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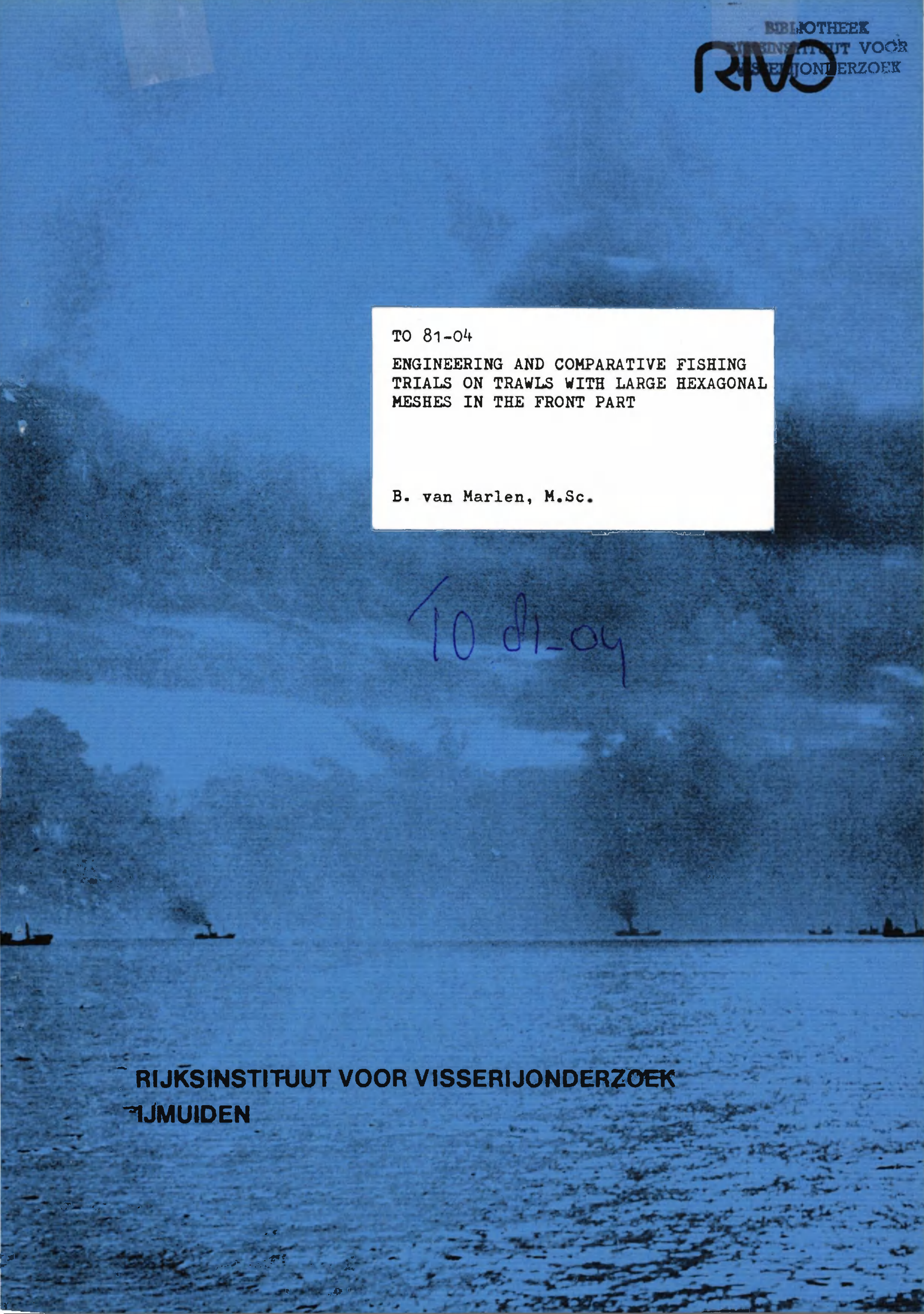

TO 81-04

ENGINEERING AND COMPARATIVE FISHING TRIALS ON TRAWLS WITH LARGE HEXAGONAL MESHES IN THE FRONT PART

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SUMMARY

As a follow-up of the measurements done in November 1979 (see reference (3)) the period of November '80 was used to do experimental trials on trawls of similar size with large hexagonal meshes in the front part. Two designs were tested. A very big net, denoted as Hexanet 3 with design openings of 70.0 m across the wing-ends horizontally and 52.0 m vertically.
The second design had been derived from the first one with reduced design openings i.e. 56.0 m (horizontal across wing-ends) and 28.0 m respectively and with a different taper of the net panels.
This one should fit better to values obtained in practice with trawls of similar size, and is denoted as Hexanet 5.
A series of tests has been conducted on both gears using the same rigging as during November '79 for hexanet 5 and different doors and heavier bridle weights with hexanet 3.
Major parameters of the rigging were varied such as warp length, bridle weight and bridle extension and both the gear geometry and its drag characteristics were measured. It became standard procedure to do the trials on two courses, one in the opposite direction, in order to determine tidal or current effects.
With the aid of a computer programme calculating the shape of the warps, **the gear drag,** being the sum of the components of the warp load in the direction of motion has been calculated with the measured door spread and door depth and the characteristics of the warps as given in reference (1) and (2) as a function of the towing speed. All other data have been processed manually on a HP 9830 desk top computer.
With 720 kg bridle weights a reduction in gear drag of appr. 10% was found for hexanet 5 when compared to the results of measurements on a 2700 meshes conventional trawl (see reference (3)).
When using 1100 kg of bridle weights both gear drags were quite similar. The first design (hexanet 3) showed a much larger gear drag then the conventional trawl.
Some other parameters of the rigging seemed to have a lot of influence too such as bridle extension and warp length.
The vertical dimensions of hexanet 5 could vary with several metres when increasing the extension from 4.50 m to 8.50 m, while in general the spreads were reduced, probably caused by a loss in door spreading force.
Usually the tilt angle of the doors increases with more extension causing the hydrodynamic efficiency of the doors to decrease.
General performance criteria such as "Swept Volume per unit time per unit load" or "Gear Drag per unit area" indicate hexanet 5 to be more efficient than a conventional trawl using 720 kg weights at speeds below 4.5 knots. The same applies to the 1100 kg case but to a much lesser extent.
The results of hexanet 3 were very poor compared to both a conventional and the smaller hexagonal trawl.
Comparative fishing trials done with hexanet 5 in March 1981 on "Tridens" showed no significant discrepancy between catches of other trawlers fishing in the same area. This has been experienced in the past with rope trawls. Indeed from the echo-sounder traces of transducers placed on two spots on the net (one at the headline centre as usual and one at the junction of hexameshes to original netwebbing) it is clear that a distinct herding effect of the hexameshes exists. This applies to both daytime and nighttime fishery.
A further reduction in gear drag may be expected from alterations of the aft part of the net. Hexanet 5 has rather large panels of 400 mm and 200 mm meshsize which can probably be shortened with no loss in fishing capability. In the near future the performance of trawls with hexagonal meshes will be compared to designs with large diamond shaped meshes, both from an engineering and a practical fishing point of view. The big-meshes concept seems to be valuable.

1. INTRODUCTION

Fishing tests with rope trawls in March 1980 on "Tridens" did confirm the application, that the herding effect of parallel ropes is less than that of net-webbing. Although actual direct observations on the reactions of fish to these nets were not done echo-sounder traces and the fact that over the entire period the catches were approximately 1/3 of those of commercial trawlers, fishing in the same area with nets of comparable sizes, pointed towards this conclusion.
Therefore it seemed a sound approach to create transverse connections to the parallel ropes, which leaded, together with experiences in other countries (Norway, Iceland, Far-Oërs) to the design of trawls with large hexagonal meshes.
Several materials were tested, particularly on breaking load and the stability of knots and splices under tension.
From these tests it was decided to use polypropyleen, three stranded ropes of diameters up to 12 mm for the rope panel and 16 mm for the selvedges.
The aim of the experiments done in November 1980 on the RSV "Tridens" was to determine the mechanical performance of two different designs of trawls with hexagonal meshes in the front part.
The research programme was completed by comparative fishing tests in March 1981 among a fleet of Dutch stern trawlers fishing for mackerel South-West of Ireland.
Chapter 2 deals with the equipment and measuring techniques.
The results of the measurements and the comparison of the gear performance under different rigging conditions will be discussed in Chapter 3, while the results of the actual fishing trials are described in Chapter 4. Finally Chapter 5 sums up the major conclusions and the future lines of the research programme.

2. EQUIPMENT AND MEASURING TECHNIQUES

2.1. Gears tested

The first stage of the development of a large trawl with hexagonal meshes led to the design denoted as Hexanet 3 and given in figure 2a, b (nr. T0803 A,B).
The philosophy behind this design is to increase the density of net material gradually starting at the wing-ends. The first part is a rope-panel as used in rope-trawl designs with a shape of the headline, footrope and side-lines calculated with the method assuming straight sections and equal load in each rope.
The length of the centre ropes was chosen to be zero, in other words the first row of the hexagonal meshes starts at the headline and footrope centre. The ropes are made of polypropylene with a diameter of 12 mm.
The second panel is a panel of large hexagonal meshes (size: 11.00 m) of 4 meshes deep, made of polypropylene (diameter 12 mm), joined to a panel of 2 meshes deep, made of thinner ropes (10 mm in diameter, poly-ester). These panels are connected to the net-webbing by two bends of smaller meshsize, just a couple of meshes in depth.
The netting-panels have a maximum mesh-size of 800 mm full bar.
The design openings of this net are: horizontal between wing-ends 70.0 m; vertical between wing-ends 52.0 m; the footrope and headline measure 104.42 m and the framelines in the side-panels 92.00 m.
This net was meant to be used for pelagic species like blue whiting.
From fishing trials done in May 1980 it was concluded that the design openings could not be reached on "Tridens" with Suberkrub doors of 7 m2 and 150 m sweeps. Especially the depth limitations of the North Sea did seem to put bounderies on the wing-end dimensions to be obtained.
During these trials net damage occured in the lower hexamesh panel

just behind the footrope. Frequently some ropes did break. Due to the large dimensions of the trawl it could not be repaired at sea.

These considerations led to an improved version of the hexagonal-meshes-trawl, denoted as hexanet 5 (figure 1a,--e, Nr. TO 810). The vertical and horizontal wing-end dimensions were reduced to 28.0 m and 56.0 m respectively, values experienced in full scale tests on 2700 <> pelagic trawls.
Modeltests of hexanet 3 in the Flume Tank in Hull supplied valuable information on the hanging ratios of the meshes to be expected in full scale conditions. At wing-end openings found in practice this net turned out to have a bad shape, in particular in the netting behind the bosoms, both in the upper/lower and side panels.
The cutting rates of the net panels behind the hexagonal meshes turned out to be too steep.

The new design (denoted hexanet 5) features an amount of improvements:
- As mentioned before: smaller wing-end spread and height;
- The rope section was extended off with 5.00 m in order to reduce net damage behind the footrope bosom;
- The step to smaller hexagonal meshes was deleted;
- The size of the hexameshes was increased to 16.00 m, except for the ones at the junction to the net-webbing;
- Shark teeths of similar design as used in the 2700 <> circumference rope trawl were applied;
- Two bends of smaller mesh-size (from 200 mm - 400 mm to 800 mm) were used;
- The cutting rates of the net panels behind the hexameshes were reduced from IN4B to IN3B (upper/lower panel) and IN2B tot IN1B (in the side panels).

After a check on the overall shape of this new design in September 1980 at the Flume Tank in Hull, it was decided to use this design in a full scale version during the trials of November 1980.

In this report the following notation is used:
NET A : will be hexanet 5, the latest design;
NET B : is hexanet 3, the larger one without floatation;
NET C : is hexanet 3 with 230 2ltr Nokalon floats on the headline.

Doors and rigging

For Net A only 7m2 (4.05 x 1.73 m) symmetrical Suberkrub doors were used with the warp attached to point b (second hole from the door surface inward).
For Net B and C 8m2 asymmetrical Suberkrub doors were used.
In all cases upper bridles of 71 fms (129,93 m) length and 22 mm in diameter and lower bridles of 70 fms (128.10 m) and 14 mm in diameter were used.
The backstrops measured 13 m in length, 22 mm in diameter.
Chain weights of 1500 kg for Nets B and C and 720 and 1100 kg for Net A were used. The bridle extension could be varied from 4.5 m to 8.5 m.
The rigging and its dimension are depicted in figure 3.

2.2. Trials technique

Table I summarises the rigging variables and the conditions of each haul.
The following parameters were varied:
- The towing speed, mostly four or five different h.p.-settings;
- The course of the vessel. In all cases reciprocal tows were carried out in order to determine current or tidal effects;

- The magnitude of the chain weights at the lower wing-ends. For Net A 720 kg and 1100 kg were applied and for Nets B and C 1500 kg;
- The warplength was kept constant at 600 m in most cases, being a representative value and making results comparable to previous tests. In order to simulate restricted depth conditions (North Sea) shorter warps were also applied such as 200 m and 400 m for Net A in the 1100 kg case and 300 and 450 m in the 720 kg case. For Net B the warps were paid out to 900 m in one case;
- The bridle extension from 4.5 m to 6.5 m with 8.5 m as an upper limit for Net A. Tests on Net B and Net C were both carried out with an extension of 8.5 m;
- The attachment point of the warp lower ends to the doors was kept at b (second hole) for Net A and at b and c for Nets B and C, using the bigger doors.

2.3. Instrumentation

This trip did not fall under a co-operative research programme. Therefore only the set of instruments used at the Technical Research Department of the Netherlands Institute for Fishery Investigations were available this time.

These include:

Instrumentation of "Tridens"

- Doppler-log and distant counter
- Deck tension load cells
  Tension load cells (calibrated) 10 tons max. load. These were attached to the warps on deck before the pulleys. Both these load cell reading and readings from the deck load cells were recorded simultaneously. No other tensions at the gear itself were measured
- Ship's compass for course-readings
- H.P. measurement done by registrating axial angular deflection of the propeller-shaft

Additional equipment

- 7 channel ELAC multi-netsonde and recorder for measurement of:
  - headline depth and height
  - sideline spread
  - wing-end height
  - section spread and height
- Cable-less FURUNO transponder and transmitter mostly used to measure the wing-end spread
- 2 channel netsonde attached on the port door, measuring door depth and spread.

2.4. Data analysis

The measurements were read from the instrument traces and recorded on tabulation sheets during the experiments in order to keep in touch with the results. With the information gathered on previous hauls the planning of the set of experiments took place from one step to another with a major reference scheme of objectives in mind (see Table I).
The main objective was to determine the geometry of both gears with different rigging parameters such as bridle weights, warplength and bridle extension, to determine their drag characteristics and to make a comparison in behaviour of both gears.

The main attention of the experiments was focussed on the latter design: hexanet 5, because of disappointing experiences both at model scale 1:25 and full scale with hexanet 3.
In the last four hauls an attempt of reaching the design openings of hexanet 3 has been made by adding floats, more weight and bridle extension to this gear.

All recorder-traces were reread and corrected afterwards.
Speed-readings recorded from the Doppler-log were compared with readings of distance sailed divided by time, read from a digital clock, during each block of measurements.
A regression of both readings clearly indicated some errors in speed-readings. The distance/time readings were chosen to be the most representative for the whole set of experiments as has been done with the November '79 trials also. The difference between both readings turned out to be fairly constant at 0.1 of a knot over the whole range of experiments in the speed range commonly used (3.0 to 5.0 knots).
The warp load was measured with the deck tension meters and with carpenters stoppers attached to the warp in such a way, that both measurements could be done simultaneously. All four signals were recorded on a Hewlett-Packerd recorder.
Similarly both sets of readings of the tension at the top-end of the warps were compared by a lineair regression for the port- and starboard side separately. Outlaying points due to misreadings have been corrected.
In this case the variation of the regression lines from one haul to another is quite more severe. The readings done with the carpenter stoppers were mostly higher. The difference could rise to approximately 1 tonne per side!
The carpenter stopper readings were chosen to be as most representative for the drag, due to the fact, that it was found on previous cruises that the deck load cell calibration curves varied a lot with time, and are not very reliable.

For the analysis a special "Warp shape routine" was written on a HP 9830 desk top computer using the equations and warp data given by McLennan in Reference (1).
The program assumes straight warp elements, the number of which can be chosen. From tests it was found, that 10 elements along the warp will give sufficient accuracy.
Input data for this program are:

- Warp diameter (mm)
- Warp weight per metre (kg/m)
- Warp length (m)
- Towing speed (kn)
- Door spread (m)
- Door depth (m)
- Bridle weight (kgf)
- Load at warp upper-end (tonne)
- Water density ($kgfm^{-4}s^2$)
- Number of elements along the warp

With measured values of door spread and depth, and calculated or measured door heel, tilt and attack angles, the exact dimensions of the doors, including the position of the transducers on one door (in this case the port one) the coordinates of the lower-end of the warp can be derived.
Additional information on the exact location of the upper-end of the warp is needed to get the coordinates of both points in relation to each other.
In our case the height and spread of the upper pulley at the gantry of "Tridens" were taken to calculate the location of the upper-ends (spread being 9.50 m and height being 5.60 m).

As there were no door-angle instruments available on this trip an estimation of door-angles is made from measurements done last year on rope- and conventional trawls of similar size (2700 meshes circumference), using the same rigging (see Reference (3)).
The magnitude of the bridle weights and the speed turned out to be the most important parameters determining the door-angles.

The average values for Net A, B and C (Reference (3)) turned out to be:

Angle of attack α:

bridle weight	Speed 4.0 knots	Speed 5.0 knots
720 kgf	$(32.50)^\circ$	$(29.50)^\circ$
1100 kgf	$(26.23)^\circ$	$(26.50)^\circ$

Angle of heel θ:

bridle weight	Speed 4.0 knots	Speed 5.0 knots
720 kgf	$(27.45)^\circ$	$(39.85)^\circ$
1100 kgf	$(17.97)^\circ$	$(32.53)^\circ$

Angle of tilt ψ:

bridle weight	Speed 4.0 knots	Speed 5.0 knots
720 kgf	$(15.80)^\circ$	$(19.15)^\circ$
1100 kgf	$(11.73)^\circ$	$(14.67)^\circ$

Linear regression of both parameters led to:

$$\alpha = (-0.0509 * W + 81.1632) + (0.0086 * W - 9.1958) * V$$

$$\theta = (-0.0477 * W + 12.1826) + (0.0057 * W + 8.3074) * V$$

$$\psi = (-0.0064 * W + 7.0042) + (-0.0011 * W + 4.1268) * V$$

With this information the program calculates the coordinates of the lower warp-end, assuming the origin of axis to be at the upper warp-end.

As a first approximation, the warps are assumed to be straight lines. From the coordinates of the lower end and including the given warp length the divergence and declination angles of the warps are calculated and used as start inputs for the first iteration.
Usually this first calculation along the warp will lead to different coordinates of the lower end and the program iterates towards the required coordinates and stops when a given accuracy is reached.
The new divergence and declination angles at the top end are printed, as are the loads at both ends and the component of the top load in the direction of movement, which is assumed to be along the centre line of the towing vessels.
The calculation of warp shape is needed for both the port- and the starboard size. The magnitude of divergence and declination angles at the top end being dependent of the load at the top, which in general will be different for both sides.
The ship's centre line and the gear centre line are supposed to coincide, in other words half of the door spread is used in the calculation of the port- and starboard component of the gear drag.
The total gear drag is derived by summing both components of the upper warp-end loads in the direction of movement.
The program uses a skin friction coefficient and a pressure drag coefficient as given in reference (3), which are slightly different from coefficients given in reference (1), but used in the analysis of the results of the experiments described in (3).

These are:

$C_f = 2.078 - 0.2984 * V$ skin friction

$C_d = 0.00625 + 0.02702/(V^{2.465})$ pressure drag

where V = towing speed in m/s.

Graphs were prepared with the aid of the HP 9830 plotter pac program, modified to special specifications. Separate plots were made for each bridle weight and bridle extension configuration for Net A, B or C.

Regression curves are calculated for sets of reciprocal tows mostly. For some hauls a significant difference in measurements occured when towing in the opposite direction.
Tables II and III summarise the data derived from the regression analysis for 3.0, 4.0 and 5.0 knots respectively.

The results of haul T80/1 en T80/2 show a very low value of the headline height and sideline spread indicating that either the transducers were fouled or the net had not been shot away properly. These data therefore were deleted from the regression analysis and have not been plotted either.
At the start of haul T80/22 (the reciprocal tow of T80/21) the wing-end spread reading suddenly increased by ca. 10 m. When hauling the gear it turned out to be heavily damaged. The readings of T80/22 were also deleted.
Haul T80/5 showed systematically low speed readings, both from the recorder trace and from the distance/time measurements.
The speed traces were very instable, probably due to air bubbles distorting a proper functioning of the Doppler-log, caused by the substantial pitch movement of the vessel. The speed reading of all blocks of T80/5 were increased with 0.4 knots, which is believed to give more reliable results in relation to those of T80/6. For the same reason the results of T80/9; block 5 resulting in a significantly outlaying point in almost all graphs have been scratched.

3. DISCUSSION OF RESULTS

3.1. General

The results for each pair of reciprocal tows are depicted in figure 4-11 (a,---,i) and the results of the regression analysis are presented in Tables II to III for a towing speed of 3, 4 and 5 knots.
For Net A the bridle extension, varied from 4.5 to 8.5 m, turned out to have an important influence on the results and therefore in most graphs separate regression lines have been drawn for each bridle extension case. The other major rigging parameters were the bridle weight (720 kgf and 1100 kgf) and the warp length, kept constant at 600 m for most hauls.
Shorter warps have been applied to both bridle weight cases for Net A and longer warps to Net B (no floats) in an attempt to reach the designed wing-end spread. These warp lengths (700 m and 900 m) were not included in the graphs.
A lineair regression seemed to be the most appropriate in all cases, although it is likely, that some parameters will have a non-lineair dependence on speed, such as the drag and the headline depth.
Given the small range of speeds (3 to 5 knots) and the considerable scatter in the data a lineair curve fit seems to be justified.

3.2. Drag forces

One of the most important measurements is the gear drag, presented in figure 4a,---,i for each bridle weight, warp length and bridle extension configuration of Net A, B and C.
For comparison the regression line of the gear drag of a conventional pelagic trawl of 2700 <> circumference, using 600 m of warp, is included in the graphs. These were measured during the November 1979 trials (see reference (3)).
The values for Net A (hexanet 5) are slightly smaller than those of the conventional net, approximately 1 tonne at 4 knots and 1.5 tonne at 3 knots. At 5 knots the difference is negligible. The best results are found with a bridle extension of 8.5 m, although the contrary would be expected as the gear opens more in this case (see section 3.3. Net geometry).

An increase in bridle weight from 720 kgf to 1100 kgf alters the picture. Now the gear drag of Net A showes to be higher at the lower speeds (ca. 0.60 tonne at 3 knots) but lower at 5 knots (ca. 1 tonne less). At 4 knots the drags of both the hexagonal trawl and the conventional one are quite similar.

Net B and C show a substantially higher gear drag.
Although a truly sound comparison can not be made, as the bridle weight of Net B and C was 1500 kgf to open this gear better,this net type is certainly in disadvantage from a drag point of view.
At 3 knots the gear drag of Net B (no floats) turns out to be 32% higher than that of the conventional net, while at 5 knots the difference is approximately 28%.

The influence of the amount of warp paid out is quite substantial.
For the 720 kgf case (Net A) two additional warp lengths have been tried, 300 m and 450 m, all with an extension of 6.5 m.
Less warp means in general a smaller mouth area of the trawl and therefore a smaller drag, apart from the drag of the warps itself.
At 4 knots there is about 1.5 tonnes difference, while at 5 knots this will be approximately 2.0 tonnes with 300 m warp.
When paying out 450 m of warp these differences are comparable to the 300 m case at 4.0 knots. At 5.0 knots however the difference is about 0.5 tonne.

A similar picture arises at 1100 kgf bridle weight with very short warps of 200 m. At 400 m however the gear drag turns out to be even higher than that of 600 m. This may be due to scatter in the data, which was approximately 2 tonnes at 4.5 knots for haul T80/10 and 11 (see figure 4e).
Generally spoken the gear drag is to increase about 2 tonnes over the whole range of speeds when paying out from 200 m to 400 m warp (figure 4g). The increase in drag did not occur when going to 600 m warp.

The total length of all ropes (excluding the selvedges) of Net A is 3655.88 m, giving a surface area of 43.87 m^2 (rope diameter 12 mm).
The netting part has a total area of 236.17 m^2. Hence the total twine area of the hexatrawl adds up to 280.04 m^2. The 2700 <> conventional trawl has a total twine surface area of 328 m^2 (including the cod-end) and the 2700 <> GDR-rope trawl has a twine surface area of 246 m^2 (including the rope section with a total length of 853 m and rope diameter of 10 mm each; excluding the selvedges).
It can be expected therefore that the drag of the hexagonal net is bigger than that of the 2700 <> rope trawl.
The gear drag of the 2700 meshes rope trawl, measured during the trials of November 1979 (see reference (3)) is quite similar to that of the

hexagonal trawl. This indicates the importance of the contribution of the actual net section of both nets which happened to be almost equal at appr. 237 m^2 (This figure does not take into account the ropes of the rope trawl or the entire part of hexagonal meshes for the hexanet).

A further reduction of the gear drag of the hexagonal trawl may very well be established by altering the aft part of the net.
The panels of 400 mm and 200 mm meshes could probably be shortened without a loss in catching capability.

Although criteria like Swept-Volume-Index or Gear Drag/Area may lead to different conclusions (see section 3.5) a feasible fuel saving will only be reached by a further reduction in gear drag. This will be the main objective in future research programmes.

3.3. Gear Geometry

A complete review of all the regression values of the major parameters describing the geometry of the Nets A, B and C and rigging is given in Table II for 3, 4 and 5 knots.
A distinction is made between all variables of the rigging such as bridle weight, warp length and bridle extension.

The best wing-end and headline mouth openings were achieved with the bridle extension of 8.5 m independent of the amount of bridle weight (figure 7a,--,i, Cross section areas vs speed).
This effect of opening the gear more is also demonstrated by the section areas, which are bigger when using 8.5 m extension, especially at speeds around 3 knots, whereas at a towing speed of 5 knots all values seem to be almost equal.

The trawl mouth openings are quite similar to those of the mouth areas of the conventional net using the same warp length of 600 m. With 720 kg bridle weights the trawl opens more at speeds lower than 4 knots, but less at higher speeds. This effect is most significant with 8.5 m extension.(See Tables II and IV).
The decrease in mouth area is less profound with the heavier weights (1100 kg) when increasing speed. At 5 knots the values are comparable to those of the conventional net.

The influence of the warp length is strong for both bridle weight cases. Paying out from 200 m to 400 m increases the wing-end area for instance with some 40% at 3 knots but almost not at all at a speed of 5 knots (1100 kg case). Increasing warp length from 300 m to 450 m with 720 kg weights has a similar effect, although less severe (20% increase at 3 knots).
Paying out from 400 m (or 450 m) to 600 m has much less effect on the mouth opening of the trawl.

For both bridle weight configurations an increase in bridle extension changes the slope of the spread regression curves in a negative sense, in other words spreads are decreasing faster with speed when the bridle extension is increased.The same spplies to the door spread, indicating that an increase in bridle extension reduces the spreading force of the doors. The dependance of the heights on the bridle extension is less severe with the heavy weights than with the small weights. In the last case changing the extension from 6.5 m to 8.5 m causes the wing-end height to increase by 5.67 m; the headline height by 6.30 m and the section height by 3.74m (See Table II).
With 1100 kg weights these amounts are respectively: 1.60 m; 2,95 m and 1.69 m.

3.4. Door and net depth

The headline depth is given as a function of speed and bridle extension at several warplengths in figure 8a,--,e and in Table II.
With 600 m warps the addition of 380 kg of weight at the lower wing-ends causes the gear to fish some 60 m deeper.
The influence of the bridle extension is quite significant.
Changing the extension with 1100 kg weights from 4.5 m to 6.5 m lifts the gear approximately 20 m and a further increase to 8.5 m extension lifts it another 20 m, indicating the gear drag to rise when increasing the bridle extension. With 720 kg weights a change from 6.5 m extension to 8.5 m extension causes the gear to rise faster at increasing speed also due to its higher drag.

Naturally the amount of warp paid out has a major influence, especially at speeds around 3 knots. An additional 150 m of warp makes the gear fish some 70 m deeper with the 720 kg weights at such a speed. At 4.5 knots however, the effect of such an increase is negligible, due to the doors reaching the surface. In the 1100 kg case increasing the warp length with 200 m causes the headline depth to increase some 90 m at 3 knots towing speed. Again at higher speeds (4.5 knots) the influence is smaller. The 200 m and 400 m cases have almost the same depth, but the 600 m case show a distinct increase in depth of some 60 m.
The difference in depth between the headline centre and the doors is approximately 20 m for Net A, irrespective of bridle weight, bridle extension or warp length, showing a slight decrease with rising speed.
The floatation added to Net B causes a rise in headline depth of some 80 m at 4 knots speed.
This difference in depth increases with speed.
The doors are approximately 14 m higher for Net B and some 10 m for Net C, indicating the floats to lift the gear relatively to the doors, as can be expected.

The difference in depth between headline and doors is smaller for the conventional net of 2700 meshes circumference. Some 16 m at 4.0 knots and about 10 m at 5.0 knots. This confirms the fact that the gear drag of this net is higher.

3.5. Performance indicators

The mechanical performance of the gears can be compared by looking at a "drag per unit area" or a "volume swept per time per load", both for a certain net cross section.
These quantities are depicted in figures 9a,--,i and 10a,--,i where the gear drag has been taken as a representative load and not the net drag as in reference (3).
The values for both wing-end and headline area are given. Table III summarises the results of the regression analysis for these parameters for a towing speed of 3, 4 and 5 knots. Both quantities are related, a higher swept volume index corresponds to a lower gear drag per area, both indicating a better performance of the gear.
Table IV also gives performance results for the 2700 meshes conventional pelagic trawl, derived from the regression analysis of the measurements on this gear described in reference (3).
The best results are obtained with the hexagonal net (Net A) at speeds lower than 4.5 knots with 720 kg weights; 8.5 m extension and 600 m warp, whereas at higher speeds the conventional trawl seems to be better off. At 3.0 knots Net A has a 52% higher swept volume index (based on the wing-end area), but at 4,0 knots the difference is only as much as 17%.

The advantage diminishes when using 6.5 m of bridle extension.
At 3.0 knots the gain will only be some 5%.

With the heavier weights there is still some superiority in swept volume of Net A (hexanet 5) when applying 8.5 m bridle extension although it is only marginal (some 6% at 3.0 knots).
The dependance on speed is less critical in this case, resulting in a quite similar performance of Net A in comparison to the conventional pelagic trawl.

The results of Net B and Net C are definitely worse.
The swept volume index of Net B at 4.0 knots towing speed is 22% less than the best values of Net A (based on the wing-end area), while that of Net C turns out to be 31% lower (based on the headline centre area).

The warplength has an important bearing on the results.
Generally spoken the performance improves when paying out warp, an effect being most significant at low speeds (less than 4.5 knots).

With 720 kg bridle weights the best improvements are found when paying out from 300 m to 450 m, but with 600 m the results are worse. This casts some doubts on the results of the measurements of haul T80/5,6 (indeed the speed readings of T80/5 were rather dubious).
In the 1100 kg case the swept volume index based on the wing-end area increases when paying out from 200 m to 600 m, although the increase is not significant in the first step of 200 m.

When looking at the gear drag per unit area the influence of warp length is not very clear with 720 kg bridle weights, while with 1100 kg weights the drag per unit area decreases with increasing warp length.

4. COMPARATIVE FISHING TRIALS (MARCH 1981)

An investigation on the fishing capability of a trawl with hexagonal meshes was done in March 1981 on RSV "Tridens" among a fleet of Dutch commercial trawlers, fishing for mackerel (position 50°-54° NB; 5°-10° WL; South of Ireland).
The rigging was the same as used during the cruise of November 1980.
In order to determine the reactions of fish to these hexagonal meshes two netsondes were placed on the net, number 1 at the headline centre and number 2 at the junction of hexagonal meshes to the conventional netting (800 mm meshes).
Samples of both netsonde traces are given in figure 12, daytime fishery is depicted in figure 12a,b while nighttime is showed in figure 12c,d. These netsonde traces show, that fish caught in the net mouth was also present at the spot of the second transducer, indicating a distinct herding effect of the hexameshes. The fish seemed to keep a certain distance away from these meshes, which continued during vertical displacements of the gear.
The catches were very well comparable to those of the commercial ships and certainly not significantly less, as experienced on fishing experiments with rope trawls done previously (March 1980).
The lower panel of the net stayed clear off the ground when fishing with the footrope hard on the seabed. Little net damage was experienced during the tests.
Both the day fishery and the night fishery showed good results although the fish seemed to be more scattered during the nighttime, while at daytime they seem to swim in denser shoals.
The results when fishing for demersal species were greatly improved by adding 50 m of bridle to the upper sweeps and 46 to the lower one, and splitting the weights: 720 kg in front of the 46 m piece and 400 kg at the lower wing-ends (see figure 3b). This must be due to the herding effect of the bottom sweeps.

5. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Hexanet 3 is not a very good design for its purpose. The openings were not reached and a drag reduction did not occur. From direct observation of a model 1 to 25 in the Flume Tank in Hull it was found to have a distorted shape at the wing-end openings obtained in practice. (Flume Tank photographs of hexanet 5 are depicted in figure 13a,--,h).
Hexanet 5 is a good design from a shape point of view.
The design openings of 56.0 m across the wing-ends and 28.0 m of wing-end height are easily reached. Its drag is smaller than that of a conventional pelagic trawl of the same dimensions, especially with 720 kg weights.
There seems to be room for improvement by changing the aft part of the gear. Possibly the diameter of ropes used in the forward part can be reduced without an increase in gear damage when fishing.
This design is quite sensible to its rigging. For instance the bridle extension seems to have a lot of influence on the openings of the trawl and on the drag. A substantial extension of 8.5 m did not distort the gear as could be seen from model experiments, but increases the vertical dimensions of the trawl considerably.
This type of trawl can be handled quite easily on stern trawlers like "Tridens", where the installed horsepower of 1800 hp maximum turned out to be sufficient for practical fishing operations. The fishing capability is similar compared to conventional trawls.
Gear damage did not occur as in the extent experienced with hexanet 3. From the netsonde traces it can be seen, that the lower panel stayed clear off the seabed when the footrope was touching it.

Another line of research that will be followed at the Netherlands Institute of Fishery Investigations will be the development of large pelagic trawls with big diamond shaped meshes comparable to French designs.
A comparison between this type and the hexagonal type will be made, both by measurements and comparative fishing trials.

Finally it seems to be certain that the big meshes trawl, either with hexagonal or diamond shaped meshes is a valuable concept.

IJmuiden, 21st May 1981

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of the Netherlands Institute for
Fishery Investigations - IJmuiden

/ML

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TABLE I

TABLE OF EXPERIMENTS

Haul nr.	Net	Weights	ext.	Warp-length (m)	H.P.-range	Doors	Course
01	A	720	4.5	600	1005-1526	I/b	216°-248°
02	A	720	4.5	600	1003-1475	I/b	67°
03	A	720	8.5	600	916-1603	I/b	226°
04	A	720	8.5	600	850-1330	I/b	55°
05	A	720	6.5	600	909-1498	I/b	210°
06	A	720	6.5	600	920-1477	I/b	40°
07	A	720	6.5	300	928-1198	I/b	320°
08	A	1100	4.5	600	869-1500	I/b	139°
09	A	1100	4.5	600	881-1587	I/b	290°
10	A	1100	6.5	600	887-1406	I/b	115°
11	A	1100	6.5	600	1310-1680	I/b	280°
12	A	1100	8.5	600	886-1588	I/b	103°
13	A	1100	8.5	600	967-1662	I/b	55°
14	A	1100	6.5	200-400	900-1570	I/b	293°
15	A	1100	6.5	200-400	887-1539	I/b	110°
16	A	720	6.5	300	967-1260	I/b	130°
17	A	720	6.5	450	900-1517	I/b	300°
18	A	720	6.5	450	853-1405	I/b	90°
19	B	1500	8.5	600	1009-1702	II/b	190°-280°
20	B	1500	8.5	600-900	1321-1737	II/b	100°
21	C	1500	8.5	600	1165-1773	II/c	280°
22	C	1500	8.5	600	1166-1550	II/c	130°

TABLE II(a) GEAR GEOMETRY NET A

	NET A, 300 m warp - 450; 6.5 m extension						600 m; 6.5			600 m; 8.5		
Bridle weight (kg)	720			720			720			720		
Speed (kn)	3	4	5	3	4	5	3	4	5	3	4	5
Wing-end height (m)	26.68	24.52	22.36	29.52	24.65	19.78	27.56	23.59	19.62	33.23	26.88	20.
Wing-end spread (m)	52.33	49.65	46.97	57.38	53.92	50.46	59.68	56.72	53.75	60.60	53.84	47.
Wing-end area (m2)	1393.54	1218.14	1042.74	1671.39	1331.26	991.12	1640.22	1339.69	1039.17	1985.92	1451.32	916.
Headline height (m)	29.43	23.44	17.45	30.82	23.36	15.90	26.36	21.64	16.93	32.66	25.63	18.
Sideline spread (m)	43.75	40.97	38.20	49.93	45.12	40.31	49.30	46.87	44.43	50.06	45.35	40.
Headline centre area (m2)	1273.74	964.38	655.02	1492.88	1057.44	622.01	1315.13	1016.08	717.03	1575.15	1172.72	770.
Section height (m)	19.38	16.84	14.31	19.34	16.58	13.82	17.35	15.27	13.19	21.09	18.29	15.
Section spread (m)	35.96	27.45	18.95	-	-	-	34.40	33.56	32.73	34.22	31.01	27.
Section area (m2)	682.64	463.67	244.70	-	-	-	595.87	513.03	430.20	715.89	568.44	420.
Headline depth (m)	120.41	62.96	5.51	196.29	96.97	-2.35	226.72	105.40	-15.91	258.47	103.17	-52.
Door spread (m)	111.30	106.18	101.08	140.89	120.80	100.71	140.16	128.81	117.46	144.89	117.47	90.
Door depth (m)	100.90	44.46	-11.98	176.98	79.72	-17.54	201.76	89.17	-23.43	235.19	83.52	-68.
HAUL NUMBER	T80/7,16			T80/17,18			T80/5,6			T80/3,4		

TABLE II(b) GEAR GEOMETRY NET A

Warplength/ bridle extension	200 m; 6.5			400 m; 6.5			600 m; 6.5			600 m; 4.5			600 m; 8.5		
Bridle weight (kg)	1100			1100			1100			1100			1100		
Speed (knots)	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5
Wing-end height (m)	32.70	28.35	24.00	32.05	27.68	23.30	34.59	29.60	24.61	34.06	28.27	22.47	36.19	31.18	26.16
Wing-end spread (m)	35.18	42.99	50.79	52.61	53.84	55.06	55.96	56.52	57.09	-	-	-	56.56	55.14	53.71
Wing-end area (m2)	1202.03	1222.33	1242.63	1690.16	1489.02	1287.88	1934.35	1672.39	1410.44	-	-	-	2043.95	1721.06	1398.17
Headline height (m)	39.51	29,84	20.17	30.43	25.86	21.29	31.99	26.76	21.53	36.79	25.61	14.43	34.94	28.99	23.04
Sideline spread (m)	24.04	33.65	43.25	43.65	44.59	45.53	45.77	47.15	48.52	42.96	47.96	52.95	47.14	46.20	45.26
Headline centre area (m2)	1032.87	992.94	953.00	1330.44	1151.52	972.59	1463.21	1259.34	1055.47	1590.58	1223.81	857.03	1644.23	1340.37	1036.51
Section height (m)	23.54	20.70	17.86	19.94	17.95	15.96	21.39	18.12	14.85	23.38	17.04	10.70	23.08	19.64	16.21
Section spread (m)	16.62	23.62	30.62	38.81	35.82	32.84	31.60	33.17	34.74	29.20	34.55	39.90	38.21	34.40	30.58
Section area (m2)	446.76	494.51	542.27	768.76	644.35	519.94	677.43	599.76	522.09	691.06	587.00	482.94	872.58	677.00	481.42
Headline depth (m)	115.81	72.36	28.91	206.92	111.20	15.49	277.35	174.40	71.46	305.75	199.52	93.28	274.54	155.64	36.74
Door spread (m)	63.14	84.08	105.03	120.35	119.22	118.09	130.75	132.22	133.68	115.20	136.48	157.76	132.42	125.32	118.23
Door depth (m)	97.74	52.15	9.57	183.14	92.30	1.45	253.65	155.41	57.18	291.08	183.56	76.03	251.56	134.62	17.69
Haul number	T80/14,15			T80/14,15			T80/10,11			T80/8,9			T80/12,13		

TABLE III(b)

GEAR PERFORMANCE AND DRAG NET A

Gear Drag (tonne)		5.72	10.85	15.98	7.88	12.92	17.96	8.79	12.65	16.50	8.10	12.34	16.58	8.28	12.58	16.89
Swept Volume Index (m3/s., tonne)	W/E	314.85	241.78	168.71	312.67	240.83	168.99	336.85	275.53	214.22	-	-	-	366.54	286.25	205.95
	H/L	213.05	184.78	156.50	245.53	186.28	127.03	254.32	207.37	160.42	294.64	205.81	116.97	295.10	223.47	151.85
Gear drag/area (kgf/m2)	W/E	3.27	8.57	13.87	4.32	8.78	13.25	4.30	7.69	11.08	-	-	-	3.65	7.48	11.30
	H/L	6.23	11.16	16.09	5.31	11.39	17.48	5.61	10.21	14.80	4.50	10.27	16.03	4.37	9.70	15.03
Haul number		T80/14,15			T80/14,15			T80/10,11			T80/8,9			T80/12,13		

TABLE II(c) - GEAR GEOMETRY

	NET B			NET C		
Warplength/ bridle extension	600 m; 8.5 m			600 m; 8.5 m		
Bridle weight (kg)	1500			1500		
Speed (knots)	3	4	5	3	4	5
Wing-end height (m)	32.47	30.29	28.11	-	-	-
Wing-end spread (m)	57.98	58.51	59.03	53.85	54.97	56.09
Wing-end area (m2)	1830.54	1769.13	1707.72	-	-	-
Headline height (m)	31.32	29.23	27.15	49.34	31.96	14.58
Sideline spread (m)	-	-	-	42.75	46.58	50.41
Headline centre area (m2)	-	-	-	2128.29	1498.86	869.43
Section height (m)	23.45	23.69	23.93	-	-	-
Section spread (m)	36.11	38.74	41.37	-	-	-
Section area (m2)	837.44	924.55	1011.66	-	-	-
Headline depth (m)	275.87	177.47	79.07	265.79	97.37	-71.06
Door spread (m)	114.68	122.94	131.21	116.31	116.29	116.28
Door depth (m)	260.28	163.01	65.74	259.63	85.16	-89.31
Haul number	T80/19,20			T80/21		

NET A

Warplength/ bridle extension		300 m; 6.5 m			450 m; 6.5 m			600 m; 6.5 m			600 m; 8.5 m		
Bridle weight		720			720			720			720		
Speed (knots)		3	4	5	3	4	5	3	4	5	3	4	5
Gear drag (tonne)		8.12	11.12	14.12	7.35	11.40	15.45	8.92	12.42	15.91	8.02	11.96	15.
Swept Volume Index (m3/s.,tonne)	W/E	263.67	225.75	187.84	330.59	243.48	156.38	263.00	217.02	171.04	378.88	253.29	127.
	H/L	240.81	178.74	116.67	293.23	194.09	94.94	217.97	160.42	102.87	304.62	206.52	108.
Gear drag/ area (kgf/m2)	W/E	5.78	9.20	12.62	3.13	8.76	14.38	5.20	9.34	13.47	3.02	8.53	14.
	H/L	5.50	11.75	18.00	1.70	11.30	20.90	5.79	12.64	19.48	3.18	10.38	17.
Haul number		T80/7,16			T80/17,18			T80/ 5,6			T80/3,4		

TABLE III(a) - GEAR PERFORMANCE AND DRAG

TABLE III(c) - GEAR PERFORMANCE AND DRAG

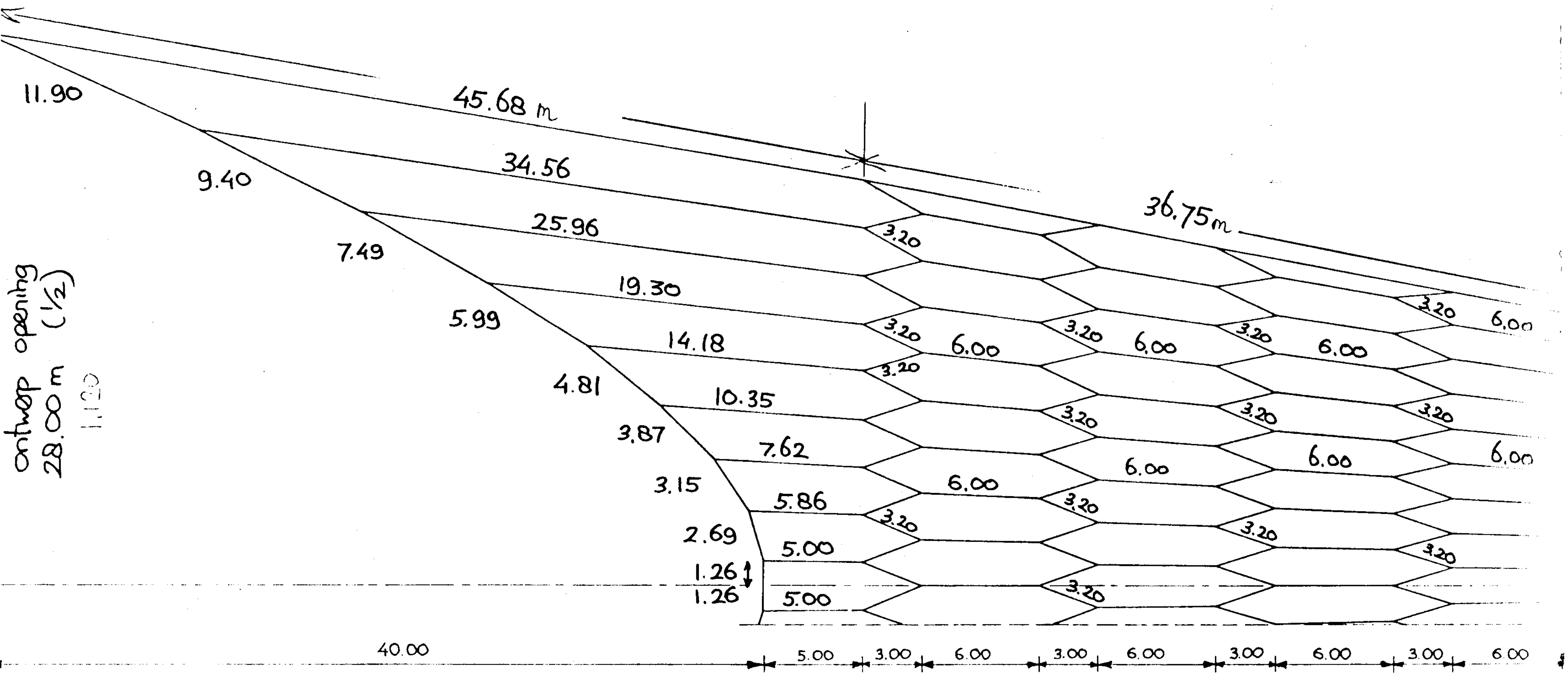
Warplength/ bridle extension		NET B			NET C	
		600 m; 8.5 m			600 m; 8.5 m		
Bridle weight		1500			1500		
Speed (knots)		3	4	5	3	4	5
Gear drag (tonne)		9.77	16.20	22.64	9.18	18.88	28.57
Swept volume index (m3/s., tonne)	W/E	277.70	224.62	171.53	-	-	-
	H/L	-	-	-	318.66	154.33	-10.00
Gear drag/ area (kgf/m2)	W/E	5.24	9.17	13.10	-	-	-
	H/L	-	-	-	3.48	12.18	20.88
Haul number		T80/19,20			T80/21		

