

## **TECHNICAL EVALUATION OF THE MARIC 65-TONNE AMPHIBIOUS HOVERCRAFT MODEL 722**

(ÉVALUATION TECHNIQUE DE L'AÉROGLISSEUR DE 65 TONNES MARIC 722)

Yun Liang, Gu Xiong and Zhu Jing Zhang, Marine Design and Research Institute of China

### **ABSTRACT**

The MARIC 65-tonne, piston-powered development hovercraft was evaluated over a number of years before its retirement. The craft, which had a 15-tonne payload capacity, is described along with its design rationale. Some trial results are given, covering cushion behaviour, cabin airborne noise and seakeeping characteristics.

### **RÉSUMÉ**

L'aéroglesseur MARIC de 65 tonnes est un véhicule de développement équipé de moteurs à piston qui fut évalué durant quelques années avant d'être réformé. Il avait une charge marchande de 15 tonnes. Une description de cet aéroglesseur est faite, ainsi que les considérations ayant dirigé sa conception. Quelques résultats d'essais sont donnés sur le comportement du coussin, le bruit intérieur et la tenue en mer.

## INTRODUCTION

The aim of the MARIC 65 tonnes amphibious development hovercraft model 722 was to evaluate technical performance, feasibility, practicality and applications of such medium size amphibious hovercraft in China.

The development and evaluation schedule of the craft was as follows:

Initial R&D on the craft	1974
Technical design	1975-76
Construction design	1976-77
Construction of the craft	1977-78
Watertight test of the buoyancy raft	1979
Bollard test on land	1979
Launching	1979
First long range sea trials	1980
Second long range sea trials	1980
Delivery to the user	1981
Tests in various operational environment	1981-87
Retirement	1987

## MARIC MODEL 722 AMPHIBIOUS HOVERCRAFT

Leading particulars of the craft and its design performance are given below. The hovercraft itself is illustrated in figures 1, 2 and 3.

### LEADING PARTICULARS

Length overall	27.4 m
Beam overall	13.9 m
Height overall	9.6 m
Length of buoyancy raft	20.0 m
Beam of buoyancy raft	7.5 m
Height of cargo cabin	2.6 m
Area of cargo cabin	80.0 m <sup>2</sup>
Height of navigation cabin	1.9 m
Cushion length (Lc)	24.6 m
Cushion width (Bc)	11.4 m
Lc/Bc	2.16
Cushion area (Sc)	270.0 m <sup>2</sup>
Cushion pressure (Pc)	2.4 kPa
Pc/Lc	97.5 Pa/m
Height of skirts, stern to bow	1.5-1.8 m
All up weight	65.0 t

## MAIN DESIGN PERFORMANCE

Payload (cargo or two cars)	15 t
Speed, maximum calm water	54 knots
maximum sea state 3	37 knots
Maximum range at 40 knot cruising speed	200 naut. miles
Seakeeping capability: Vehicle to operate safely on cushion in Sea State 4	
Amphibious capability: Vehicle to be operated overland and overwater	
Ground obstacles clearance	1.1 m
Ditch crossing capability, width	2.5 m
Floodability: Total buoyancy of craft/ craft weight	1.85
Buoyancy raft is divided in 19 compartments allowing floatation with two compartments flooded	

## DESIGN CONSIDERATIONS

In the early 70's, CSSC (China State Shipbuilding Corp.) and MARIC as well as some potential users, planned to evaluate the feasibility and the practicability of medium sized amphibious hovercrafts. These characteristics are difficult to predict from model tests or from small manned test crafts. Therefore the 65 tonnes MARIC hovercraft was designed and built in order to evaluate and predict manoeuvrability, amphibious and seakeeping capabilities, speed performance, reliability of power transmission system and skirts, etc, of a medium sized ACV in various operational environments.

This craft had to be built from material available in China. This, and the objectives to be met by the craft, led to the following design considerations and constraints.

### 1. Structural Material

The main hull structure use riveted duralumin (non sea water resistant) as the main material because a reliable, sea water resistant aluminium alloy was not available in China at that time.

### 2. Engines

There were also no China made reliable marine gas turbines available at the time, so that, in order to complete the craft within schedule, use was made of piston engines built in China. Model "651" and "690" aviation engines were used respectively as propulsion and lift engines. The main characteristics of these engines are as follows:

<u>Engine models</u>	"651"	"690"
Rated power (hp)	1530	1430
Fuel brand	Aviation gasoline No. 95	
Weight of each engine (kg)	935	1100
Specific weight (kg/hp)	0.612	0.769
Overhaul life (hr)	300	300
Rated revolution (rpm)	2400	2400
Maximum revolution (rpm)	2600	2600

### 3. Air Cushion Design

Considering the probability of craft weight increase during construction and the lack of a prototype, a low cushion pressure to length ratio ( $P_c/L_c=10$ ) and a high cushion length to beam ratio ( $L_c/B_c=2.4$ ) were chosen in order to reduce peak resistance. A longitudinally tapered bag and finger skirt with a slope of 1.2 (height of bow skirt over height of stern skirt) was mounted in order to improve seakeeping qualities. "D" type bag were also added to the bow skirt to effectively prevent tuck under (figures 2 and 4).

### 4. Lift and Auxiliary Propulsion Systems

Two aviation piston type engines model 651, each rated at 1530 hp, were installed to drive, via transmission gearbox and flexible coupling, six centrifugal fans and two propellers mounted on swiveling pylons for auxiliary propulsion. Each fan, of 1.49 m diameter, consumed 333 hp at the maximum speed of 1275 rpm.

