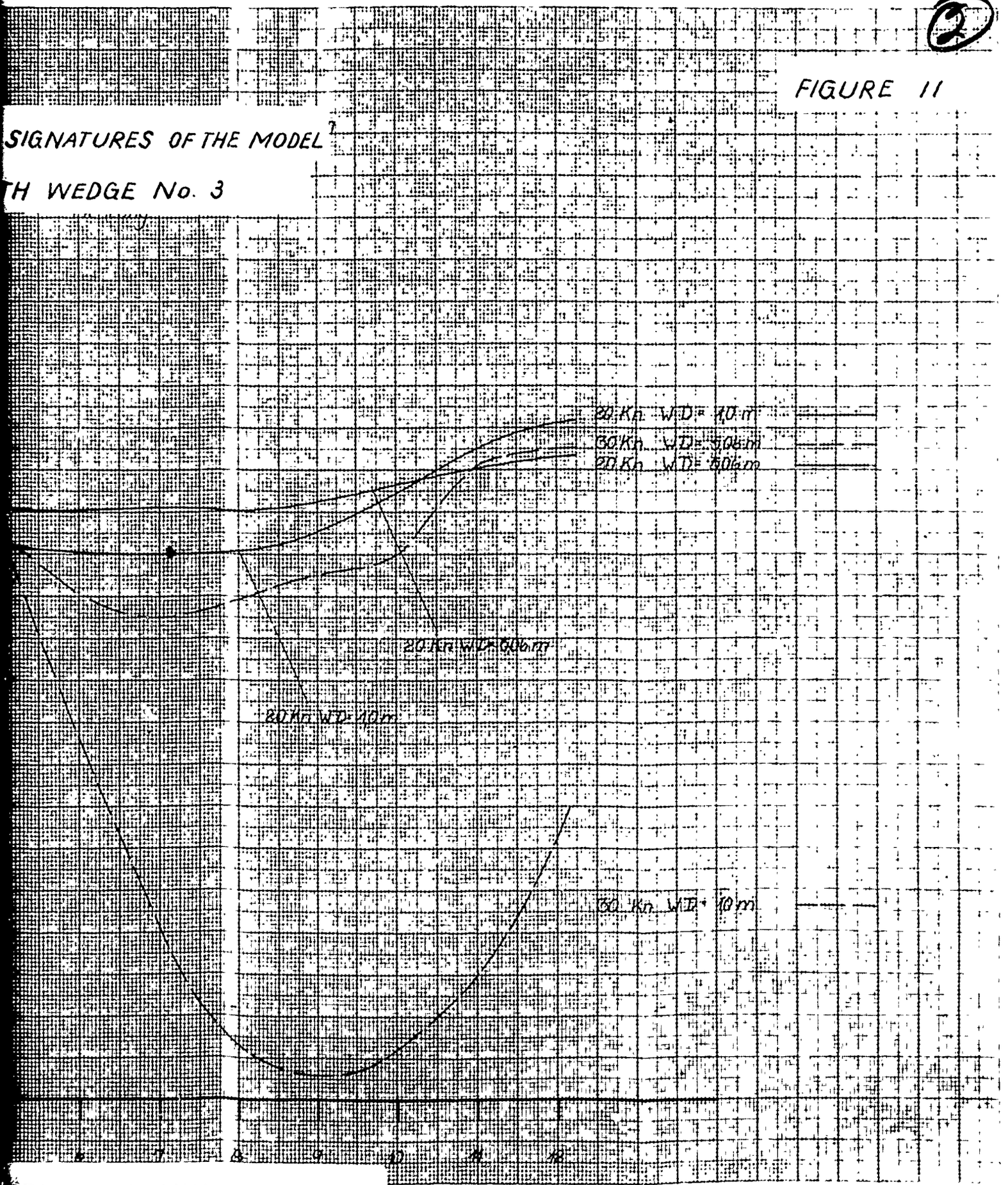

HSVA
KEEL SIGNATURES OF THE MODEL
WITH WEDGE No. 3
PRESSURE CHANGE (mm WATER)
20
10
0
10
20
30
40
50
60
70
30 Kn WD=5.06 m
30 Kn WD=10 m
20 Kn WD=10 m
20 Kn
1
2
3
4
5
6
7
8
9
10
PIEZOMETER NUMBER

FIGURE 11

SIGNATURES OF THE MODEL

TH WEDGE No. 3



ZOMETER NUMBER

45VII

KEEL SIGNATURES OF THE MODEL WITH WEDGE No. 4

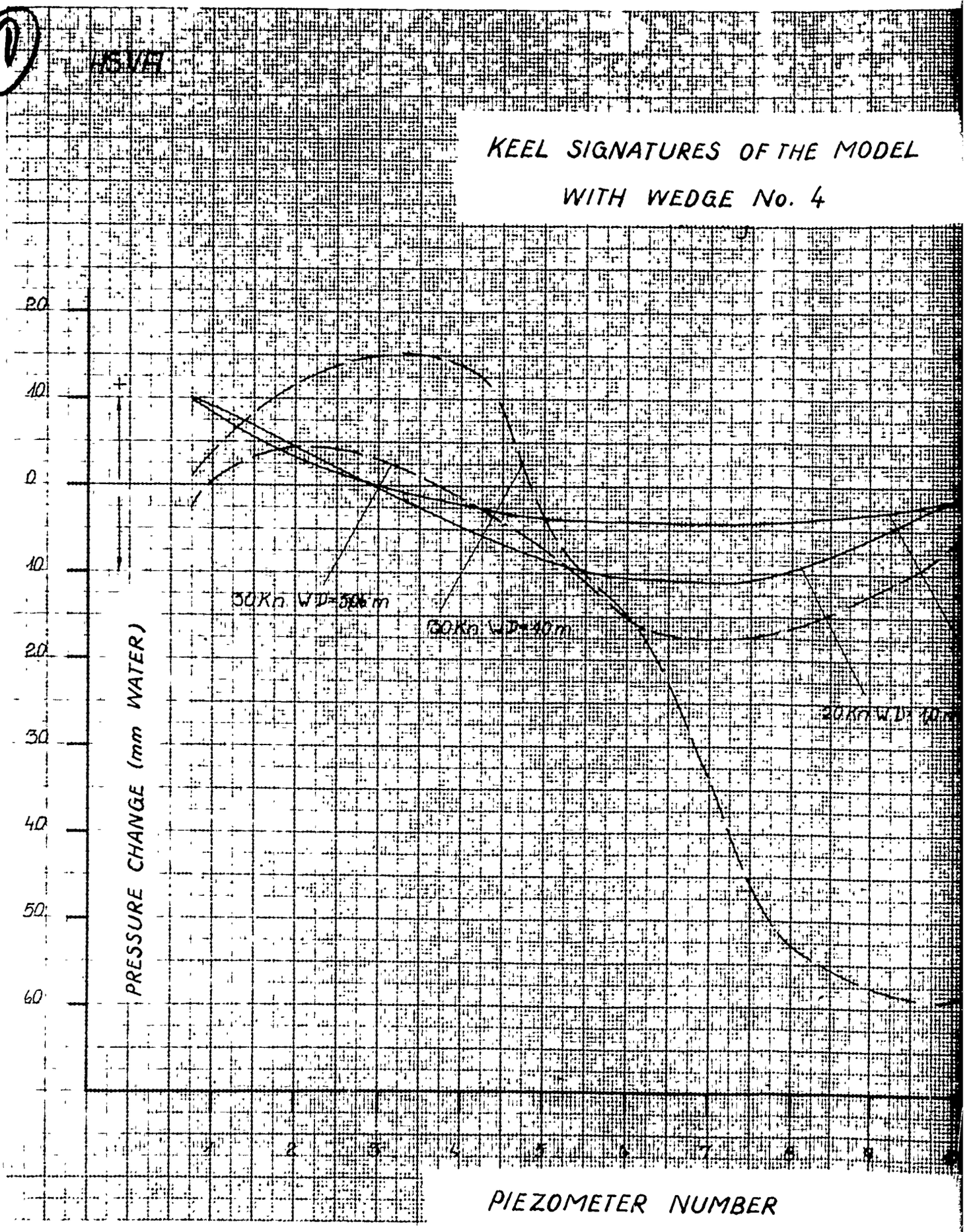
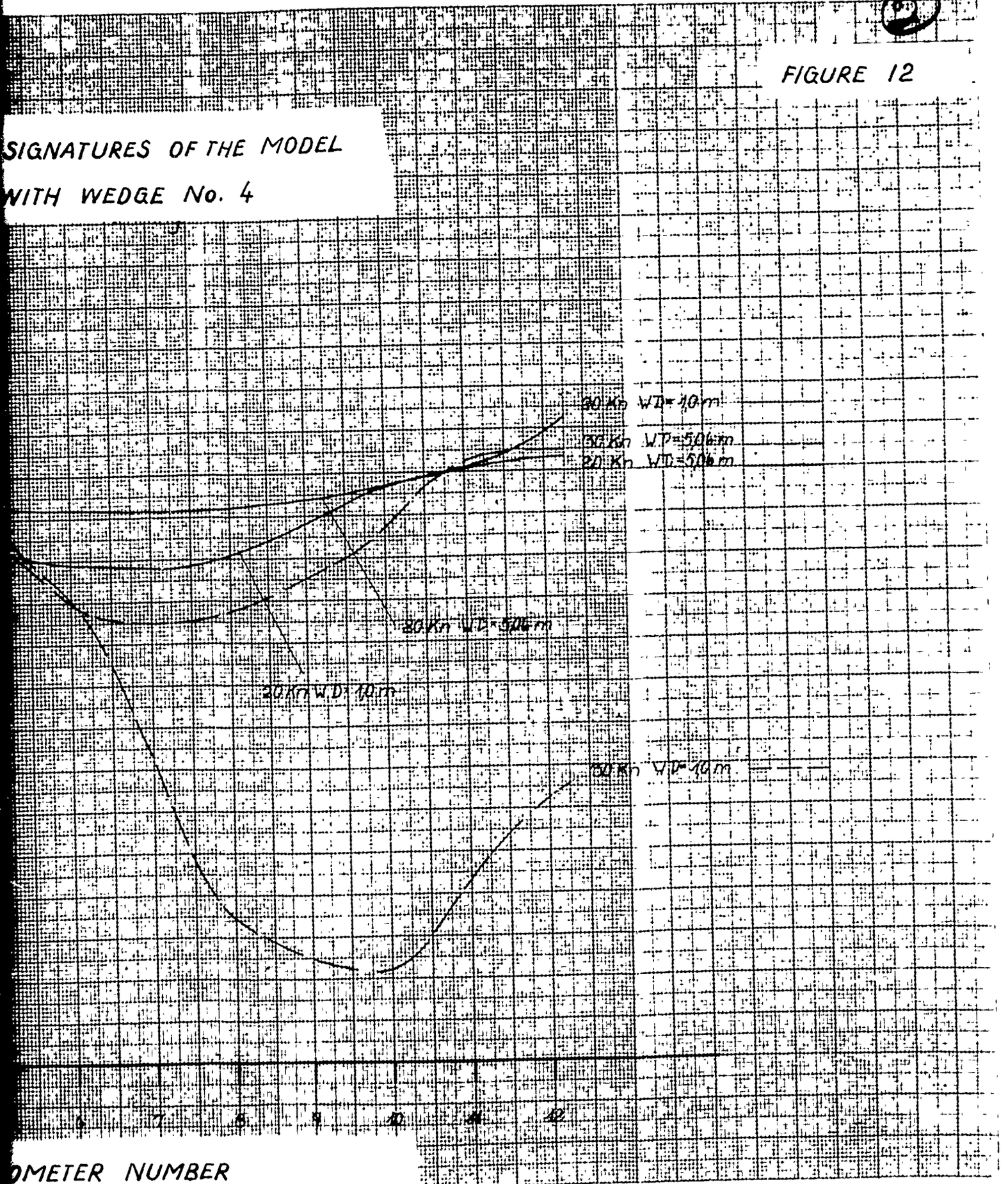


FIGURE 12

SIGNATURES OF THE MODEL

WITH WEDGE No. 4



OMETER NUMBER

D. 165m

KEEL SIGNATURES OF THE MODEL WITH WEDGE No 5

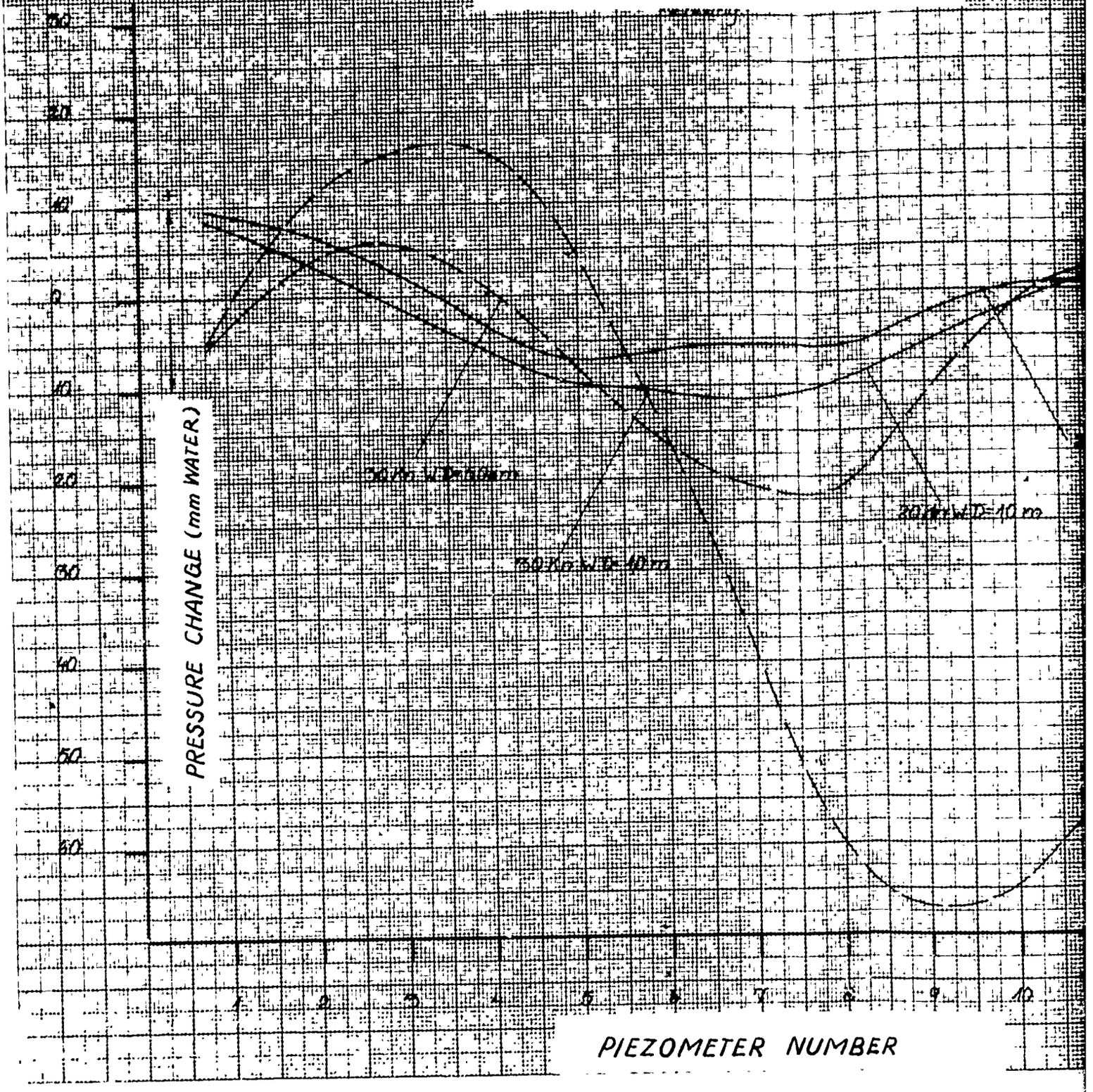
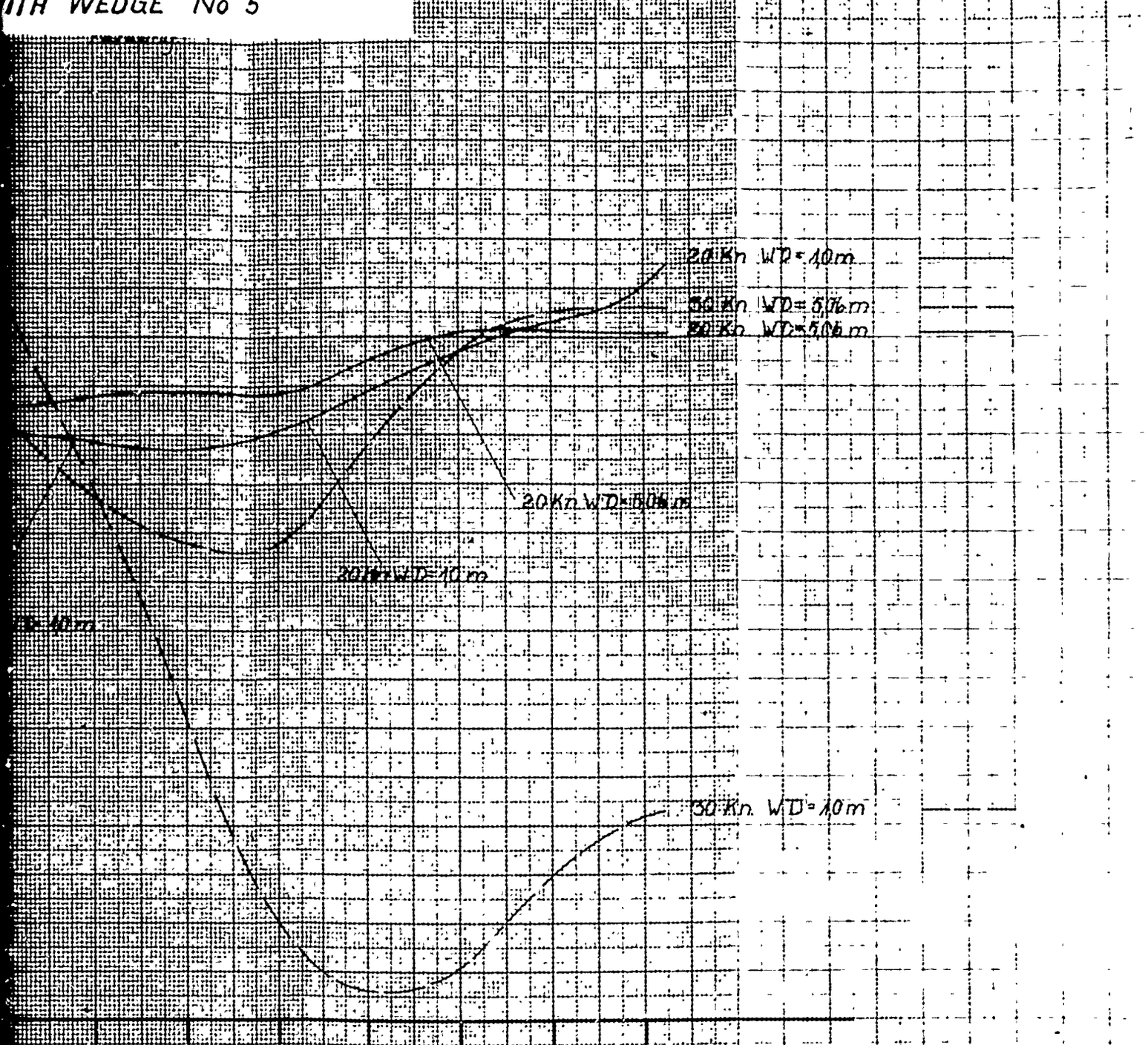


FIGURE 13

IGNATURES OF THE MODEL

ITH WEDGE No 5



V

FISVR

KEEL SIGNATURES OF THE MODEL WITH WEDGE No. 6

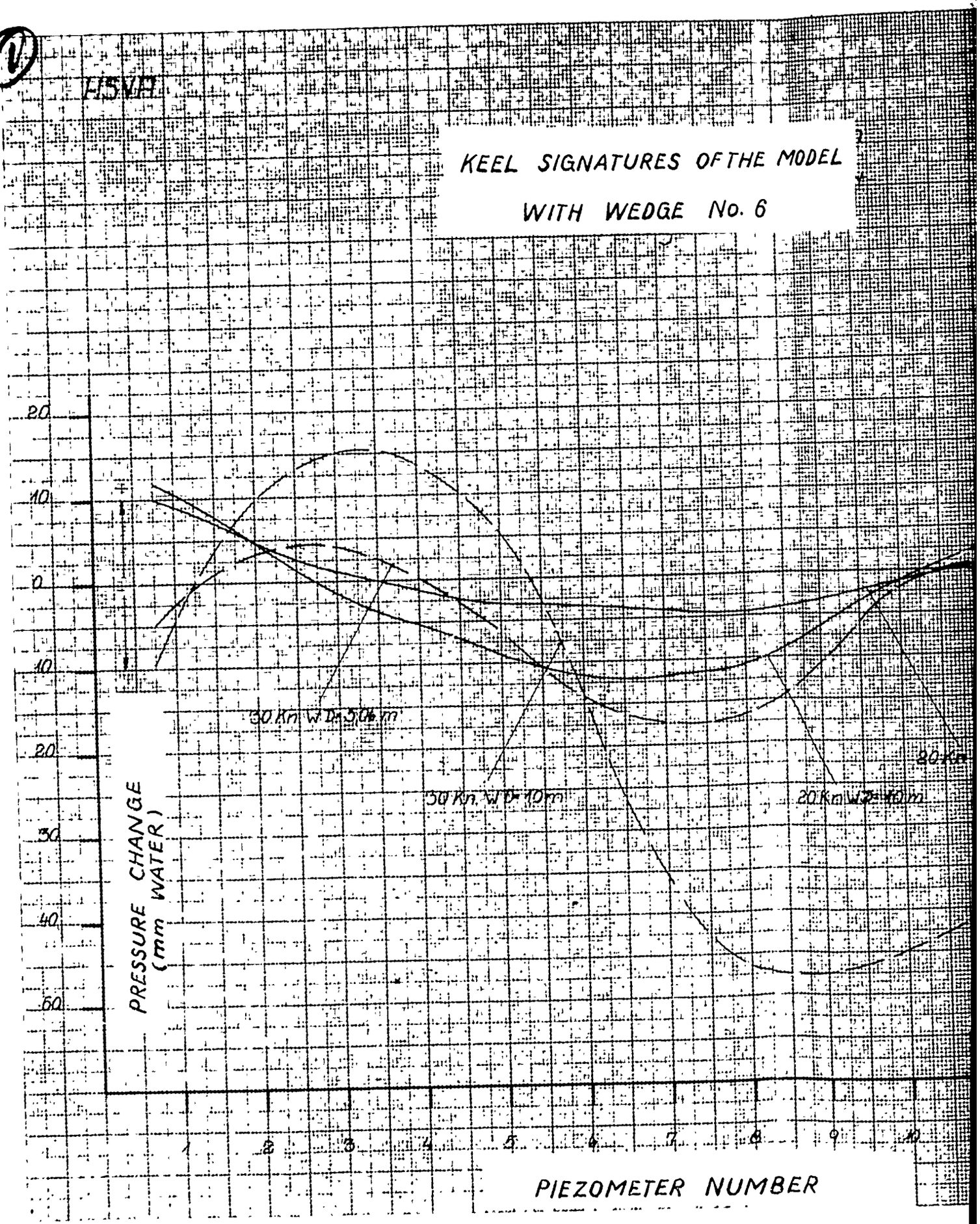
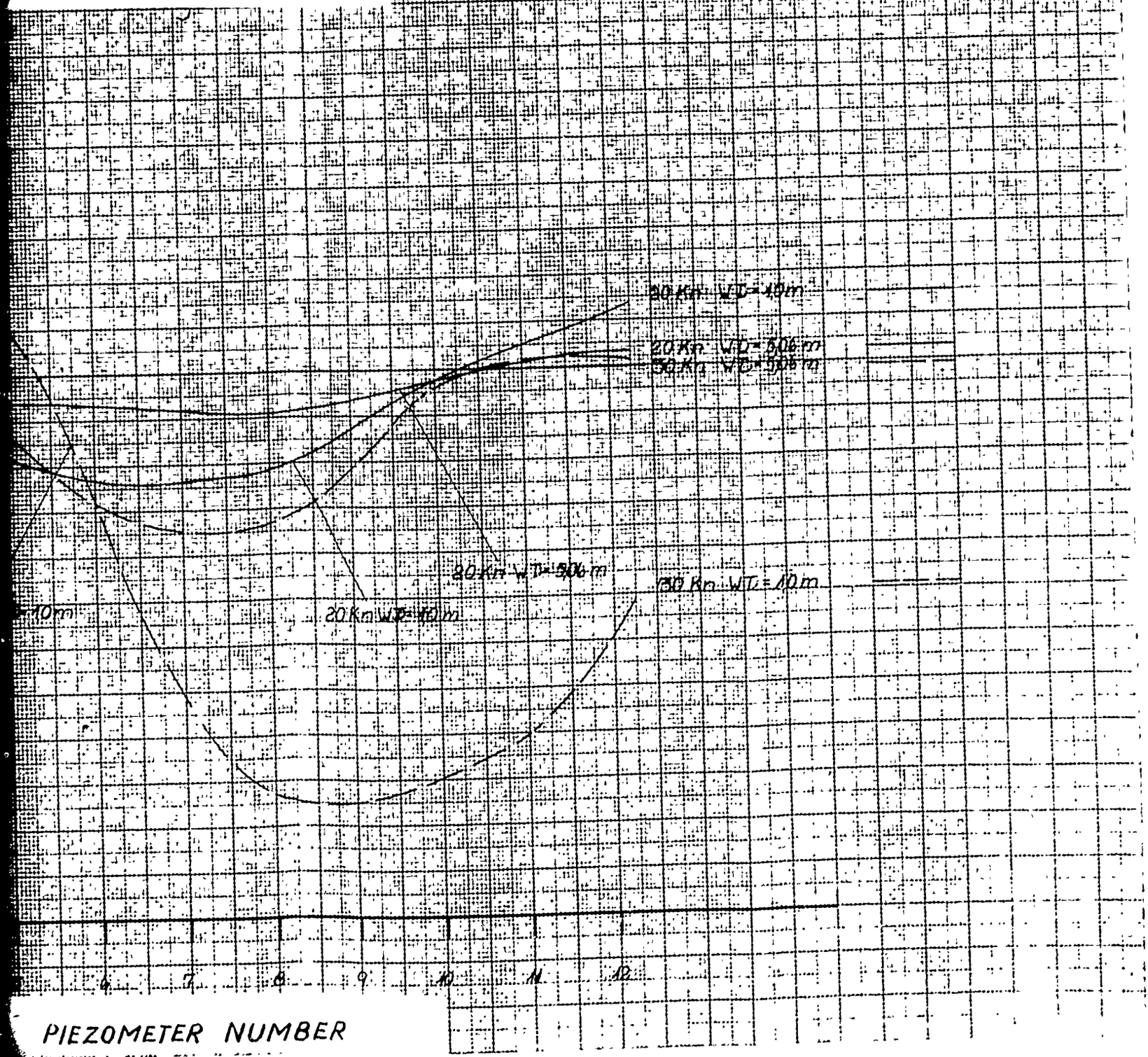


FIGURE 14

L SIGNATURES OF THE MODEL

WITH WEDGE No. 6



D

HSVP

KEEL SIGNATURES OF THE MODEL WITH WEDGE No. 7

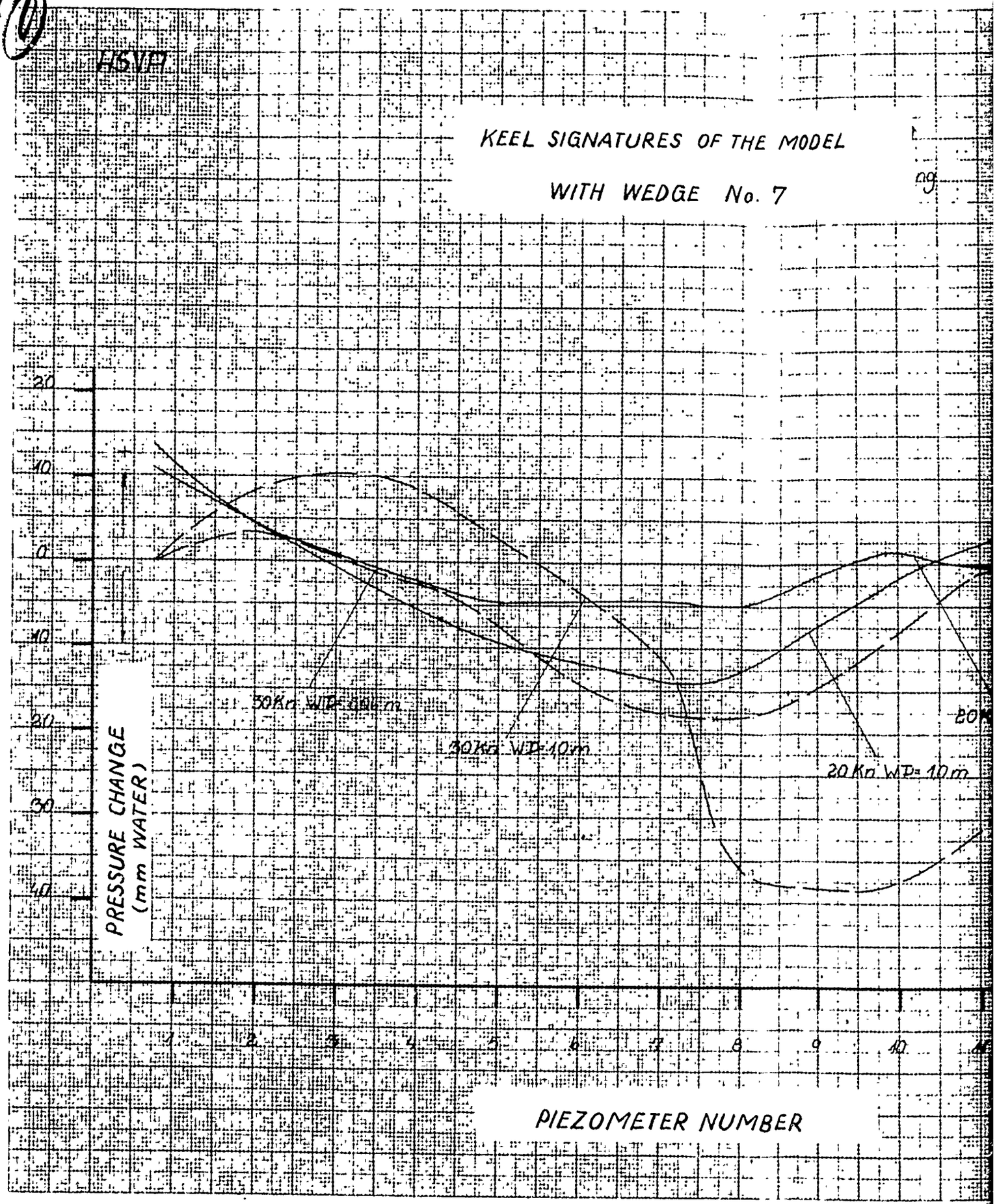
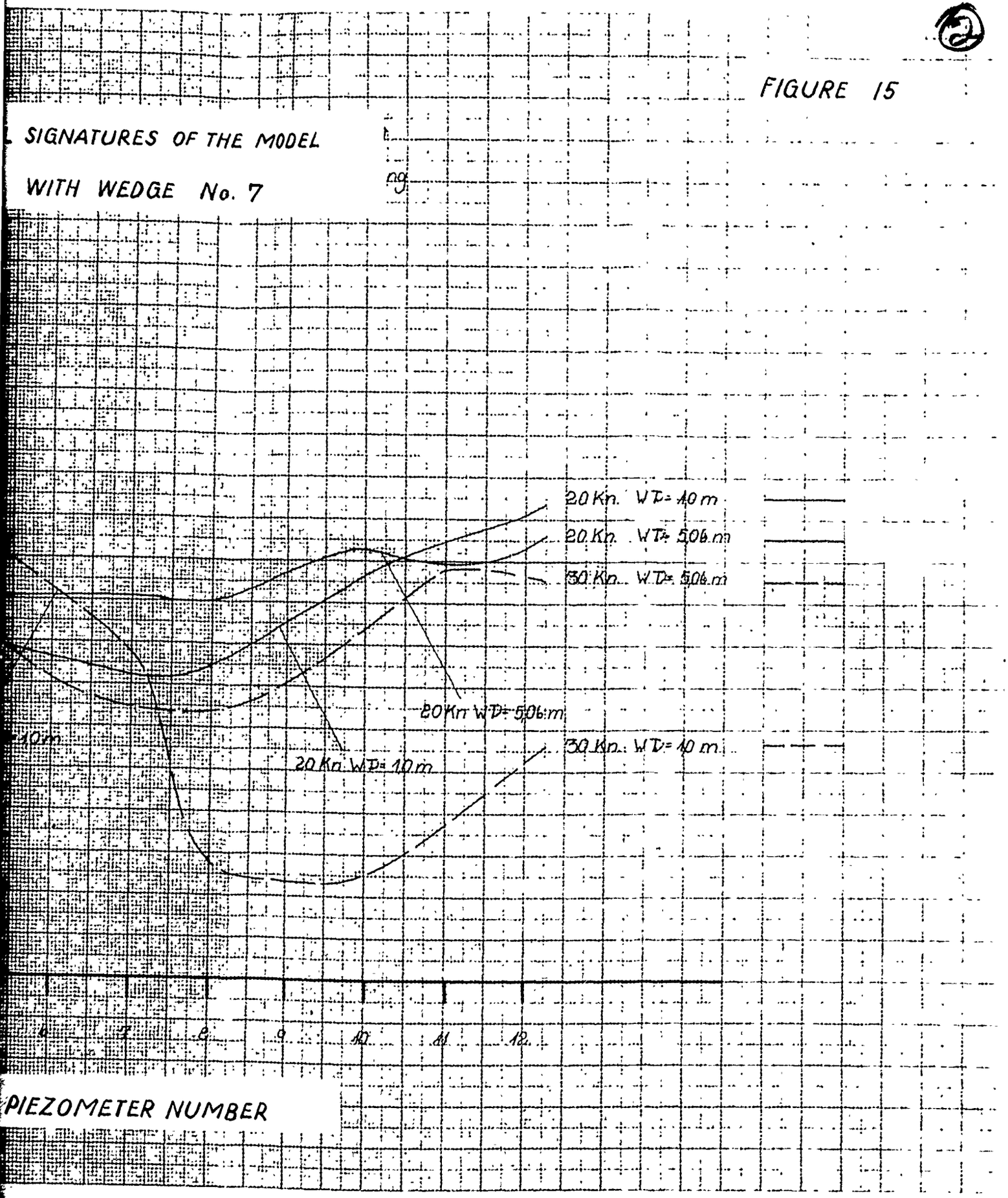


FIGURE 15

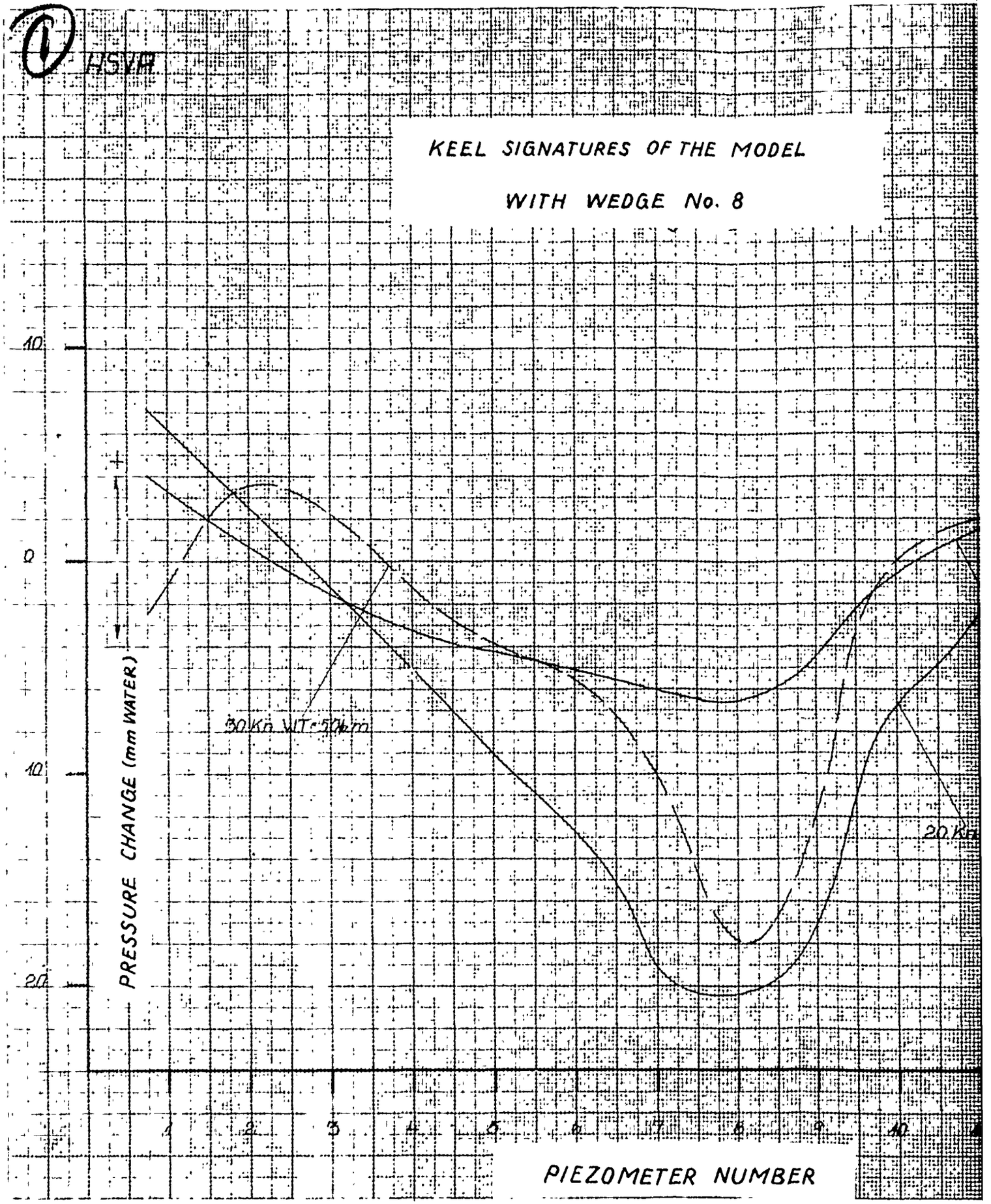
SIGNATURES OF THE MODEL

WITH WEDGE No. 7



HSVR

KEEL SIGNATURES OF THE MODEL WITH WEDGE No. 8

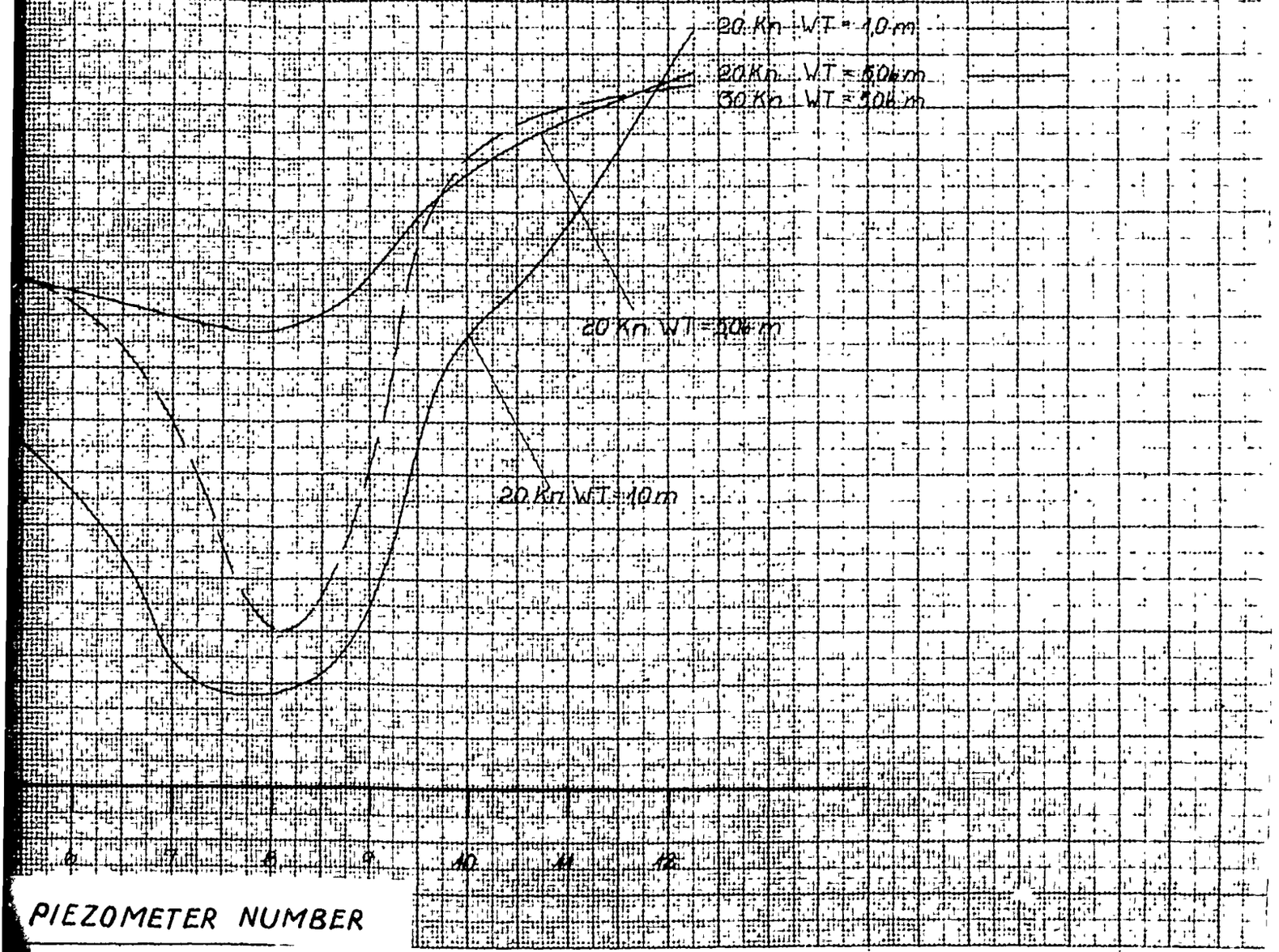


(2)