TABLE IV - GEAR GEOMETRY, DRAG AND PERFORMANCE 2700 MESHES PELAGIC TRAWL (Net C, Report TO 80-03)

Warplength (m)/bridle extension		600 ; 9,82		600 ; 9,82	
Bridle weight (kg)		720		1100	
Speed (knots)		4	5	4	5
Wing-end height (m)		25.3	21.5	30.3	24.7
Wing-end spread (m)		53.9	52.6	54.7	55.6
Wing-end area (m2)		1362	1135	1659	1372
Headline height (m)		23.5	19.6	28.7	22.5
Sideline spread (m)		47.2	45.3	48.2	49.4
Headline centre area (m2)		1111	889	1383	1110
Section height (m)		11.9	9.9	14.2	12.8
Section spread (m)		26.2	25.4	26.8	28.2
Section area (m2)		311	253	380	361
Headline depth		121.9	29.6	167.3	60.4
Door spread		126.6	120.3	129.1	132.4
Door depth		106.4	18.9	151.2	47.4
Gear drag (tonne)		12.96	16.03	12.57	17.73
Swept Volume Index	(W/E)	216.24	182.11	271.56	199.03
(m3/sec., tonne)	(H/L)	176.39	142.64	226.39	161.02
Gear drag/area	(W/E)	9.52	14.12	7.58	12.92
(kgf/m2)	(H/L)	11.67	18.03	9.09	15.97

ONTWERPMATEN

totale naadlengte 82.43 m ; peeslengte : 101.12 m



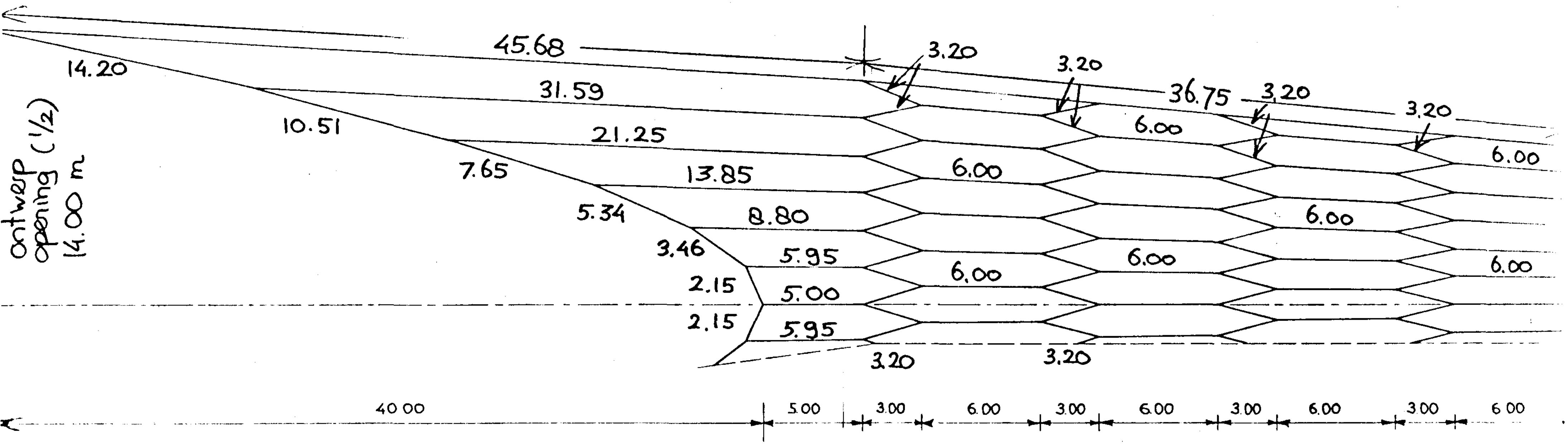
lijnen : polypropyleen , ϕ = 12 mm
hexagonale mazen , idem
naden : polypropyleen : ϕ = 16 mm (dubbel)

FIG. 1A UPPER / LOWER PANEL NET A

Benaming VOORKOP HEXAGONAAL NET , ONTWERP V BOVEN / ONDERZIJDE			Formaat A3
R.I.V.O TECHNISCH ONDERZOEK Auteursrecht voorbehouden volgens de wet	Schaal 1 : 200	Gecontroleerd	
	Getekend BvM	Gezien 13/08/80	Rangschikmerk NR TO

ONTWERPMATEN

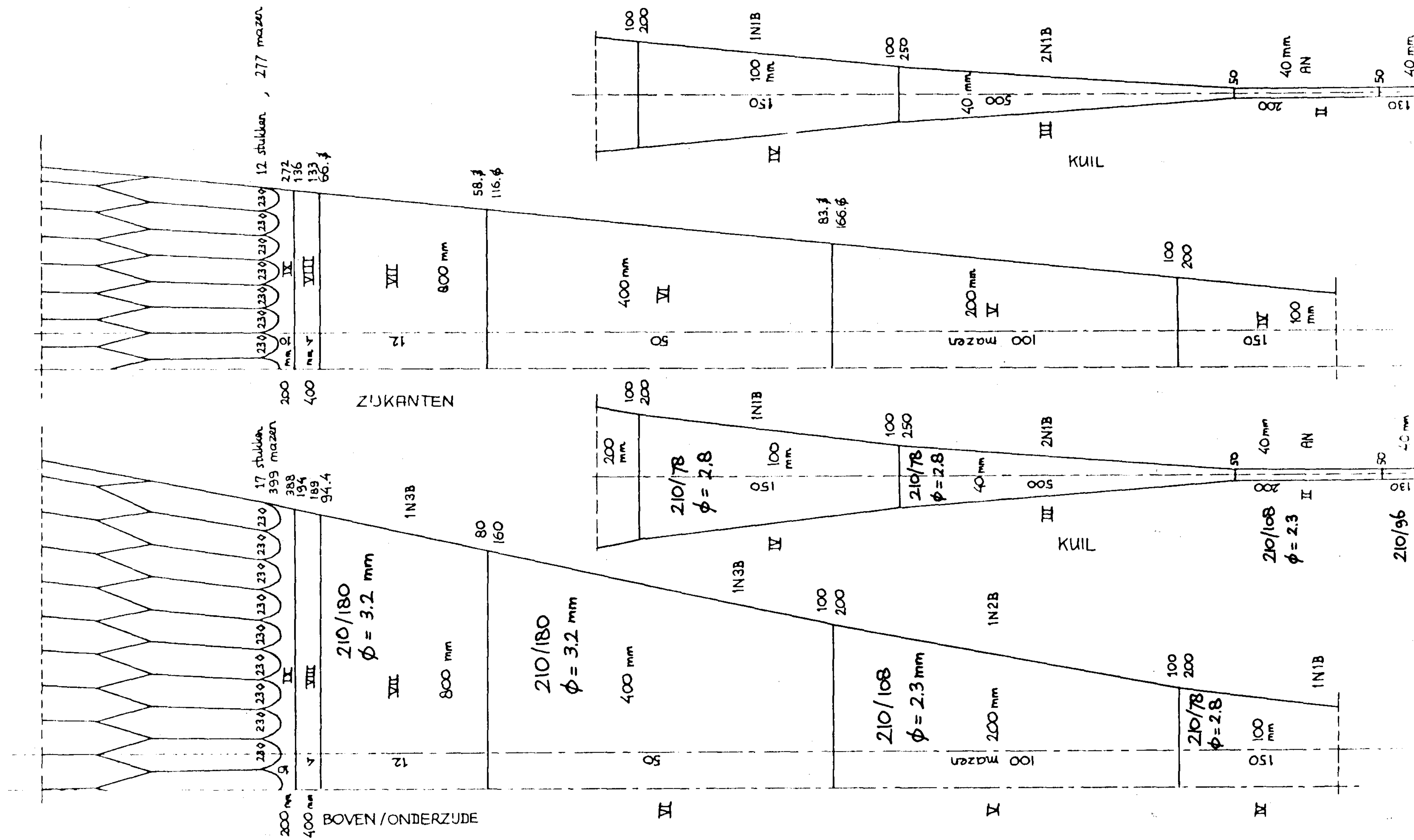
totale naadlengte 82.43m
peeslengte 86.62 m



tijnen: polypropyleen, $\phi = 12$ mm
hexagonale mazen ; idem.
naden: polypropyleen, $\phi = 16$ mm
(dubbel uitgevoerd)

FIG. 1B SIDE PANELS NET A

Benaming	VOORKOP HEXAGONAAL NET , ONTWERP V ZIJKANTEN		Formaat A3	14 AUG. 19..
R.I.V.O. TECHNISCH ONDERZOEK	Schaal 1 : 200	Gecontroleerd		



AFT PART NET A

Benaming	HEXAGONAAL NET , ONTWERP V , ACHTERNET		Formaat A3	FIG. 1C
R.I.V.O TECHNISCH ONDERZOEK	Schaal 1 : 200	Gecontroleerd		
Auteursrecht voorbehouden volgens de wet	Getekend BvM	Gezien 27/08/80	Rangschikmerk	TO 81(

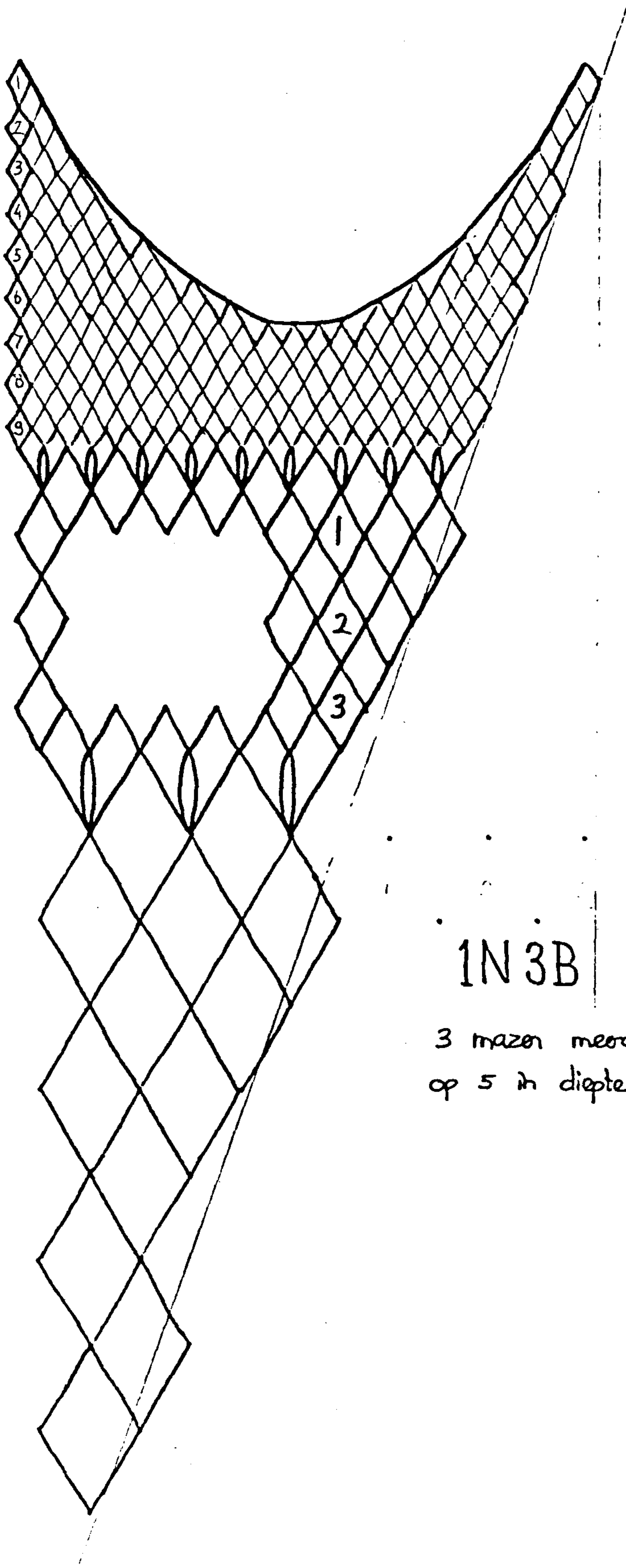
UPPER / LOWER PANEL SHARK TEETH
BOVEN / ONDER
HEXANET IV

Nodig 17 * 23 = 391 ◊
+ 6 mazen = 397 ◊

200 mm

400 mm

800 mm



1N3B

3 mazen meerderen
op 5 in diepte

NR. T.O. 810 E

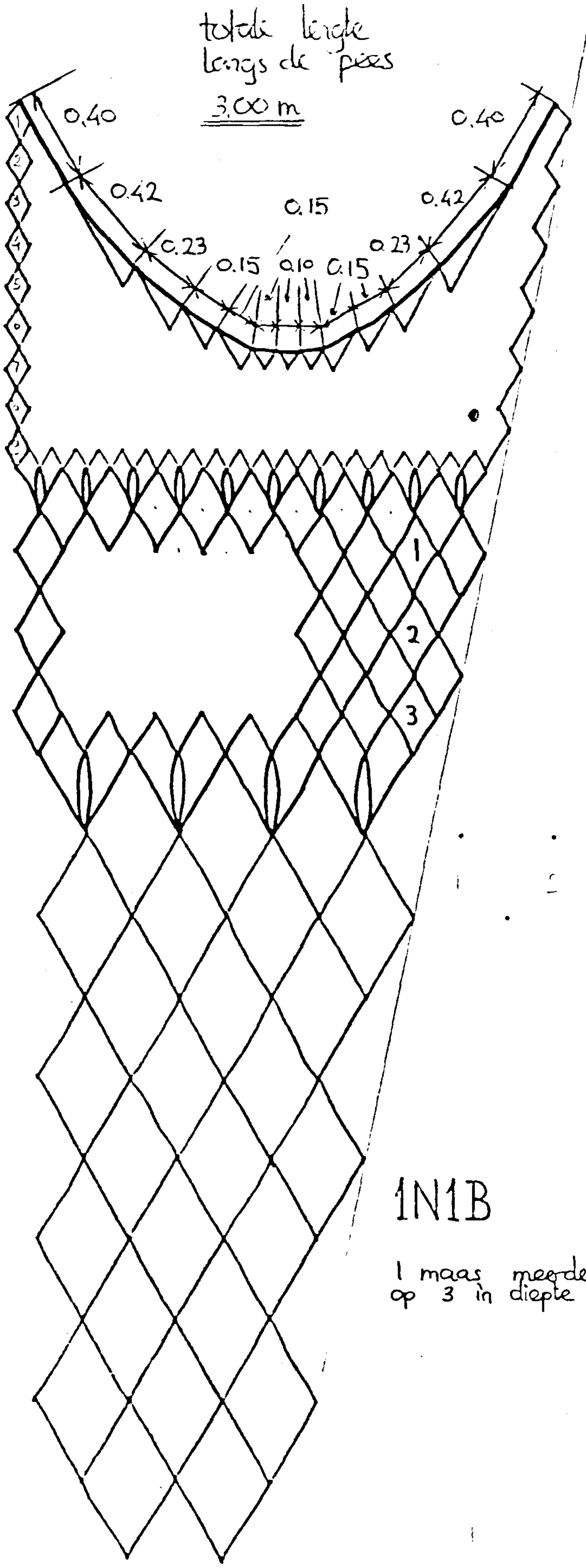
FIG. 1D

Nodig : 12 * 23 ◊ = 276 ◊
+ ± 6 ◊ voor de nader
= 282 ◊

200 mm

400 mm

800 mm

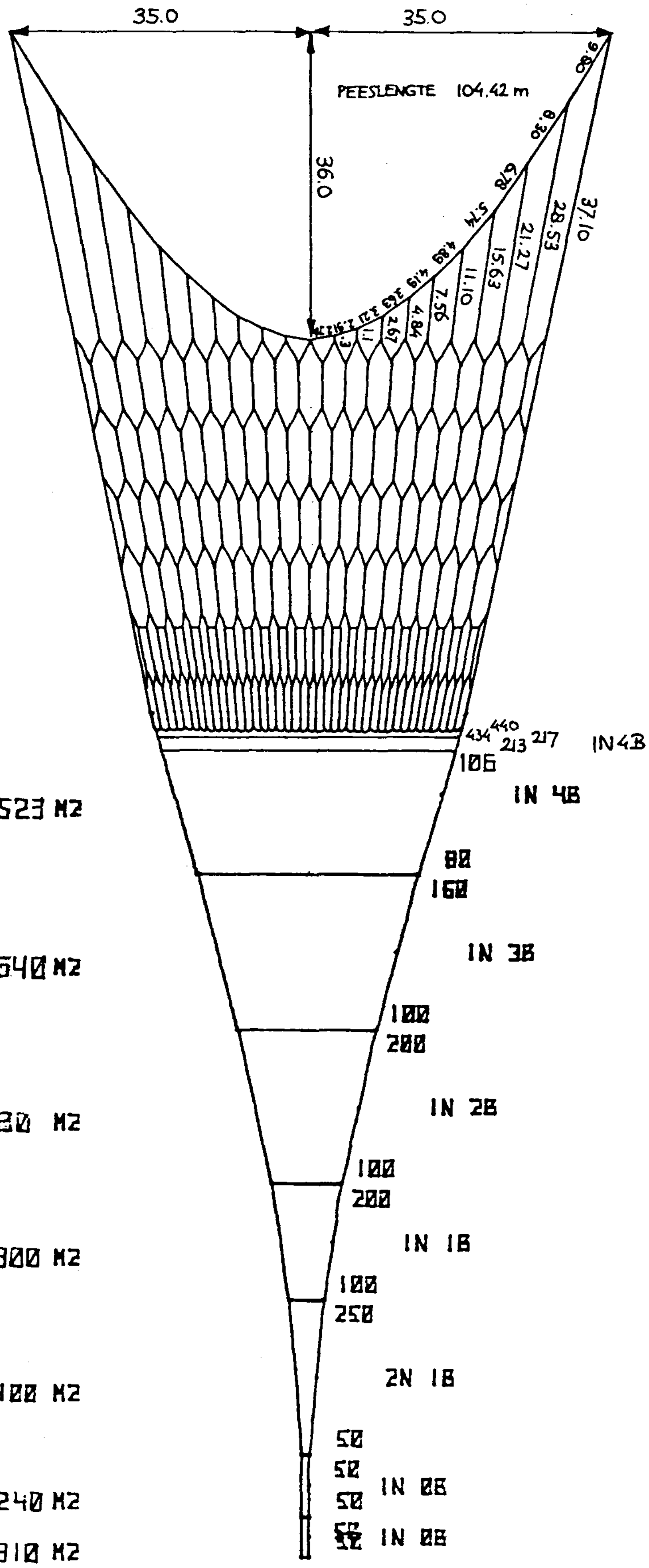


1N1B

1 maas meerderen
op 3 in diepte

NR. TC 810 D

FIG. 1E



MAZEN	(MM)	BOVEN-/ONDERKANT (UPPER / LOWER PANEL)	DIKTE (MM)	(M)
			12 mm	36.00
4	11000		12 mm	3.00
				5.00
				3.00
			12 mm	5.00
				3.00
				5.00
				3.00
				5.00
				2.00
2				5.00
				2.00
				5.00
3	800		210/108, 2.3	1.60
4	400		210/108, 2.3	1.60
20	800	UI= 0.40 OPP.= 9.523 M2	210/ 102 3.2	16.00
50	400	UI= 0.40 OPP.= 16.640 M2	210/ 108 3.2	20.00
100	200	UI= 0.40 OPP.= 13.20 M2	210/ 108 2.3	20.00
150	100	UI= 0.40 OPP.= 6.300 M2	210/ 39 1.4	15.00
500	40	UI= 0.40 OPP.= 8.400 M2	210/ 39 1.4	20.00
200	40	UI= 0.40 OPP.= 1.240 M2	210/ 48 1.6	8.00
130	40	UI= 0.40 OPP.= 0.910 M2	210/ 62 1.8	5.20

BENAMING: CONCEPT DESIGN OF A ROPE-MESHES TRAWL
(CIRCUMFERENCE 2700 MESHES OF 20 (M.)

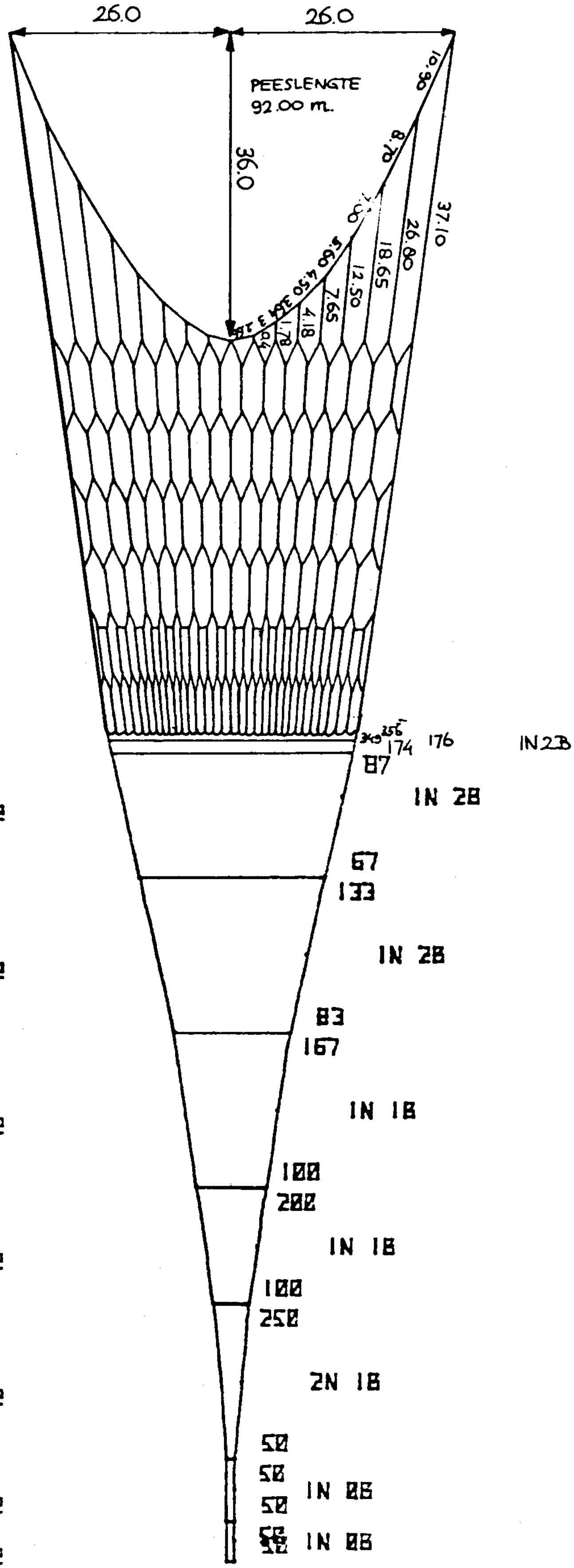
FIG. 2A

NR.: 803 A

SCHAAL

RIVO AFDELING TECHNISCH ONDERZOEK DATUM: 29 JAN.'80 GETEK.: BvM

IN MAZEN	WIJDTE (MM)	ZIJKANTEN (SIDE-PANELS)	DIKTE (MM)	BESTREK (M)
			12 mm	36.00
			12 mm	3.00
4	11000			5.00
				3.00
			12 mm	5.00
				3.00
				5.00
				3.00
				5.00
				2.00
2				5.00
				2.00
				5.00
2	200		210/108 2.3	1.80
4	400		210/108 2.3	1.60
20	800	UI= 0.40 OPP.= 7.851 M2	210/ 108 3.2	16.00
50	400	UI= 0.40 OPP.= 13.870 M2	210/ 108 3.2	20.00
100	200	UI= 0.40 OPP.= 12.270 M2	210/ 108 2.3	20.00
150	100	UI= 0.40 OPP.= 6.300 M2	210/ 39 1.4	15.00
500	40	UI= 0.40 OPP.= 8.400 M2	210/ 39 1.4	20.00
200	40	UI= 0.40 OPP.= 1.240 M2	210/ 46 1.6	8.00
130	40	UI= 0.40 OPP.= 0.910 M2	210/ 62 1.8	5.20



BENAMING: CONCEPT DESIGN OF A ROPE-MESHES TRAWL CIRCUMFERENCE 2700 MESHES OF 20 CM.

FIG. 2B

NR.: 803 B

SCHAAL

RIVO AFDELING TECHNISCH ONDERZOEK DATUM: 29 JAN '80 GETEK.: B.M.

FIG. 3 A Sketch of rigging, used for measurements and fishing trials.

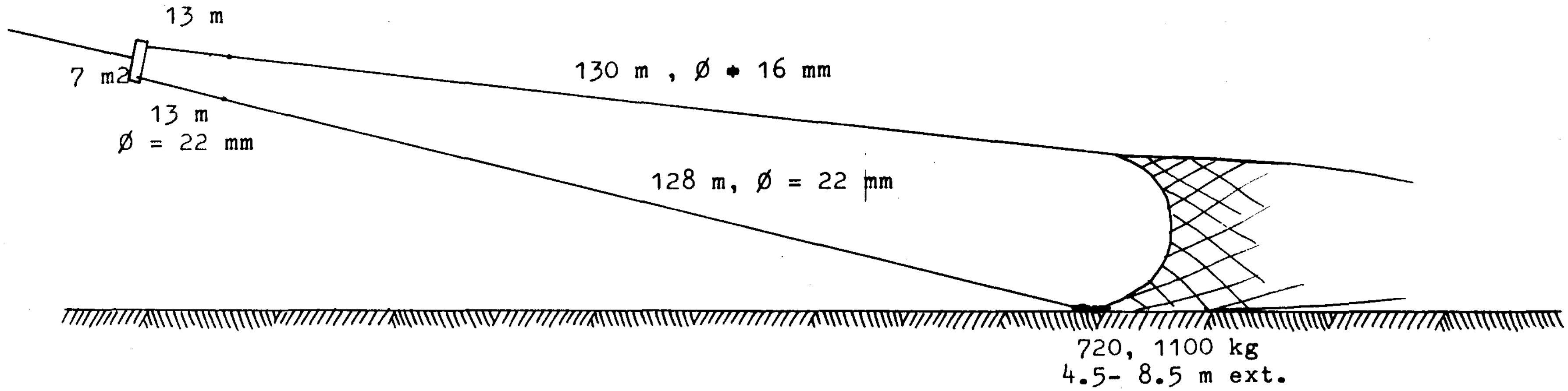
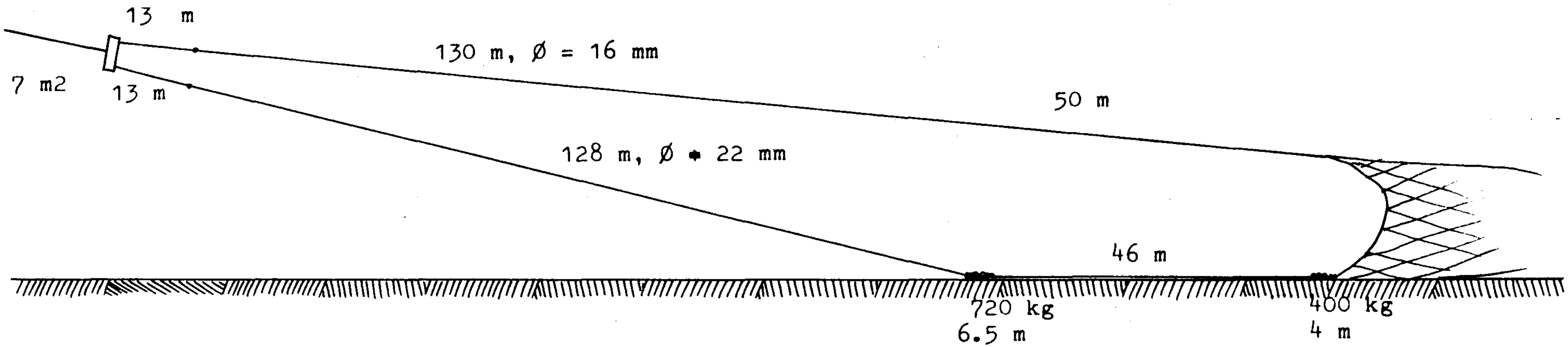


FIG. 3 B Sketch of rigging as used during fishing trials.



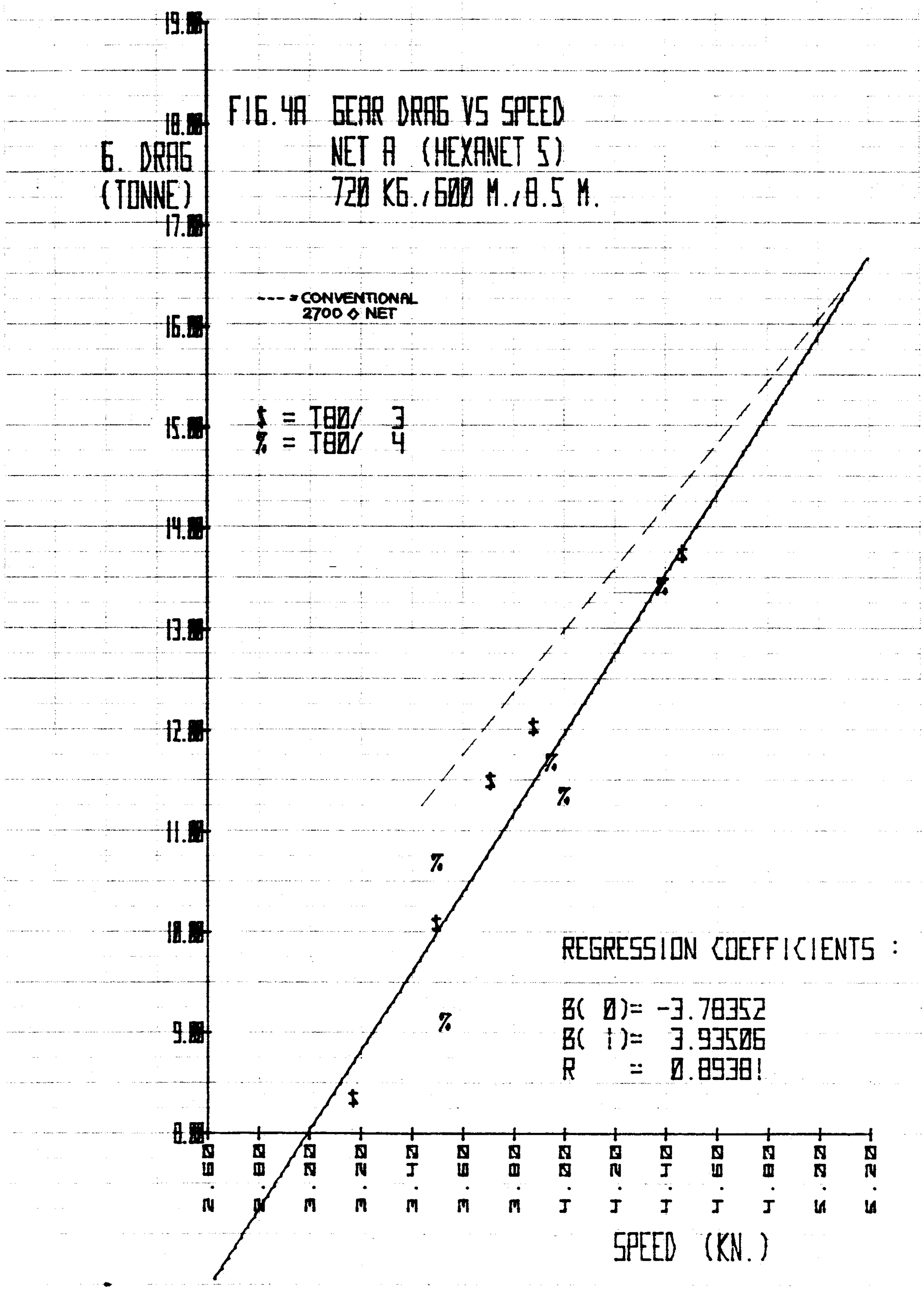


FIG.4A GEAR DRAG VS SPEED
NET A (HEXANET 5)
720 KG./600 M./8.5 M.
G. DRAG (TONNE)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
--- = CONVENTIONAL 2700 ◇ NET
$ = T80/ 3
% = T80/ 4
REGRESSION COEFFICIENTS :
B(0)= -3.78352
B(1)= 3.93506
R = 0.89381
SPEED (KN.)

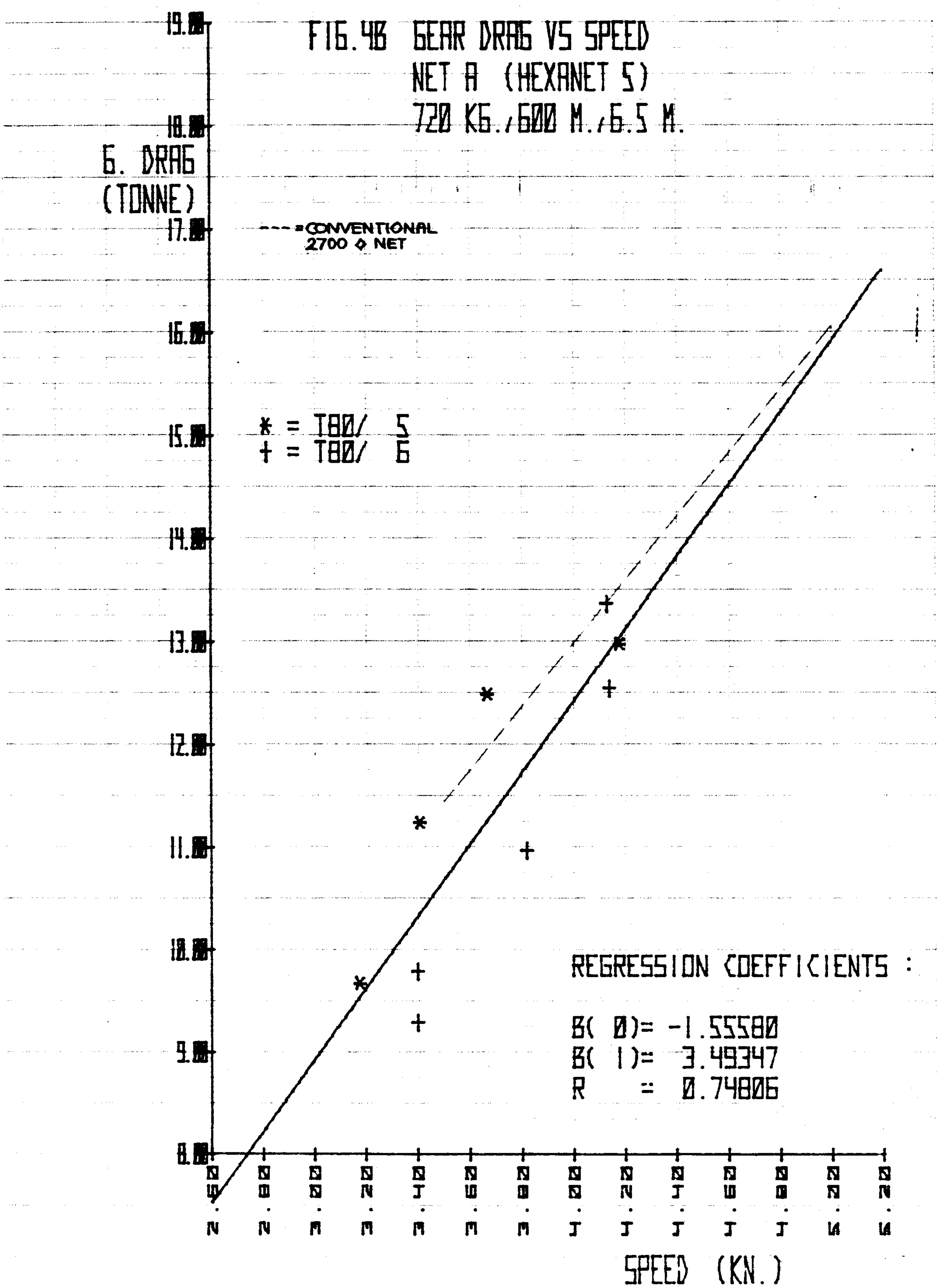


FIG.4B GEAR DRAG VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.
G. DRAG (TONNE)
---=CONVENTIONAL 2700 ◊ NET
* = T80/ 5
+ = T80/ 6
REGRESSION COEFFICIENTS :
B(0)= -1.55580
B(1)= 3.49347
R = 0.74806
SPEED (KN.)

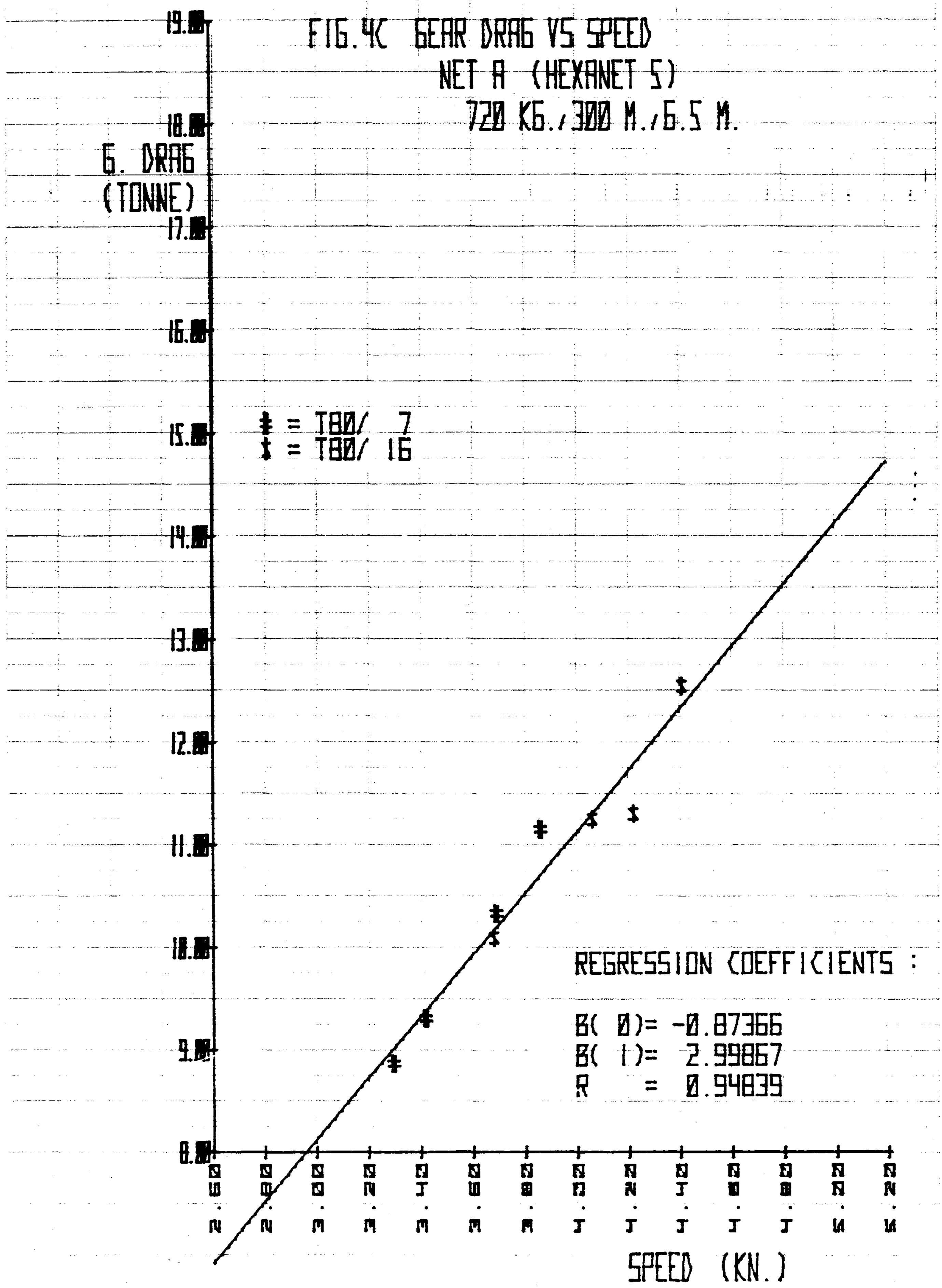


FIG. 4C GEAR DRAG VS SPEED
NET A (HEXANET 5)
720 KG./300 M./6.5 M.

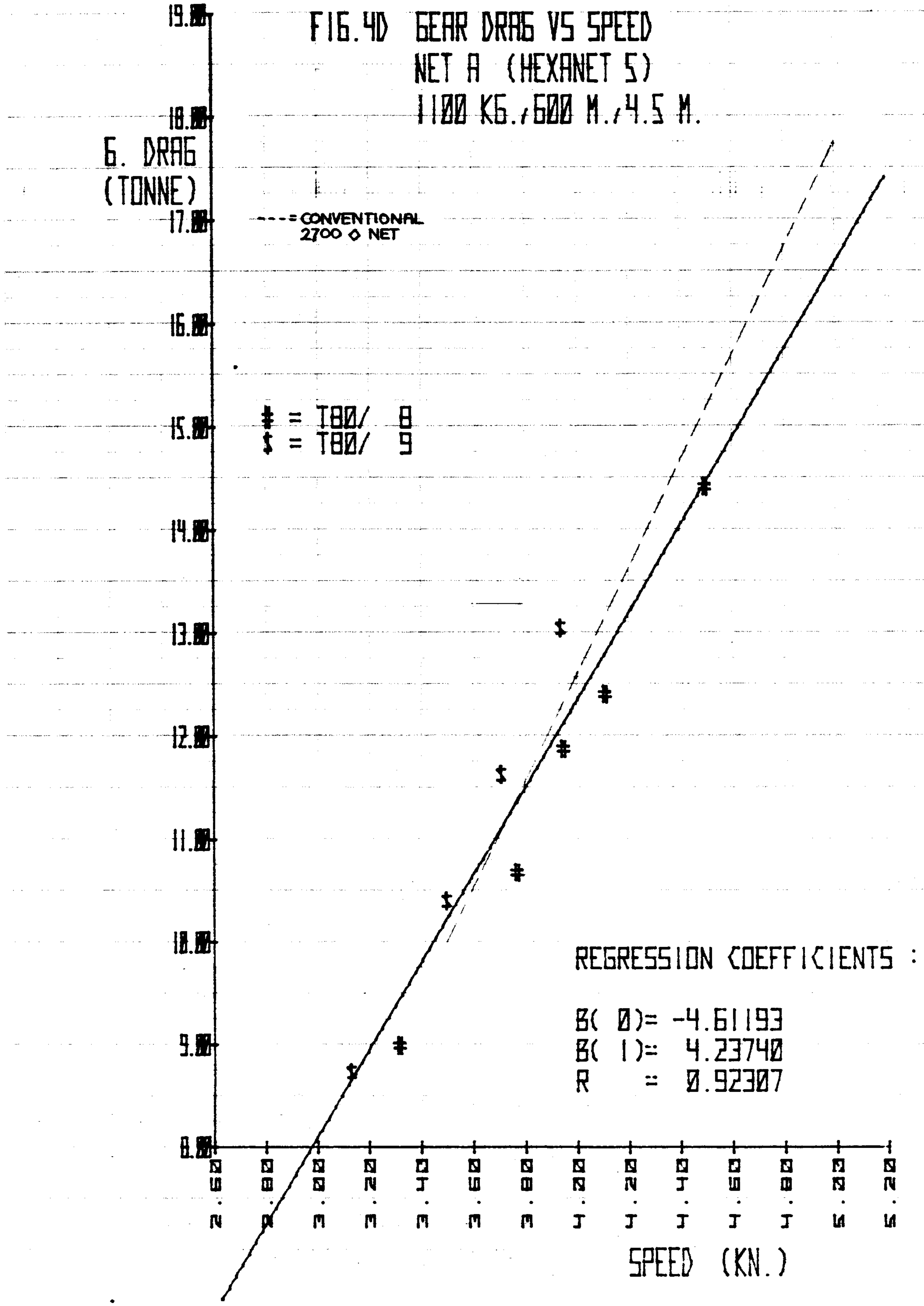


FIG. 4D GEAR DRAG VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.