Auxiliary Propellers: These propellers, 2.6 m in diameter, could be regulated in pitch from -13 to 19 degrees in order to balance power output between fans and propellers, and also to obtain reverse thrust from these propellers. The maximum power output for each auxiliary propellers was about 400 hp.

Fans: Six industrial fans, model 4-73, were mounted on the craft and the skirt bags used as main duct for distribution of the pressurised air (figures 5, and 8). This system was highly efficient.

Propeller Pylons: The swiveling pylon could be turned 48 degrees on either side through the action of hydraulic actuators controlled by an electro-electric system (figures 6 and 7). This improves manoeuvrability and course keeping ability in quartering wind.

Obviously, the design and manufacturing of the power transmission system, particularly the swiveling pylon, were very difficult due to the long transmission shaft. There were strong excitation sources with a wide range of frequencies to interact with the light and flexible hull structure, the light transmission shafts, bearings, gearboxes and mountings. Engines vibrations and torque oscillations, wave slamming, etc, compounded the problem.

## 5. Propulsion System

Two aviation piston type engines model 690, each rated at 1430 hp, were mounted on lattice towers aft, driving 3.8 m propellers.

## 6. Craft Control System

In order to test the effectiveness of different control devices to obtain good manoeuvrability of the craft, a number of control devices were mounted on the craft. These were:

- \* Two vertical air rudders with stability fins;
- \* An horizontal air rudder and fin (elevator);
- \* Differential thrust for the two main air propellers;
- \* Differential pitch angle for the two auxiliary air propellers;
- \* Swiveling pylons;
- \* Air duct valves for regulating the cushion pressure in forward and rear cushions so as to change the trim angle in various operational environment;
- \* Skirt lift system permitting transverse motion of the craft.

## GROUND TESTS AND SEA TRIALS

Tests were carried out covering stability and other characteristics of the air cushion, seakeeping and general behaviour of the craft in various operational situations.

### 1. Static Hovering Tests

The craft was hovered freely over the ground and the bag/cushion pressure was measured at a number of locations (figure 9).

The tests showed that the cushion pressure was distributed uniformly, with a mean cushion pressure of 2.04 kPa (Pc) and a mean bag pressure of 2.32 kPa (Pt).

$$\begin{aligned} Pt/Pc &= 1.135 \\ \text{Air flow rate} &= 250 \text{ m}^3/\text{s} \\ \text{Skirt clearance} &= 0.071 \text{ m (space between skirt tip and ground)} \end{aligned}$$

## 2. Static Stability Tests

The static longitudinal and transverse stability on the ground were measured as follows:

$$M_p/\psi = 314.2 \text{ m.kN/deg.} \quad \frac{M_p/\psi}{W.Lc} = 2.1\% \text{ per degree of pitch}$$

$$M_r/\theta = 26.7 \text{ m.kN/deg.} \quad \frac{M_r/\theta}{W.Bc} = 0.4\% \text{ per degree of roll}$$

Where	M	Restoring moment (m.kN)
	W	Craft weight (kN)
	$\psi$	Pitch angle (deg)
	$\theta$	Roll angle (deg)

## 3. Calm Water Speed Tests

Tests to measure the maximum calm water speed and corresponding cushion pressure were carried out in Qing dao in 1980. Figure 10 shows the thrust and drag of the craft versus the speed. It was found that the cushion pressure of the craft at top speed was also distributed uniformly. The mean cushion pressure was reduced a little because of the aerodynamic lift of the craft at speed.

Maximum velocity measured,	V = 28.2 m/s (54.8 knots)
Craft weight during test,	W = 59.1 t
Cushion pressure,	Pc = 1.88 kPa
Bag pressure,	Pt = 2.39 kPa

## 4. Manoeuvrability Tests

Manoeuvrability tests were carried out in Qing dao. Manoeuvrability of the craft was satisfactory, not only at high speed on cushion, but also at low speed, due to its effective control devices. With control through the air rudders, the turning diameter of the craft was about 6.4 L at a speed of 30 km/h and 19.5 L at 50 km/h.

## 5. Airborne Noise

Inside airborne noise was measured in various part of the craft; the measurements are given in the table below. The external airborne noise, measured 50 m from the rear of the craft, was about 95-100 dBA. The noise level, both internally and externally, was high due to the experimental nature of the craft.

<u>Location</u>	<u>Airborne Noise (dBA)</u>
Forward passenger cabin	82-84
Navigation post	101
Radio cabin	93
Cargo area	98-106
Machinery bay (starboard)	116

6. Long Range Continuous Operations

The craft has been operated continuously on two occasions in 1980. The first time was from Tien-Jin to Qin huang dao (figure 11) and return (240 naut. miles), the second time, from Tien-Jin to Qing dao (550 naut. miles). These trips showed that the craft endurance was satisfactory.

7. Amphibious and Obstacle Clearing Tests

These tests were carried out in 1979 and 1980 (figures 12, 13 and 14). They showed that the craft could clear a clay obstacle of 1 to 1.1 m, cross a ditch 2.5 m wide and traverse a maximum gradient of 3% in a short distance.

8. Seakeeping Tests

Seakeeping tests were carried out in July of 1981 in Qing dao. The test results are shown in the table below.

