

NRC Publications Archive Archives des publications du CNRC

An overwater heave experiment with research air cushion vehicle HEX-5

Fowler, H. S.; Smith, R. R.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:

<https://doi.org/10.4224/40003600>

Laboratory Technical Report (National Research Council Canada. Division of Mechanical Engineering. Engine Laboratory); no. LTR-ENG-89, 1979-03

NRC Publications Archive Record / Notice des Archives des publications du CNRC :

<https://nrc-publications.canada.ca/eng/view/object/?id=dfac897a-9544-42d2-aea7-cd962796804d>

<https://publications-cnrc.canada.ca/fra/voir/objet/?id=dfac897a-9544-42d2-aea7-cd962796804d>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at

PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.



National Research
Council Canada

Conseil national
de recherches Canada

DIVISION OF MECHANICAL
ENGINEERING

DIVISION DE GÉNIE
MÉCANIQUE

PAGES 14
PAGES _____

**REPORT
RAPPORT**

REPORT LTR-ENG-89
RAPPORT _____

FIG. 8
DIAG. _____

LABORATORY / LABORATOIRE

DATE March 1979
DATE _____

TABLES 5
TABLES _____

ENGINE LABORATORY

LAB. ORDER 18638A
COMM. LAB. _____

FILE 3515-2
DOSSIER _____

FOR
POUR

REFERENCE
RÉFÉRENCE

LTR - ENG-89

AN OVERWATER HEAVE EXPERIMENT WITH
RESEARCH AIR CUSHION VEHICLE HEX-5

SUBMITTED BY E.H. Dudgeon
PRÉSENTÉ PAR _____
LABORATORY HEAD
CHEF DE LABORATOIRE

AUTHOR S H.S. Fowler
AUTEUR R.R. Smith

APPROVED D.C. MacPhail
APPROUVÉ _____
DIRECTOR
DIRECTEUR

Distribution: Unlimited
Classification: Unclassified

THIS REPORT MAY NOT BE PUBLISHED WHOLLY OR IN
PART WITHOUT THE WRITTEN CONSENT OF THE DIVISION
OF MECHANICAL ENGINEERING

CE RAPPORT NE DOIT PAS ÊTRE REPRODUIT, NI EN ENTIER
NI EN PARTIE, SANS UNE AUTORISATION ÉCRITE DE LA
DIVISION DE GÉNIE MÉCANIQUE

COPY NO. 19
COPIE NR. _____

SUMMARY

As part of a program of research into the vertical oscillation ("heave") to which air cushion vehicles are liable, experiments have been made on a vehicle (HEX-5) in attempts to measure heave. Overland the vehicle would not heave at any point in its operating range, but overwater it showed heave oscillation clearly and systematically. Frequency, acceleration and amplitude were measured over a range of vehicle weights and lift airflows. This report records the experiments and data obtained.

CONTENTS

	<u>PAGE</u>
SUMMARY	i
CONTENTS	ii
LIST OF FIGURES	iii
1.0 INTRODUCTION	1
2.0 DESCRIPTION OF VEHICLE AND SITE	1
3.0 DESCRIPTION OF EXPERIMENT	1
4.0 INSTRUMENTATION AND ANALYSIS	2
5.0 CONCLUSIONS	3
APPENDIX 1 DESCRIPTION OF RESEARCH VEHICLE HEX-5	5
APPENDIX 2 INSTRUMENTATION USED	6

LIST OF FIGURES

<u>Figures</u>	<u>TITLE</u>	<u>Page</u>
1	Uplands Pond Soundings	5
2	Research ACV HEX-5	6
3	Sections to Show Size and Shape of Cushion Cavity	7
4	HEX-5 Lift Fan Characteristics	8
5	Heave Frequency vs. Lift Airflow	9
6	Heave Acceleration vs. Lift Airflow	10
7	Heave Amplitude vs. Lift Airflow	11
8	Vehicle Vibration Range	12

HEX-5 Overwater Heave Test Data Summary

Runs 1-5

Tables 1-5

Pages 13-17

1.0 INTRODUCTION

The small air cushion vehicle HEX-5 has been operated over hard smooth concrete, grass, and thick vegetation, at speeds of from zero to 14 m/s, and at weights of from 6500N (unloaded) up to 10800N, and has shown no tendency whatever to go into heave oscillation. However, it was noted that over water it would go into heave at over specific repeatable lift airflows. The heave motion was damped out as soon as forward speed was applied.

A series of experiments over water was therefore carried out, in static hover, to determine the heave frequency, severity, and boundaries, over a range of total vehicle weights.

2.0 DESCRIPTION OF VEHICLE AND SITE

The experiments were carried out using the vehicle HEX-5 on the pond at the NRC Railroad Laboratory (U-89) site. The pond is in a sand spoil-pit, and in the region used has a fairly flat bottom, at a depth between 1.7 and 1.9 metres. A chart is shown in Fig. 1.

The vehicle HEX-5 is a light ACV, hovering on an HDL-type segmented skirt, with separate lift and propulsion systems. The propulsion system was not used in this experiment. An accelerometer was mounted rigidly to the hull, and its output recorded on magnetic tape for subsequent analysis in the laboratory. Relevant details of HEX-5 are shown in Figs. 2-4.

3.0 DESCRIPTION OF EXPERIMENT

HEX-5 was trimmed to hover level over hard flat ground, with full fuel tanks and the pilot on board. Any required ballast for a particular run was then placed symmetrically on board to retain level hover.

The craft was then pushed off and hauled along a cable stretched across the pond to the test position, and tethered to the cable by a 2 metre length of rope hitched to the roll-bar, almost central on the vehicle just behind the driver's head.

The craft's lift engine was then set at a series of rpm's, and identifying signals put into the tape recorder, which ran continuously throughout the test. Readings of the lift engine tachometer, lift airflow measuring manometer and cushion pressure manometer were tabulated by the pilot. These instruments were heavily damped, and did not indicate any cyclic variations.

After running from minimum hover to maximum attainable rpm, the craft was untethered and hauled to shore, to add ballast weight and top up fuel tanks before the next run.

The data obtained are tabulated in reduced form in Tables 1-5, and displayed graphically in Figs. 5-7.

4.0 INSTRUMENTATION AND ANALYSIS

The instrumentation used to obtain the experimental data and analyse it is detailed in Appendix 2.

The accelerometer was mounted vertically and rigidly to the right of the cockpit on the deck (Fig. 2). The accelerometer signal was amplified with a calibrated servo amplifier and in turn recorded onto magnetic tape.

Each test run covered the period from the time the ACV was started on shore, tethered in the test position, operated from minimum to maximum rpm in stages, and returned to shore. The recorder operated continuously throughout each test run.

Ambient noise levels prevented intelligible voice recording. Individual test points were identified by recording a coded series of ambient noise blips at the start of each (steady) state condition. The recorder counter was used to identify each complete test run.

