APPENDIX VI

NSU TRAINING COURSE AT NECKARSULM

Training courses organised by NSU at their school at Neckarsulm are frequent throughout the year but are in German. Those listed below are relevant to the Ro80 motor car and engine and are considered by NSU to be desirable for independent work on the KKM 612 engine by a leading fitter, whilst a week's instruction would suffice for a driver mechanic carrying out general adjustments only.

"T Ro80 – Course	**Technical Course on the Ro80**
Main subjects:	Ro80 engine and gearbox, fixing the wear limits, repair hints, ignition and carburettor.
Training period:	4-5 days.
D Ro80 – Course	**Instruction Course on Ro80 Engine Unit – Diagnosis**
Main subjects:	Practical trouble shooting, explanation of any repair measures, test and adjusting works on the vehicle.
Training period:	2 days.
TEA – Course	**Instruction Course on Testing any AUDI Models***
Main subjects:	Structure and operation of the ignition system, measuring possibilities at the electrical equipment, the fuel system and the engines of the AUDI vehicles. Reasonable application of the test apparatus being necessary. Practical trouble shooting.
Training period:	2 days."

Quoted from NSU brochure

Because of the way the curriculum of the school is arranged these three courses may not be run consecutively and approximately three weeks should be allowed for their completion.

* This section, although not specifically concerned with the Wankel engine, covers engine and automobile electrics and is deemed advisable basic knowledge.

APPENDIX VII

CLASSIFICATION OF WANKEL ENGINES

Although the standard classification established by Wankel has not been used in this report, it may be useful to explain it for the benefit of those undertaking further reading. The type of Wankel engine which is the subject of this report is classified as PLM 2:3 Sli: this is derived as follows:-

(a) PLM indicates a Planetary Rotation Machine in which either the rotor or the housing is fixed. The rotating part turns about an axis which itself moves in a circle around the centroid of the fixed part. The other type of rotation is the Single Rotation Machine, or SIM, in which both the rotor and the housing rotate in the same direction, (though not at the same speed), about their respective fixed axes. An early Wankel engine of this type is mentioned in 2.1.

(b) 2:3 defines the ratio of number of lobes in the housing to number of rotor flanks. Other ratios are possible and a 3:4 machine is referred to under 6.2.1(e).

(c) Sli indicates the so-called 'slip engagement', that is, the complex manner of the interaction between the two eiptrochoidal figures, i.e. the rotor and the housing. For the precise definition, reference should be made to 'Rotary Piston Machines' by Felix Wankel, Iliffe 1966. All Wankel engines fall into this category.

The whole family of machines to which all Wankel and other rotary engines belong are included under the generic term, Rotary Piston Machines. Wankel engines fall within this group and their correct title is Wankel RC engines.

APPENDIX VIII

COST BREAKDOWN OF WANKEL INSTALLATION IN HM2 HOVERCRAFT AND BRIEF DETAILS OF HM2 AND CC-7 CRAFT

A. ESTIMATED ECONOMICS OF AN HM2 MK.III, WITH ROTARY POWER INSTALLATION DRIVING PROPELLERS

Assumptions

1. Cummins propulsion and lift systems replaced by 2 x M 950 and 2 x KKM 612 rotary engines respectively.

2. Installation costs are similar to those of the Cummins system.

3. Rotary engines converted for kerosene at £100/engine.

4. Rotary engine installation results in additional cabin space for 7 passengers and luggage while increasing service speeds by 2–3 knots.

5. Modified craft first cost estimated as follows:

		£	£
(i)	Basic first cost, standard craft ex works, U.K.		110,900
	Cummins engines, 3	13,632	
	Gear boxes and top drive	1,000	14,632
			96,268
	Rotary system:		
	Lift: 2 x KKM 612 engines at £350 each	700	
	2 x gearboxes at £200 each	400	
	Propulsion: 2 x M 950 engines at £700 each	1,400	
	2 x gearboxes at £300 each	600	3,100
	Conversion for kerosene fuel		400
	Estimated Basic First Cost of Modified Craft		99,768
(ii)	Spares holding for 200 hours utilisation:		
	with Cummins system		10,000
	Engine parts (at £0.5/hr)	1,000	
	Gearbox parts (at £0.1/hr)	200	1,200
			8,800
	KKM 612 spares*	300	
	M 950 spares	600	900
	Estimated spares holding		9,700

* Derived from Sections 5.2.5 and 5.2.6 assuming for the KKM 612 an average cost of £13 per 80 hours, of which £11 is materials, and double these costs for the M 950, plus 1,000 hour services.