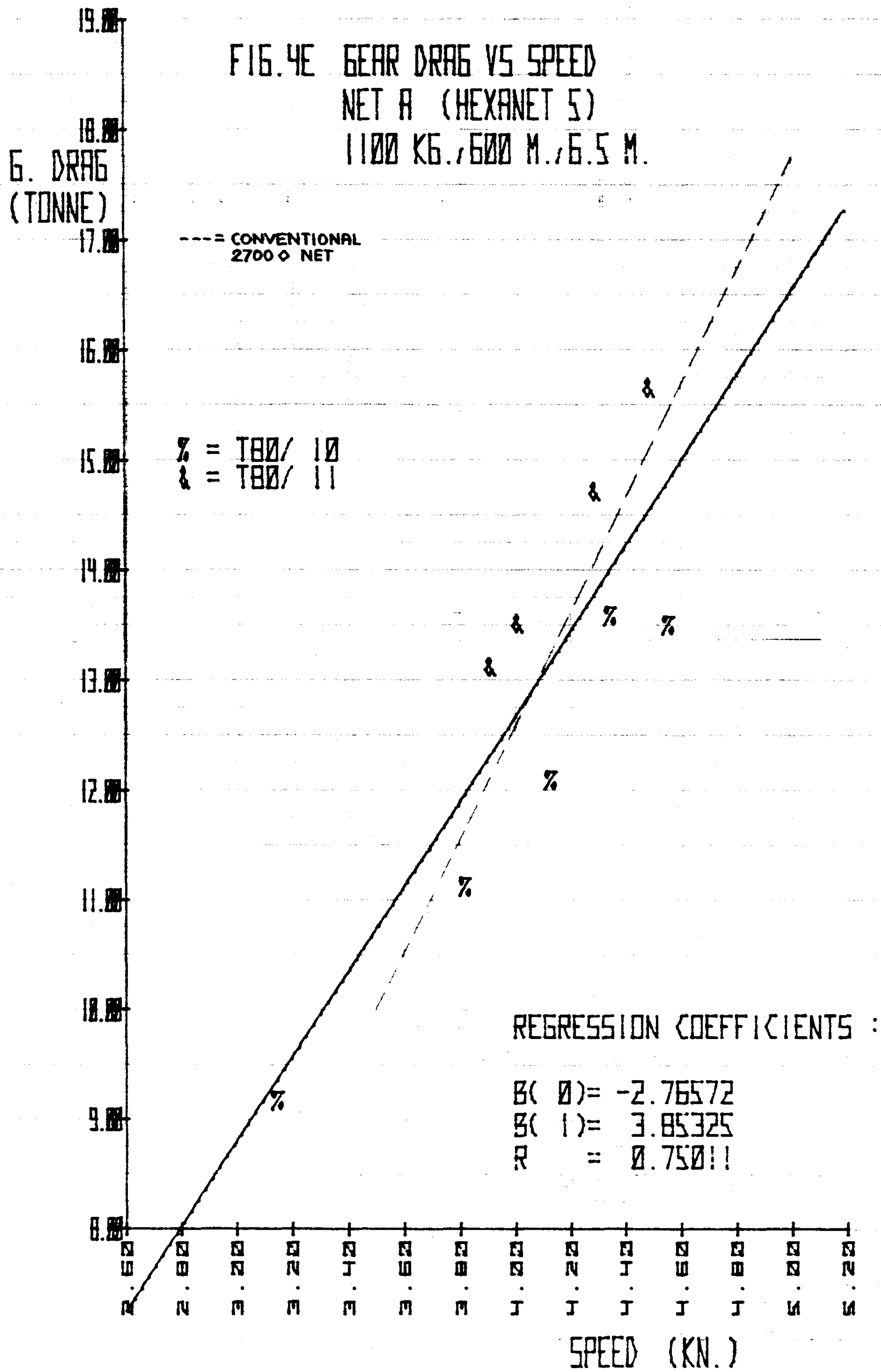


FIG.4E GEAR DRAG VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./6.5 M.
G. DRAG (TONNE)
---= CONVENTIONAL 2700 ◇ NET
% = T80/ 10
& = T80/ 11
REGRESSION COEFFICIENTS :
B(0)= -2.76572
B(1)= 3.85325
R = 0.75011
SPEED (KN.)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00

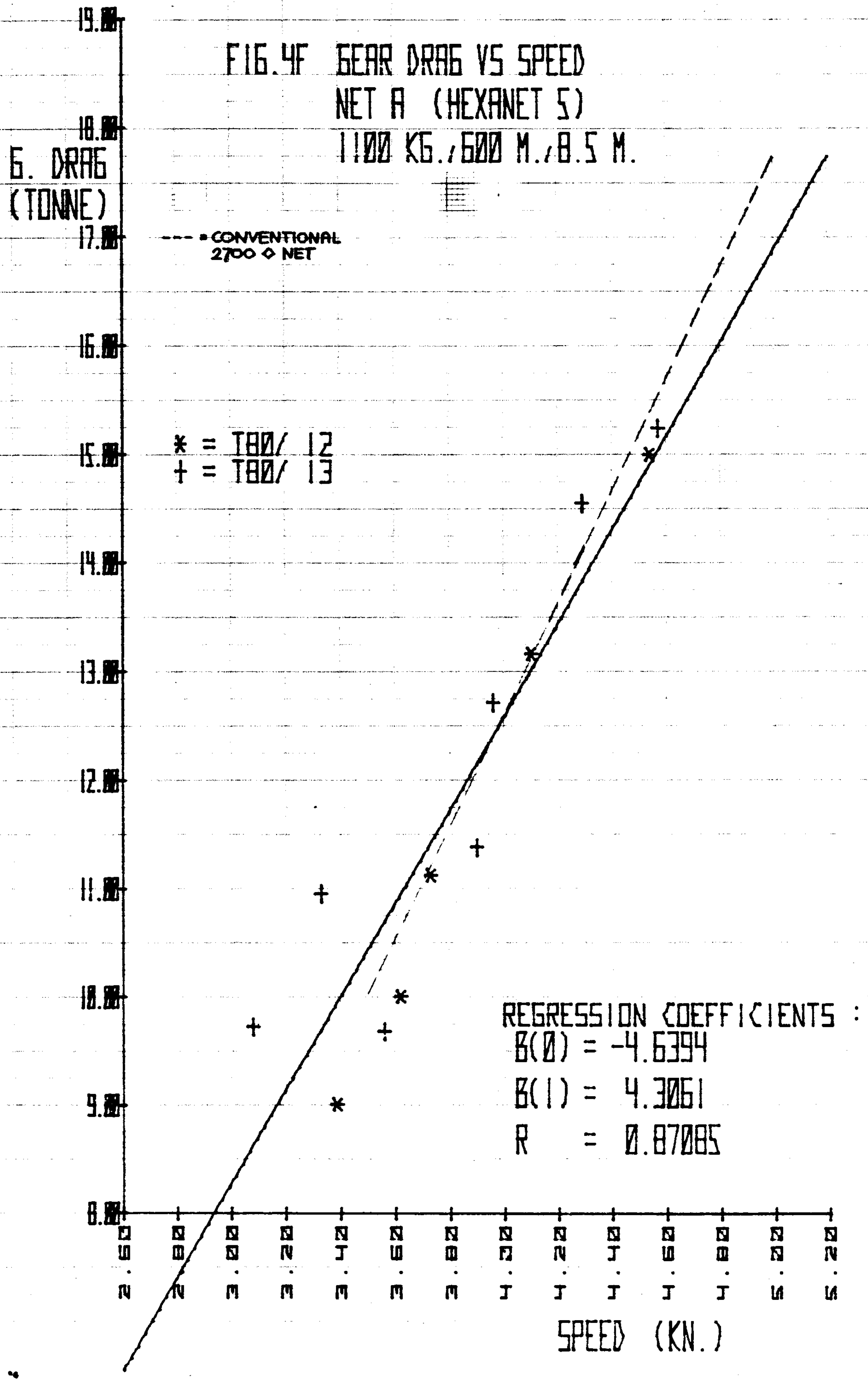


FIG.4F GEAR DRAG VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./8.5 M.
G. DRAG
(TONNE)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
---- = CONVENTIONAL
2700 ◇ NET
* = T80/ 12
+ = T80/ 13
REGRESSION COEFFICIENTS :
B(0) = -4.6394
B(1) = 4.3061
R = 0.87085
SPEED (KN.)

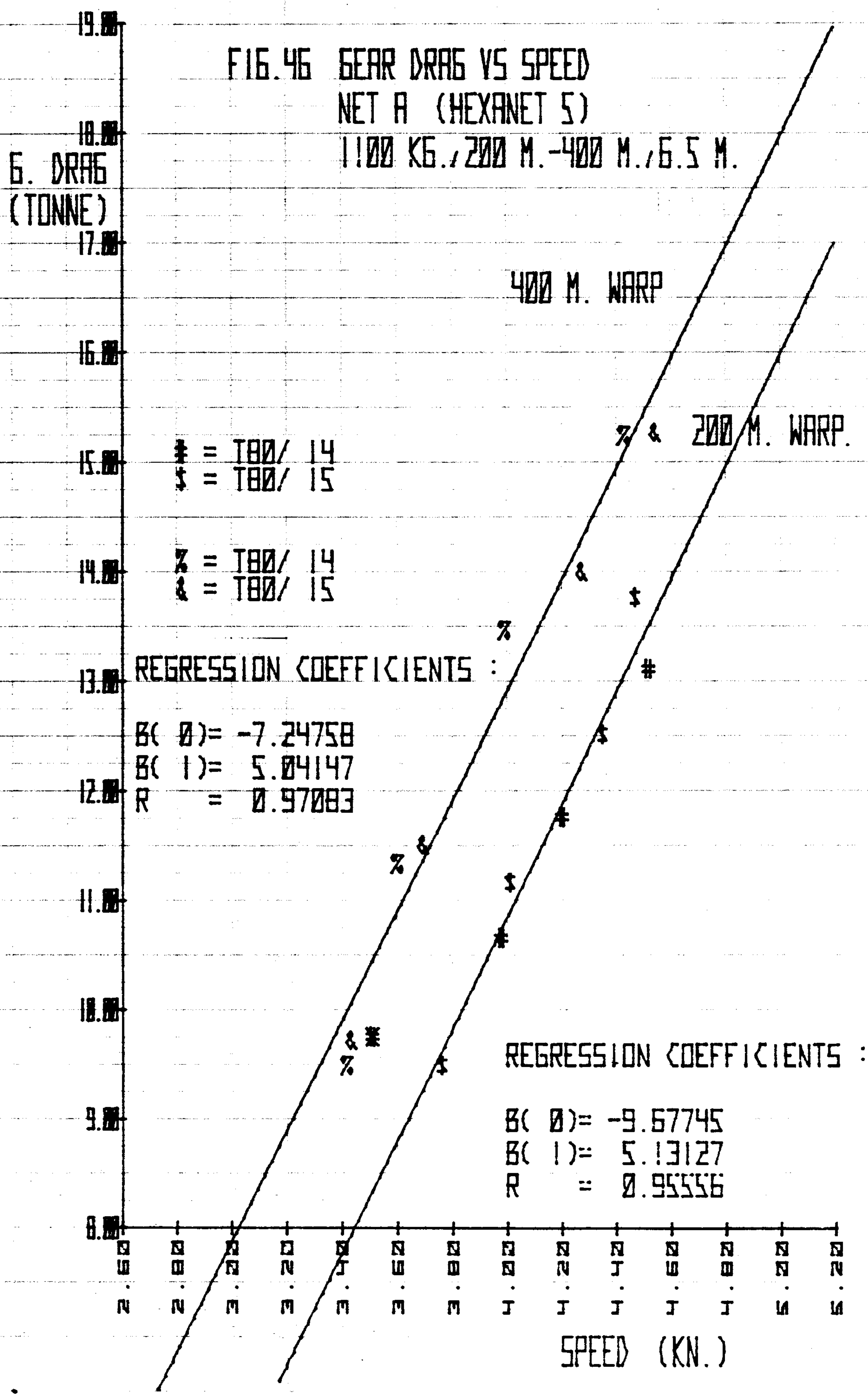


FIG.46 GEAR DRAG VS SPEED
NET A (HEXANET 5)
1100 KG./200 M.-400 M./6.5 M.
G. DRAG
(TONNE)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
400 M. WARP
200 M. WARP.
= T80/ 14
$ = T80/ 15
% = T80/ 14
& = T80/ 15
REGRESSION COEFFICIENTS :
B(0)= -7.24758
B(1)= 5.04147
R = 0.97083
REGRESSION COEFFICIENTS :
B(0)= -9.67745
B(1)= 5.13127
R = 0.95556
SPEED (KN.)

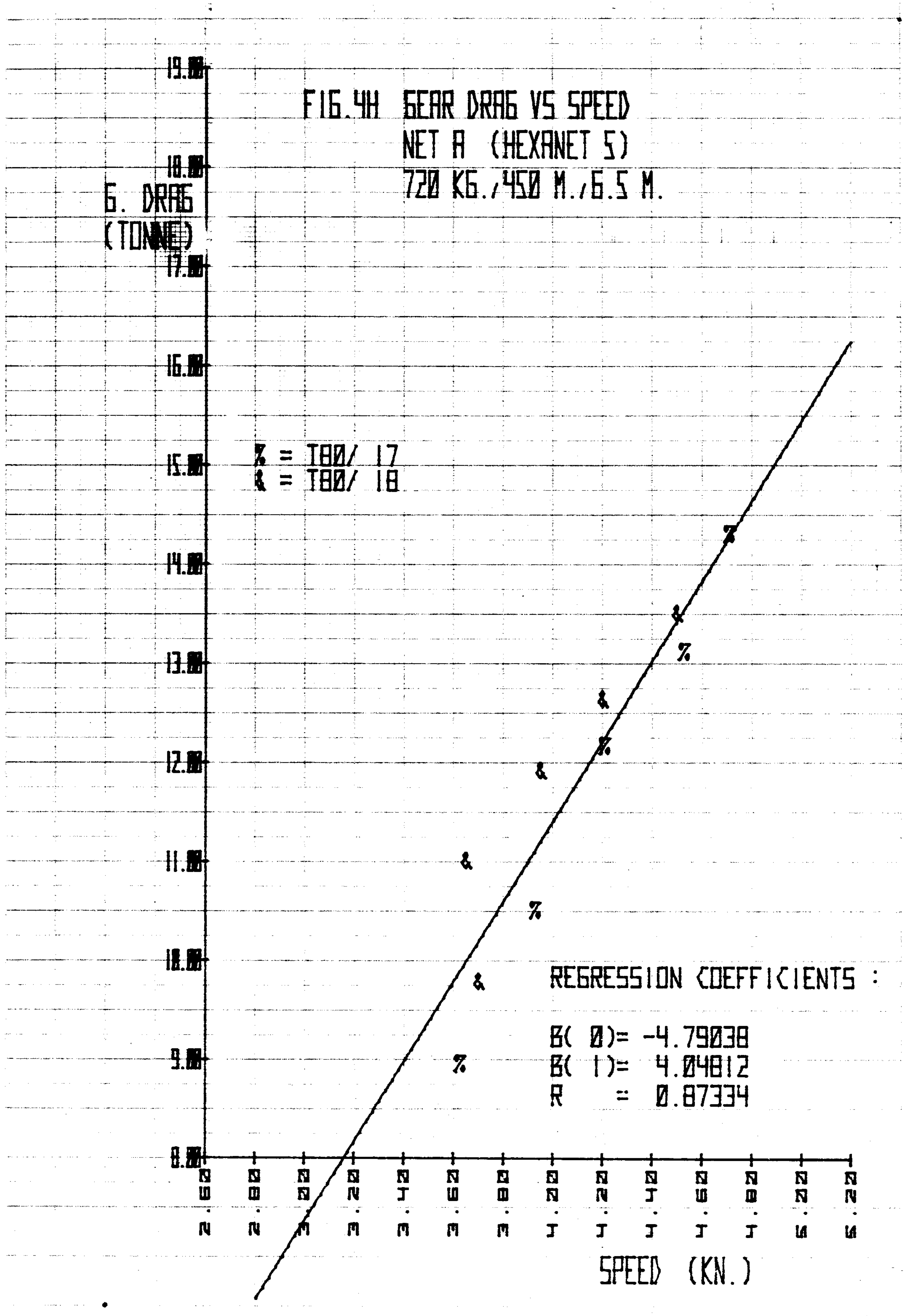


FIG.4H GEAR DRAG VS SPEED
NET A (HEXANET 5)
720 KG./450 M./6.5 M.
G. DRAG
(TONNE)
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
% = T80/ 17
& = T80/ 18
REGRESSION COEFFICIENTS :
B(0)= -4.79038
B(1)= 4.04812
R = 0.87334
SPEED (KN.)

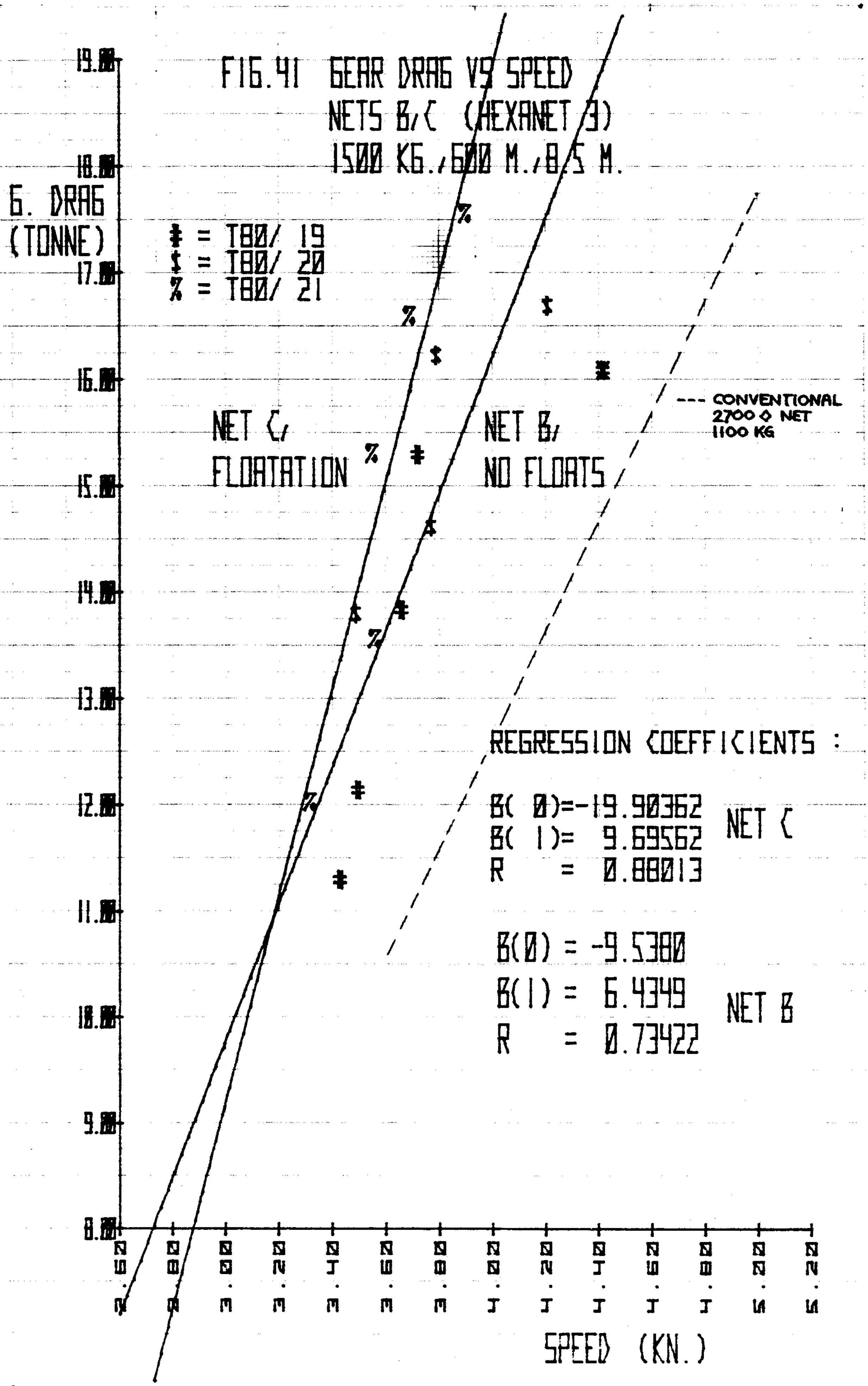
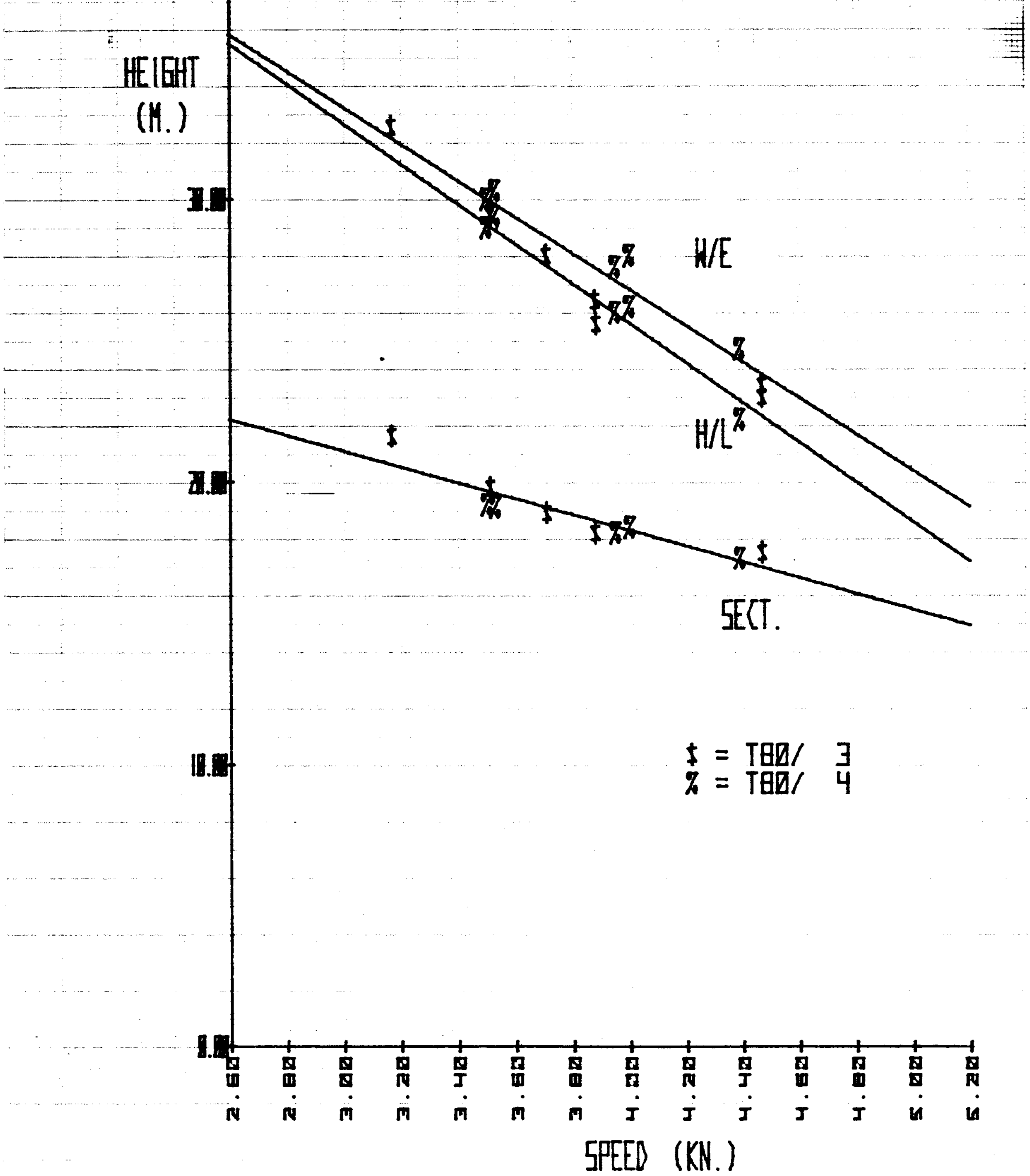


FIG.41 GEAR DRAG VS SPEED
NETS B/C (HEXANET 3)
1500 KG./600 M./8.5 M.
G. DRAG
(TONNE)
= T80/ 19
$ = T80/ 20
% = T80/ 21
NET C/
FLOATATION
NET B/
NO FLOATS
--- CONVENTIONAL
2700 ◇ NET
1100 KG
REGRESSION COEFFICIENTS :
B(0)=-19.90362
B(1)= 9.69562
R = 0.88013
NET C
B(0) = -9.5380
B(1) = 6.4349
R = 0.73422
NET B
19.00
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
9.00
8.00
SPEED (KN.)

FIG.5A HEIGHTS VS. SPEED
NET A (HEXANET 5)
720 KG. ;600 M. WARP; 8.5 M. EXT.



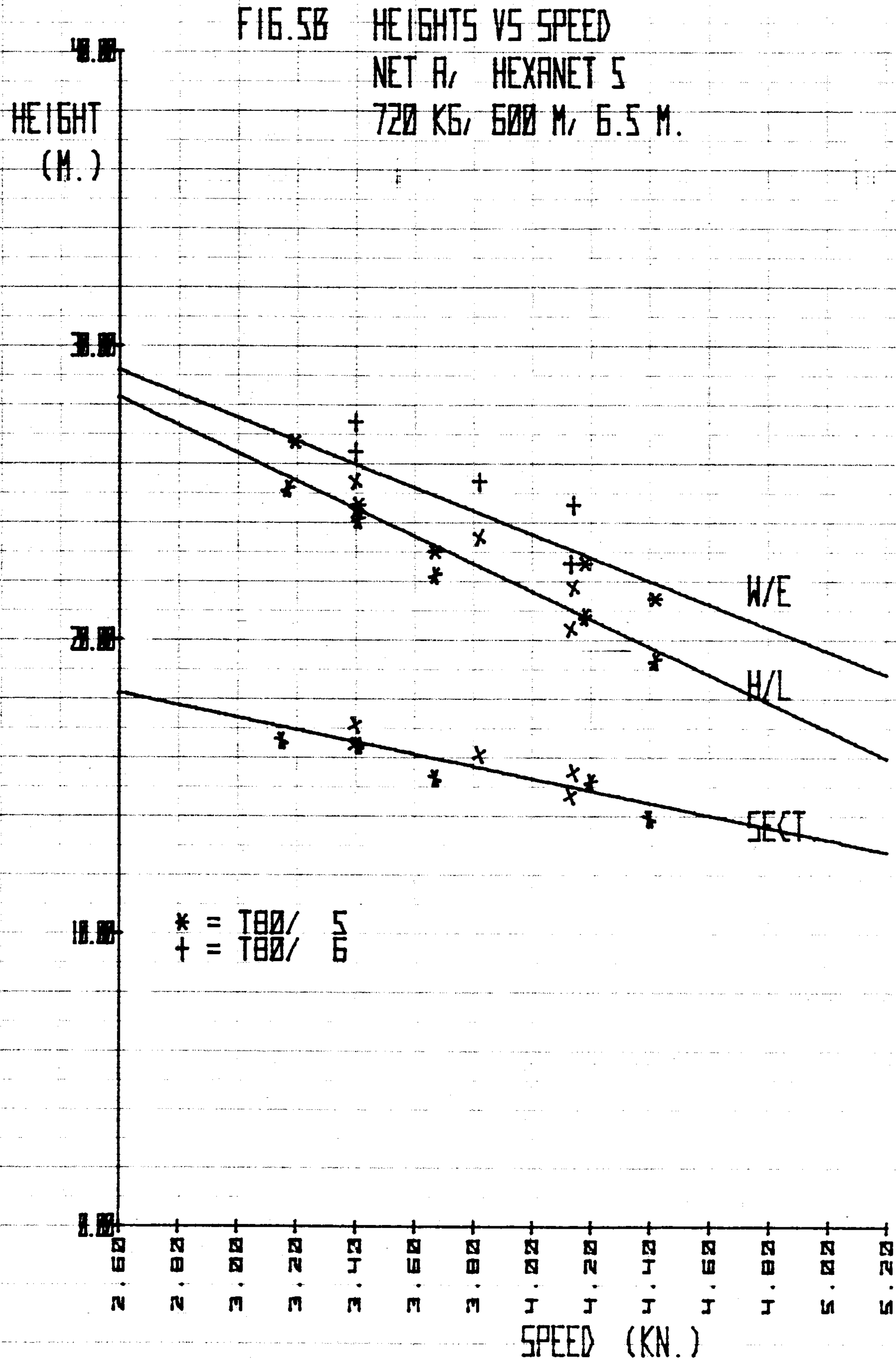
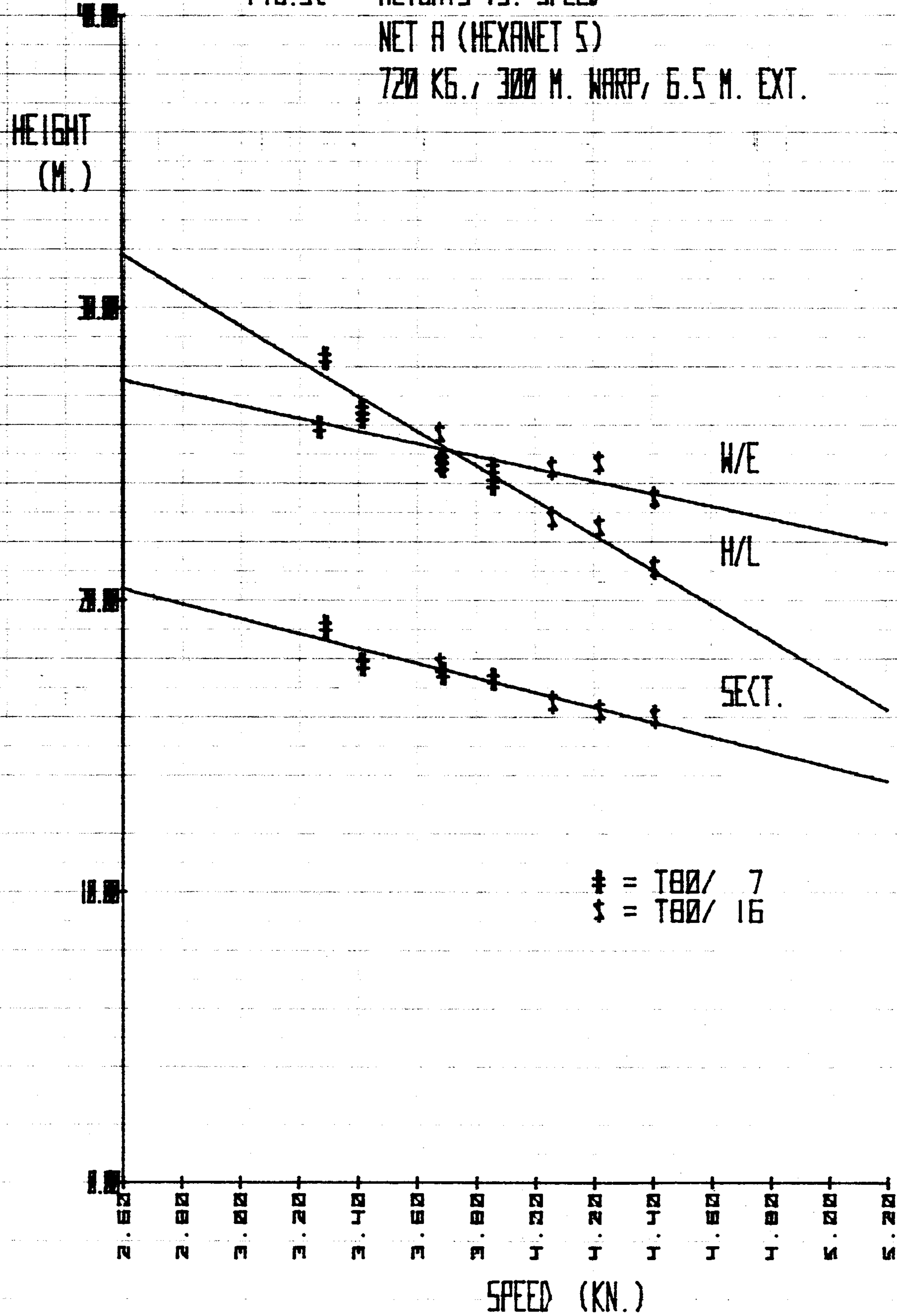


FIG.5B HEIGHTS VS SPEED
NET A, HEXANET 5
720 KG, 600 M, 6.5 M.
HEIGHT (M.)
40.00
30.00
20.00
10.00
0.00
W/E
H/L
SECT
* = T80/ 5
+ = T80/ 6
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

FIG.5C HEIGHTS VS. SPEED
NET A (HEXANET 5)
720 KG./ 300 M. WARP/ 6.5 M. EXT.



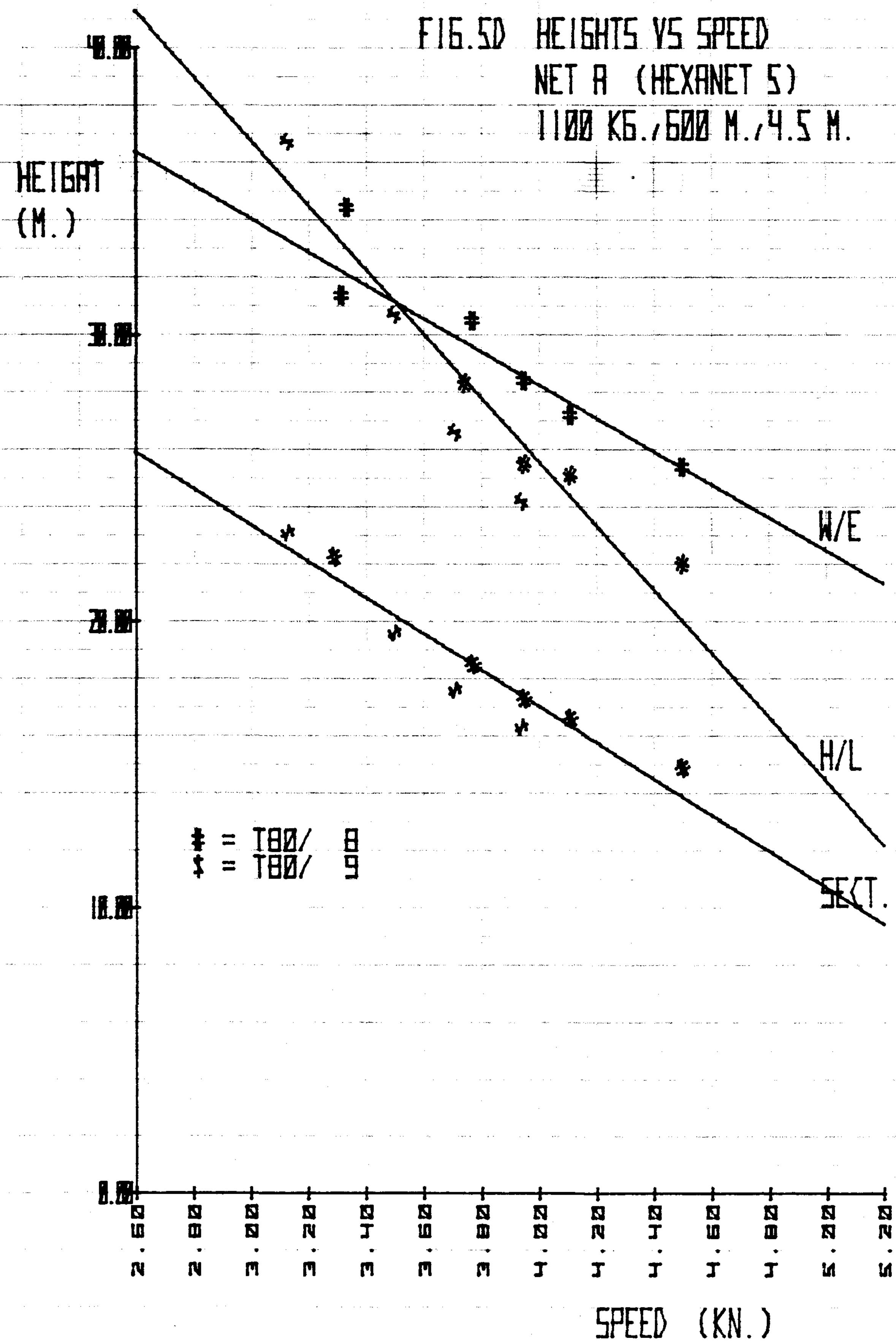


FIG.5D HEIGHTS VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.
HEIGHT
(M.)
40.00
30.00
20.00
10.00
0.00
W/E
H/L
SECT.
= T80/ 8
$ = T80/ 9
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

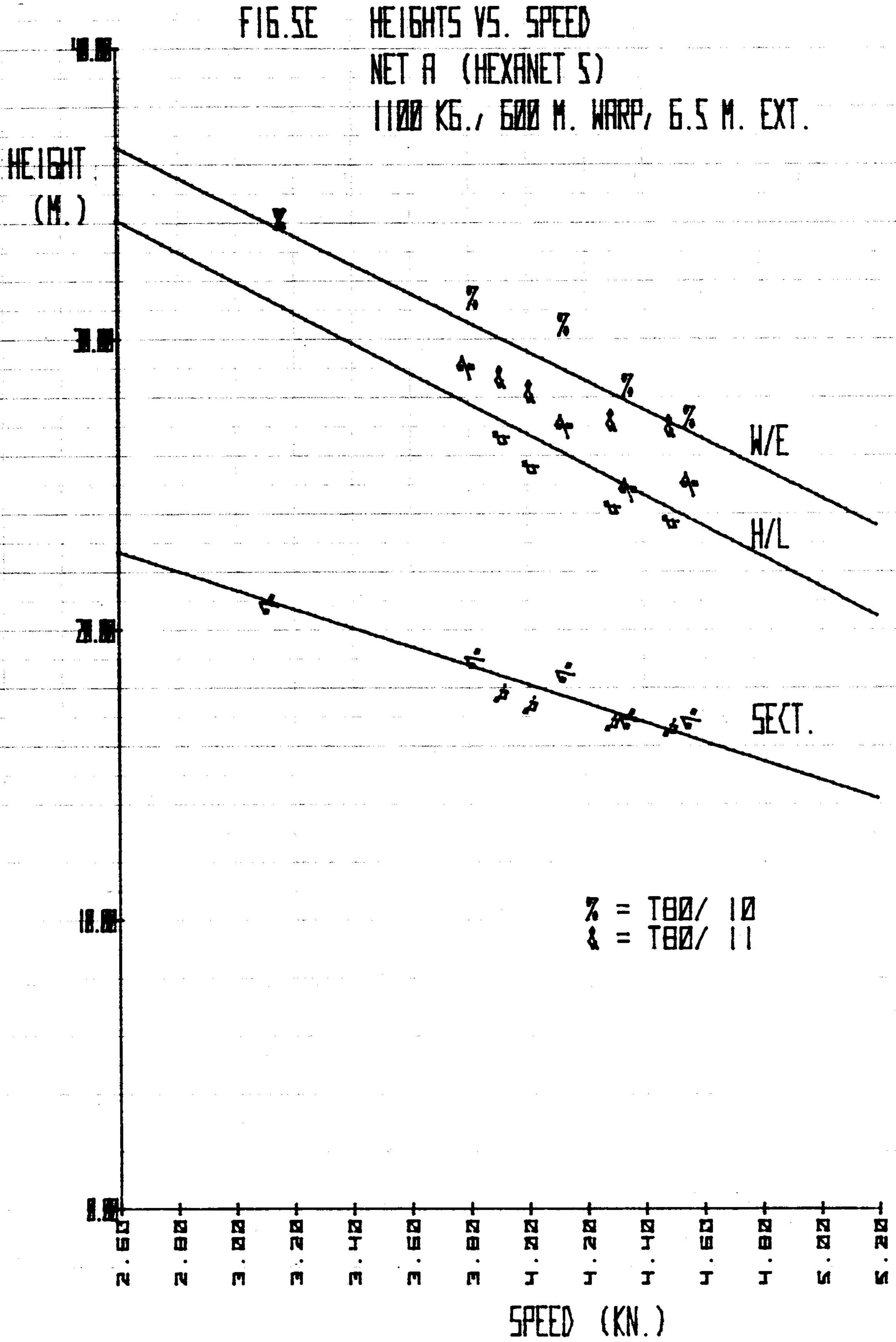


FIG.5E HEIGHTS VS. SPEED
NET A (HEXANET 5)
1100 KG./ 600 M. WARP/ 6.5 M. EXT.
HEIGHT (M.)
40.00
30.00
20.00
10.00
0.00
W/E
H/L
SECT.
% = T80/ 10
& = T80/ 11
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

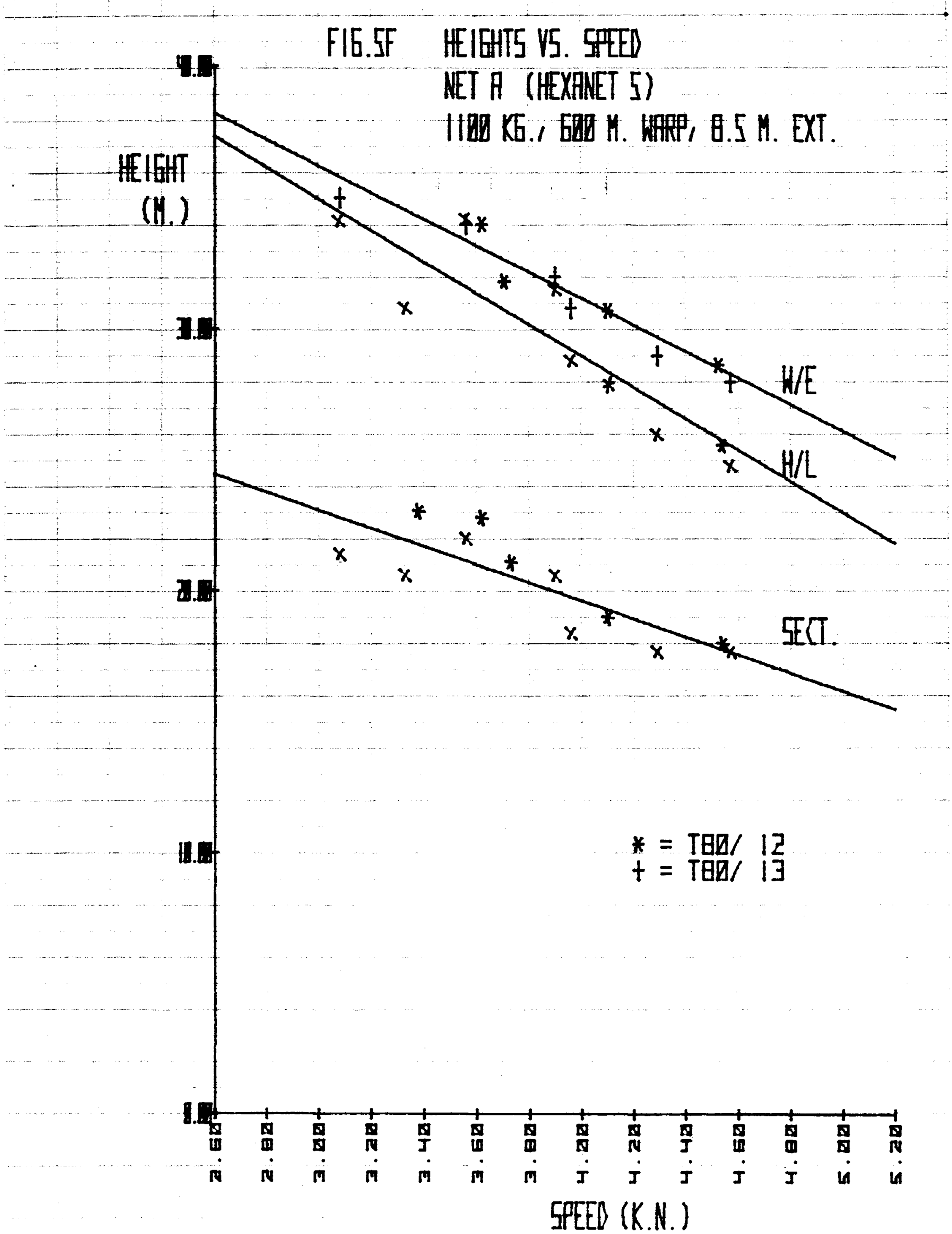


FIG.5F HEIGHTS VS. SPEED
NET A (HEXANET 5)
1100 KG./ 600 M. WARP/ 0.5 M. EXT.
HEIGHT (M.)
W/E
H/L
SECT.
* = T80/ 12
+ = T80/ 13
SPEED (K.N.)

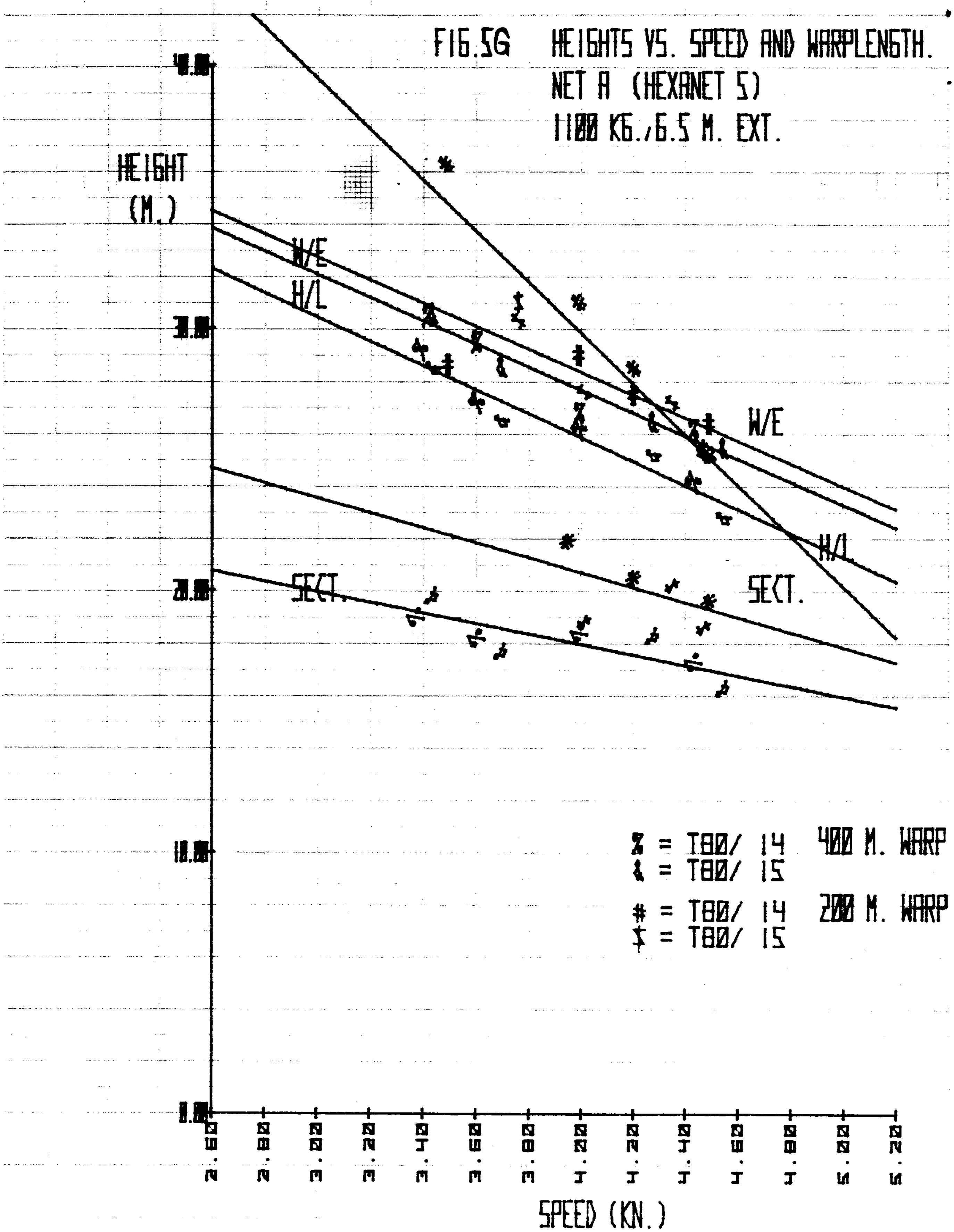


FIG.5G HEIGHTS VS. SPEED AND WARPLENGTH.
NET A (HEXANET 5)
1100 KG./6.5 M. EXT.