<u>Parameters</u>	<u>Mean Values for four Routes</u>			
	1st (head sea)	2nd (following sea)	3rd (head sea)	4th (following sea)
Pitch angle (deg)	5.33	2.59	5.46	4.14
Roll angle (deg)	5.13	2.03	4.30	2.02
Bow acceleration (g)	0.23	0.12	0.23	0.11
Pressure fluctuation				
Front cushion (kPa)	0.91	0.56	1.36	0.50
Rear cushion (kPa)	1.10	0.59	1.27	0.79
	<u>Maximum Values for Routes</u>			
Pitch angle	12.34	6.17	12.36	7.45
Roll angle	15.64	4.94	14.94	3.92
Bow acceleration	0.61	0.25	0.63	0.25
Pressure fluctuation				
Front cushion	2.59	1.18	4.04	1.46
Rear cushion	2.63	1.13	2.57	1.85
	<u>Wave Characteristics</u>			
Fraction of waves	100%	33%	3%	
Mean wave height (m)	1.09	1.65	2.18	

Figure 15 shows the time history of the pressure fluctuations in the bags and in the front and rear cushions.

## SUMMARY

- I Trials of the medium size air cushion vehicle model 722 has been carried out over a long period of time, during which a lot of data and experience has been accumulated. This has been very important for later designs and operations.
- II The test results in various environments show that hovering performance, speed, stability, manoeuvrability, strength of hull structure, power transmission system (including fans and other rotating machinery), skirts, etc, were satisfactory.
- III The trials showed that the practicability, feasibility and maintainability of the various components of the craft were not satisfactory, and that there was still room for improvements.
- IV The craft could have benefitted from the use of responsive skirts with larger deformation and better ride control. The effectiveness of such skirts has been demonstrated both in static test rig and in towing tank experiments.

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2. Zhu Jing Zhang, Shen Yiang Xian: "Design and Development of the Power Plant of the 65 ton class Model 722 Prototype Landing Air Cushion Vehicle" International High Performance Vehicle Conference, Shanghai, China, November 1988
3. Zheng Chong Qing, Chen Li Ying: "Test and Analysis of the Cushion/Bag Pressure and its Fluctuation on the 65 tonn Amphibious Hovercraft" MARIC Report 1982
4. Zheng Chong Qing, Chen Li Ying: "Seakeeping Test of 65 ton Amphibious Hovercraft" MARIC Report 1981
5. Yun Liang: "Development of Hovercraft at Home and Abroad During the Last Decade" The Second Conference on High Speed Craft in China, 1984

