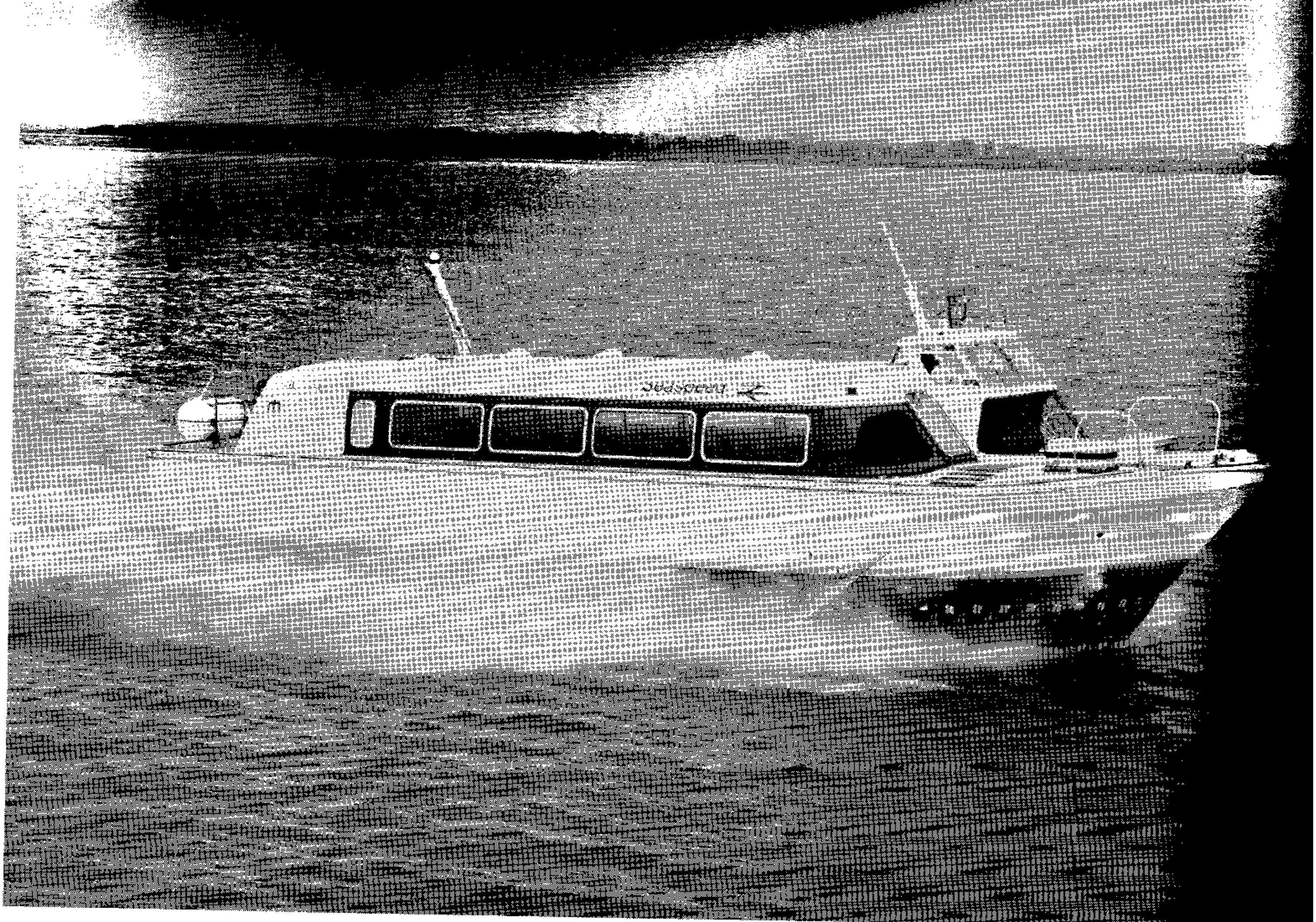
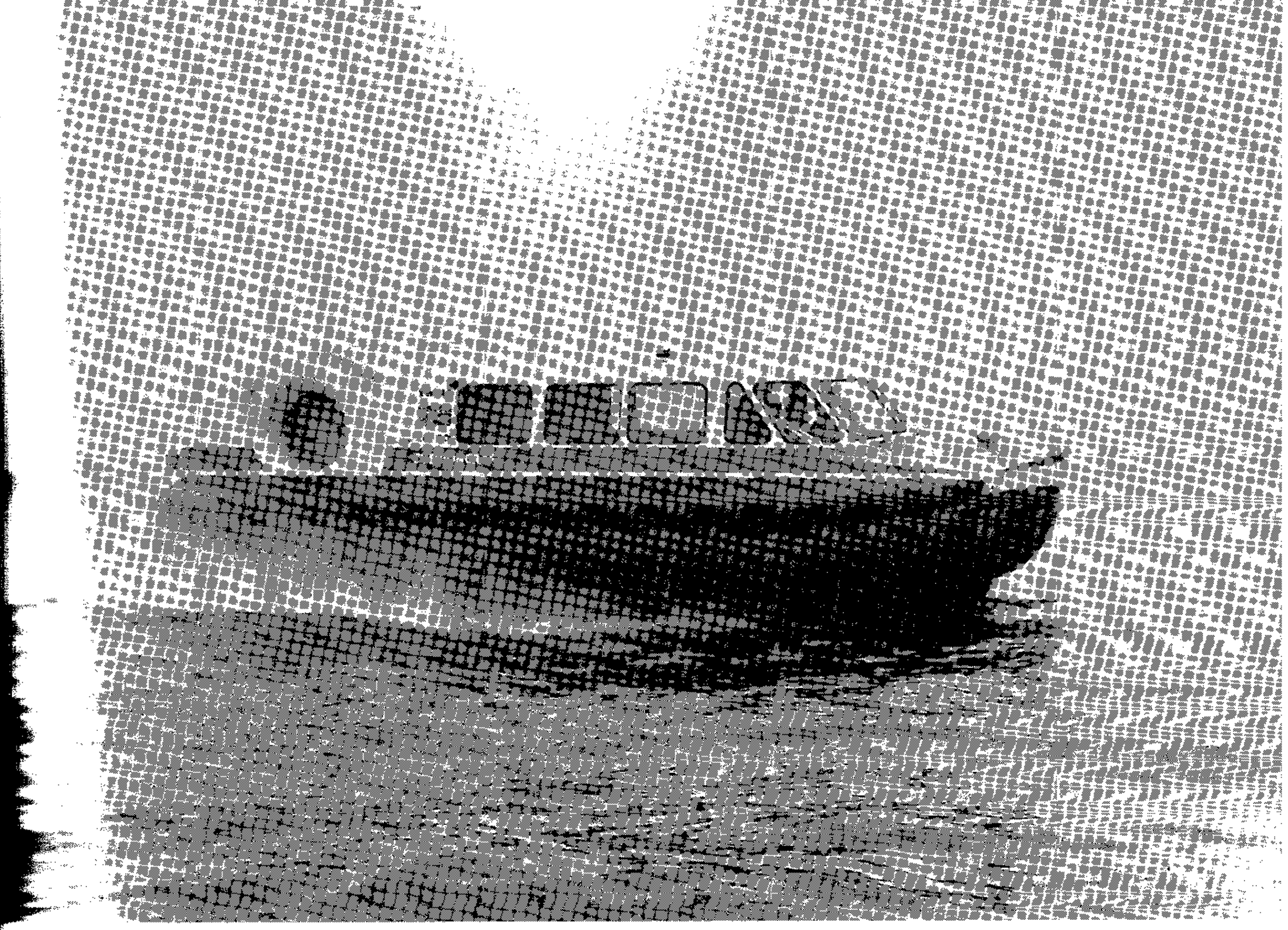
B. BRIEF DATA SHEETS ON HM2 AND CC-7 HOVERCRAFT



