UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE **DTIC FILE COPY**

AD-A223 795

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b.

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

4. PERFORMING ORGANIZATION REPORT NUMBER(S): MAR Technical Report No. 564

5. MONITORING ORGANIZATION REPORT NUMBER(S): DTNSRDC-SSID-CR-17-86

6a. NAME OF PERFORMING ORGANIZATION: MAR, INC

6b. OFFICE SYMBOL *(If applicable)*:

7a. NAME OF MONITORING ORGANIZATION: David W. Taylor Naval Ship R&D Center

6c. ADDRESS *(City, State, and ZIP Code)*:
6110 Executive Blvd., Suite 410
Rockville, MD 20852

7b. ADDRESS *(City, State, and ZIP Code)*:
CODE 1240
BETHESDA, MD 20084-5000

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: David W. Taylor Naval Ship R&D Center

8b. OFFICE SYMBOL *(If applicable)*:

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N00600 82 D 3166 DEL ORD 0133

8c. ADDRESS *(City, State, and ZIP Code)*:
Code 1240
Bethesda, MD 20084-5000

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62543N	F43455		DN978568

11. TITLE *(Include Security Classification)*: HWSTD HIGH WATER SPEED TECHNOLOGY DEMONSTRATOR - POWER PACK - CONCEPTUAL DESIGN STUDY

12. PERSONAL AUTHOR(S): ZOLLER

13a. TYPE OF REPORT: FINAL

13b. TIME COVERED: FROM 8/85 TO 4/86

14. DATE OF REPORT *(Year, Month, Day)*: 86 April 22

15. PAGE COUNT: 79

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*: TRACKED AMPHIBIOUS VEHICLE. (SDW)

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Conceptual Design Study that encompasses the layout and design of the engine and powerpack assembly as required to meet the requirements of land borne, transition, and seaborne modes of operation of a 14-ton amphibious vehicle.

DTIC ELECTE JUL 02 1990 S E D

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: WALTER ZEITFUSS

22b. TELEPHONE *(Include Area Code)*: (310) 227-1852

22c. OFFICE SYMBOL: DTRC-MCPO

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

HWSTD

HIGH WATER SPEED
TECHNOLOGY DEMONSTRATOR

POWER PACK

CONCEPTUAL DESIGN STUDY

MAR Technical Report No. 564

mtu
FRIEDRICHSHAFEN

TECHNICAL REPORT

MOTOREN- UND TURBINEN UNION
(MTU)

April 22, 1986

prepared for

US-NAVY MAR, Inc./S. Simko

Contract No.: N00600-82-D-3166

Purchase Order No. 301133

Author:

Approved:

TABLE OF CONTENTS

L I S T   O F   I L L U S T R A T I O N S

1. Overview

1.1 Summary

This Conceptual Design Study has been executed according to the Purchase Order No. 301133, issued under the Contract No. N00600-82-D-3166 and the Scope of Work listed herein.

The Marine Corps Program Office is planning to produce a High-Water-Speed Technology Demonstrator (H.W.S.T.D.) that requires approx. 1500 HP for watermode and reduced power for landmode. As prime mover the new MTU 12-cylinder light-weight and low volume MT 883 Ka-500 diesel engine has been selected.

The drive system for both operating conditions is solely hydraulic. The engine drives three hydraulic pumps via a splitter box which is directly connected with the engine output flange. During watermode, three water jets driven by hydromotors provide the vehicle propulsion. During landmode, the sprockets on both sides are driven by separate hydromotors.

The task of the study is the concept design of the propulsion system, to analyse the interface requirements of the engine and vehicle and to verify the utilization of the engine in the H.W.S.T.D.

The evaluated concept shows that the MT 883 Ka-500 fulfils the power requirements for the H.W.S.T.D. and fits the given vehicle envelope. The power pack concept (see Attachment 1) with the peripheral components arranged over the engine as charge-air system, cooling system and fan drive system and the directly flanged splitter box results in a very short power pack length. The engine and all components are easily accessible even in the installed position - an important factor for a test vehicle with new components.

All required performance targets have been reached and are fully described in the report.

For the specified watermode power of 1500 HP, the engine operates with a max. speed of 3000 rpm. During land mode the engine max. speed range is limited to 2200 rpm with regard to the lower fuel consumption in the lower speed range.