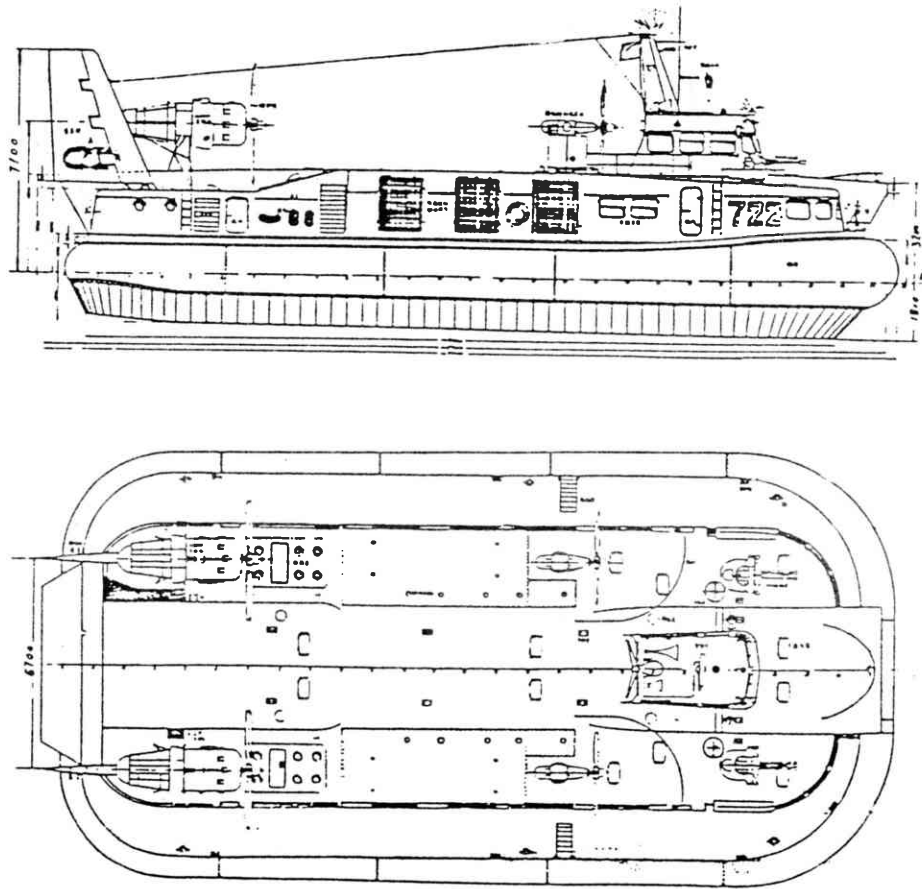


Figure 1. MARIC Model 722: Side and Plan Views

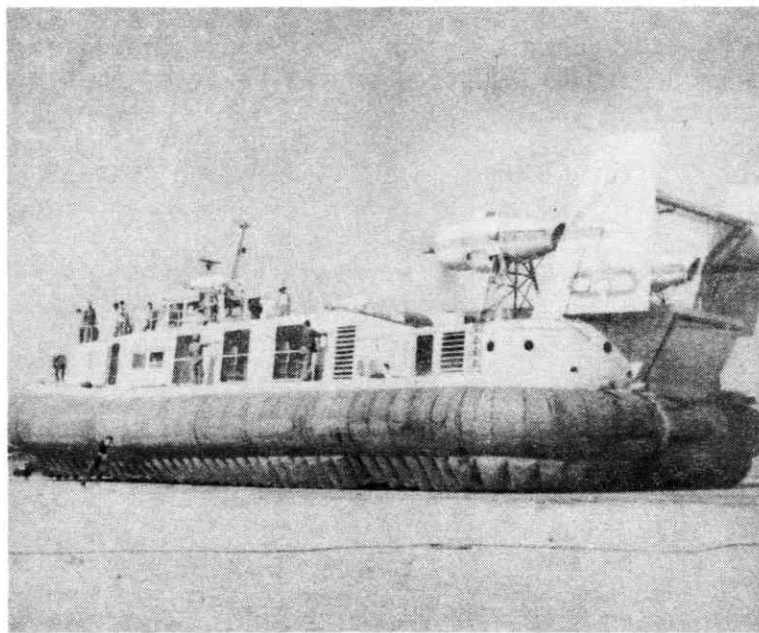


Figure 2. MARIC Model 722: Craft in Static Hover

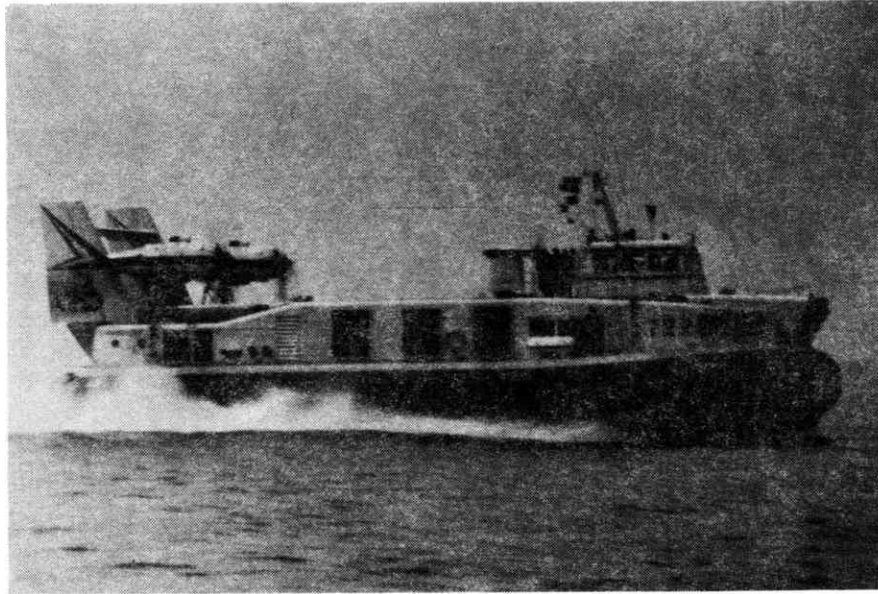