The recorded signal was analysed in the laboratory using a Nicolet 444A FFT Spectrum Analyser. The amplitude displayed on the analyser was compared to a pre-calibrated signal (volts r.m.s.) representing a 9.81 m/s^2 (r.m.s.) acceleration output of the accelerometer.

The peak-to-peak amplitude of the heave oscillation was calculated using the formula:-

$$S_{pp} = 0.7028 \frac{G}{f^2}$$

where S_{pp} = peak-to-peak displacement (m)
 G = measured acceleration r.m.s. (m/s^2)
 f = frequency (Hz)

This assumes that the oscillation was sinusoidal. In view of the taped traces displayed on the oscilloscope, this assumption was considered reasonable.

The values thus obtained are shown in Tables 1 to 5, and plotted in Figs. 5-7.

5.0 CONCLUSIONS

- a. Previous experiments with the air cushion vehicle HEX-5, have shown that over a hard flat ground surface, and over the total weight range of from 7120N to 1246N, this vehicle will not oscillate in heave.
- b. The present series of experiments shows that over water the vehicle becomes unstable and oscillates in heave at any lift airflow above $2 \text{ m}^3/\text{s}$, over the weight range tested, 7120N to 10680N.
- c. The heave frequency is almost constant at 4.6 Hz, over the range of airflow and weight tested. Figure 5 does however suggest that the frequency does increase with decreased weight to some extent at the low airflows, converging to the constant value of 4.6 Hz at airflows of $3 \text{ m}^3/\text{s}$ and above. The amount of data available is not sufficient to make this suggestion more than tentative.

d. The heave amplitude and acceleration increase approximately linearly with lift airflow, rising from zero at 1.8 m³/s flow to 0.011 m amplitude and 0.3 g acceleration at about 4.2 m³/s airflow.

APPENDIX 1

AIR CUSHION VEHICLE HEX-5

DESCRIPTION OF THE RESEARCH VEHICLE HEX-5

General Description

The research vehicle consists essentially of a buoyant fibreglass hull, on which are mounted a lift system, a thrust system, a position for the pilot/observer, minimal fixed instrumentation, and detachable pods containing additional instrumentation when required.

The skirt system being tested is mounted directly on the underside of the hull.

The whole vehicle, mounted on an HDL/HSL segmented skirt is shown in figure 2.

HEX-5 Research ACV, Relevant Data

Hard Structure

Length - 4.15 m
Width - 2.44 m
All Up Mass (1st Experiment) - 680 kg
All Up Weight - 6680 Newtons

(Including 270N of fuel, and one driver/observer, weighing 300N).

Lift System

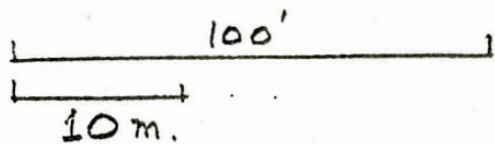
Engine	- 2 cyl. 2 stroke Kohler air cooled
Fans	- 2x.40m diameter centrifugal (9 blades)
Flow	- up to 4.0 m ³ /s (see fan curve)
Maximum Power	- 40 kw at 5500 engine rpm (rated)

APPENDIX 2
INSTRUMENTATION USED

<u>INSTRUMENTATION ON BOARD VEHICLE</u>	<u>COMMENTS</u>
1) Stewart Warner Tachometer	Lift engine rpm
2) 0.765 Sp. Gr. Manometer	Calibrated to measure lift airflow (m ³ /s)
3) Meriam-3 Manometer	Calibrated to measure cushion pressure (Pa)
4) Kistler 305T Accelerometer	Servo, closed loop, DC coupled device using the force feedback principle
5) Kistler 515 Servo Amplifier	Used with the accelerometer
6) Cornell-Dubilier 12SH22 Inverter	120 v, 60~ ac power supply for servo amplifier
7) Bruel & Kjaer 7003F Tape Recorder	1/4" tape, 4 channel, portable

IN LABORATORY

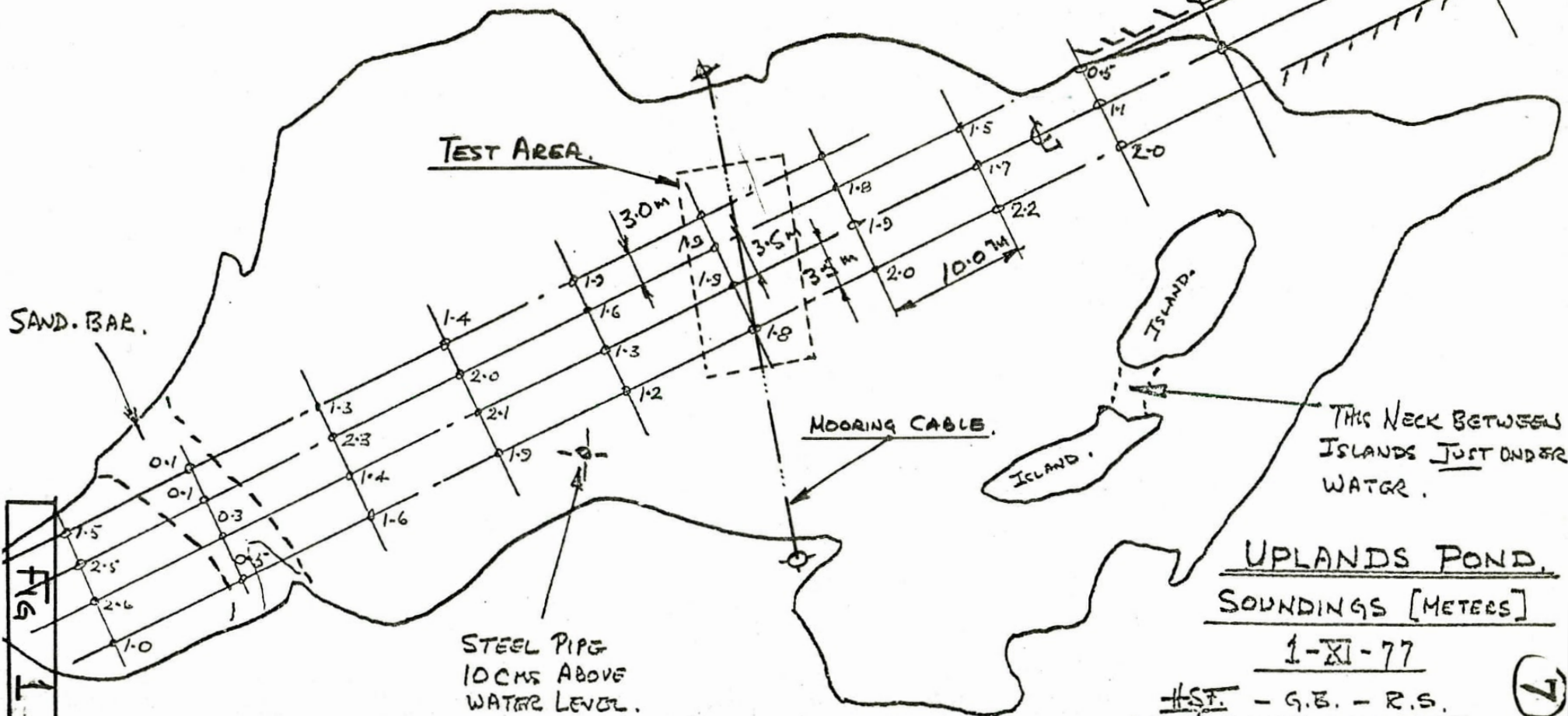
1) Nicolet Scientific Corp. 444A Mini-Ubiquitous FFT Computing Spectrum Analyser	For analysis of tape recordings
---	---------------------------------



U.S.S.