Two max. landmode power levels have been considered at 2200 rpm. The first power level assures an hydraulic pump input power of 400 HP, which the cooling system is designed for. The second power level is based on a 400 HP engine output, which gives a similar tractive effort as the present test vehicle regarding the required cooling-fan power and splitter box losses.

It should be noted that a parallel procurement of MVO-contract engines with the two H.W.S.T.D. engines shows cost improvements for the basic engines as described in 2.12.

In addition to the contract-defined responsibility, the subcontractor offers to provide the splitter box with mounting equipment to be developed and built in collaboration with the German firm, "Zahnradfabrik Friedrichshafen" (ZF). This would minimize the interface clarification effort of the subcontractor. In addition, with respect to the required test of the engine with the splitter box, shipment cost can be reduced.

The cost and time schedule shows that 10 months after the main contract signing, the power pack is ready for delivery. This is based on a pre-contract signing for long-lead basic engine parts 5 months previously.

All technical data is based on the preliminary power pack design. It should be mentioned that the preliminary power pack design can be further adapted to not yet fully defined vehicle interfaces.

In addition, the subcontractor shall have the opportunity to introduce any technical improvements thought necessary during later detailed-design stages.

1.2 Scope of Work According to Contract

The Contractor shall design as many components around commercially available items that can be found in the Continental United States.

1.1 The Contractor shall address the following items when preparing the conceptual design layout:

1.1.1 - Utilization of one 12-Cylinder diesel engine (MT 883) rated at 1500 HP at 3000 RPM

1.1.2 - The engine will provide power to two Government Furnished gearboxes that will mount either transmission drive hydrostatic pumps or electric generators. Auxiliary system hydraulic pumps and alternators/generators can be either gearbox driven or engine mounted and driven. Gearbox drive shall be from both sides of the engine and the preliminary design shall incorporate a suitable coupling (such as a "Geislinger" coupling) between the engine and gearbox connections

1.1.3 - The engine shall have the ability to be derated and scheduled over its full speed range while providing only 600 HP in the land and transition modes of operation in a fuel efficient manner

1.1.4 - The engine shall be shock mounted with the definition of a suitable mounting/isolation system and all required brackets and assembly parts

1.1.5 - Air filtration system design of the combustion air intake system for all three modes of operation (land/transition/sea) (aspiration system with seawater plenum and shut-off will be part of the vehicle design and need not be covered), however engine demands shall be definitized

1.1.6 - Cooling system requirements and design for all three modes of operation that include:

1.1.6.1 - layout and design requirements for seaborne cooling for 1500 HP at seawater temperature of 70 degrees Fahrenheit

1.1.6.2 - layout and design requirements for landborne cooling for approximately 600 HP at an ambient air temperature of 100 degrees Fahrenheit

1.1.6.3 - layout and design requirements for transition mode cooling for approximately 600 HP at an ambient air temperature of 100 degrees Fahrenheit

1.1.6.4 - Layout of cooling fan drive system and speed control

1.1.6.5 - Layout of engine compartment venting system that will be at below ambient pressure

1.1.6.6 - mode control and seawater heat exchangers will be part of the vehicle design

1.1.7 - Layout and interface requirements of engine monitoring, protection, diagnostic and engine mounted control system to allow tie-in with vehicle computer system

1.1.8 - Complete electrical wiring of powerpack. This includes engine mounted electrical DC generator capable of 30 kW with associated protection

1.1.9 - Layout and identification of quick disconnect couplings, breakpoints, fittings, and wiring for powerpack quick removal and description for all electrical connectors and hydraulic and pneumatic fittings

1.1.10 - Description and requirements of any special hydraulic needs or electrical signal conditioning

1.2 The Contractor shall provide the following technical and descriptive data that will be utilized by the Government and HWSTD vehicle fabricator for the vehicle design and provisioning in the vehicle for the powerpack. All installation drawings shall be in English units and to either 1/8 or 1/4 scale.