6. Fuel costs derived as follows:

Lift:	KKM 612, S.F.C. 0.62 lb/bhp hr, hp – 113/engine hourly consumption = 9 gals x 2 engines	18 gals/hr
Propulsion:	M 950, S.F.C. 0.49 lb/bhp hr, hp – 350/engine hourly consumption = 22 gals x 2 engines	44 gals/hr
Total hourly consumption at cruise speed		62 gals/hr
Allow 20% for idling time		12 gals/hr
Total hourly fuel consumption		50 gals/hr

Kerosene cost – 1.5 shillings/gal.

7. Maintenance costs/hour, at 2,000 hours annual utilisation:

Standard HM2	£	£	£	£
(i) Materials		4.0		
Engines	0.5			
Gearboxes	0.1	0.6		3.4
(ii) Labour		2.0		
Engines and gearboxes	1.0	1.0		1.0
Craft hourly maintenance cost, less Cummins system				4.4

Modified HM2

Estimated Annual Maintenance Costs of Wankel Engines

(a) KKM 612:			
Service every 80 hours at £12-£15 (say £13)	x 23	299	
Service every 1,000 hours at £72	x 2	144	
		443	
	x 2 engines		886
(b) M 950: (estimated costs)			
Service every 80 hours at £25-£30 (say £26)	x 23	598	
Service every 1,000 hours at £144	x 2	288	
		886	
	x 2 engines		1,772
Estimated annual maintenance cost			2,658
Hourly cost at 2,000 hours (engines)			1.33
Modified complete craft hourly maintenance cost			5.73

ECONOMIC COMPARISON OF A STANDARD HM2 MK.III, WITH A ROTARY ENGINE POWERED HM2

	Standard craft	*Modified craft*
	£	£
Basic first cost	110,900	99,768
Spares holding	10,000	9,700
Total capital cost	120,900	109,468
Saving		11,432 (9.5%)
First cost/seat	1,860 (65 seats)	1,520 (72 seats)
First cost/seat kt.	62 (30 kt.)	48 (32 kt.)

Operating Costs

(Assuming craft is one of a fleet of 2 vessels with annual utilisation of 2,000 hours each)

	Standard craft		*Modified craft*	
		£		£
Direct Costs				
(i) Fixed annual costs:				
Depreciation, 8 years to 10% residual value		12,476		11,224
Average interest on capital borrowed, at 5%		6,045		5,473
Insurance: hull, 3% of craft value	3,327		2,993	
Third Party	600		600	
Passenger, £30/seat/p.a.	1,950	5,877	2,160	5,753
Operating crew: Captain at £2,300 Radar/1st Officer at £2,000 x 2.5 crews		10,750		10,750
Total fixed annual costs		35,148		33,200
Cost/hr at 2,000 hours		17.57		16.60
(ii) Running Costs/hr.:				
Fuel, 38 gph at 1.25 sh/gal.		2.38	50 gph at 1.5 sh/gal. (cruise rating x 0.8)	3.75
Oil, 3% of fuel cost		0.07		0.11
Maintenance, labour & materials		6.00		5.73
Total running costs		8.45		9.59
Total Direct Operating Cost/hr.		26.02		26.19
Indirect Costs, at 25% of D.O.C.		6.50		6.55
Total Operating Cost/hr.		32.52		32.74
Annual T.O.C.		65,040		65,480

		Standard craft	*Modified craft*
Cost/mile at:			
(i) 100% load factor		£32.52 x 240 pence / 30 kt. x 65 pass.	£32.74 x 240 pence / 32 x 72
	=	4 pence/pass. n. mile	3.4 pence/pass. n. mile
(ii) 50% load factor	=	8 pence/pass. n. mile	6.8 pence/pass. n. mile

A similar evaluation has not been carried out for the CC-7 as detailed costs were not available.