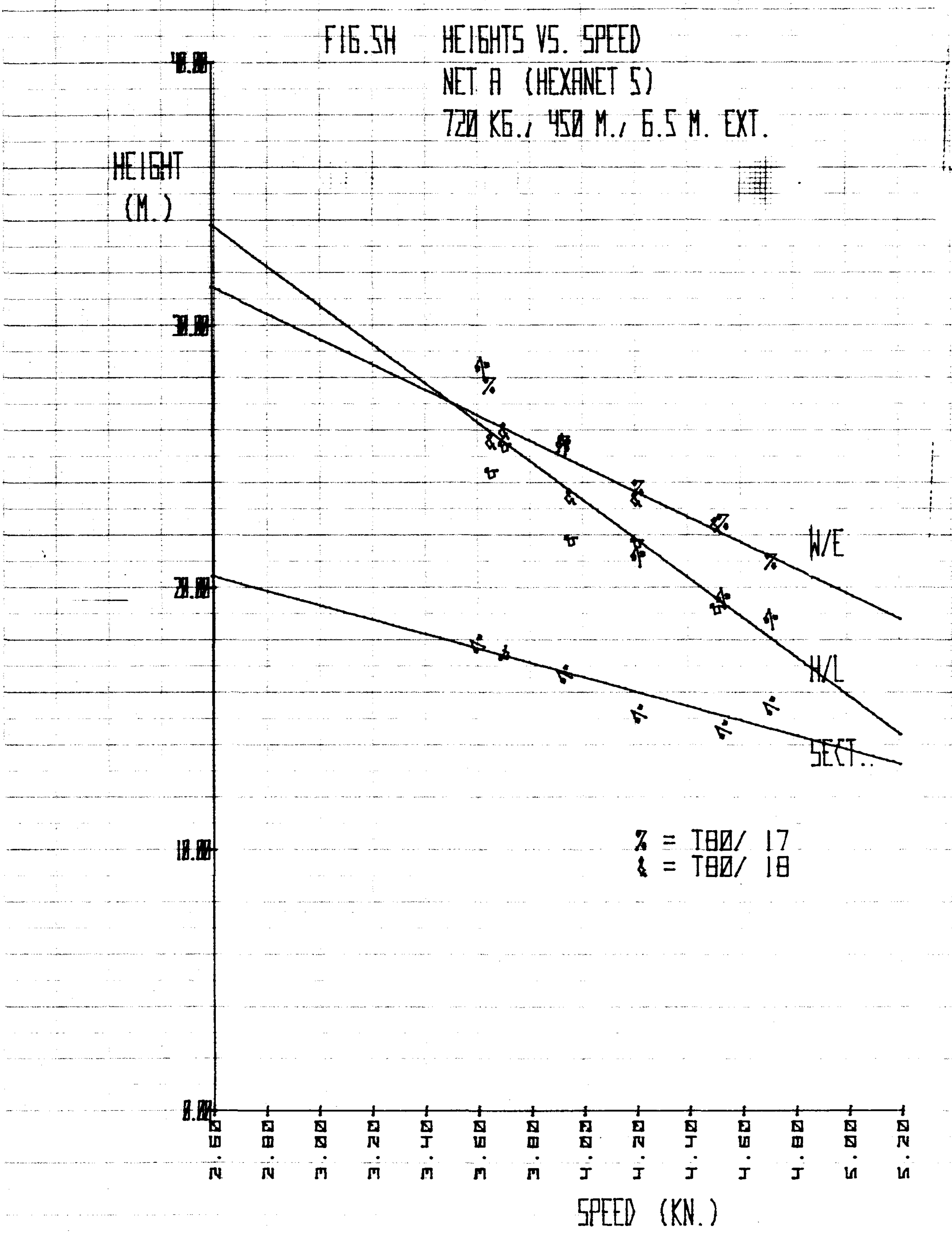


FIG.5H HEIGHTS VS. SPEED
NET A (HEXANET 5)
720 KG./ 450 M./ 6.5 M. EXT.

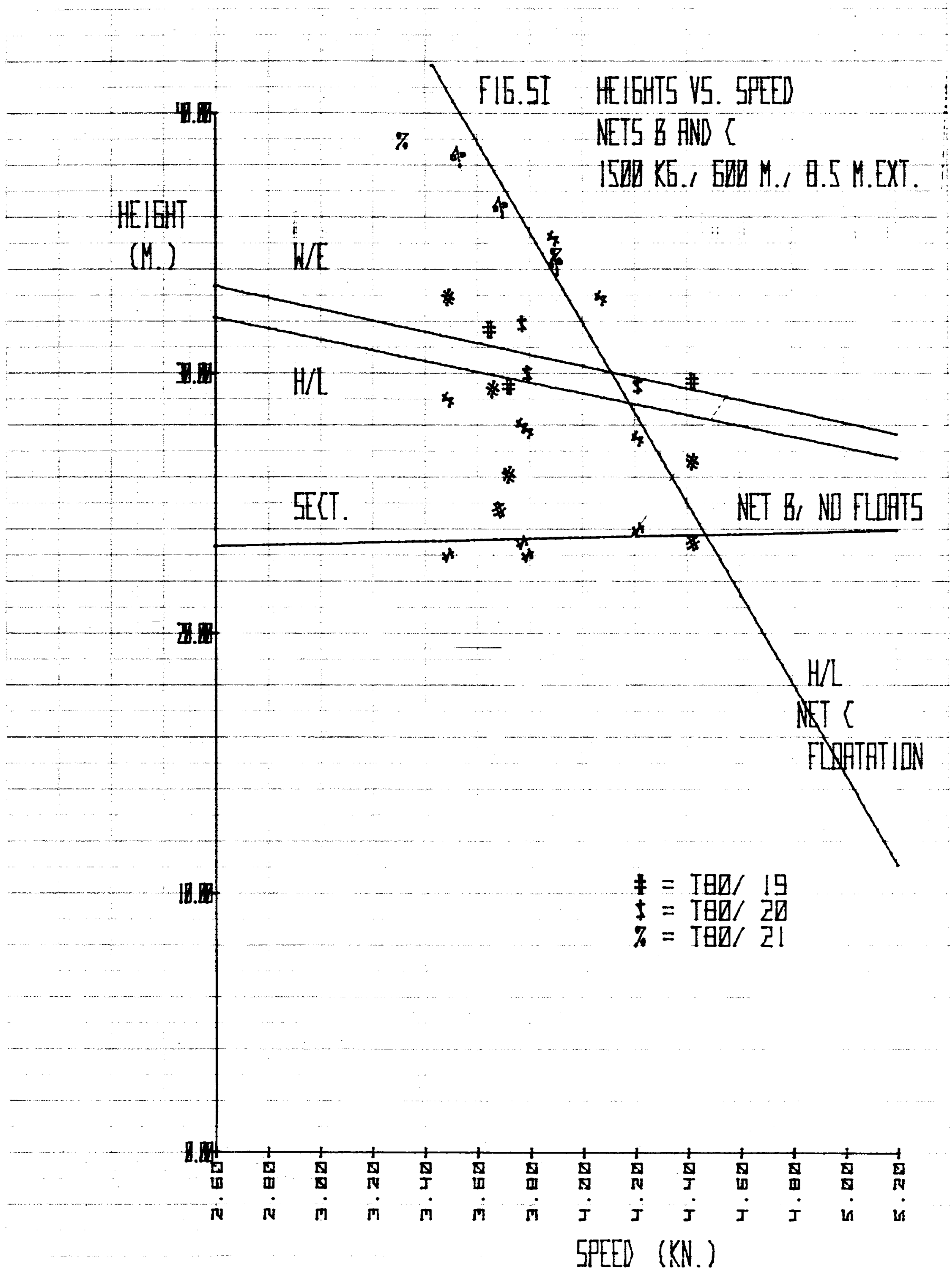


FIG.51 HEIGHTS VS. SPEED
NETS B AND C
1500 KG./ 600 M./ 8.5 M.EXT.
HEIGHT
(M.)
40.00
30.00
20.00
10.00
0.00
W/E
H/L
SECT.
NET B/ NO FLOATS
H/L
NET C
FLOATATION
= T80/ 19
$ = T80/ 20
% = T80/ 21
SPEED (KN.)

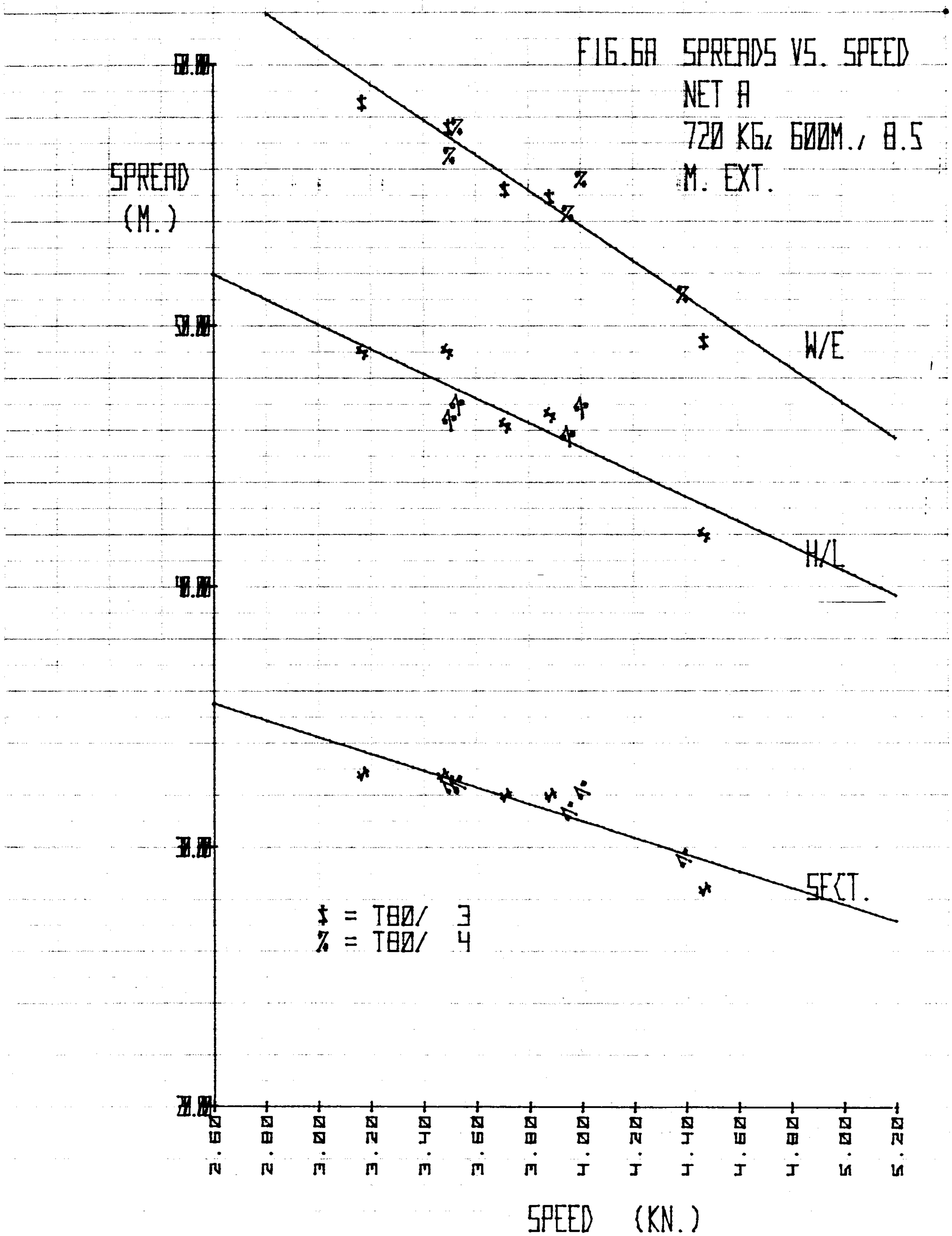


FIG.6A SPREADS VS. SPEED
NET A
720 KG, 600M., 8.5
M. EXT.
SPREAD
(M.)
W/E
H/L
SECT.
$ = TBØ/ 3
% = TBØ/ 4
SPEED (KN.)

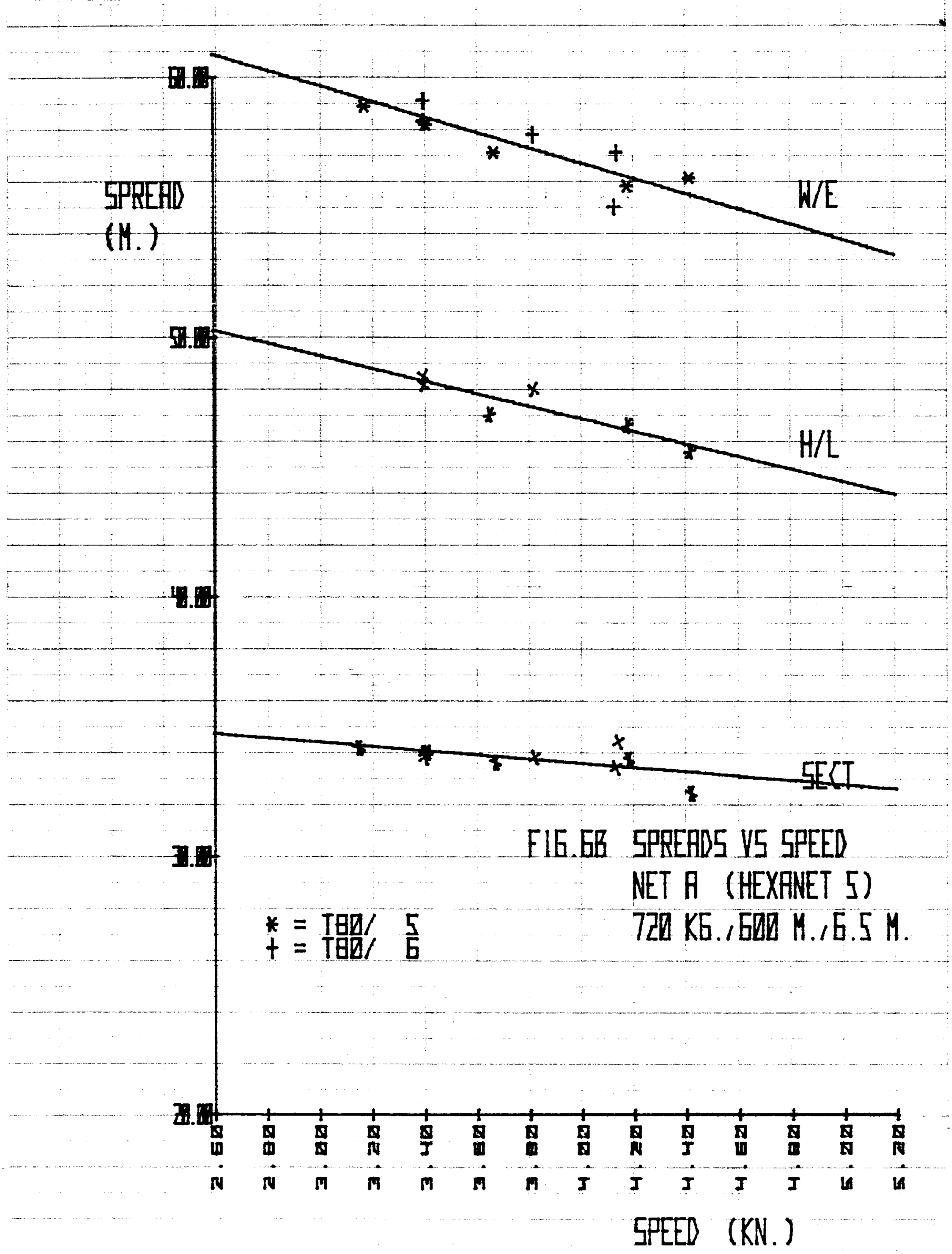


FIG.6B SPREADS VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.

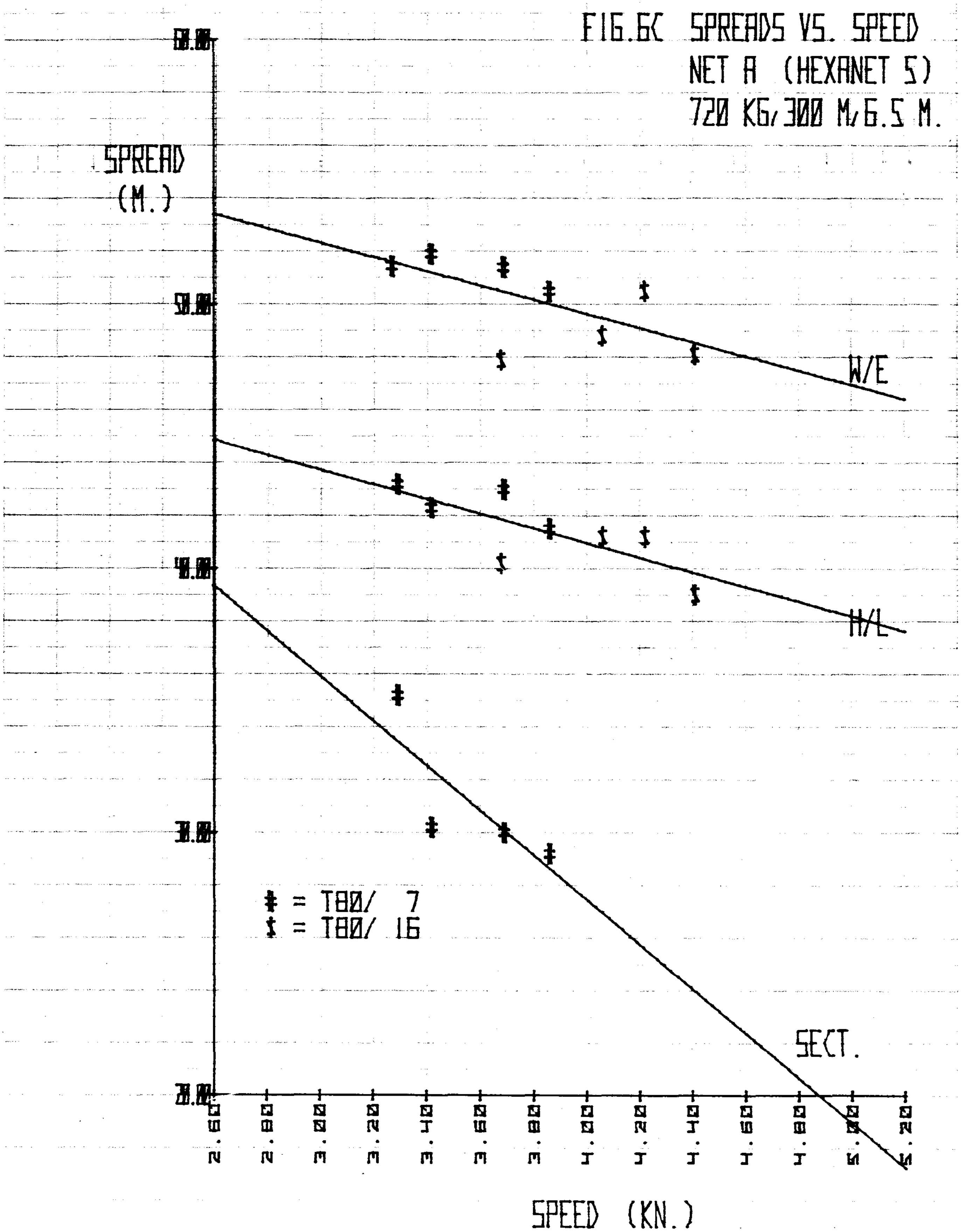


FIG.6C SPREADS VS. SPEED
NET A (HEXANET 5)
720 KG/300 M/6.5 M.
SPREAD
(M.)
W/E
H/L
SECT.
= T80/ 7
= T80/ 16
SPEED (KN.)

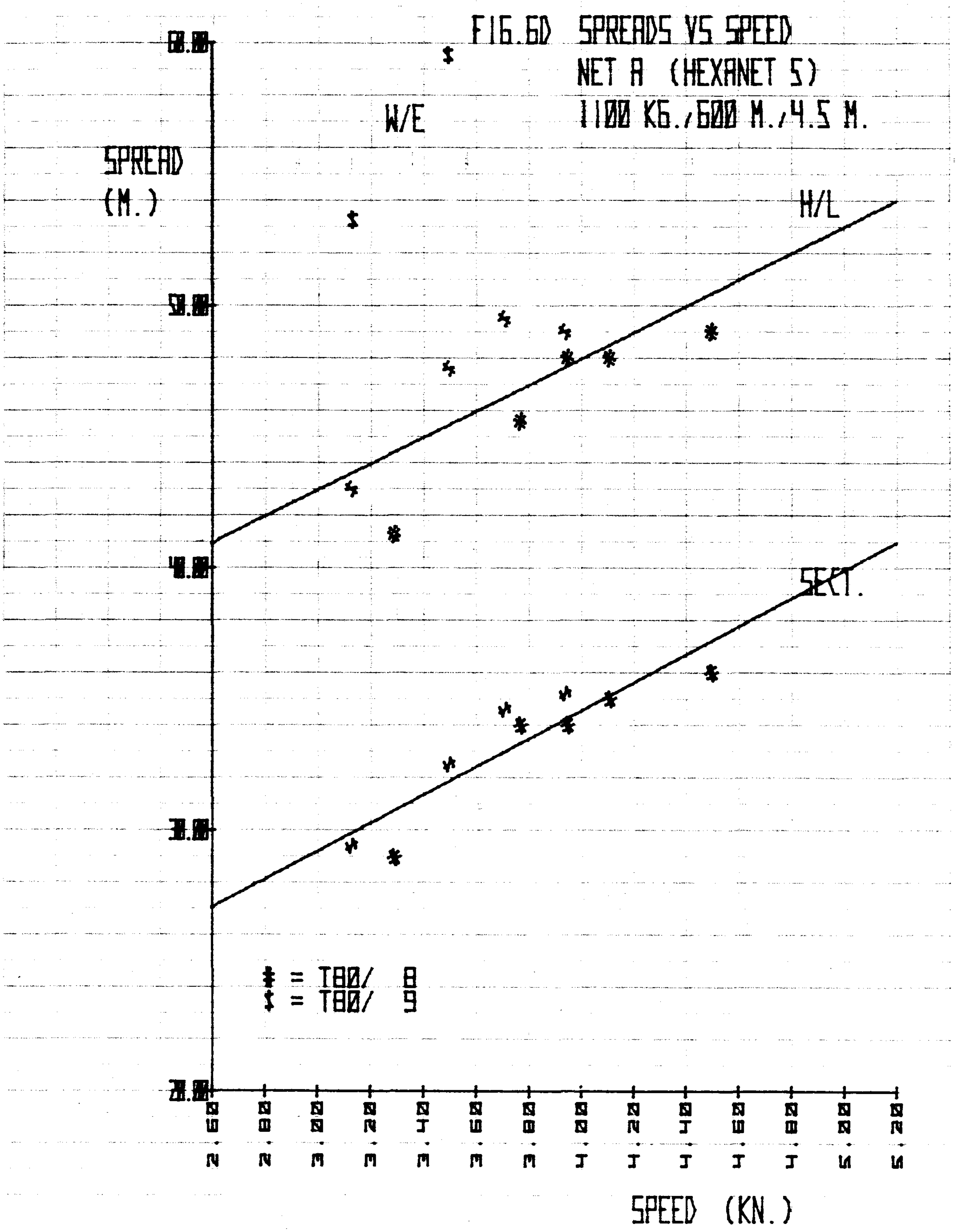


FIG.6D SPREADS VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.
W/E
SPREAD
(M.)
H/L
SECT.
* = T80/ 8
$ = T80/ 9
SPEED (KN.)

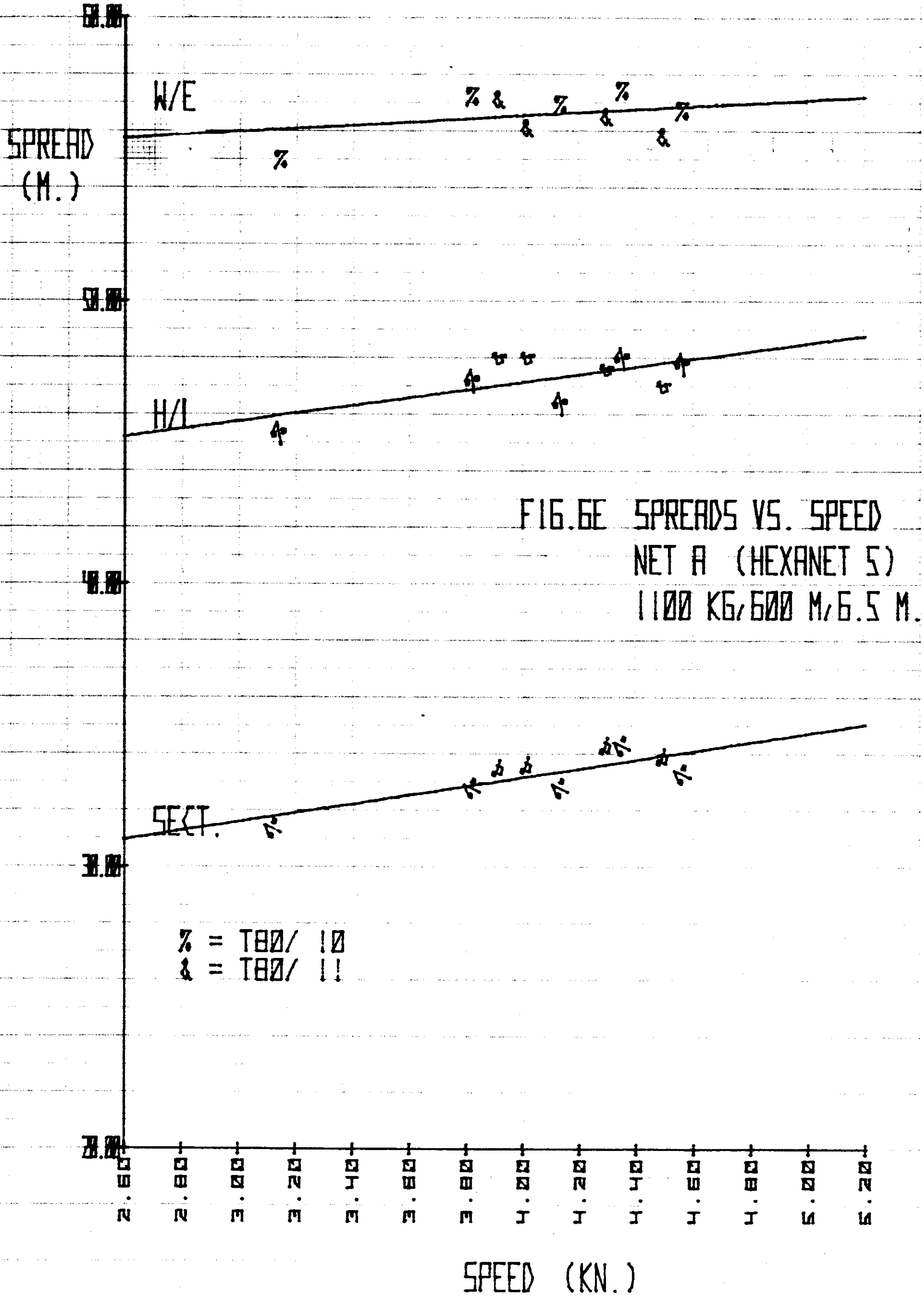


FIG.6E SPREADS VS. SPEED
NET A (HEXANET 5)
1100 KG/600 M/6.5 M.

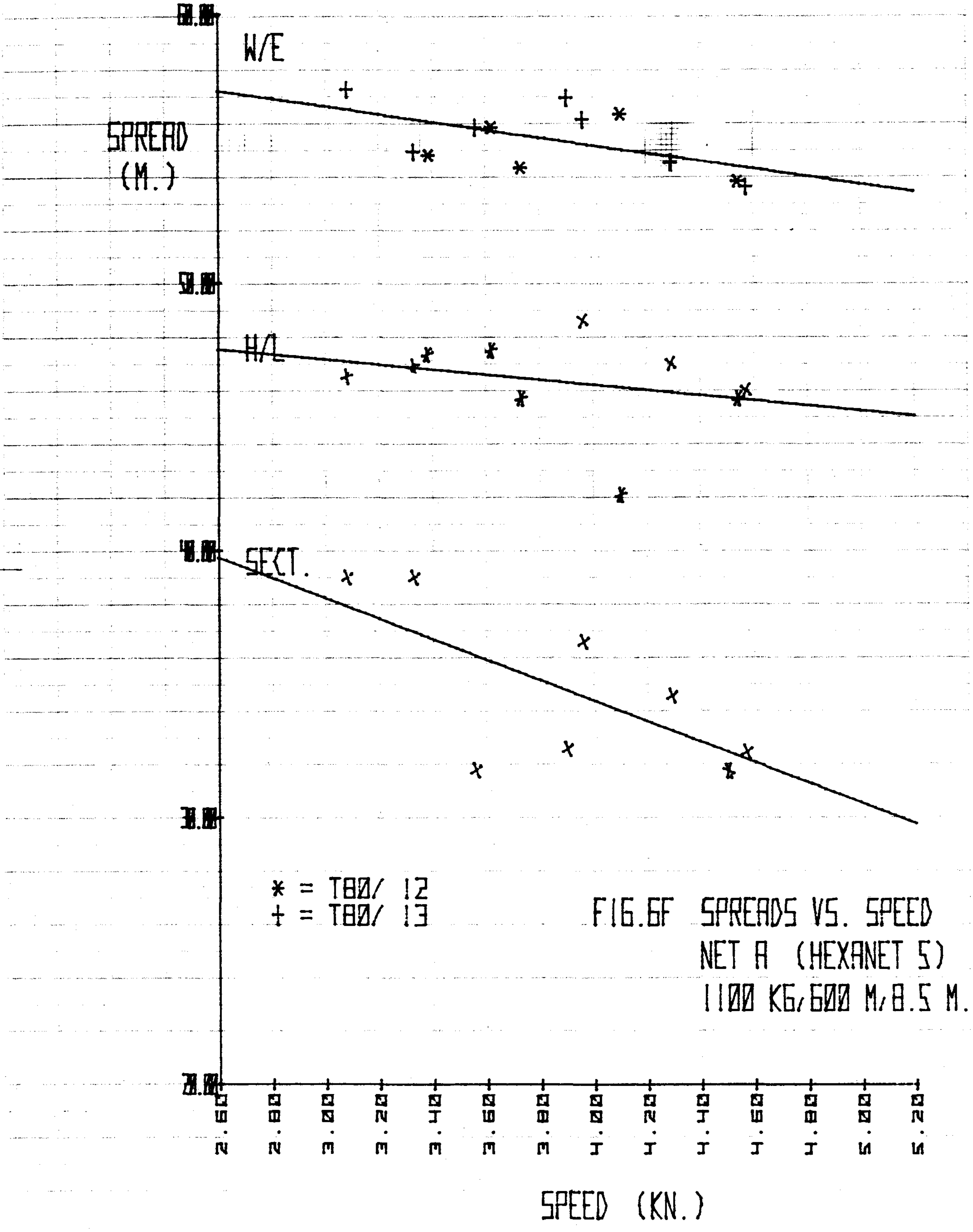


FIG.6F SPREADS VS. SPEED
NET A (HEXANET 5)
1100 KG/600 M/8.5 M.

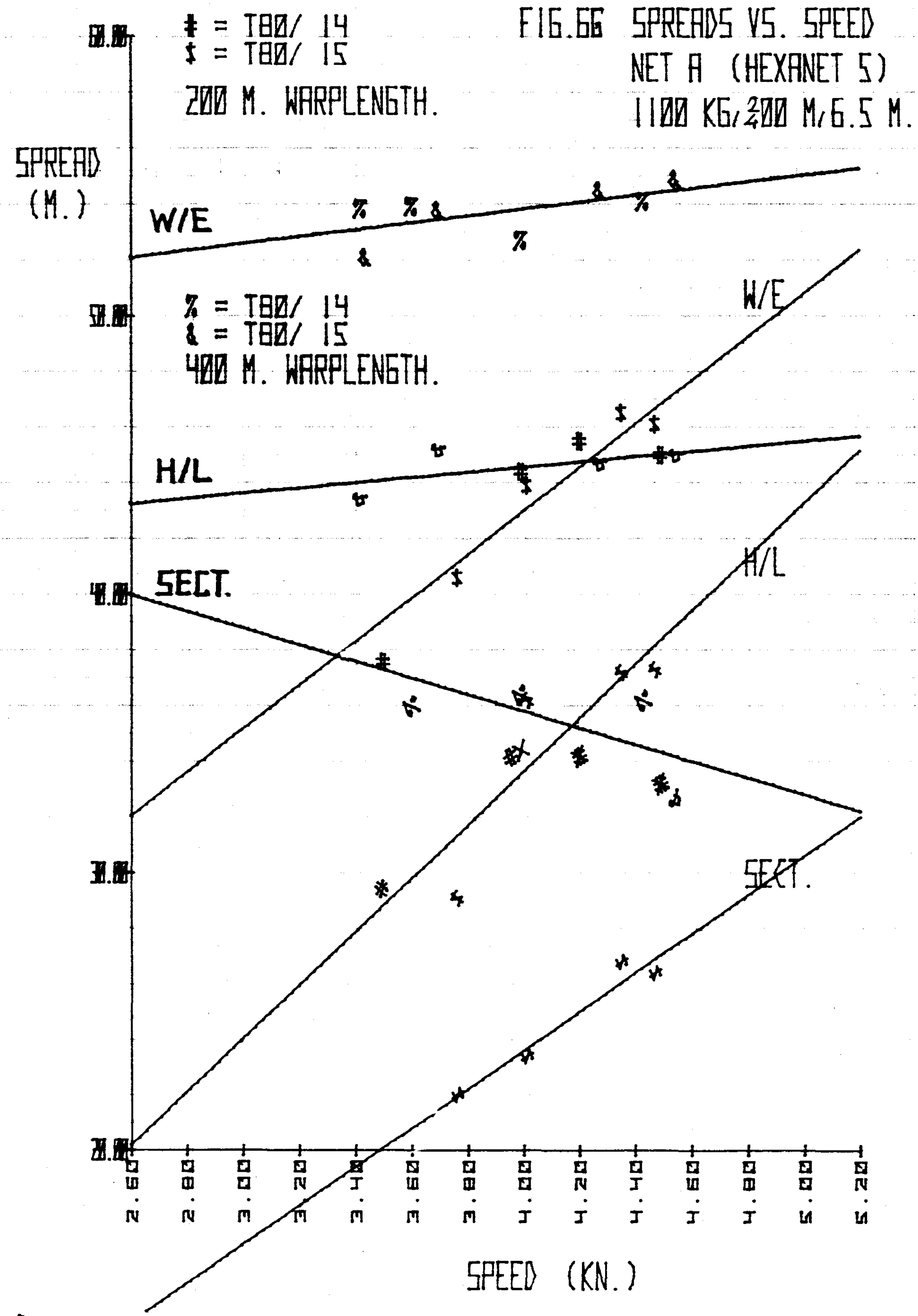


FIG.6G SPREADS VS. SPEED
NET A (HEXANET 5)
1100 KG/200 M/6.5 M.
= T80/ 14
$ = T80/ 15
200 M. WARPLENGTH.
% = T80/ 14
& = T80/ 15
400 M. WARPLENGTH.
SPREAD
(M.)
W/E
H/L
SECT.
W/E
H/L
SECT.
SPEED (KN.)

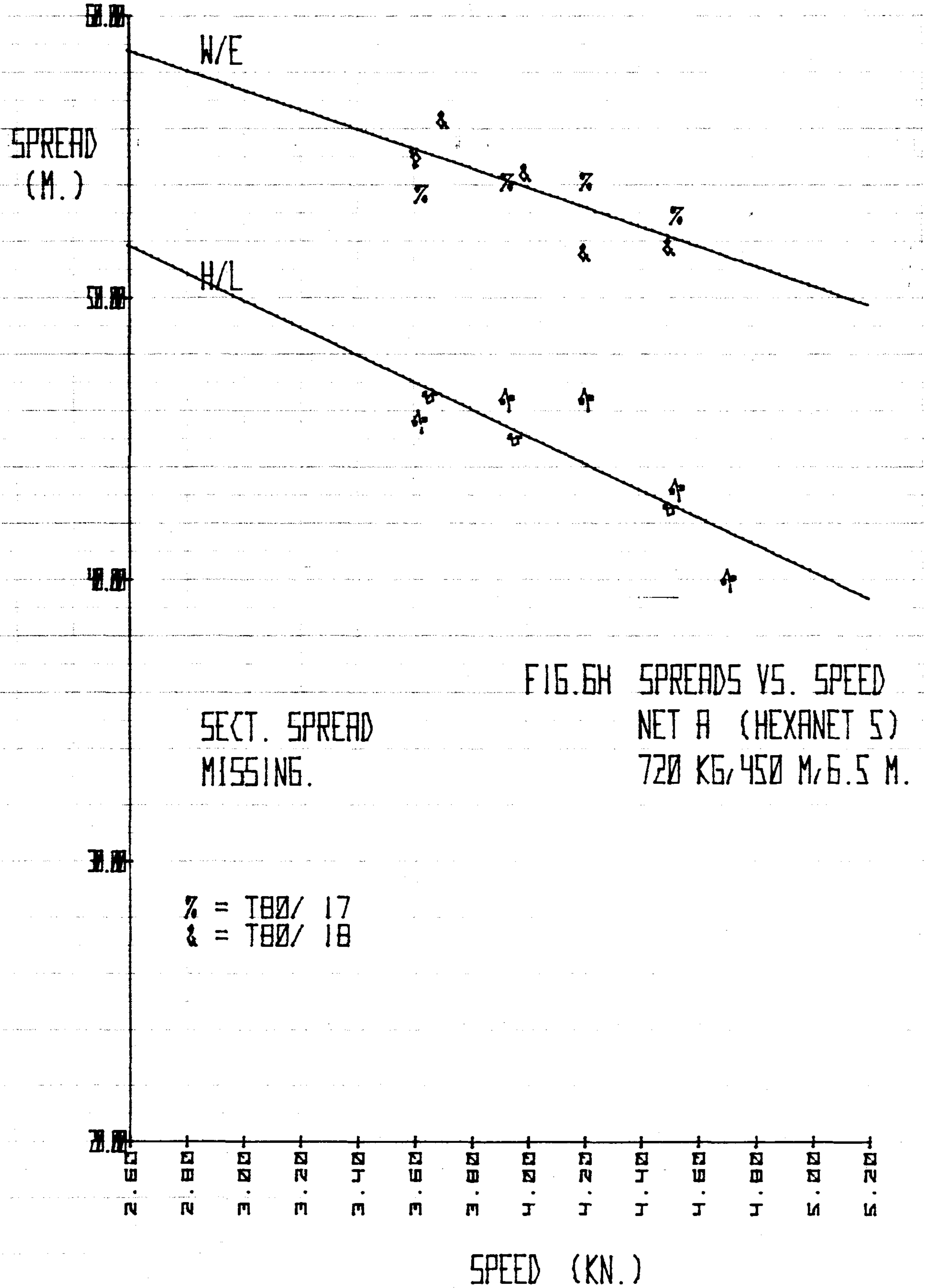


FIG.6H SPREADS VS. SPEED
NET A (HEXANET 5)
720 KG/450 M/6.5 M.

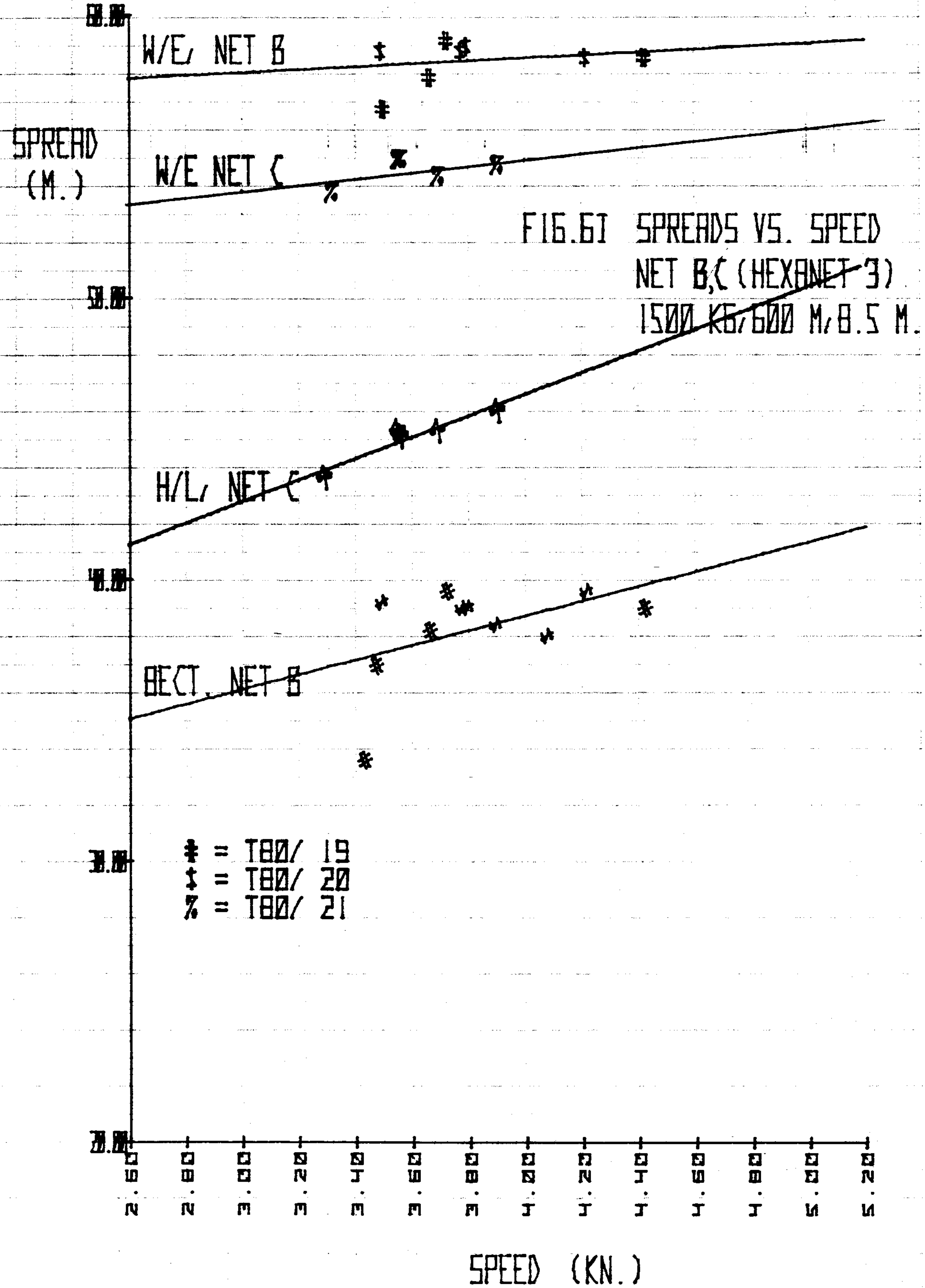


FIG.61 SPREADS VS. SPEED
NET B,C (HEXANET 3)
1500 KG/600 M/8.5 M.

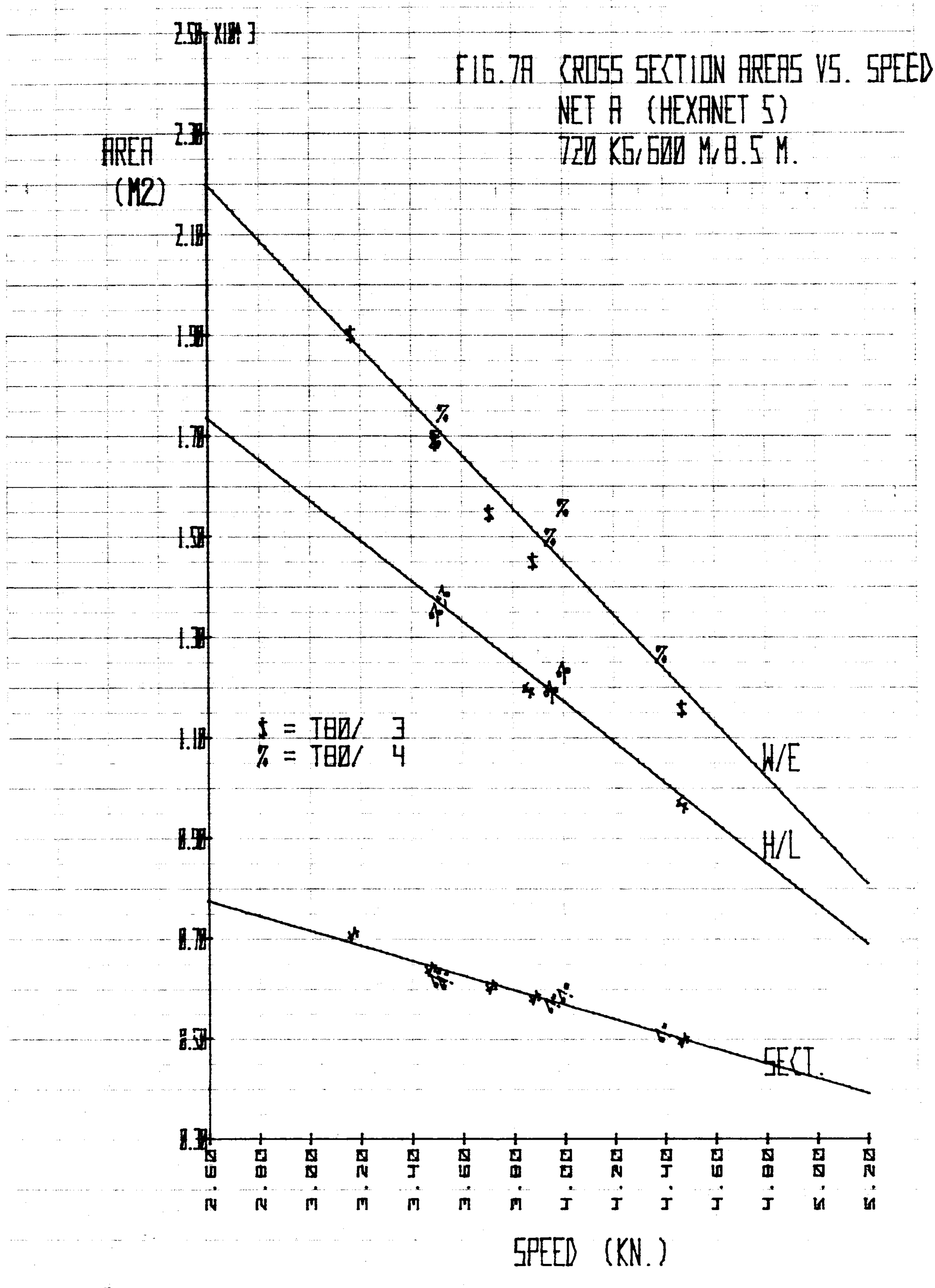


FIG.7A CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
720 KG/600 M/8.5 M.