1.2.1 - Engine data:

Technical description
Dimensions, including inertias and center-of-gravity
Weight (dry)
Performance map for 70 degrees F
Maximum Power loss versus Ambient Temperature
Fuel Map curves for 1500 HP and expanded for 600 HP
Heat Rejection requirements for: Coolant
Oil Systems
Charge Air
Survey of proposed or currently availble hardware

1.2.2 - Air Filtration System:

Technical description
Dimensions
Weight
Pressure loss
Effectiveness
Service Life (utilizing components available in CONUS)
Maintenance requirements
Filtering means, provisions, and availablity
Survey of proposed or currently availble hardware

1.2.3 - Cooling System

- Technical description
- Dimensions
- Weight
- Coolant ciruit for each mode of operation and required coolant/air flows
- Coolant/air temperatures
- Valving system, selection and control process for each mode of vehicle operation
- Performance prediction and degradation as a function of ambient air temperature rise for land operation
- Performance prediction for seaborne and transition operation
- Required heat capacity for seawater heat exchanger
- Air/coolant pressure loss
- Survey of proposed or currently availble hardware

1.2.4 - Coolant Fan Drive System

- Technical description
- Dimensions
- Weight
- Required Fan Power
- Fan Drive Efficiency
- Proposed Drive Circuitry (electric or hydraulic)
- Fan Speed Control
- Survey of proposed or currently availble hardware

1.2.5 - Engine Compartment Venting System

- Technical description
- Cooling flow requirements for each mode of operation
- Maximum Pressure Loss
- Survey of proposed or currently available system

1.2.6 - Vehicle/Powerpack Interface

- Definition of, number, and locations of connectors, and self-sealing couplings for fuel, oil and coolant
- Mounting requirements in hull
- Inlet and Exhaust Grill requirements
- Sealing and Screen System requirements
- Powerpack removal provisions
- Maintenance access openings

1.2.7 - Engine Monitoring and Control System

- Technical description
- Dimensions
- Weight
- Electrical Block diagrams and schematics
- Interface capabilities with other vehicle controls

1.2.8 - Performance Calculations

- Degradation of performance due to power derating
- Projected vehicle performance for each mode of operation
- Maximum available net power in seaborne mode of operation

1.2.9 - Fuel Requirements

Projection for vehicle operating range based on 70 and 100 degrees Fahrenheit days, in landborne and seaborne modes of operation

1.2.10 - Fuel, Oils, and Coolant Requirements

Indication of any special requirements for special fuels, oils or coolant types to be used
Indication of quantities of each to be required

1.2.11 - Weight Estimates

Weight break-down, inertia and center-of-gravity figures provided for dry and operating wet weight

1.2.12 - Cost and Schedule Estimate of the following tasks

Development effort of the powerpack
Hardware and assembly effort (including nominal spare parts for two years operation)
Test Cell effort to cerify engine and provide engine performance and fuel use/scheduling curves
Technical Assistance for 400 Technician Man-hours during the vehicle fabrication and testing phases in 1987, and 800 Technician man-hours during FY-88 vehicle testing

1.3 - The Contractor shall submit the following technical and narrative descriptions during the performance of this effort:

1.3.1 - Monthly Progress Reports to document progress being made in the course of performance of work. These reports shall be due by the fifth day of each month during each month. (DD Form 1423, CDRL Item A001)

1.3.2 - Level 1 Engineering and Associated Drawi·gs and Lists for all major systems as listed in Sectio· ·.2 above. These shall be due 140 days after contract award. (DD Form 1423, CDRL Item A002)

1.3.2 - Final Technical Report that describes and details the tradeoffs, studies, analyses, and designs performed in the completion of this design study. This report shall be due 140 days after contract award. (DD Form 1423, CDRL Item A003)

2. Results

2.1. Engine Data

Technical Description

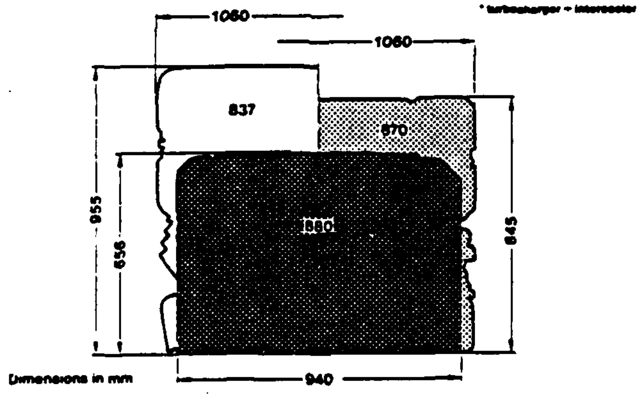
2.1.1 Introduction/History

The technical concepts of the Series 837 engines were laid-down in the mid-fifties. To date more than 14000 of these 6, 8 and 10-cylinder, liquid-cooled, V-configuration engines have been delivered. They have proven extremely successful in practical service in a great number of different types of vehicles as naturally aspirated, mechanically supercharged or turbocharged engines.