HOVERMARINE TRANSPORT HM2

PASSENGER CAPACITY	.60
LENGTH OVERALL	51′
BREADTH OVERALL	20′
DRAUGHT HOVERING	2.2′
DRAUGHT FLOATING	4.9′
HEIGHT TO TOP OF STRUCTURE (HOVERING)	12′
HEIGHT TO TOP OF STRUCTURE (FLOATING)	9.5′
NORMAL OPERATING WEIGHT	18½ tons
ENGINE TYPE	Diesel
TOTAL INSTALLED POWER	820 h.p.
POWER AT MAXIMUM CONTINUOUS OPERATING	780 h.p.
SERVICE SPEED IN UP TO 2 FT. SEA	32 kt.
FUEL CONSUMPTION AT MAXIMUM CONTINUOUS POWER	35 gals/hr
ENDURANCE	4 hours



CUSHIONCRAFT LTD. CC-7

LENGTH, OVERALL	24′ 6″
BEAM, OVERALL	15′ 2″
BEAM (SIDEBODIES DEFLATED)	7′ 6″
HEIGHT, OVERALL	7′ 8″
DRAUGHT, HOVERING	NIL
DRAUGHT, FLOATING	4″
NORMAL GROSS WEIGHT	5,600 lb
LIFT/PROPULSION ENGINE POWER (MAX. CONT.)	390 hp
SERVICE SPEED	30 kts
RANGE	100 nm
PASSENGER CAPACITY	9

APPENDIX IX

ATMOSPHERIC POLLUTION FROM EXHAUST EMISSIONS

The exhaust emissions of hovercraft engines may have to be within the same stipulated legal limits as those of cars and trucks whenever a craft is to operate in city or urban areas where regulations concerning atmospheric pollution are in force.

NSU, Toyo Kogyo, Curtiss-Wright and Daimler-Benz are known to have been preoccupied with exhaust emission problems for quite a time, because more and more stringen requirements are coming into force in the U.S.A. and other parts of the world.

The formation of undesirable exhaust emissions in automotivé engines running on petrol and the evolution of methods of reducing them to acceptable levels is a complex subject on which a great deal of work has been carried out..

The emissions with which current or proposed legislation is concerned and their generally accepted causes are as follows:-

(a) Carbon monoxide, from incomplete combustion.

(b) Hydrocarbons, from unburnt fuel from areas where combustion has been quenched, (e.g. close to relatively cool surfaces), from valve overlap, etc.

(c) Oxides of nitrogen, the quantity produced increasing with the local peak combustion temperatures.

Methods of reducing these emissions, frequently referred to in the literature mentioned in the bibliography, are:-

(i) Modifying the induction system to promote better mixing of the fuel and the air, using leaner mixtures and careful attention to ignition timing. Such systems tend to be complex if used alone, but simplified versions are used in conjunction with an exhaust reactor. Generally they affect only the CO and hydrocarbon emissions.

(ii) By fitting a thermal exhaust reactor in place of the exhaust manifold. The reactor has a core which reaches a high enough temperature to continue the combustion of the CO and the hydrocarbons, but additional air is usually required. This is supplied by an air injector situated either immediately downstream of the exhaust valve or close to the exhaust ports, fed by a small air pump driven by the engine.

(iii) Injecting additional fuel into an afterburner, which has much the same effects as the exhaust reactor, but increases fuel consumption and is seldom used.

(iv) Recirculating a metered quantity of cleaned exhaust gas through the engine to dilute the charge, so reducing peak combustion temperatures and therefore the oxides of nitrogen. This tends to increase fuel consumption.

(v) Catalytic reactors which are most effective in dealing with CO and hydrocarbon emissions. Unfortunately they are expensive and short lived, besides being 'poisoned' by any lead additives in the fuel.

Evidently it is possible to reduce the CO and hydrocarbon emissions, whilst the methods proposed for dealing with the oxides of nitrogen, i.e. reduction of compression ratios, recirculation of exhaust gases, are not very attractive. All the methods mentioned apply equally to reciprocating piston and Wankel engines.