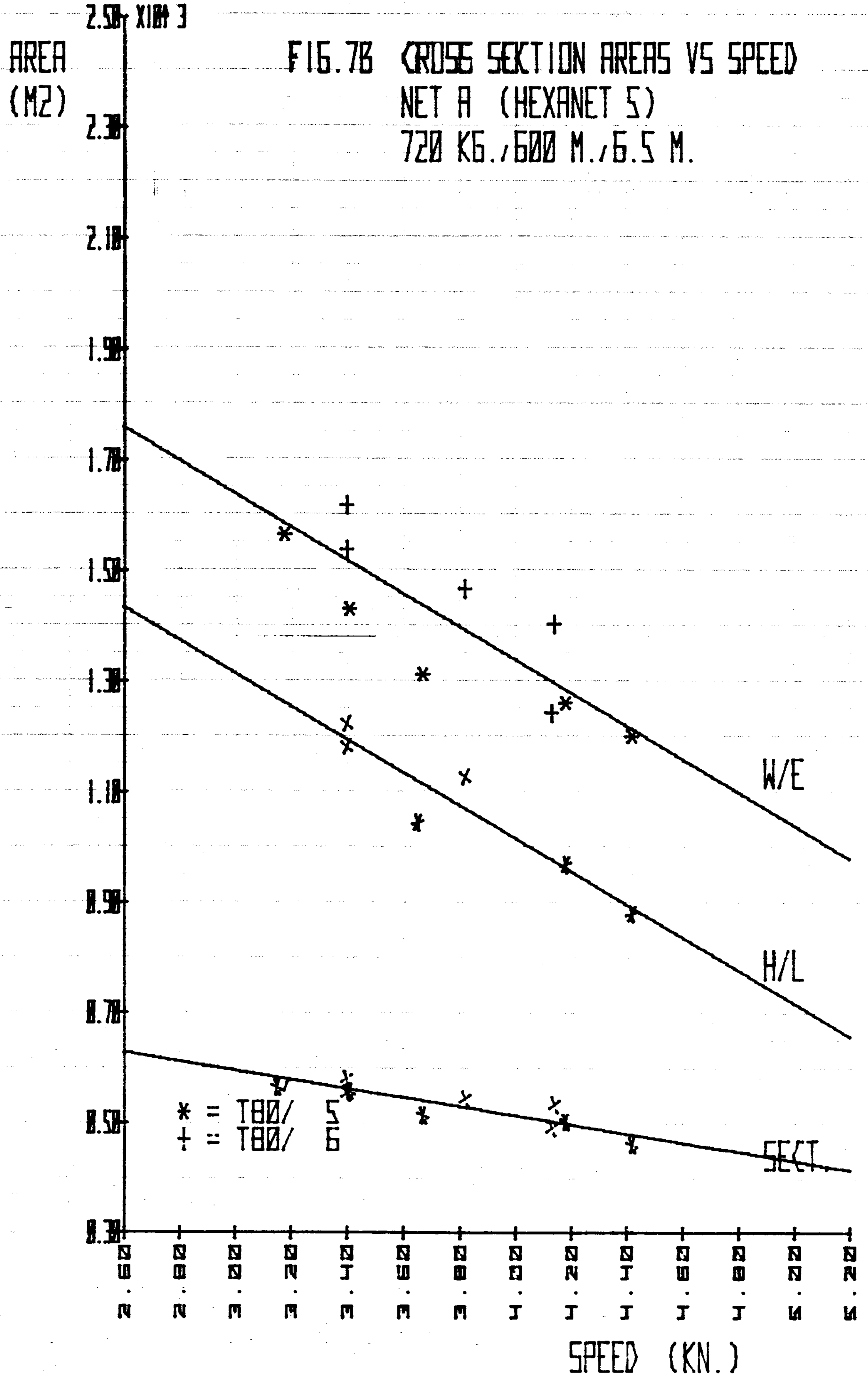


FIG.7B CROSS SECTION AREAS VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.
AREA
(M2)
X10 3
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
W/E
H/L
SECT.
* = T80/ 5
+ = T80/ 6
SPEED (KN.)

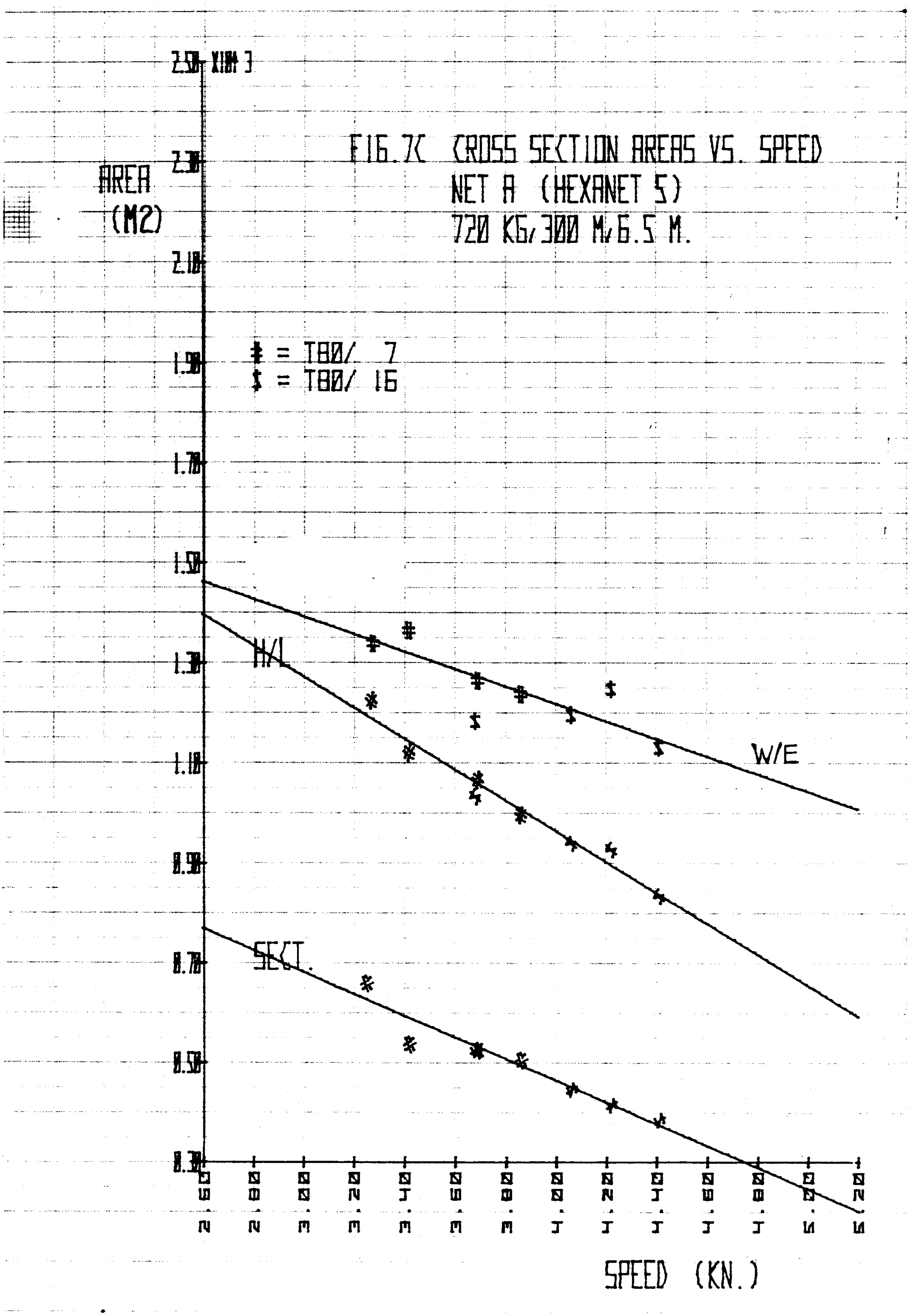


FIG.7C CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
720 KG/300 M/6.5 M.
AREA (M2)
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
= T80/ 7
$ = T80/ 16
H/L
W/E
SECT.
SPEED (KN.)

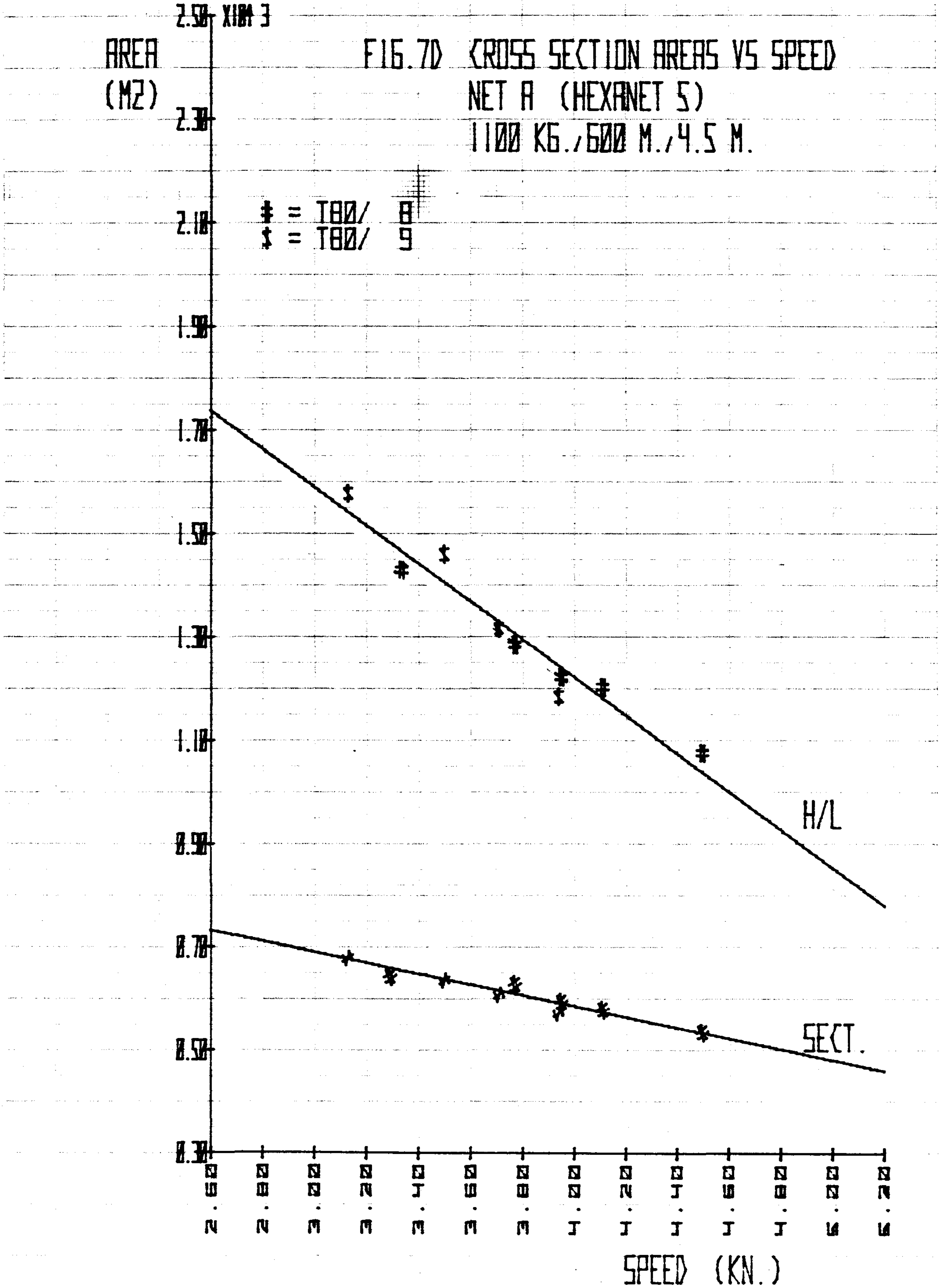


FIG. 7D (CROSS SECTION AREAS VS SPEED)
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.
AREA
(M2)
= T80/ 8
$ = T80/ 9
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
H/L
SECT.
SPEED (KN.)

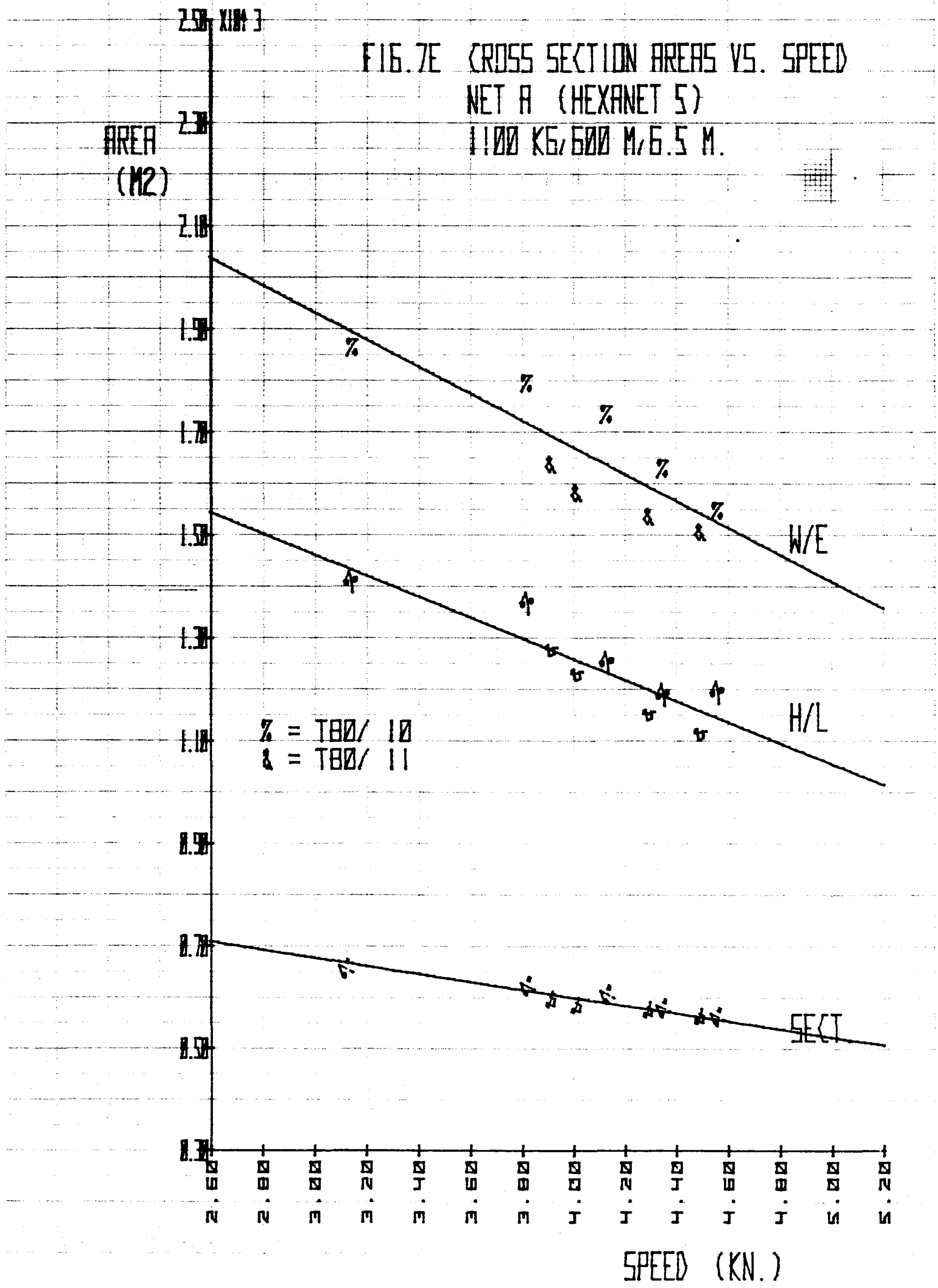


FIG. 7E CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
1100 KG/600 M/6.5 M.
AREA
(M2)
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
W/E
H/L
SECT
% = T80/ 10
& = T80/ 11
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

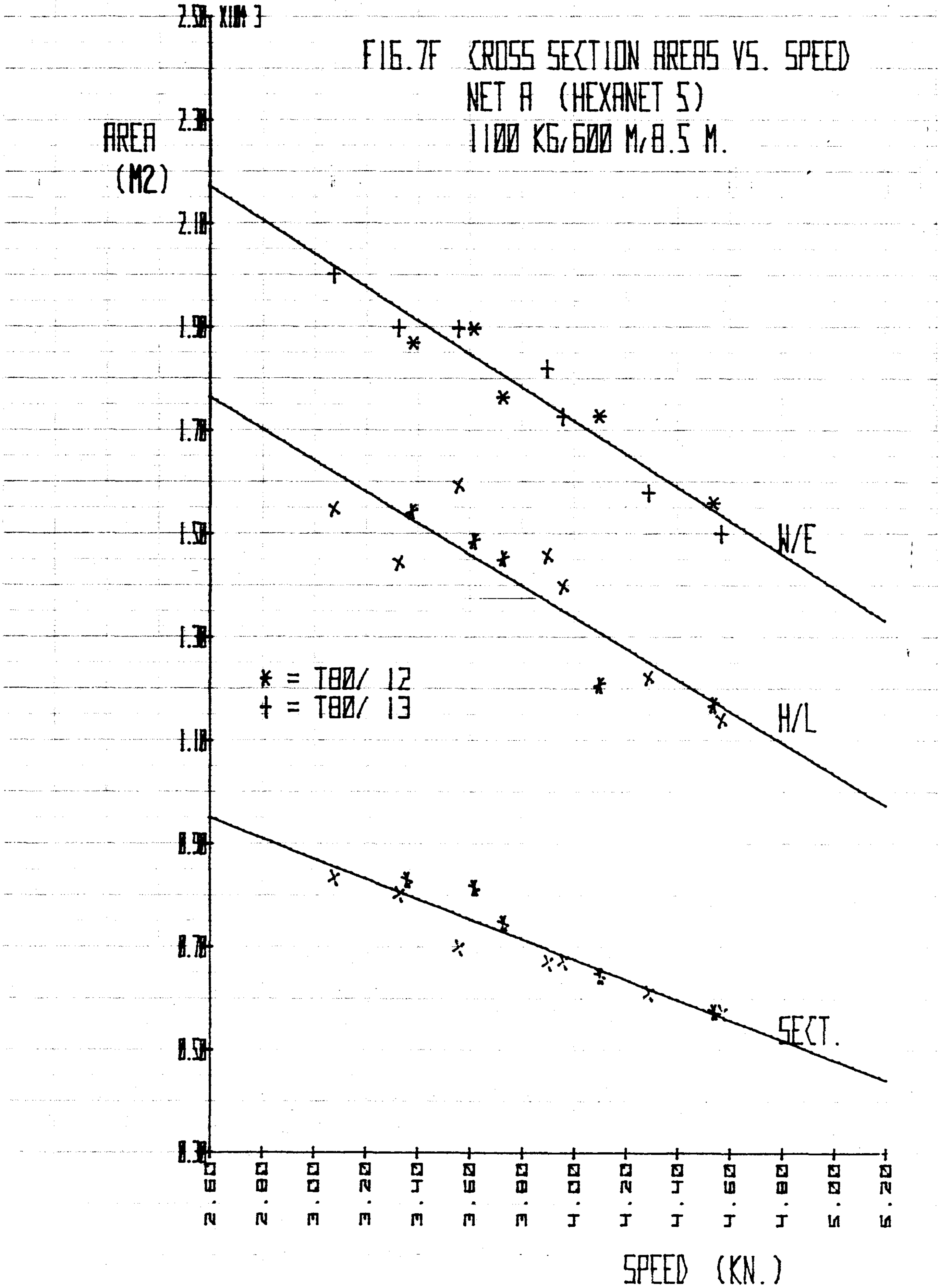


FIG.7F CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
1100 KG/600 M/8.5 M.
AREA
(M2)
2.50
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
* = T80/ 12
+ = T80/ 13
H/E
H/L
SECT.
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

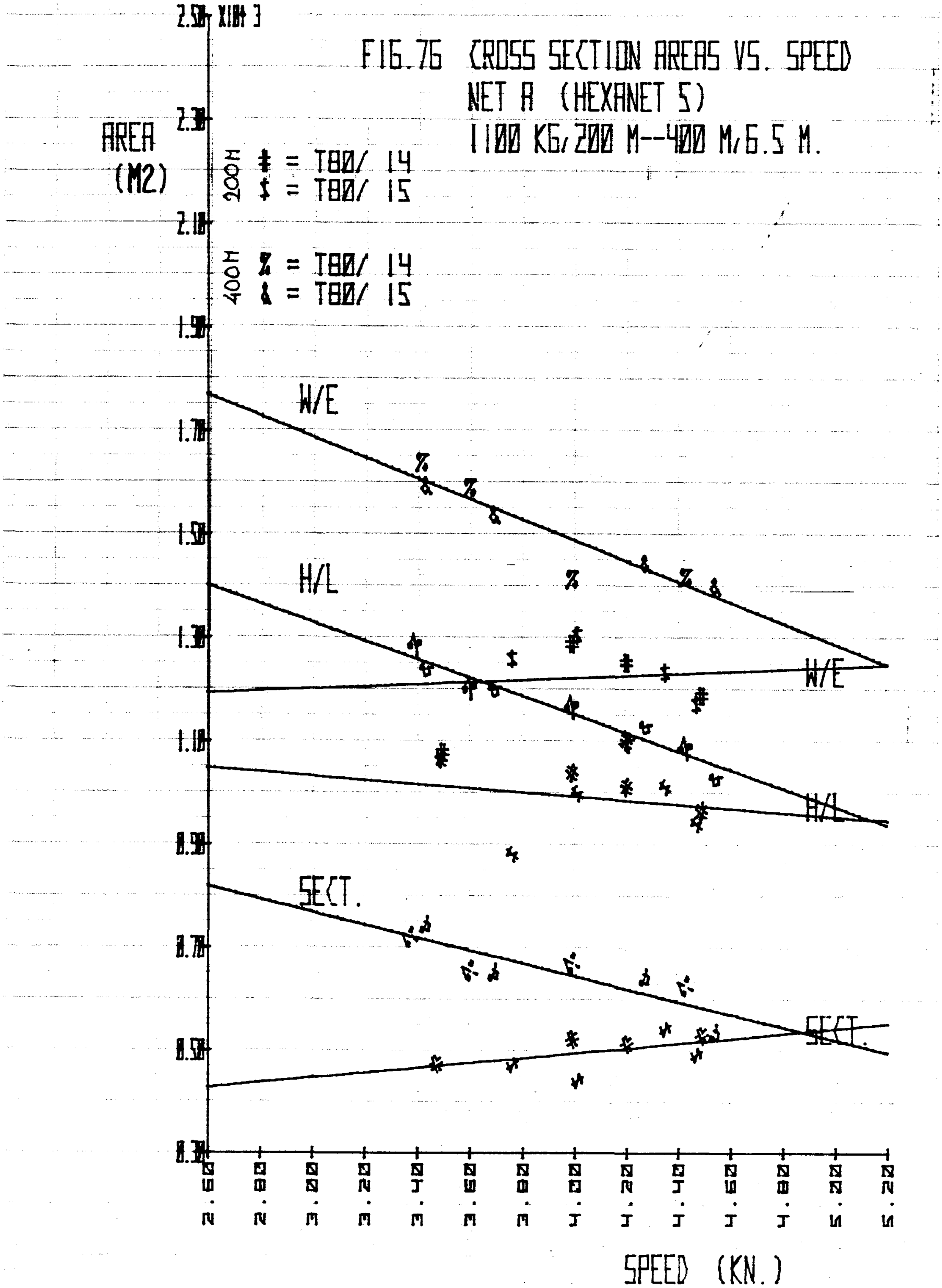


FIG.76 CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
1100 KG/200 M--400 M/6.5 M.

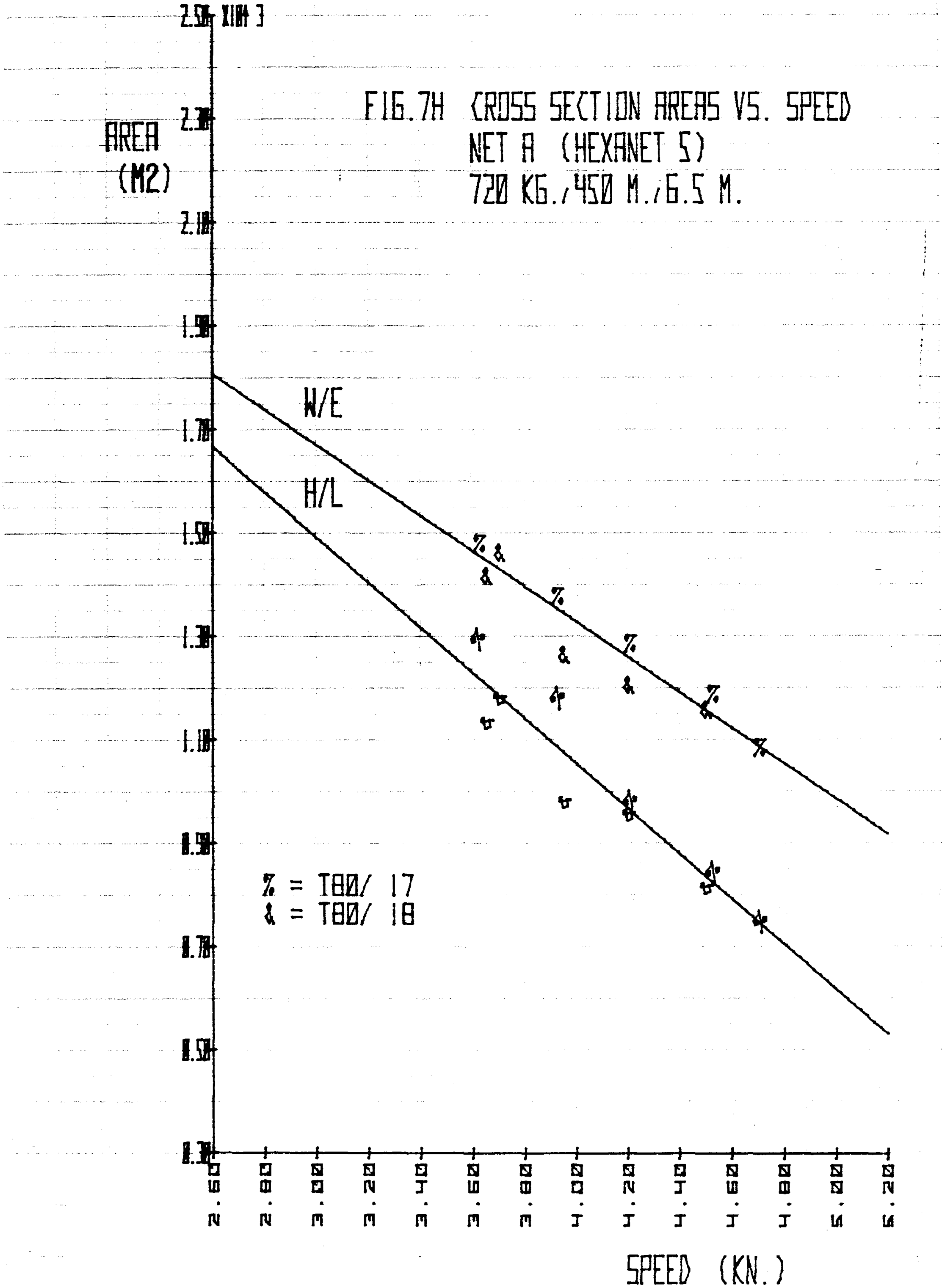


FIG.7H CROSS SECTION AREAS VS. SPEED
NET A (HEXANET 5)
720 KG./450 M./6.5 M.
AREA (M2)
W/E
H/L
% = T80/ 17
& = T80/ 18
SPEED (KN.)

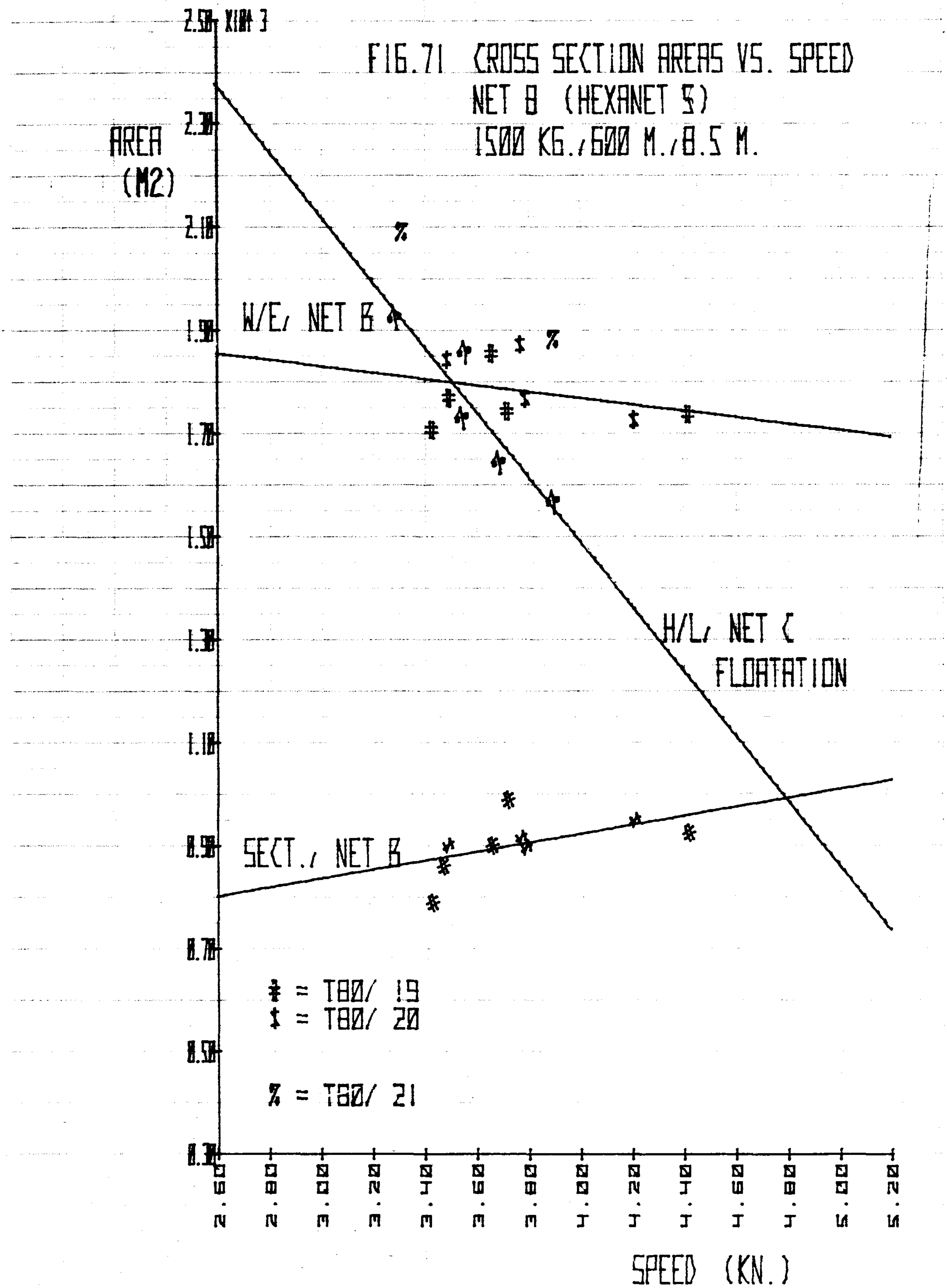


FIG.71 CROSS SECTION AREAS VS. SPEED
NET B (HEXANET 5)
1500 KG./600 M./8.5 M.
AREA (M2)
2.50 X10 3
2.30
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
W/E, NET B
H/L, NET C
FLOATATION
SECT., NET B
= T80/ 19
$ = T80/ 20
% = T80/ 21
2.60
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

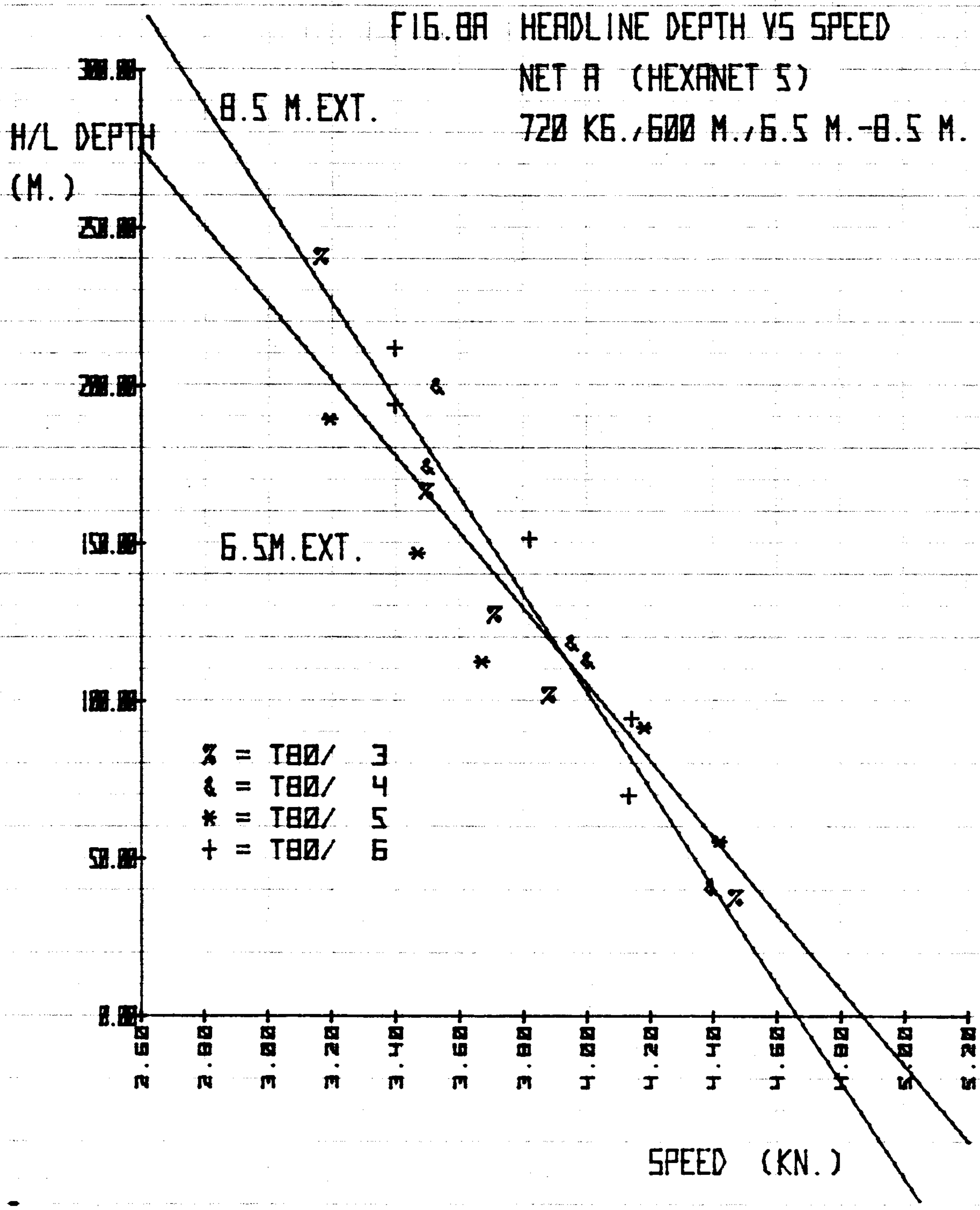


FIG.8A HEADLINE DEPTH VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.-8.5 M.

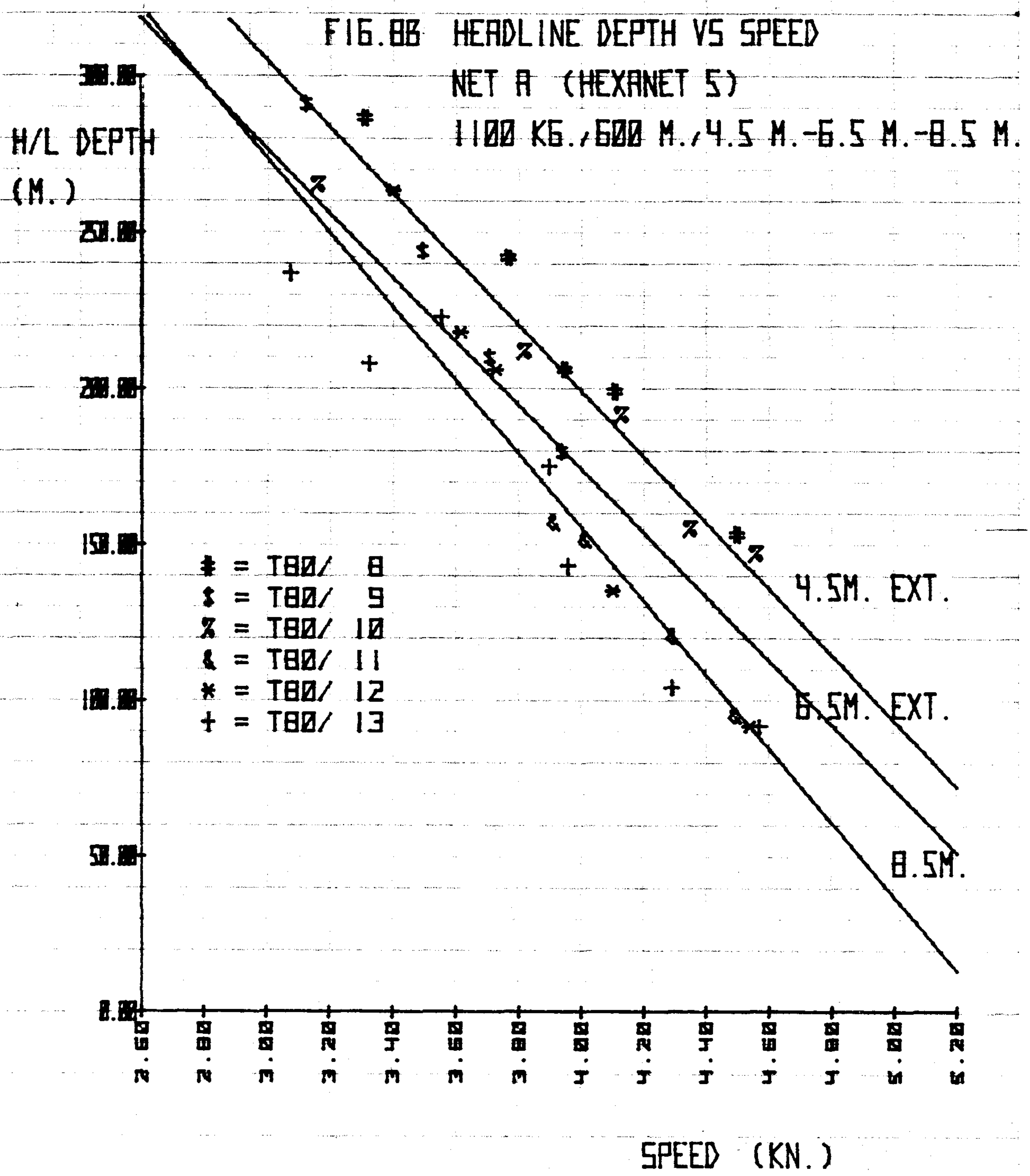


FIG.8B HEADLINE DEPTH VS SPEED

NET A (HEXANET 5)

1100 KG./600 M./4.5 M.-6.5 M.-8.5 M.

FIG.8C HEADLINE DEPTH VS. SPEED
NET A (HEXANET 5)
720 KG. BRIDLEWEIGHT
6.5 M. BRIDLE EXTENSION.

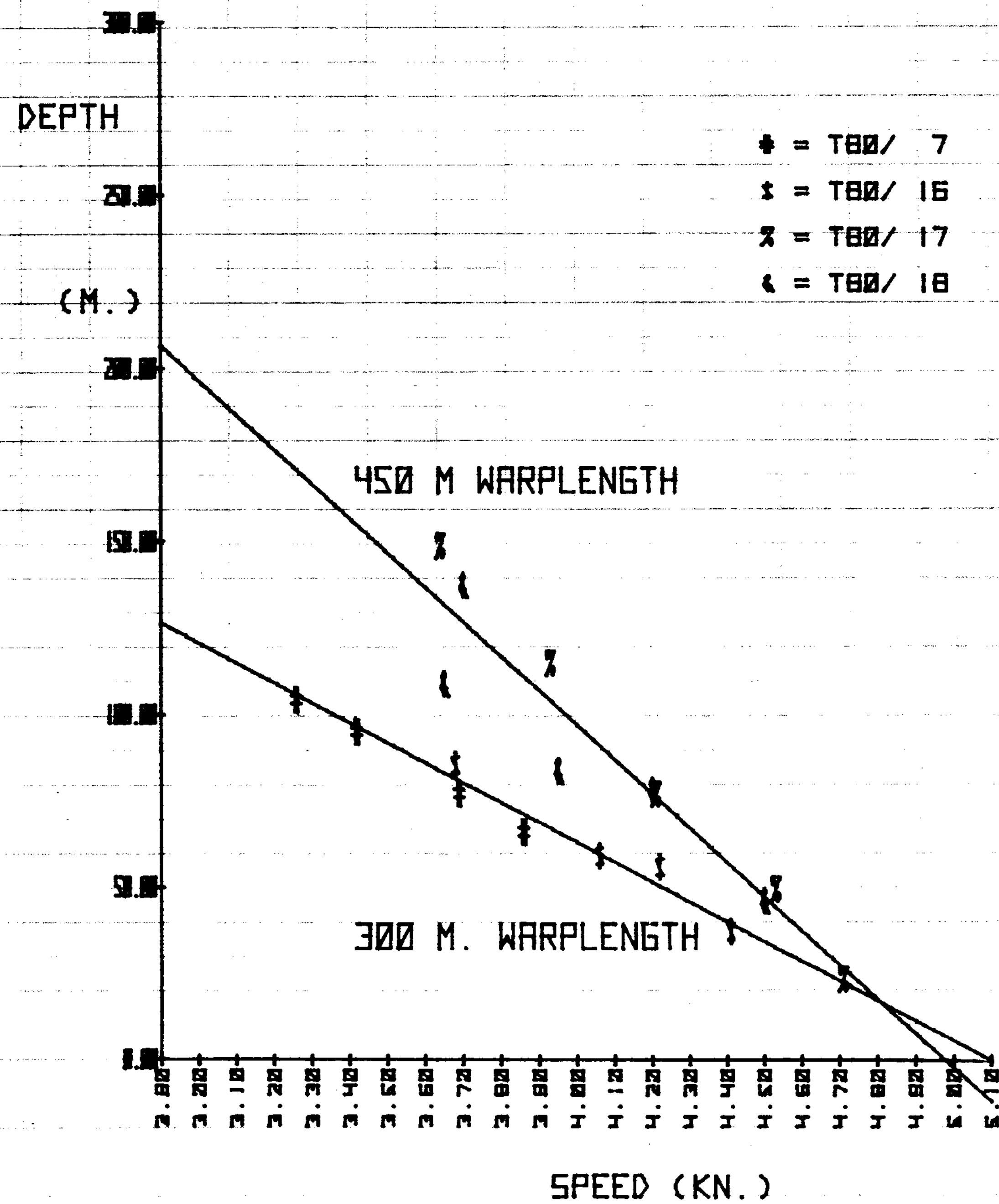


FIG. 8D HEADLINEDEPTHVS. SPEED
NET A(HEXANET 5)
1100 KG. BRIDLE WEIGHT
6.5 M. BRIDLE EXTENSION.

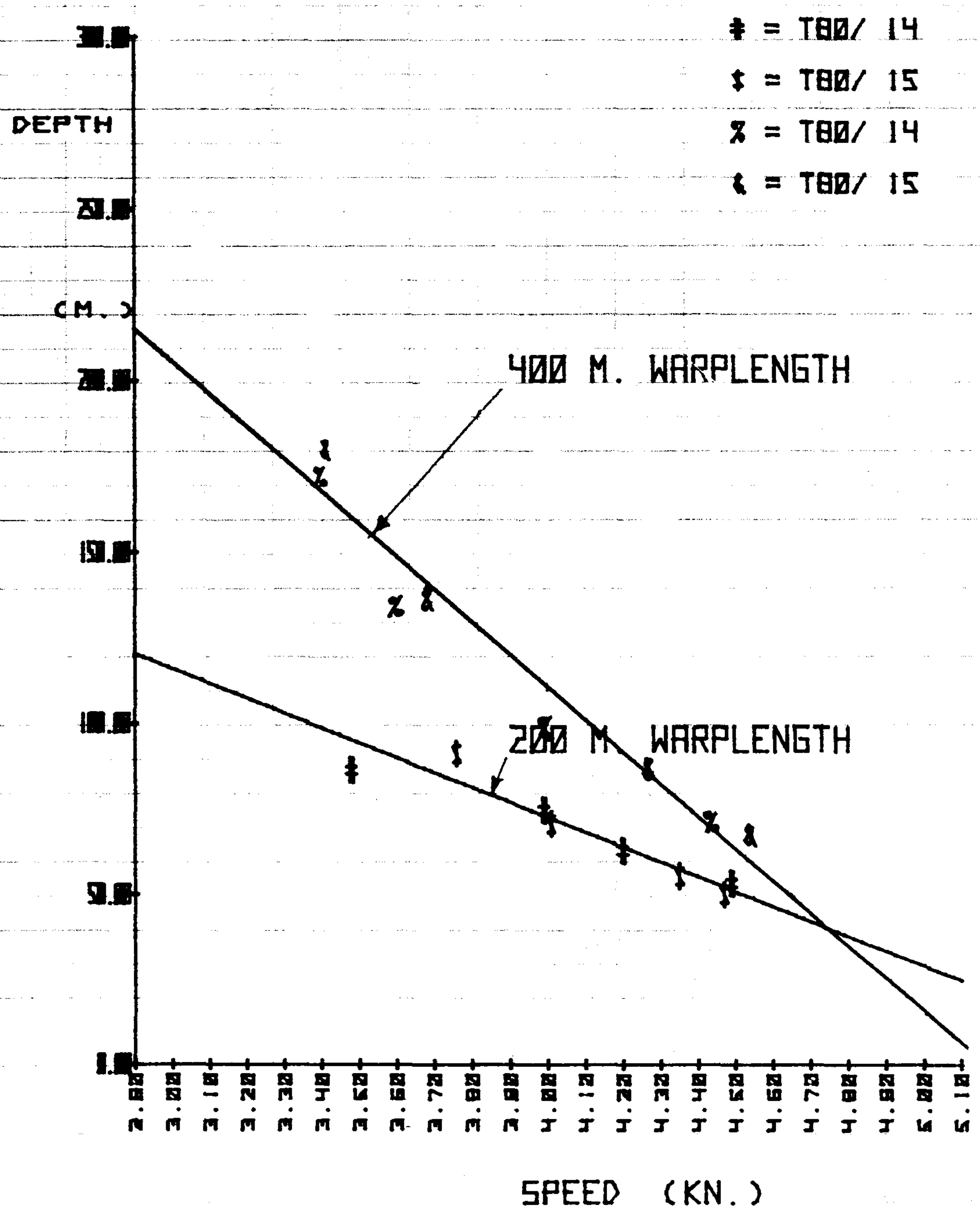
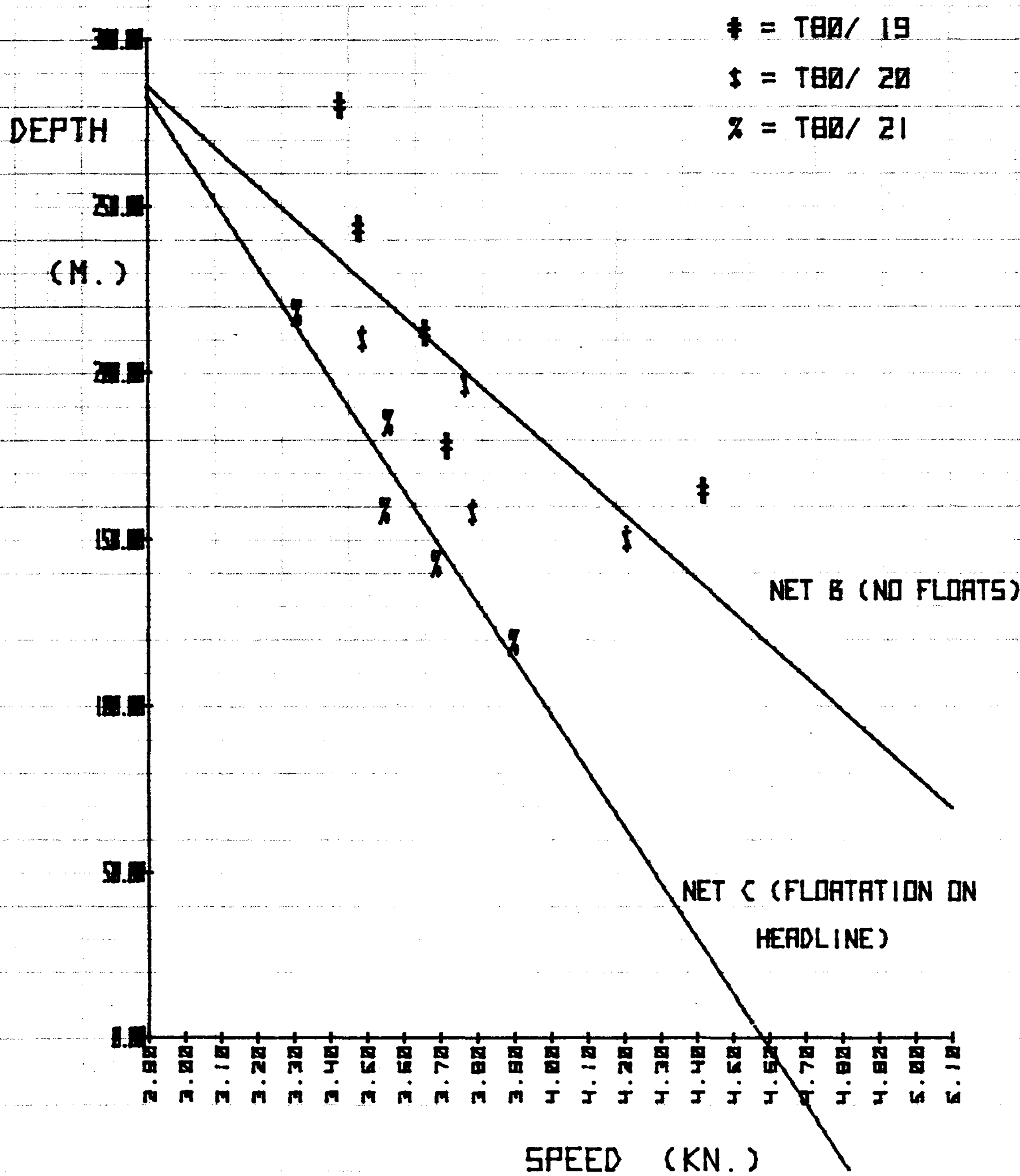


FIG. 8E HEADLINE DEPTH VS. SPEED
NETS B AND C (HEXANET 3)
1500 KG. BRIDLE WEIGHT
8.5 M. BRIDLEEXTENSION.