APPROX.

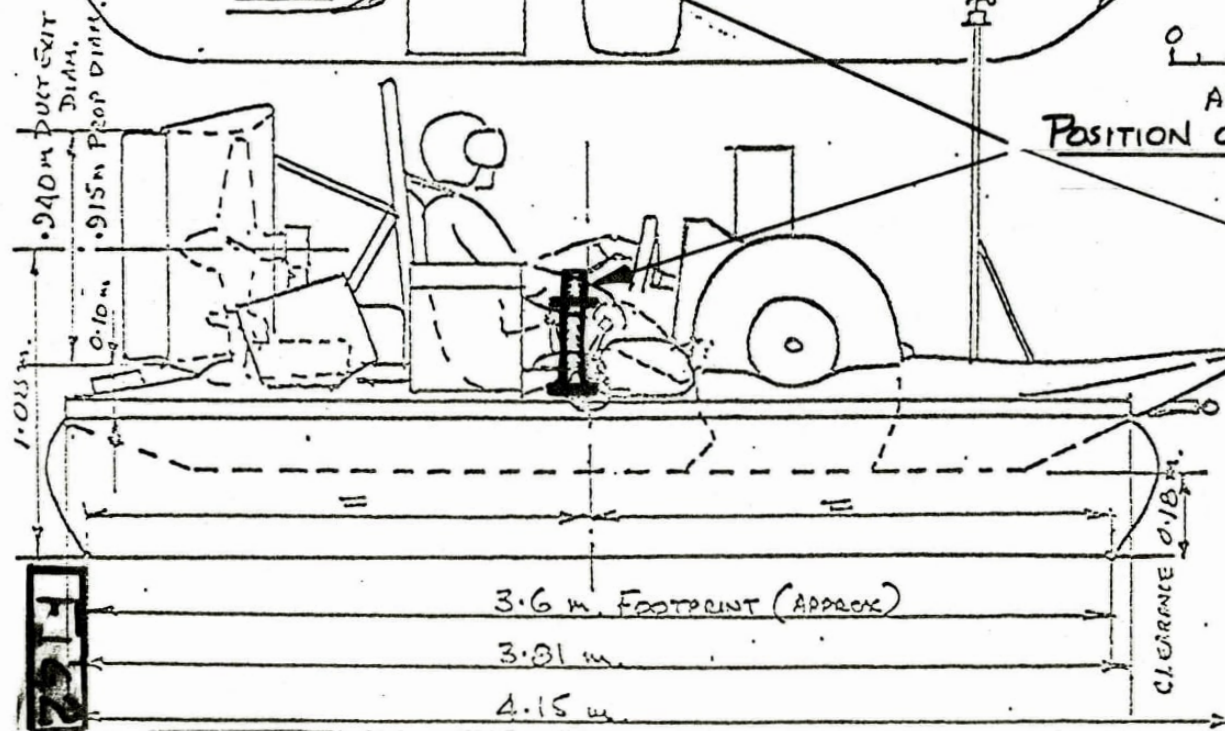
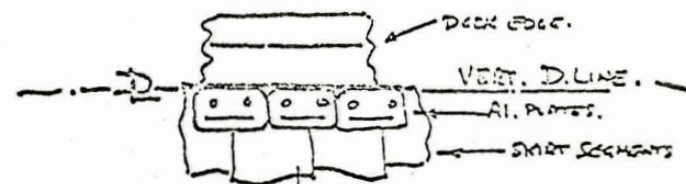
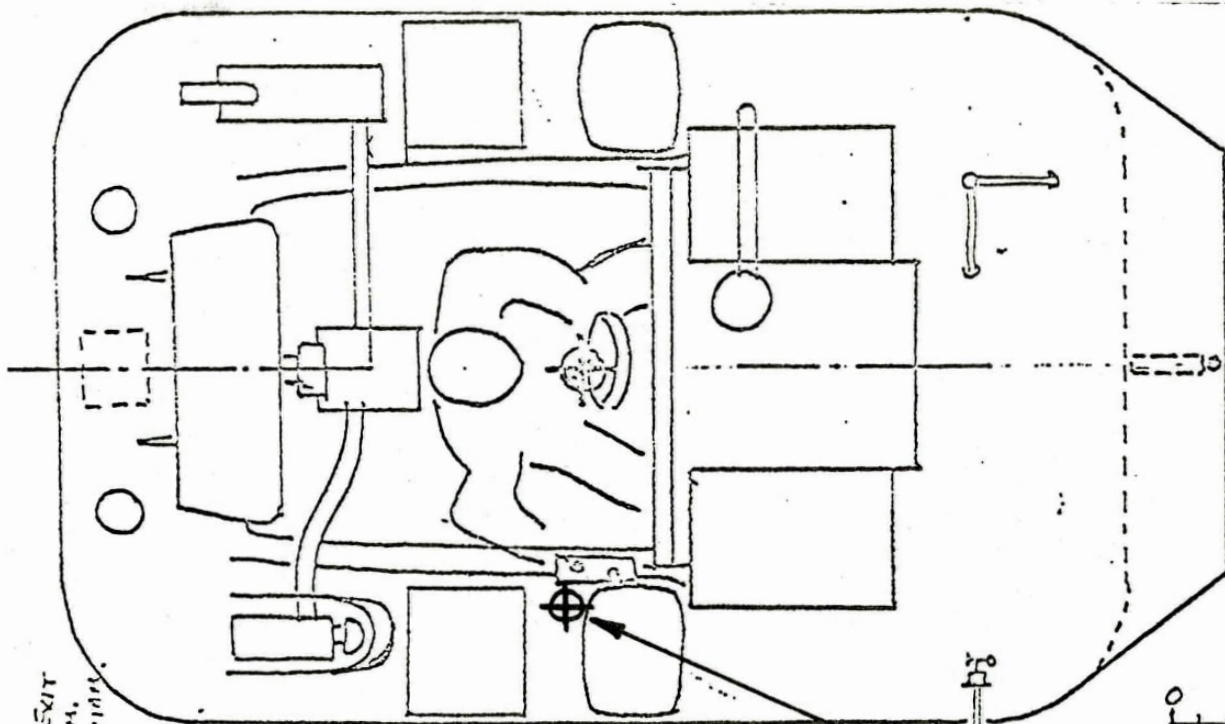
6.7 m. WIDE RAMP.