FIGURE 16

NATURES OF THE MODEL

I.H WEDGE No. 8

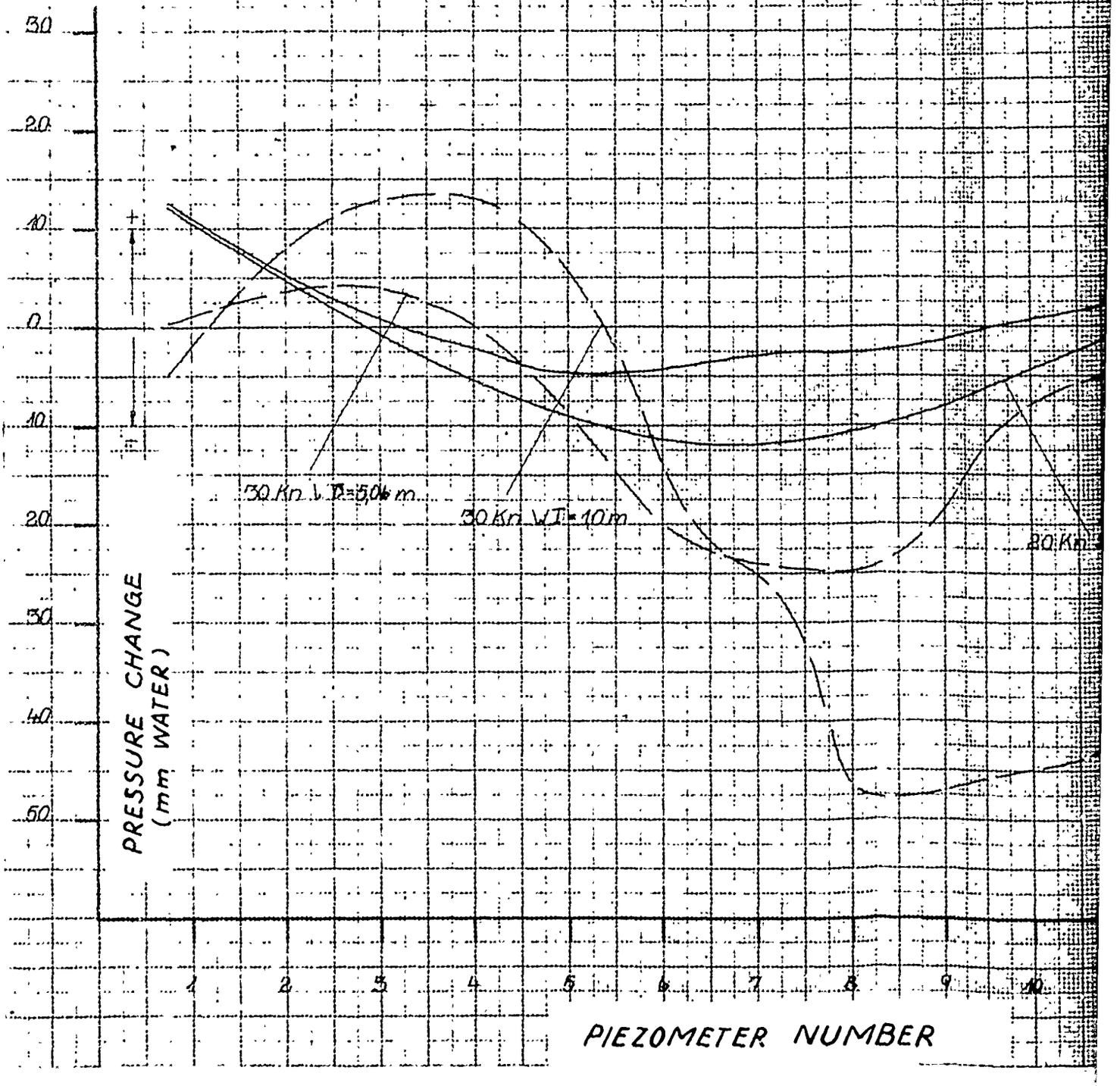


(1)

HSVA

KEEL SIGNATURES OF THE MODEL

WITH DOUBLE WEDGE ARRANGEMENT

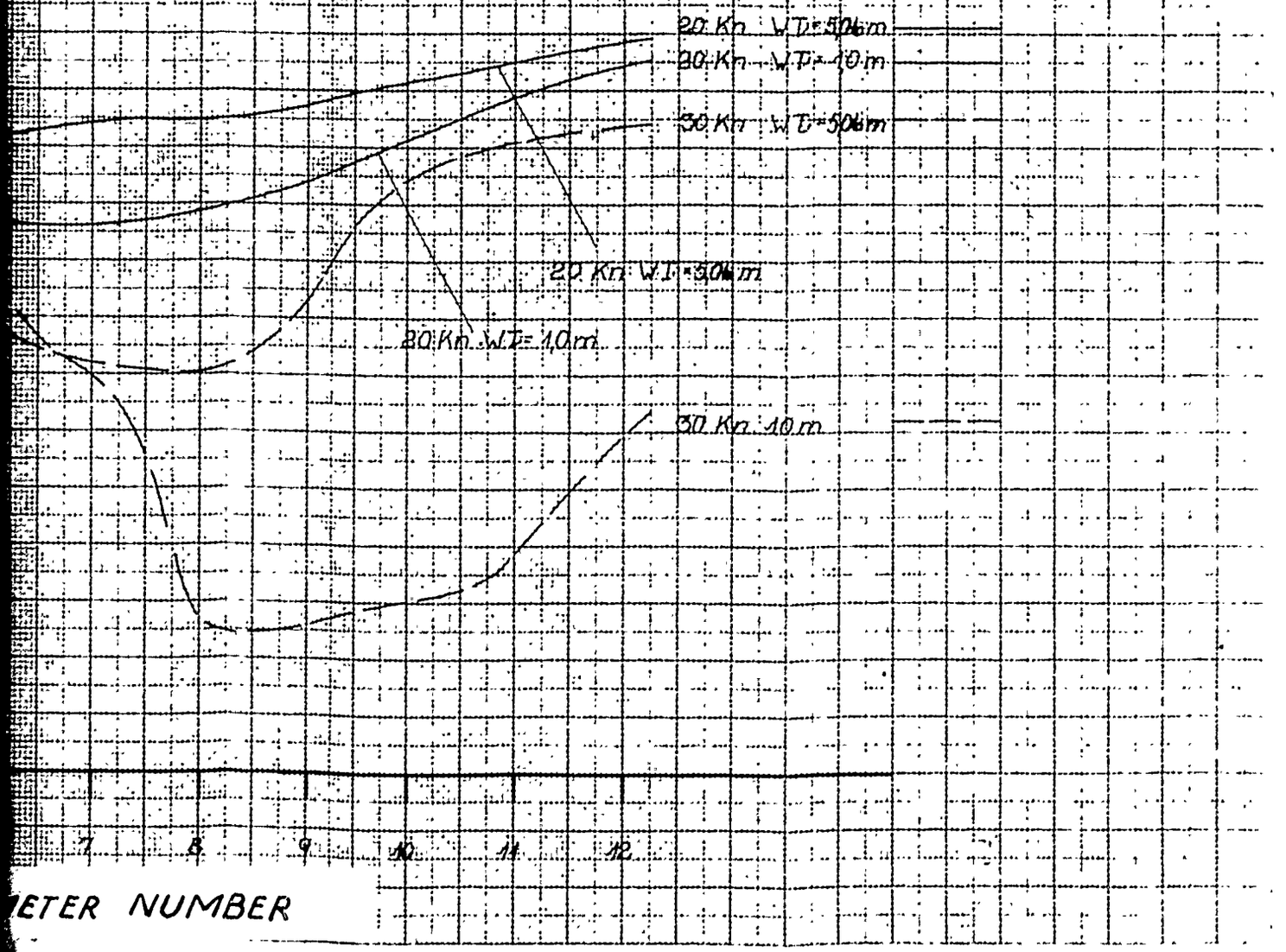


(2)

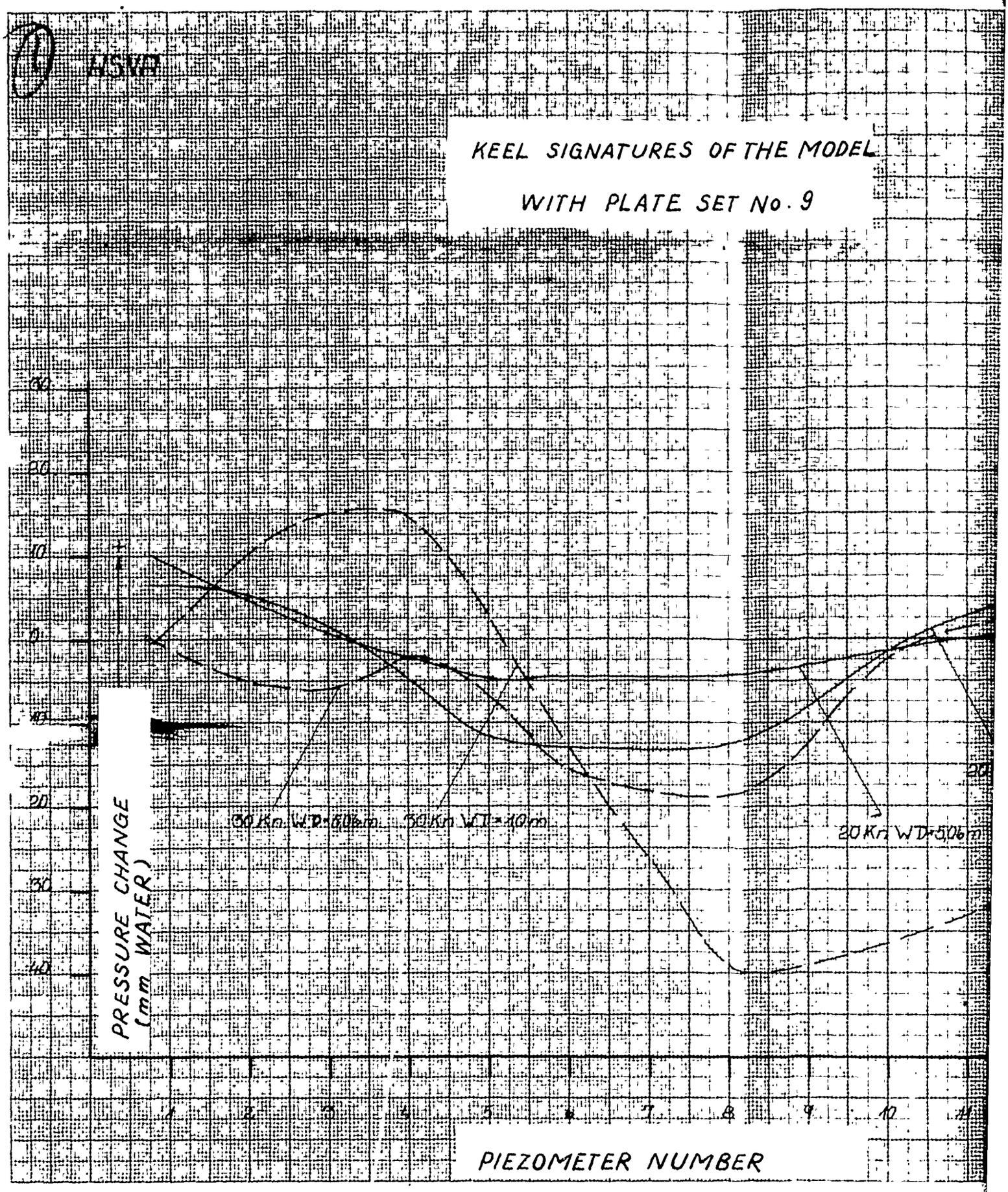
FIGURE 17

SIGNATURES OF THE MODEL

DOUBLE WEDGE ARRANGEMENT



METER NUMBER



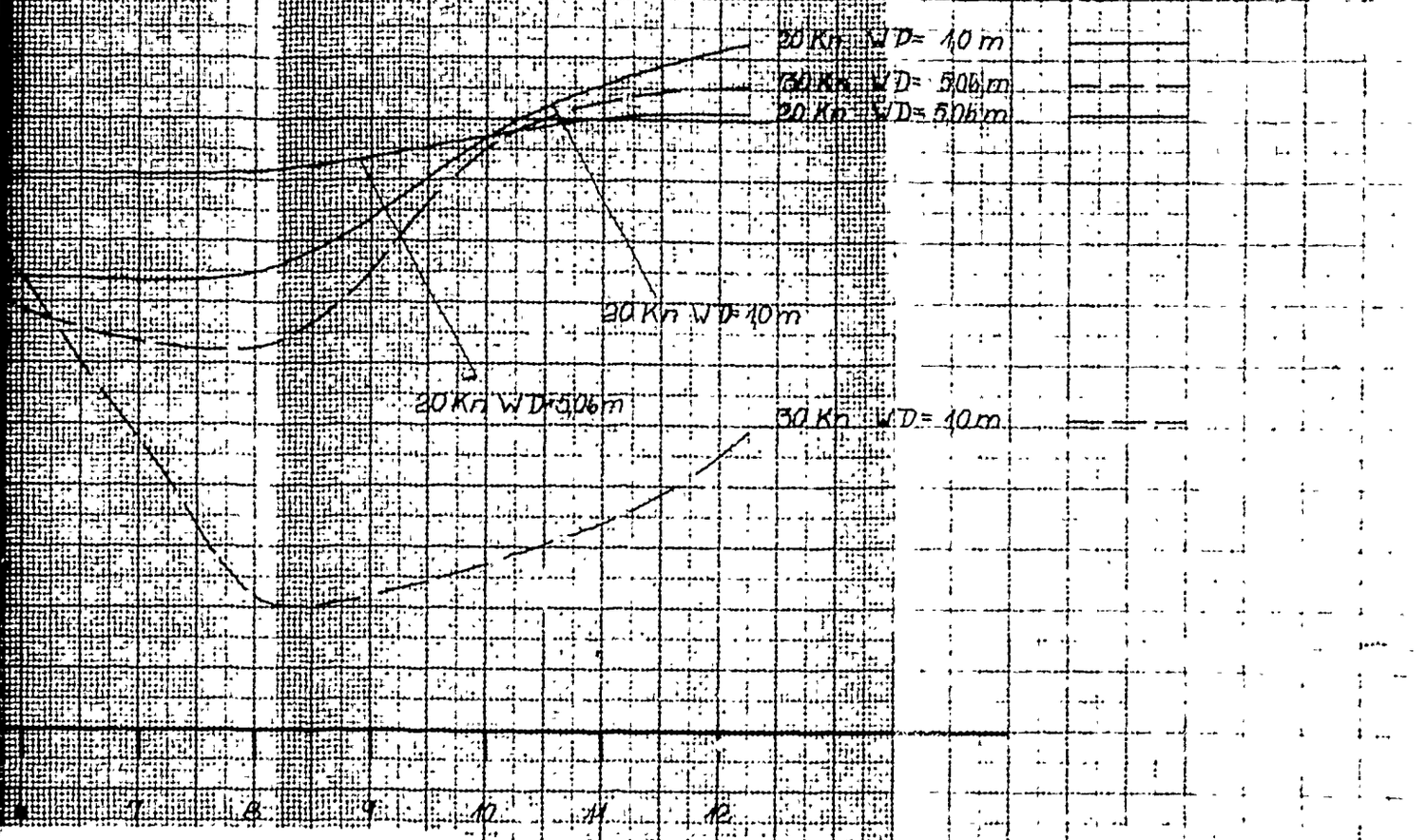
HSVA
KEEL SIGNATURES OF THE MODEL
WITH PLATE SET No. 9
30
20
10
0
10
20
30
40
PRESSURE CHANGE (mm WATER)
30 Kn WD=5.06m
30 Kn WT=10m
20 Kn WD=5.06m
1
2
3
4
5
6
7
8
9
10
11
PIEZOMETER NUMBER

(2)

FIGURE 18

IGNATURES OF THE MODEL

TH PLATE SET No. 9



METER NUMBER

HSVA

KEEL SIGNATURES OF THE MODEL WITH PLATE SET No. 10

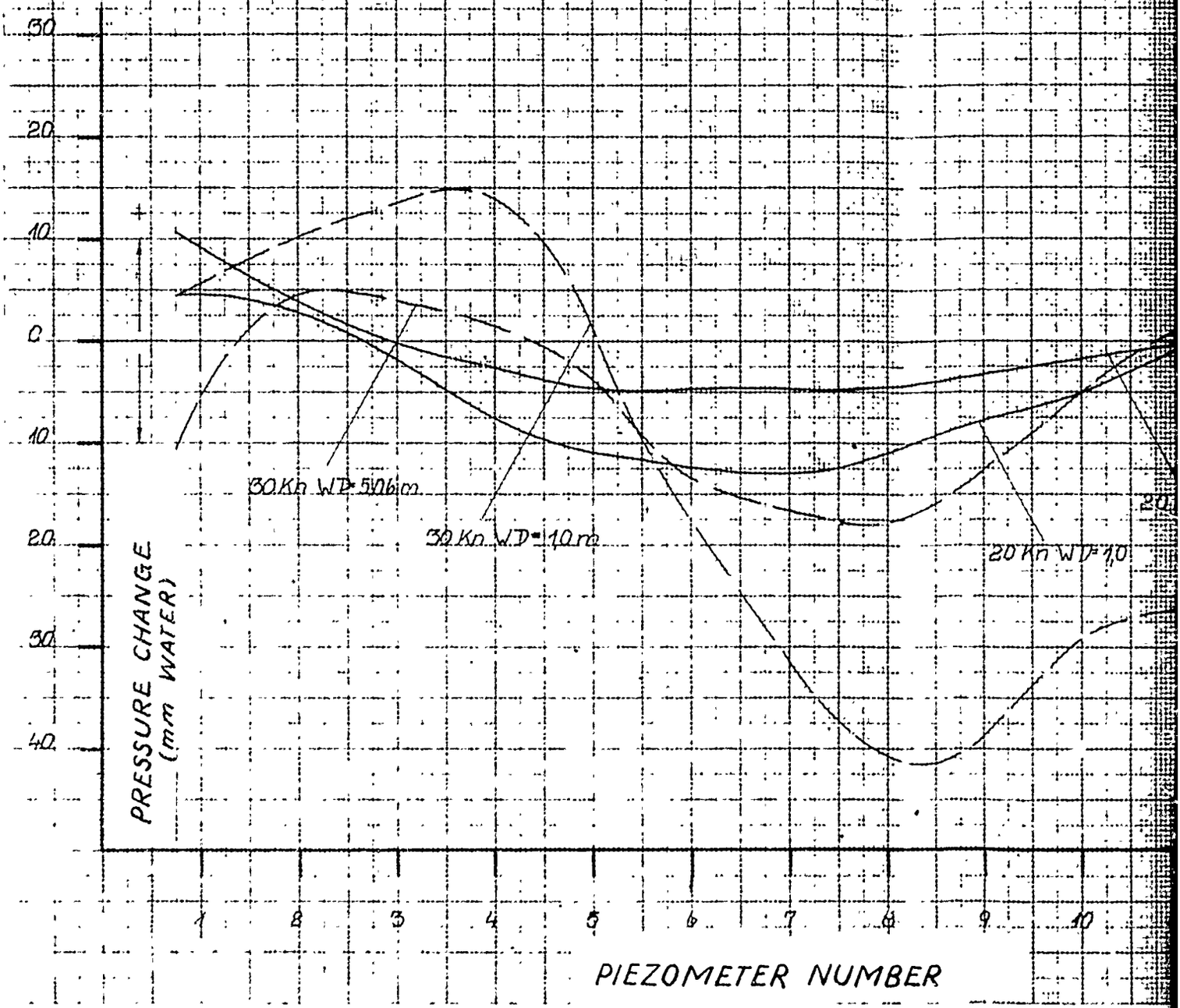
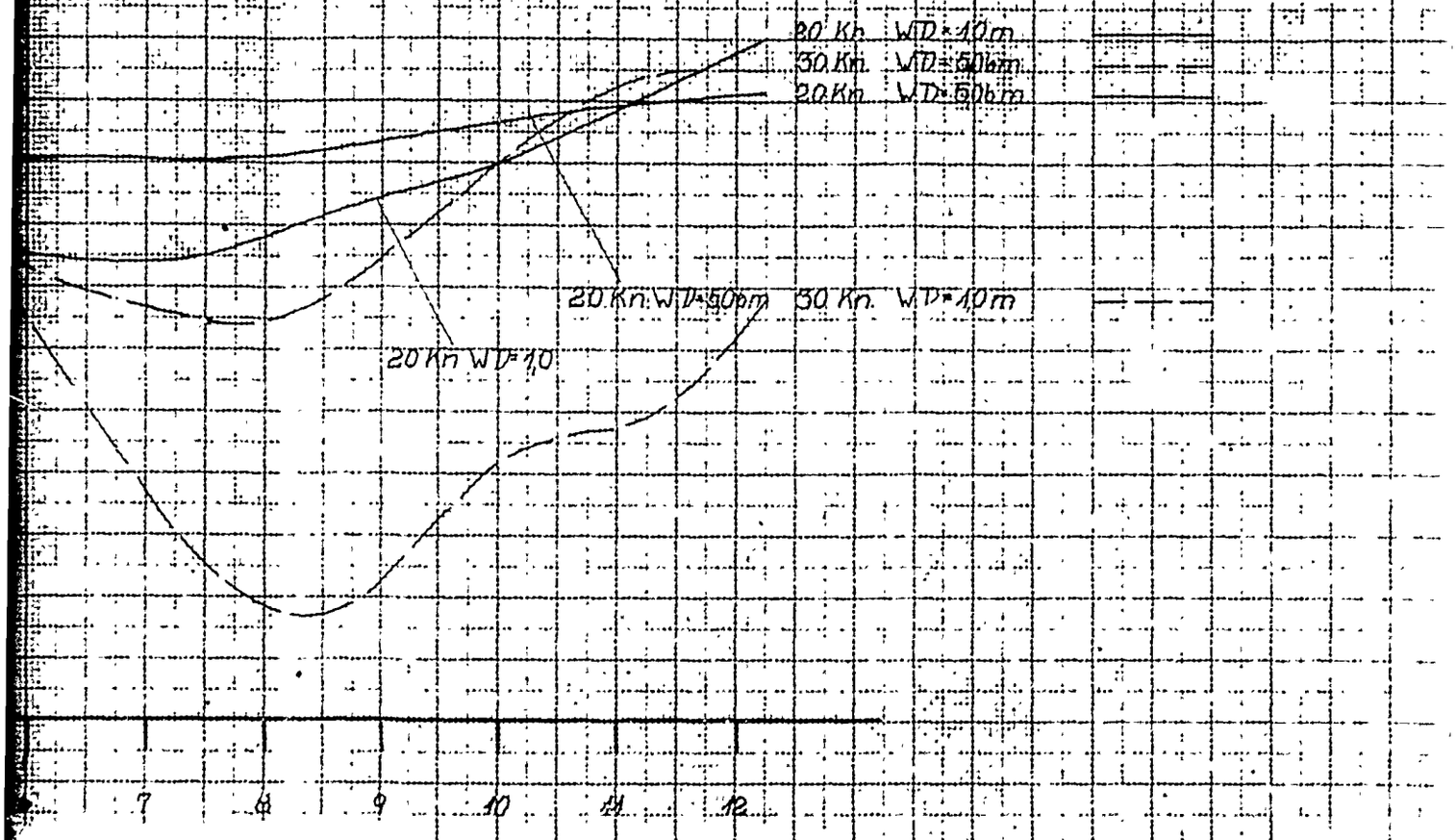


FIGURE 19

EL SIGNATURES OF THE

L WITH PLATE SET No. 10



7 8 9 10 11 12

METER NUMBER

D HSVRI

KEEL SIGNATURES OF THE MODEL WITH PLATE SET No II

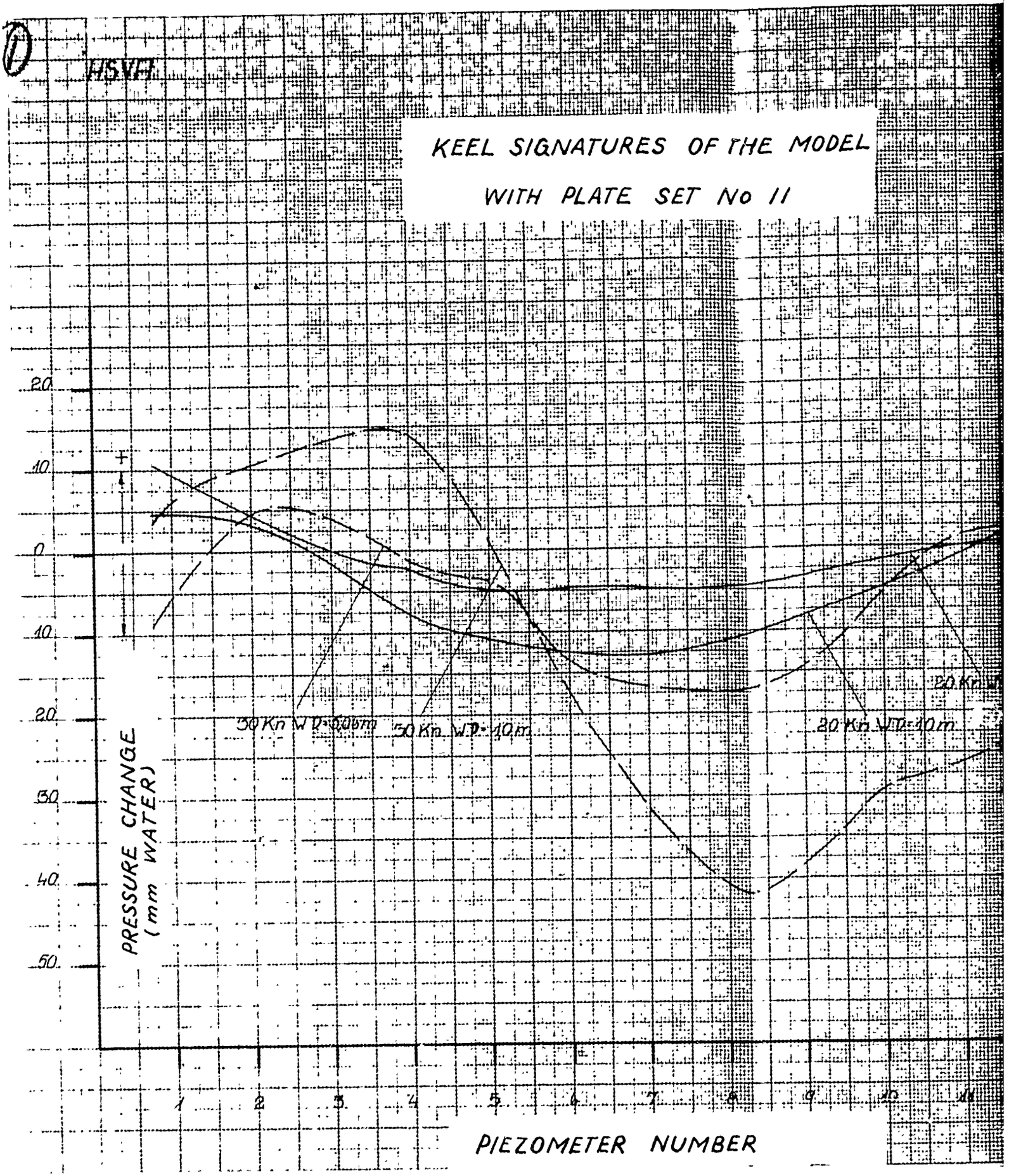
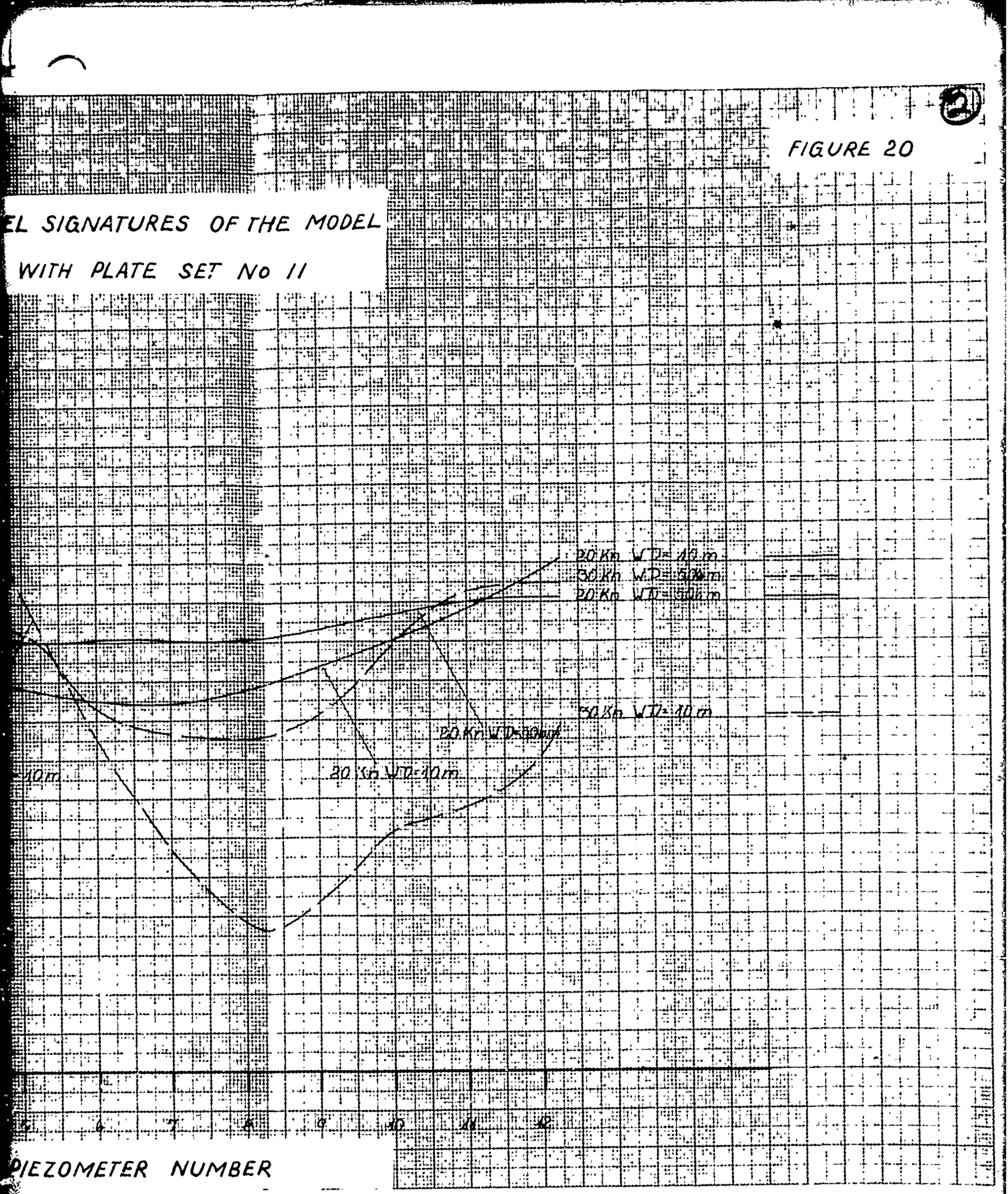


FIGURE 20

EL SIGNATURES OF THE MODEL

WITH PLATE SET No 11



H5VA

KEEL SIGNATURES OF THE MODEL WITH PLATE SET No 12

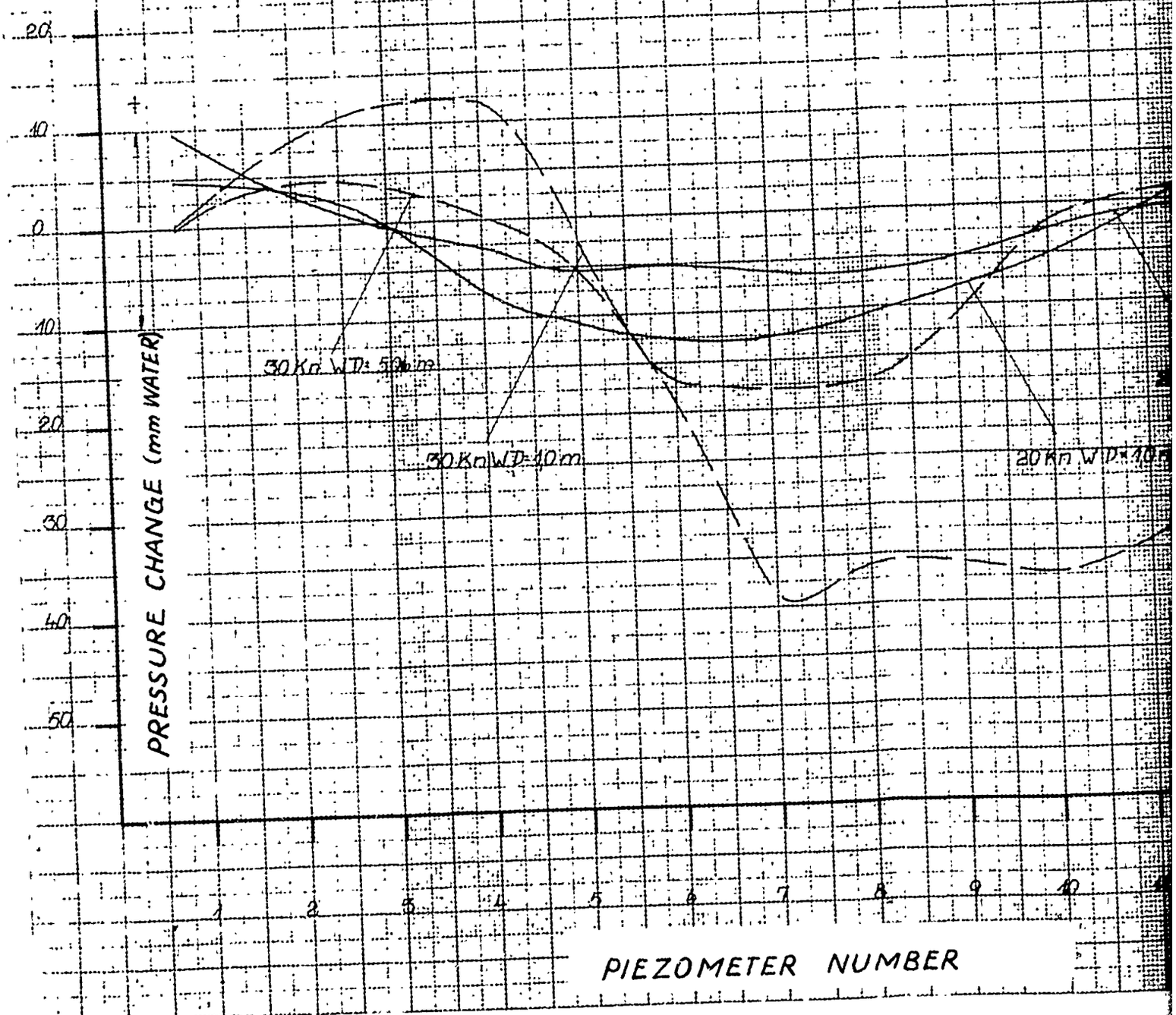
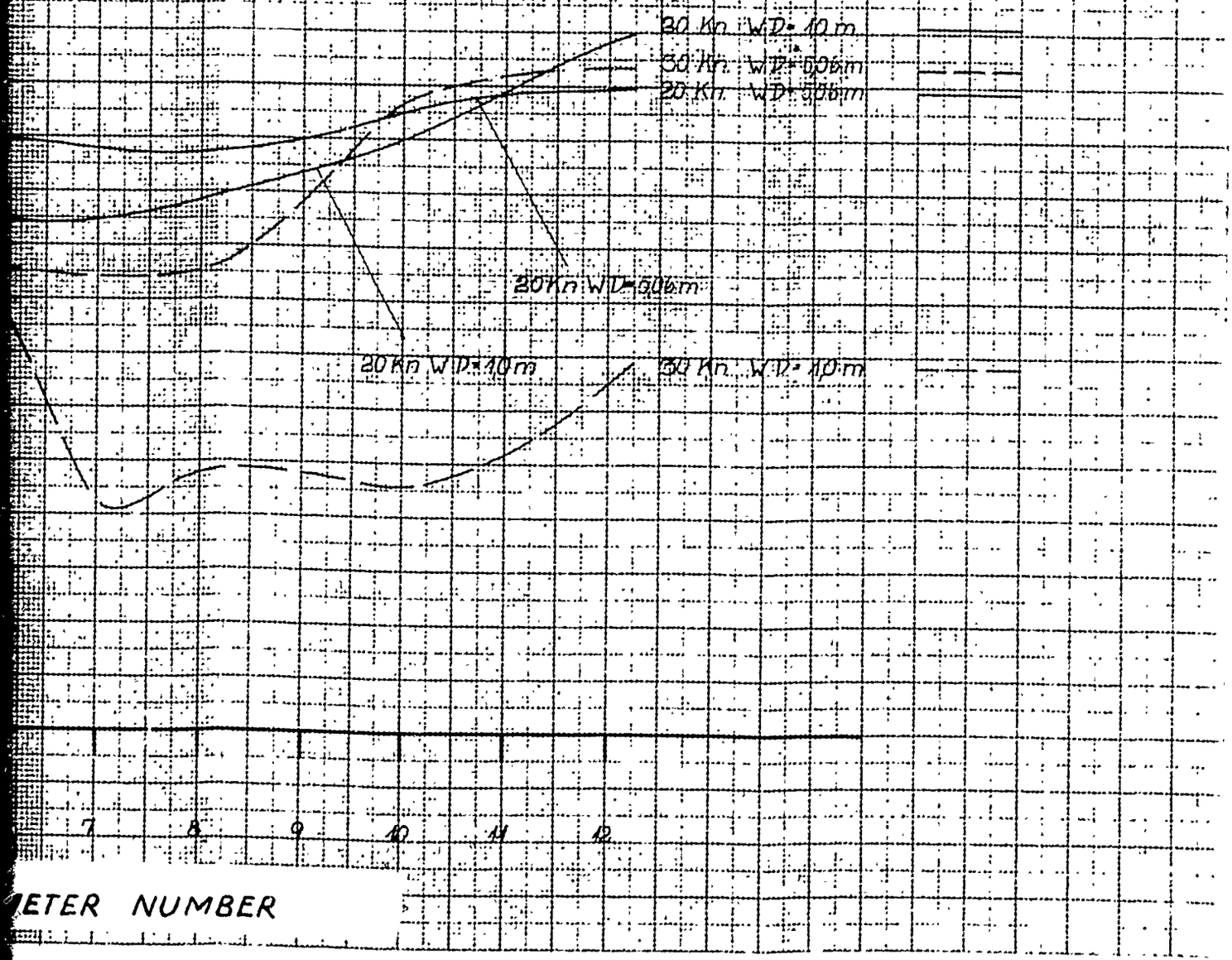