Figure 3. MARIC Model 722: Craft at Speed



Figure 4. MARIC Model 722: Side Skirts

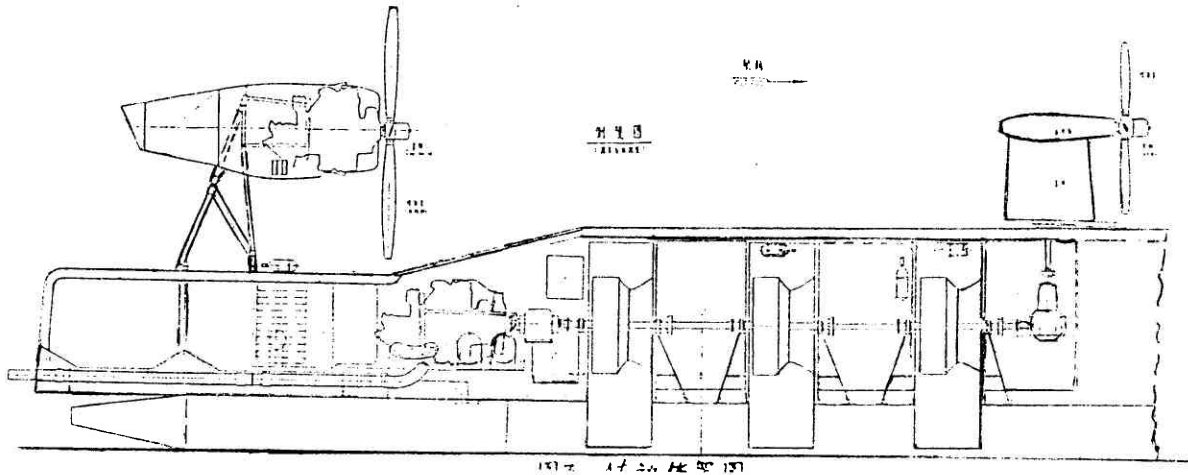


Figure 5. Arrangement of Power Plant and of Lift/Propulsion System