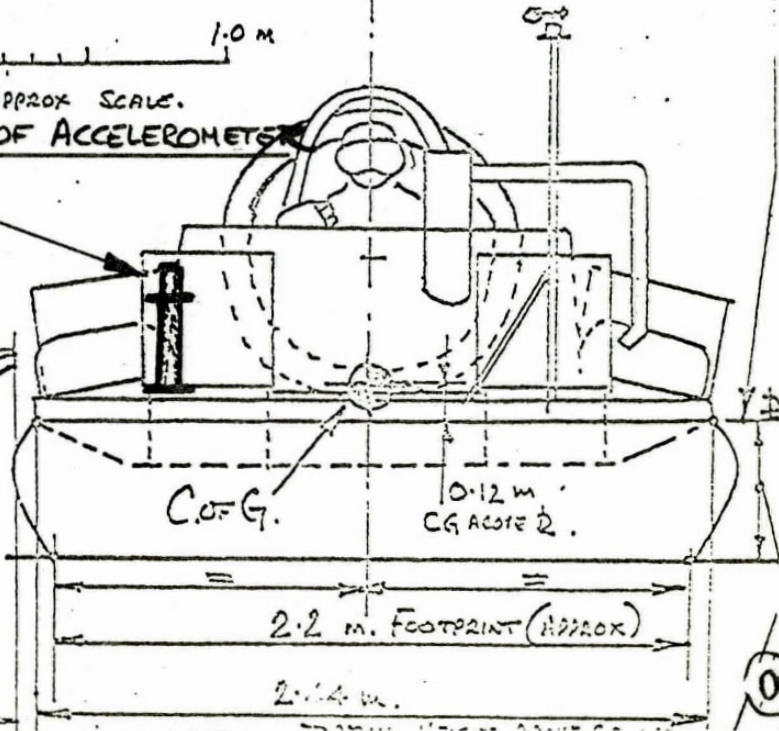
RESEARCH A.C.V. HEX-5.

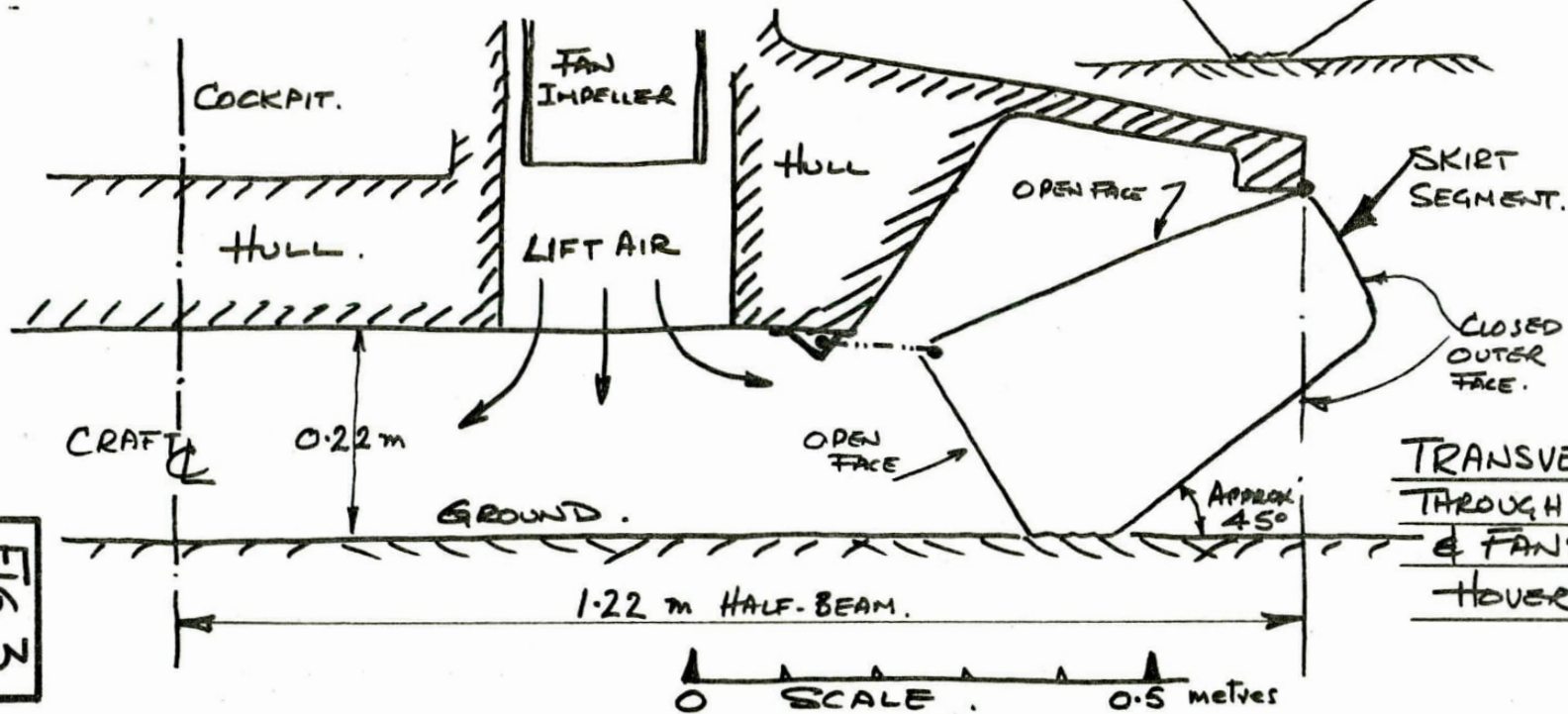
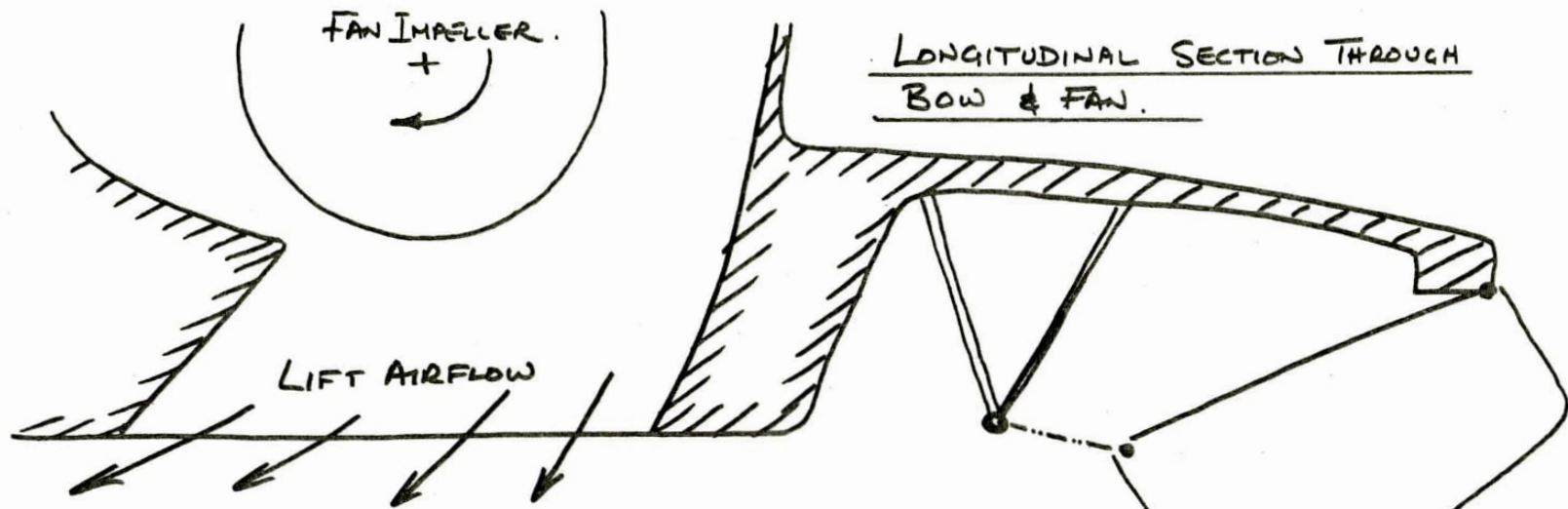
MOUNTED ON HDL/HSL SKIRT.