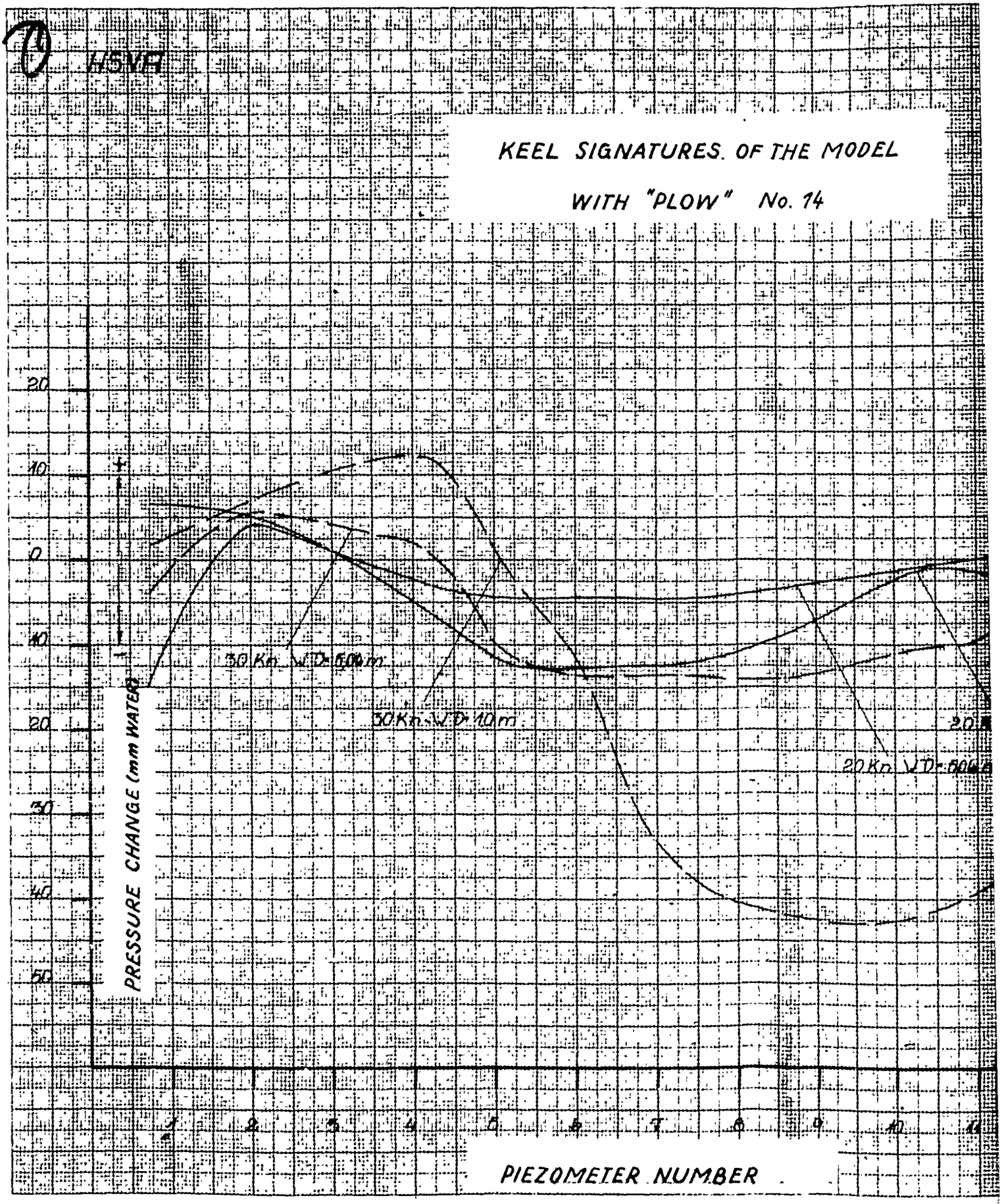
FIGURE 21

TURES OF THE MODEL

PLATE SET No 12



METER NUMBER

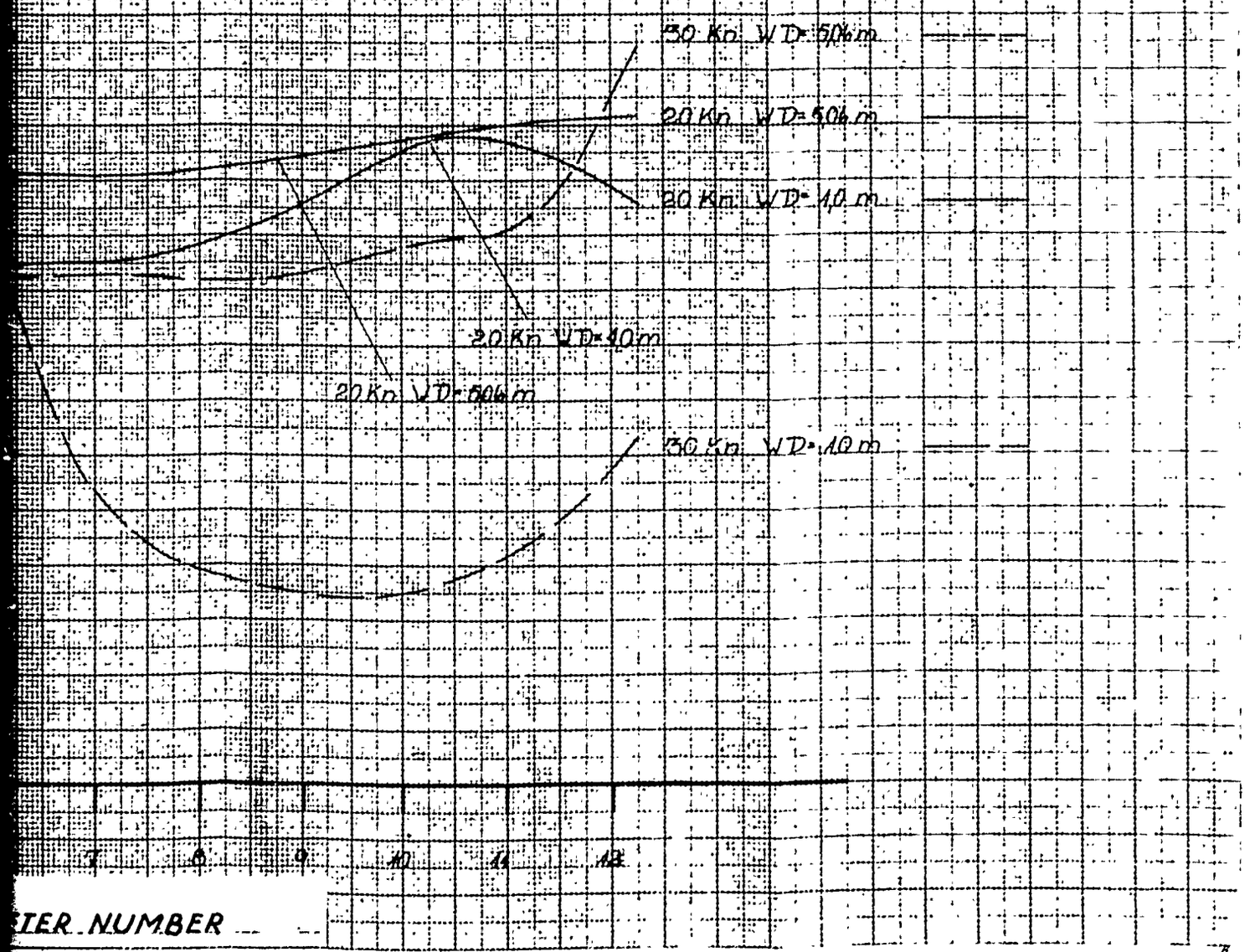


HSVA
KEEL SIGNATURES OF THE MODEL
WITH "PLOW" No. 14
20
10
0
10
20
30
40
50
PRESSURE CHANGE (mm WATER)
30 Kn WD=5.04m
30 Kn WD=10m
20 Kn WD=5.04
1
2
3
4
5
6
7
8
9
10
PIEZOMETER NUMBER

FIGURE 22

IGNATURES OF THE MODEL

ITH "PLOW" No. 14



TER NUMBER

VSVA

KEEL SIGNATURES OF THE MODEL WITH "PLOW" No. 15

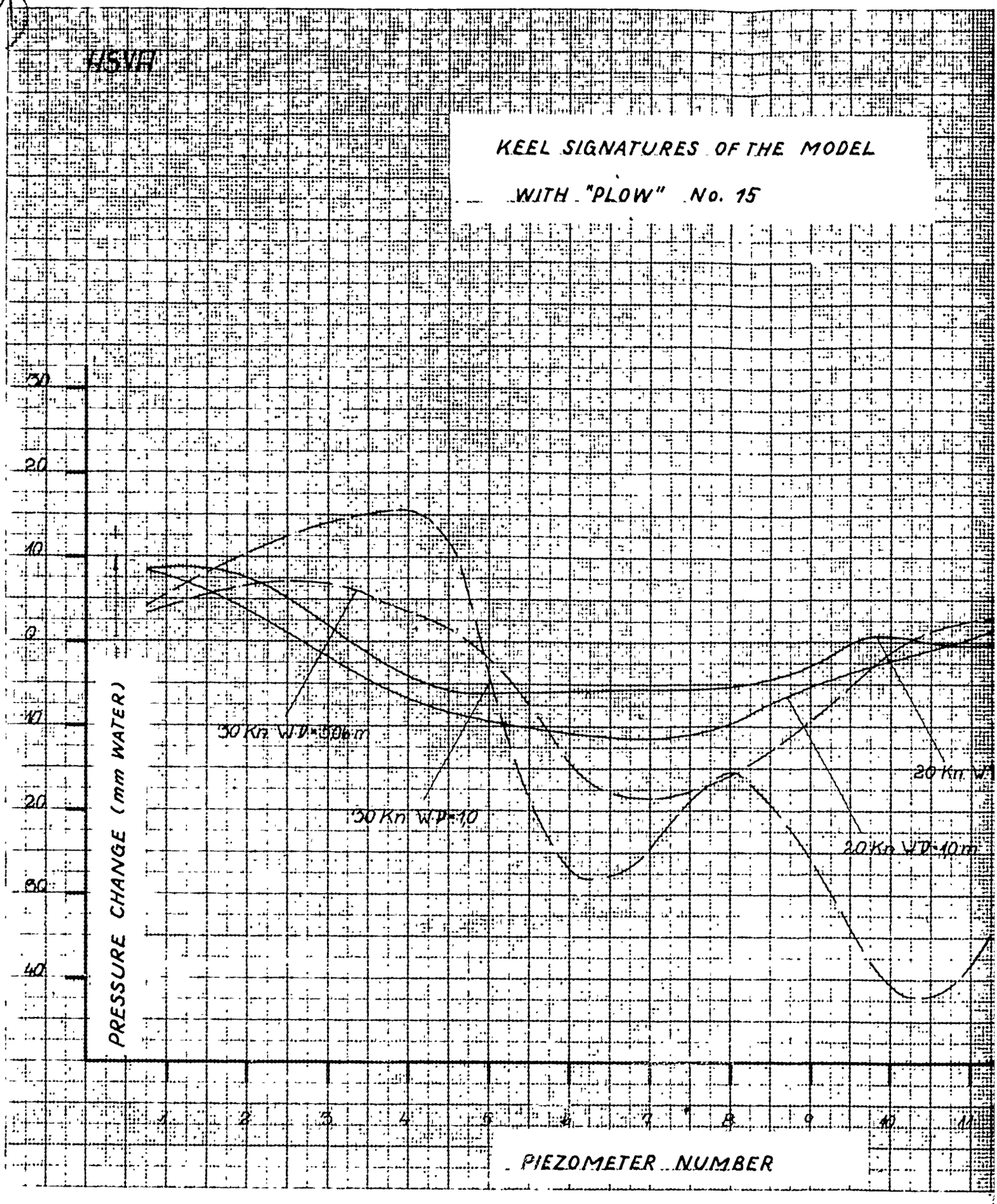
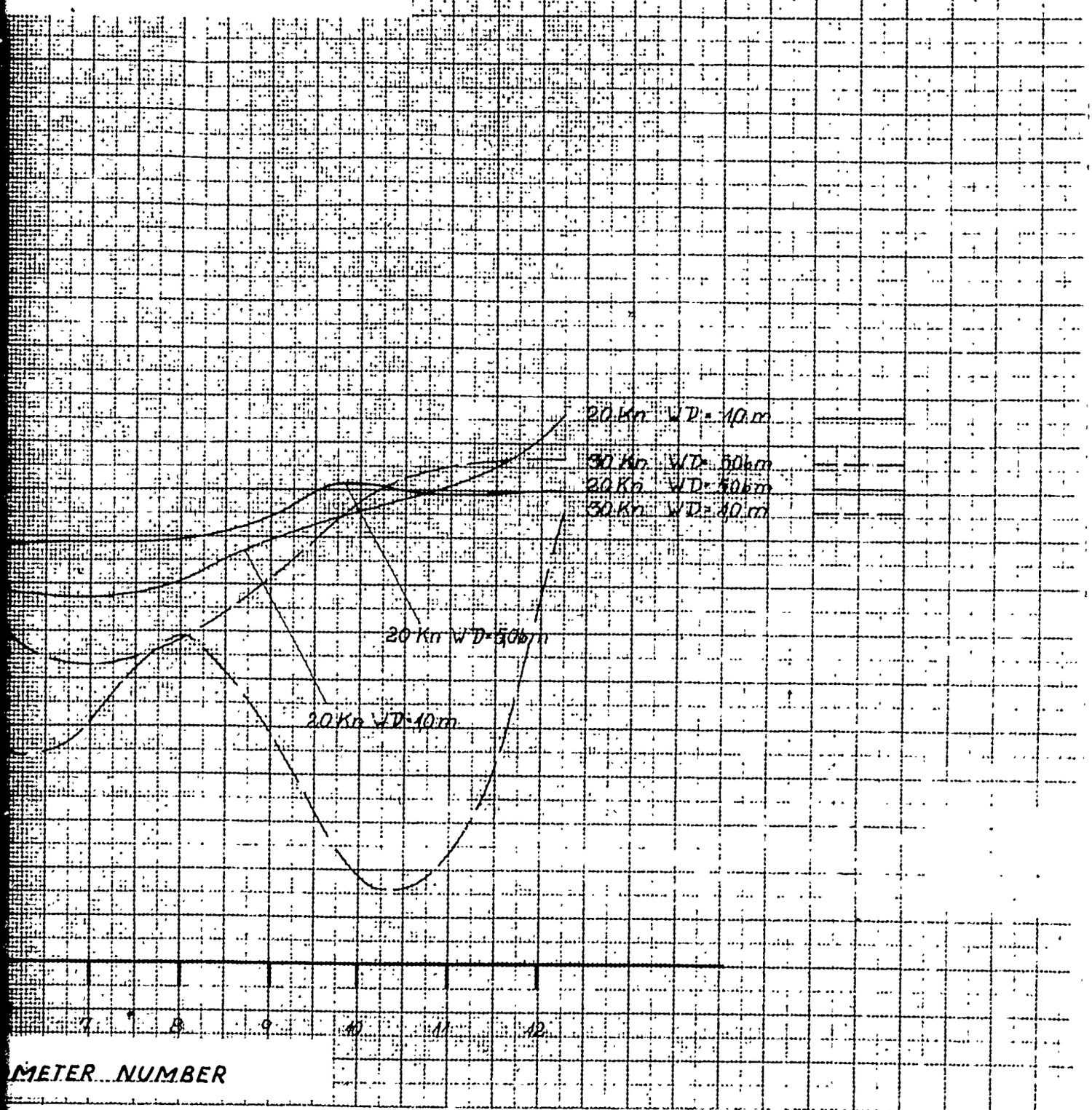


FIGURE 23

IGNATURES OF THE MODEL

"PLOW" No. 15



METER NUMBER

(1)

H.S.V.A.

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 1.88 m
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m

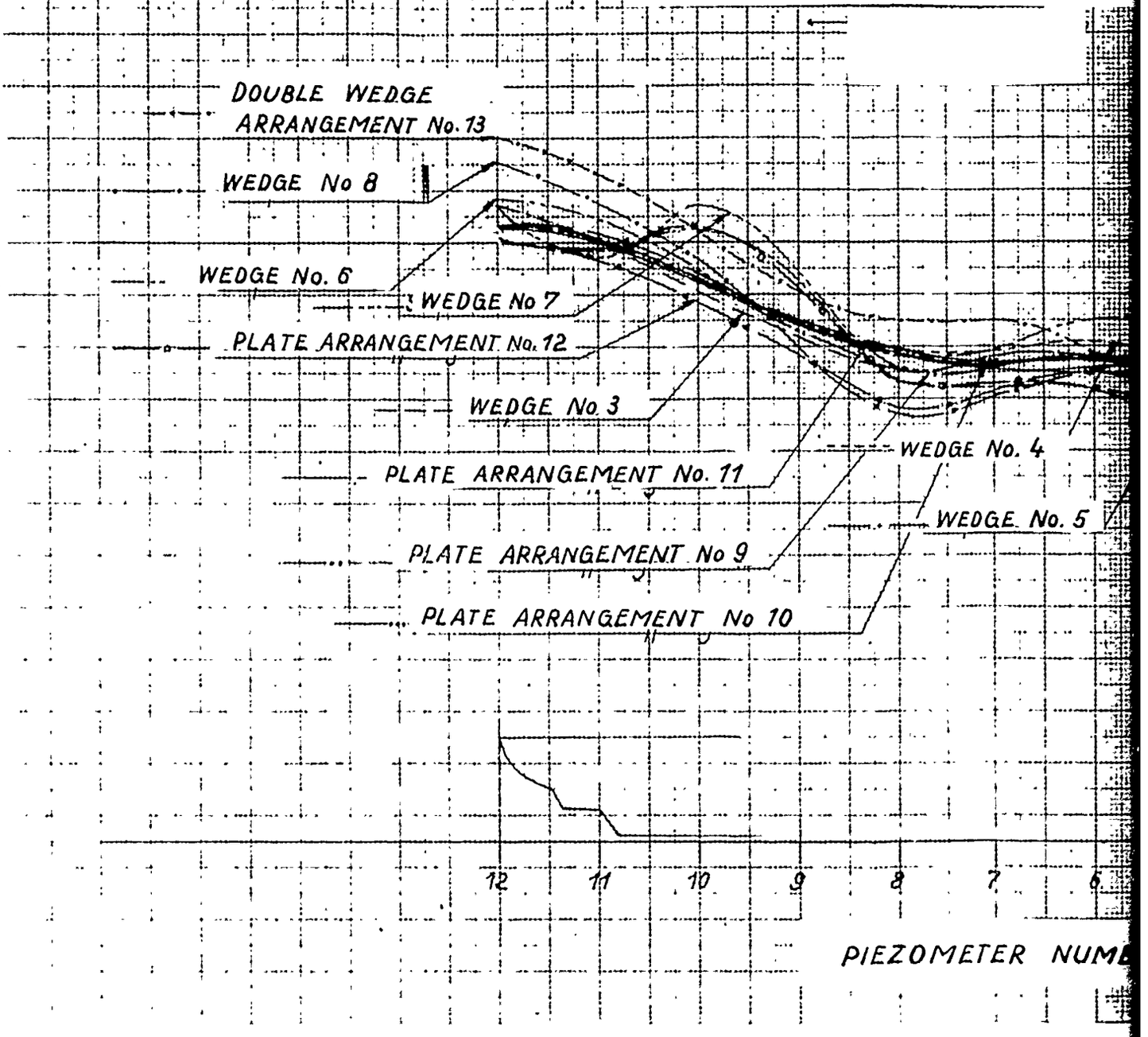
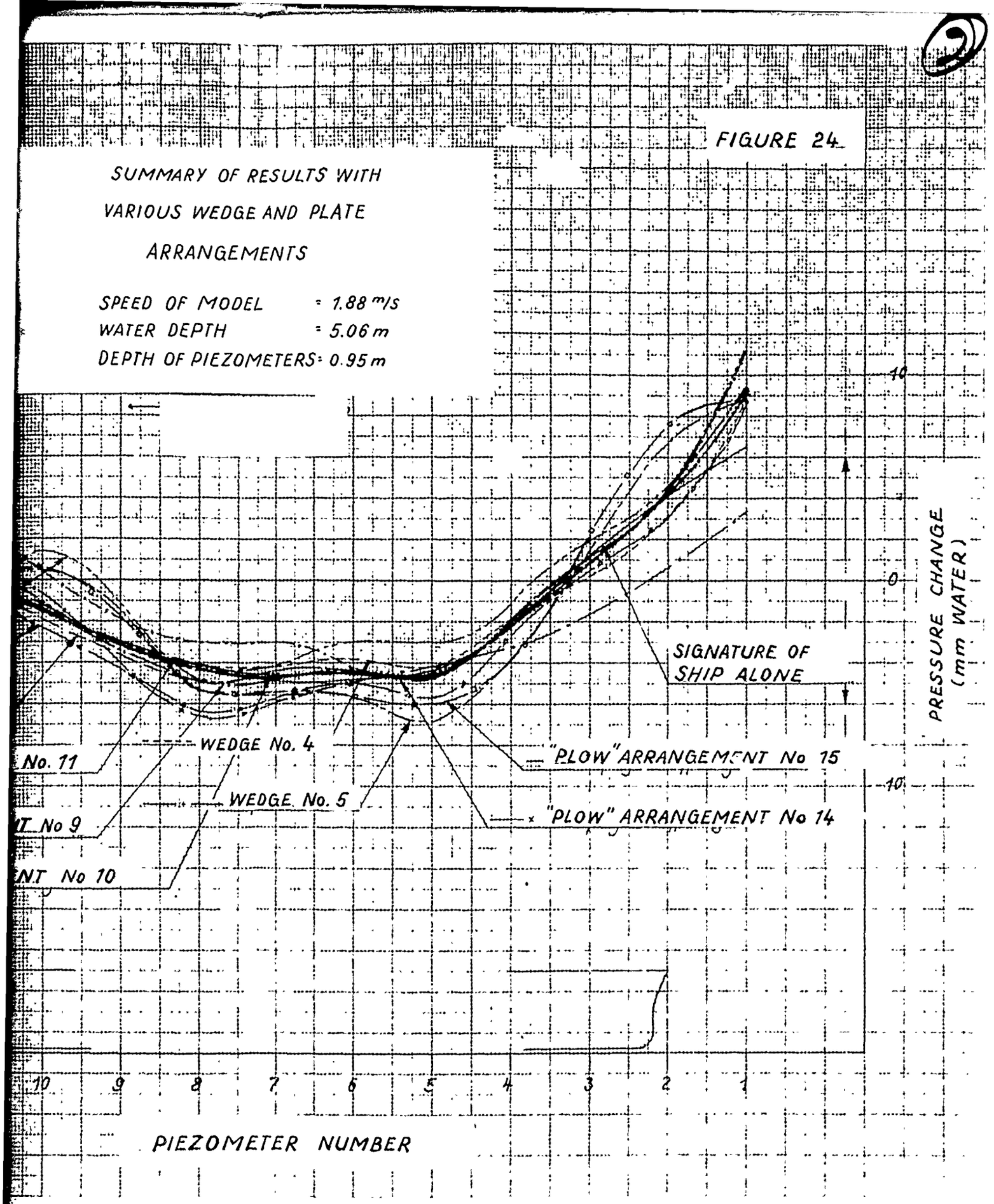


FIGURE 24

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



D

H.S.V.A

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m

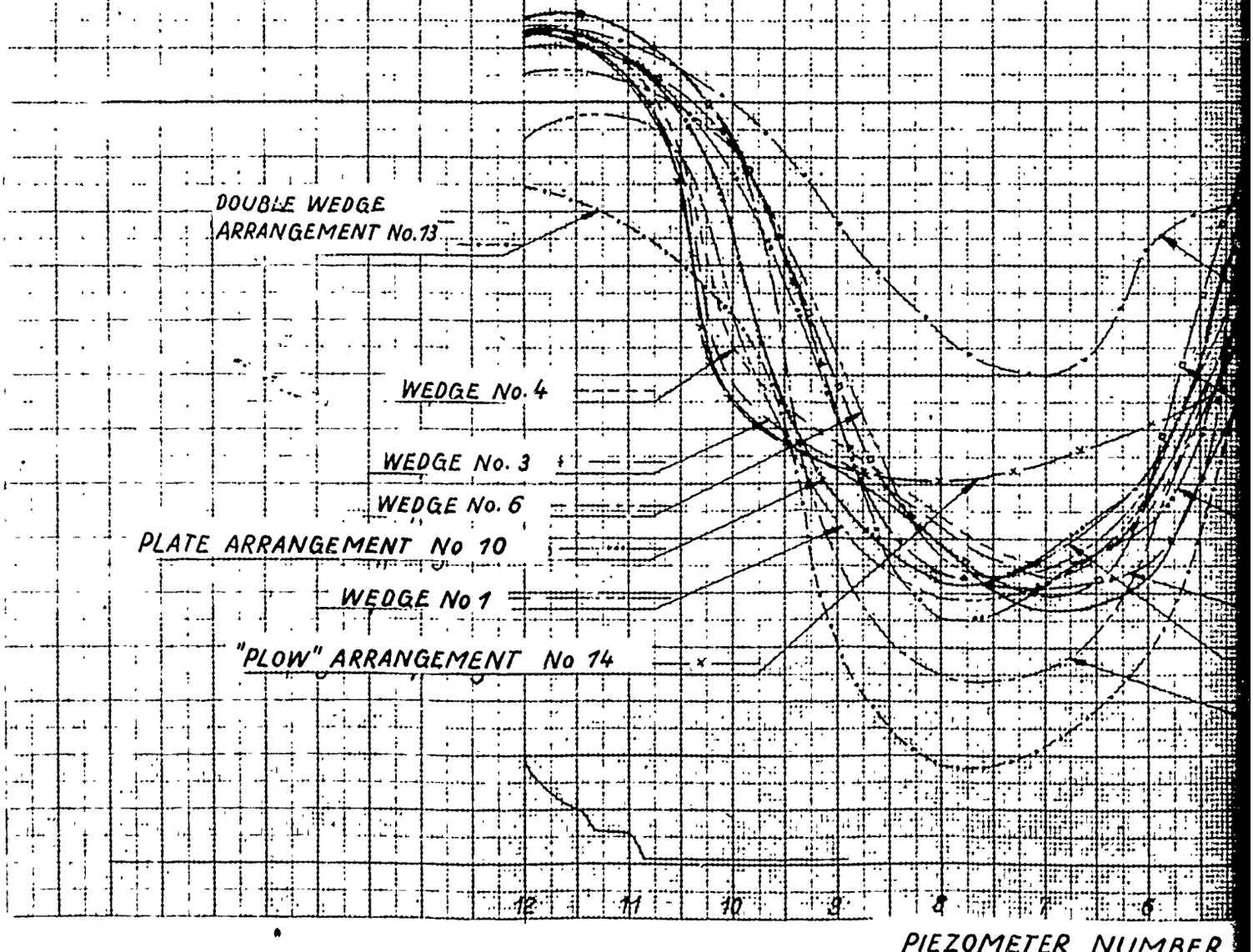
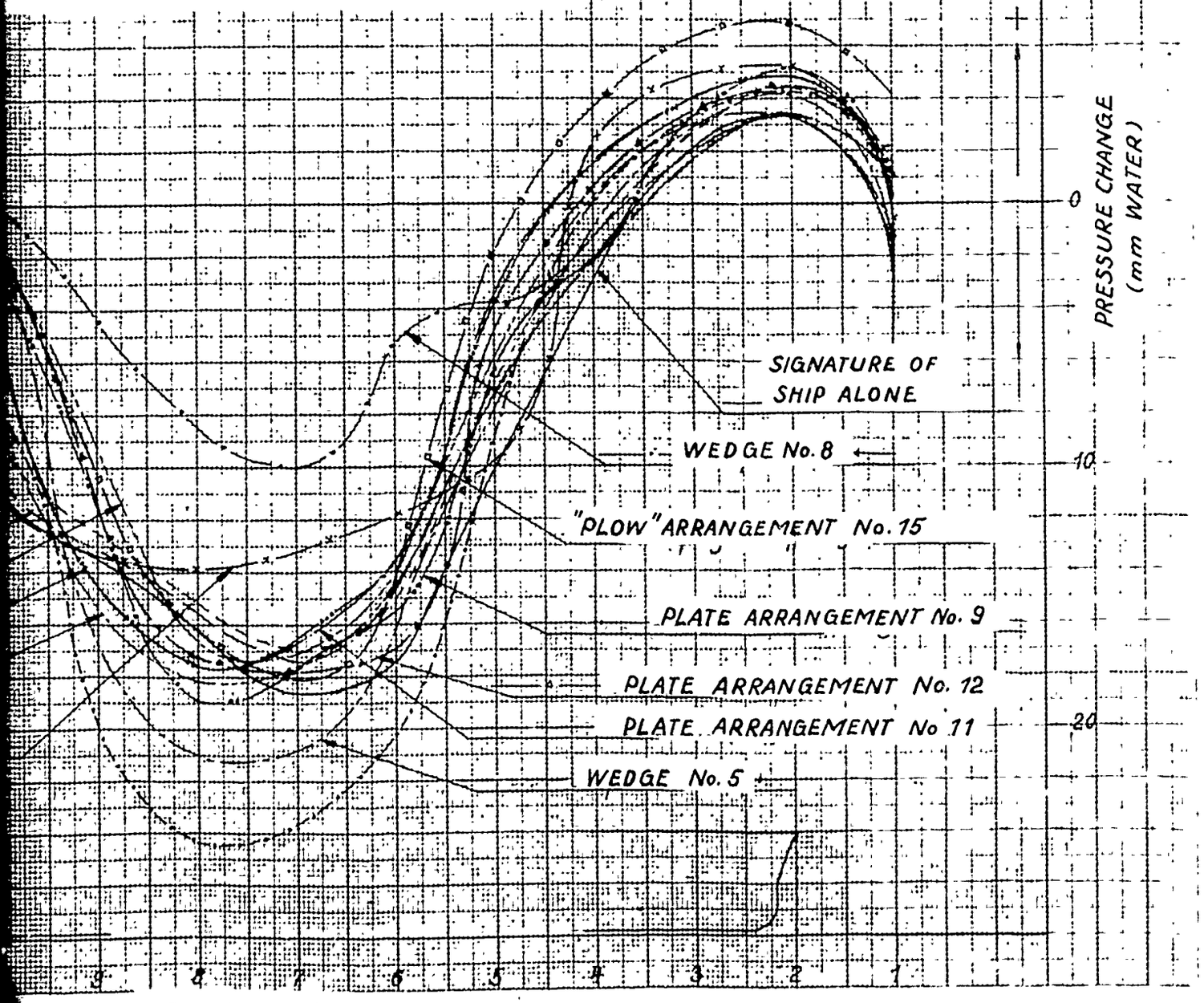


FIGURE 25

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



H.S.V.A.

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m

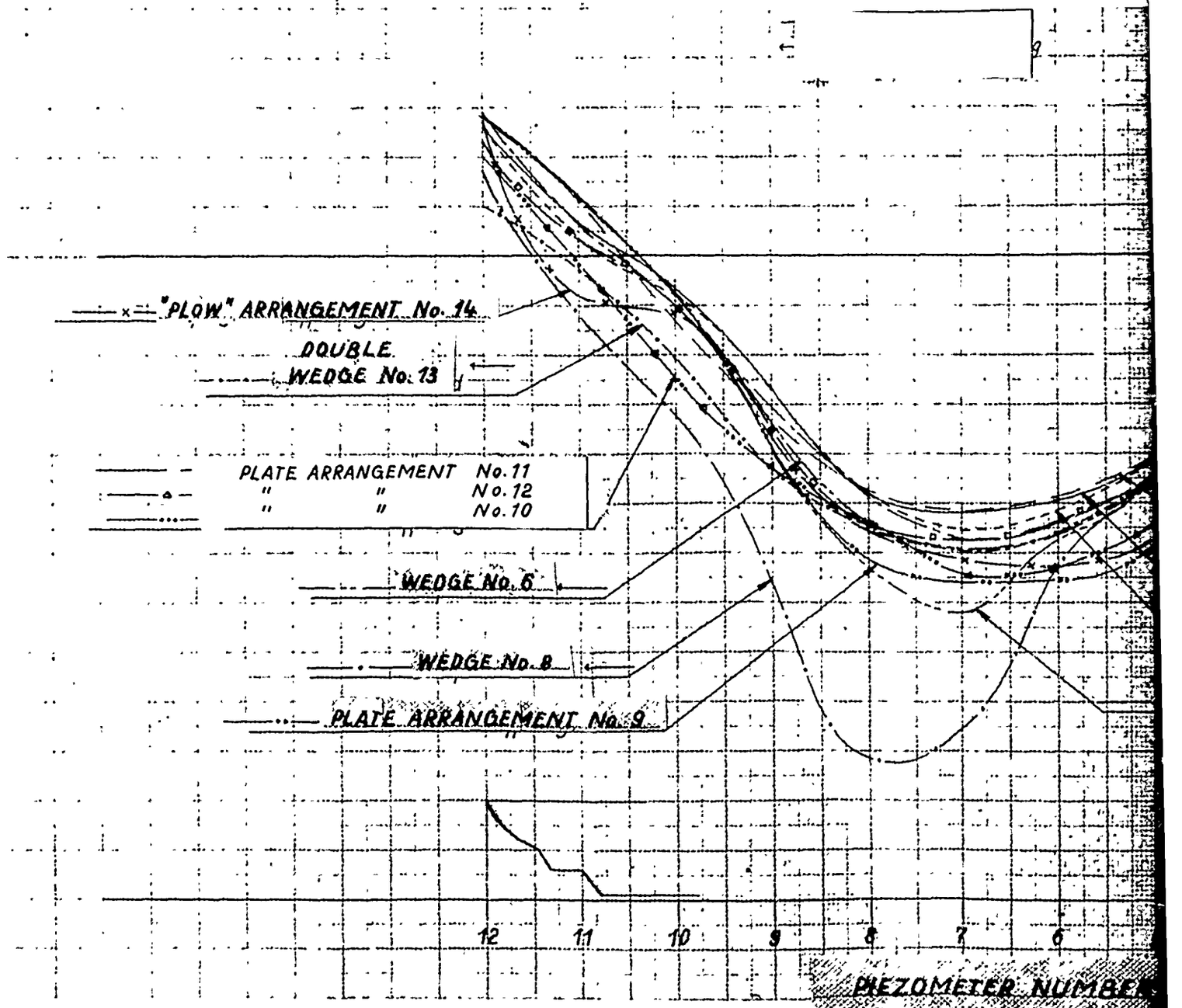
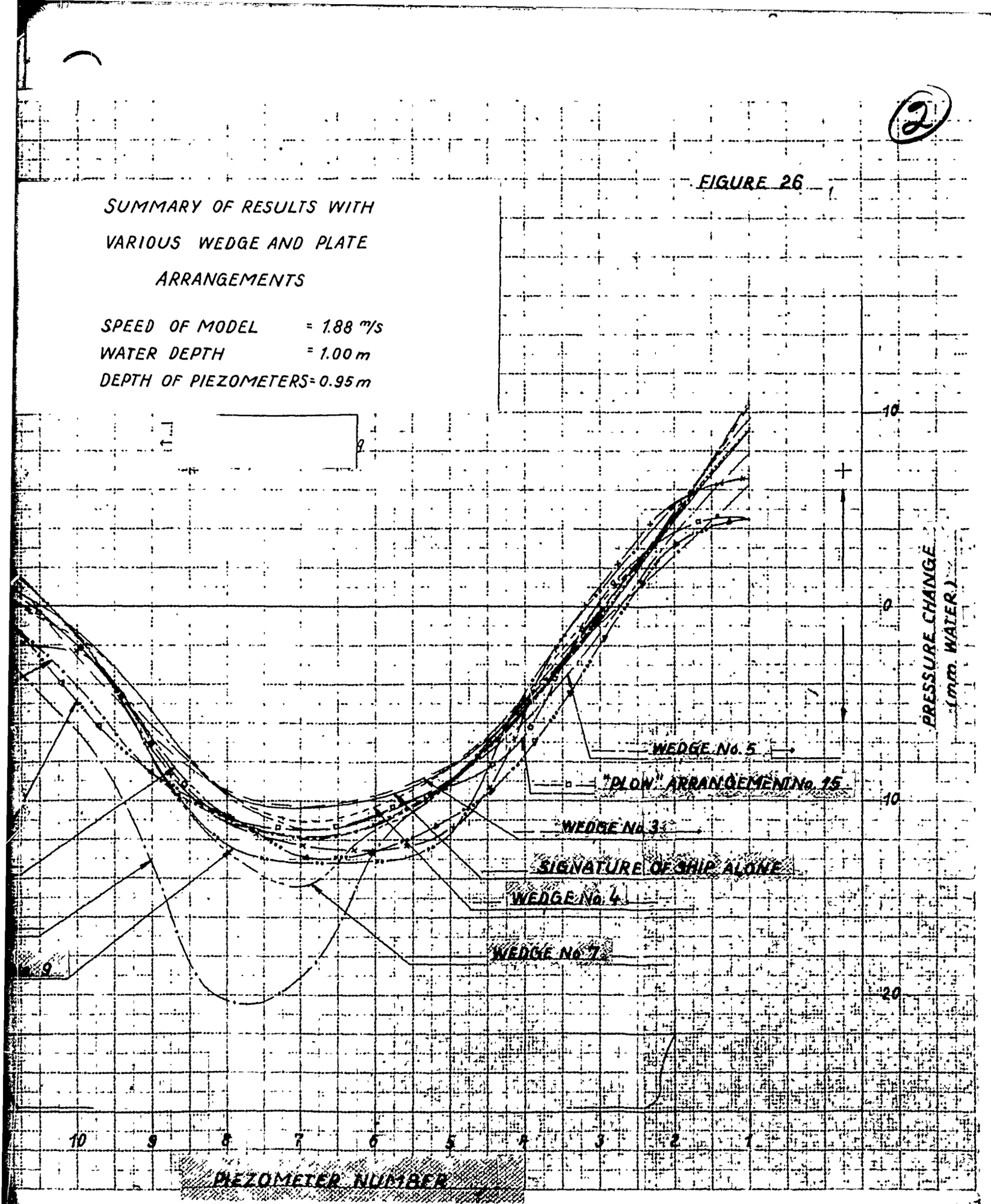


FIGURE 26

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



(1)