Undue publicity has recently been given to the lead additives of petrol and the lead content of exhaust gases. The only certain method of dealing with these emissions so far is to avoid the lead additives in the fuel. Unfortunately, the alternative aromatic and oleofine additives required to maintain the octane rating of the fuel in the absence of lead additives, themselves cause emissions which are known to trigger off cancer.

With regard to Wankel engines, the base CO and hydrocarbon emissions are somewhat higher than those of reciprocating piston engines of equal power output, but can be dealt with effectively by air injection in combination with an exhaust reactor and at less sacrifice in fuel consumption than in the case of a piston engine. On the other hand, slow combustion within the Wankel engine results in substantially lower emissions of oxides of nitrogen (see 2.1). Because of its lower octane requirement the Wankel engine does not need alternatives to the lead additives in the fuel. Wankel engined cars exported to the U.S.A. in increasing numbers are equipped with exhaust reactors and air pumps as fitted to reciprocating engines.

Tests carried out by an independent authority in the U.S.A. on an NSU Ro80, a Toyo Kogyo Mazda and on a Ford Galaxy 500 fitted with a Curtiss-Wright RC2-60US engine gave the following results:-

Engine	HC	CO	NO_x
NSU Ro80	1.54	19.7	– grams/mile
Toyo Kogyo (Mazda)	1.40	11.9	– grams/mile
Curtiss-Wright	1.11	17.8	1.44 grams/mile
1971 spec. limits	2.20	23.0	4.0 grams/mile
1974 spec. limits	1.50	23.0	1.3 grams/mile

In considering these figures it should be borne in mind that the displacement of the NSU and Toyo Kogyo engines is approximately half that of the Curtiss-Wright and that emission levels tend to vary approximately in inverse ratio to the displacement volume. The Curtiss-Wright figures, on the other hand, represent work which was restricted in scope and was carried out in 1966 and 1967 when Curtiss-Wright were investigating this subject in co-operation with the University of Michigan*.

In view of the fact that General Motors' interest in the Wankel engine is said to be based on their assessment of this engine's emission capabilities, it may be of interest that Prof. D.E.Cole, who carried out the work on the Curtiss-Wright engine at the University of Michigan, is the son of the President of G.M.C.

Whilst the foregoing attempts to simplify a very complex subject, it indicates that the emissions of Wankel engines may be reduced at less cost and without so much sacrifice of efficiency, compared to equivalent piston engines because the technical problems involved are less difficult to deal with. Emission control systems are still under investigation in the research departments of the Wankel engine manufacturers.

Figure IX.1 shows Toyo Kogyo and NSU engines fitted with air pump, air injector and simple thermal exhaust reactor.

The problem of exhaust emissions described above refers mainly to engines burning petrol and would in any case be greatly reduced with engines burning kerosene or diesel fuel.