2-8-78.



APPROX SCALE.
POSITION OF ACCELEROMETER





SECTIONS TO SHOW SIZE & SHAPE OF CUSHION CAVITY & AIR INLET FROM FANS.

[NOTE, SKIRT HULL FORM IS THE SAME AS THAT AT SPEED. BOW IS DISTORT, AS SHOWN]

FIG 3

HEX-5 LIFT FAN CHARACTERISTIC

(AT STANDARD DAY 288°K 101.3kPa)

2 FANS IN PARALLEL
0.4 m. DIAM, 9 BLADES (BACK CURVED)

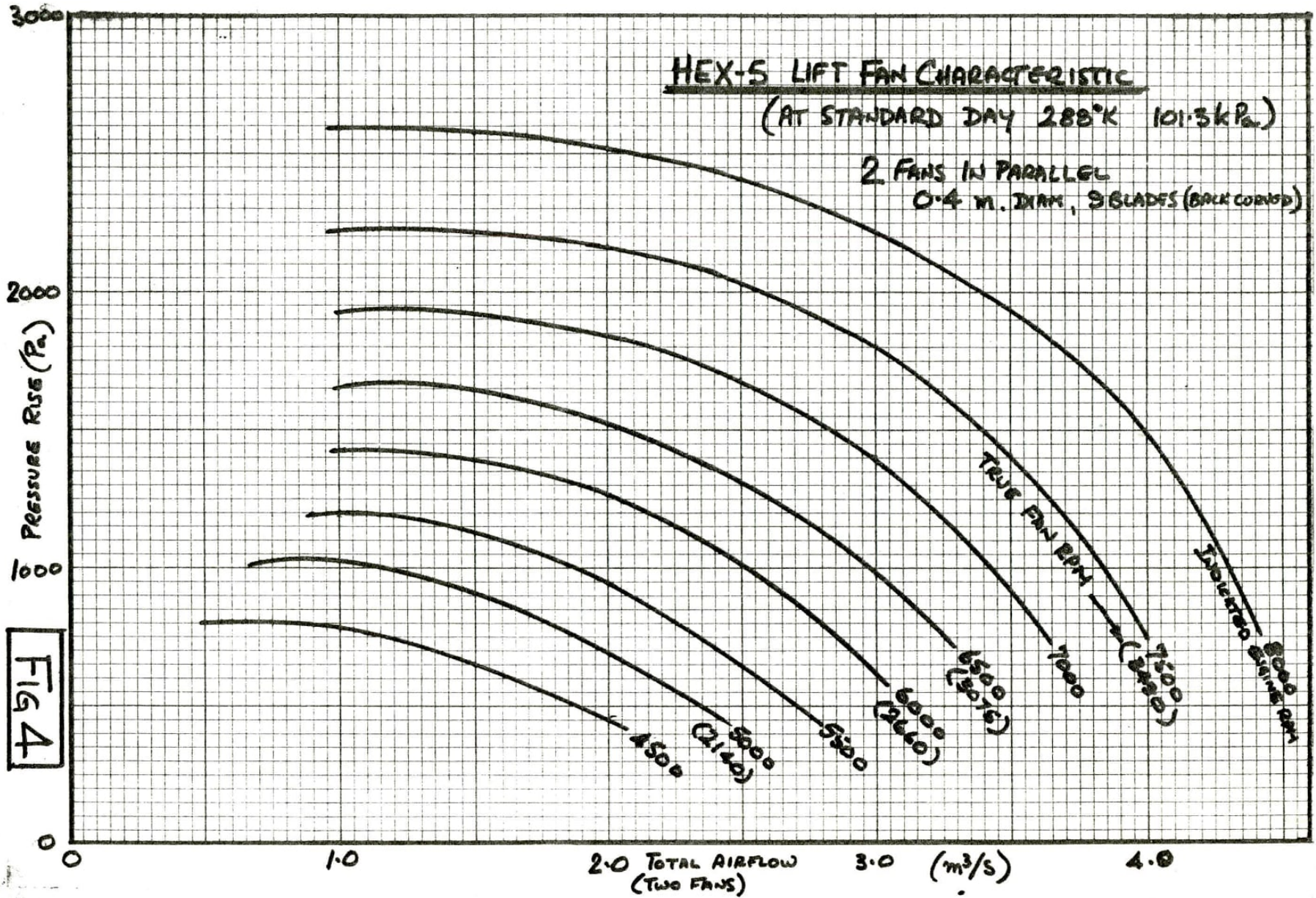


FIG 4

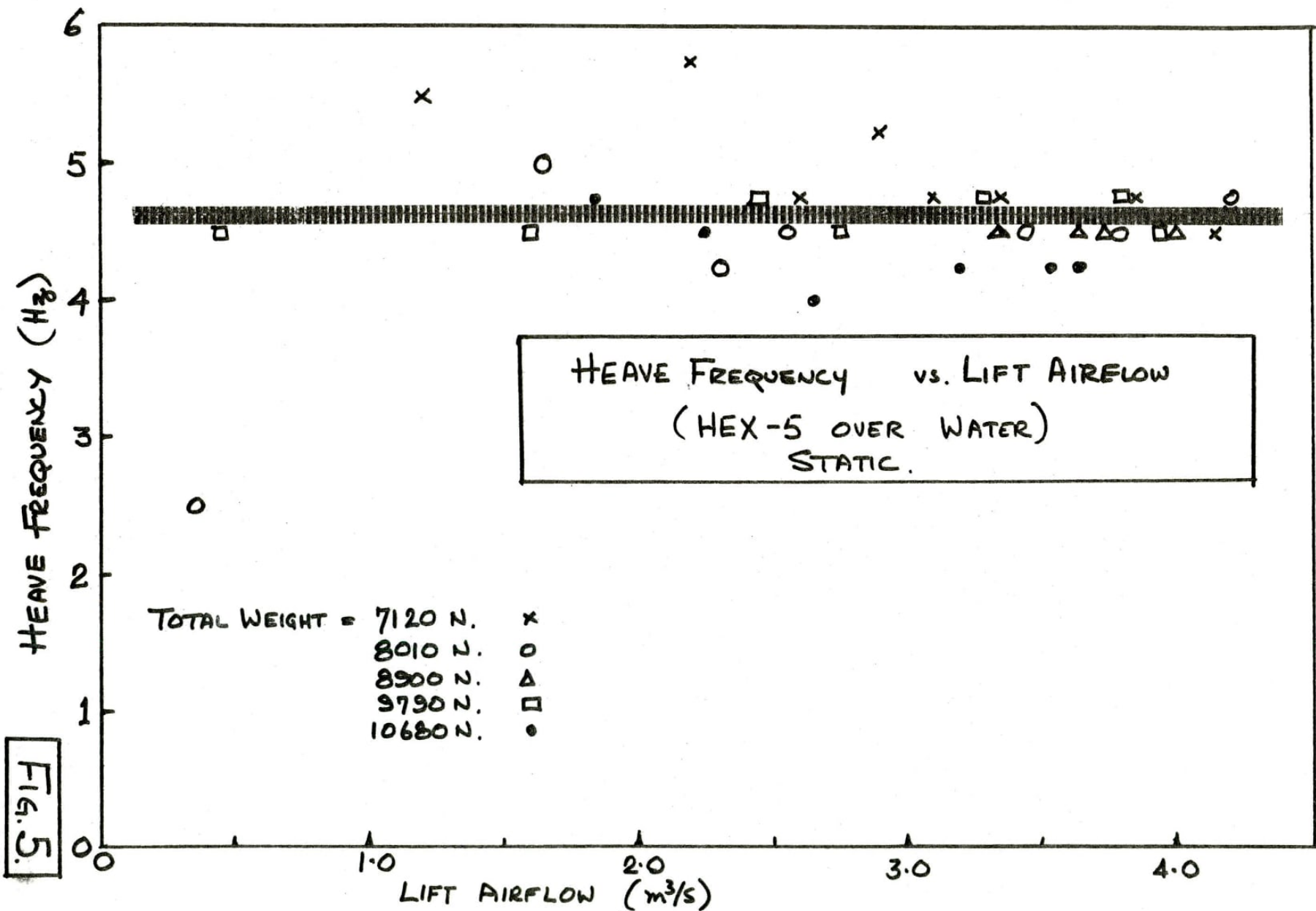


FIG. 5.

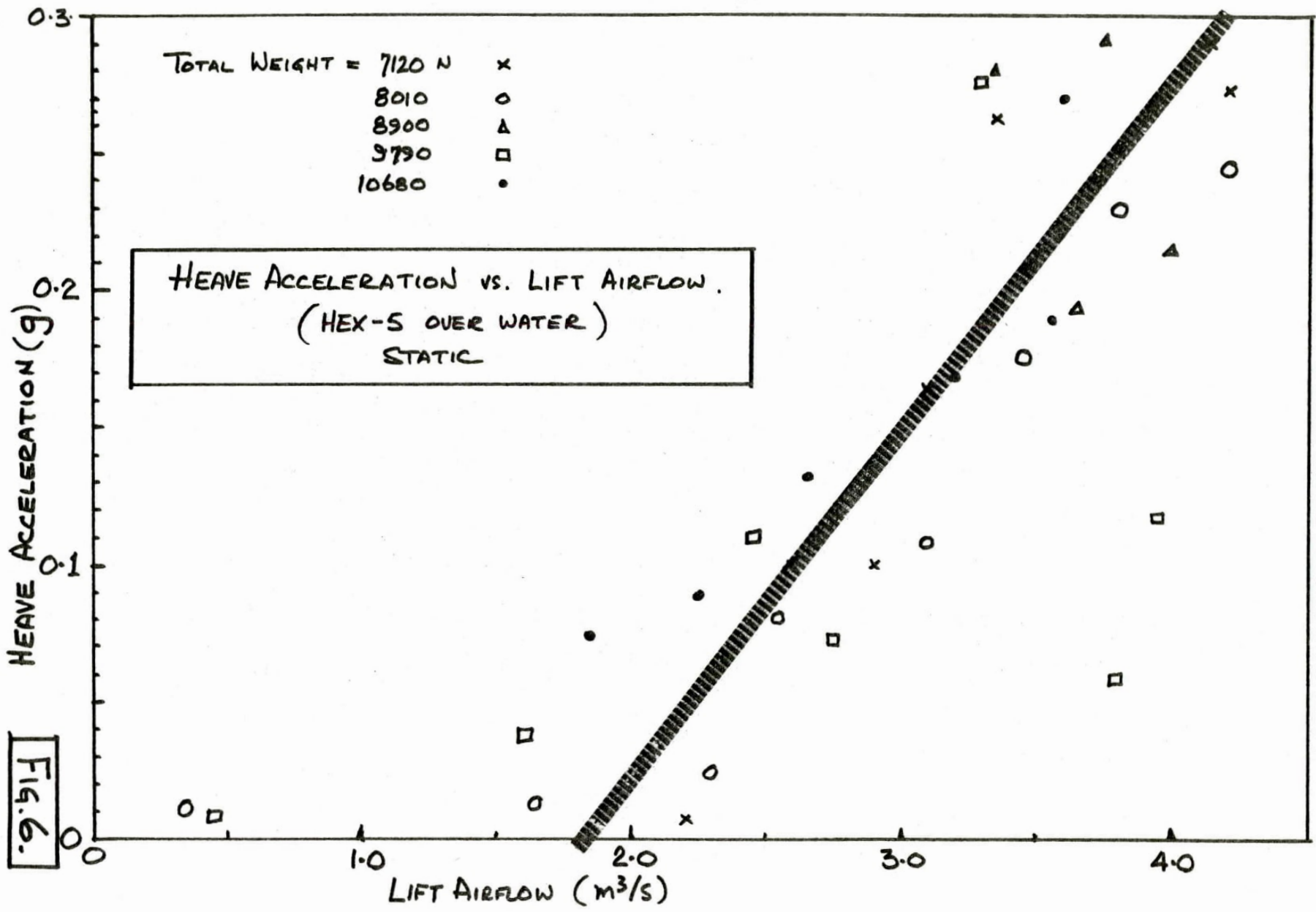


Fig. 6.