H.S.V.A

SUMMARY OF RESULTS WITH VARIOUS WEDGE AND PLATE ARRANGEMENTS

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m

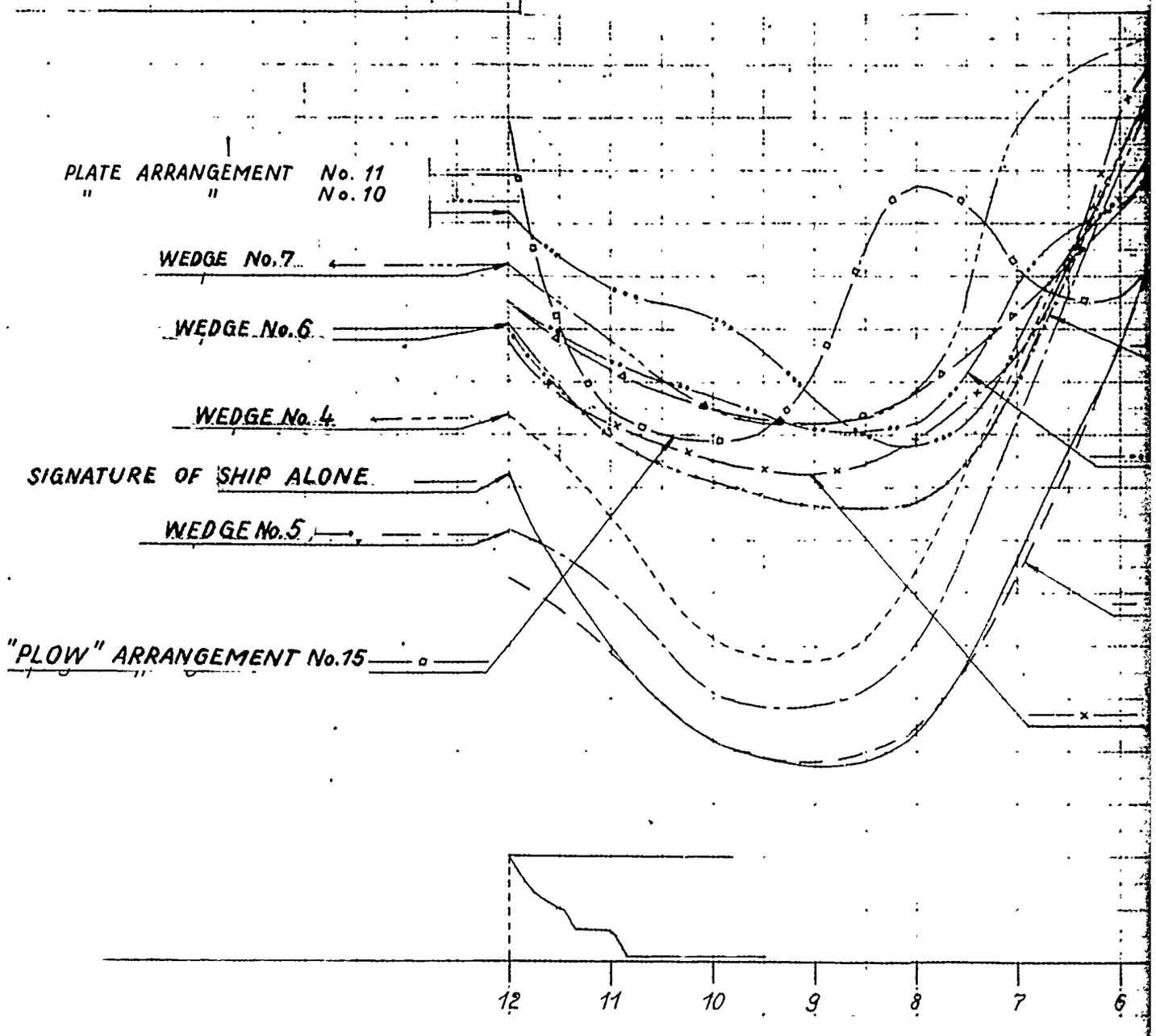
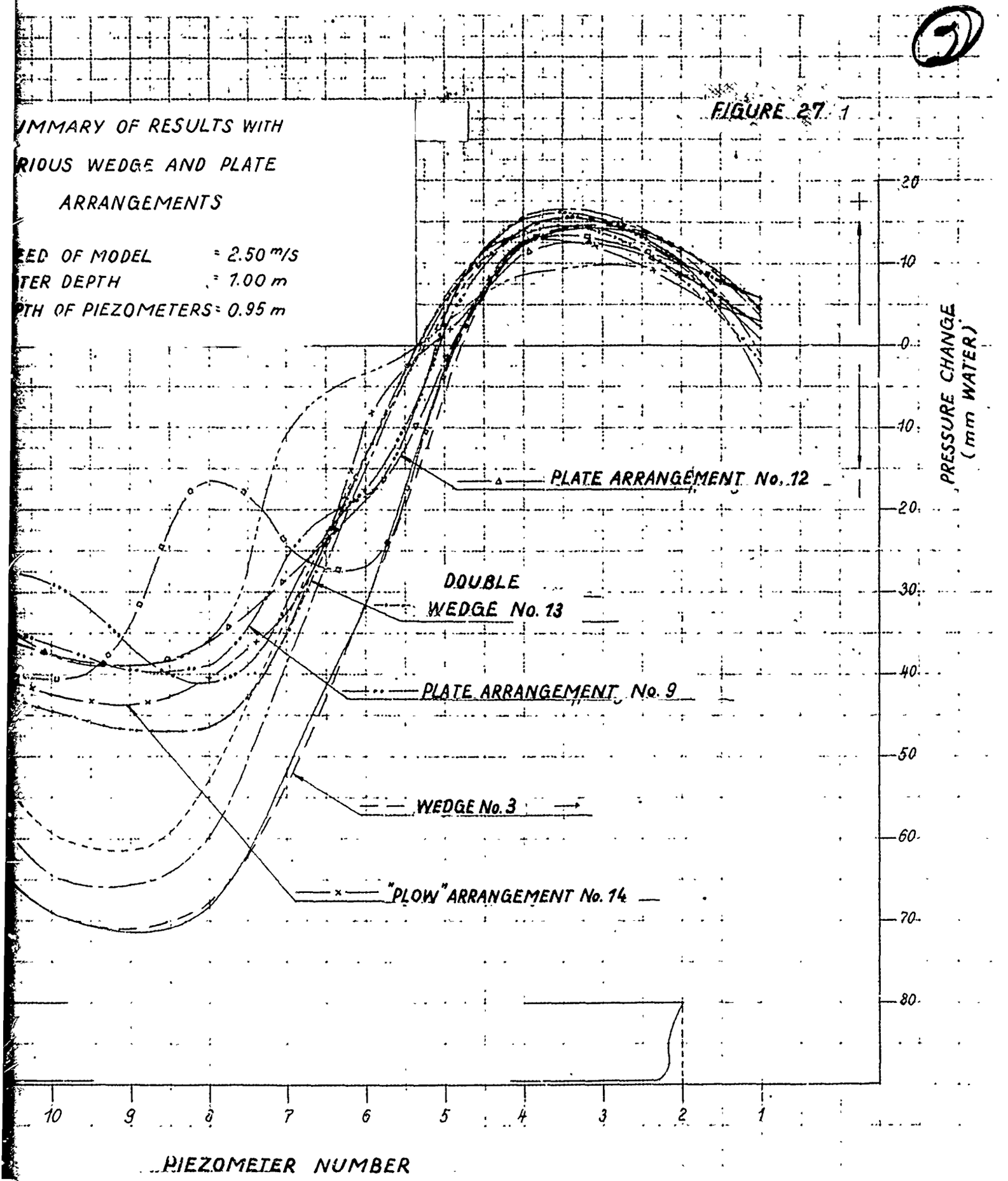


FIGURE 27.1

UMMARY OF RESULTS WITH
RIOUS WEDGE AND PLATE
ARRANGEMENTS

EED OF MODEL = 2.50 m/s
TER DEPTH = 1.00 m
PTH OF PIEZOMETERS = 0.95 m



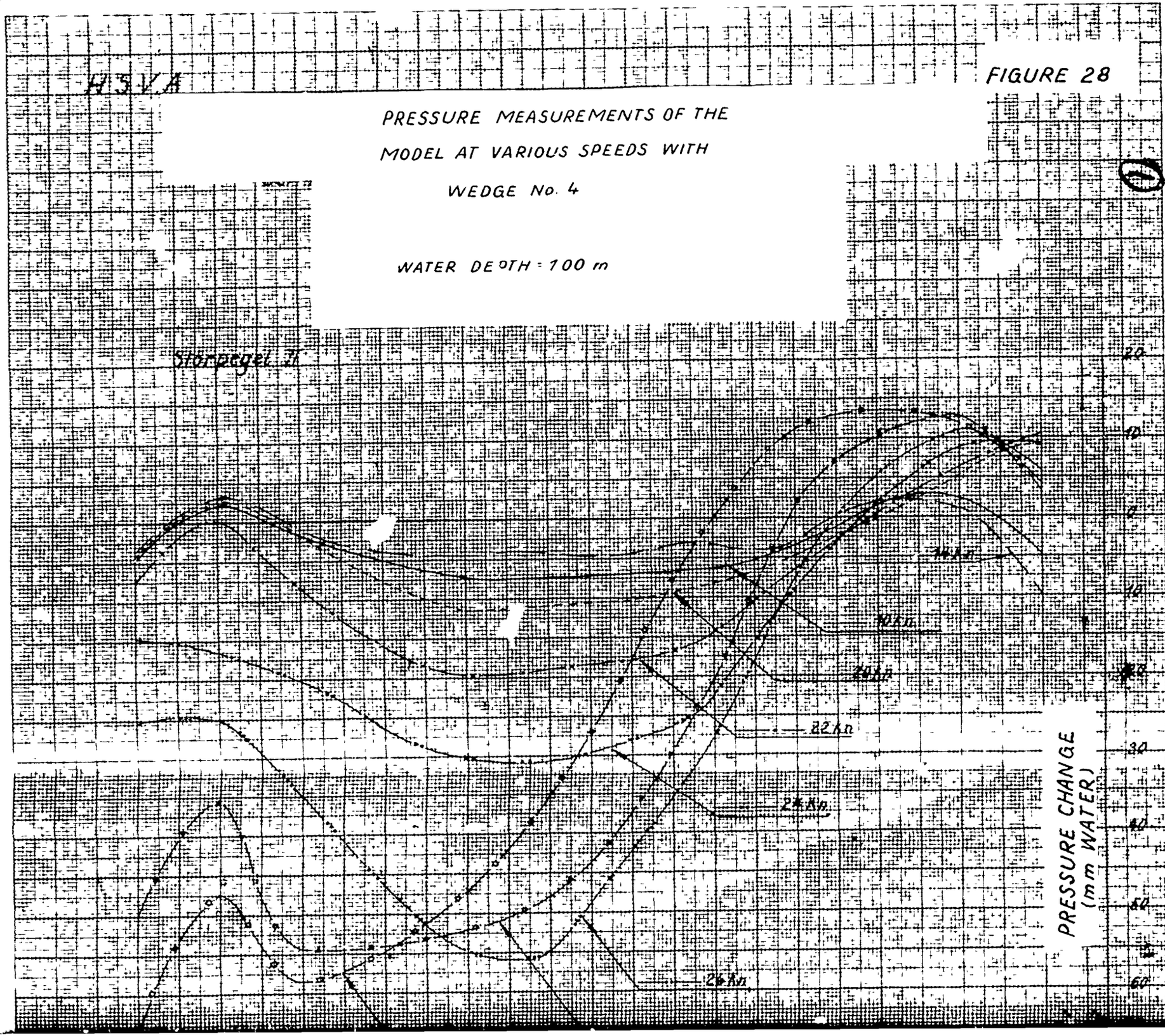
HSVA

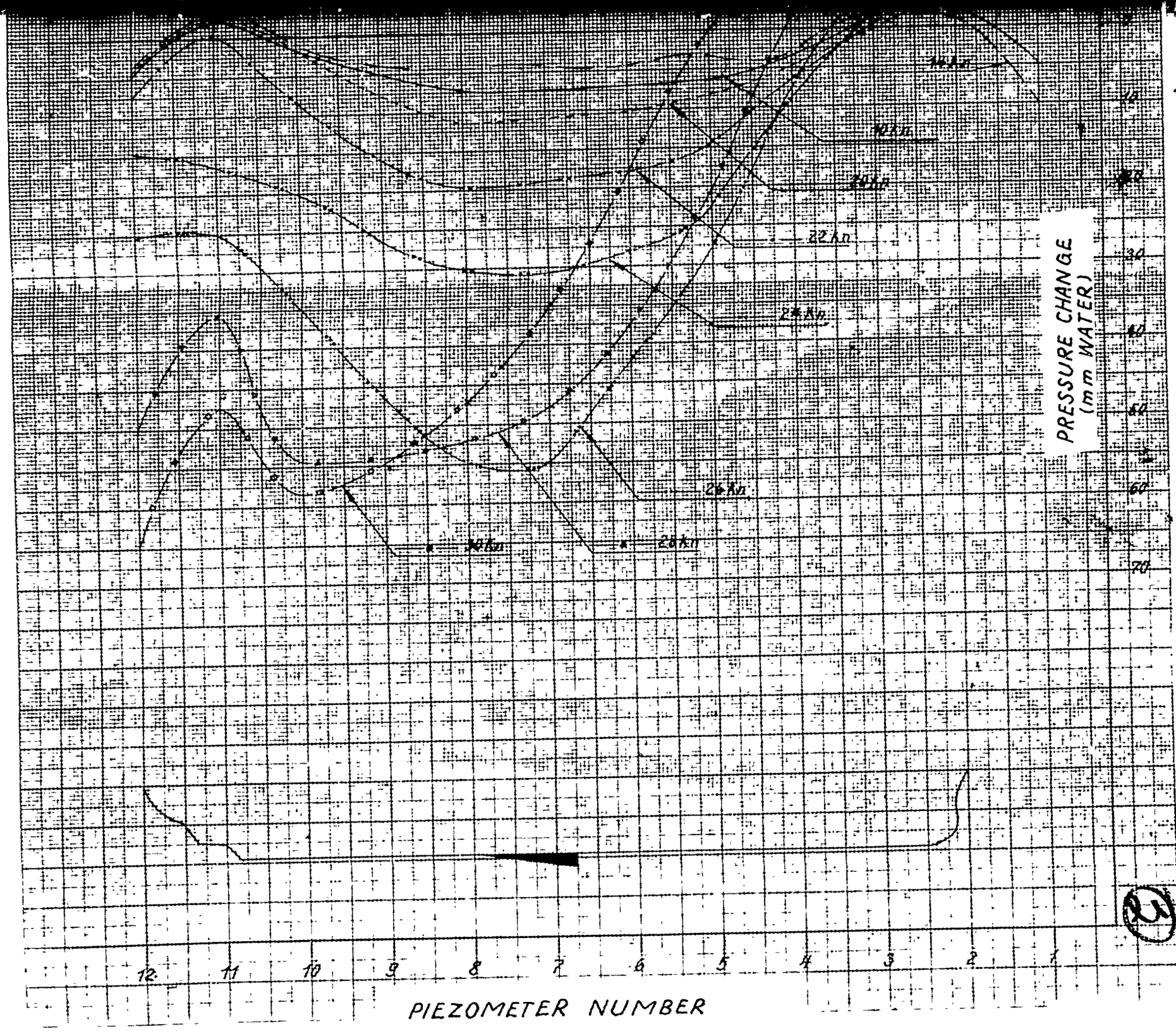
FIGURE 28

PRESSURE MEASUREMENTS OF THE MODEL AT VARIOUS SPEEDS WITH WEDGE No. 4

WATER DEPTH = 100 m

Storpegel Z



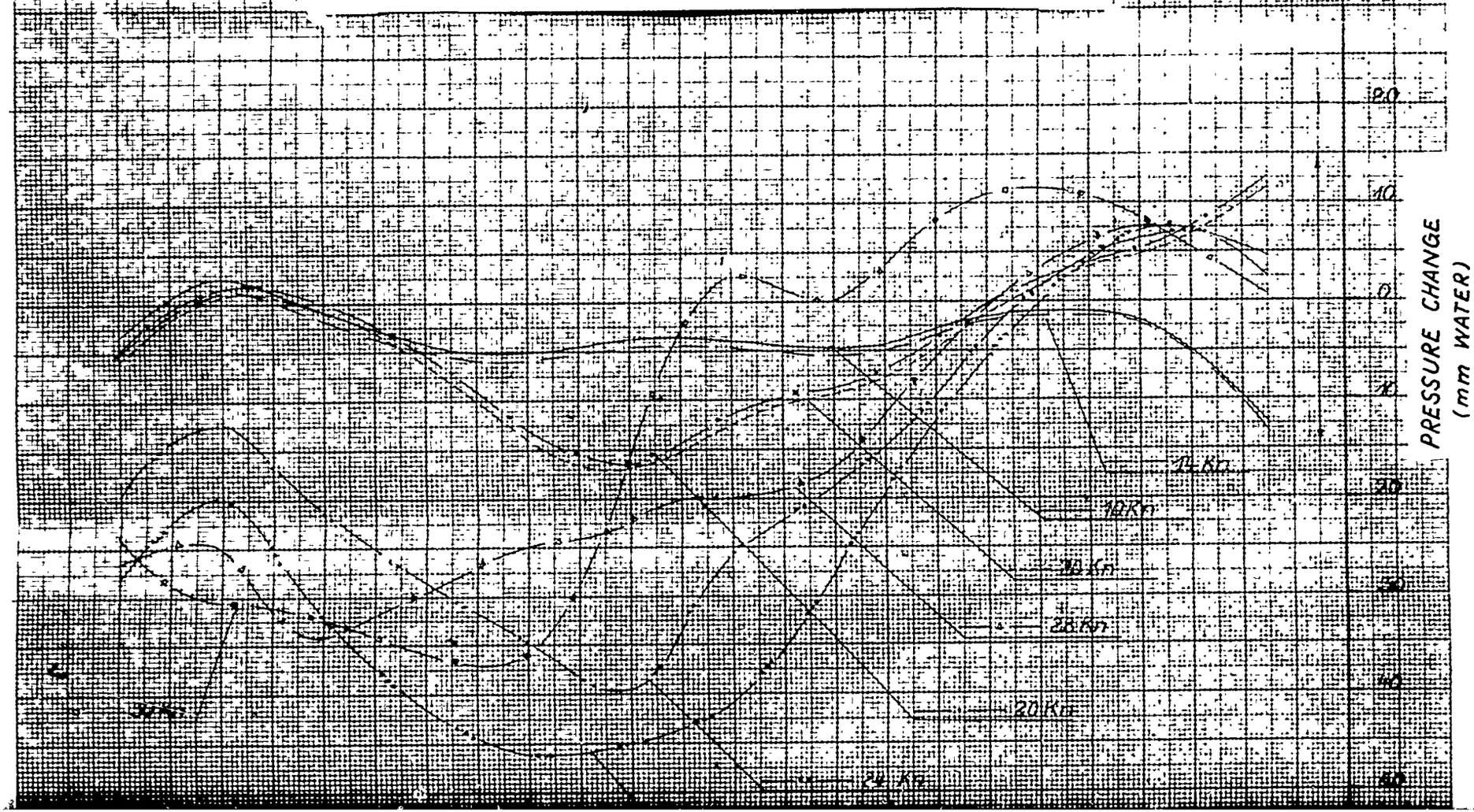

PRESSURE CHANGE
(mm WATER)
10
20
30
40
50
60
70
14 Kn
10 Kn
18 Kn
22 Kn
2* Kn
26 Kn
30 Kn
28 Kn
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

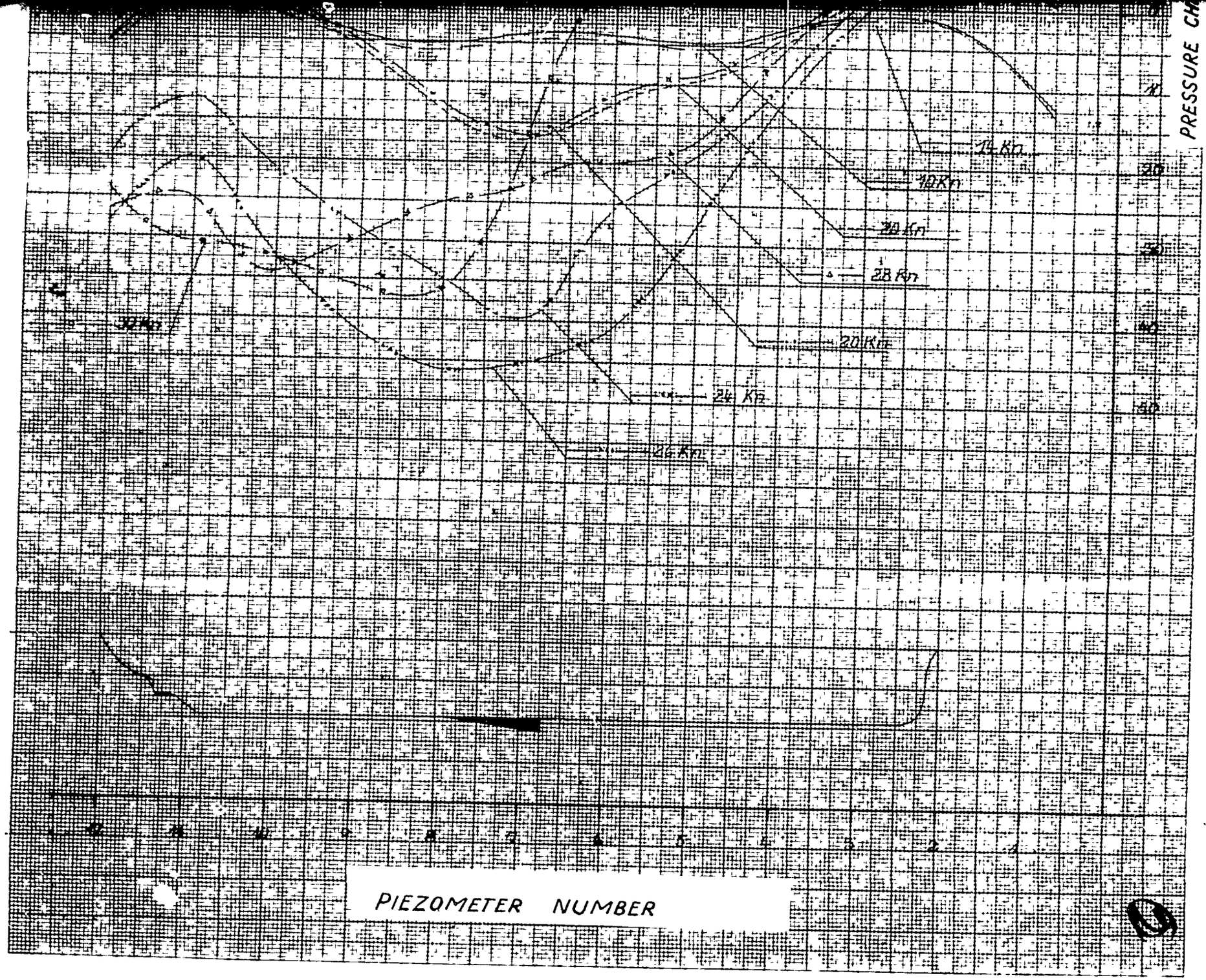
HSVH

FIGURE 29

PRESSURE MEASUREMENTS OF THE MODEL AT VARIOUS SPEEDS WITH WEDGE No. 7

WATER DEPTH = 100 m



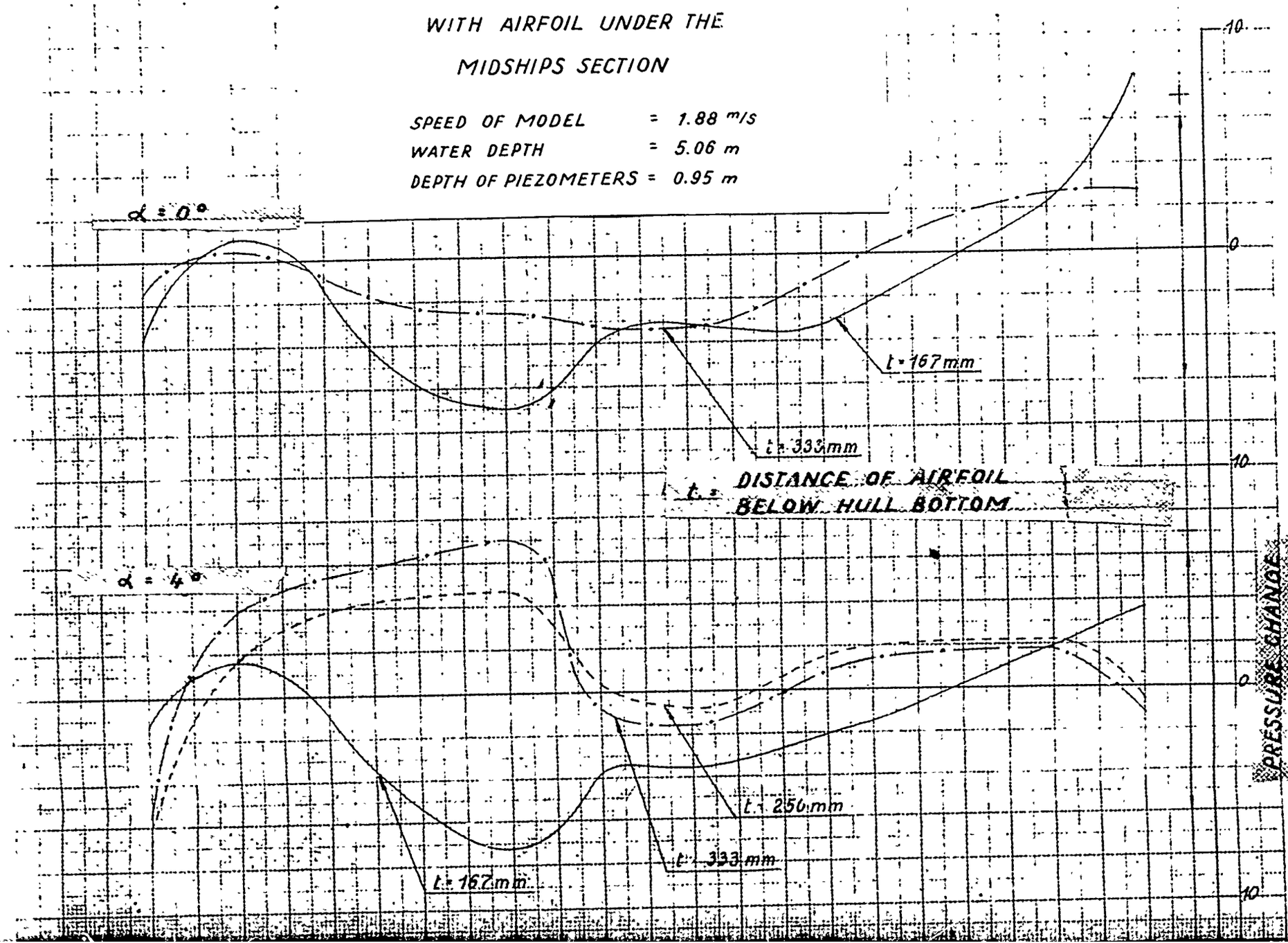

PRESSURE CH
(mm WATE
14 Kn
10Kn
30 Kn
28 Kn
32 Kn
20 Kn
24 Kn
26 Kn
PIEZOMETER NUMBER

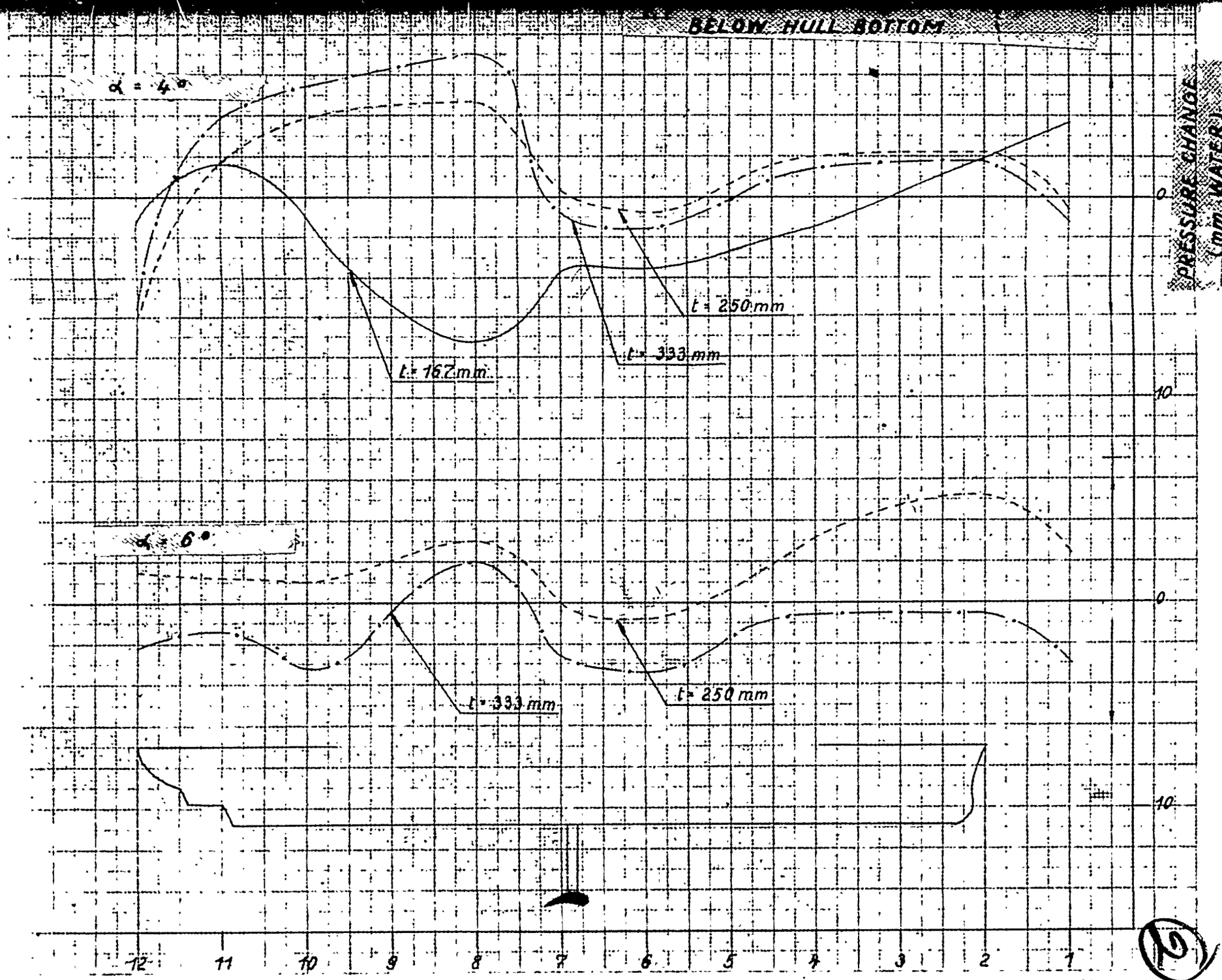
H.S.V.A.

FIGURE 30

KEEL SIGNATURES OF THE MODEL
WITH AIRFOIL UNDER THE
MIDSHIPS SECTION

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



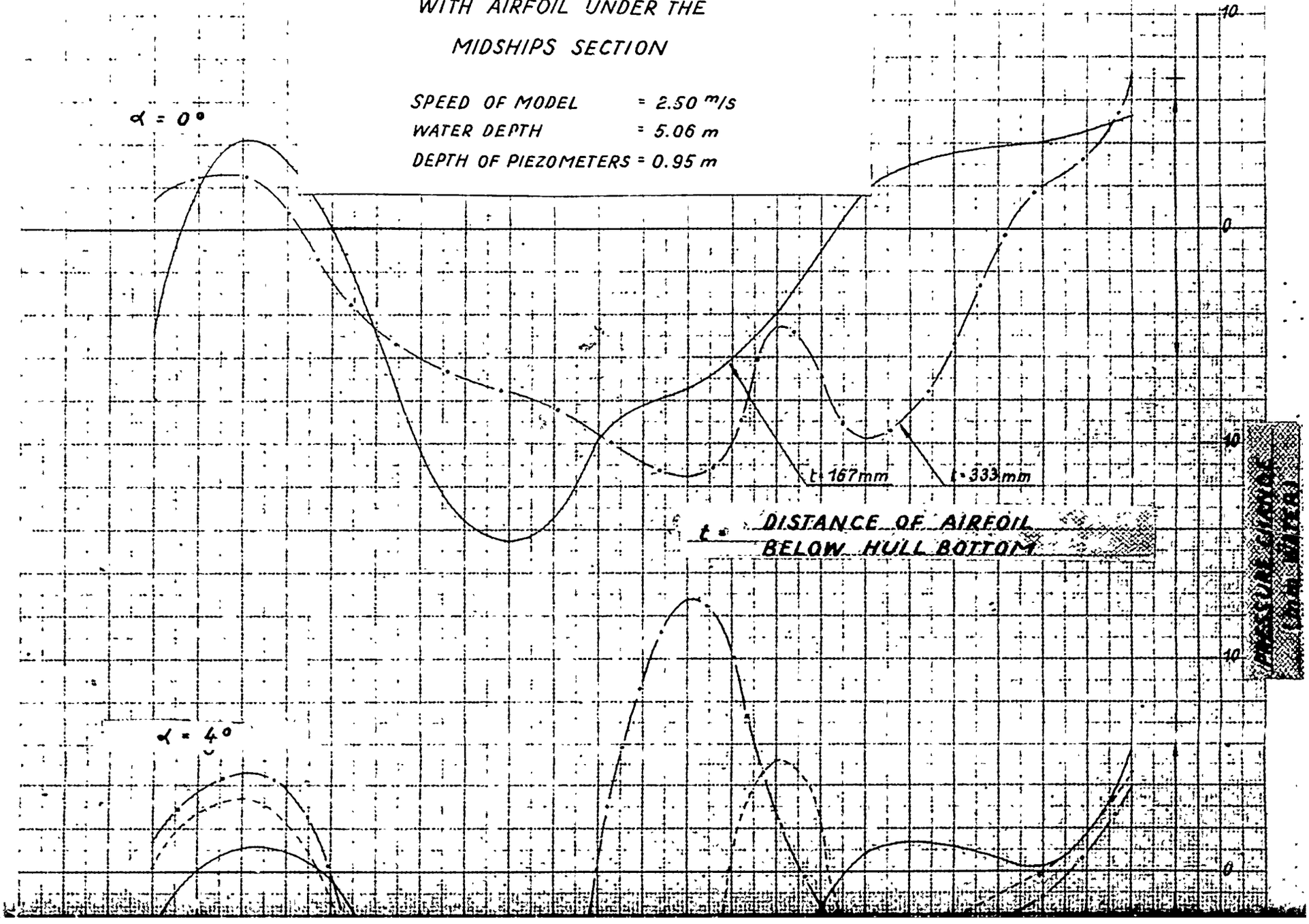

BELOW HULL BOTTOM
α = 4°
t = 250 mm
t = 333 mm
t = 167 mm
α = 6°
t = 333 mm
t = 250 mm
PRESSURE CHANGE (mm WATER)
0
10
0
10
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER
20.12.44 Jü.

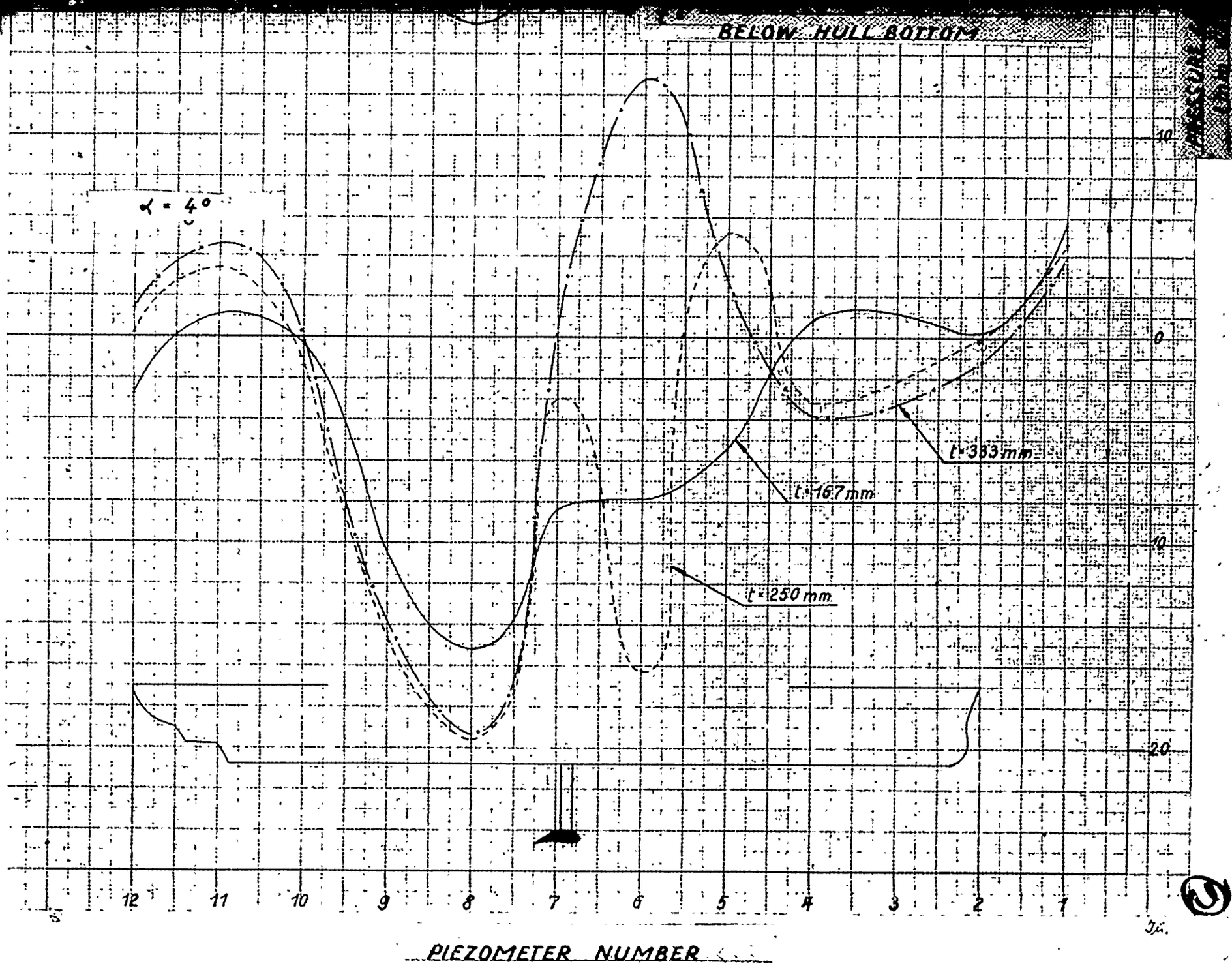
H.S.V.A.

FIGURE 31

KEEL SIGNATURES OF THE MODEL WITH AIRFOIL UNDER THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



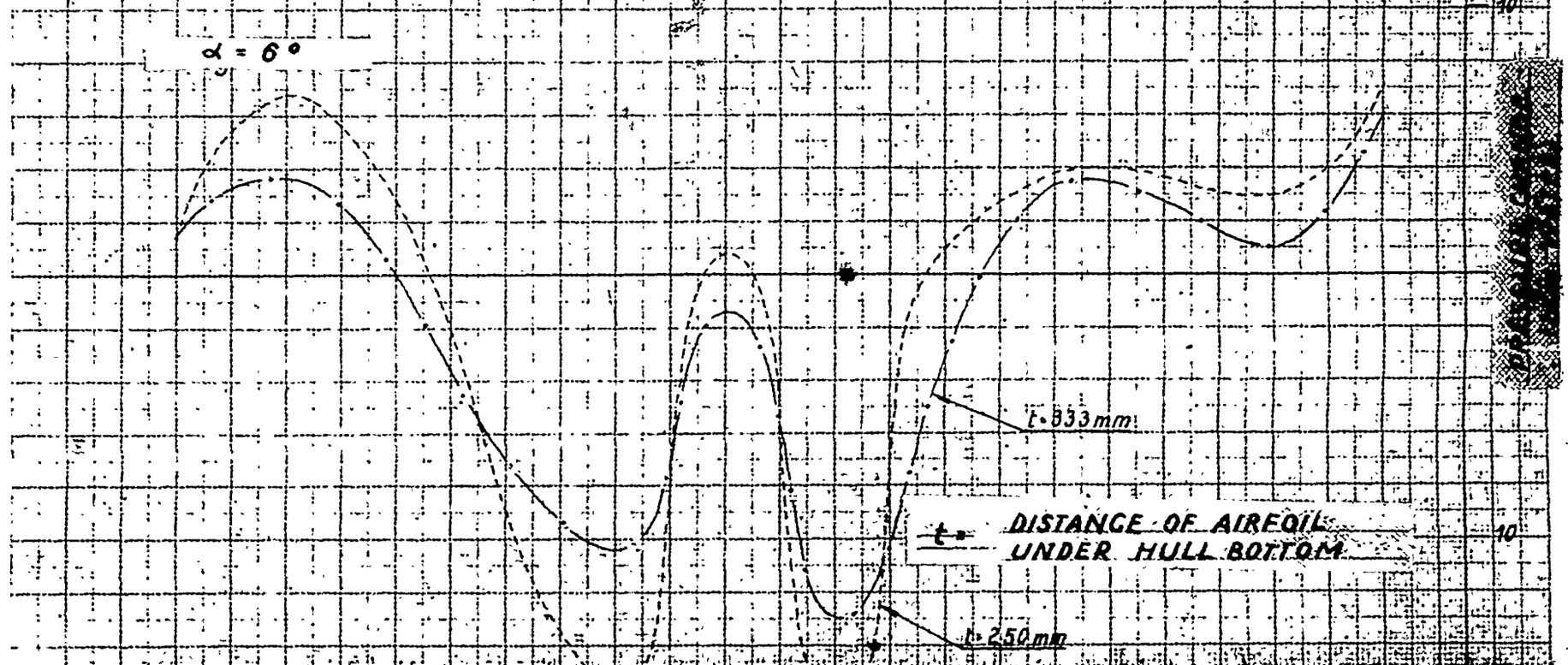

BELOW HULL BOTTOM
α = 40°
10
0
10
20
t = 383 mm
t = 167 mm
t = 250 mm
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

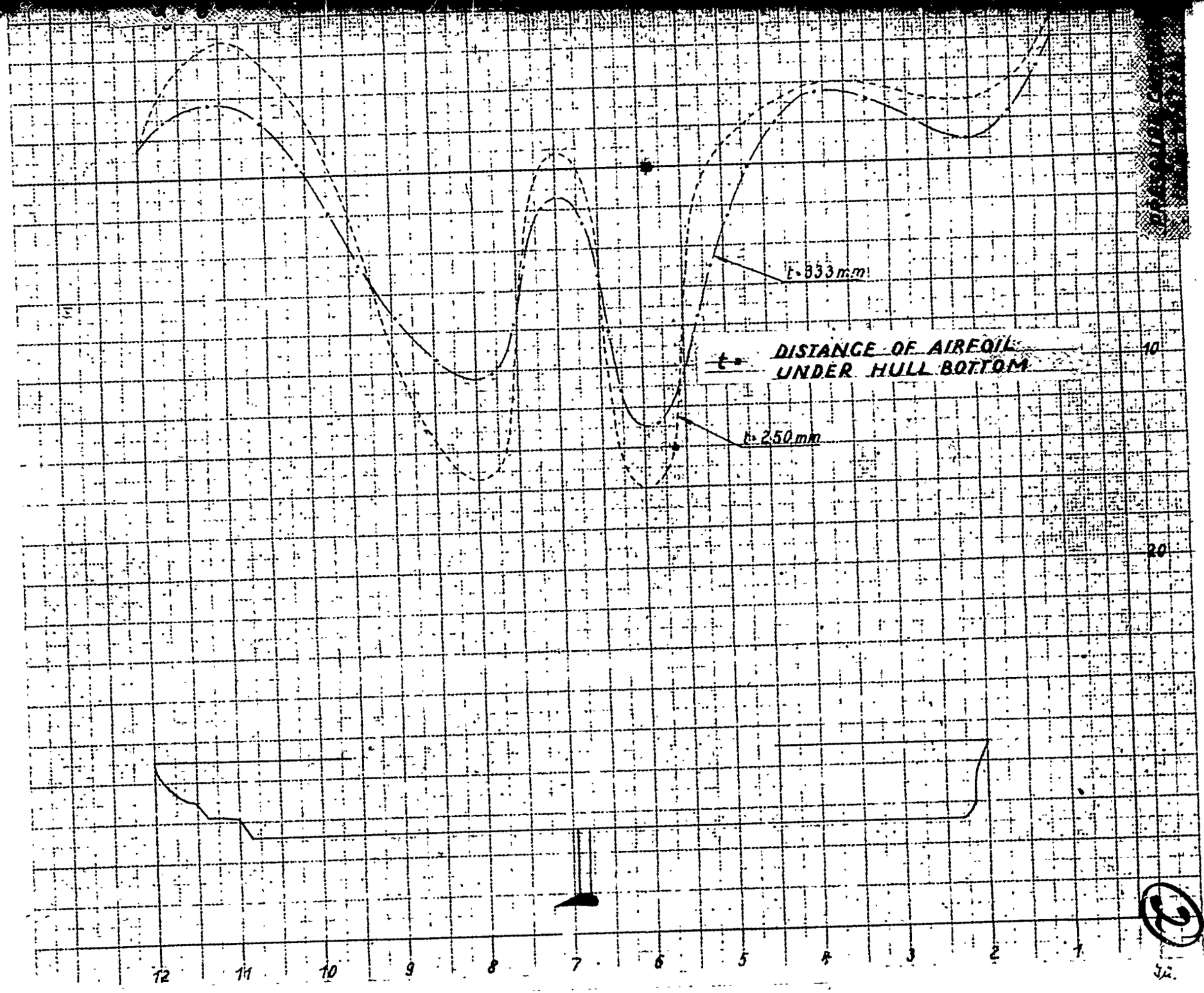
H.S.V.A.