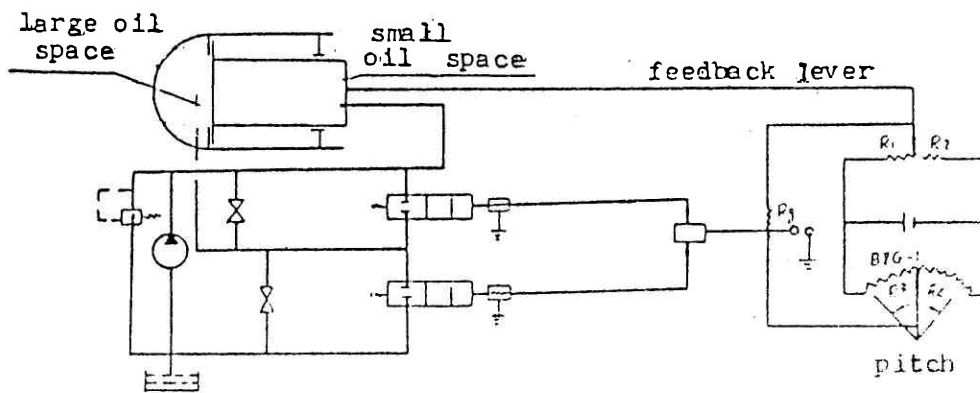


Figure 6. Diagram of Pitch Control System for the Auxiliary Propeller

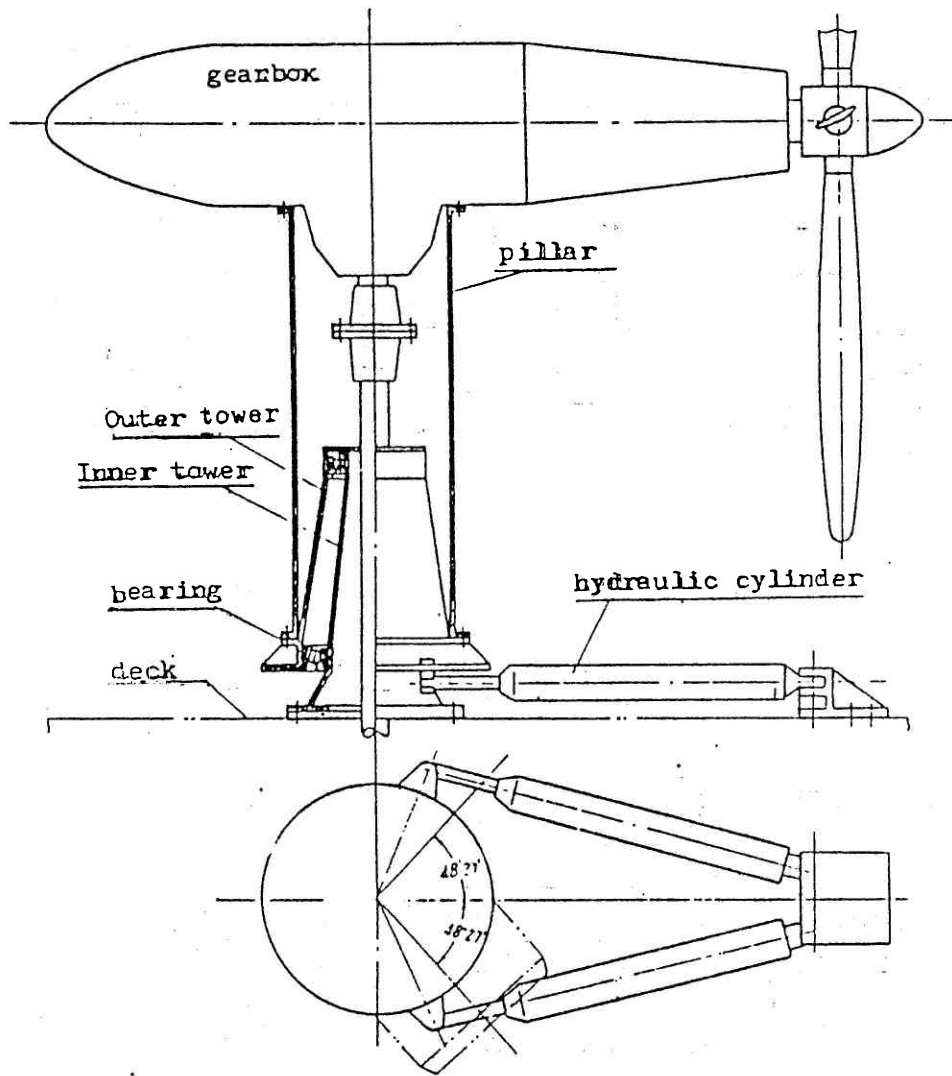
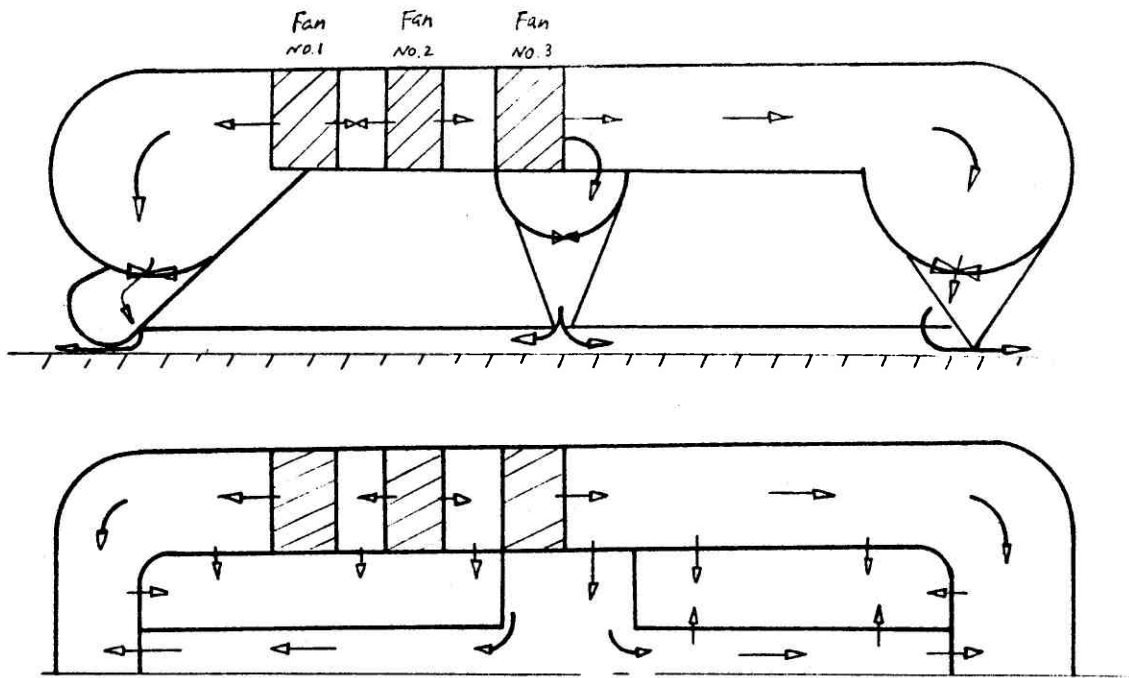
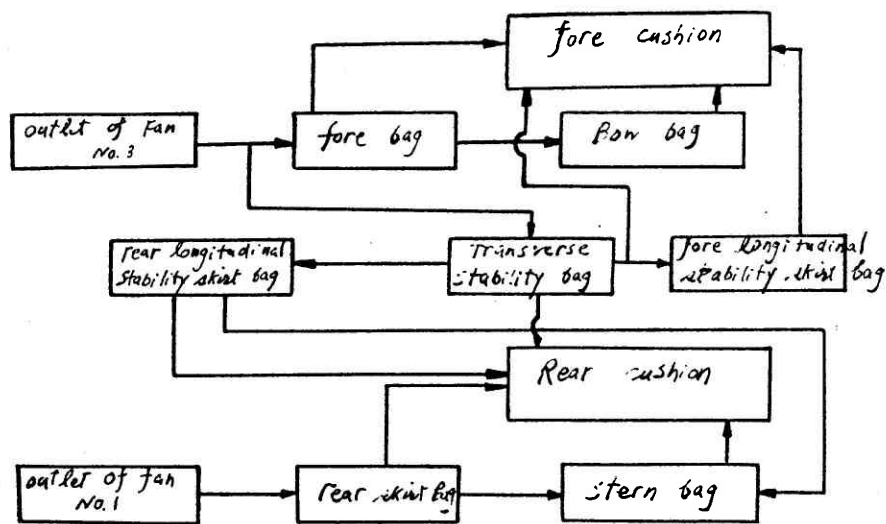