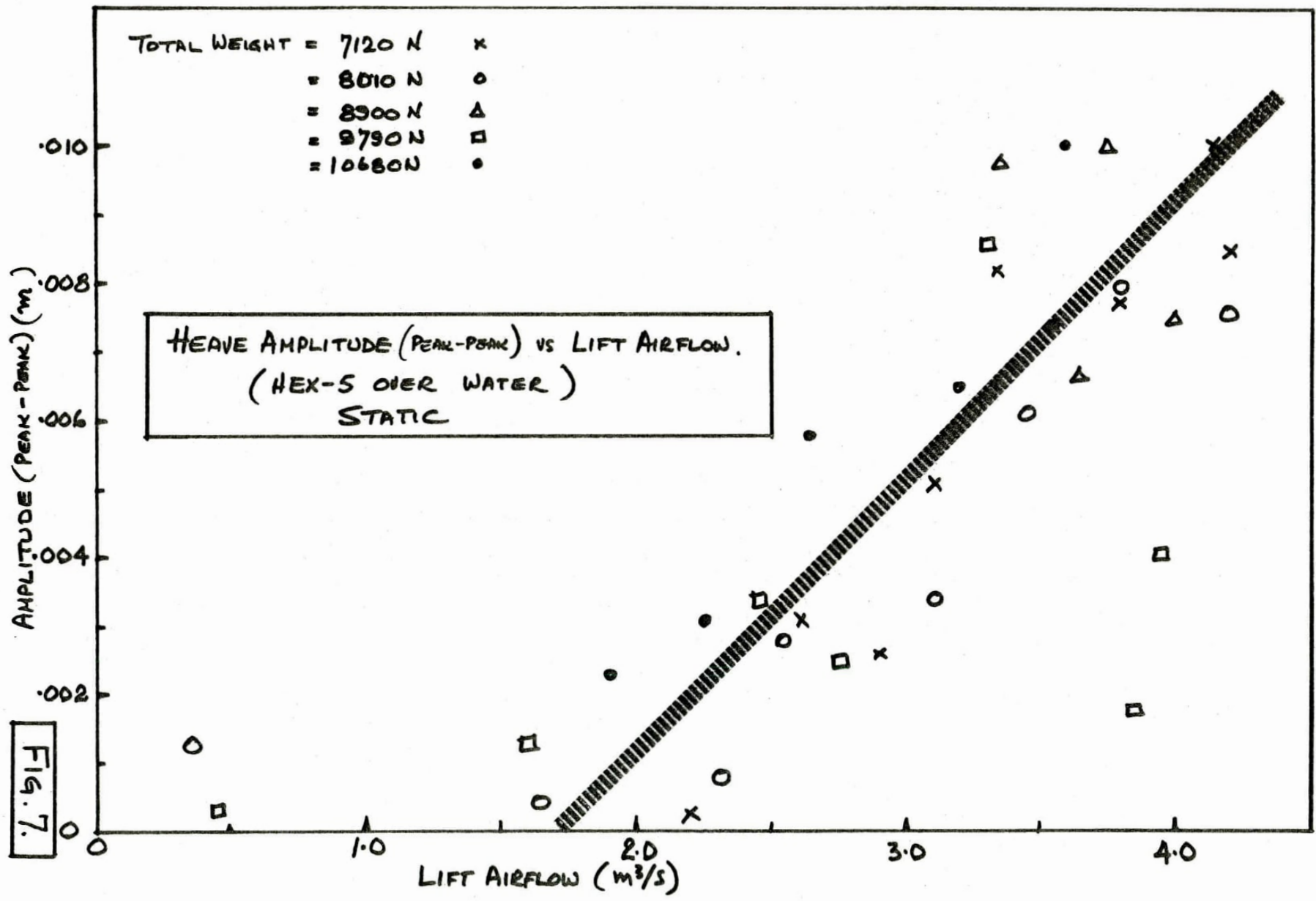


FIG. 7.

VEHICLE VIBRATION RANGE.