FIGURE 32

KEEL SIGNATURES OF THE MODEL WITH AIRFOIL UNDER THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



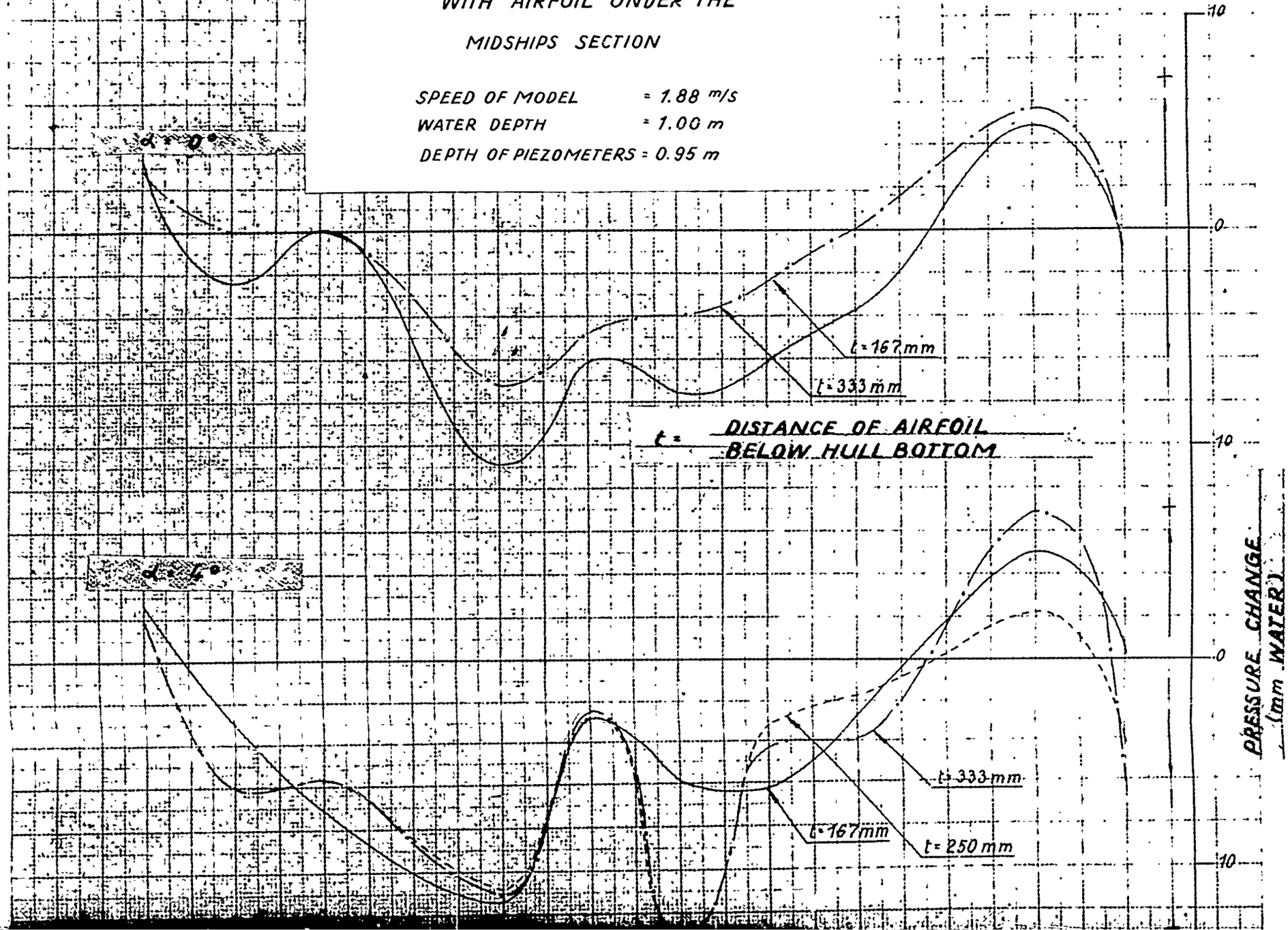

t=333 mm
t= DISTANCE OF AIREOIL UNDER HULL BOTTOM
t=250 mm
10
20
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

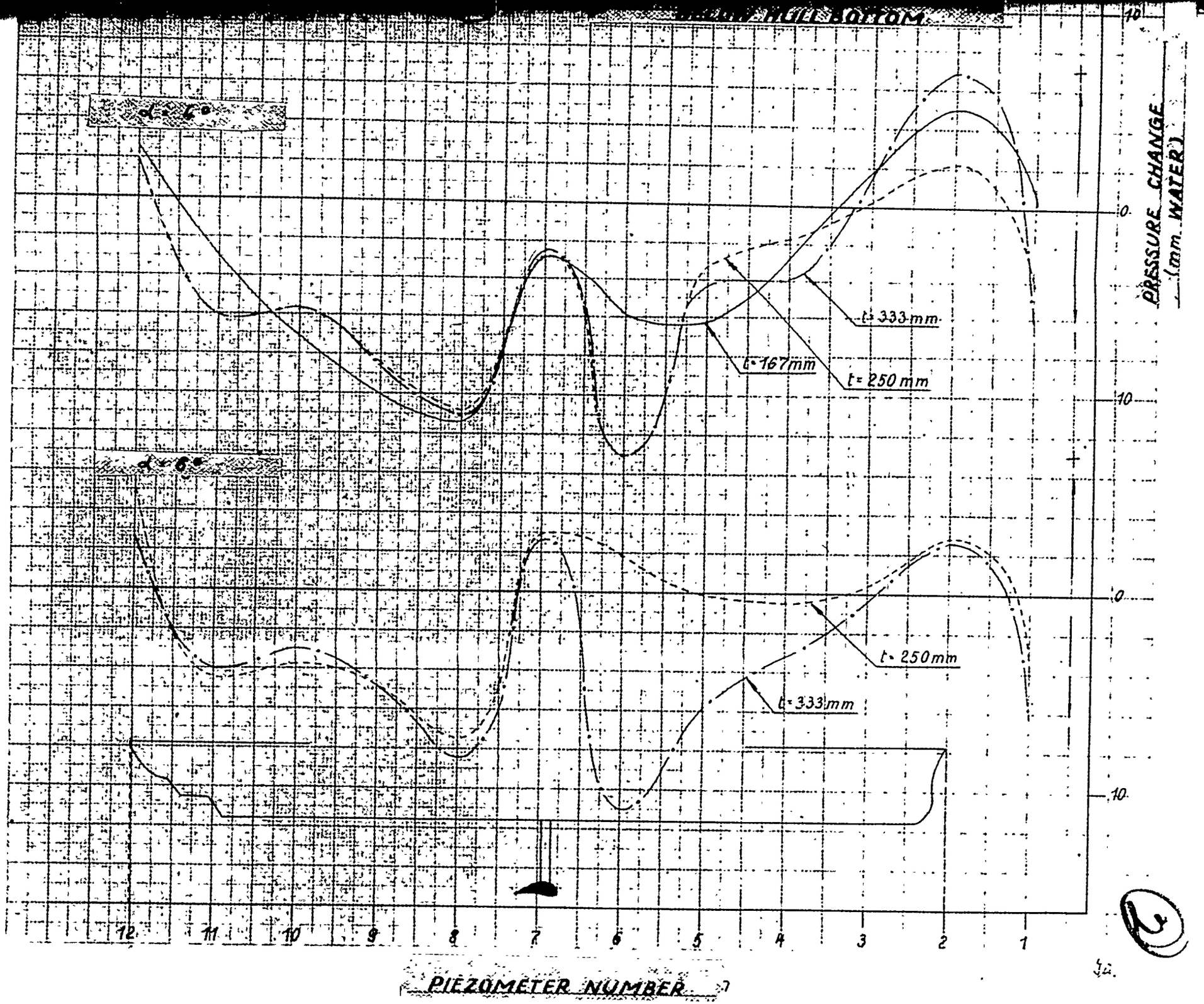
HSVA

FIGURE 33

KEEL SIGNATURES OF THE MODEL WITH AIRFOIL UNDER THE MIDSHIPS SECTION

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



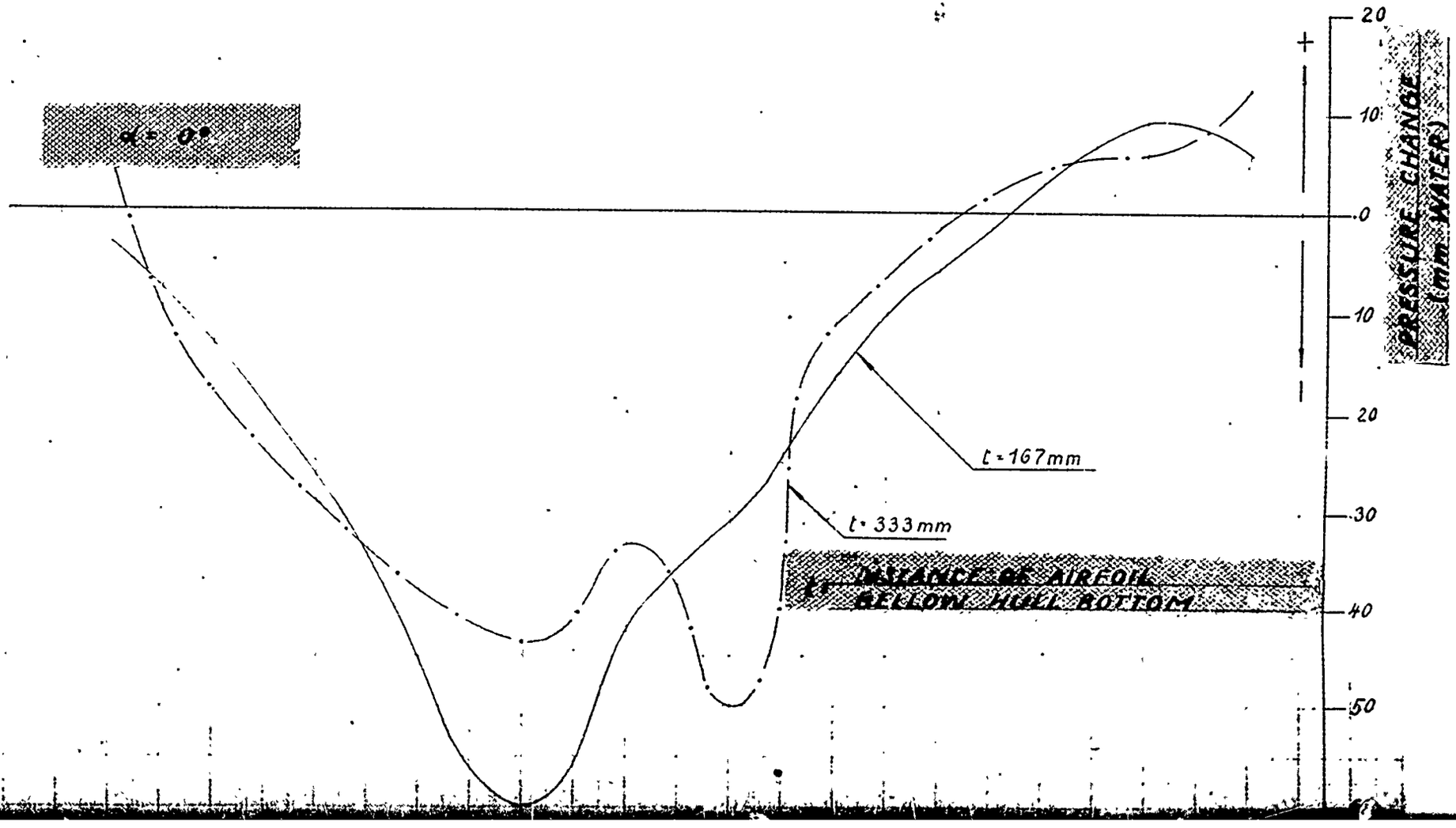

d = 6"
d = 6"
t = 333 mm
t = 167 mm
t = 250 mm
t = 250 mm
t = 333 mm
10
0
10
0
10
PRESSURE CHANGE (mm. WATER)
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

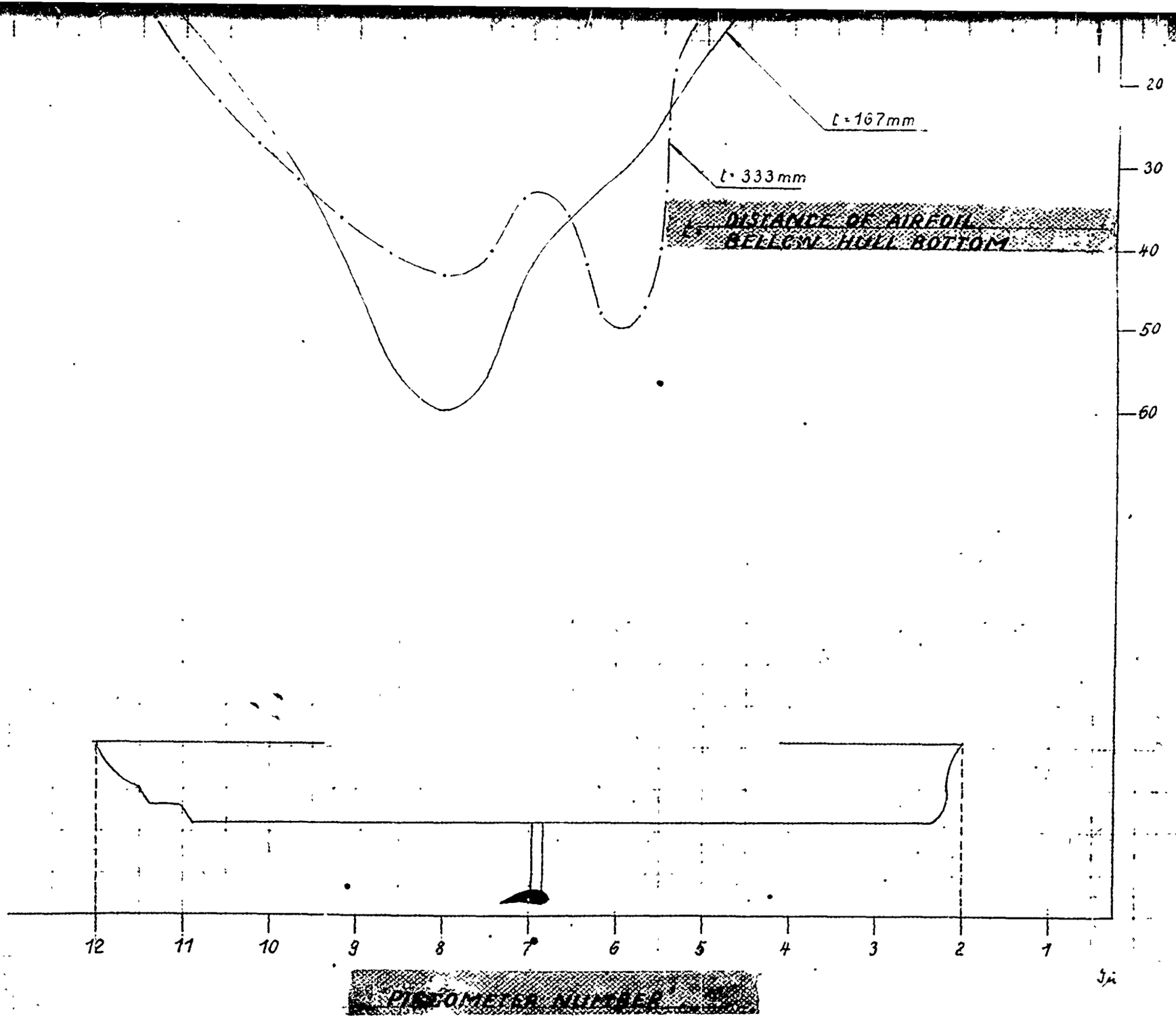
H.S.V.A.

Beilage 4

KEEL SIGNATURES OF THE MODEL WITH AIRFOIL UNDER THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



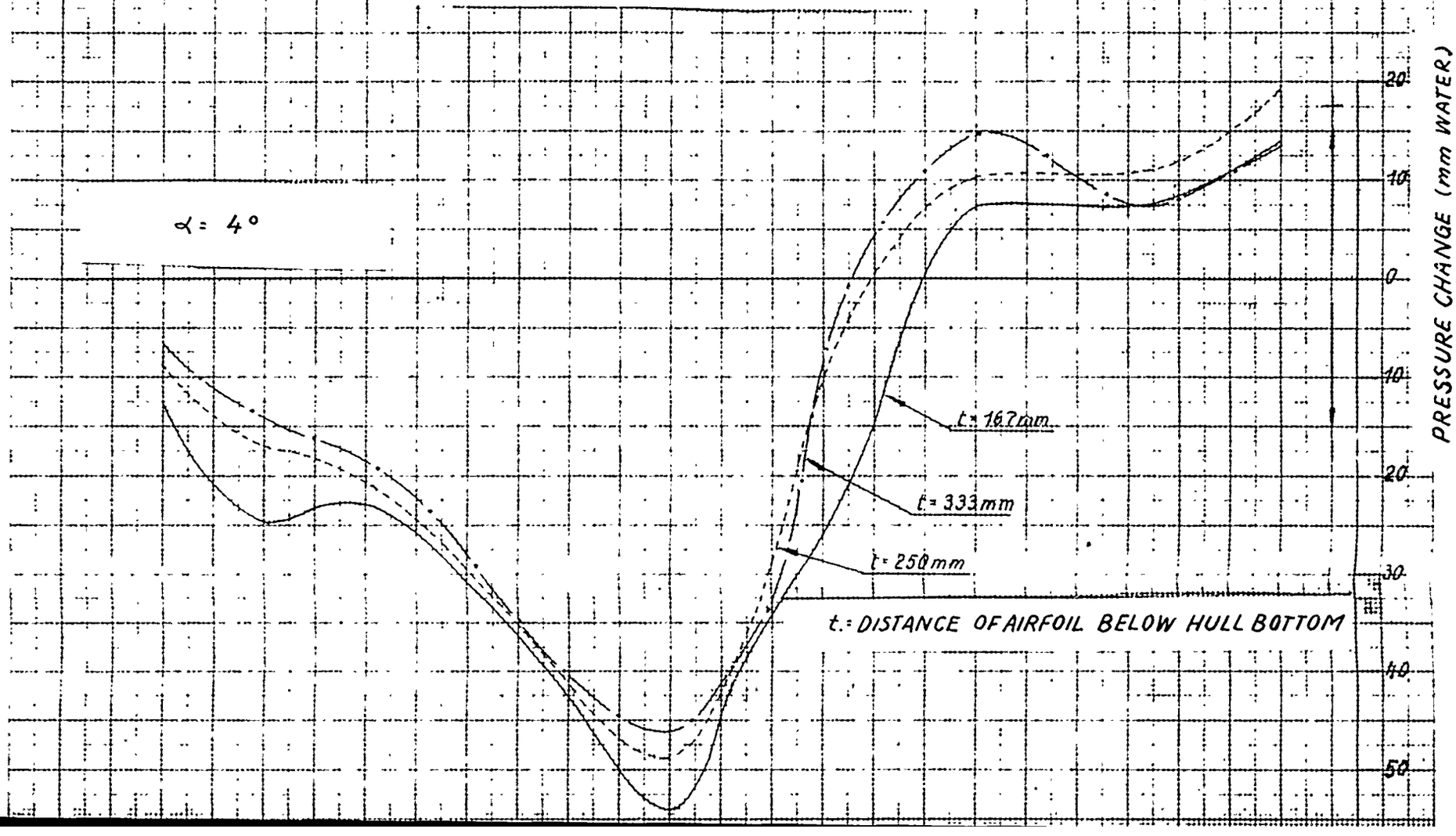

t = 167mm
t = 333mm
t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
20
30
40
50
60
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

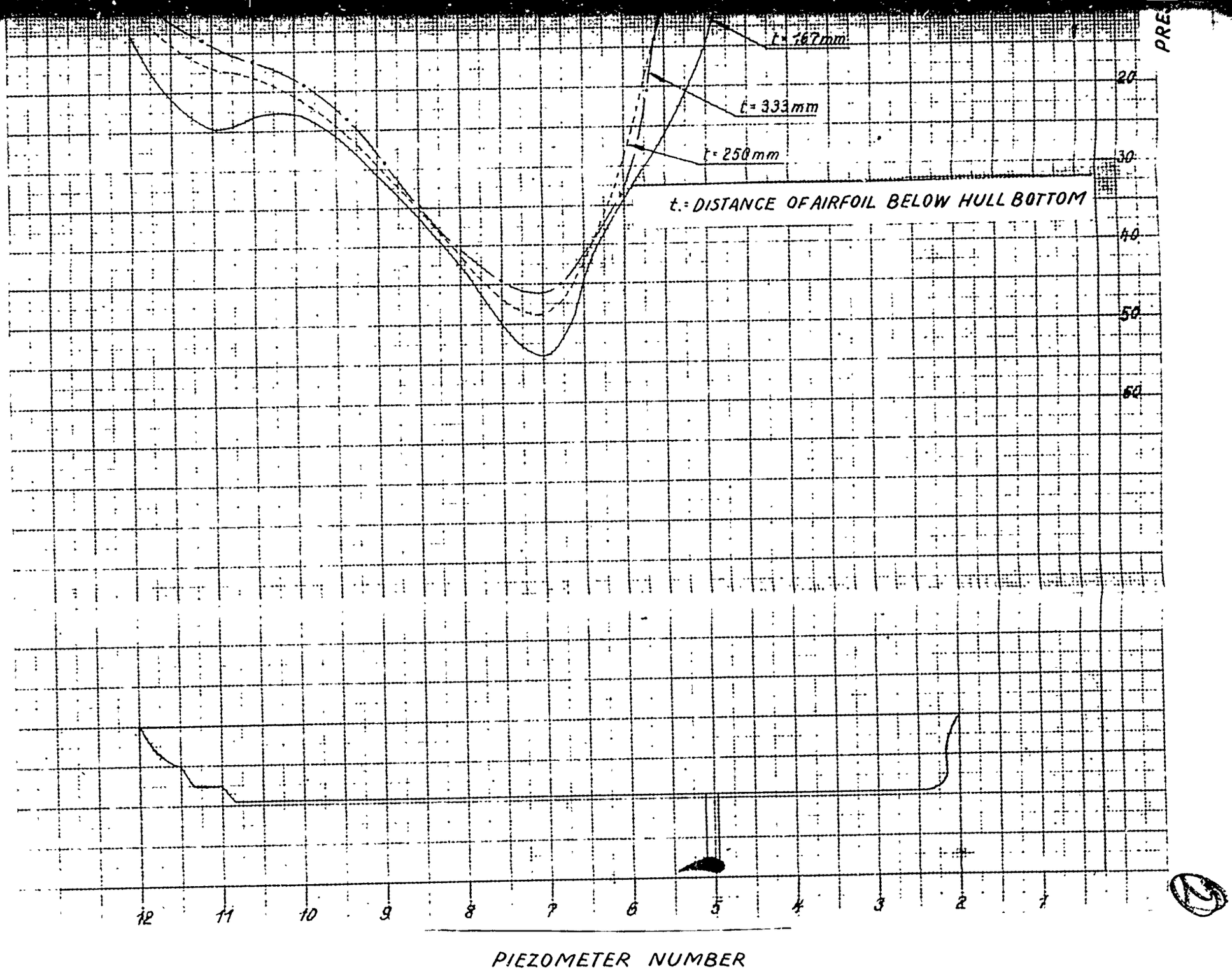
H.S.V.A

FIGURE 35

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL UNDER
THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m




t = 167mm
t = 333mm
t = 250mm
t.= DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRE
20
30
40
50
60
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

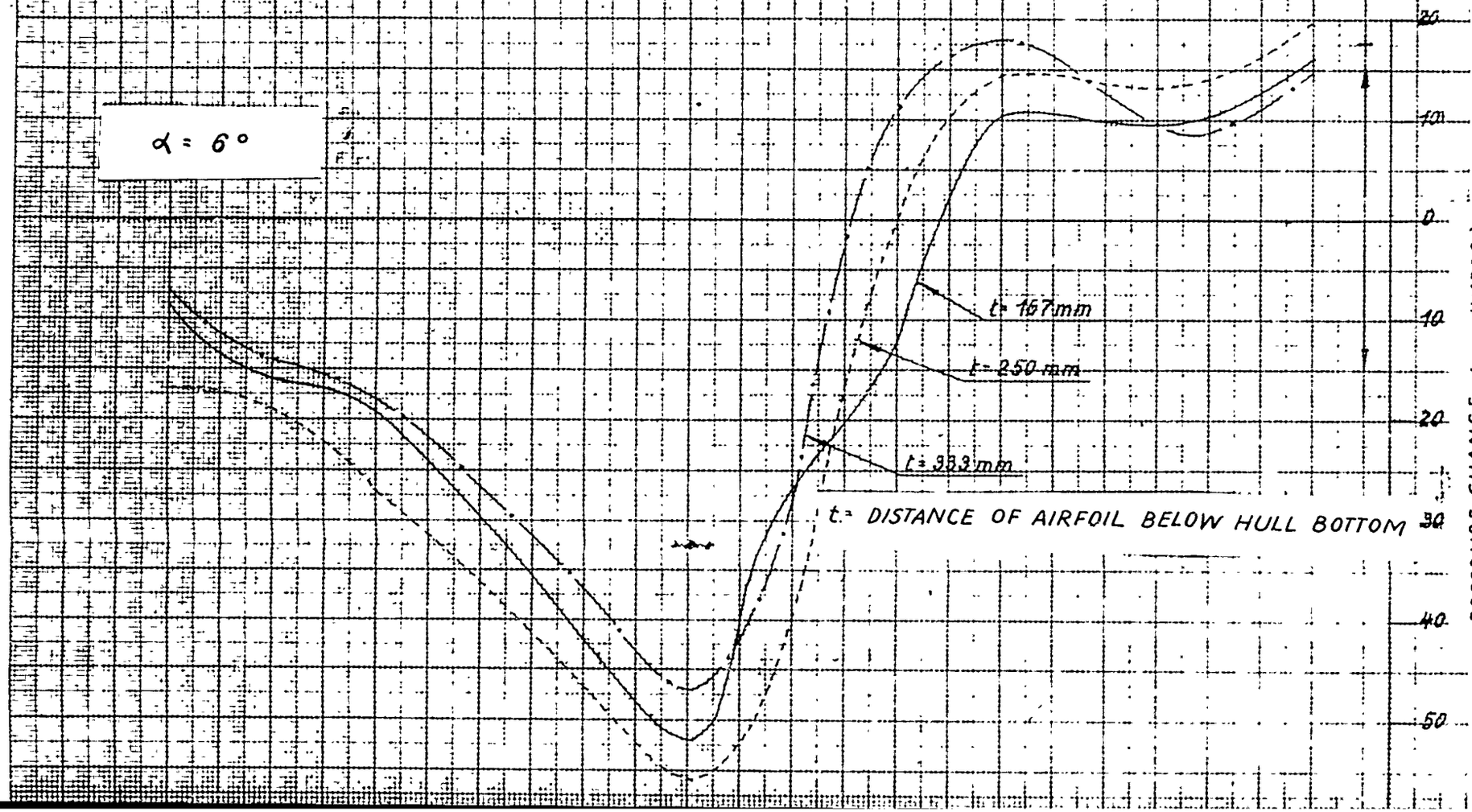
HSVA

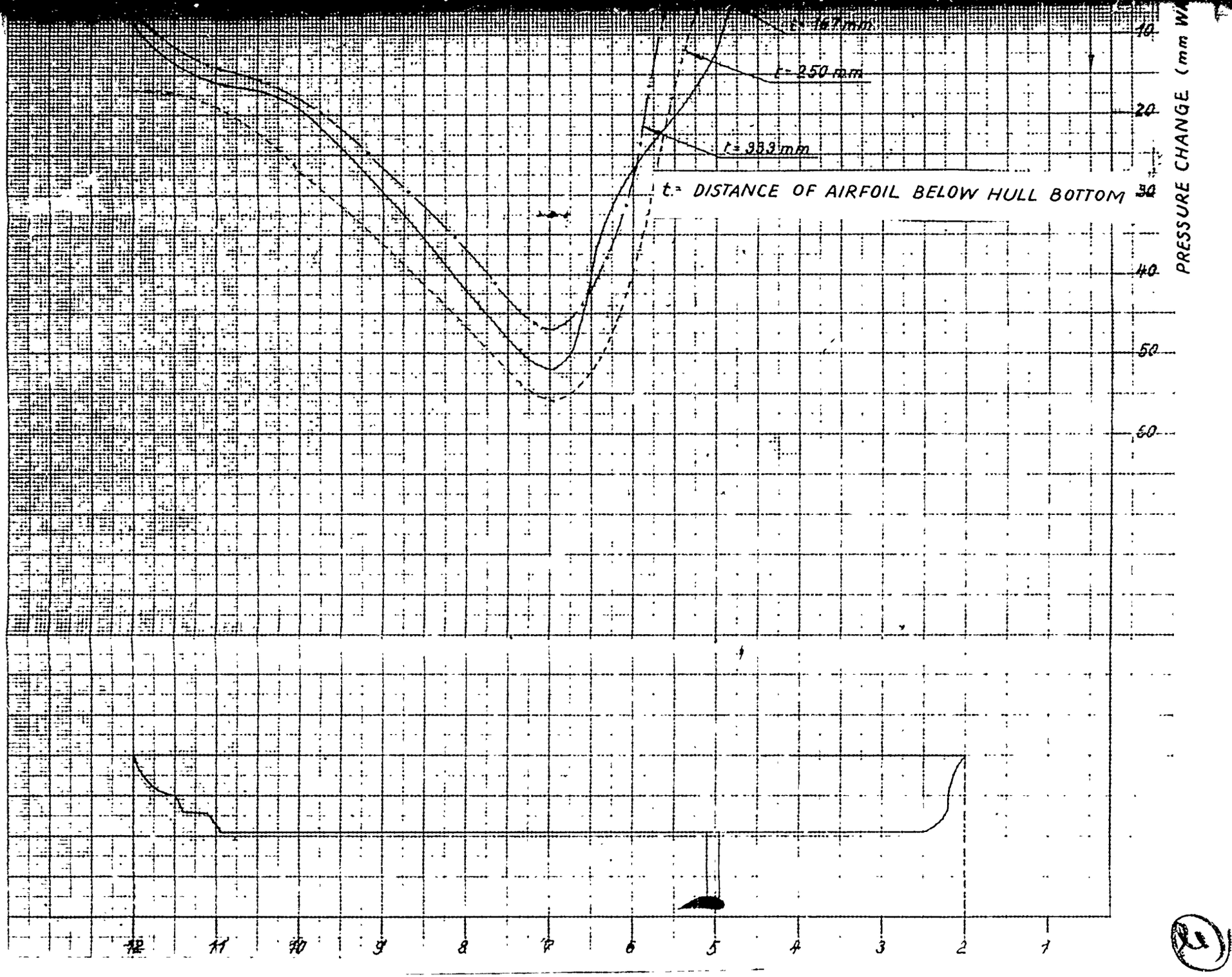
FIGURE 36

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL UNDER
THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m

$\alpha = 6°$



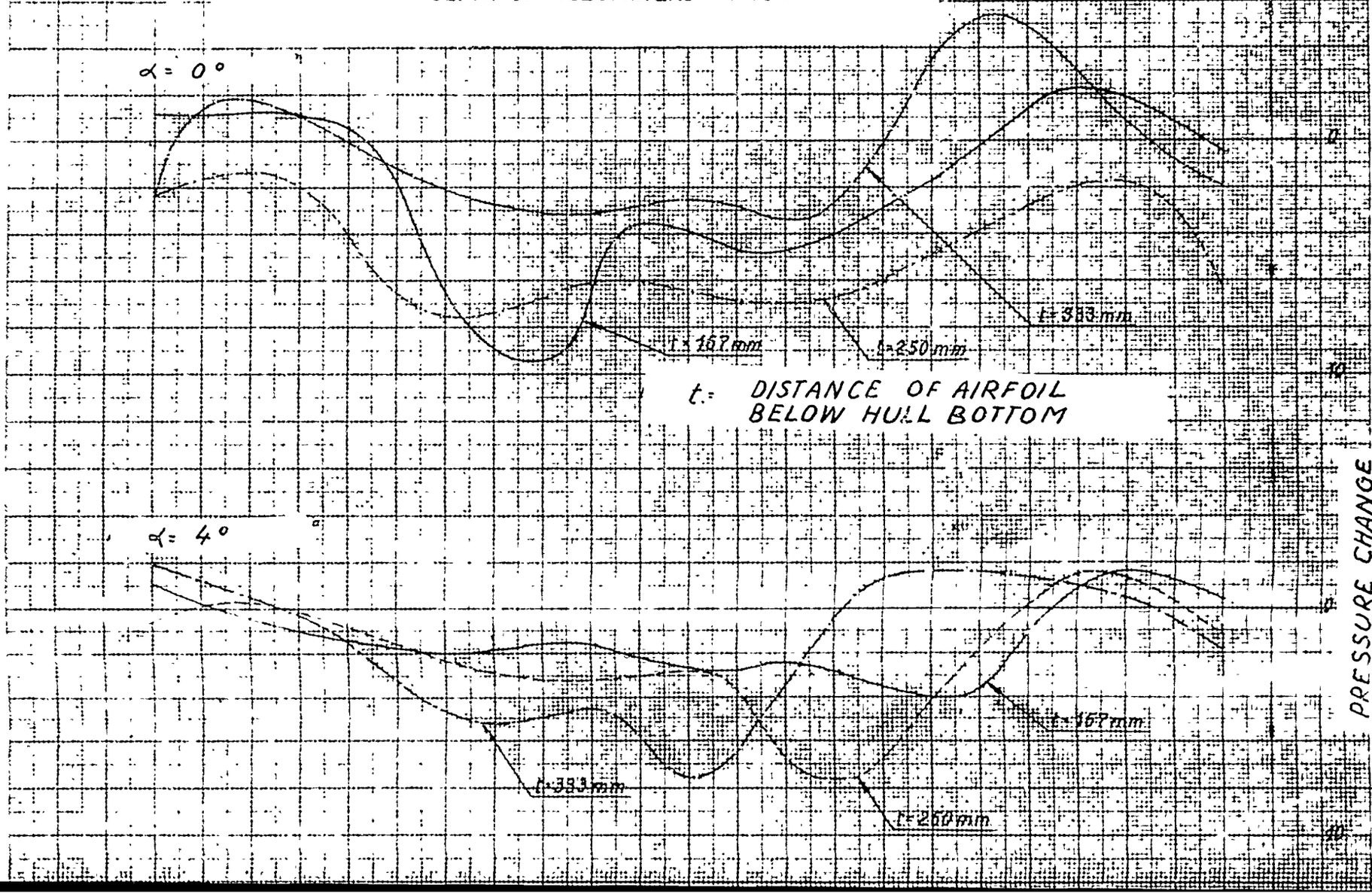

t = 167 mm
t = 250 mm
t = 333 mm
t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE (mm W
10
20
30
40
50
60
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

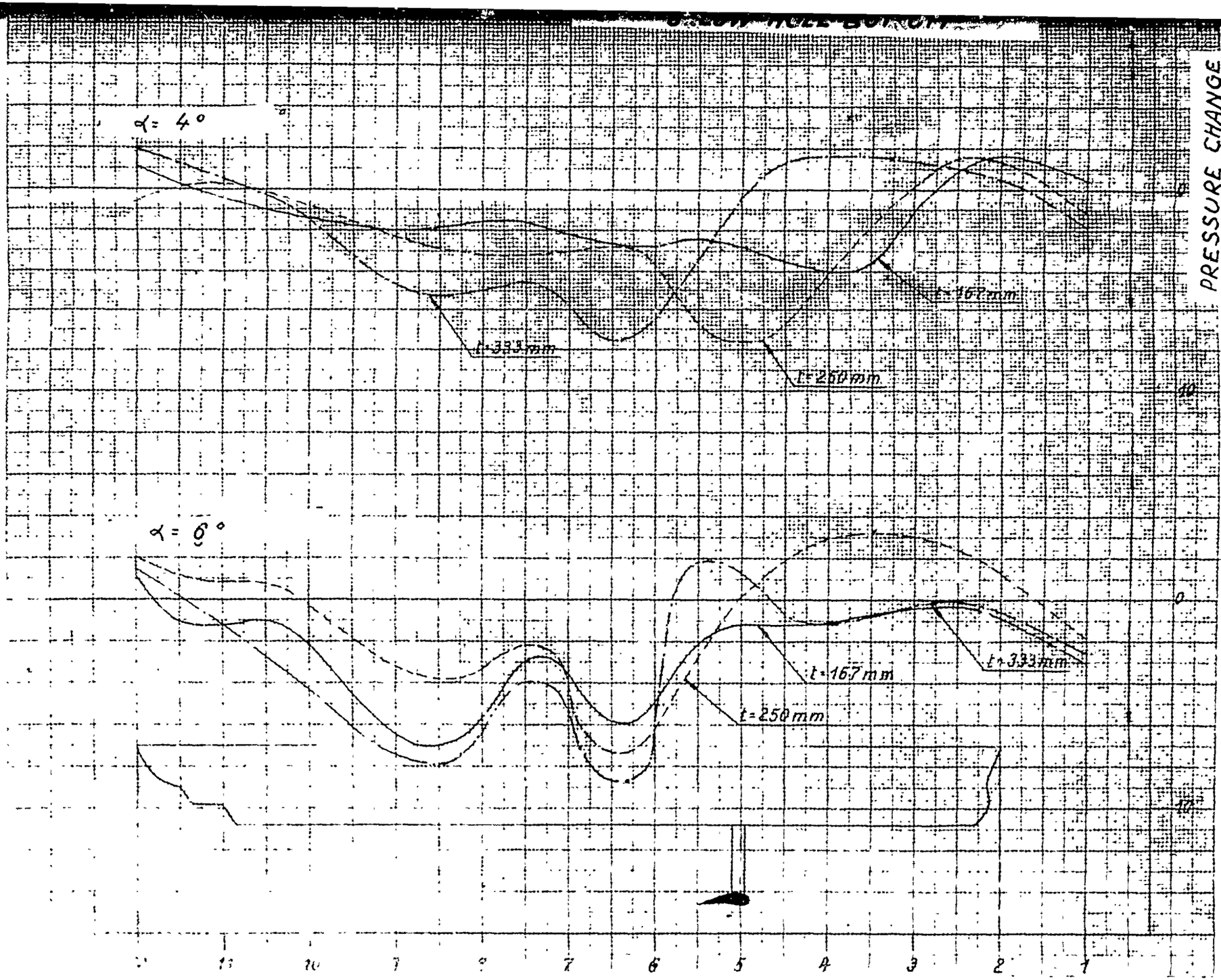
HLS

KEEL SIGNATURES OF THE MODEL WITH AIRFOIL 1440 mm FORWARD OF MIDSHIPS SECTION

FIGURE 37

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m




α = 4°
t = 333 mm
t = 250 mm
t = 167 mm
α = 6°
t = 167 mm
t = 250 mm
t = 333 mm
PRESSURE CHANGE (mm WATER)
10
0
10
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