Comparison, Series 837-870-880

Series	837		870	880
Cylinder displacement	3.74 Liter		3.97 Liter	2.08 Liter
Supercharging	mech.	ATL + LLK*	ATL + LLK*	ATL + LLK*
Rated speed	2200 rpm	2400 rpm	2600 rpm	3000 rpm
Cylinder output	83 mHP	125 mHP	150 mHP	125 mHP
M. E. P.	bar	12.3 bar	12.8 bar	17.6 bar
Mean piston speed	1. m/s	14.0 m/s	15.2 m/s	13.6 m/s
Power-to-volume ratio	545 mHP/m³	680 mHP/m³	1090 mHP/m³	1500 mHP/m³
Change	–	+ 25 %	+ 100 %	+ 175 %
Weight-to-power ratio	2.0 kg/mHP	1.6 kg/mHP	1.2 kg/mHP	1.1 kg/mHP

* turbocharger + intercooler



Development of the second-generation tank engine, the Series 870, started in the mid-sixties. With reduced external dimensions and higher cylinder power ratings it has considerably higher power utilization than the Series 837. The 12-cylinder MB 873 engine with 1500 mHP for the Leopard 2 and the 8-cylinder MB 871 with 1200 mHP are currently in series production.

Since the mid-seventies, MTU has been working on the third-generation tank engine, the Series 880. With these engines the installation volume has again been considerably reduced so that, in future, engines with extremely small external dimensions will be available to cover the 500 to 1500 mHP power range. For instance, the 12-cylinder MT 883 engine has the same power rating as the Leopard 2 engine but requires only 60% of the installation space.

2.1.2 Technical Concept

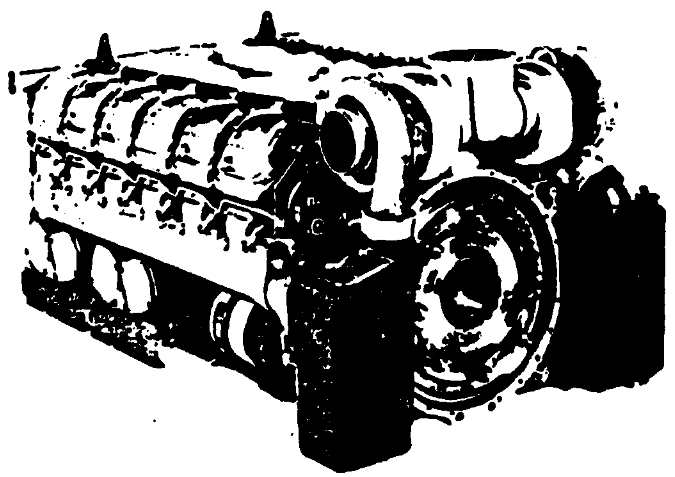
The design of this new engine series was based on the fact that the mean piston speed should be maintained at a level which had already been introduced, and proven, in series production but that the Mean Effective Pressure (MEP) - the second important design parameter for reciprocating piston engines - could be raised without exceeding mechanical or thermal load limits.

An additional design condition was that the highest power rating required for battle tank propulsion should represent the optimum for the engine series. The 12-cylinder version was selected for this purpose as it offers the most favourable power-to-weight and power-to-volume ratios. Together with the bore/stroke relationship determined by design considerations, this led to a cylinder displacement of 2.09 liters with a bore of 140 mm and a stroke of 136 mm.

The 10, 8 and 6-cylinder V-configuration versions were based on the 12-cylinder engine and these, in turn, led to the development of the 6, 5 and 4-cyl. in-line models so that in future the 500 to 1500 mHP power range can be covered by a technically highly attractive engine series with common, standardized logistics requirements.

The arrangement of the sub-assemblies required for engine operation is determined in consideration of the engine being an individual part of the complete propulsion system of an armoured vehicle. Thus, for instance, a generator with a max. electrical output of 23 kW can be include within the engine envelope. Furthermore, the positions of turbochargers and intercoolers can be matched to the in-vehicle combustion air and exhaust systems as arranged for the HWSTD engine. A particular advantage in this respect is the arrangement of the exhaust pipework in the engine saddle.