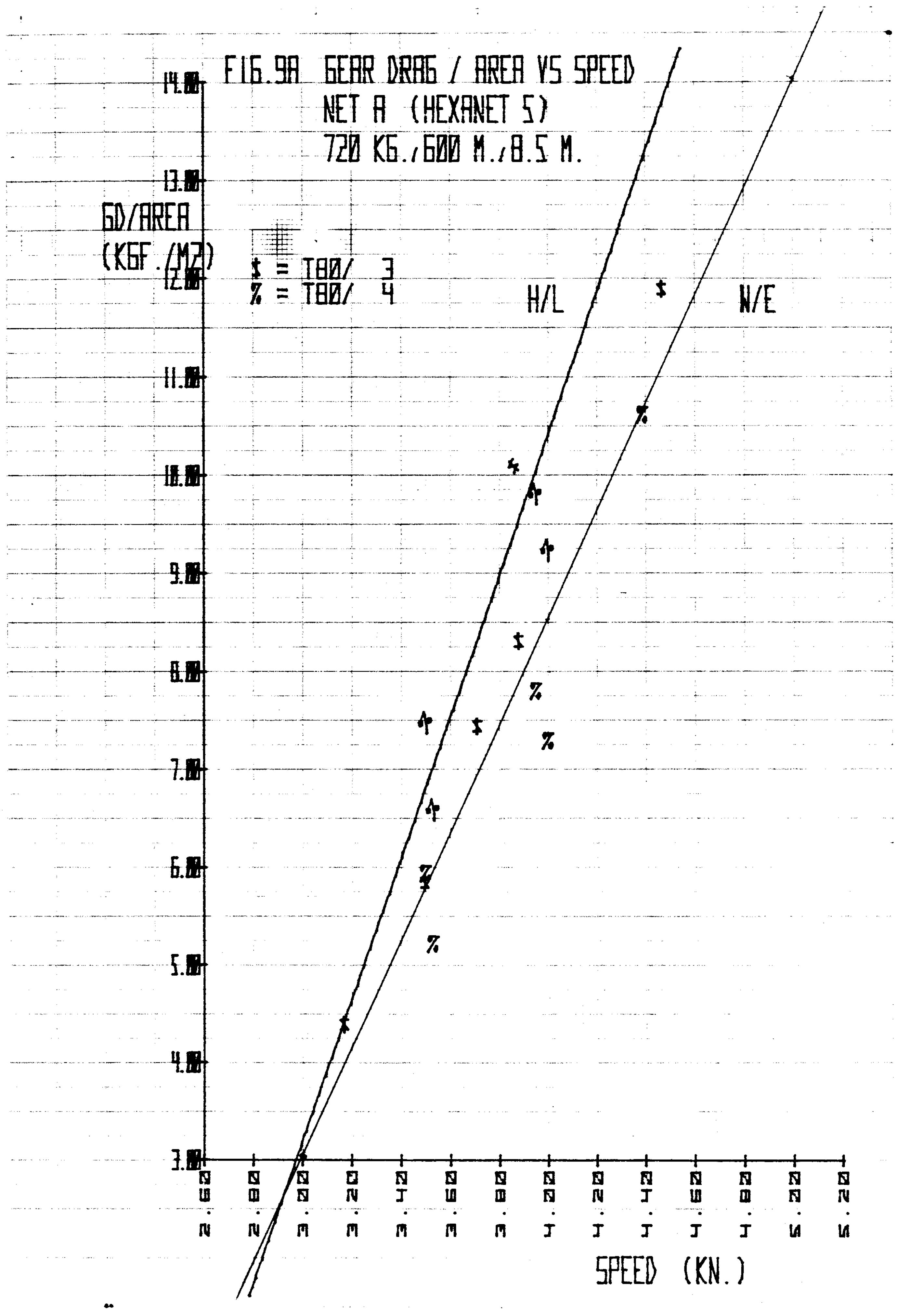


FIG.9A GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
720 KG./600 M./8.5 M.
GD/AREA
(KGF./M2)
$ = T80/ 3
% = T80/ 4
H/L
W/E
SPEED (KN.)

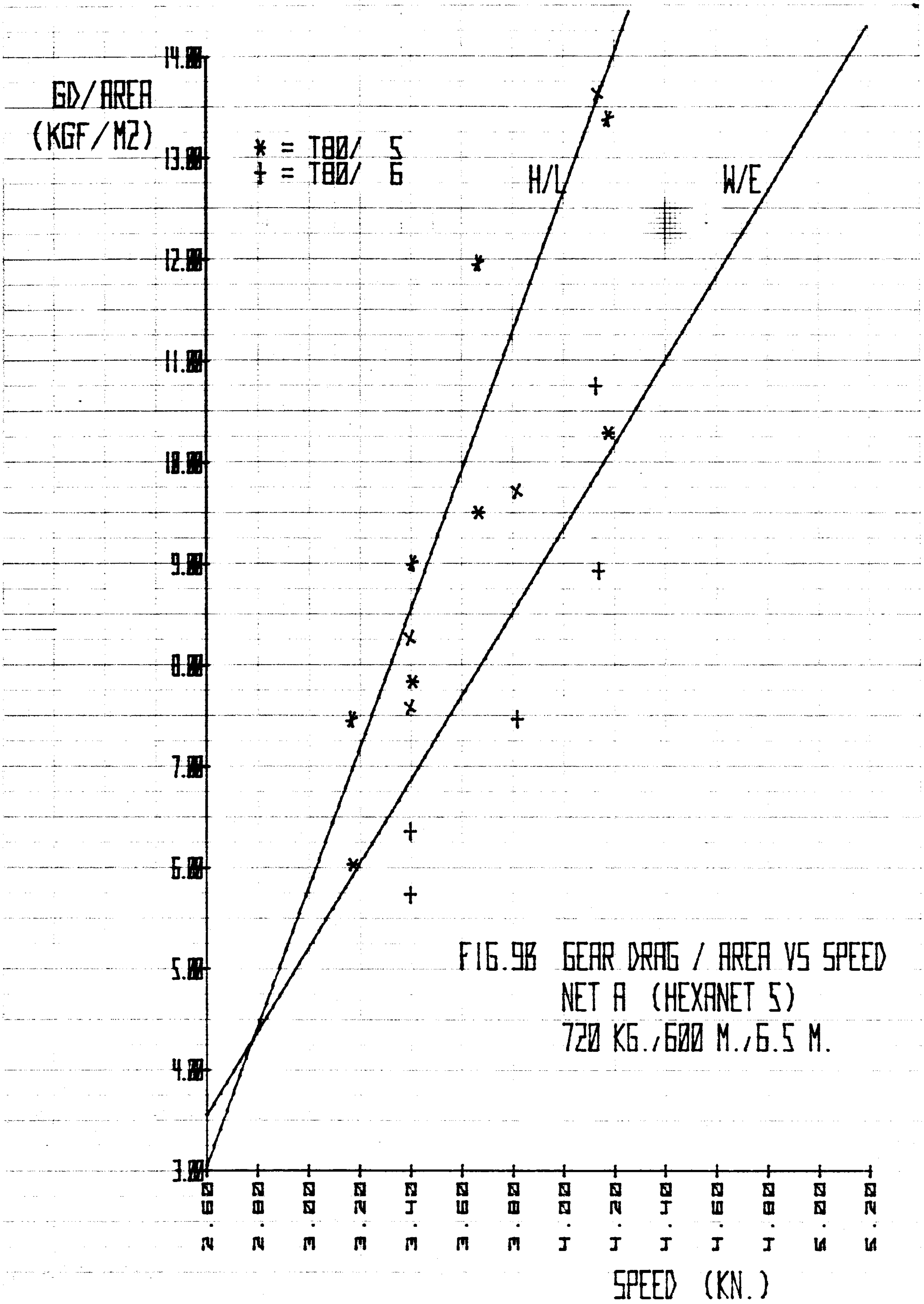


FIG.9B GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.

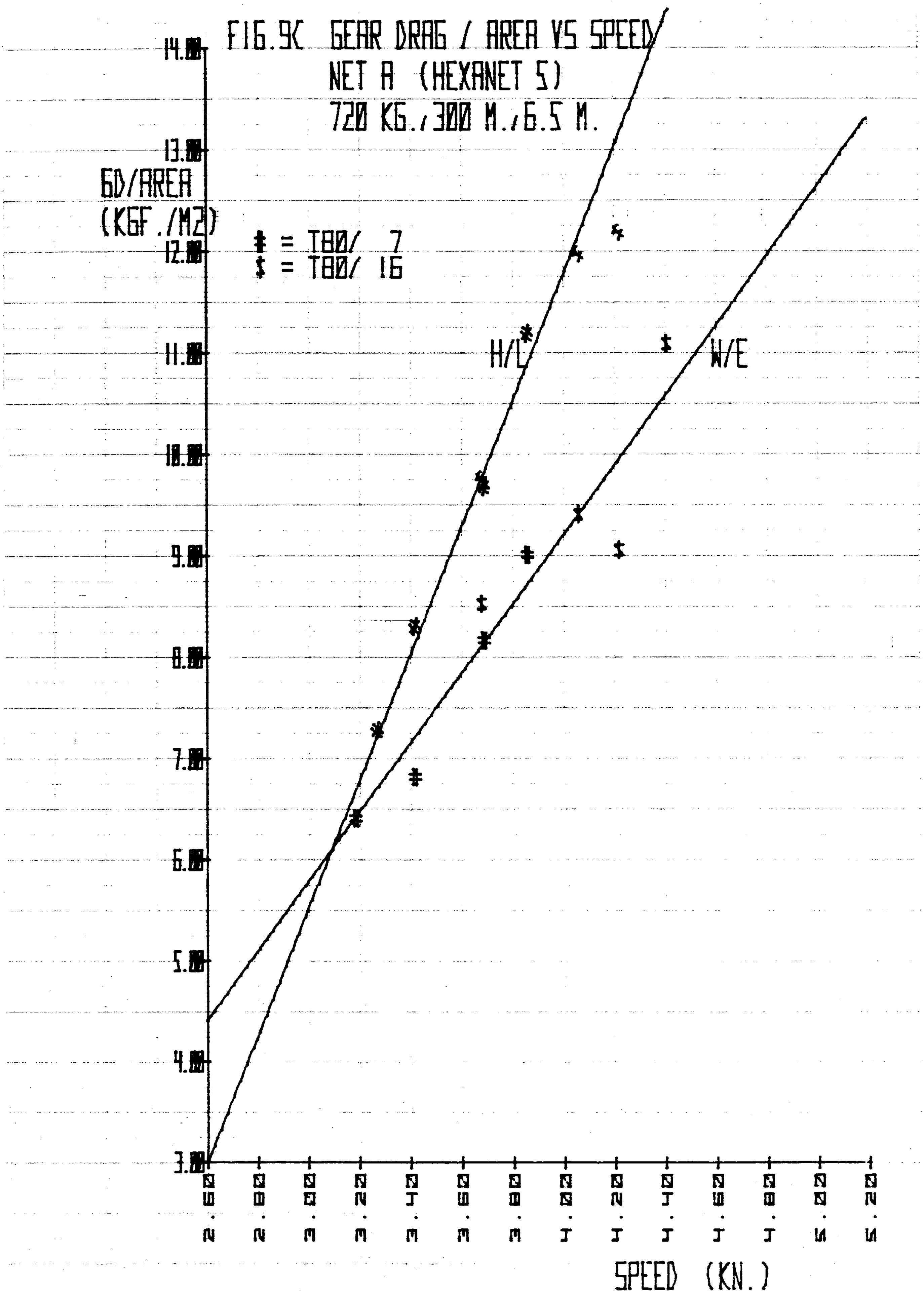


FIG.9C GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
720 KG./300 M./6.5 M.
GD/AREA
(KGF./M2)
= T80/ 7
$ = T80/ 16
H/L
W/E
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
SPEED (KN.)

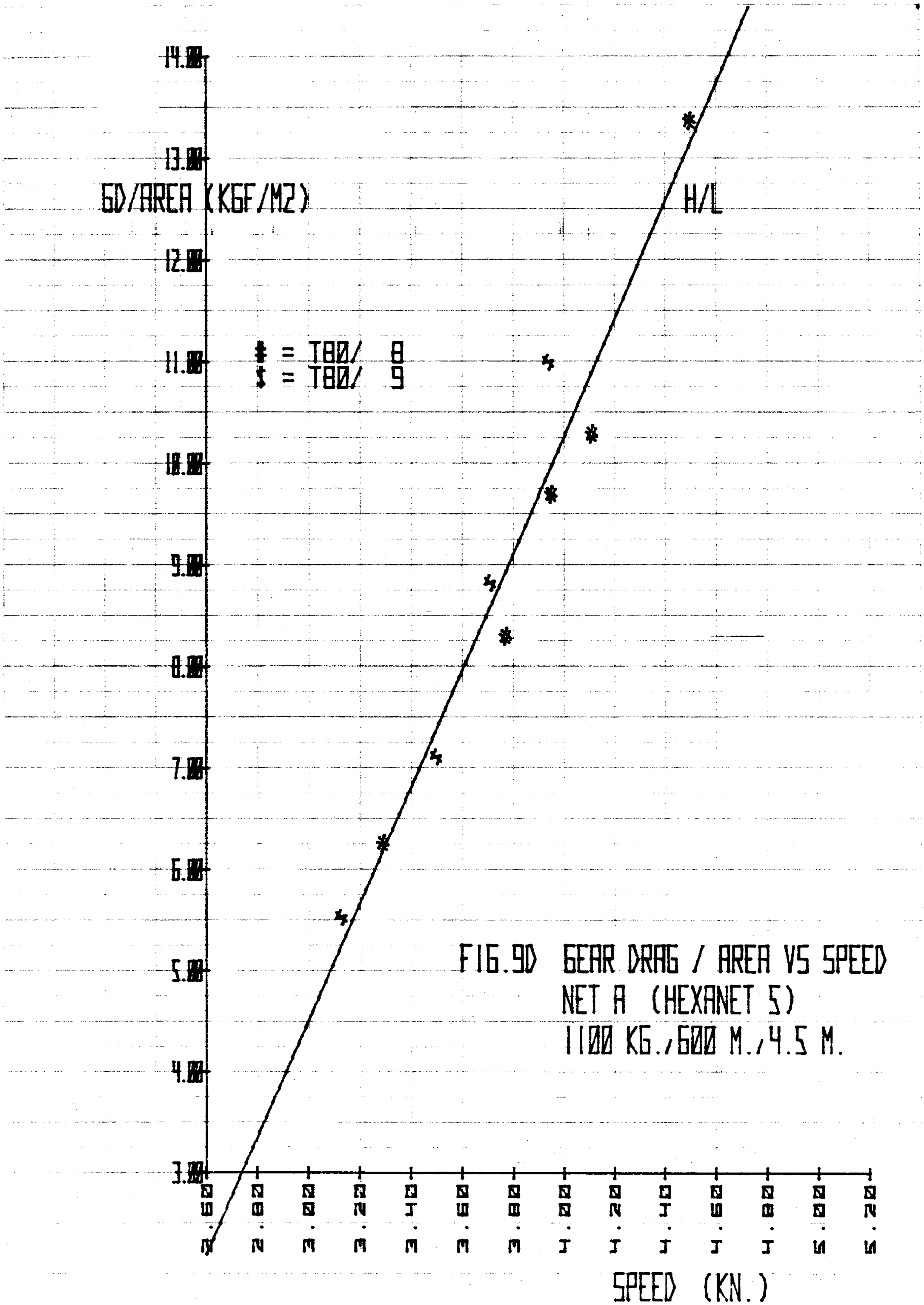


FIG.9D GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.

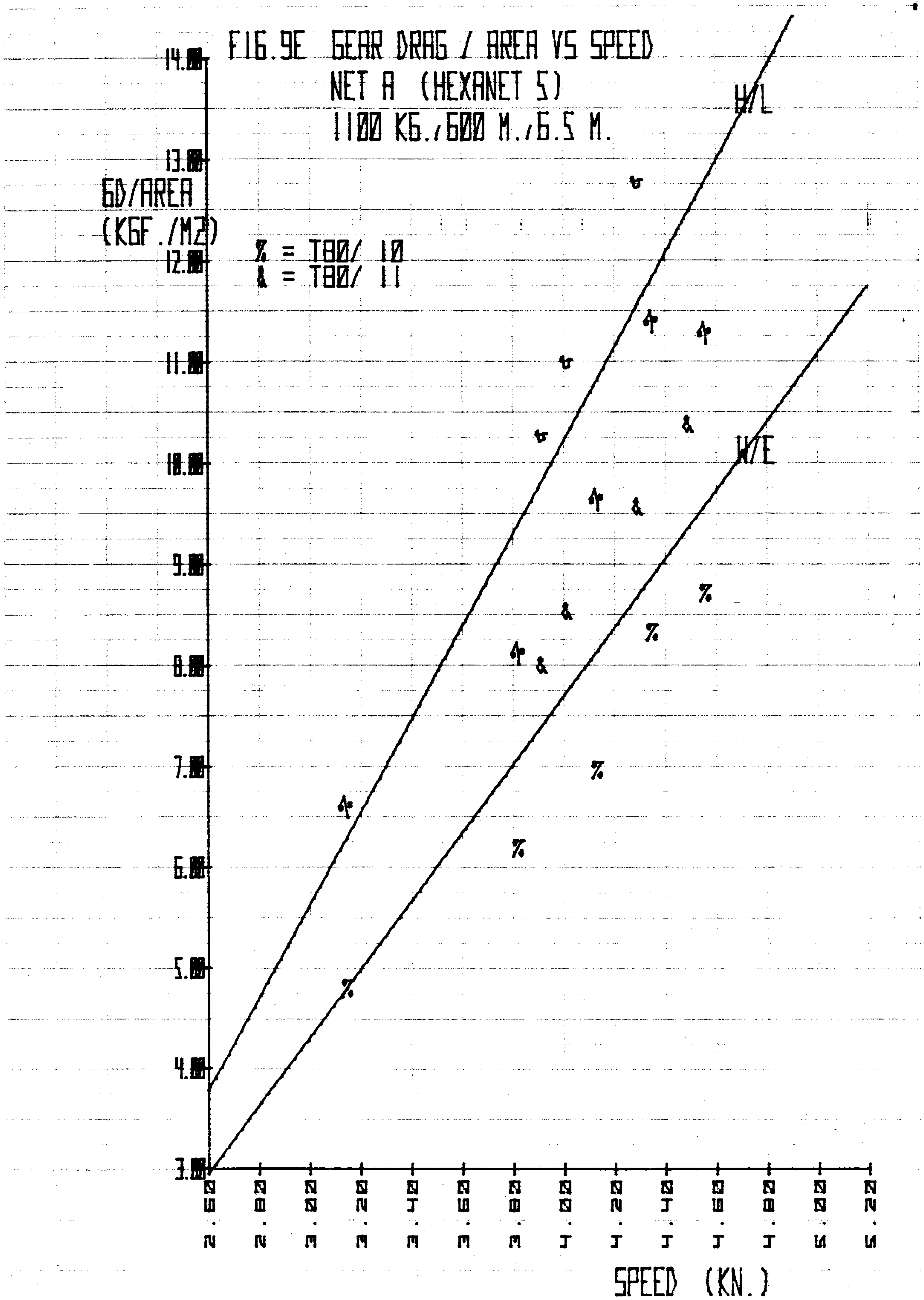


FIG.9E GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./6.5 M.
GD/AREA
(KGF./M2)
% = T80/ 10
& = T80/ 11
W/L
W/E
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
SPEED (KN.)

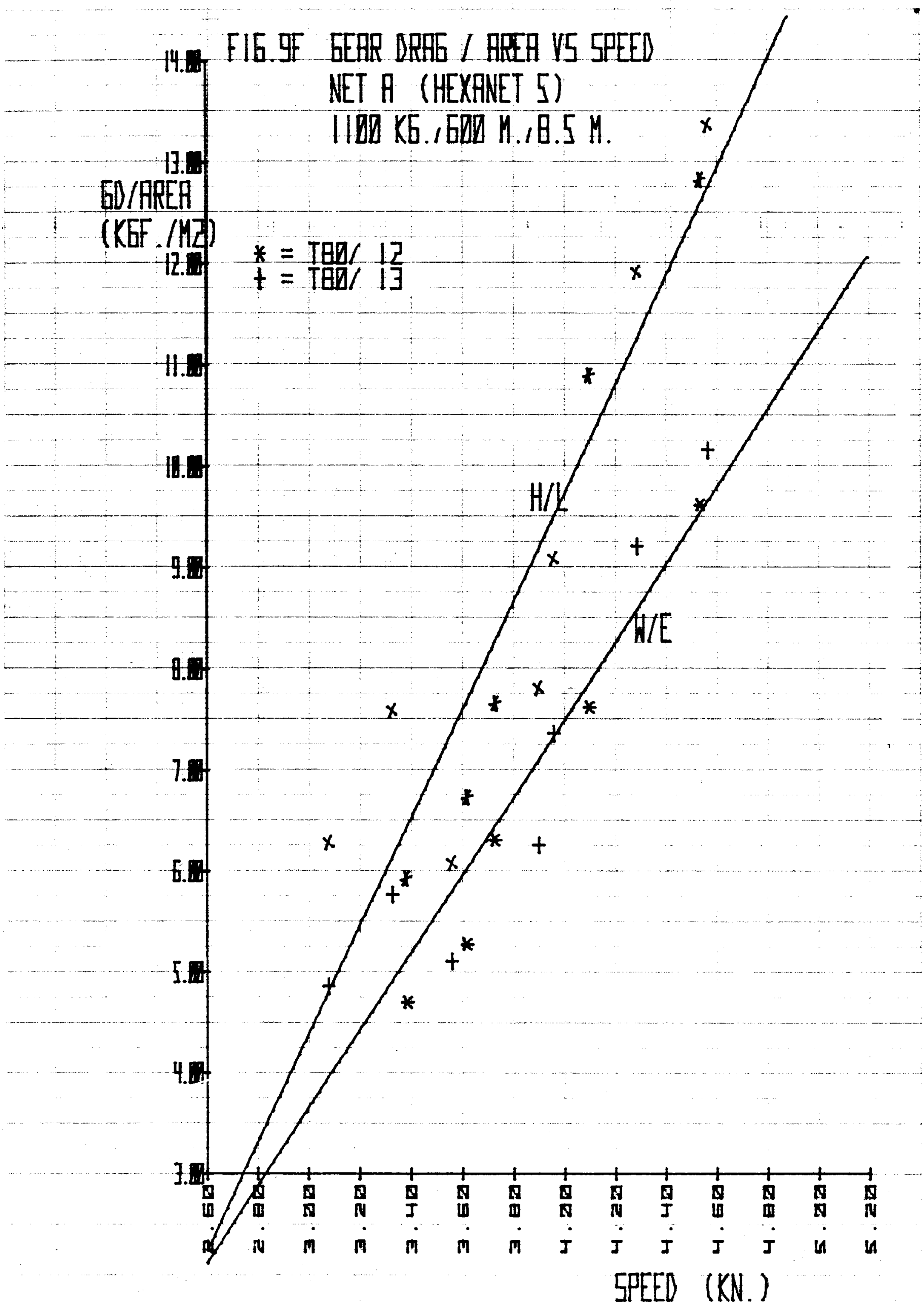


FIG.9F GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./8.5 M.
GD/AREA
(KGF./M2)
* = T80/ 12
+ = T80/ 13
H/L
W/E
SPEED (KN.)

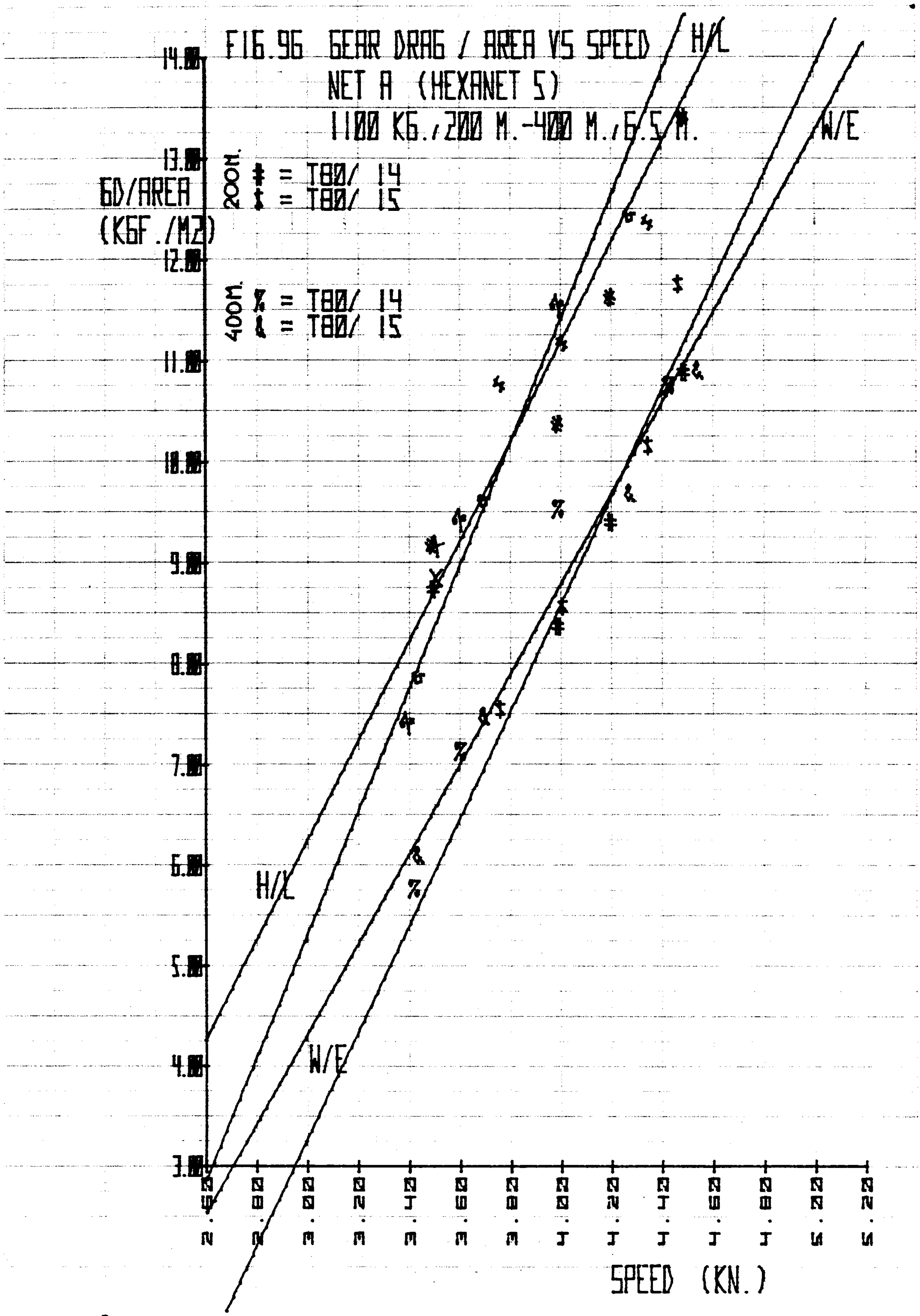


FIG.96 GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
1100 KG./200 M.-400 M./6.5 M.
GD/AREA
(KGF./M2)
200M.
= T80/ 14
$ = T80/ 15
400M.
% = T80/ 14
& = T80/ 15
H/L
W/E
SPEED (KN.)

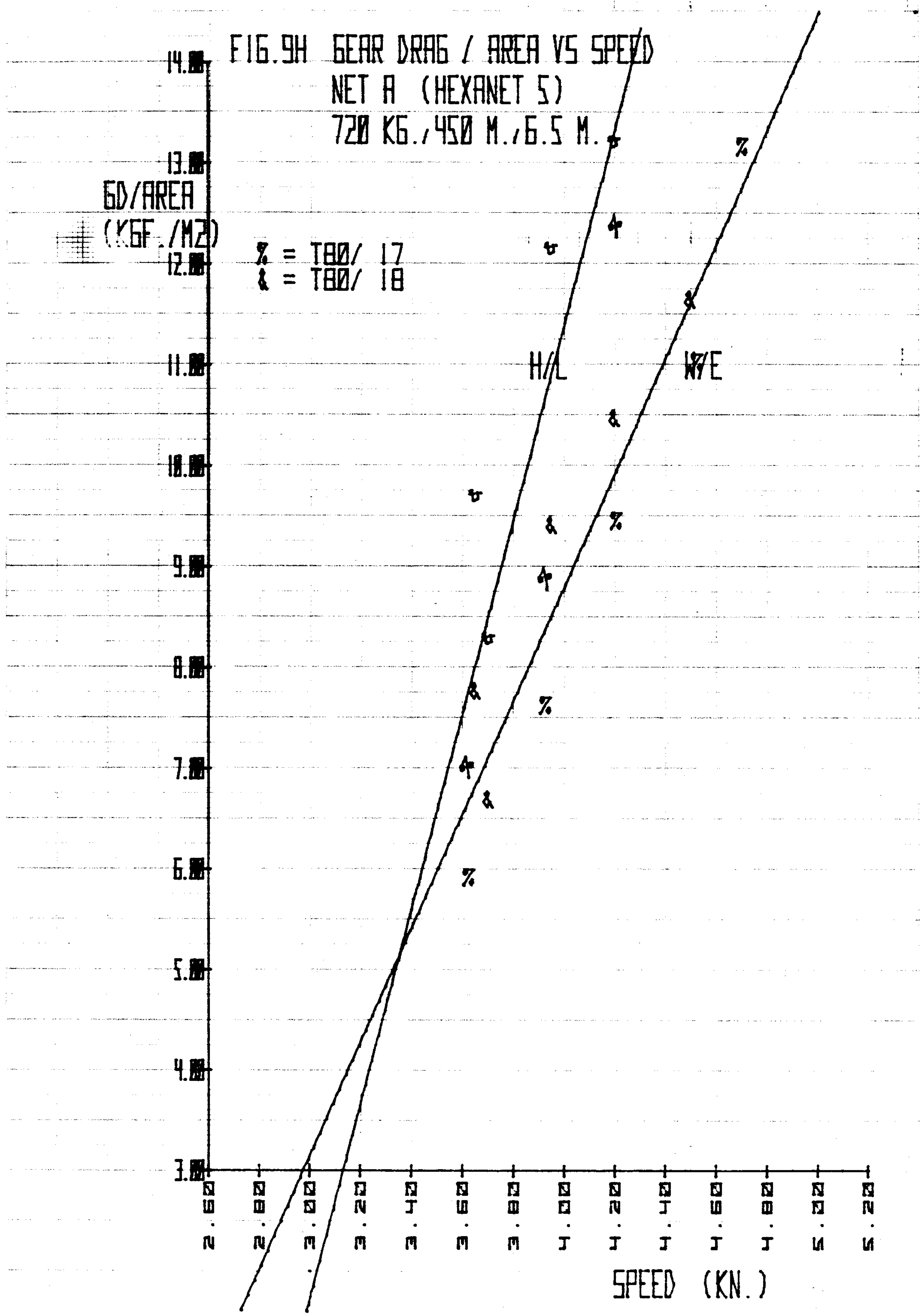


FIG.9H GEAR DRAG / AREA VS SPEED
NET A (HEXANET 5)
720 KG./450 M./6.5 M.
GD/AREA
(KGF./M2)
% = T80/ 17
& = T80/ 18
H/L
W/E
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
SPEED (KN.)

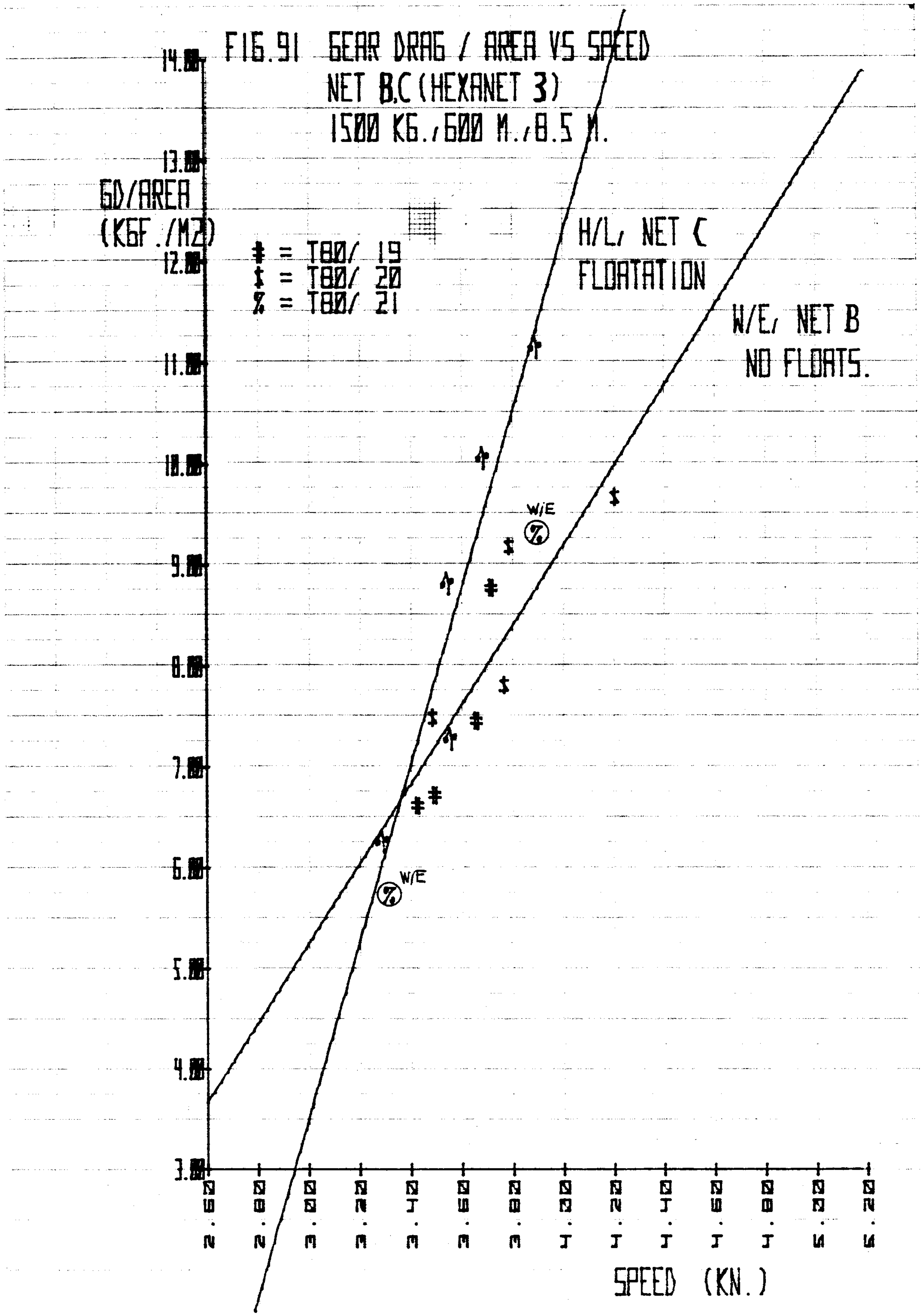


FIG.91 GEAR DRAG / AREA VS SPEED
NET B,C (HEXANET 3)
1500 KG./600 M./8.5 M.
GD/AREA
(KGF./M2)
14.00
13.00
12.00
11.00
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
= T80/ 19
$ = T80/ 20
% = T80/ 21
H/L, NET C
FLOATATION
W/E, NET B
NO FLOATS.
W/E
W/E
2.50
2.80
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.80
5.00
5.20
SPEED (KN.)

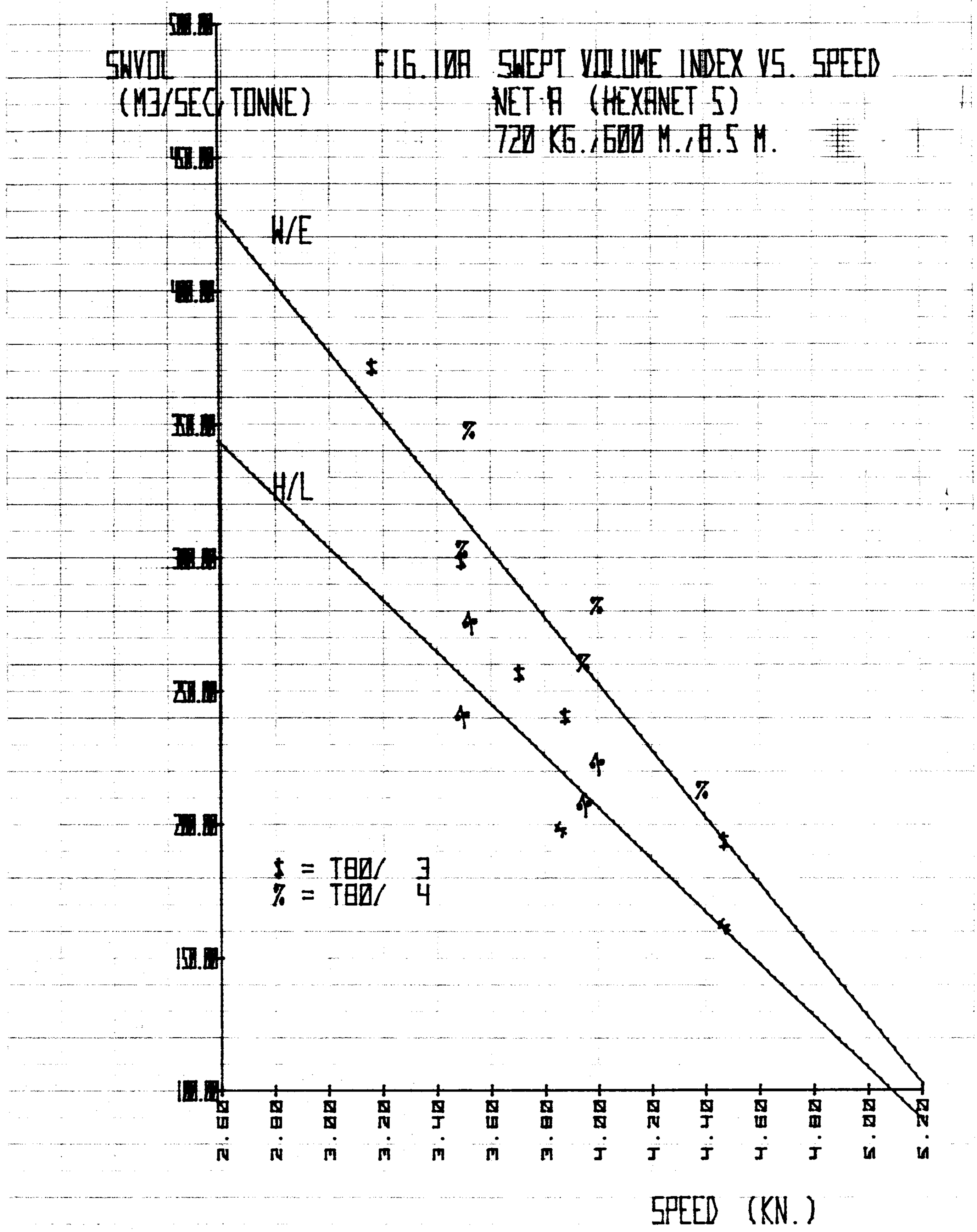


FIG.10A SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
720 KG./600 M./8.5 M.
SWVOL
(M3/SEC/TONNE)
W/E
H/L
$ = T80/ 3
% = T80/ 4
SPEED (KN.)

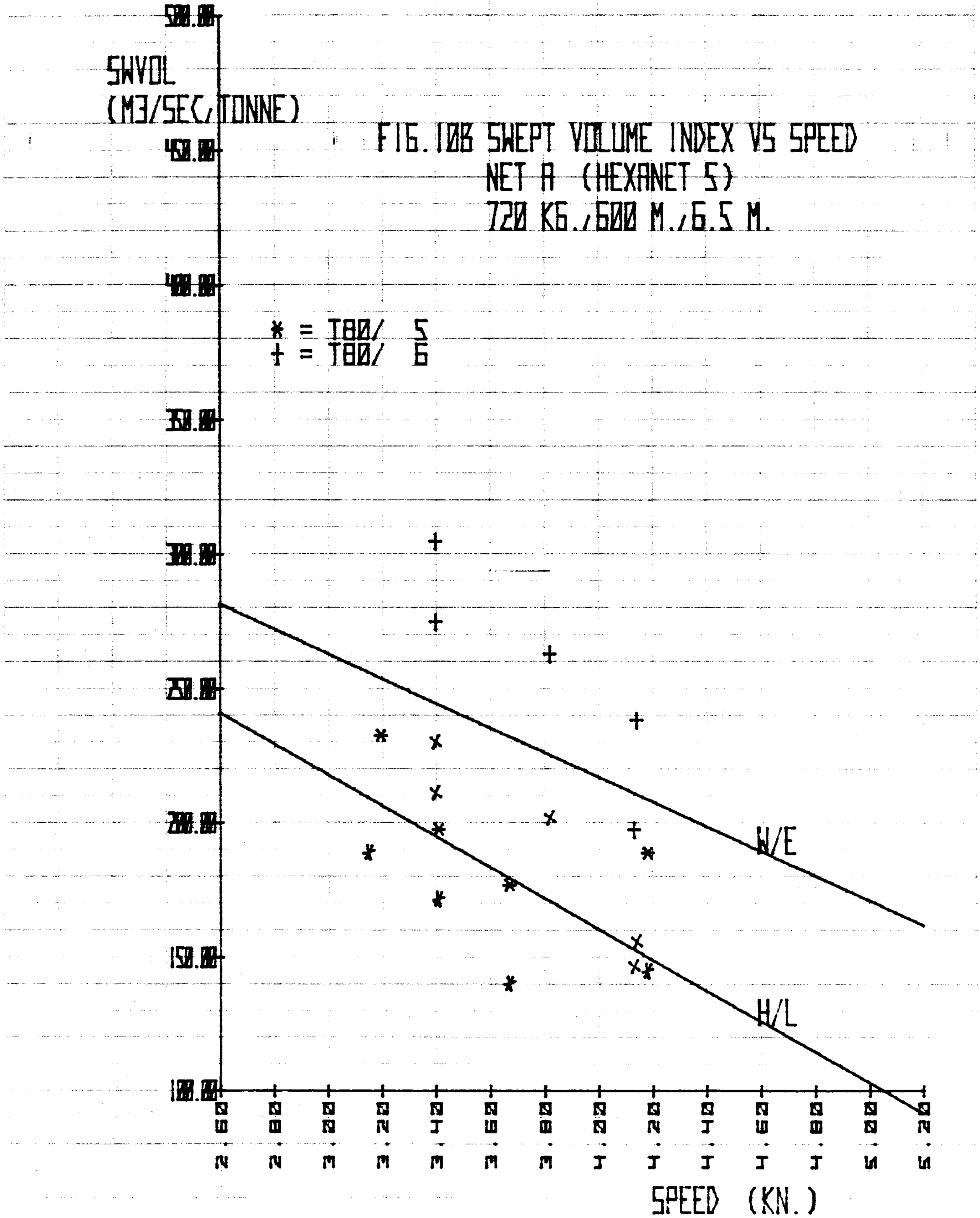
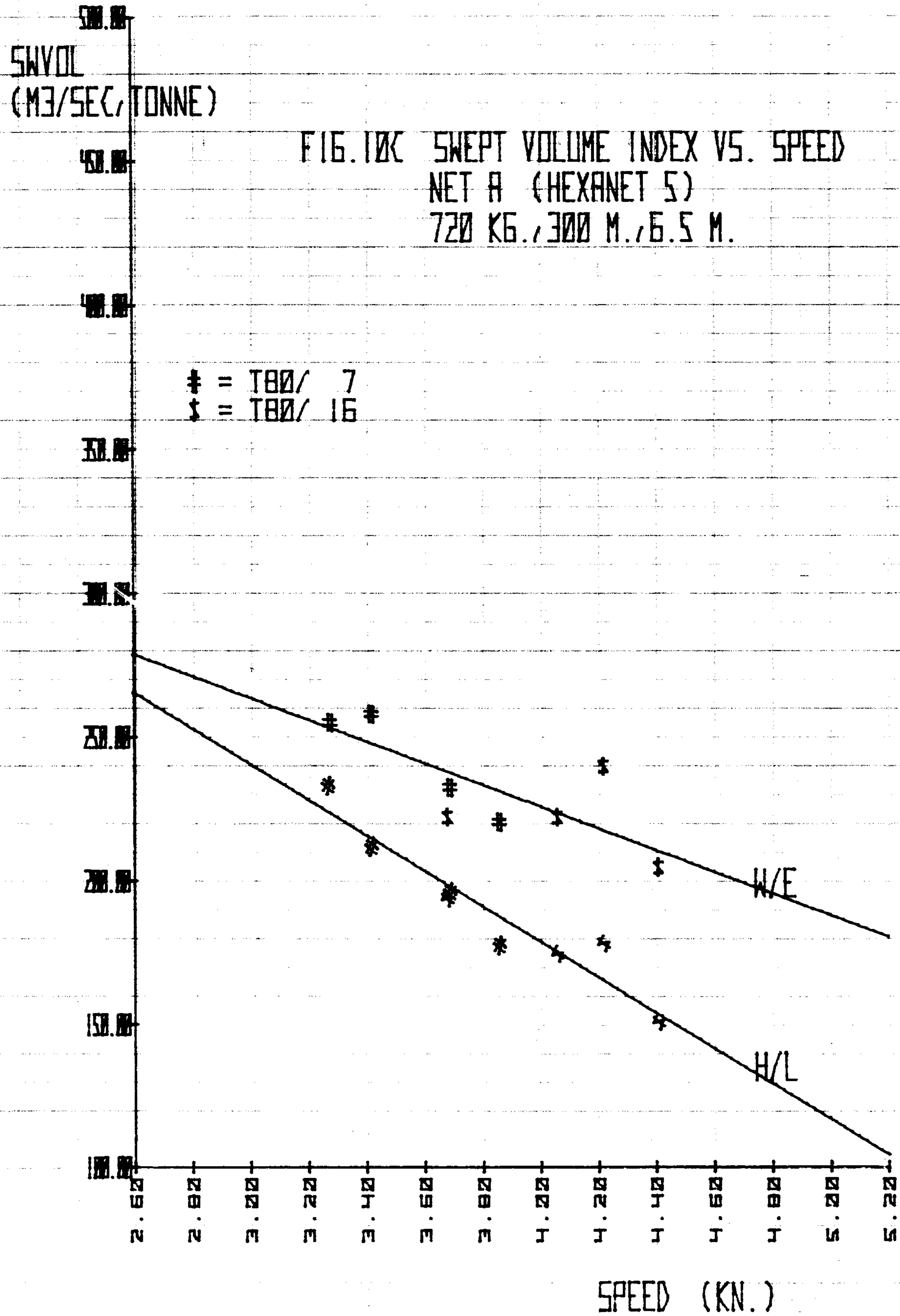


FIG. 10B SWEPT VOLUME INDEX VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.
SWVOL
(M3/SEC/TONNE)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
* = T80/ 5
+ = T80/ 6
W/E
H/L
SPEED (KN.)