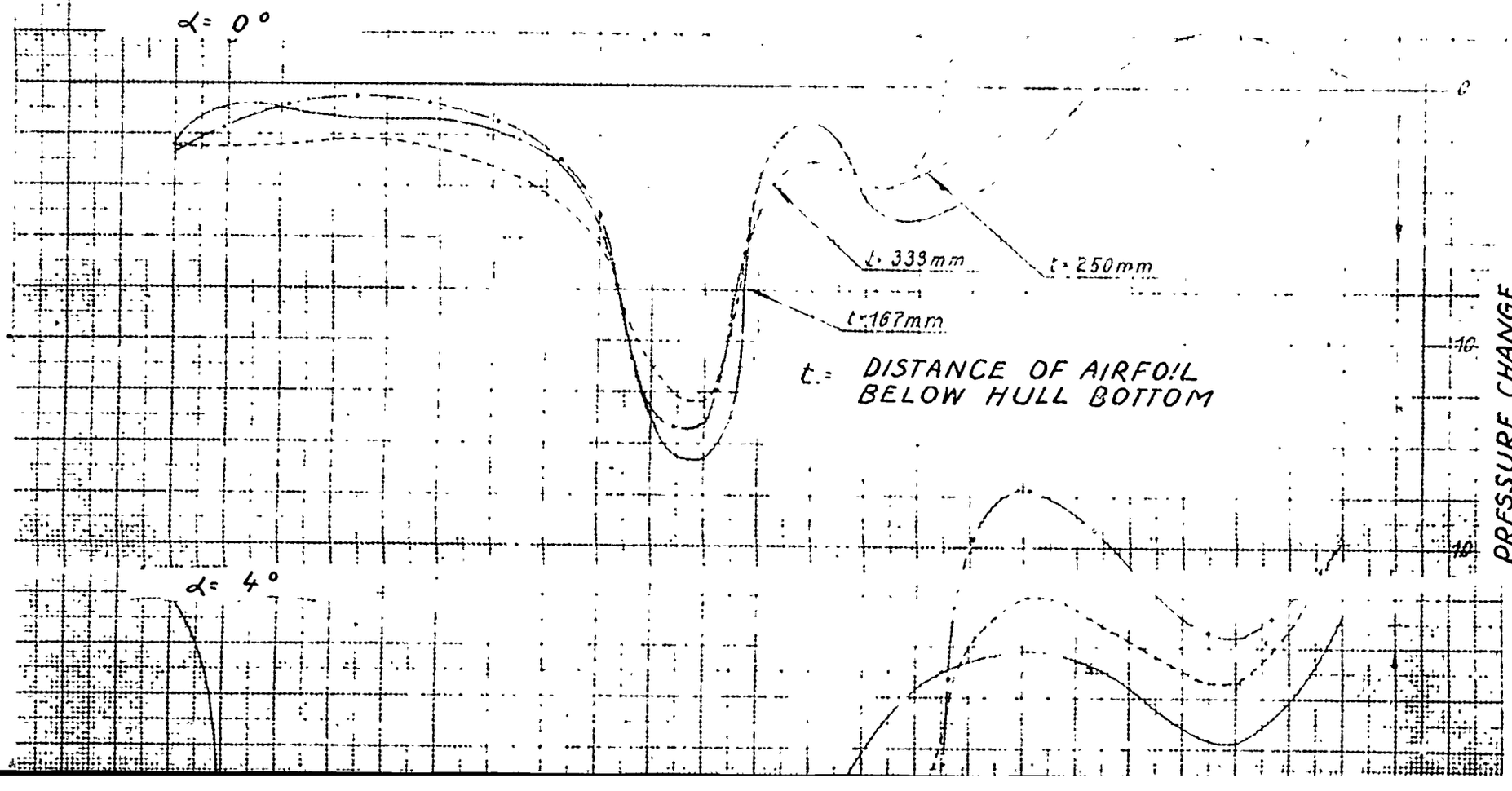
(2)

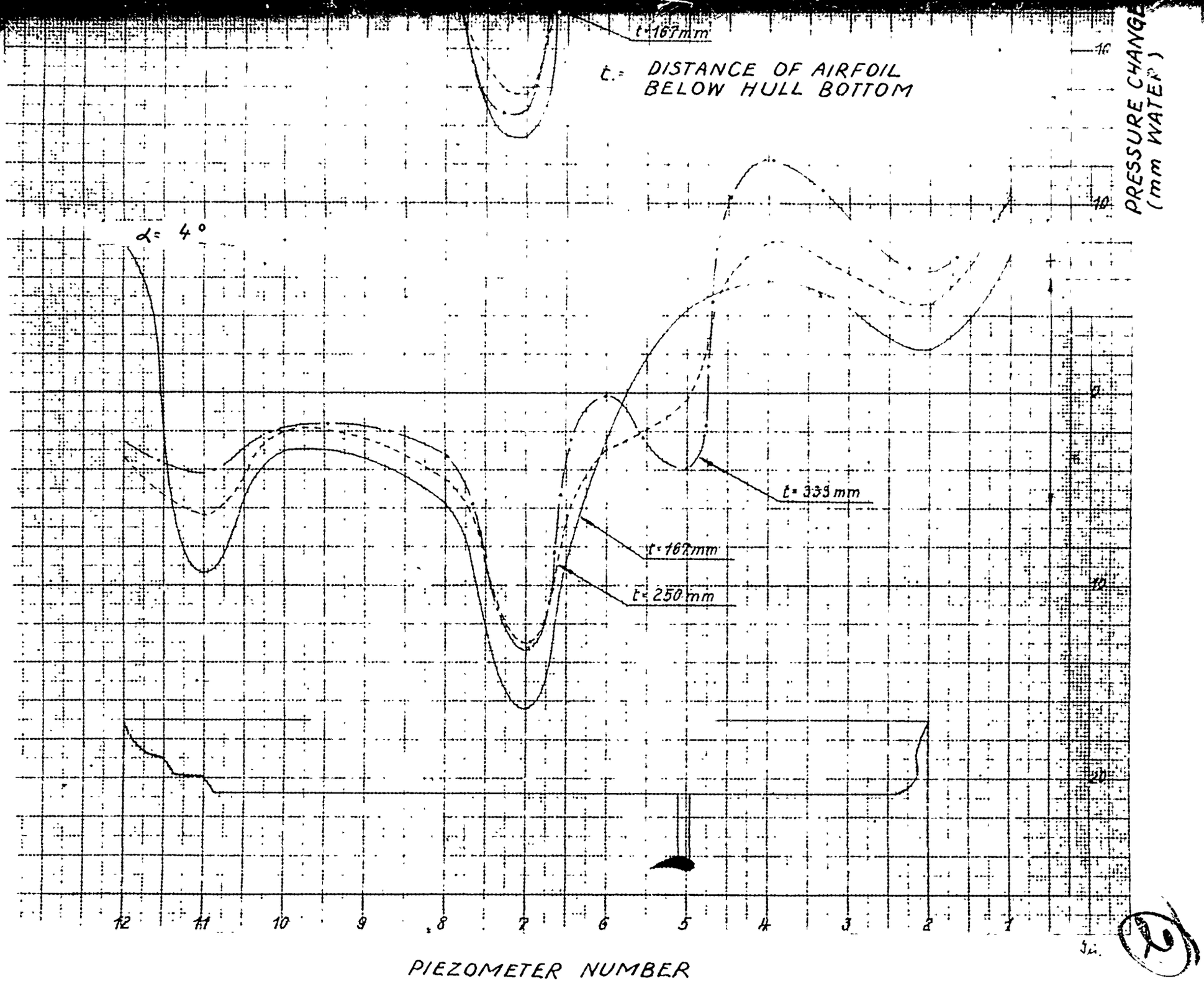
H.S.V.A

FIGURE 38

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL - 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m



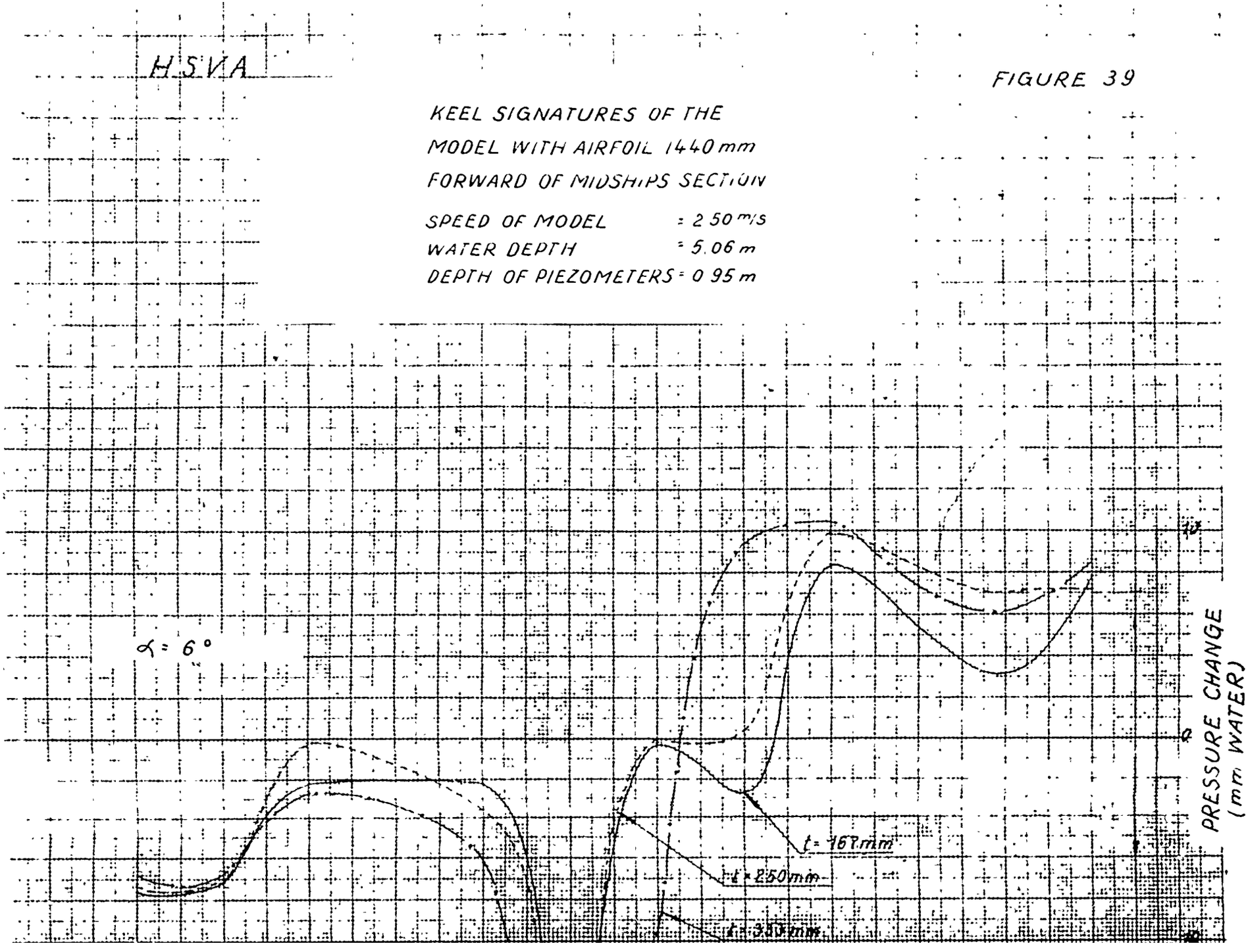

t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
t=167mm
α = 4°
t=333mm
t=167mm
t=250mm
PRESSURE CHANGE (mm WATER)
16
10
8
12
20
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

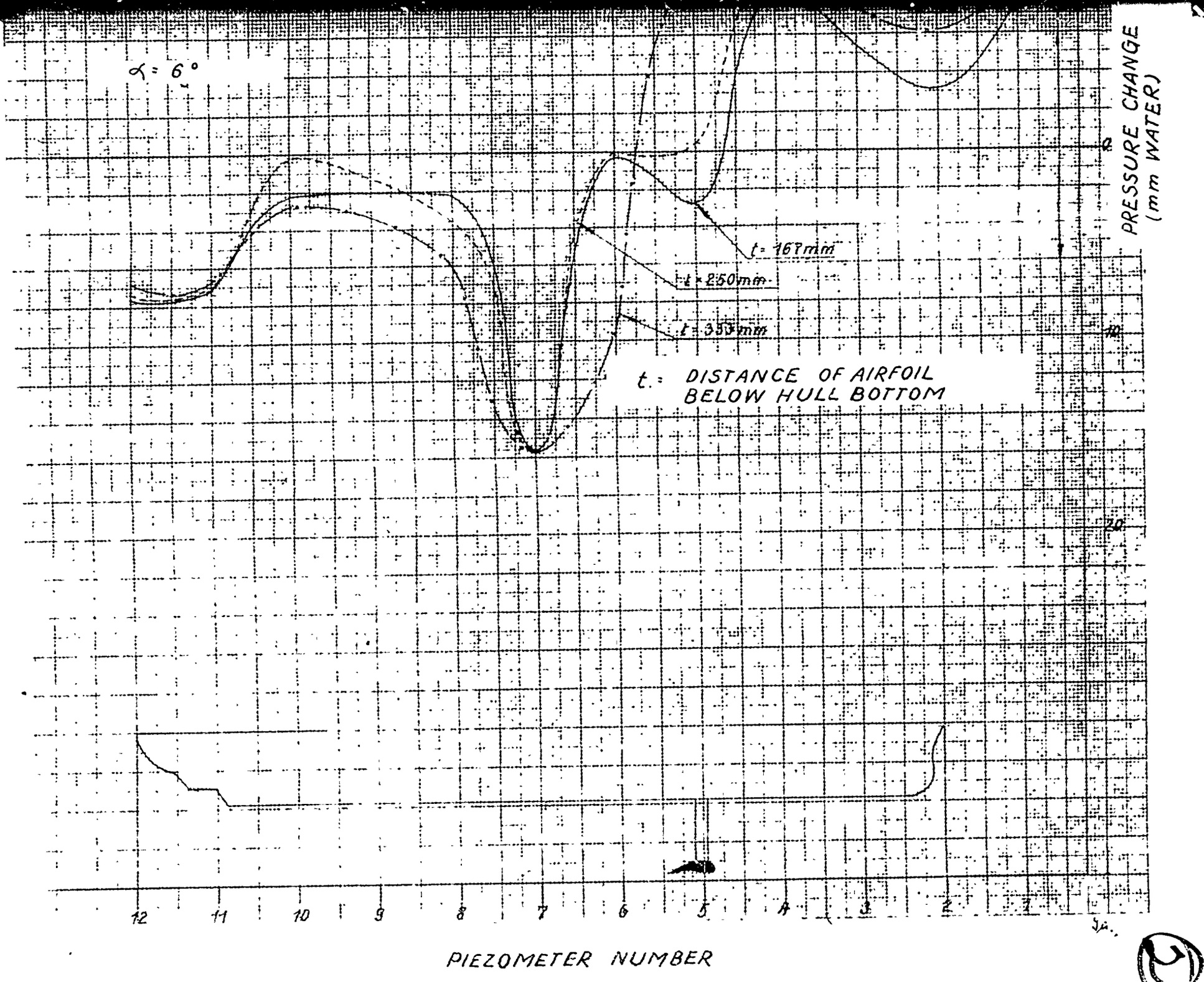
HSVA

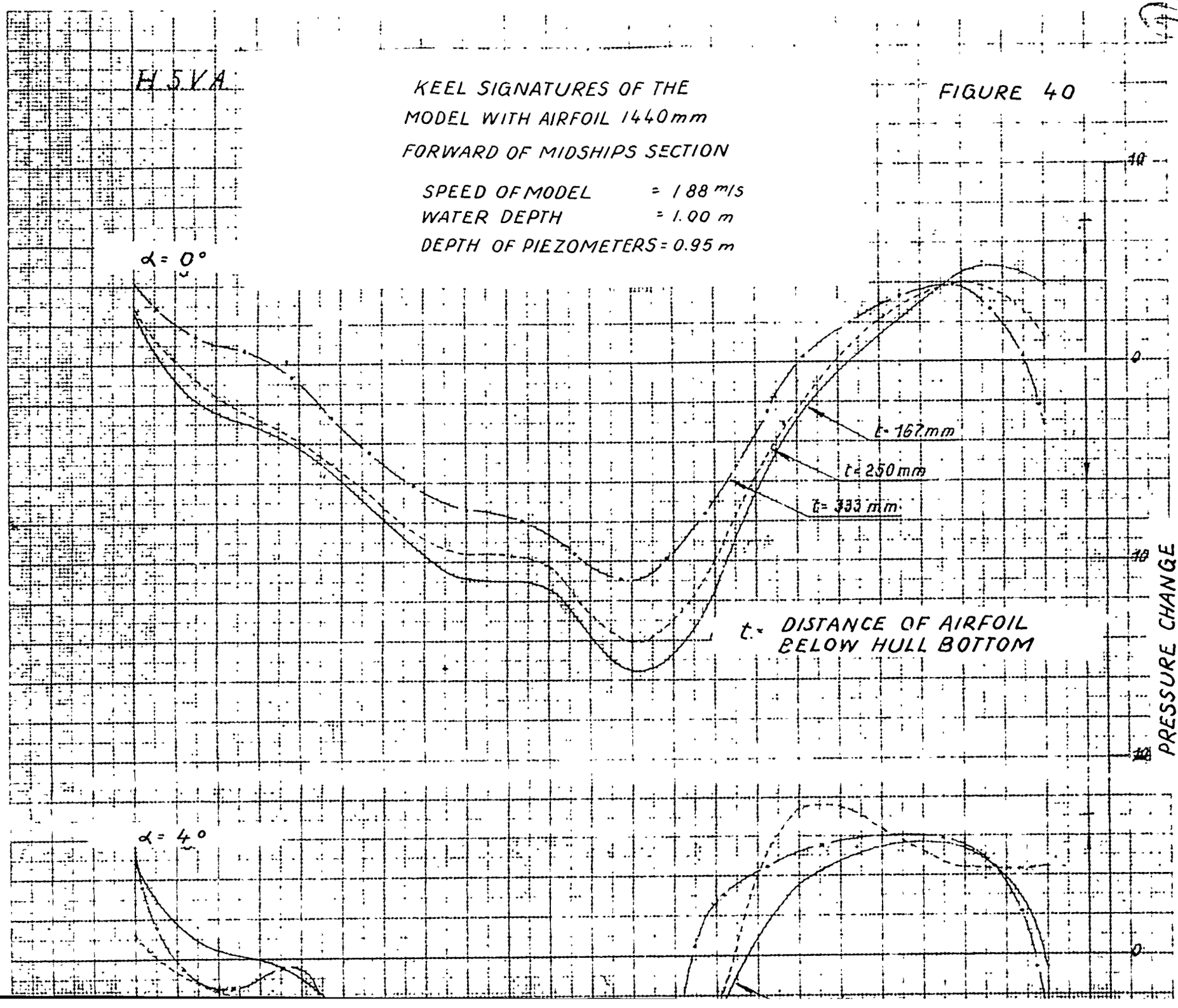
FIGURE 39

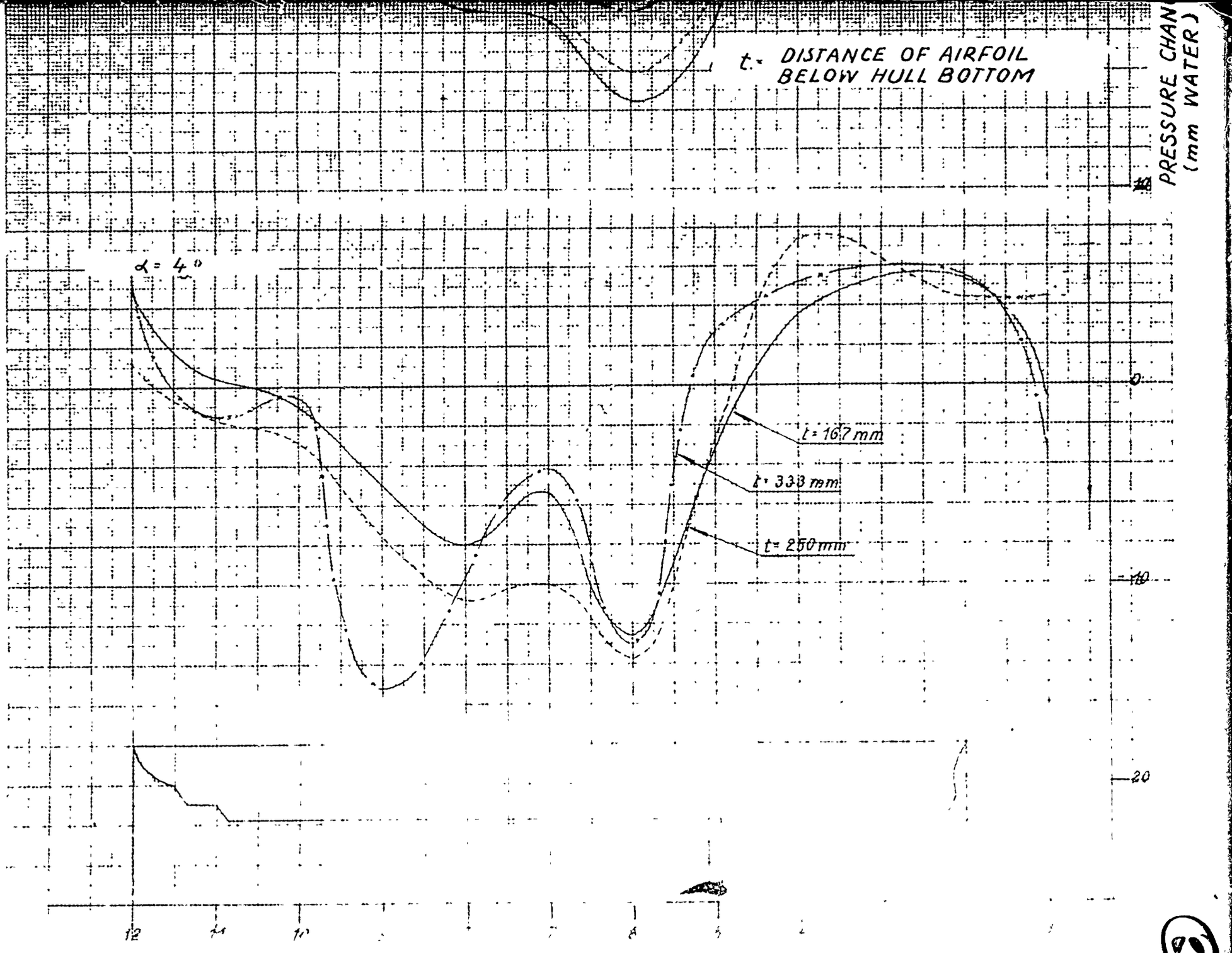
KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440 mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m




α = 6°
t = 167mm
t = 250mm
t = 353mm
t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE (mm WATER)
0
10
20
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER


H5VA
KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION
SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m
FIGURE 40
α = 0°
α = 4°
t = 167mm
t = 250mm
t = 333 mm
t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE (mm WATER)
10
0
10
10
0

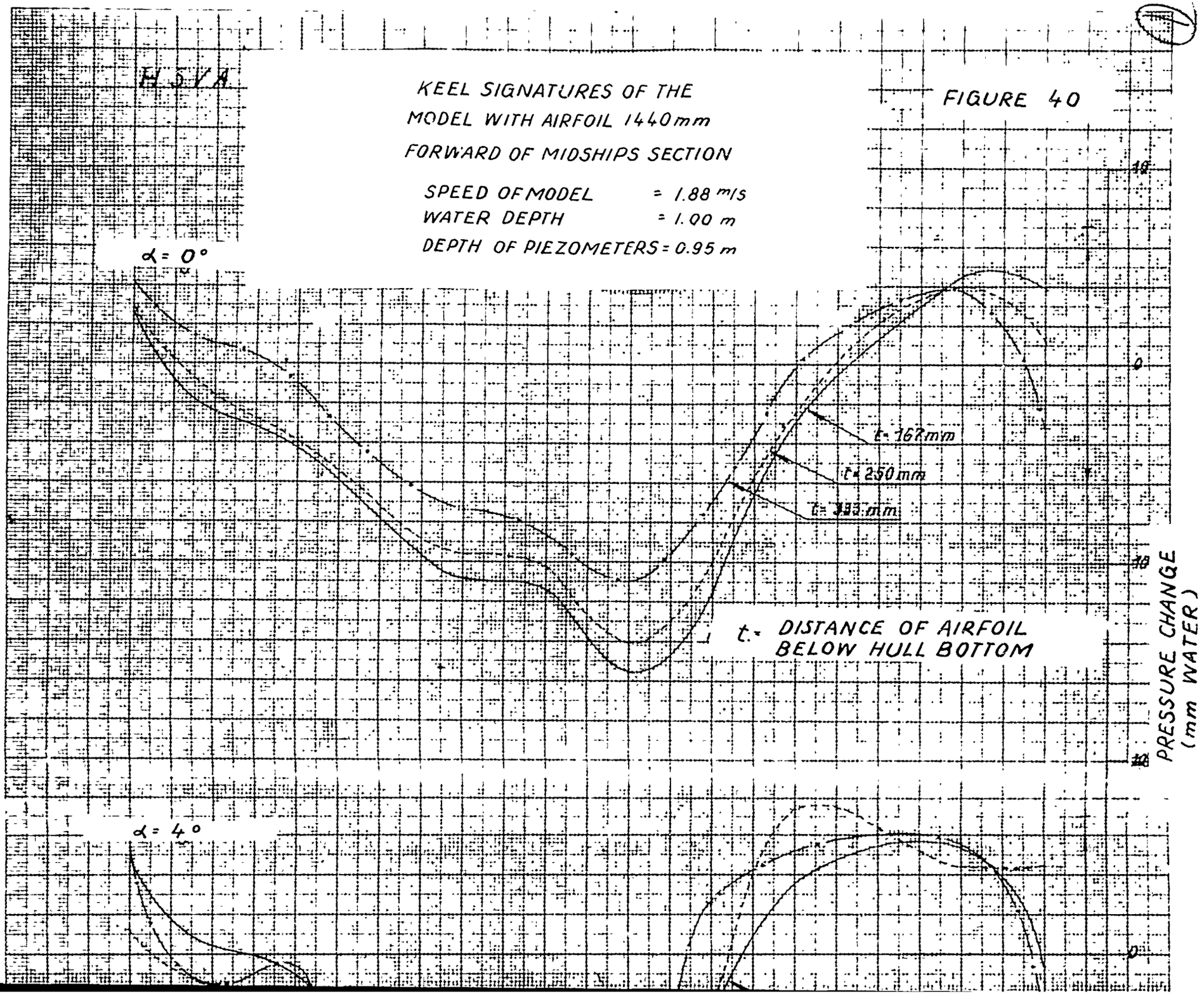

t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHAN
(mm WATER)
α = 4°
t = 167 mm
t = 333 mm
t = 250 mm
10
0
10
20
12
11
10
8
5
PIEZOMETER NUMBER

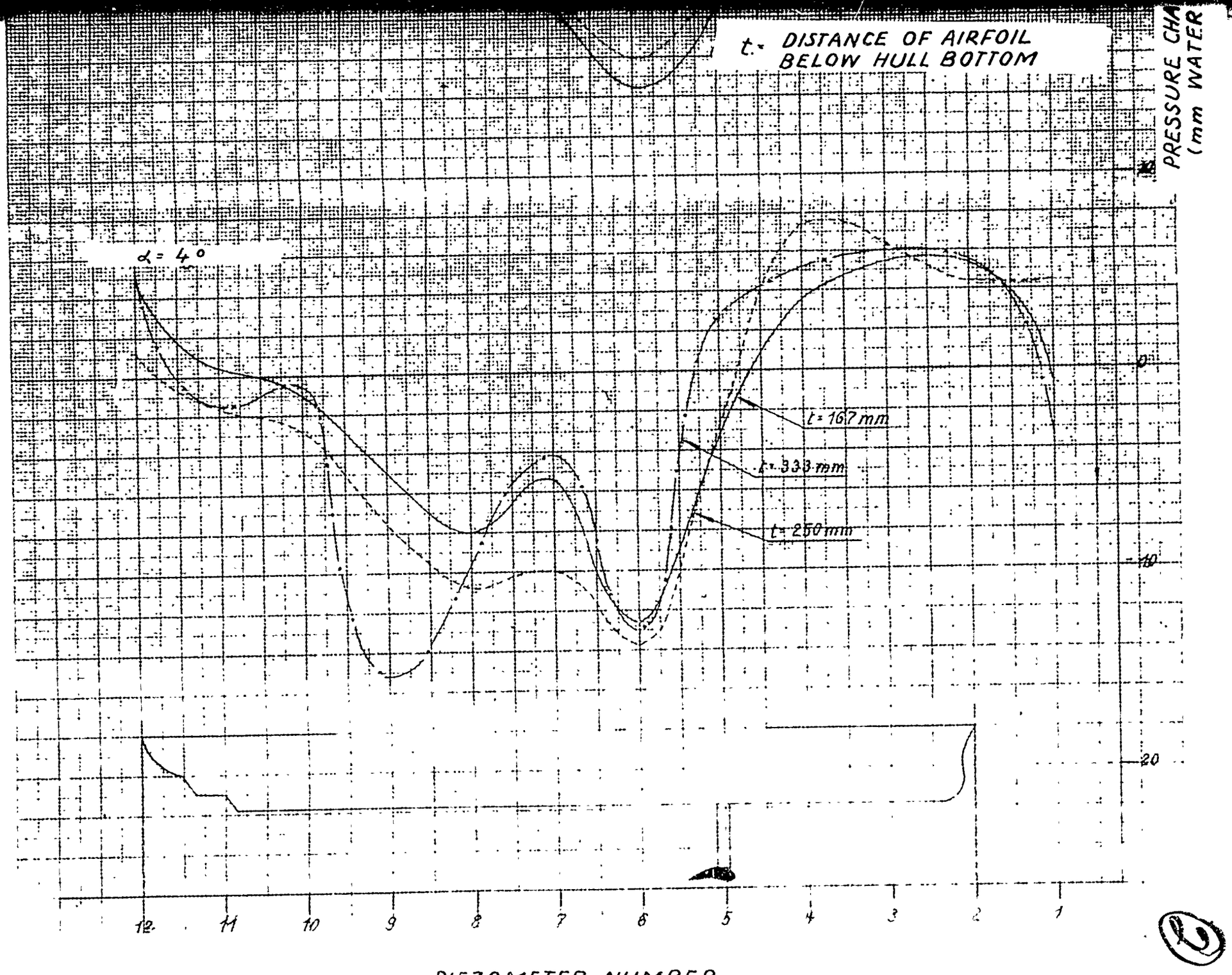
HSVA

FIGURE 40

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



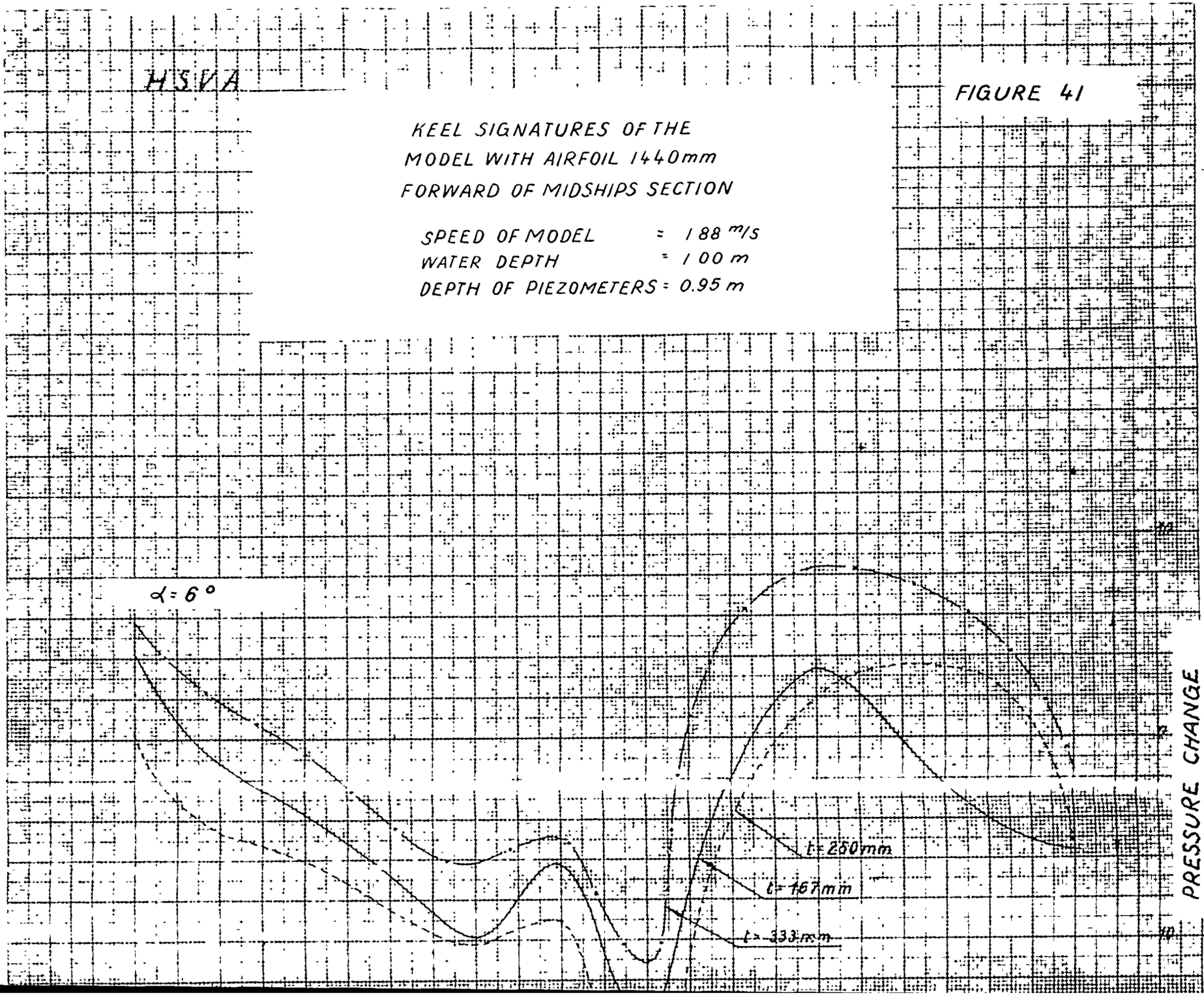

t.- DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHA
(mm WATER
α = 4°
t = 167 mm
t = 333 mm
t = 250 mm
0
10
20
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

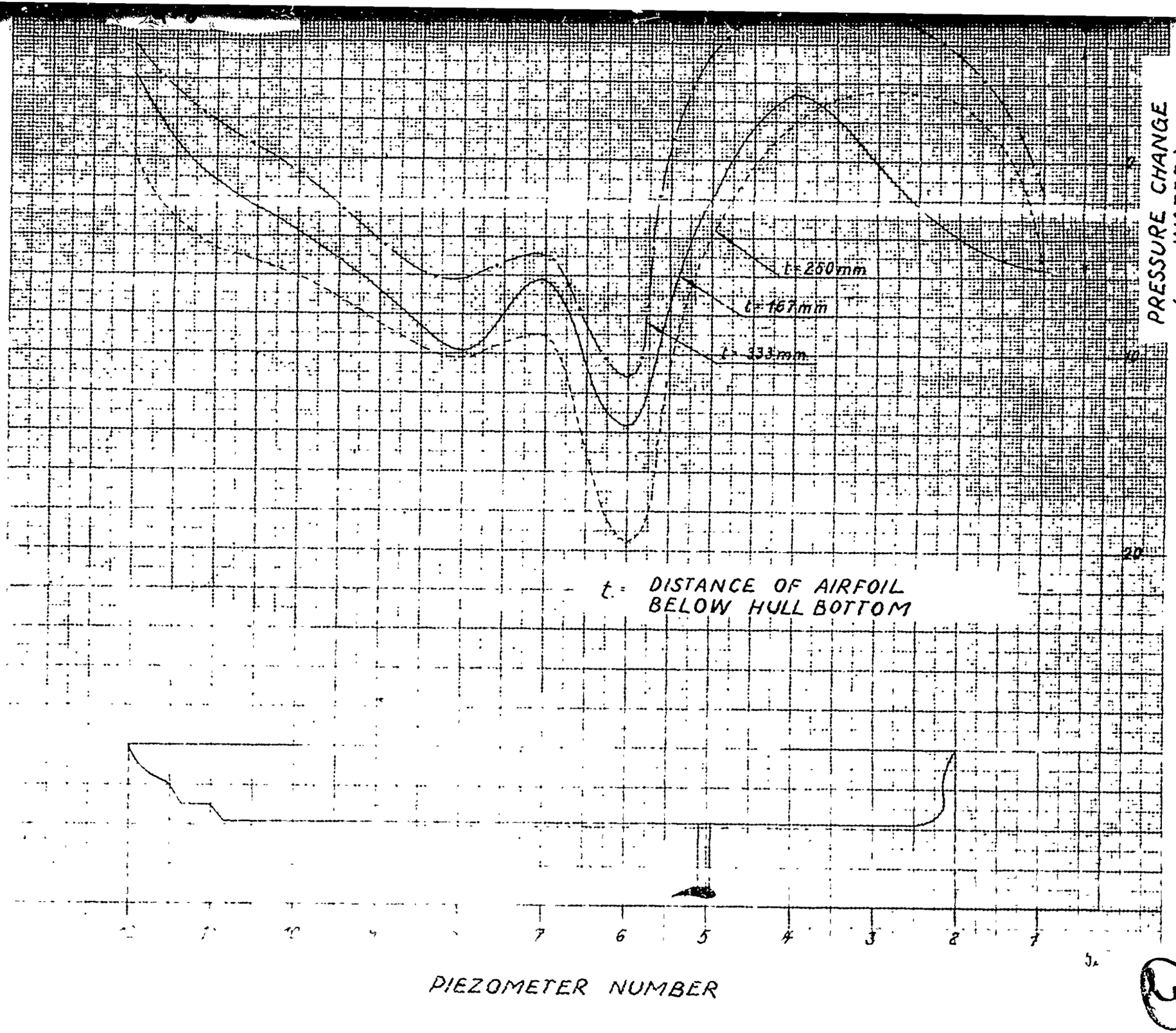
HSVA

FIGURE 41

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



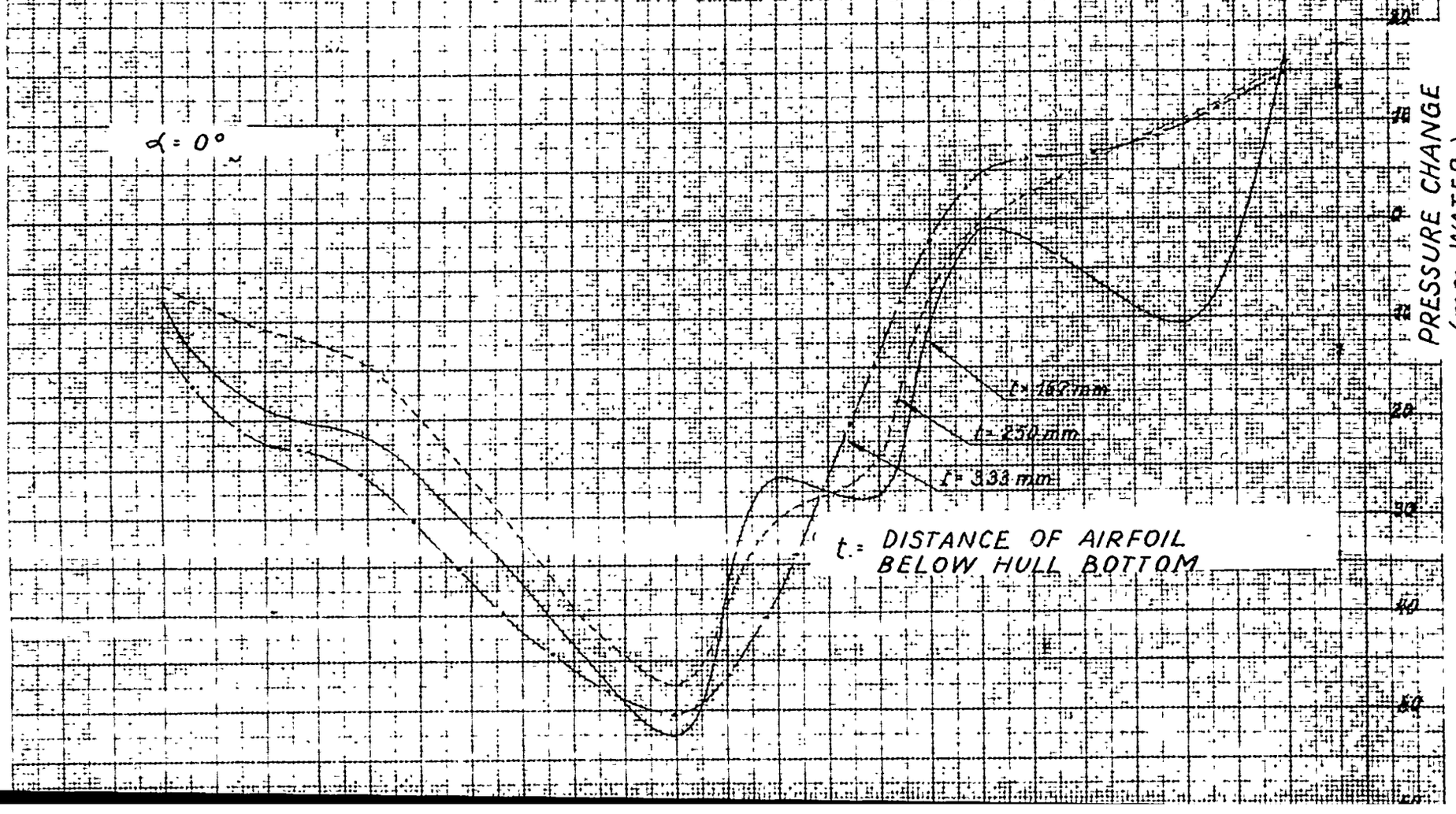

PRESSURE CHANGE
(mm WATER)
t= 260mm
t= 167mm
t= 333mm
t = DISTANCE OF AIRFOIL
BELOW HULL BOTTOM
20
7
6
5
4
3
2
1
PIEZOMETER NUMBER

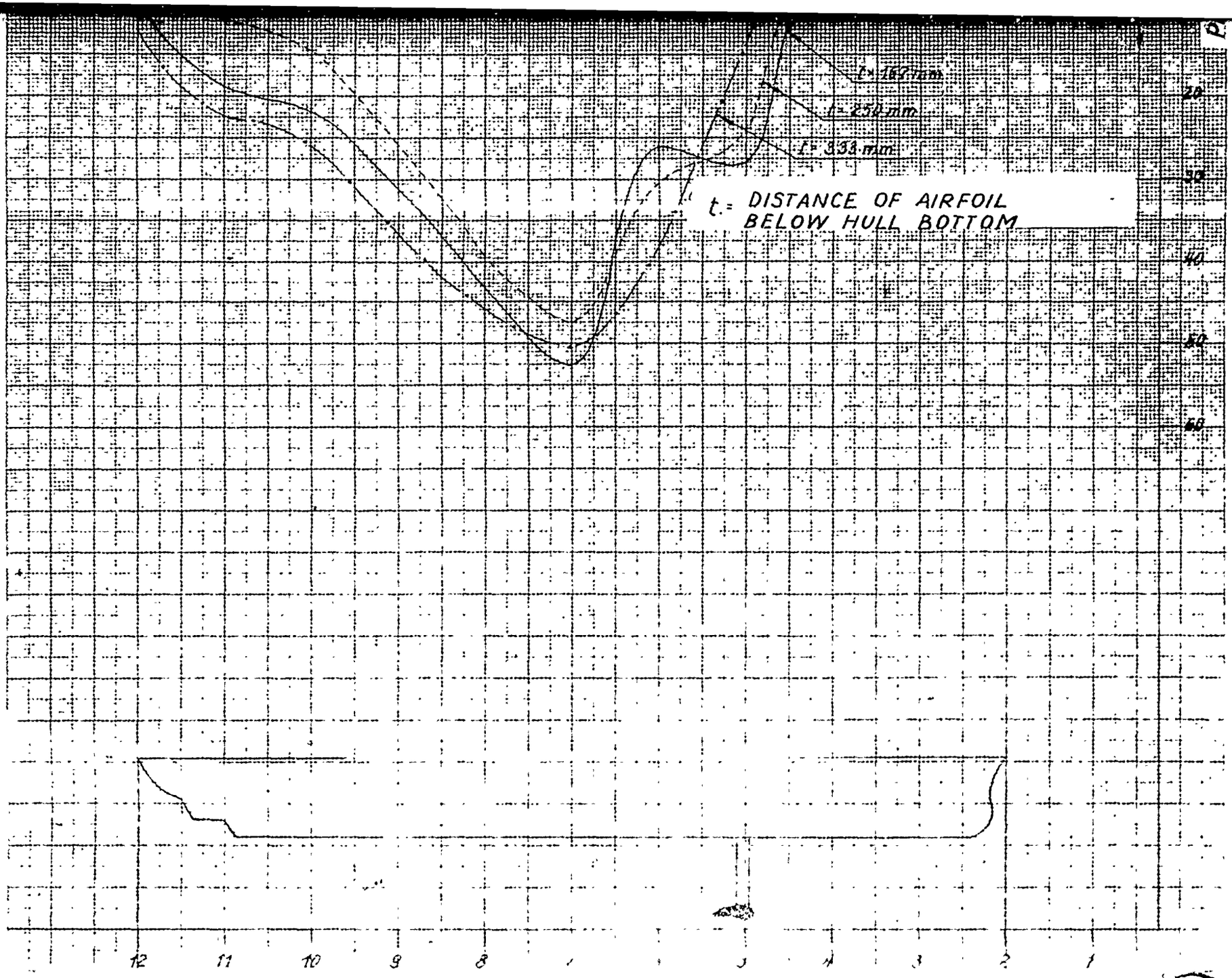
HSVA

FIGURE 42

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440 mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m.