Figure 7. Sketch of the Swiveling Pylon



A) Distribution Channels on Port Side



B) Air Flow Circuits

Figure 8. Cushion Air Flow Distribution

Location of Measurement Points	1. Front Cushion (Port)	2. Front Cushion (Starboard)	3. Rear Cushion (Port)
Pressure at Static Hover (kPa)	2.05	2.11	2.11
Pressure at Top Speed (kPa)	1.99	2.06	1.81
	4. Rear Cushion (Port)	5. Rear Cushion (Starboard)	6. Bow Bag (Port)
Pres. Static Hover	1.99	1.72	2.36
Pres. Top Speed	1.81	----	2.65
	7. Stern Bag (Port)	8. Bow Bag (Starboard)	9. Stern Bag (Starboard)
Pres. Static Hover	2.40	2.35	2.36
Pres. Top Speed	2.06	2.70	2.16

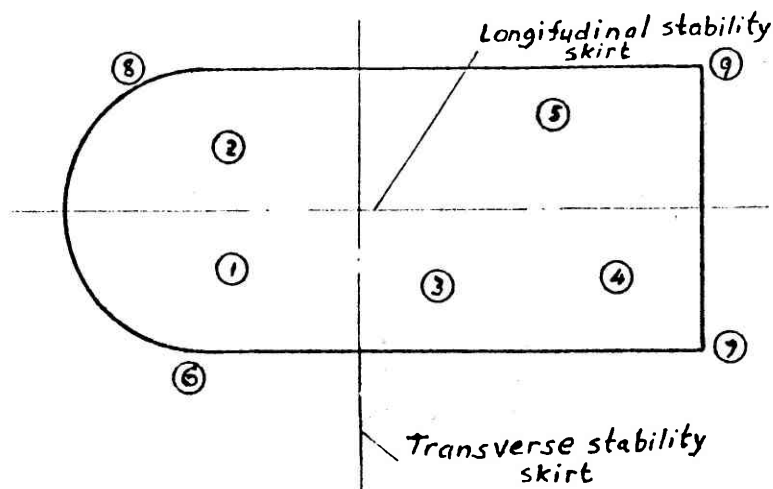


Figure 9. Bag and Cushion Pressure at Various Locations

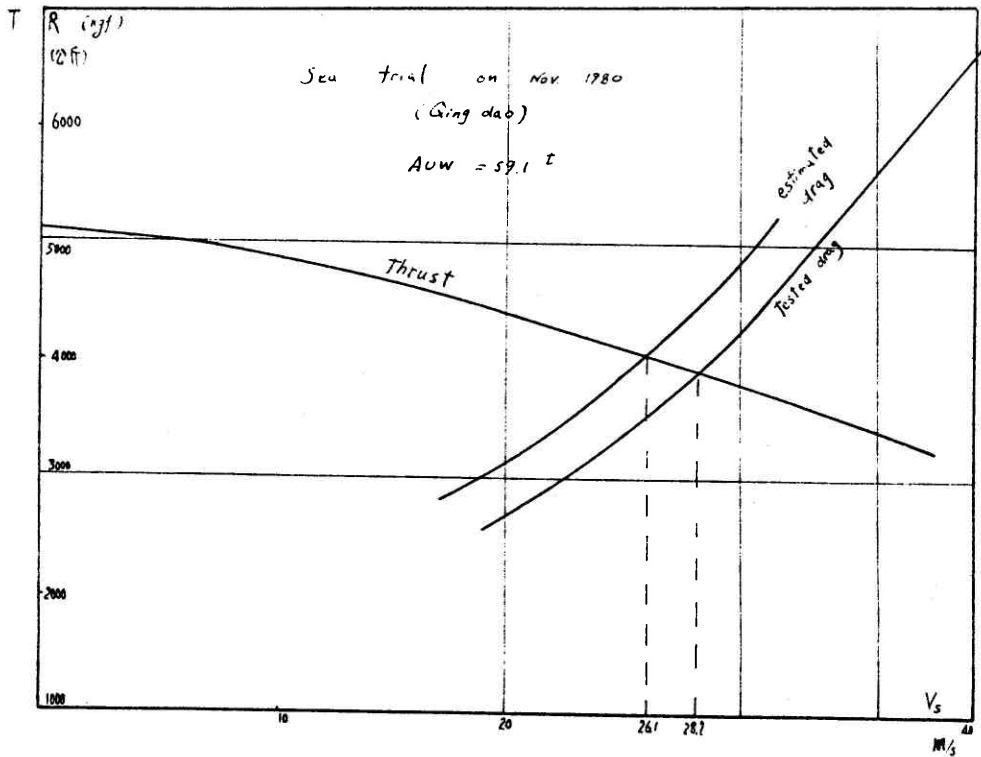


Figure 10. Thrust and Drag of MARIC Model 722

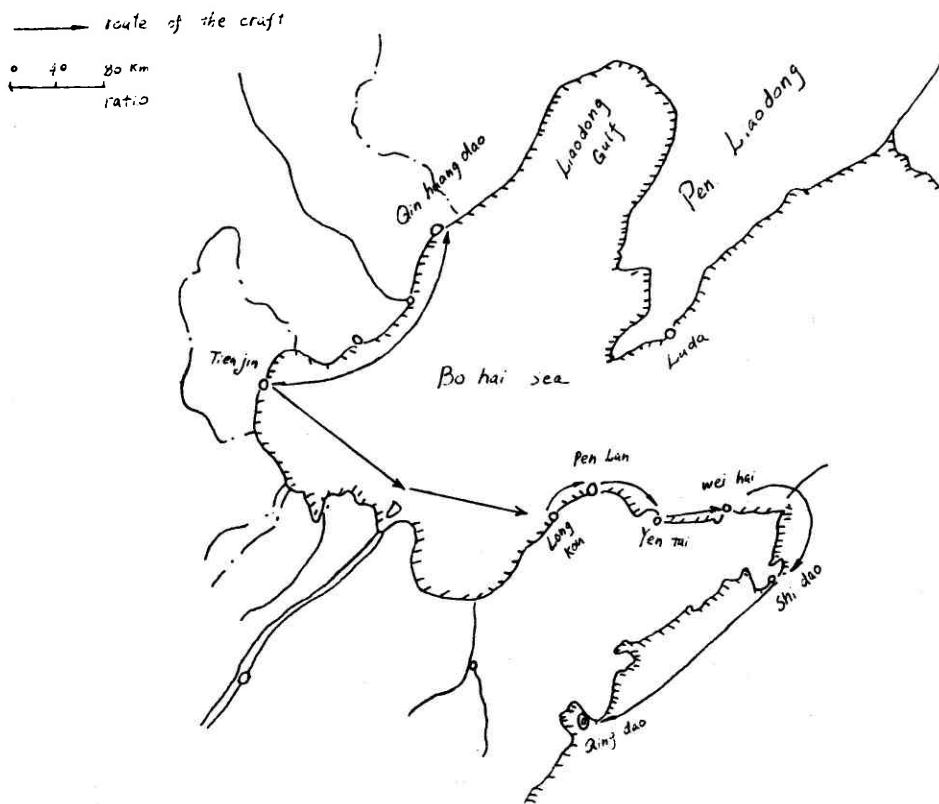


Figure 11. Trial Area and Craft Route

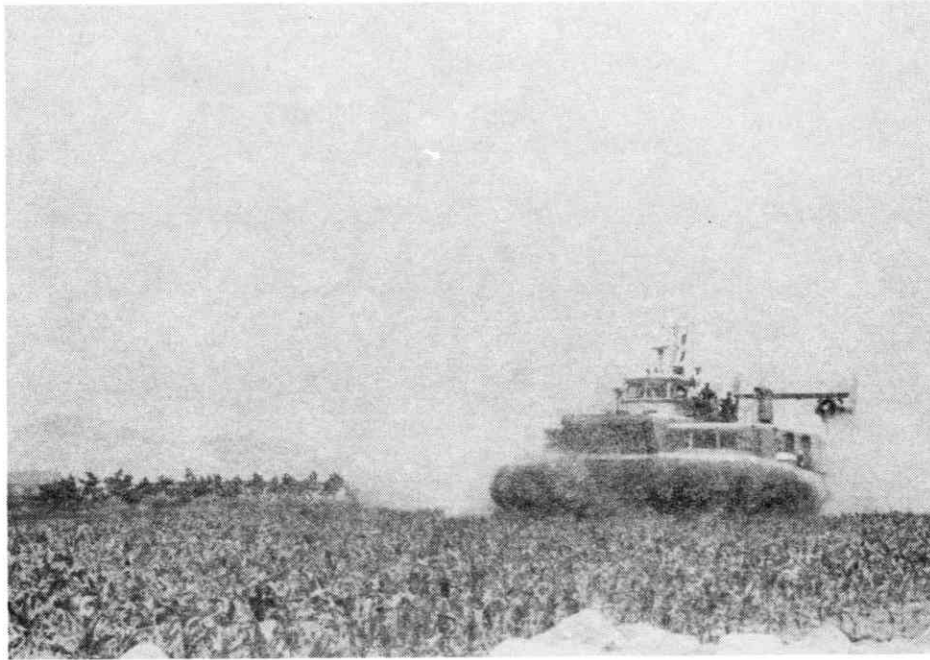


Figure 12. Operation on Maize Field

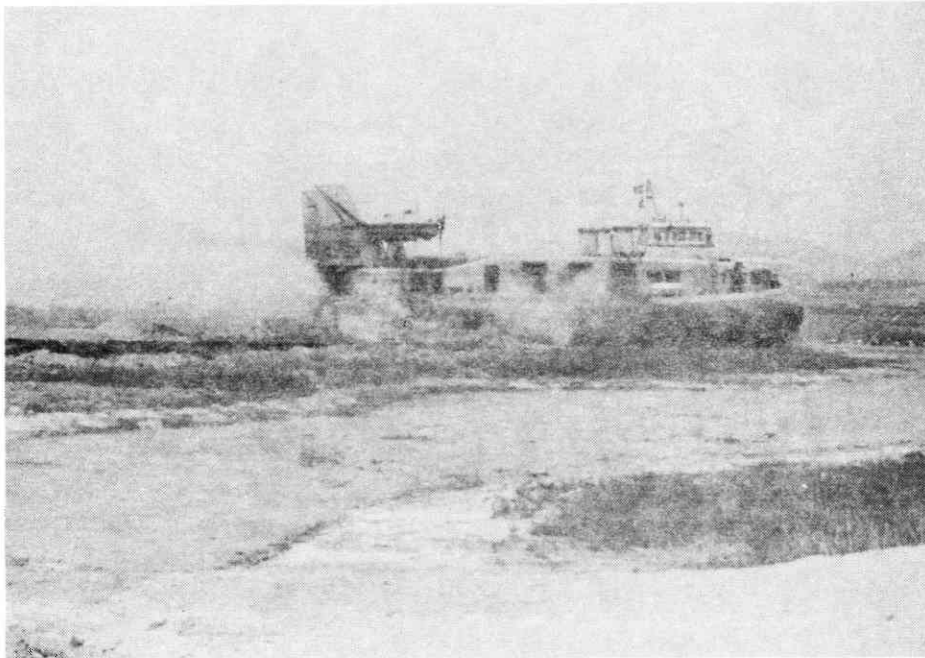


Figure 13. Crossing a Complex Ground Area



Figure 14. Crossing Clay Obstacles

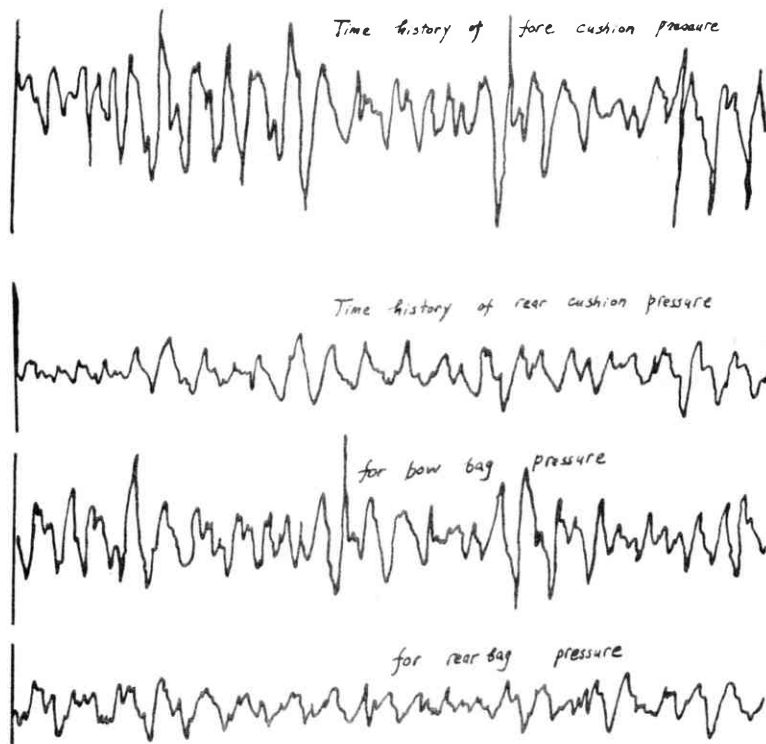


Figure 15. Time History of Cushion and Bag Pressures