SWVOL
(M3/SEC/TONNE)
FIG.10C SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
720 KG./300 M./6.5 M.
= T80/ 7
$ = T80/ 16
W/E
H/L
SPEED (KN.)

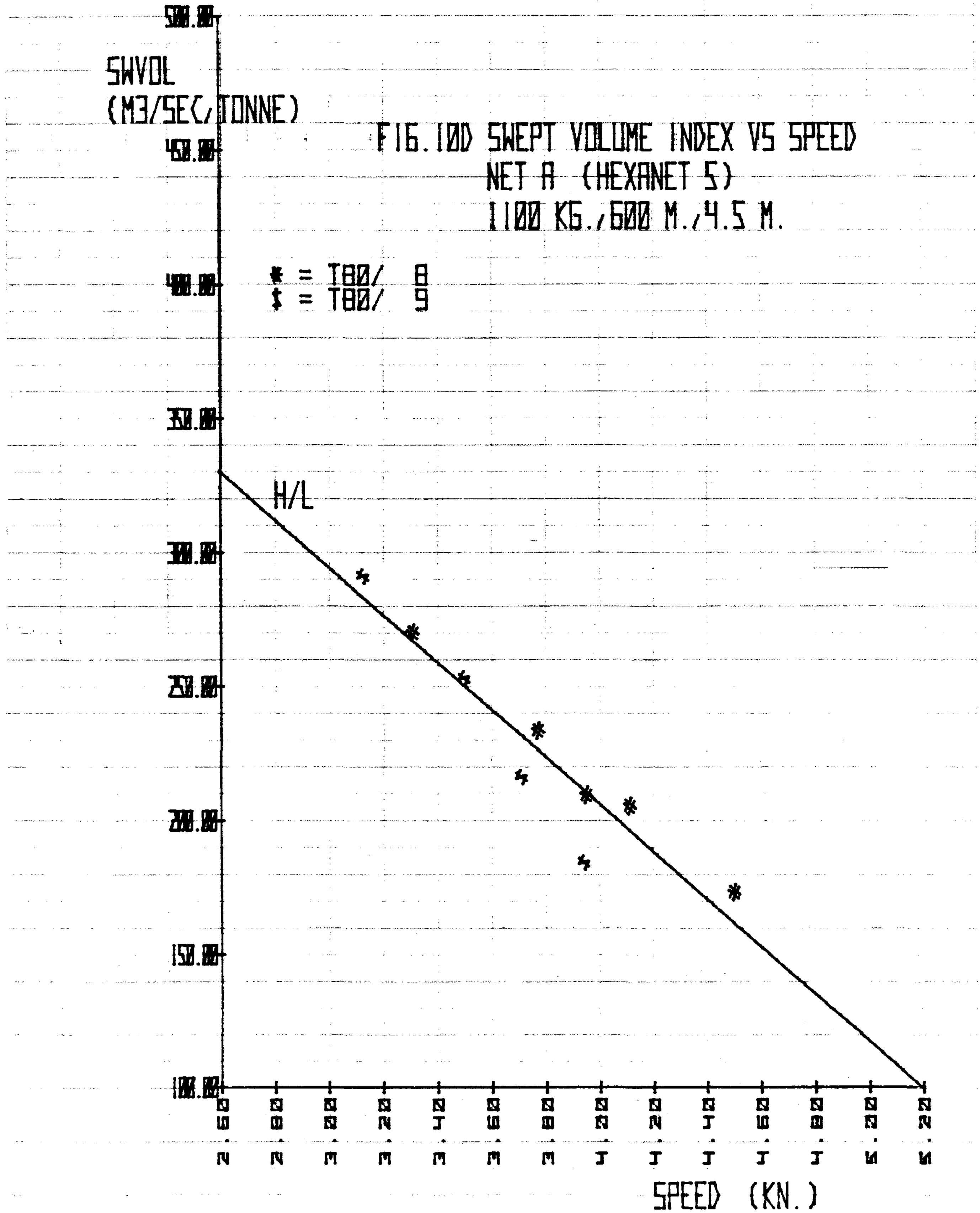
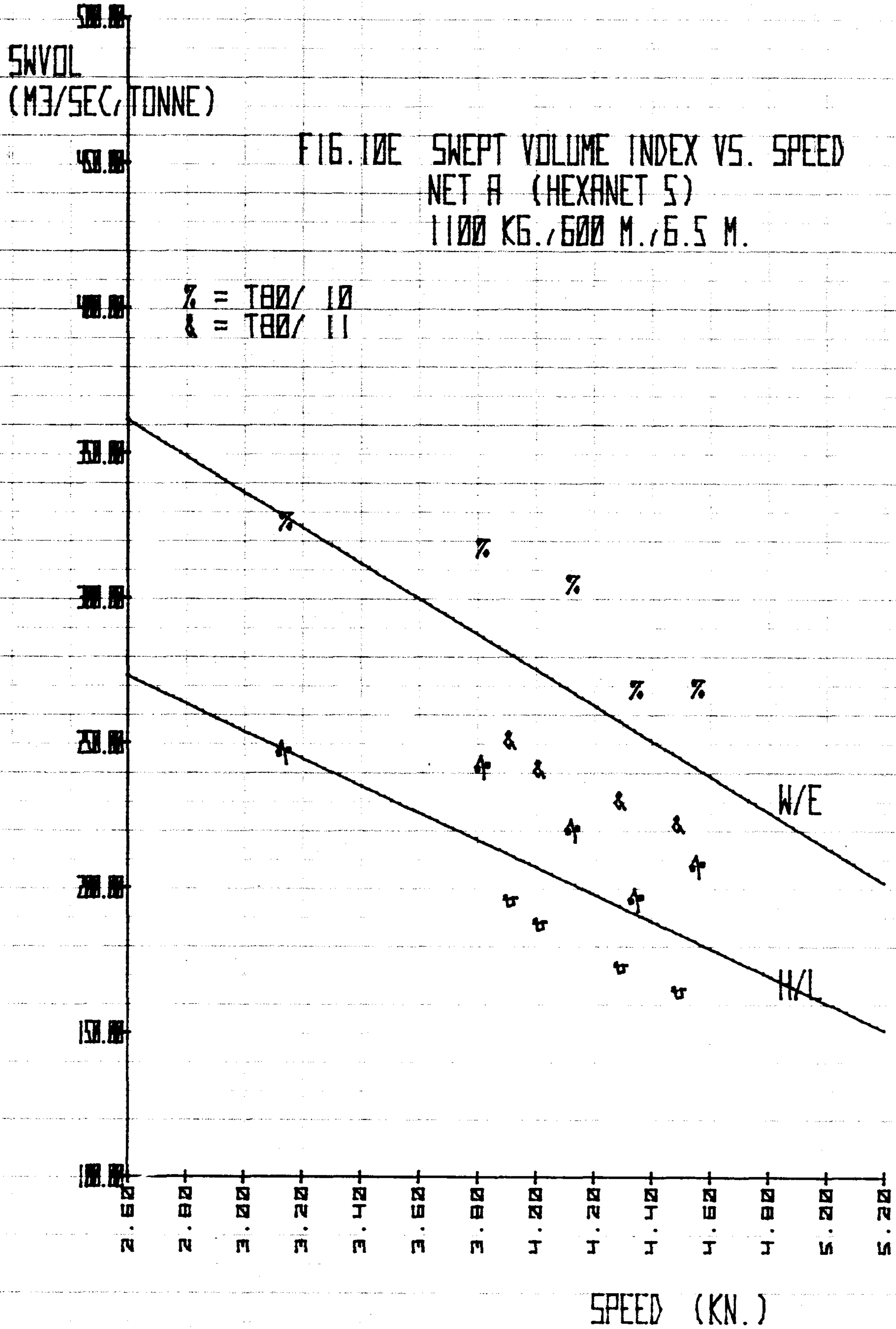


FIG.10D SWEPT VOLUME INDEX VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.
* = T80/ 8
$ = T80/ 9
SWVOL
(M3/SEC/TONNE)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
H/L
SPEED (KN.)


SWVOL
(M3/SEC/TONNE)
FIG.10E SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
1100 KG./600 M./6.5 M.
% = T80/ 10
& = T80/ 11
W/E
H/L
SPEED (KN.)

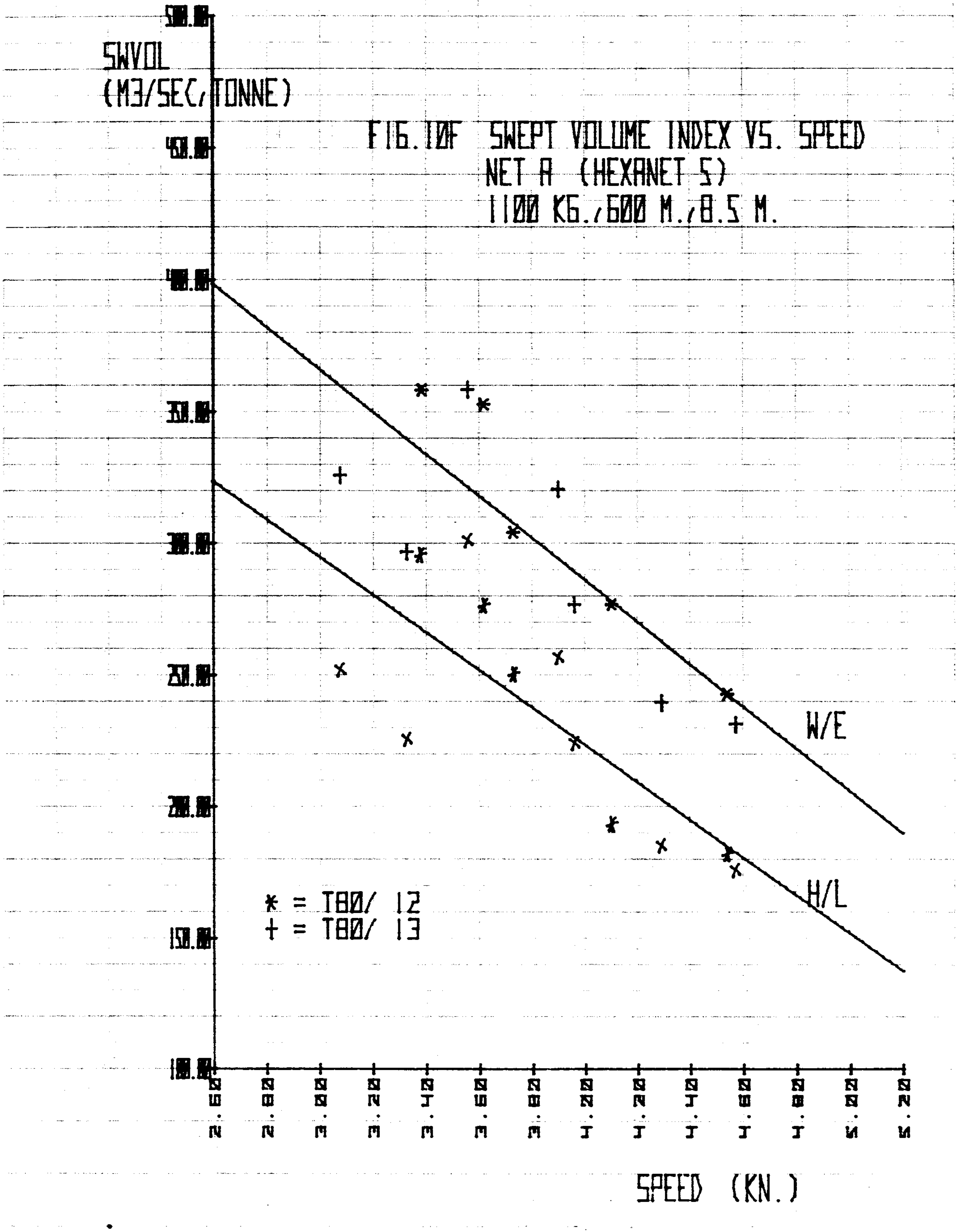


FIG. 10F SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
1100 KG./600 M./8.5 M.

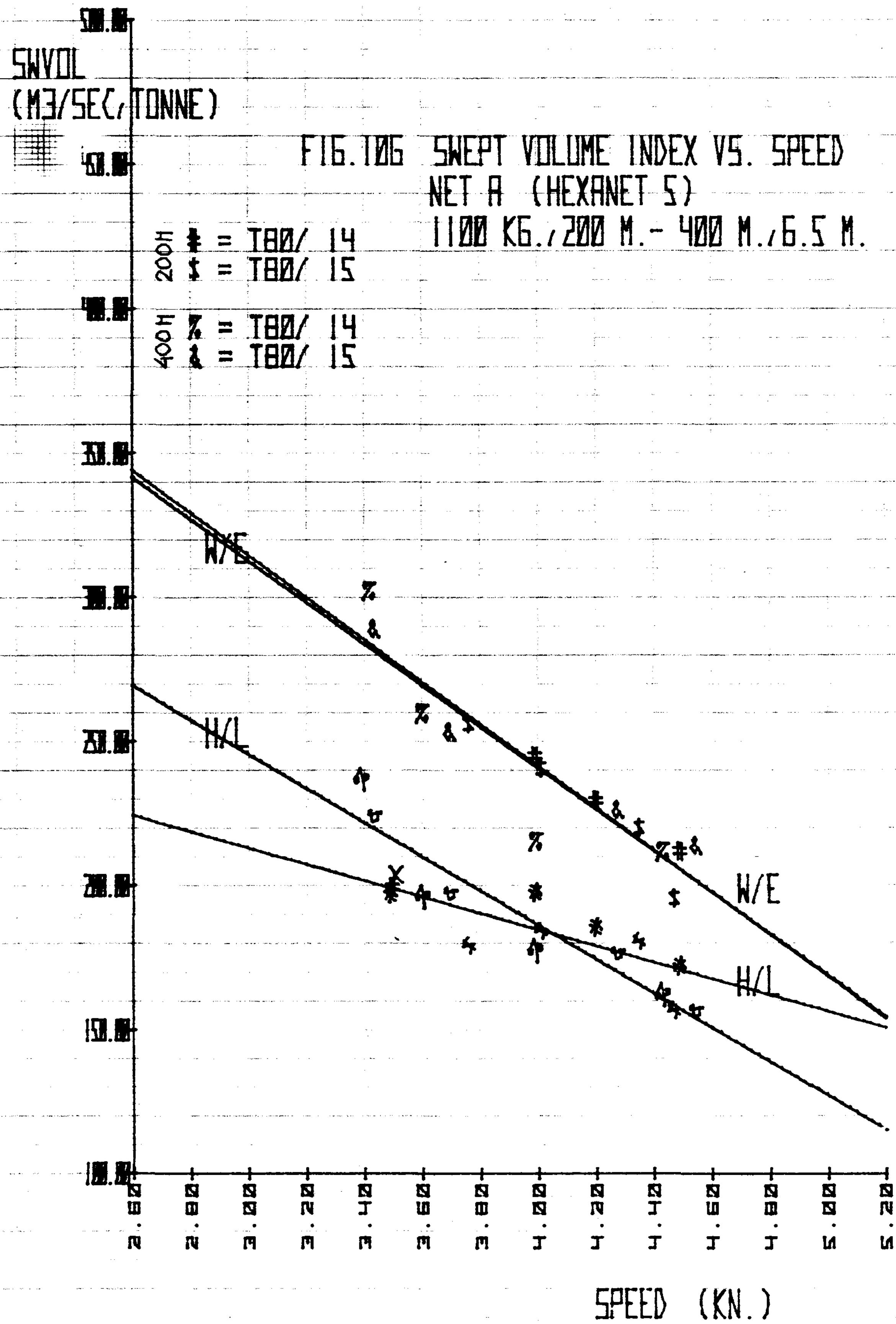
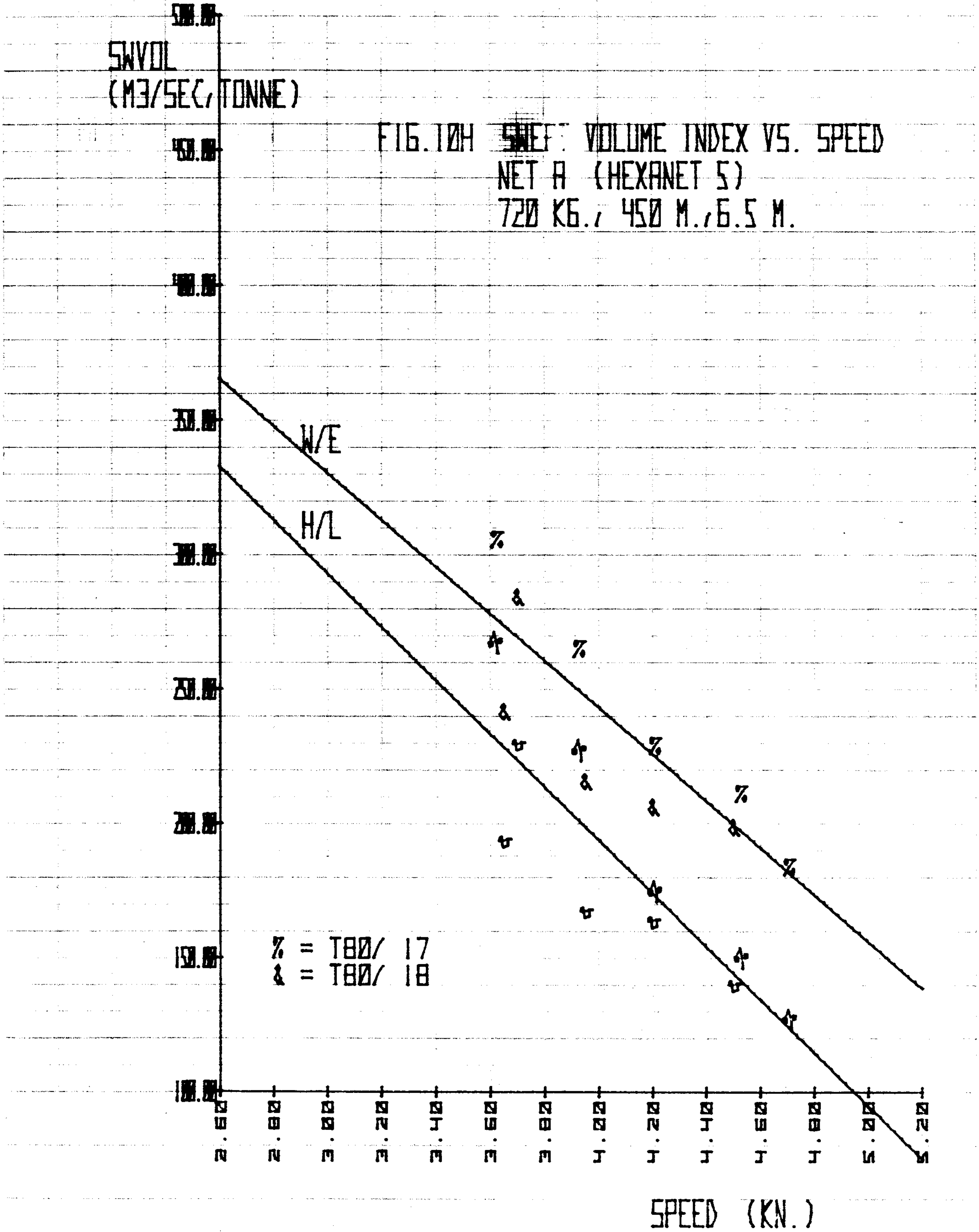


FIG.10G SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
1100 KG./200 M.- 400 M./6.5 M.


SWVOL
(M3/SEC/TONNE)
FIG.10H SWEPT VOLUME INDEX VS. SPEED
NET A (HEXANET 5)
720 KG./ 450 M./6.5 M.
W/E
H/L
% = T80/ 17
& = T80/ 18
SPEED (KN.)

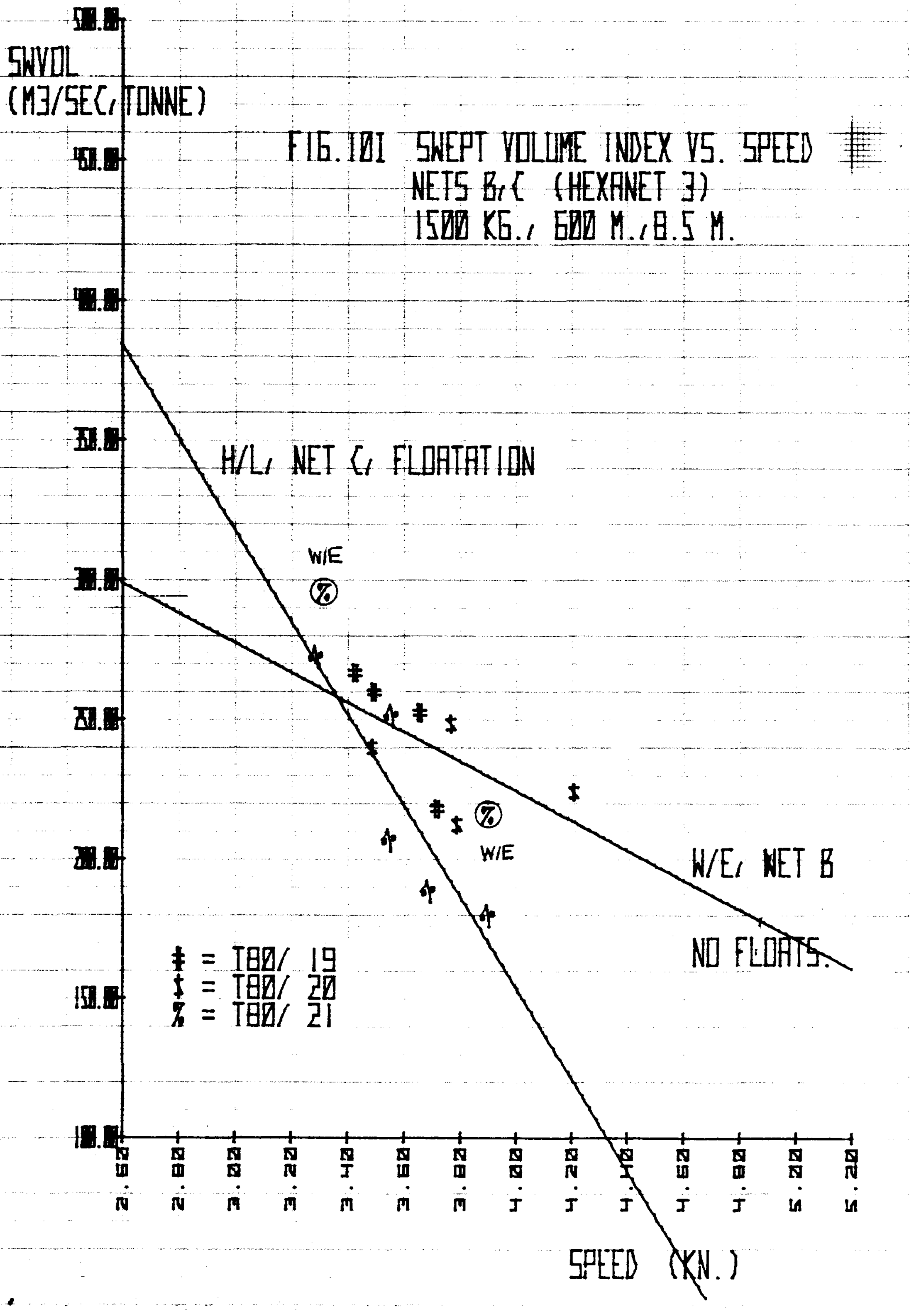
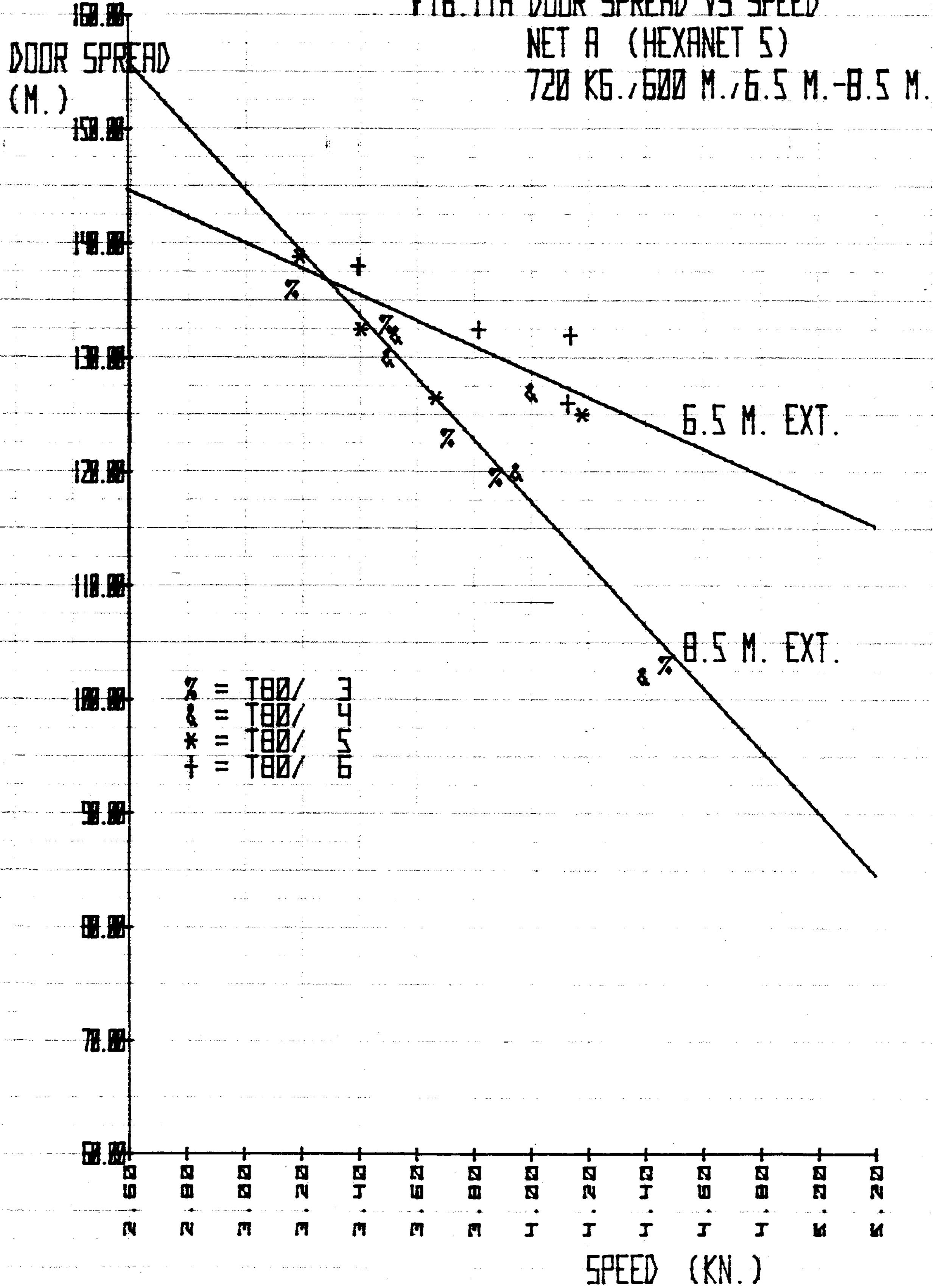


FIG.101 SWEPT VOLUME INDEX VS. SPEED
NETS B, C (HEXANET 3)
1500 KG., 600 M., 8.5 M.
SWVOL
(M3/SEC, TONNE)
H/L, NET C, FLOATATION
W/E
W/E
W/E, NET B
NO FLOATS.
= T80/ 19
$ = T80/ 20
% = T80/ 21
SPEED (KN.)

FIG.11A DOOR SPREAD VS SPEED
NET A (HEXANET 5)
720 KG./600 M./6.5 M.-8.5 M.



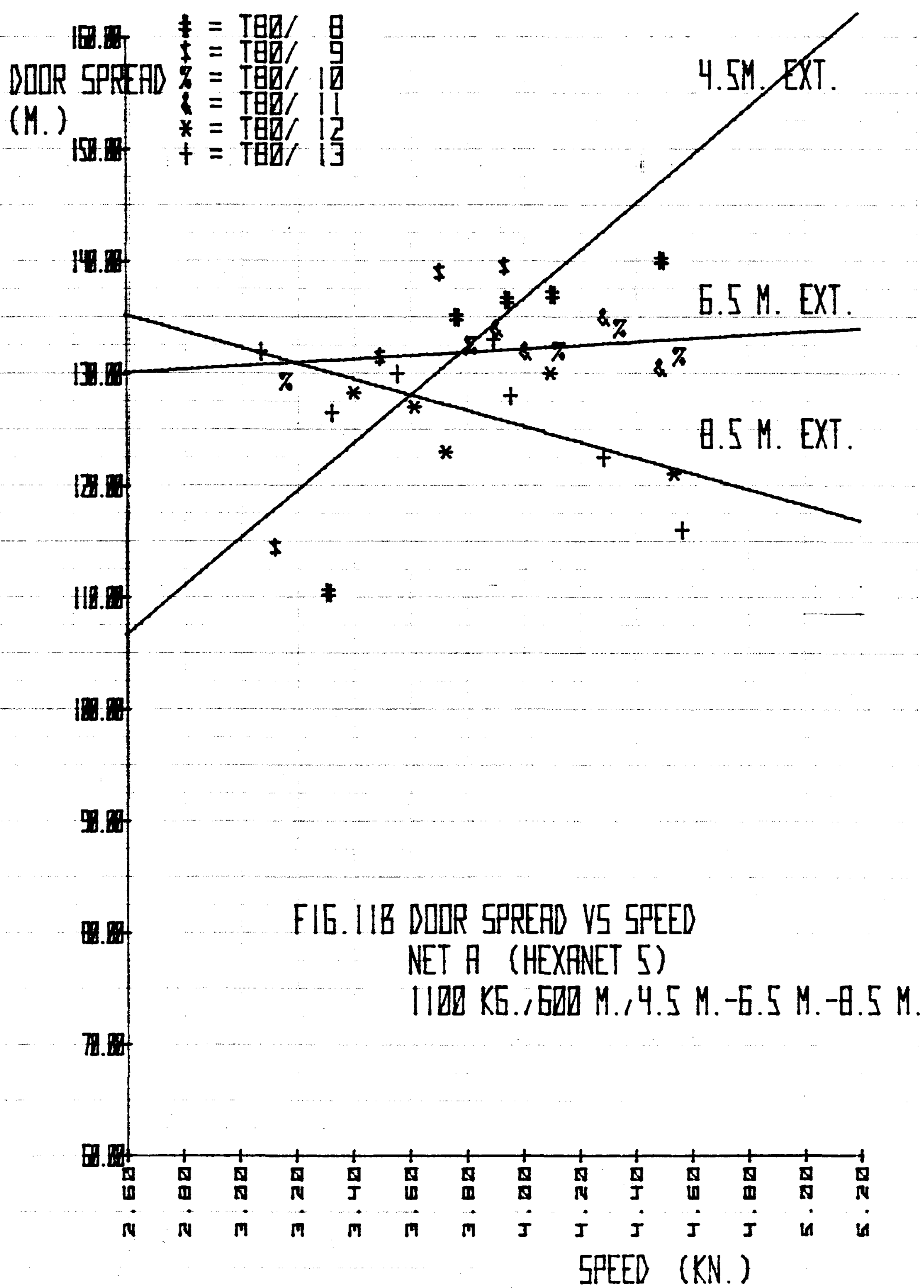


FIG. 11B DOOR SPREAD VS SPEED
NET A (HEXANET 5)
1100 KG./600 M./4.5 M.-6.5 M.-8.5 M.

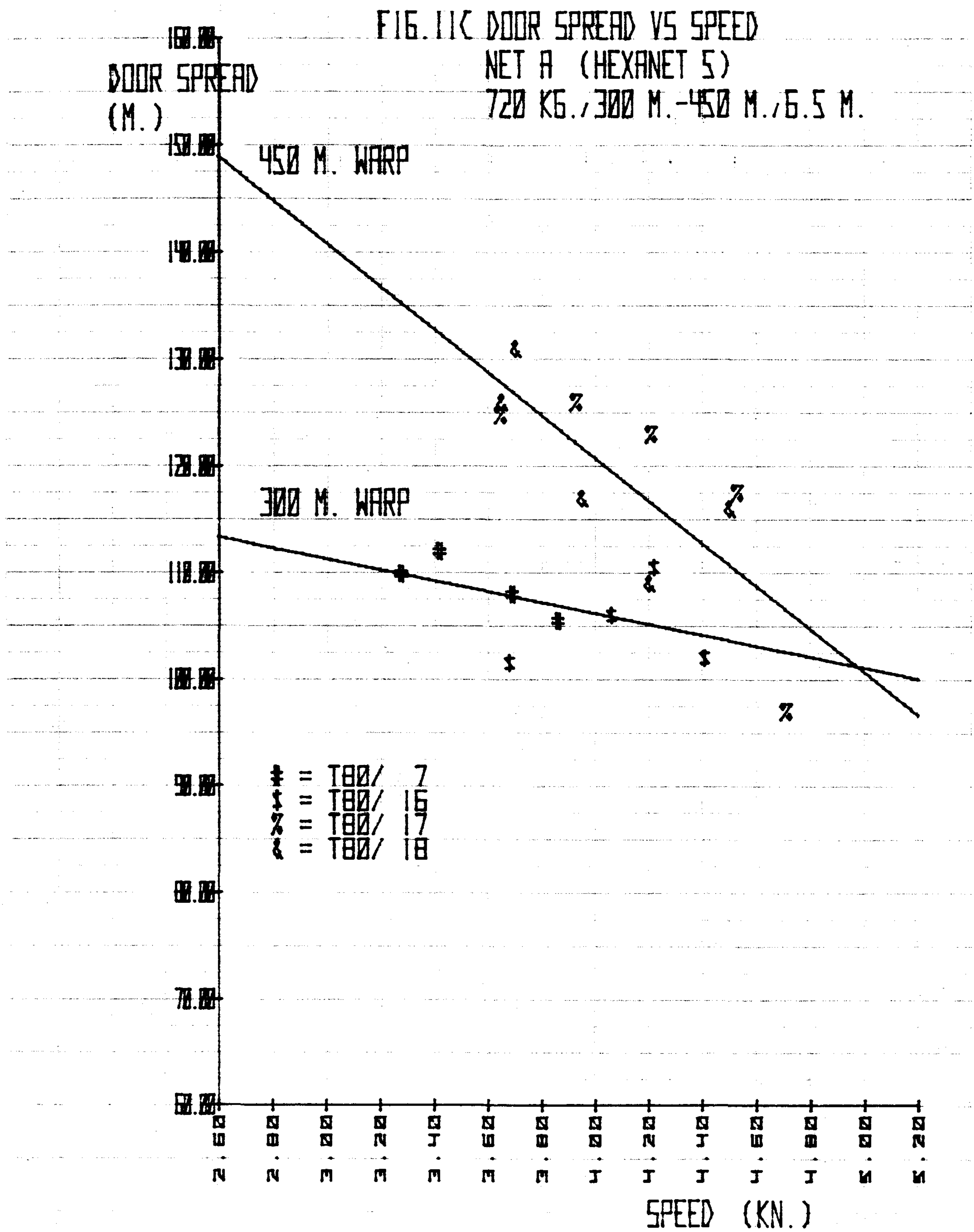


FIG. 11C DOOR SPREAD VS SPEED
NET A (HEXANET 5)
720 KG./300 M.-450 M./6.5 M.
DOOR SPREAD
(M.)
450 M. WARP
300 M. WARP
= T80/ 7
$ = T80/ 16
% = T80/ 17
& = T80/ 18
SPEED (KN.)

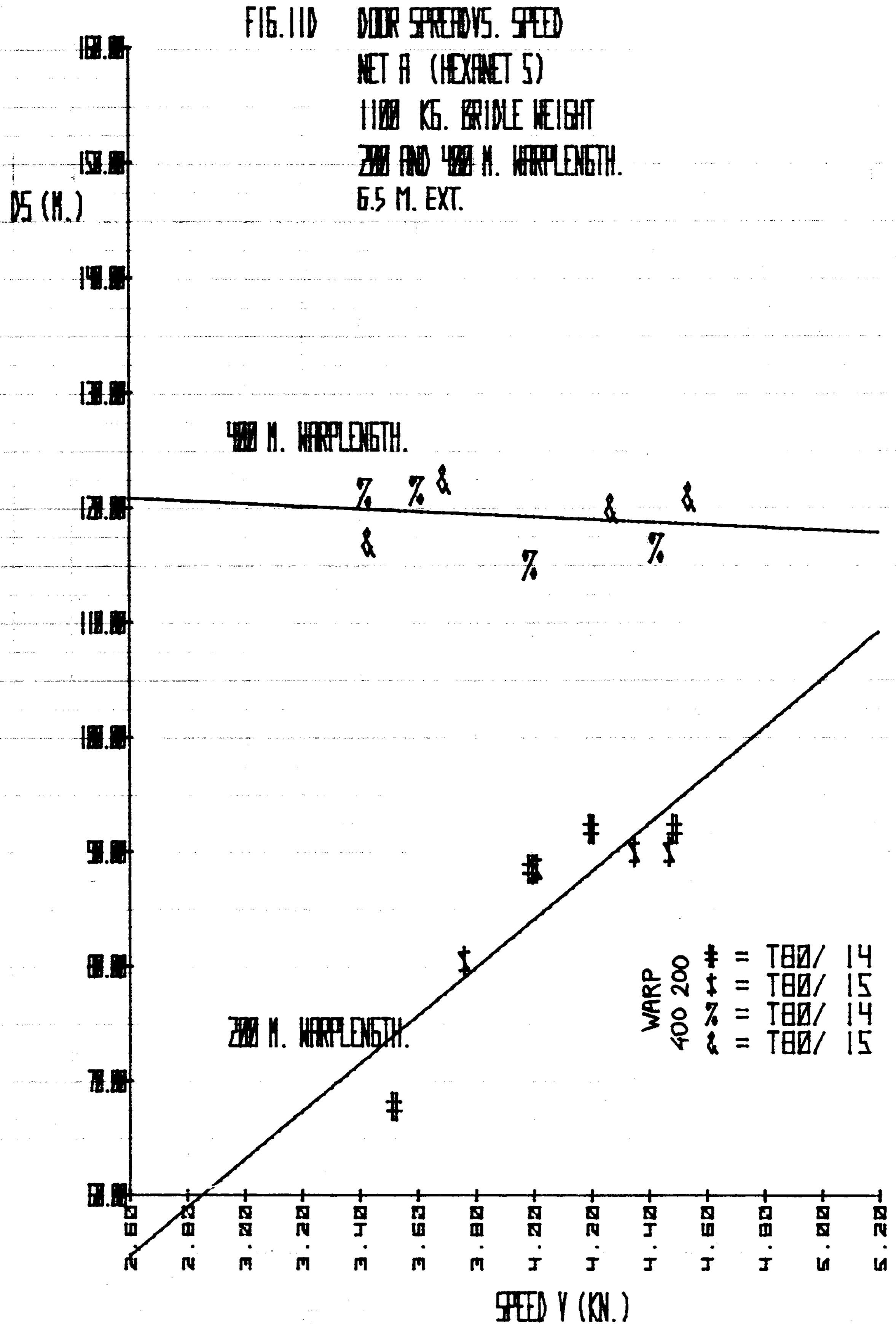


FIG.11D DOOR SPREAD VS. SPEED
NET A (HEXANET 5)
1100 KG. BRIDLE WEIGHT
200 AND 400 M. WARPLENGTH.
6.5 M. EXT.
DS (M.)
160.00
150.00
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
400 M. WARPLENGTH.
200 M. WARPLENGTH.
WARP
400 200
= T80/ 14
‡ = T80/ 15
= T80/ 14
& = T80/ 15
2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20 4.40 4.60 4.80 5.00 5.20
SPEED V (KN.)

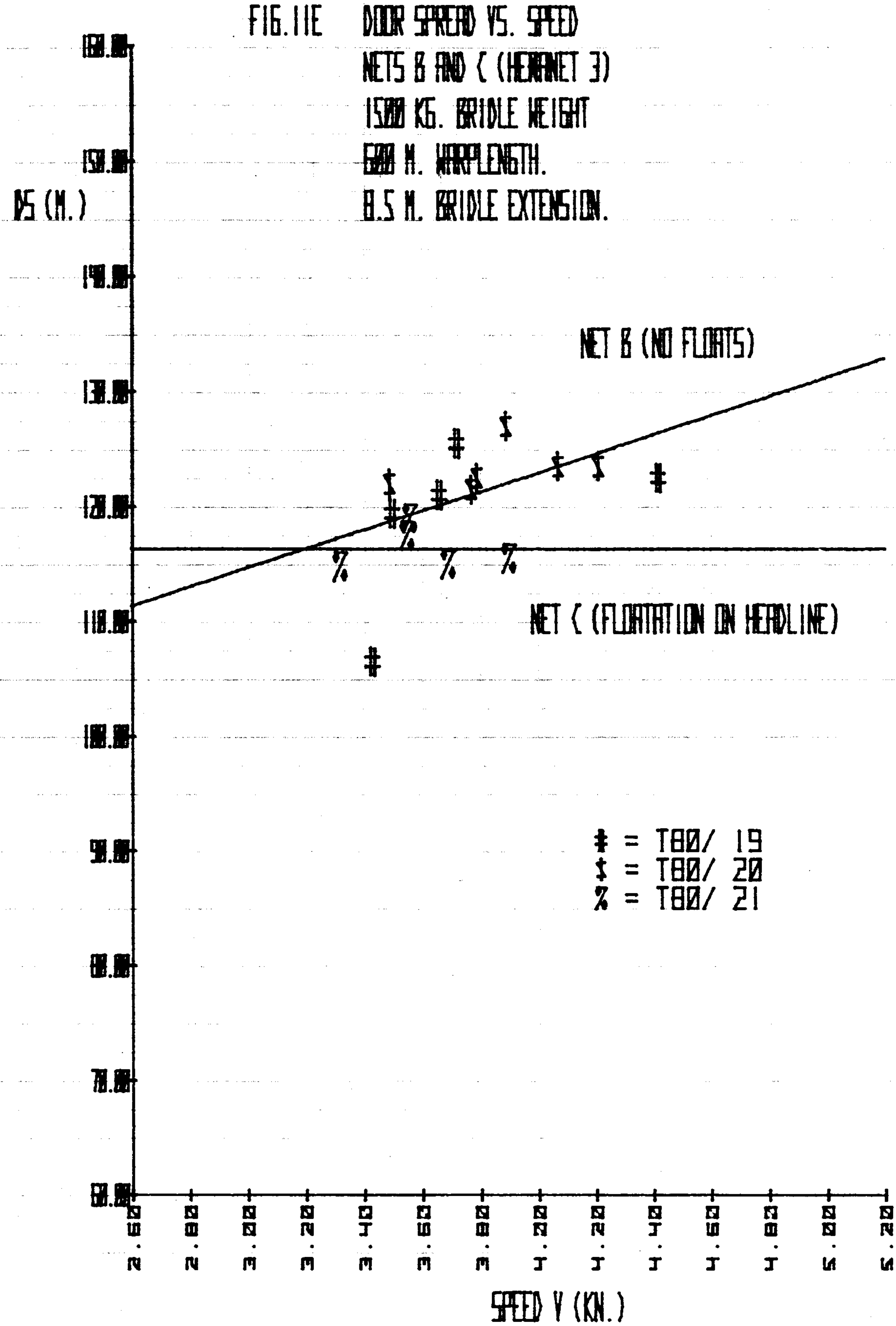


FIG.11E DOOR SPREAD VS. SPEED
NETS B AND C (HENNET 3)
1500 KG. BRIDLE WEIGHT
600 M. WARPLENGTH.
0.5 M. BRIDLE EXTENSION.
DS (M.)
NET B (NO FLOATS)
NET C (FLOATATION ON HEADLINE)
= T80/ 19
$ = T80/ 20
% = T80/ 21
SPEED V (KN.)