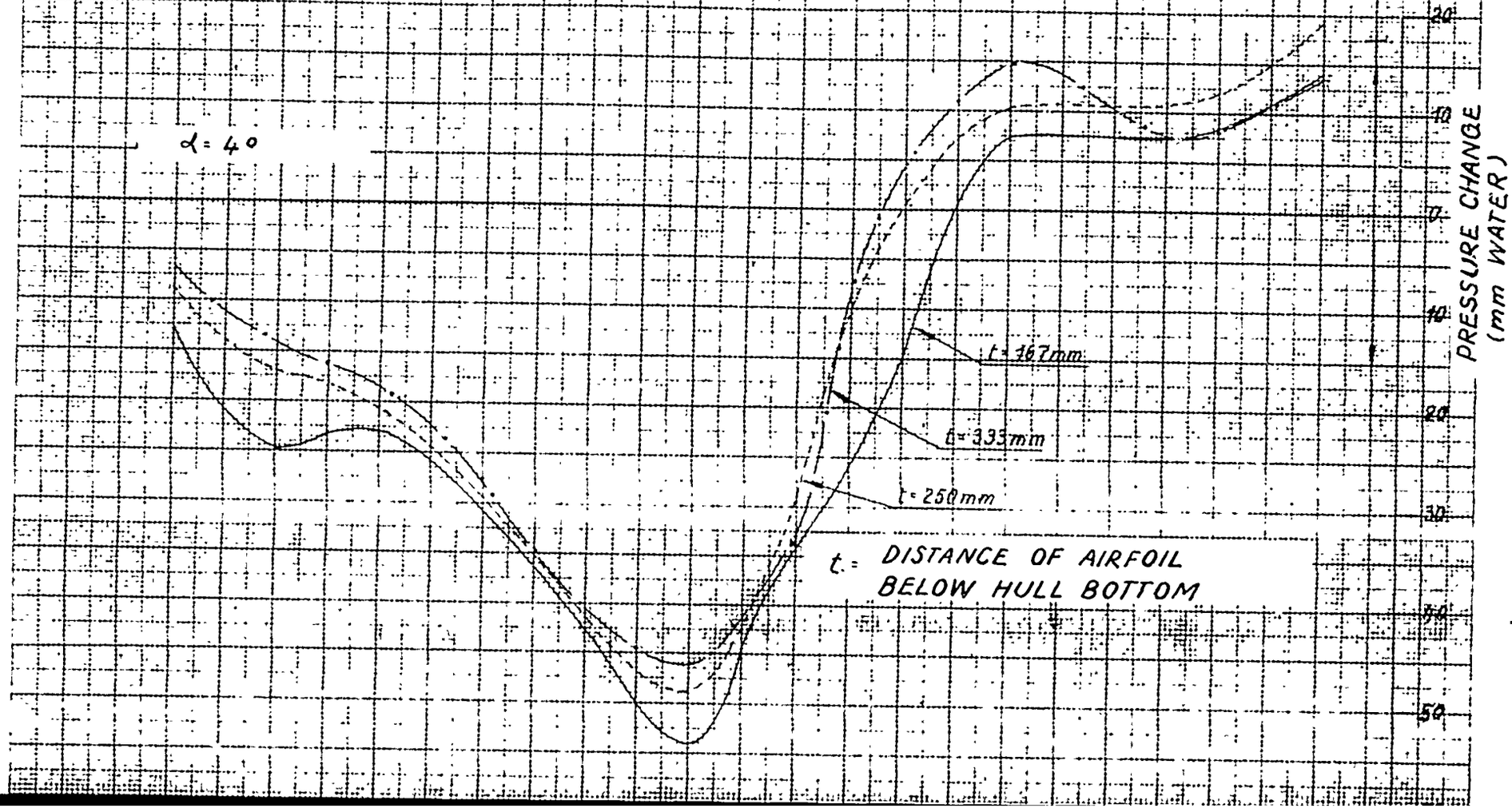

t= 167 mm
t= 250 mm
t= 333 mm
t.= DISTANCE OF AIRFOIL BELOW HULL BOTTOM
20
30
40
50
60
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

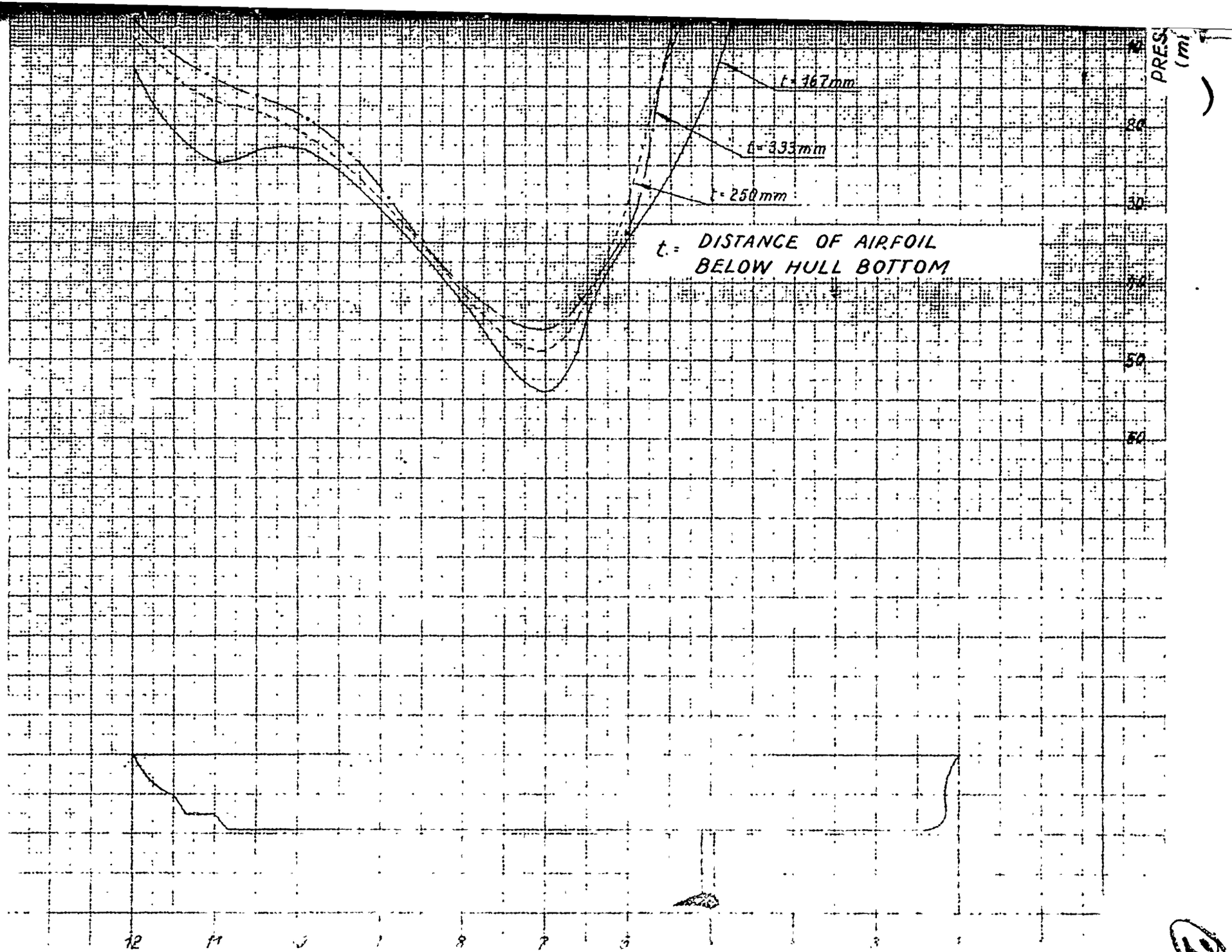
HSVA

FIGURE 43

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m





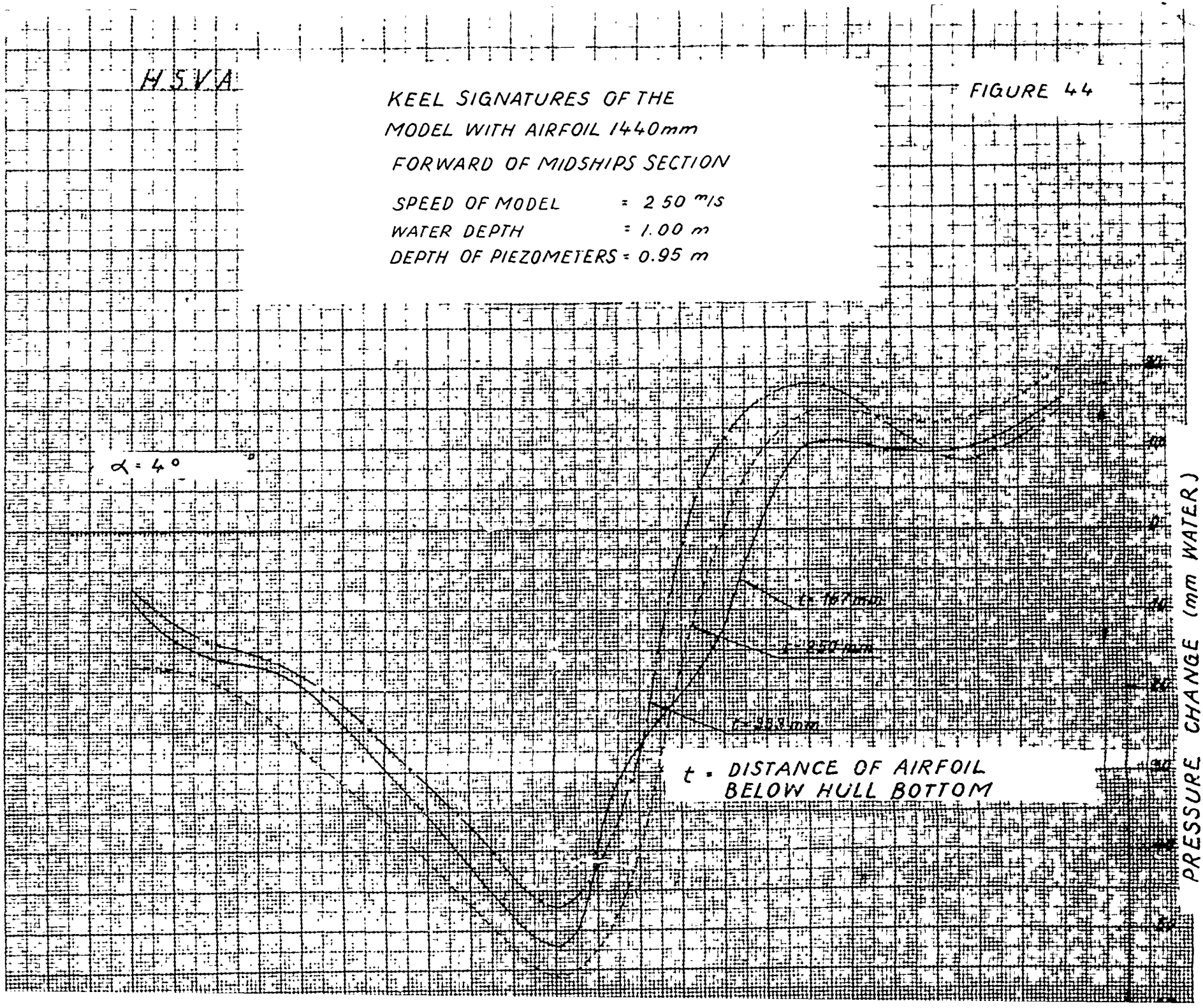
t = 167mm
t = 333mm
t = 250mm
t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRES
(m
80
30
40
50
60
12
11
8
7
PIEZOMETER NUMBER

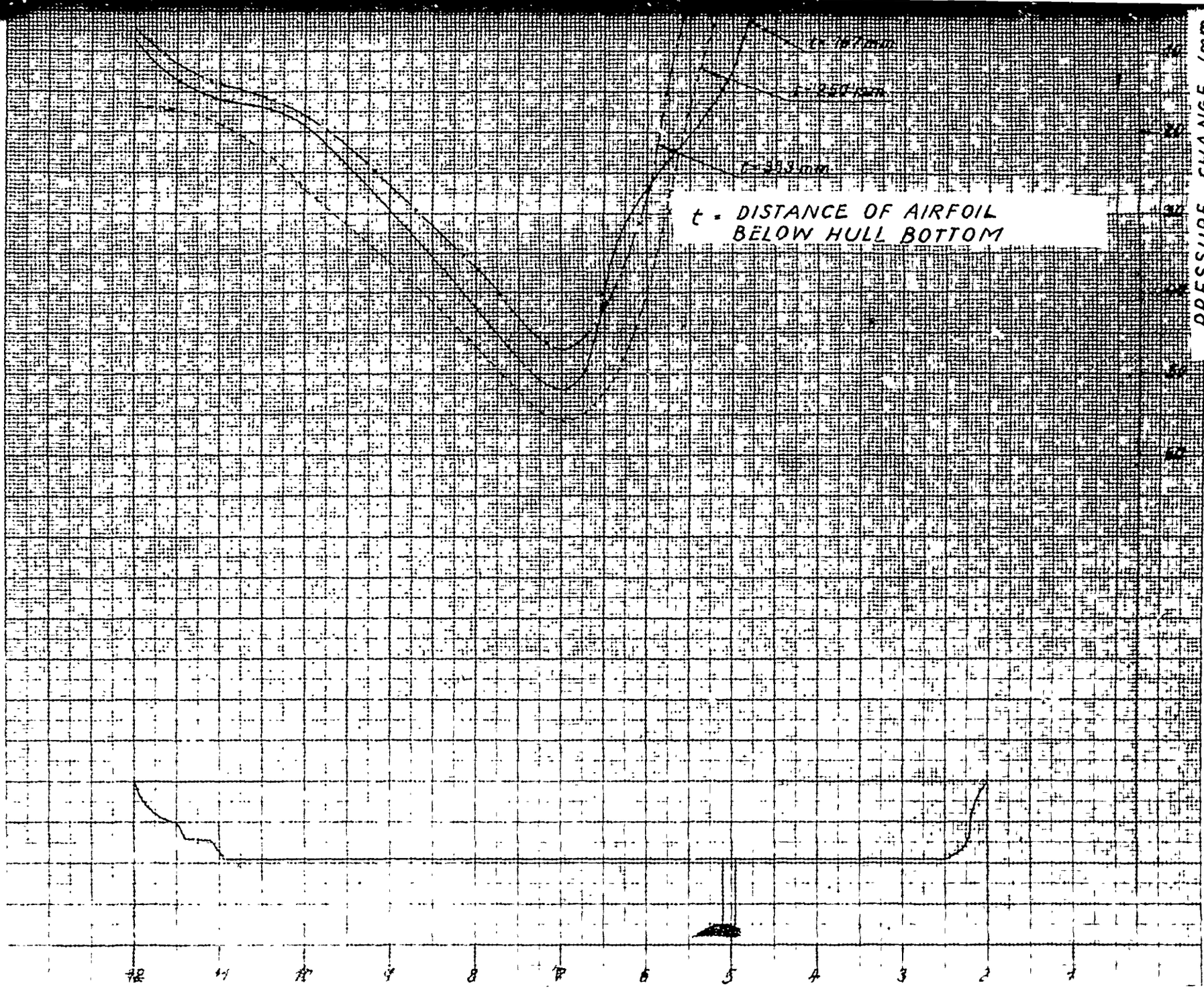
HSVA

FIGURE 44

KEEL SIGNATURES OF THE
MODEL WITH AIRFOIL 1440mm
FORWARD OF MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



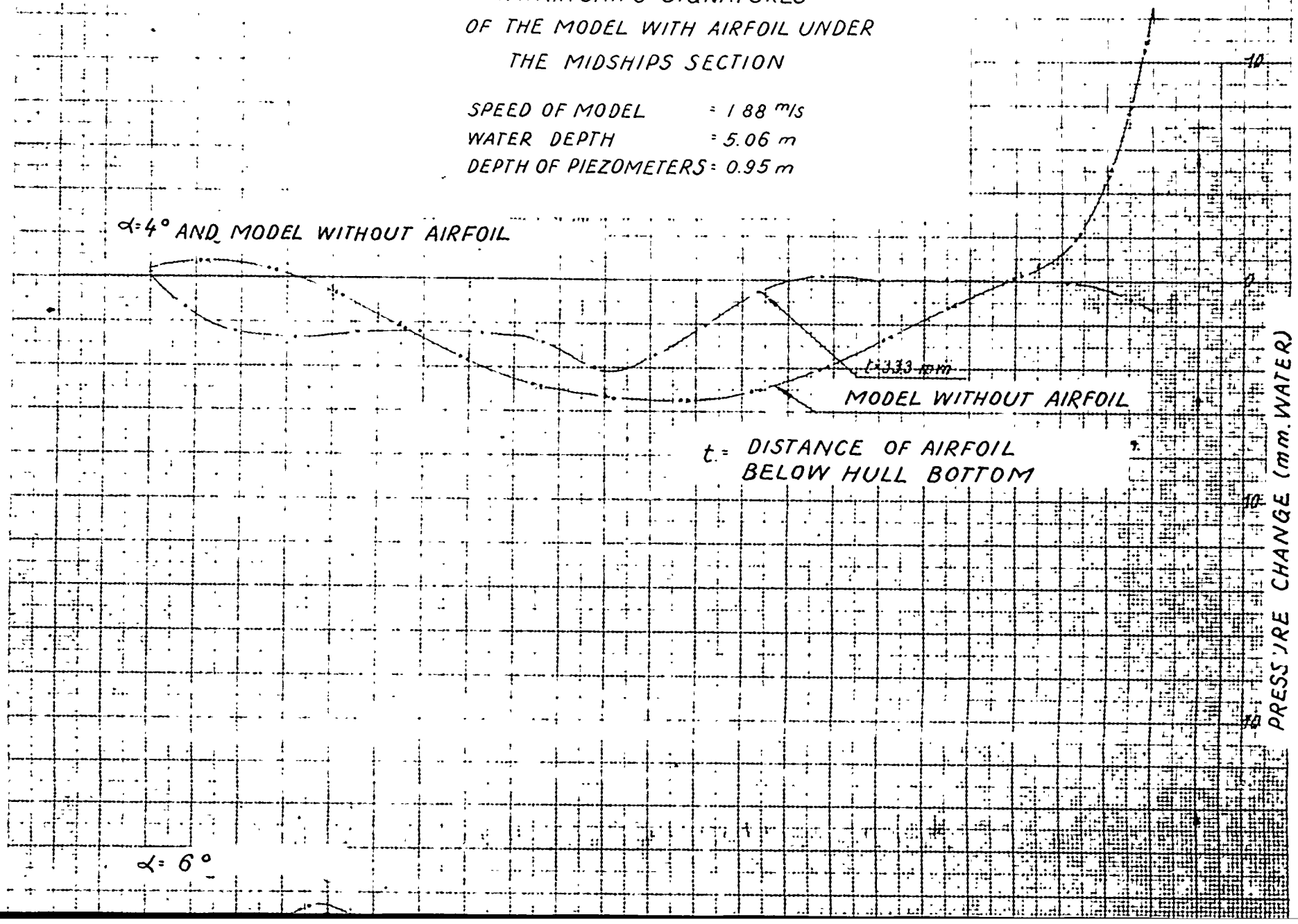

t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE (mm
PIEZOMETER NUMBER

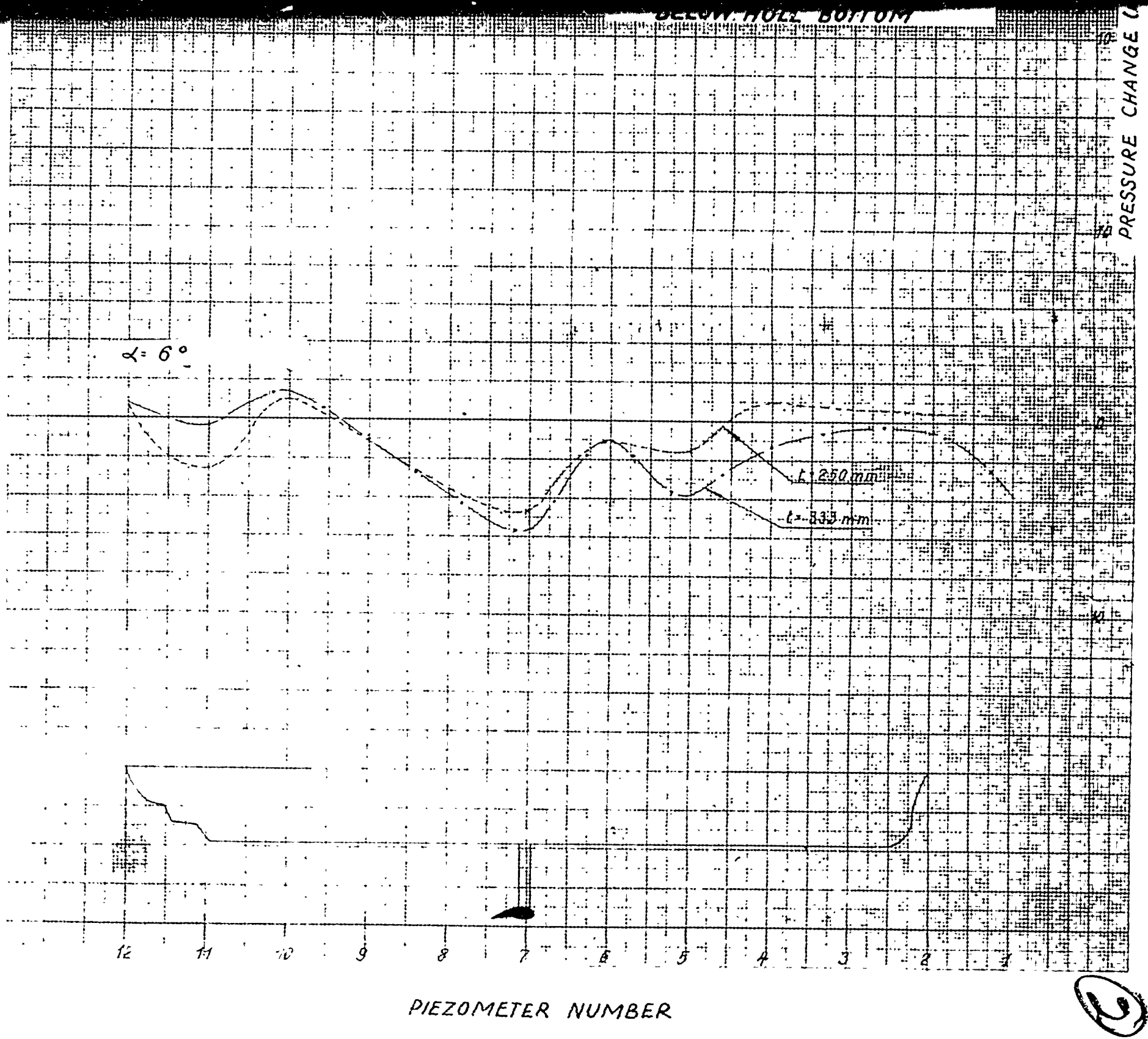
H.S.V.A

FIGURE 45

ATHWARTSHIPS SIGNATURES
OF THE MODEL WITH AIRFOIL UNDER
THE MIDSHIPS SECTION

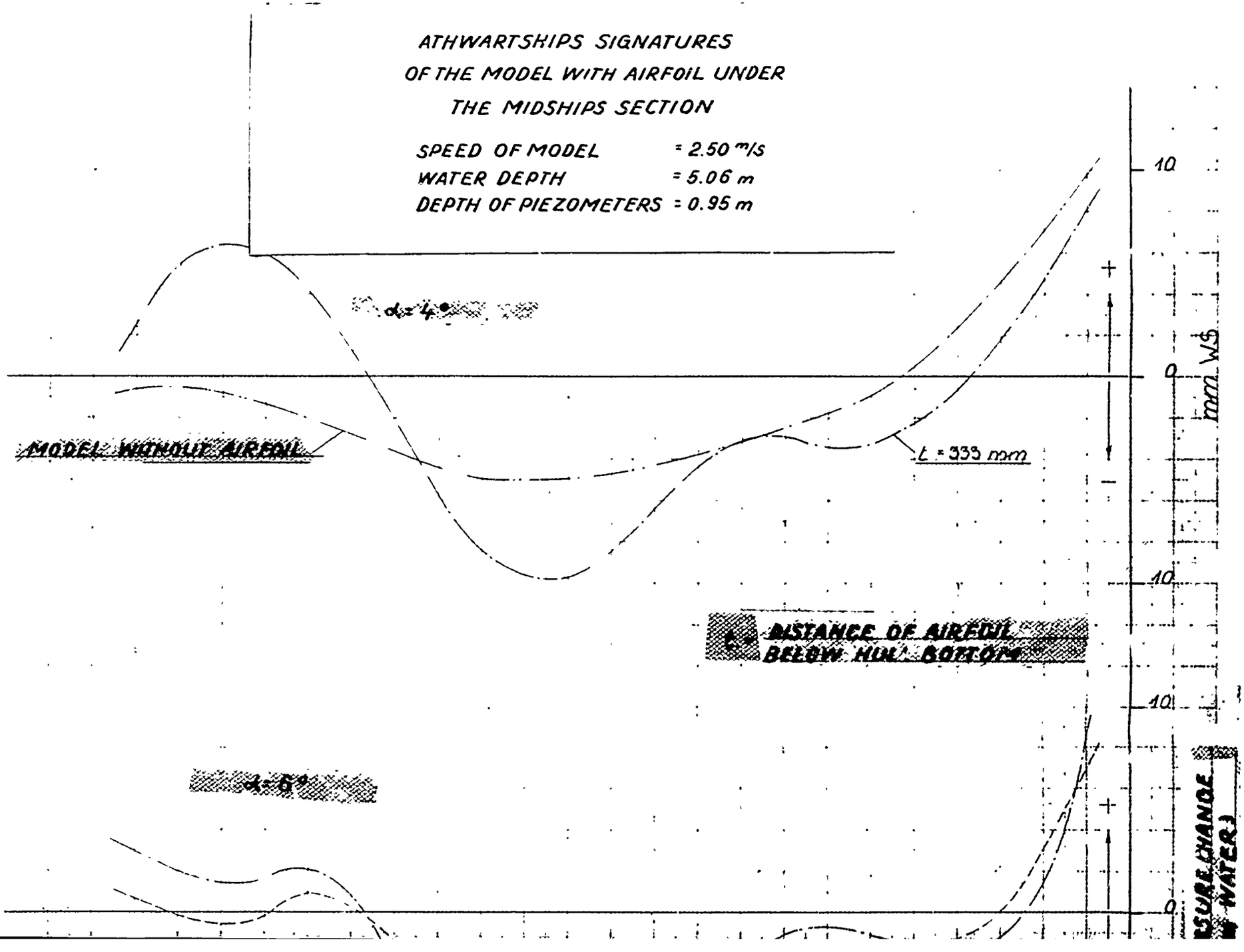
SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 5.06 m
DEPTH OF PIEZOMETERS = 0.95 m

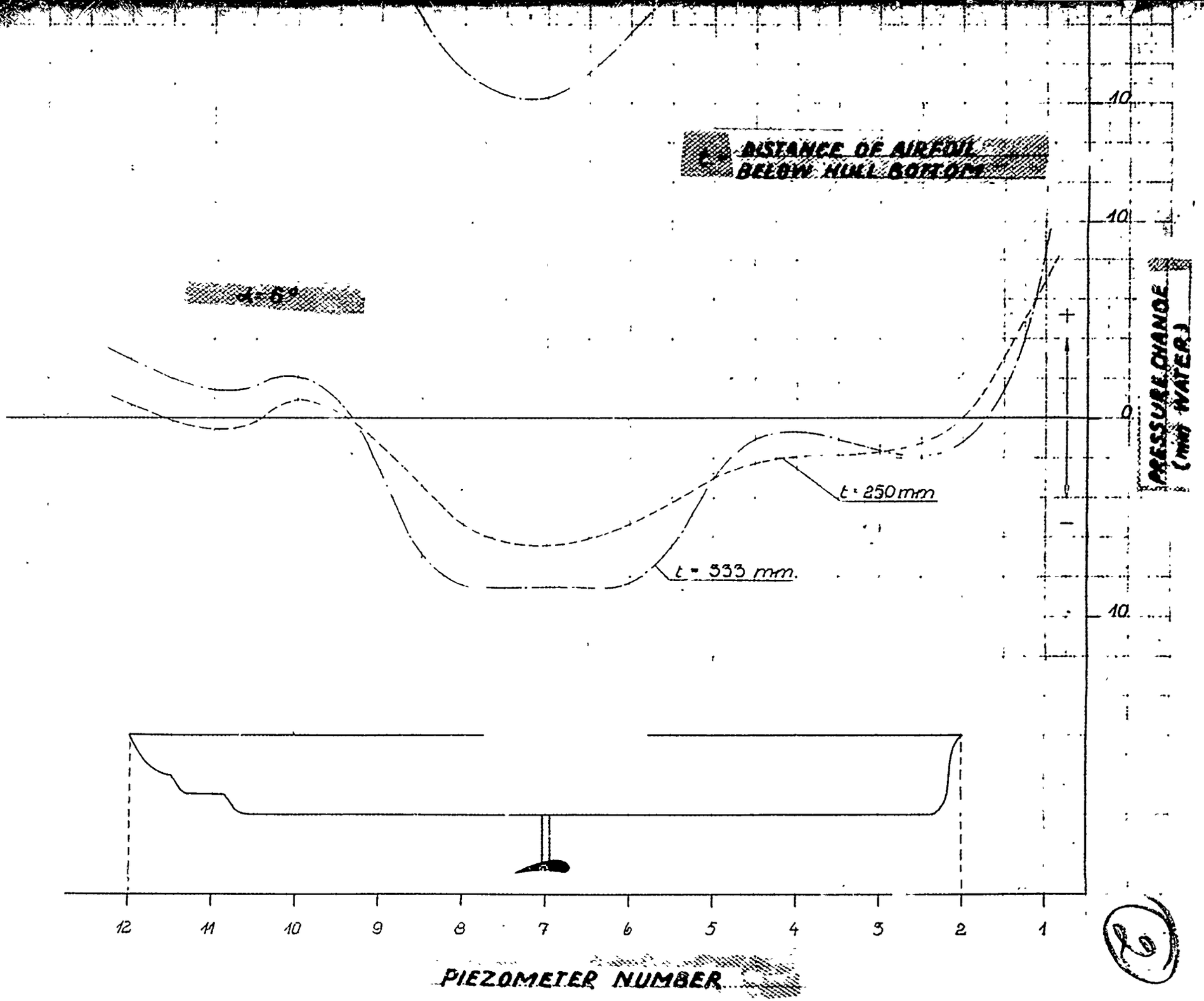



BELOW HOLE BOTTOM
PRESSURE CHANGE
α = 6°
t = 250 mm
t = 333 mm
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

HSVA

FIGURE 46



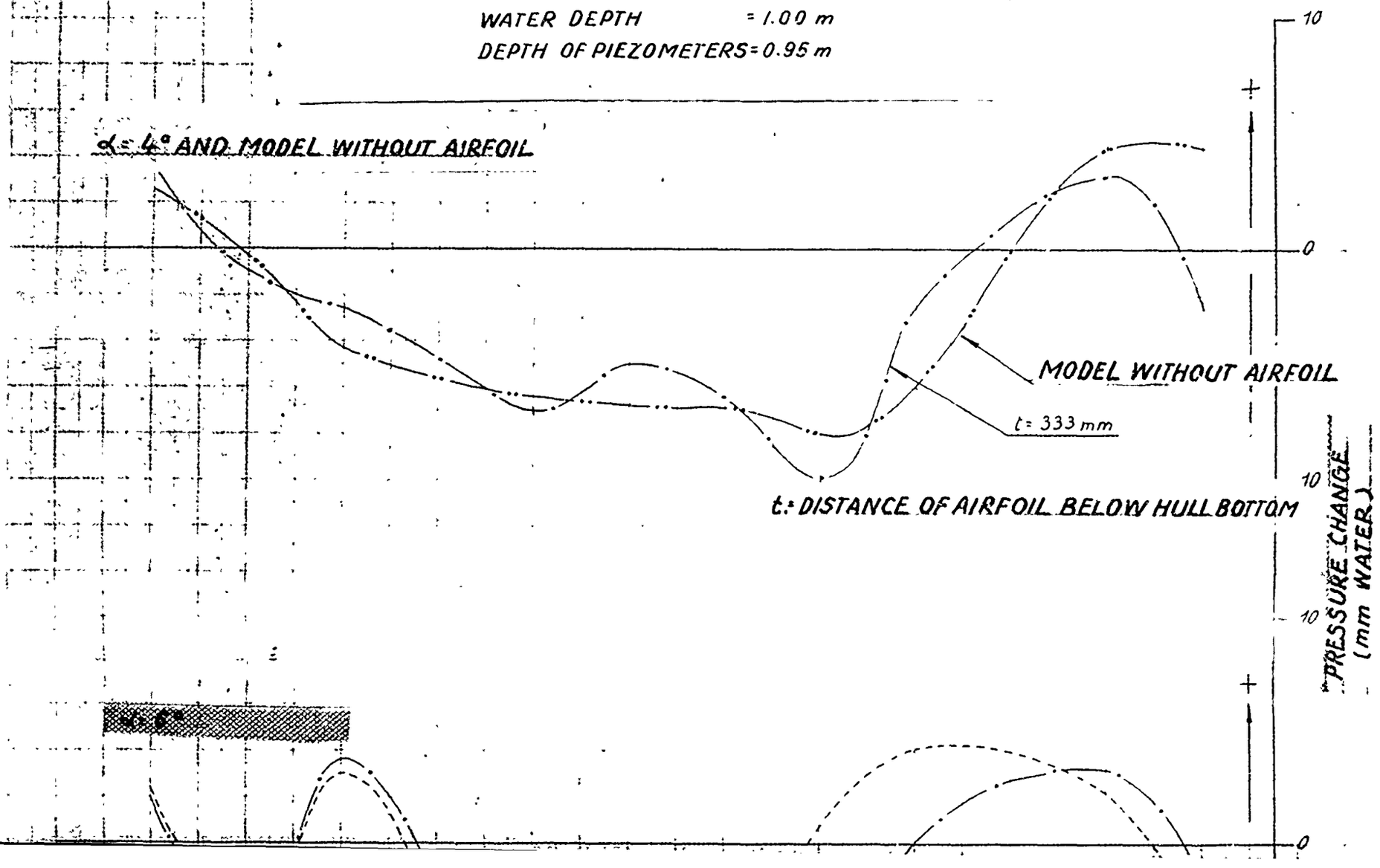

t = DISTANCE OF AIRFOIL BELOW HULL BOTTOM
α = 6°
t = 250 mm
t = 333 mm.
10
10
0
10
+
−
PRESSURE CHANGE (mm WATER)
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

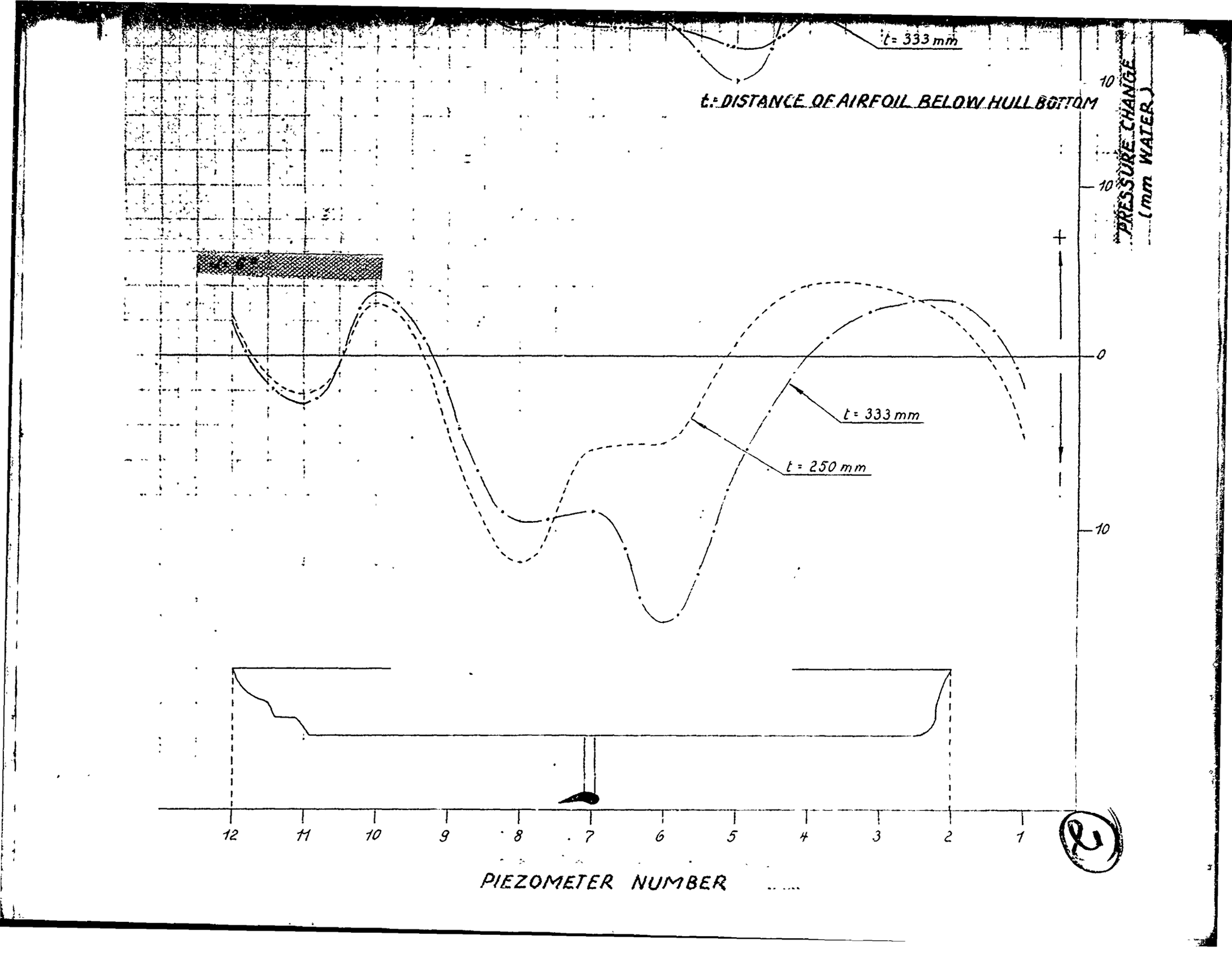
H.S.V.A.