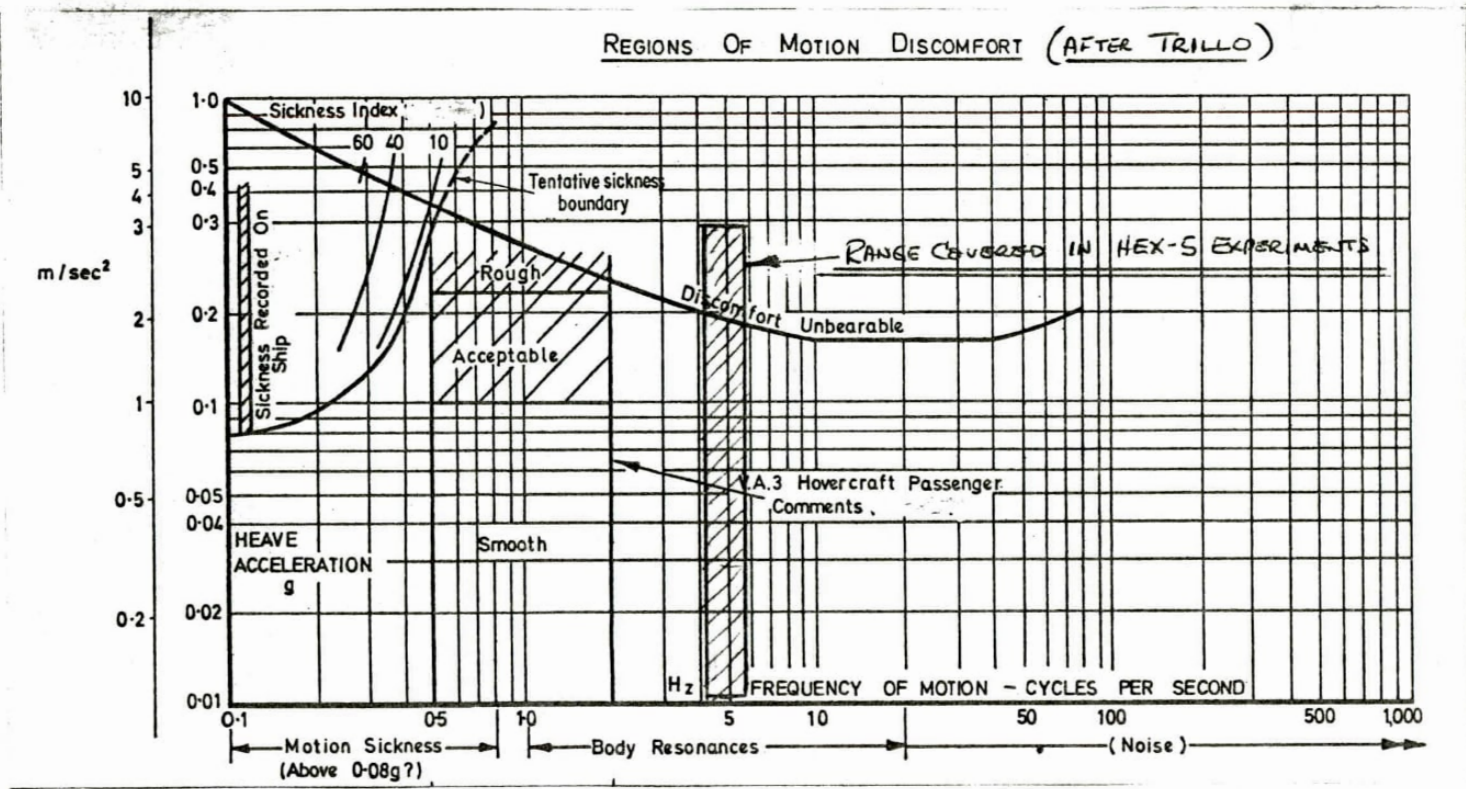


FIG. 8.

HEX-5 OVERWATER HEAVE TEST
SUMMARISED DATA

Run No. 1 Date 24-10-78
 Total Weight = 7120N
 Water Depth = 1.7/1.9 m
 Air Temp. = 0°C Bar. = 101.2 kPa

TEST POINT	AIRFLOW m ³ /s	CUSHION PRESS Pa	ENGINE SPEED REV/S	FAN SPEED REV/S	HEAVE FREQUENCY Hz	HEAVE ACCELERATION rms g	AMPLITUDE (PEAK-PEAK) m
1	1.2	923	52.5	39.4	5.5	-	-
2	2.2	893	59.2	44.4	5.75	.014	.0003
3	2.6	900	62.5	46.9	4.75	.101	.0031
4	2.9	930	64.2	48.2	5.25	.101	.0026
5	3.1	930	66.7	50.0	4.75	.164	.0051
6	3.35	930	69.2	51.9	4.75	.263	.0082
7	3.8	893	74.2	55.6	4.75	.252	.0078
8	4.15	930	75.5	56.6	4.50	.292	.0101
9	4.2	893	78.3	58.7	4.75	.273	.0085
10					4.50	.280	.0097

(9 blades on fan - 2 fans in parallel on same shaft)

TABLE 1

HEX-5 OVERWATER HEAVE TEST
SUMMARISED DATA

Run No. 2 Date 24-10-78
 Total Weight = 8010N
 Water Depth = 1.7/1.9 m
 Air Temp. = +2°C Bar. = 101.2 kPa

TEST POINT	AIRFLOW m ³ /s	CUSHION PRESS Pa	ENGINE SPEED REV/S	FAN SPEED REV/S	HEAVE FREQUENCY Hz	HEAVE ACCELERATION rms g	AMPLITUDE (PEAK-PEAK) m
1	0.35	975	52.5	39.4	2.5	.012	.0013
2	1.65	960	56.7	42.5	5.0	.013	.0004
3	2.3	998	60.8	45.6	4.25	.023	.0008
4	2.55	1005	63.3	47.5	4.5	.080	.0028
5	3.1	1005	68.3	51.2	4.75	.108	.0034
6	3.45	983	71.7	53.8	4.5	.176	.0061
7	3.8	983	75.0	56.2	4.5	.229	.0079
8	4.2	983	78.3	58.7	4.75	.245	.0076
9							
10							

TABLE 2

HEX-5 OVERWATER HEAVE TEST
SUMMARISED DATA

Run No. 3 Date 24-10-78
 Total Weight = 8900N
 Water Depth = 1.7/1.9 m
 Air Temp. = +3°C Bar. = 101.2 kPa

TEST POINT	AIRFLOW m ³ /s	CUSHION PRESS Pa	ENGINE SPEED REV/S	FAN SPEED REV/S	HEAVE FREQUENCY Hz	HEAVE ACCELERATION rms g	AMPLITUDE (PEAK-PEAK) m
1	1.75	1088	59.2	44.4			
2	2.5	1110	64.2	48.2			
3	2.7	1118	66.7	50.0			
4	3.1	1118	69.2	51.9			
5	3.35	1095	71.7	53.8	4.5	.281	.0098
6	3.65	1073	74.7	56.0	4.5	.193	.0067
7	3.75	1088	75.5	56.6	4.5	.292	.0101
8	4.0	1103	78.3	58.7	4.5	.215	.0075
9							
10							

TABLE 3

HEX-5 OVERWATER HEAVE TEST
SUMMARISED DATA

Run No. 4 Date 24-10-78
Total Weight = 9790N
Water Depth = 1.7/1.9 m
Air Temp. = +6.5°C Bar. = 101.2 kPa

TEST POINT	AIRFLOW m ³ /s	CUSHION PRESS Pa	ENGINE SPEED REV/S	FAN SPEED REV/S	HEAVE FREQUENCY Hz	HEAVE ACCELERATION rms g	AMPLITUDE (PEAK-PEAK) m
1	0.45	1170	59.2	44.4	4.5	.009	.0003
2	1.6	1185	62.5	46.9	4.5	.038	.0013
3	2.45	1223	65.0	48.8	4.75	.110	.0034
4	2.75	1208	68.3	51.2	4.5	.072	.0025
5	3.3	1200	71.7	53.8	4.75	.277	.0086
6	3.8	1200	75.5	56.6	4.75	.059	.0018
7	3.95	1200	78.3	58.7	4.5	.117	.0041
8							
9							
10							

TABLE 4

HEX-5 OVERWATER HEAVE TEST
SUMMARISED DATA

Run No. 5 Date 24-10-78
Total Weight = 10680N
Water Depth = 1.7/1.9 m
Air Temp. = +6.5°C Bar. = 101.2 kPa

TEST POINT	AIRFLOW m ³ /s	CUSHION PRESS Pa	ENGINE SPEED REV/S	FAN SPEED REV/S	HEAVE FREQUENCY Hz	HEAVE ACCELERATION rms g	AMPLITUDE (PEAK-PEAK) m
1	0.35	1200	62.5	46.9	-	-	-
2	1.85	1298	65.0	48.8	4.75	.074	.0023
3	2.25	1298	67.5	50.6	4.5	.089	.0031
4	2.65	1275	70.0	52.5	4.0	.132	.0058
5	3.2	1275	71.7	53.8	4.25	.168	.0065
6	3.55	1290	74.7	56.0	4.25	.189	.0074
7	3.6	1275	76.7	57.5	4.25	.271	.0105
8							
9							
10							

TABLE 5