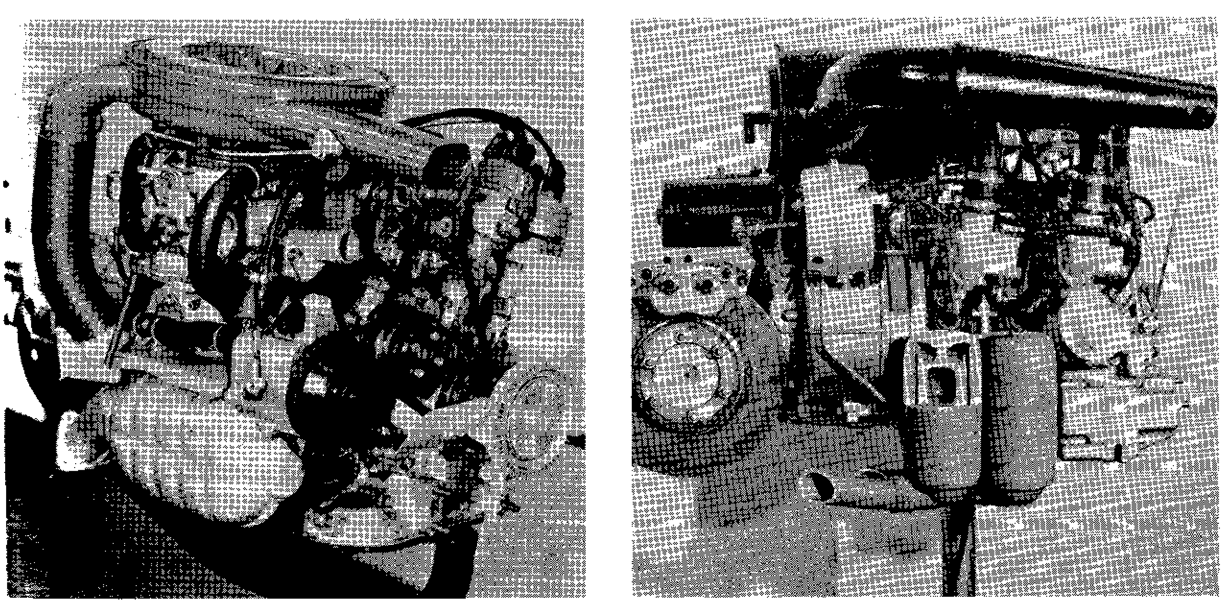


Fig.IX.1 The Toyo Kogyo Mazda R100 and the NSU KKM 612 Wankel engines fitted with equipment for reducing exhaust emissions

* Cole, D.E. and Jones, C. Reduction of emissions from the Curtiss-Wright Rotating Combustion engine with an exhaust

APPENDIX X

APEX SEAL AND ROTOR HOUSING MATERIALS

During the course of development of the Wankel engine different licensees have applied different solutions to overcoming a common problem. A case in point is the matching of materials for the apex seals and the bore of the rotor housing. Among the requirements are:-

(i) Minimum friction losses.

(ii) Wear to take place on the seal rather than the bore, as the seal is the cheaper and more readily replaced of the two components.

(iii) The rate of wear to be low enough to give a satisfactory life between overhauls.

NSU. Wear and chatter triggered off a determined research programme on apex seal design and experiments on various material combinations. The original combination of ferrous seal running on hard chromed bore was replaced by carbon type apex seal for the KKM 502 engine of the NSU Spider car but these carbon seals proved to be susceptible to fracture under engine knock conditions. They were therefore replaced again by ferrous apex seals running on EINISIL. This is an electrochemical deposit of nickel containing fine particles of silicon carbide which migrate on to the surface during the plating process, where they get embedded and form a low friction, wear resistant surface. An incidental benefit of this was a considerable reduction of manufacturing time and costs. The plating process constitutes a development of the American C.E.M. depositing process (C.E.M. = Composite Electrochemical Material).

Fichtel & Sachs, as well as Daimler-Benz use the EINISIL coating for the epitrochoidal bores of their Wankel engines.

Toyo Kogyo started using the same material combinations as NSU but they were able to develop a cheaper and more durable chromium plating technique. The process, licensed from a division of the National Lead Co., relies upon a thin layer of steel sprayed onto the core of the light alloy centre housing. This steel is firmly bonded to the light alloy housing cast round it. The bore is machined, leaving sufficient steel to facilitate superior bonding of a thin layer of hard chrome which requires only a final honing operation. Special carbon type apex seals are used, the carbon containing a certain amount of aluminium, which increases their strength and reduces brittleness.

Curtiss-Wright deposit tungsten carbide on the epitrochoidal bore by a plasma-spraying technique, which is rather expensive but possibly the most superior surface coating tested to date.

Fichtel & Sachs, as well as other manufacturers, experimented with molybdenum sprayed end covers as well as with steel and bronze deposits but found that aluminium alloy containing about 18 to 20% silicon needed no other surface coating and now use this as standard. NSU and Toyo Kogyo have developed a sophisticated induction hardening process which hardens only parts of the plates in zones which radiate outward like the spokes of a wheel.