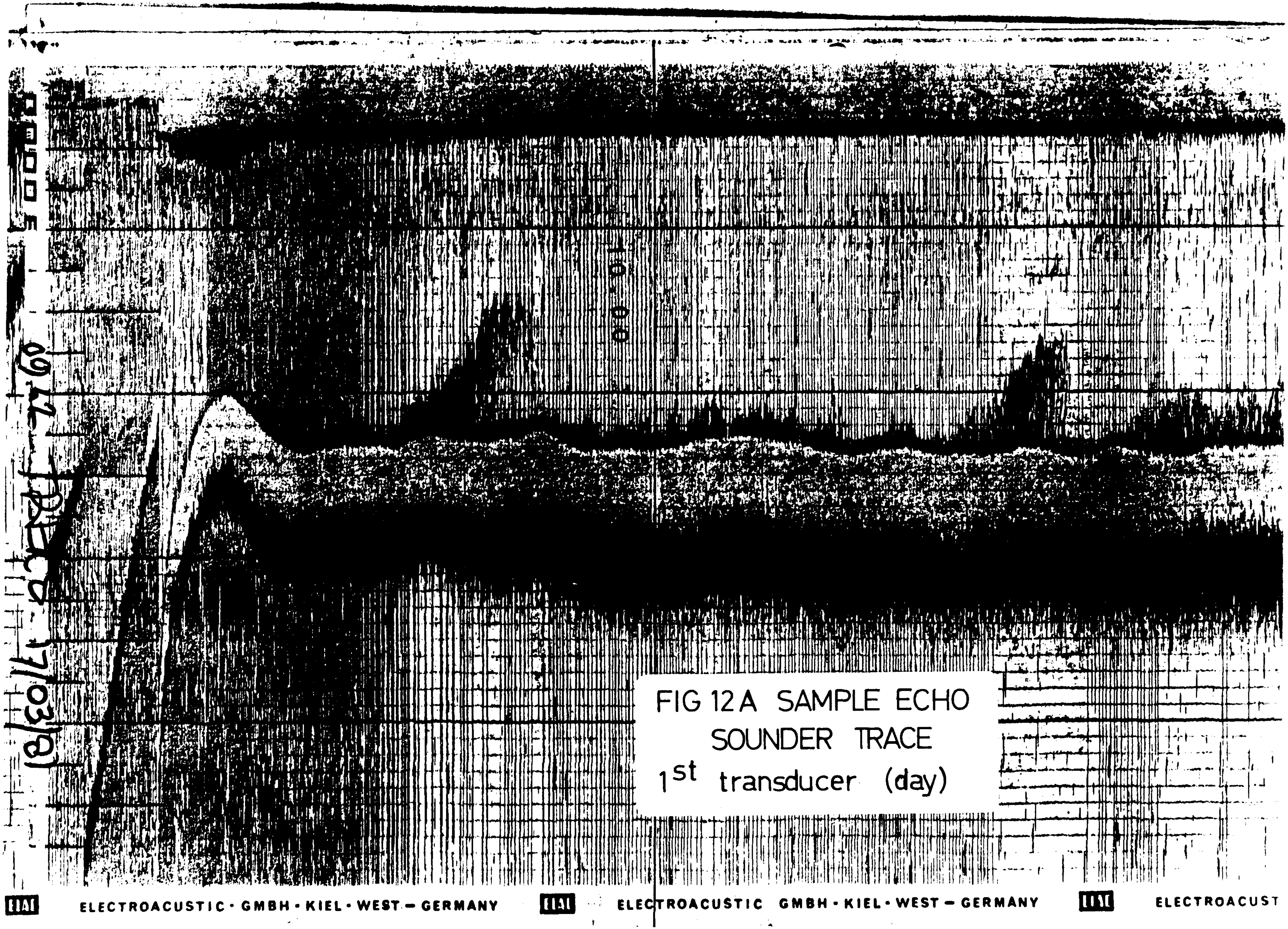


FIG 12A SAMPLE ECHO SOUNDER TRACE
1st transducer (day)

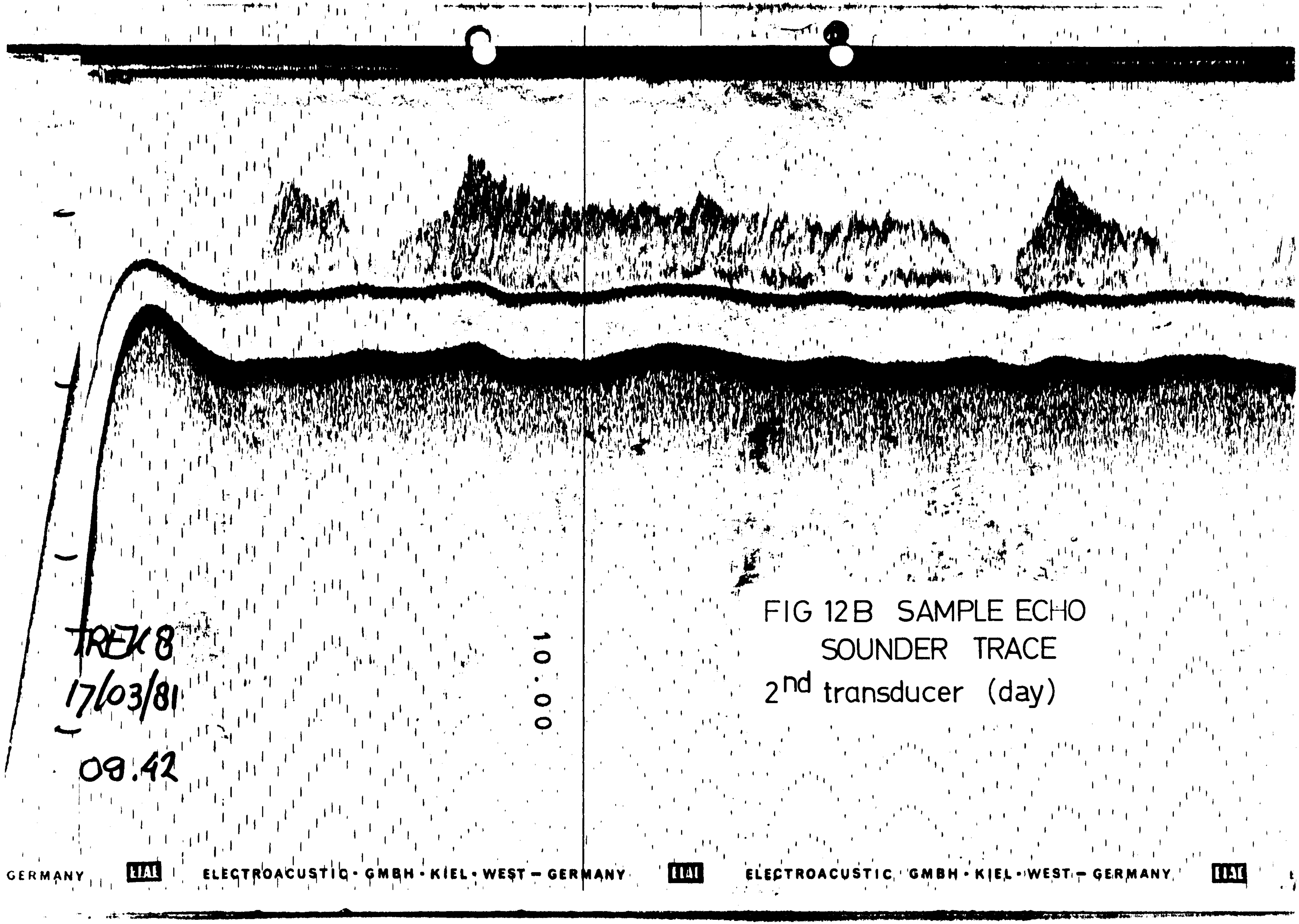


FIG 12B SAMPLE ECHO SOUNDER TRACE
2^{nd} transducer (day)

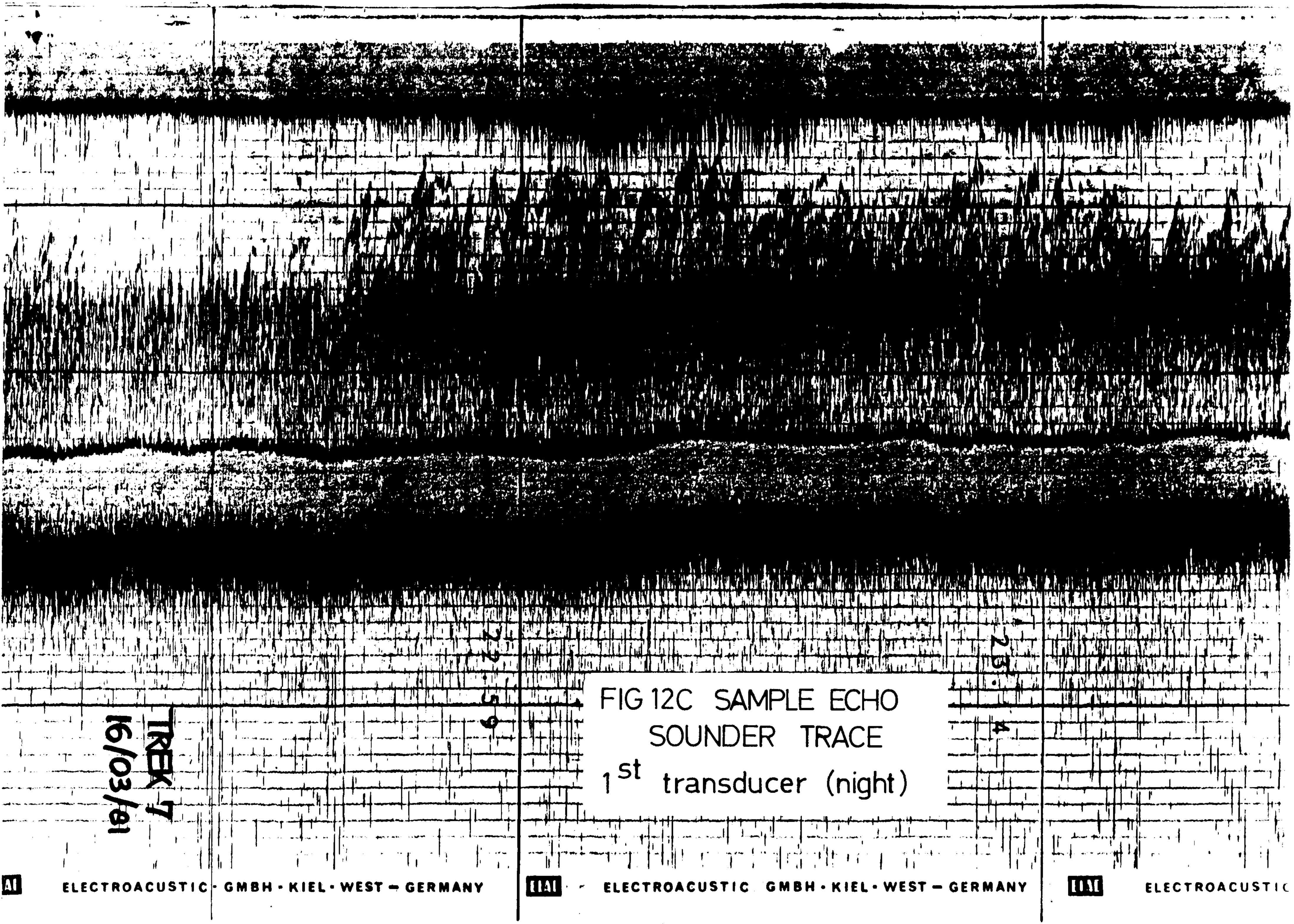


FIG 12C SAMPLE ECHO SOUNDER TRACE
1st transducer (night)

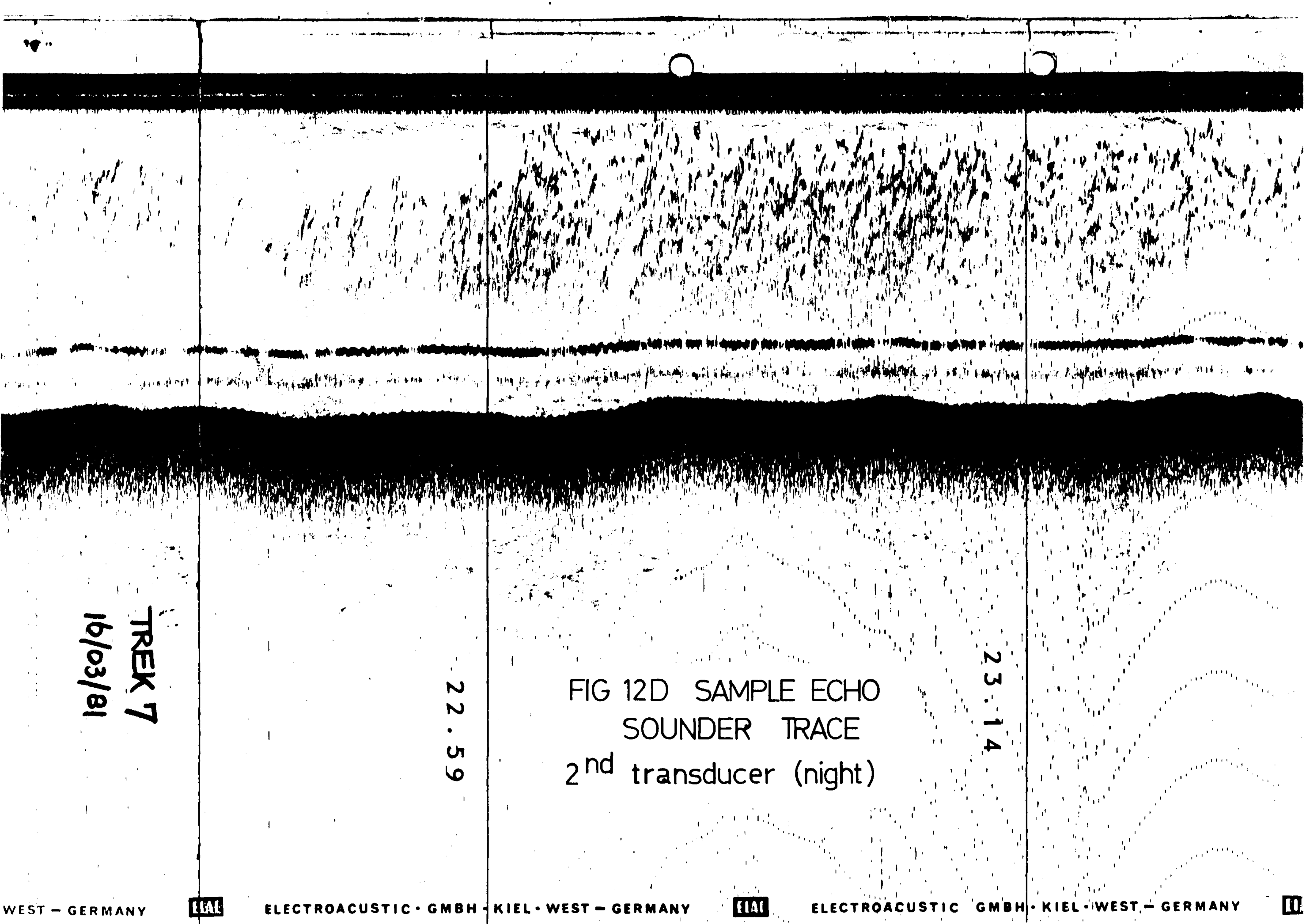


FIG 12D SAMPLE ECHO SOUNDER TRACE
2nd transducer (night)

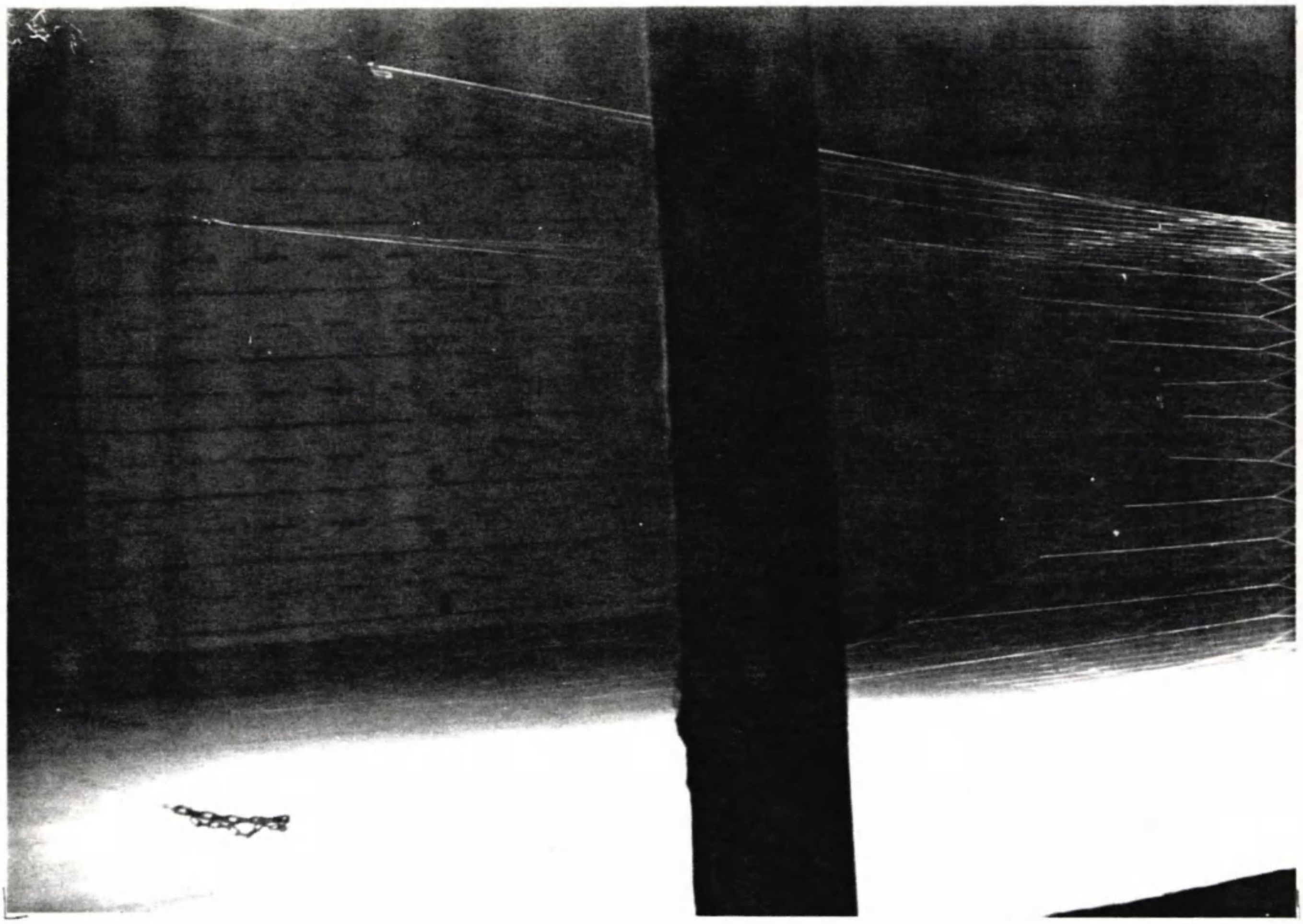


FIG. 13 A Hexanet 5, model scale 1: 25
Netmouth
1300 kg weights, 8.5 m ext., speed 3.0 kn.

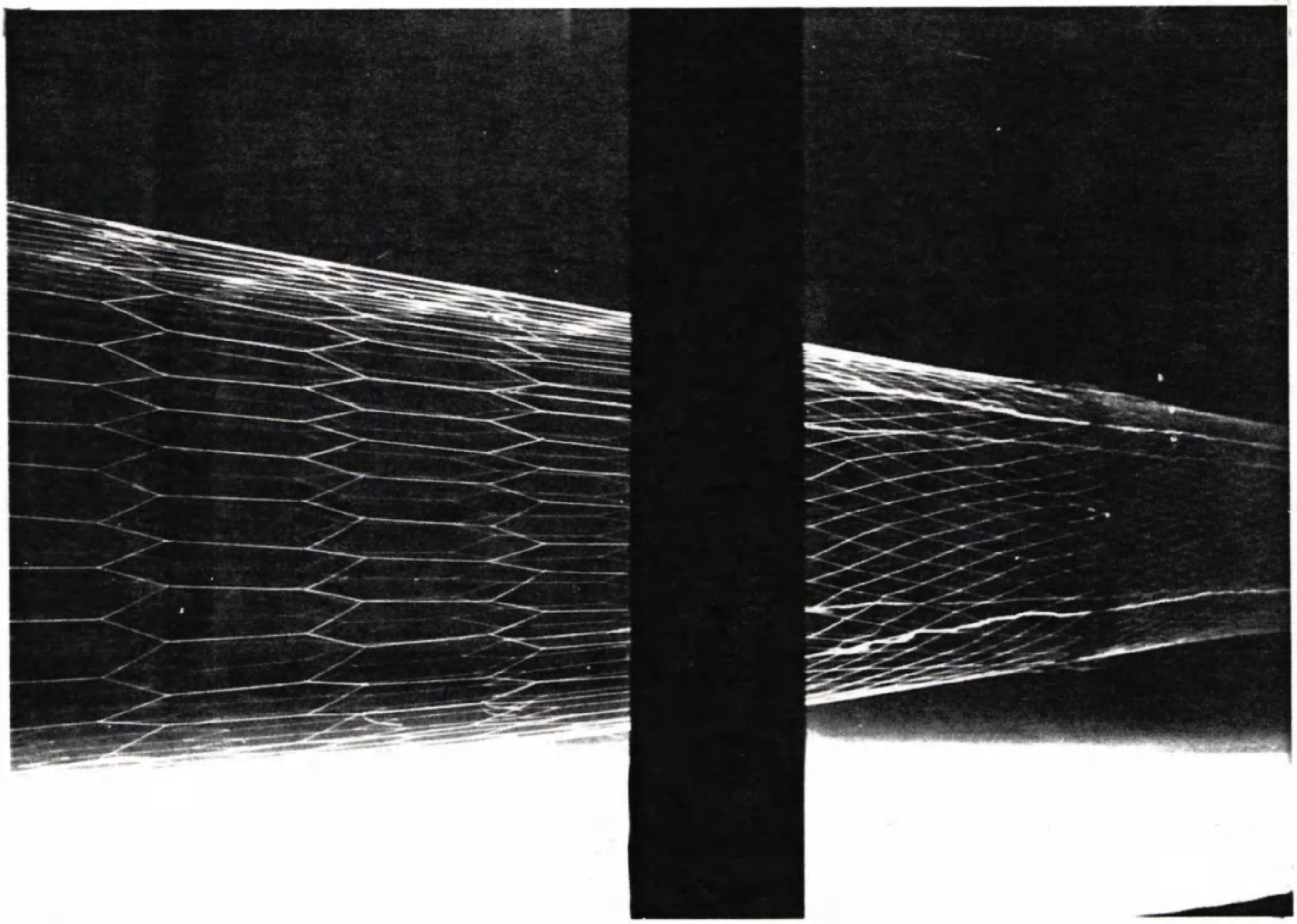


FIG. 13 B Hexanet 5, model scale 1 : 25
Junction of hexameshes to netting
1300 kg weights, 8.5 m ext., speed 3.0 kn.

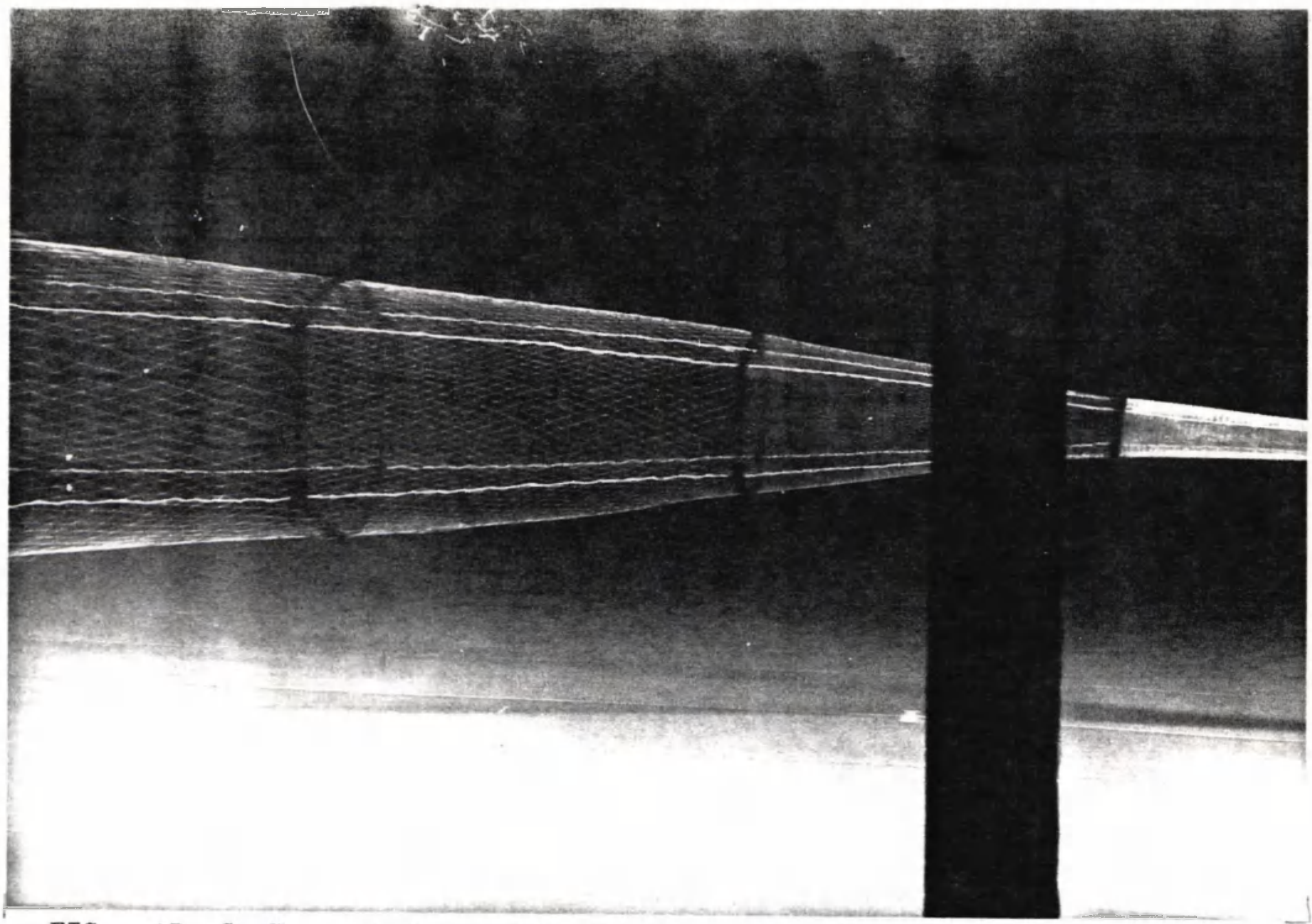


FIG. 13 C Hexanet 5, model scale 1 : 25
Aft part of gear.
1300 kg weights, 8.5 m ext., speed 3.0 kn.

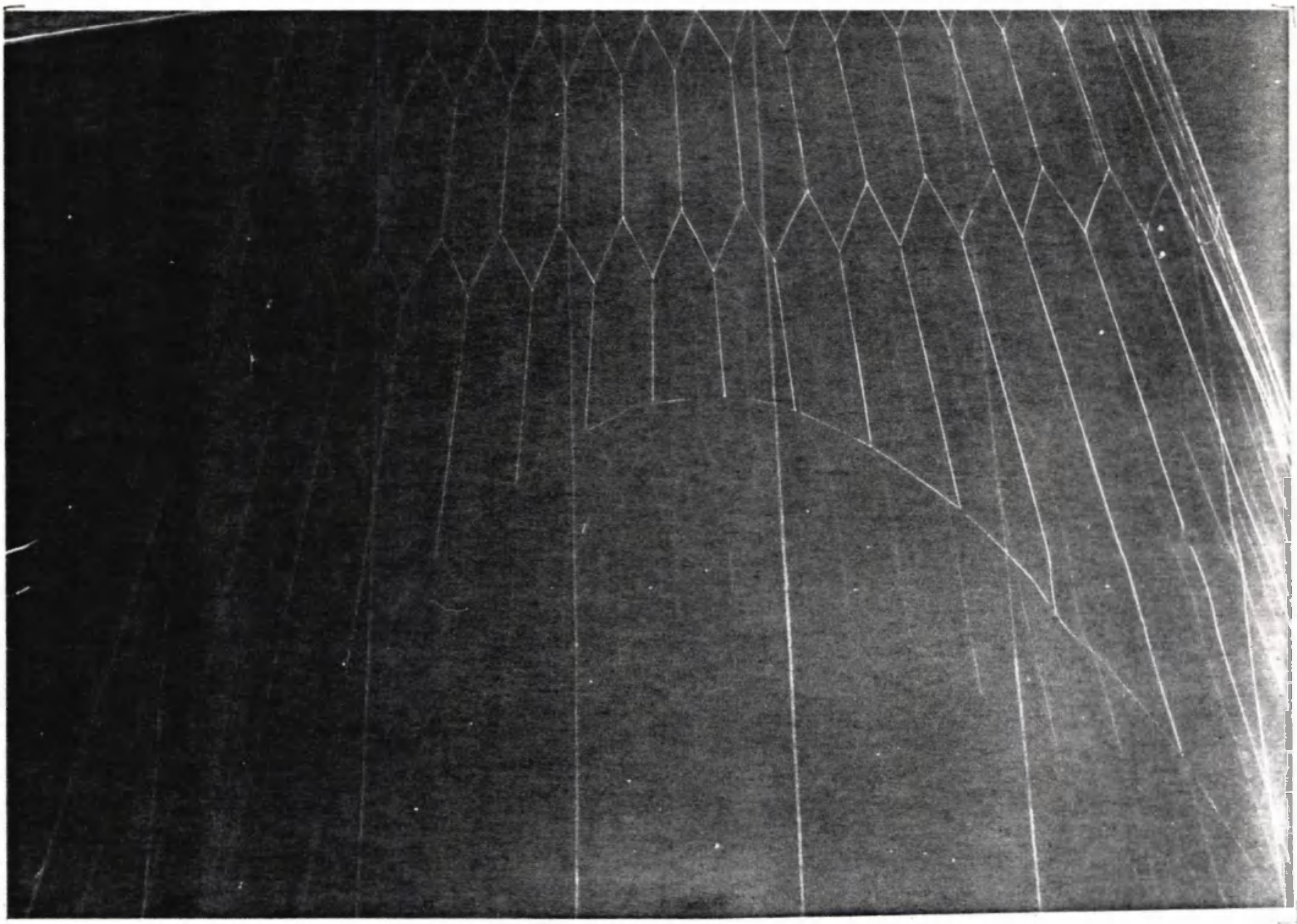


FIG. 13 D Hexanet 5, model scale 1 : 25
Footrope and headline.
1300 kg weights, 8.5 m ext., speed 3.0 kn.

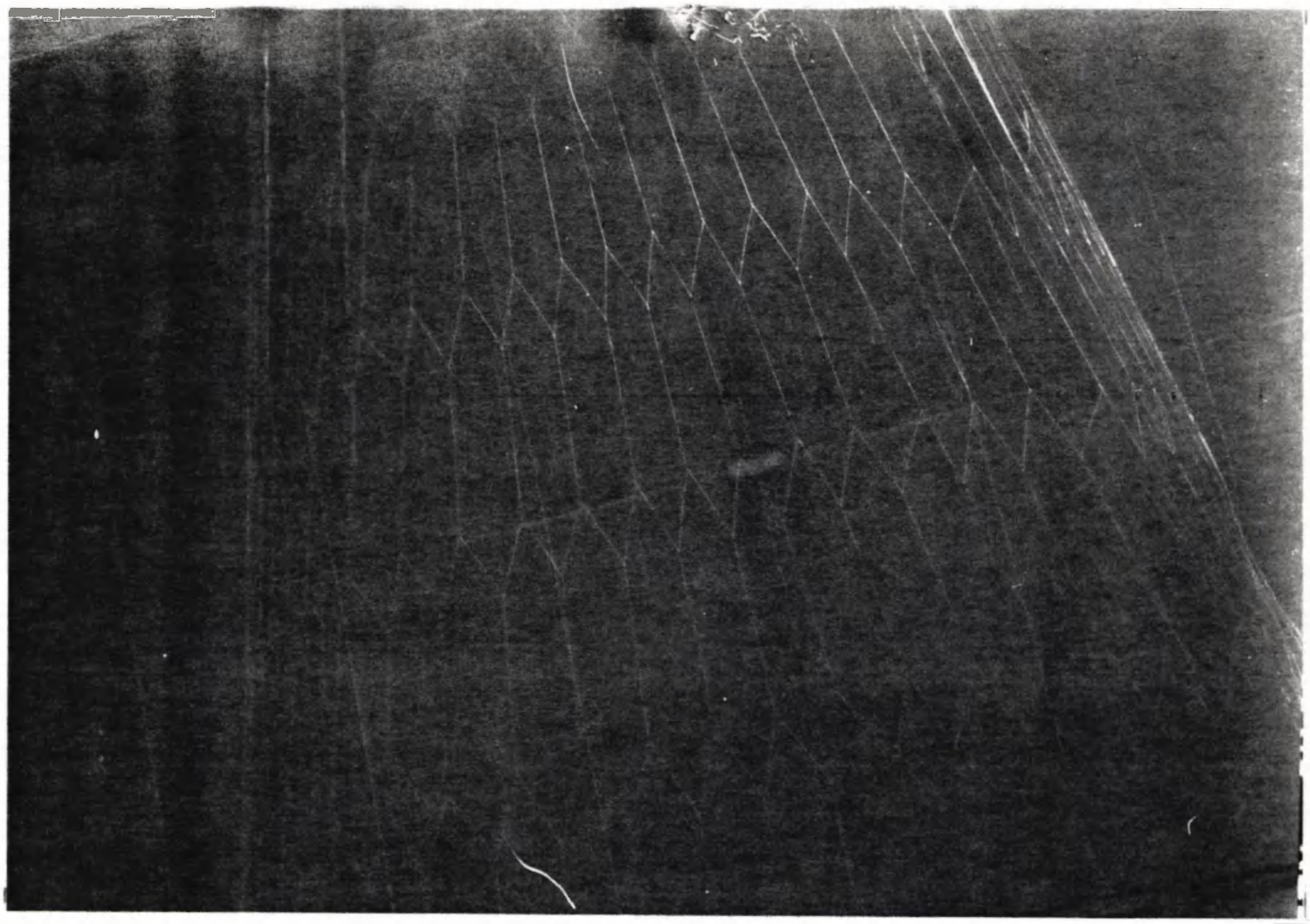


FIG. 13 E Hexanet 5, model scale 1 : 25
Hexagonal meshes top panel.
1300 kg weights, 8.5 m ext., speed 3.0 kn.

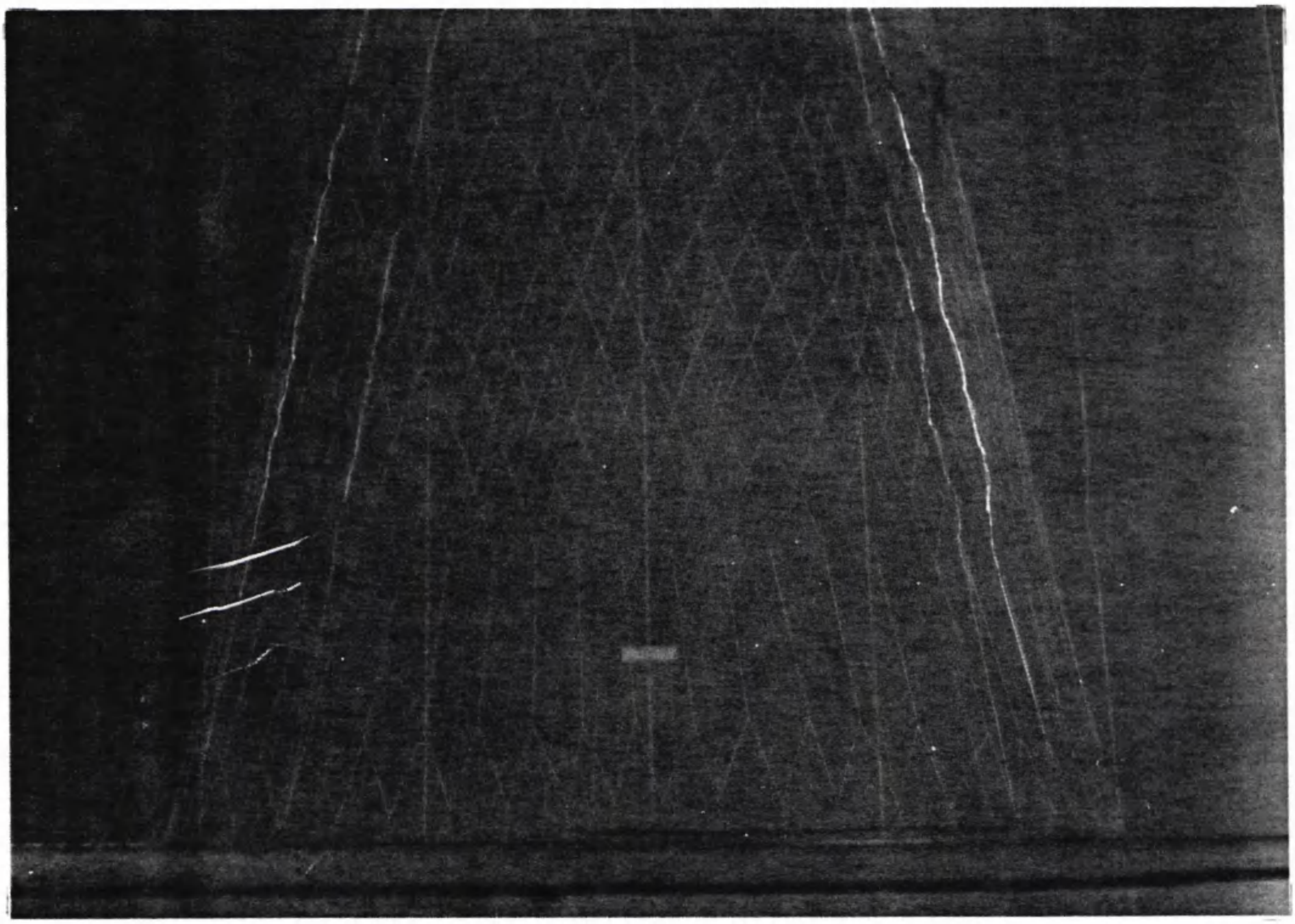


FIG. 13 F Hexanet 5, model scale 1 : 25
Junction of hexameshes to netting.
1300 kg weights, 8.5 m ext., speed 3.0 kn.

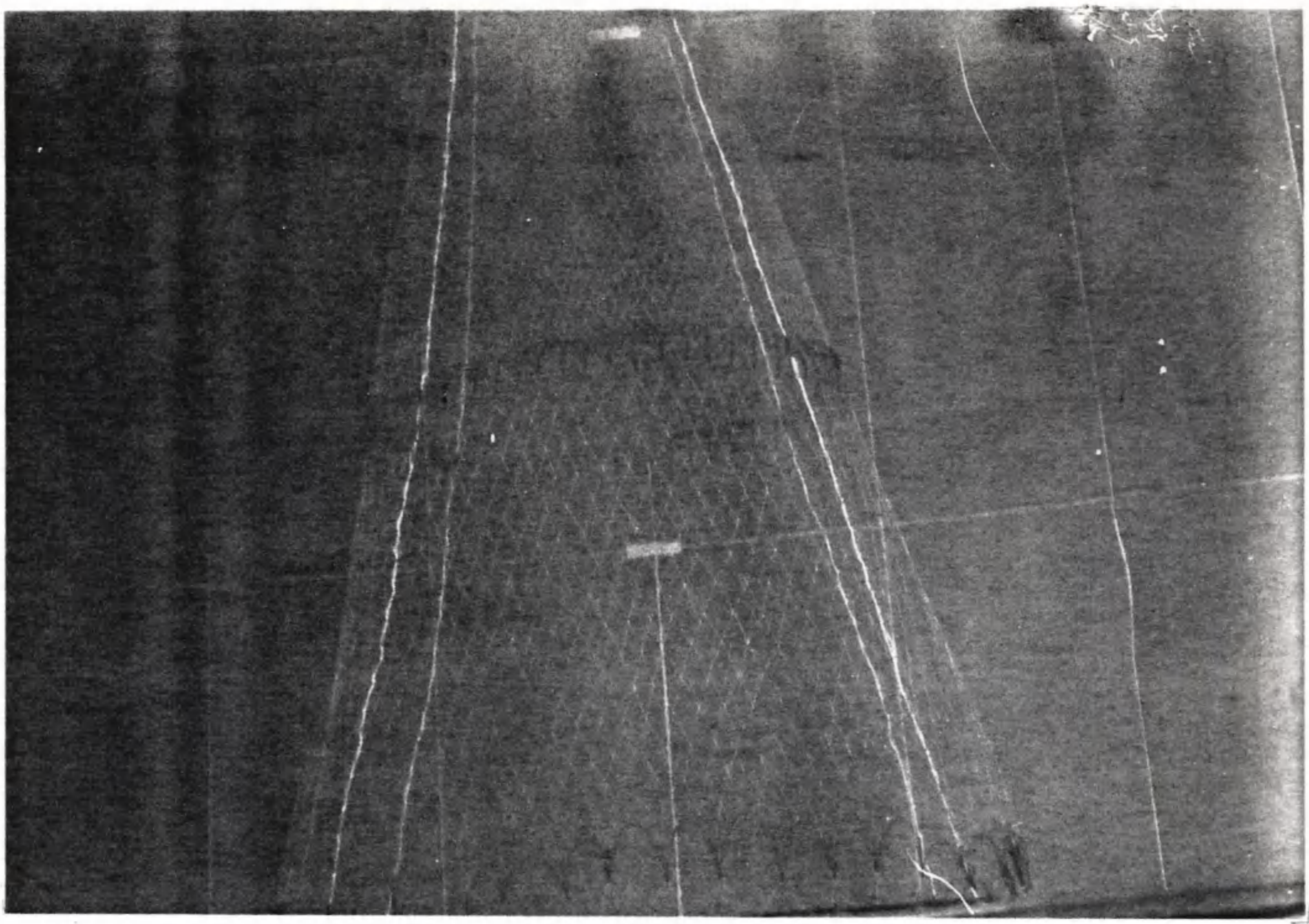


FIG. 13 G Hexanet 5, model scale 1 : 25
400 mm and 200 mm net panels.
1300 kg weights, 8.5 m ext., speed 3.0 kn.

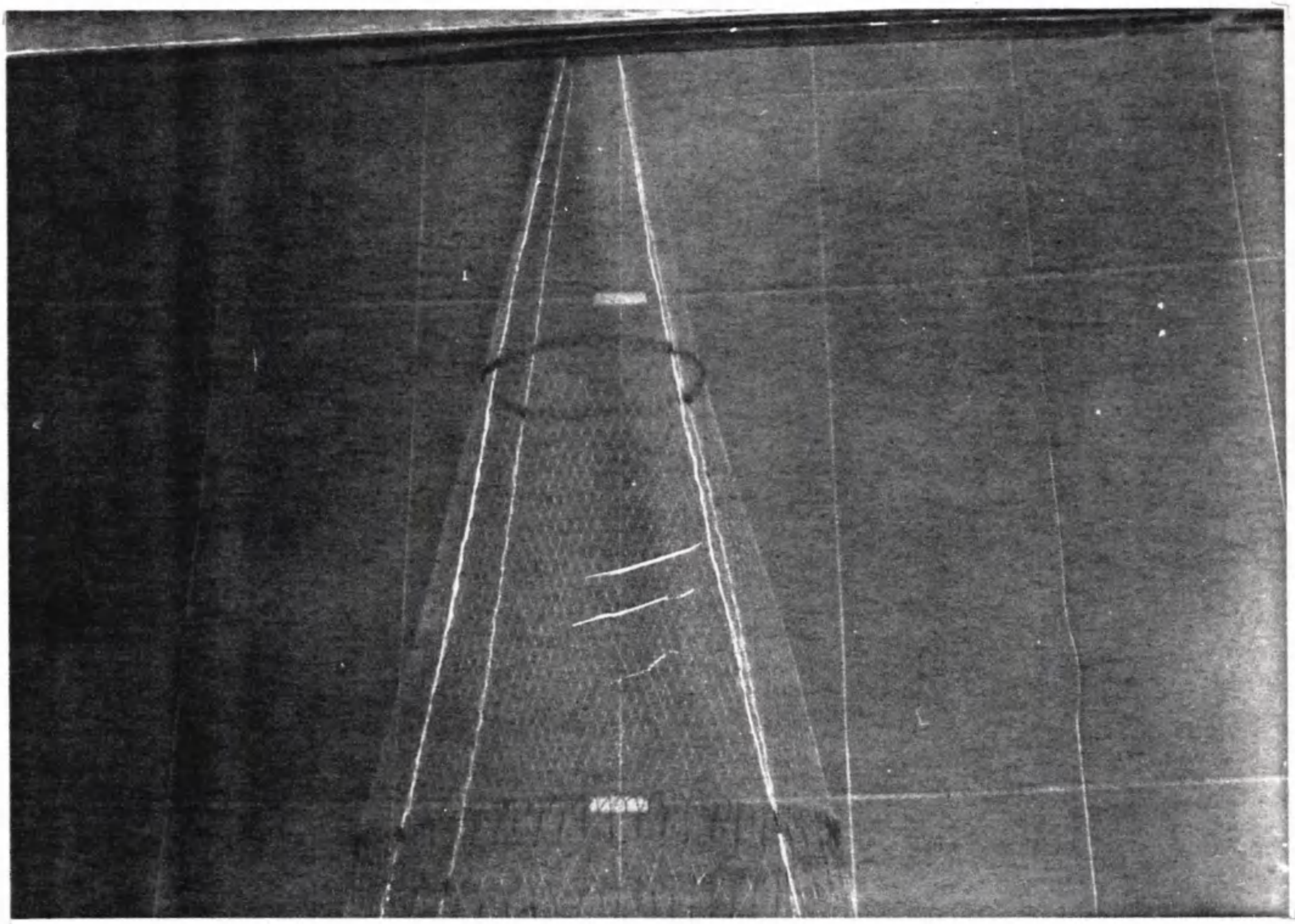


FIG. 13 H Hexanet 5, model scale 1 : 25
400 mm, 200 mm and 100 mm net panels.
1300 kg weights, 8.5 m ext., speed 3.0 kn.