FIGURE 47

ATHWARTSHIPS SIGNATURES
OF THE MODEL WITH AIRFOIL UNDER
THE MIDSHIPS SECTION

SPEED OF MODEL = 1.88 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m



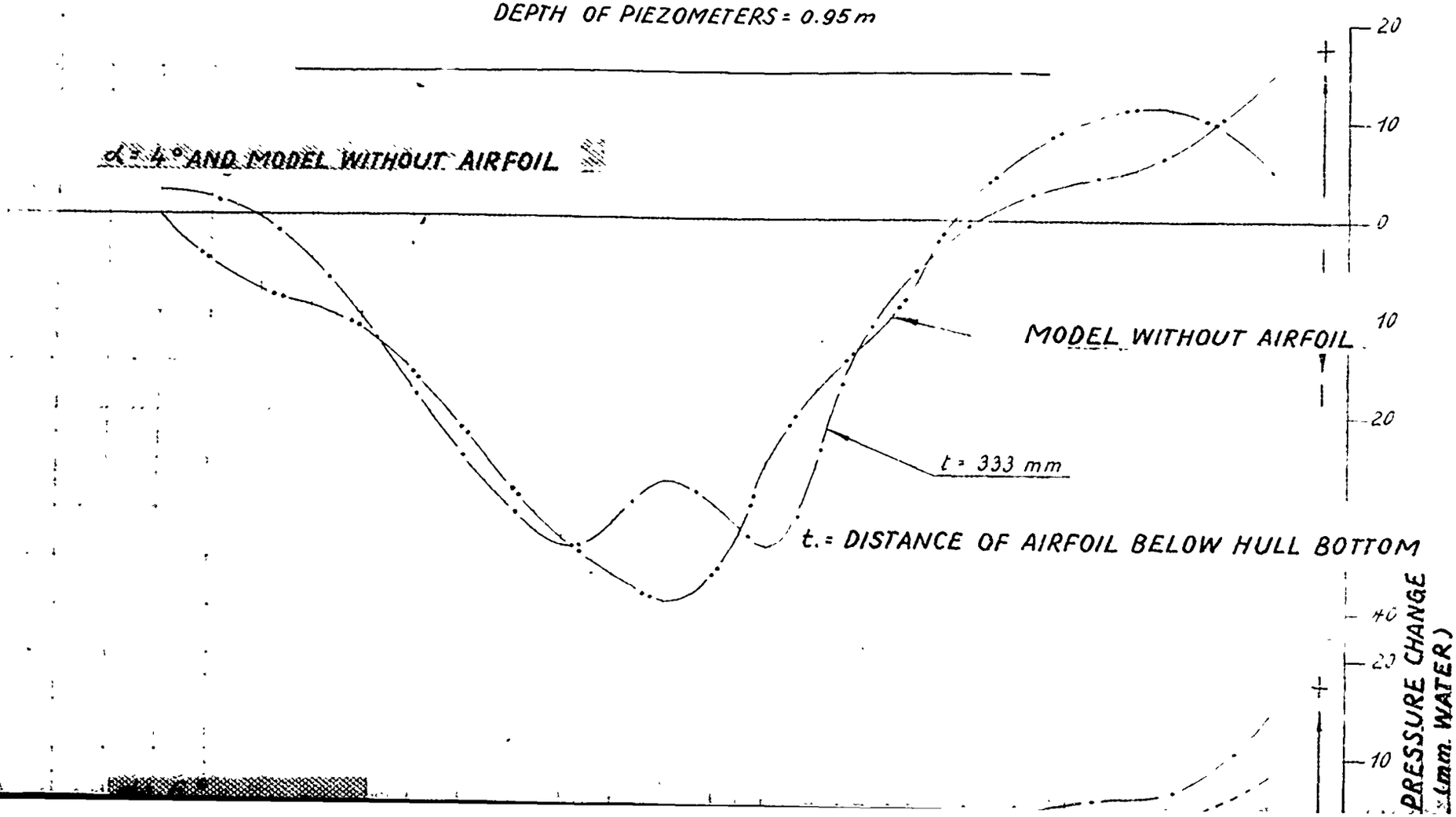

t = 333 mm
t: DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE (mm WATER)
10
10
0
10
t = 333 mm
t = 250 mm
12
11
10
9
8
7
6
5
4
3
2
1
PIEZOMETER NUMBER

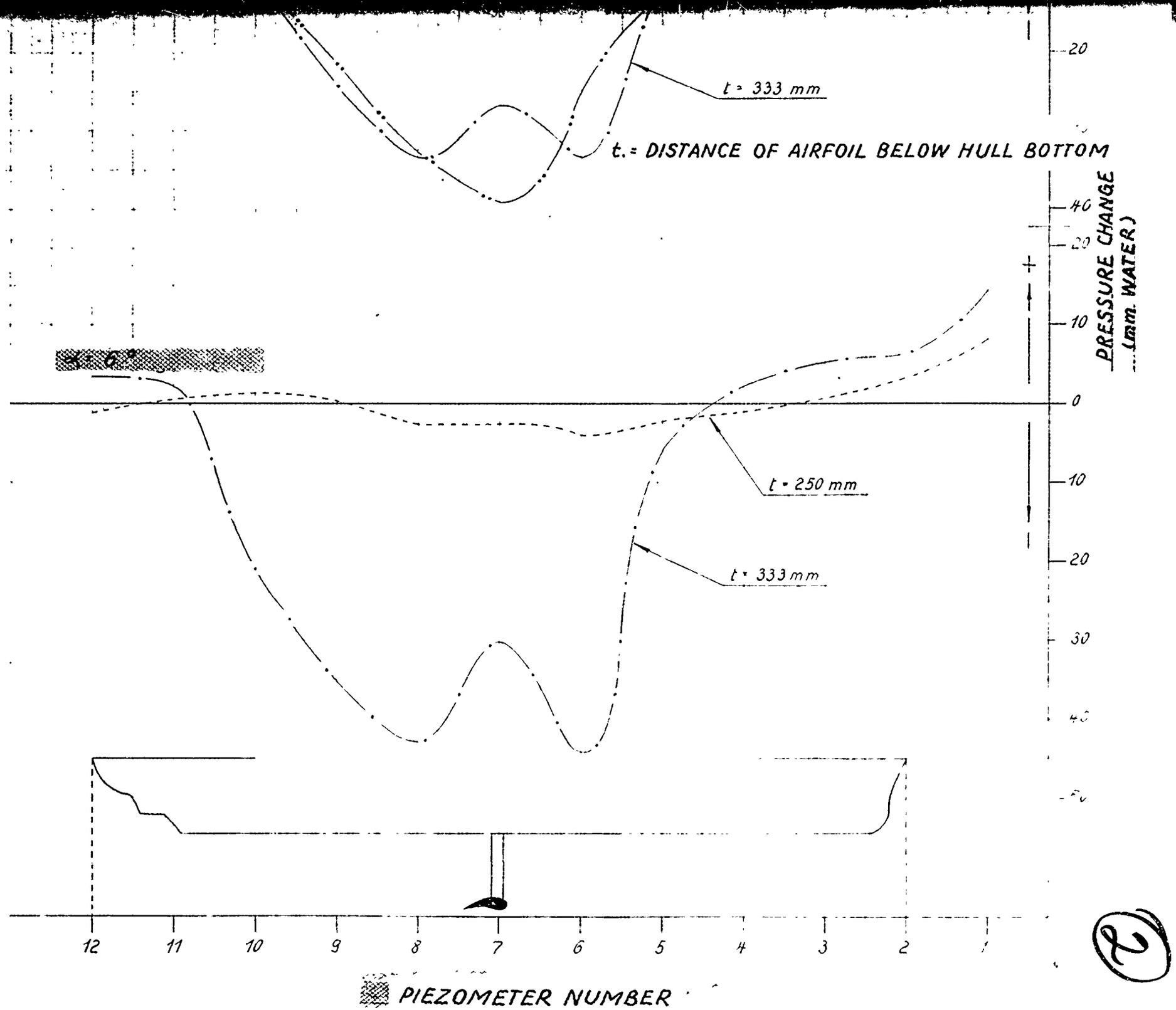
H.S.V.A

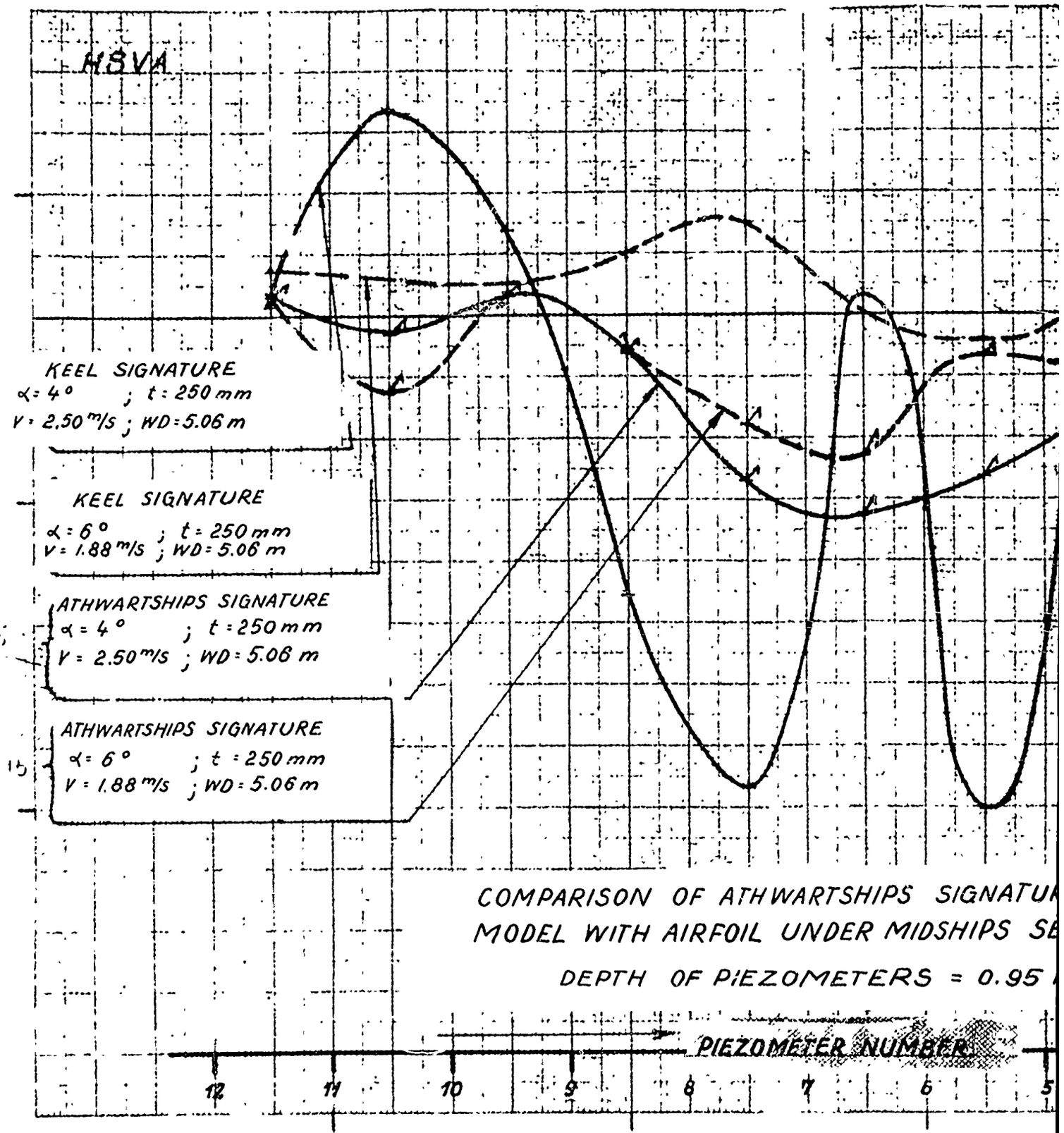
FIGURE 4.8

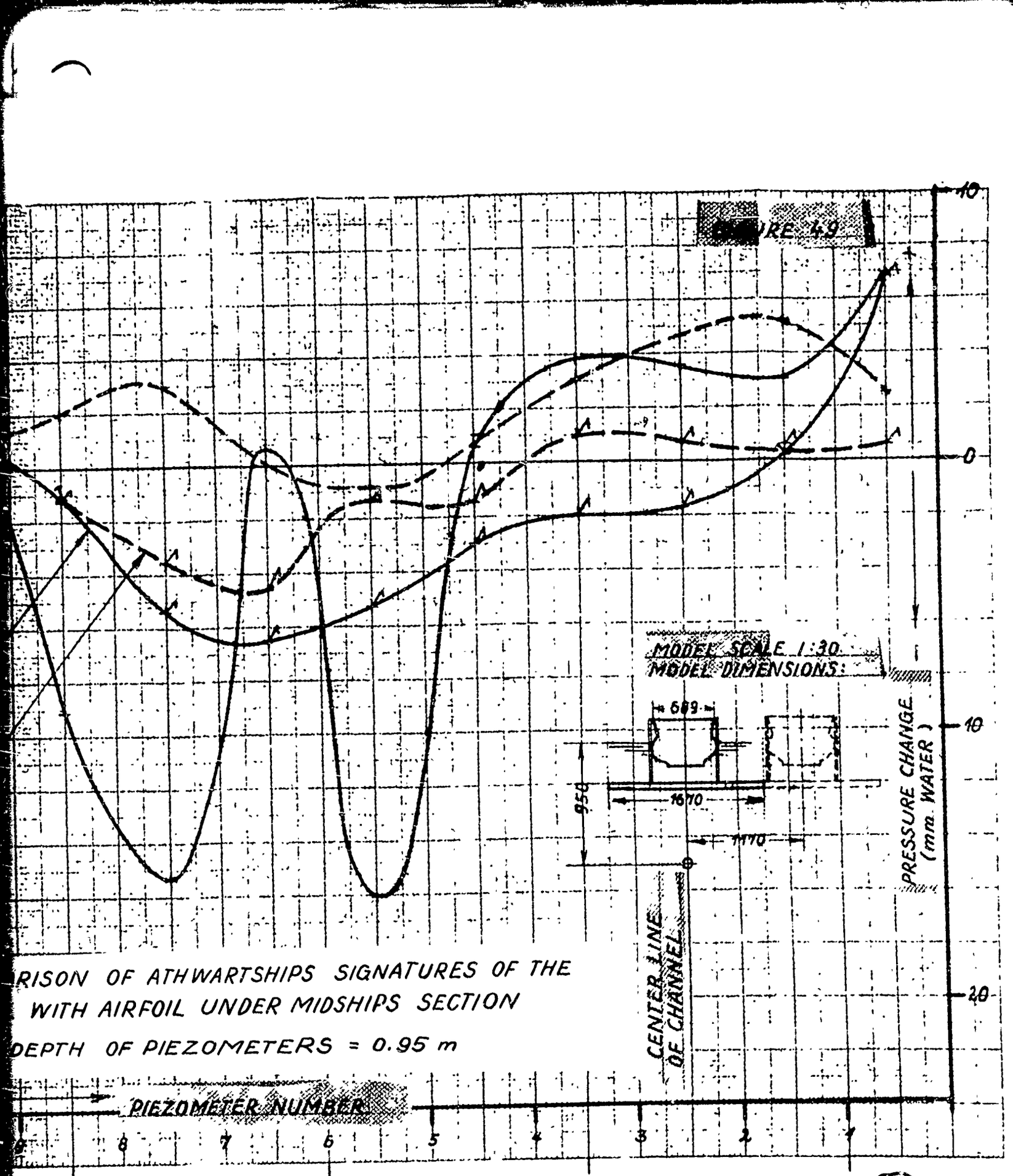
ATHWARTSHIPS SIGNATURES
OF THE MODEL WITH AIRFOIL UNDER
THE MIDSHIPS SECTION

SPEED OF MODEL = 2.50 m/s
WATER DEPTH = 1.00 m
DEPTH OF PIEZOMETERS = 0.95 m




t = 333 mm
t.= DISTANCE OF AIRFOIL BELOW HULL BOTTOM
PRESSURE CHANGE
(mm. WATER)
20
40
20
10
0
10
20
30
α = 6°
t = 250 mm
t = 333 mm
12
11
10
9
8
7
6
5
4
3
2
PIEZOMETER NUMBER


HSVA
KEEL SIGNATURE
α = 4° ; t = 250 mm
V = 2.50 m/s ; WD = 5.06 m
KEEL SIGNATURE
α = 6° ; t = 250 mm
V = 1.88 m/s ; WD = 5.06 m
ATHWARTSHIPS SIGNATURE
α = 4° ; t = 250 mm
V = 2.50 m/s ; WD = 5.06 m
ATHWARTSHIPS SIGNATURE
α = 6° ; t = 250 mm
V = 1.88 m/s ; WD = 5.06 m
COMPARISON OF ATHWARTSHIPS SIGNATU
MODEL WITH AIRFOIL UNDER MIDSHIPS SE
DEPTH OF PIEZOMETERS = 0.95
PIEZOMETER NUMBER
12
11
10
9
8
7
6
5



RISON OF ATHWARTSHIPS SIGNATURES OF THE
WITH AIRFOIL UNDER MIDSHIPS SECTION

DEPTH OF PIEZOMETERS = 0.95 m

(2)

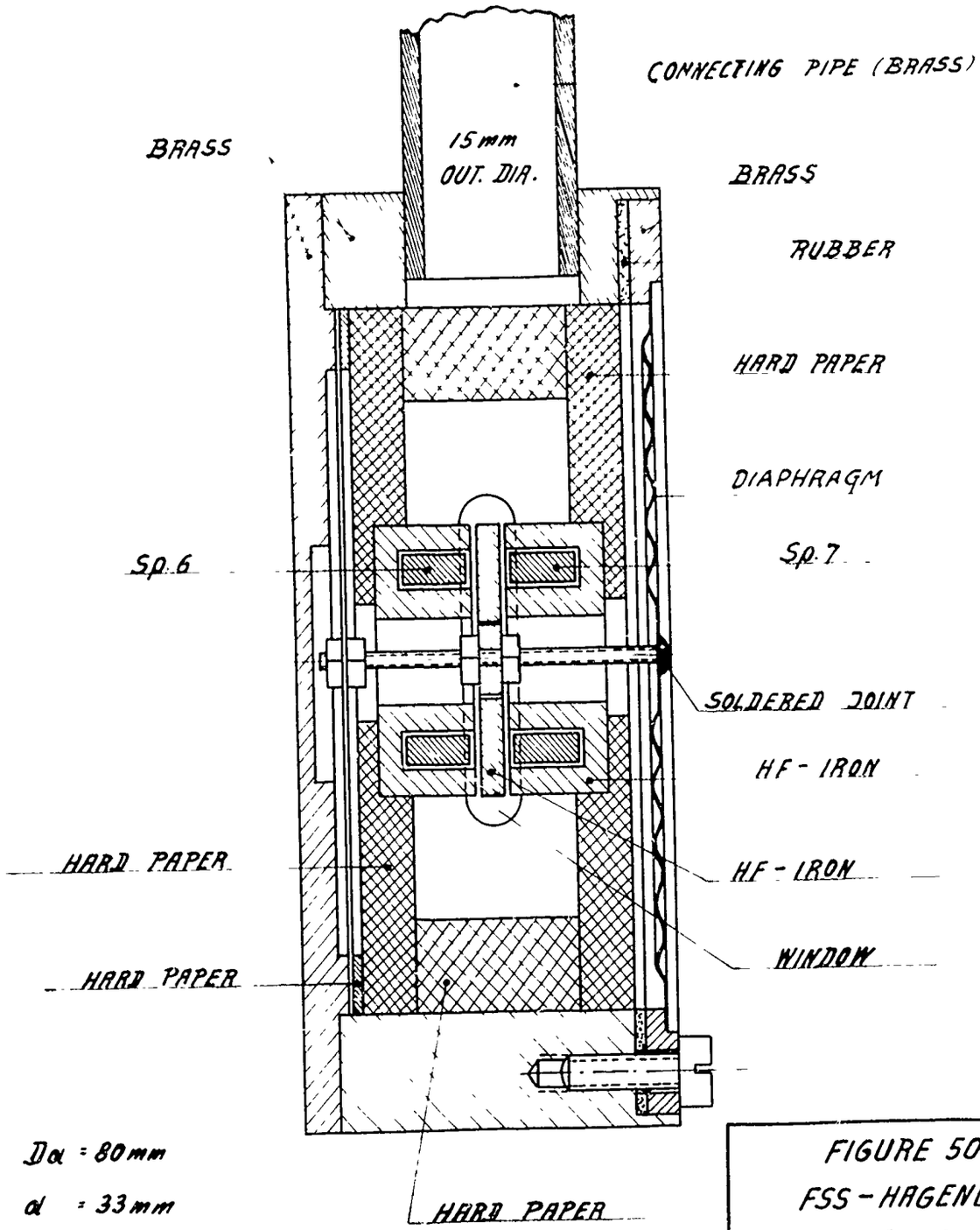
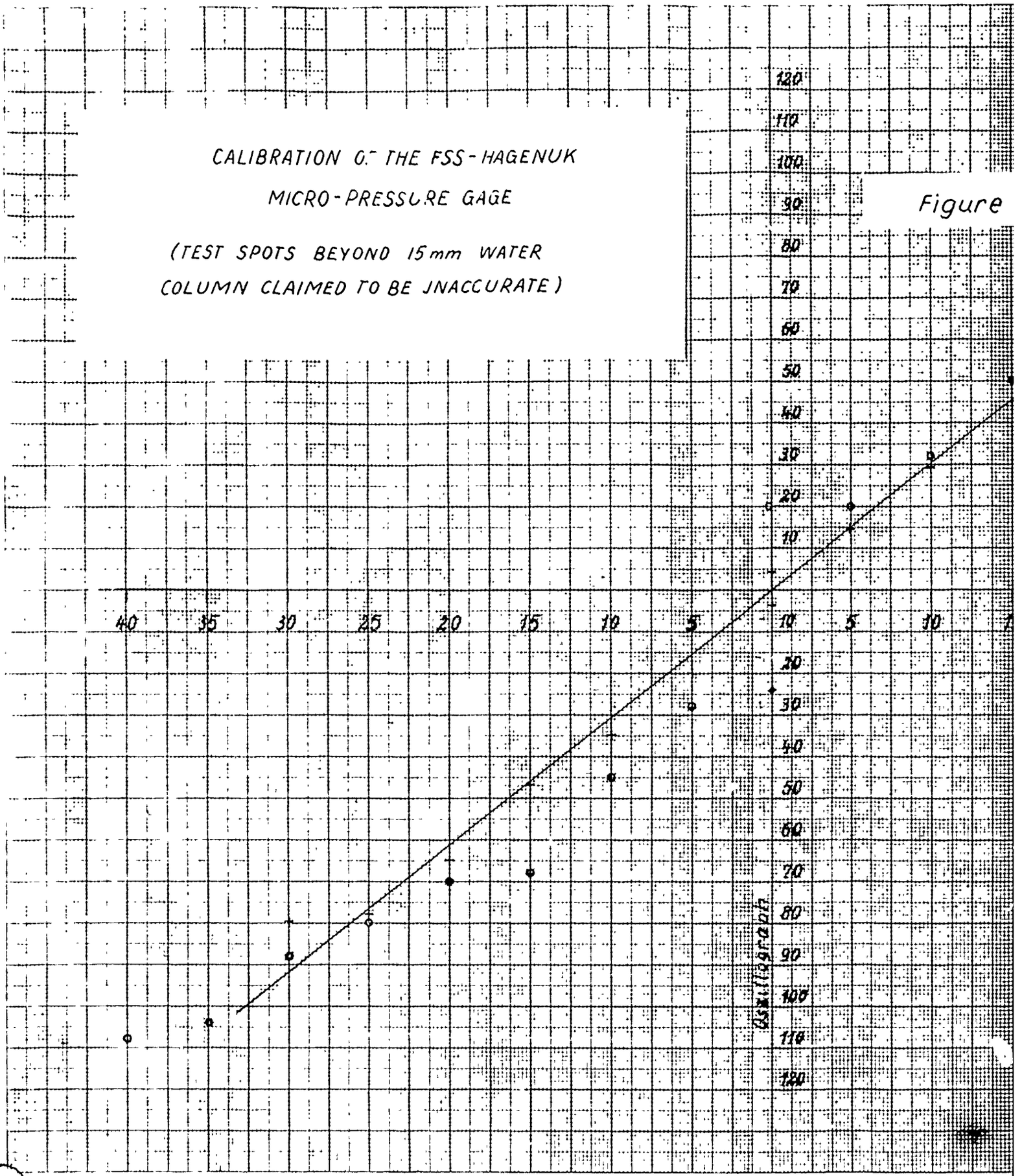


FIGURE 50
FSS - HAGENUK
MICRO - PRESSURE
GAGE


CALIBRATION OF THE FSS-HAGENUK
MICRO-PRESSURE GAGE
(TEST SPOTS BEYOND 15 mm WATER
COLUMN CLAIMED TO BE JNACCURATE)
Figure
40
35
30
25
20
15
10
5
10
5
10
120
110
100
90
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90
100
110
120
Oszillograph

1

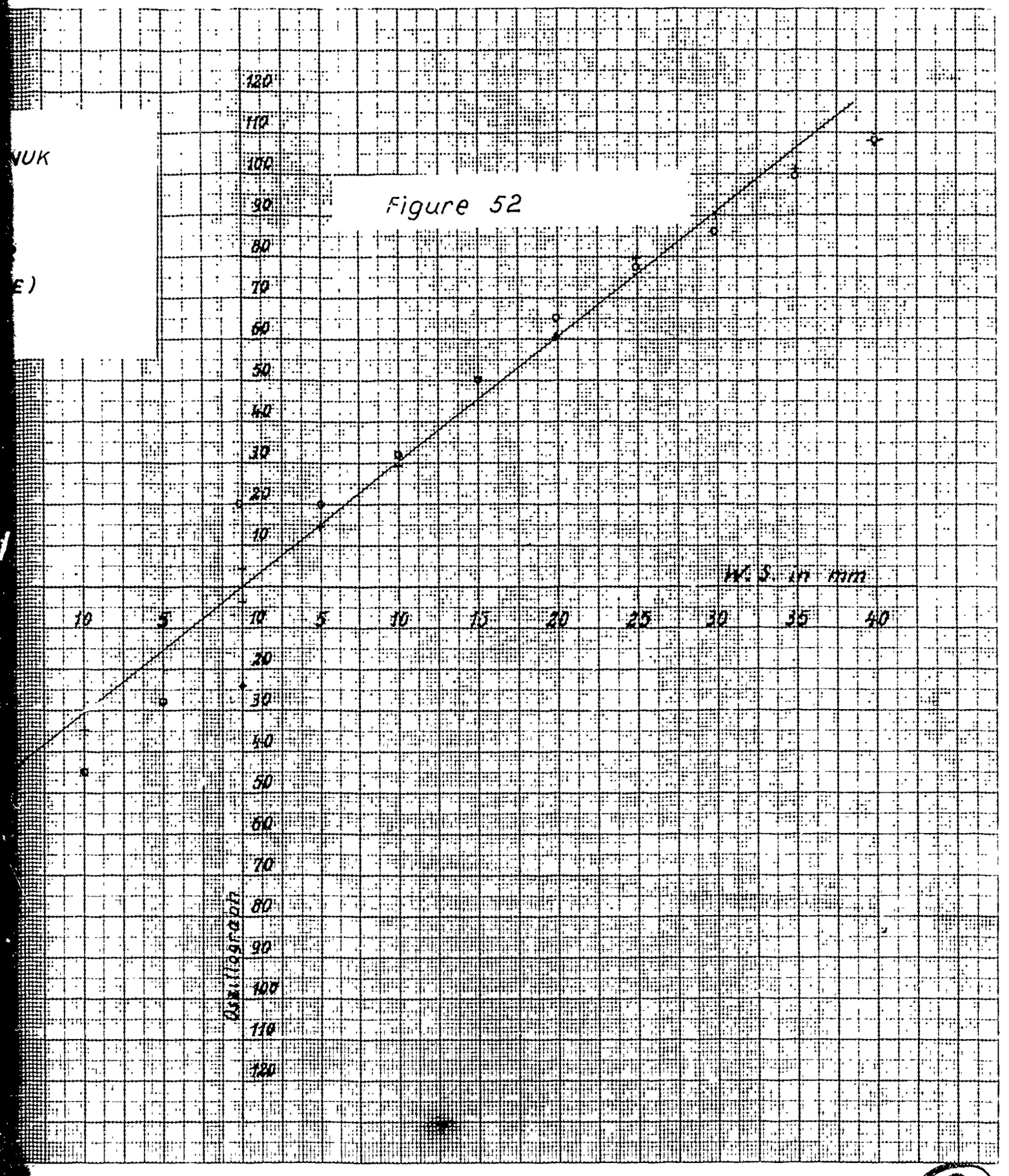
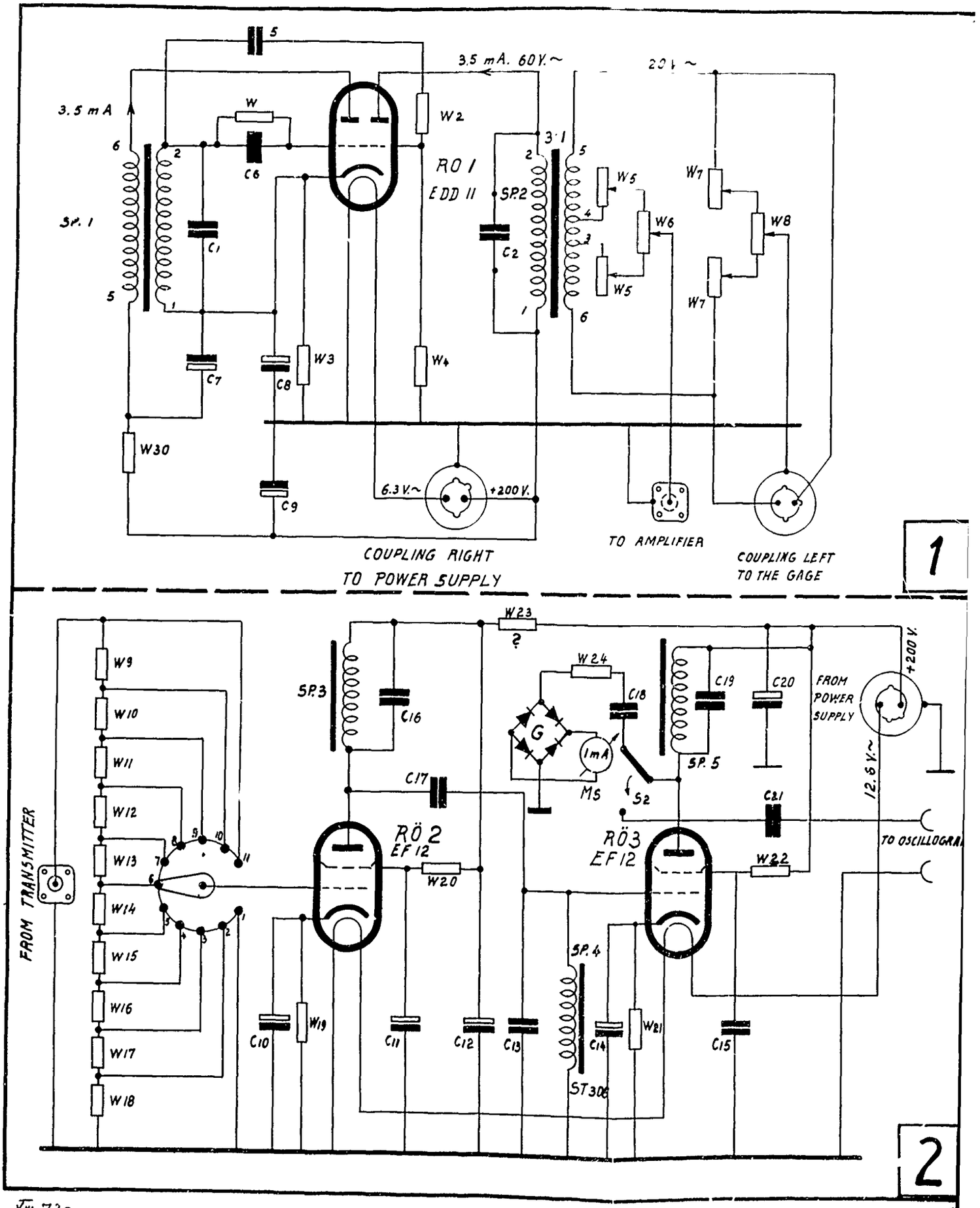


Figure 52
W.S. in mm
Oszillograph
10
5
10
5
10
15
20
25
30
35
40
120
110
100
90
80
70
60
50
40
30
20
10
20
30
40
50
60
70
80
90
100
110
120



3.5 mA
3.5 mA. 60V.~
20V ~
W
W2
C6
RO 1
EDD 11
SP. 1
SP.2
3:1
C1
C2
W5
W6
W7
W8
C7
C8
W3
W4
W30
C9
6.3 V.~
+200 V.
TO AMPLIFIER
COUPLING RIGHT
TO POWER SUPPLY
COUPLING LEFT
TO THE GAGE
1
W23
?
W24
C18
C19
C20
FROM
POWER
SUPPLY
+200 V.
12.6 V.~
SP.3
C16
G
1mA
MS
S2
SP. 5
C17
C21
TO OSCILLOGRA
RÖ 2
EF 12
RÖ3
EF12
W20
W22
FROM TRANSMITTER
W9
W10
W11
W12
W13
W14
W15
W16
W17
W18
SP. 4
C10
W19
C11
C12
C13
C14
W21
C15
ST308
2

VIII 720

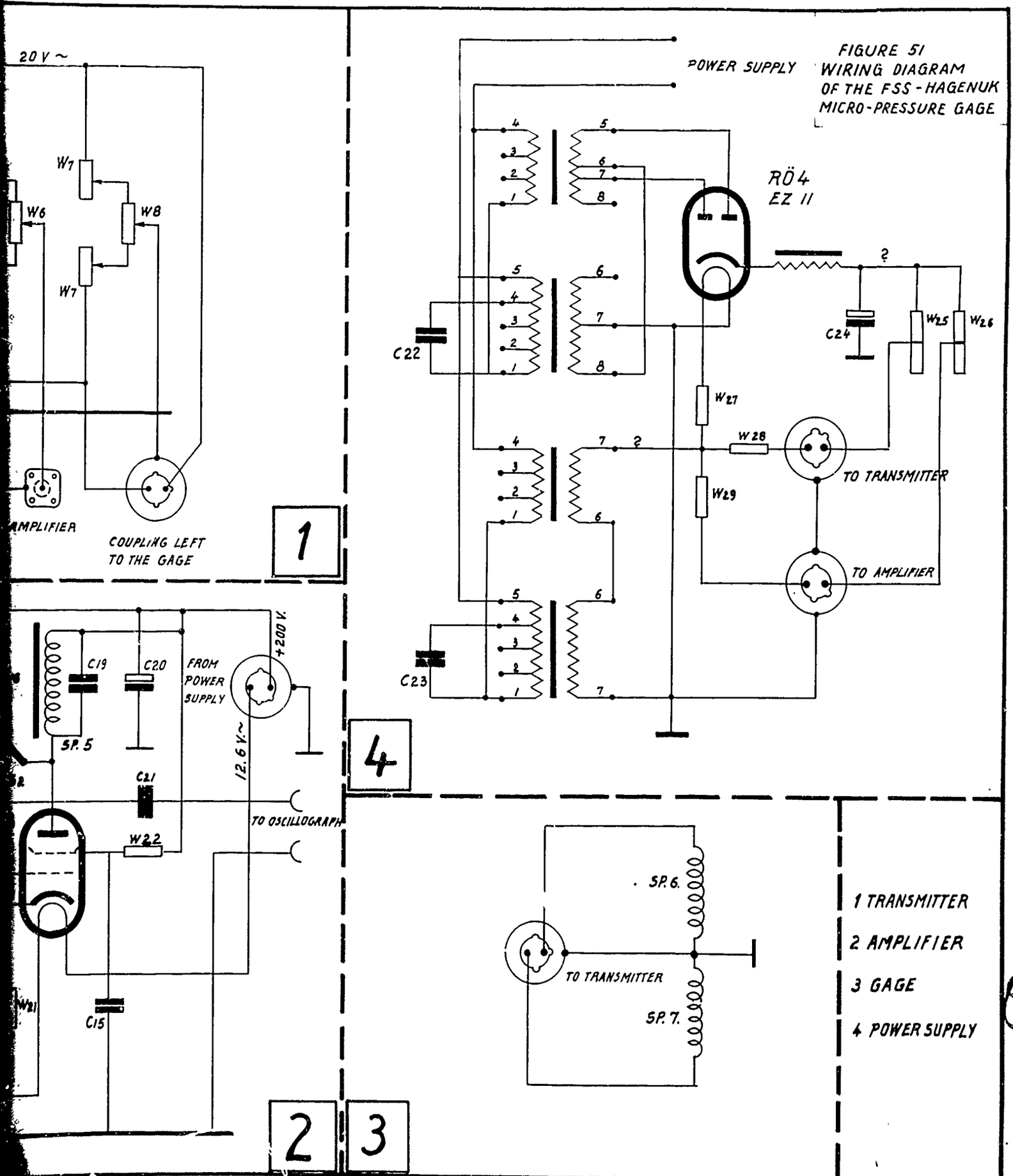


FIGURE 51
WIRING DIAGRAM
OF THE FSS - HAGENUK
MICRO-PRESSURE GAGE

(Suspended Document) Classification:

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Author(s)

Date

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