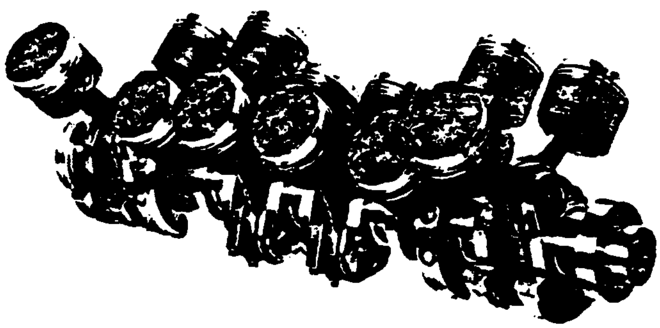
12-Cylinder Engine MT 883



To reduce space and weight, particular care was taken to keep the pipework connecting the various sub-assemblies as short as possible. Thus, for instance, the oil cooler and oil filter have been combined into a single unit, the coolant manifolds have been integrated into the cylinder heads and the lengths of both the combustion air and exhaust pipework minimized. Hose lines have been completely eliminated.

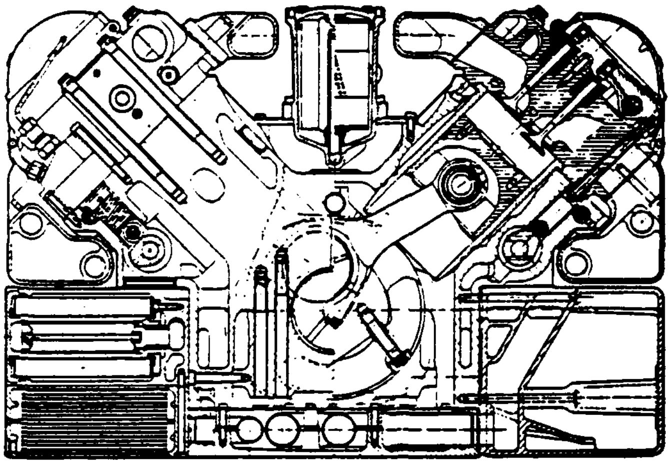
Above all, the total number of components required has been considerably reduced in comparison to the tank engines now in service. The resultant advantages are favourable for both reliability and logistics.

Running Gear for 12 Cylinder Engine MT 883



2.1.3 Design Characteristics

Cross Section



During the design phase, special emphasis was laid on the use of series-standard materials and production methods and that the mechanical and thermal loads on the individual components were maintained at proven levels.

Equal importance was attached to the arrangement and construction of the various functional groups. Novel design solutions were thus found for the connecting rods and the crankshaft counterweights which resulted in extremely small crankshaft chambers. Unit injection pumps were assigned to each individual cylinder and located, in the otherwise unused space, between the cylinder heads; injection pump drive is direct from the camshaft. The inlet and exhaust valves are identical and are actuated via three push rods. This allows extremely low valve gear dimensions and distributes the actuating forces equally between the roller tappets. The dry-sump oil pan, with side-mounted oil tank, is extremely flat and meets all operational requirements for inclined vehicle positions. As a matter of course, all sub-assemblies such as oil pumps, coolant pump and generator are gear-driven, the drive gear shafts being supported in ball bearings. As with the other tank engines, the crankcase is of cast aluminium and the main bearing caps are of forged steel. The individual grey cast-iron cylinder heads can be supplied for both pre-chamber and direct fuel injection.

Main Data

		125 mHP per cylinder						
		In-line engines			90° V-engines			
Engine Type		MT 884	MT 885	MT 886	MT 880	MT 881	MT 882	MT 883
No. of cylinders		R 4	R 5	R 6	V 6	V 8	V 10	V 12
Displacement	l	8.4	10.5	12.6	12.6	16.7	20.9	25.1
Bore	mm	140	140	140	140	140	140	140
Stroke	mm	136	136	136	136	136	136	136
Engine Speed	rpm	3000	3000	3000	3000	3000	3000	3000
Power	metric HP	500	625	750	750	1000	1250	1500
Mean Effective Pressure	bar	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Mean Piston Velocity	m/s	13.6	13.6	13.6	13.6	13.6	13.6	13.6
Installation Volume	dm^3	531	628	701	674	804	878	975
Dry Engine Weight	kg	800	940	1050	1010	1220	1430	1650

2.1.4 Dimensions

Dimension of basic engine (individual dimension depends on specific application and component arrangement as turbocharger and charge-air cooler)

Length:

Hard crankcase length	1210 mm	47.6"
Accessory gear case at main output	129 mm	5.1"
Front casing for injection control and damper	130 mm	5.1"
Total hard length	1459 mm	57.8"
Width	950 mm	37.4"
Height over crankshaft	442 mm	17.4"
Height below crankshaft	214 mm	8.4"
at output flange	284 mm	11.2"
Total height	656 mm	25.8"
with turbocharger	915 mm	36.0"

- Dimension of H.W.S.T.D. engine see drawing No. 657 883 Fig. 1.
- Center-of-gravity - see drawing No. 657 883 Fig. 1.

2.1.5 Engine Dry Weight

Including starter 1650 kg 3637.6 lb

2.1.6 Performance Map for Water Mode

See drawing No. 657 893 Fig. 2
Performance map for land mode 100°F drwg. No. 657 898 Fig. 3.

2.1.7 Maximum Land Mode Power over Ambient Temperature

See drawing No. 657 894, Fig. 4.

Based are 4 percent power degradation per 10°C, 18°F totally.

Influence parameters:	fuel temp.	2.5% per 10°C
	ambient temp.	1.0% per 10°C
	coolant temp.	0.5% per 10°C

2.1. Heat Rejection Requirements

Water Mode

Conditions:	1100 kW at 3000 rpm	
	1475 HP at 3000 rpm	
	- seawater temp.:	26.7°C (80°F)
	- ambient temp.:	30.0°C (86°F)
Heat Sources:	- engine coolant	550 kW (521 BTU/sec)
	- engine oil	140 kW (133 BTU/sec)
	- charge air	190 kW (180 BTU/sec)
	Engine total heat	880 kW (834 BTU/sec)

Engine heat over speed see drwg. No. 657 887, Fig. 5.

- oil heat splitter box	43.8 kW (41.5 BTU/sec)
- oil heat hydr. drive system	156.6 kW (148.5 BTU/sec)
Total heat to be absorbed	1080.4 kW (1024 BTU/sec)

Land Mode

Condition for power level 1, 400 HP pump input:

404 kW at 2200 rpm

542 HP at 2200 rpm

- ambient temp.: 38°C (100°F)
- cooling air inlet temp.: 43°C (109°F)

  (5°C, 9°F hot air recirculation assumed)
- max. coolant design temperature: 107°C (224.6°F)

Heat Sources:	- engine coolant	260 kW	(246.4 BTU/sec)
	- engine oil	65 kW	(61.6 BTU/sec)
	- charge air	10 kW	(9.5 BTU/sec)
	Engine total heat	335 kW	(317.5 BTU/sec)
	- oil heat splitter box	18 kW	(17.1 BTU/sec)
	- oil heat hydr. drive system	70 kW	(66.4 BTU/sec)
	Total heat to be absorbed	423 kW	(401.0 BTU/sec)

Condition for power level 2 400 HP engine output:

298 kW at 2200 rpm

400 HP at 2200 rpm

	- ambient temp.:	38°C	(100°F)
	- cooling air inlet temp.:	43°C	(109°F)
	(5°C, 9°F hot air recirculation assumed)		
	- max. coolant temp.:	99.3°C	(211°F)
Heat Sources:	- engine coolant	192 kW	(182 BTU/sec)
	- engine oil	60 kW	(56.9 BTU/sec)
	- charge air	2 kW	(1.9 BTU/sec)
	Engine total heat	254 kW	(240.8 BTU/sec)
	- oil heat splitter box	17 kW	(16.1 BTU/sec)
	- oil heat hydr. drive system	50 kW	(47.4 BTU/sec)
	Total heat to be absorbed	321 kW	(304.3 BTU/sec)

2.1.8 Proposed Available Hardware

Basic test engines are currently in procurement for one other project of the same horsepower and speed.

The arrangement of engine peripheral equipment as location of turbocharger, charge-air cooler, mounting, piping, connecting parts and engine control must be modified for the H.W.S.T.D.

The turbochargers and the piping can be used as for the planned engines.

The charge-air cooler and connecting pipes must be new designed. The rear and forward engine flange must be adapted on the mounting requirement of the H.W.S.T.D. engine.

The individual engine coolant piping must be new designed for the H.W.S.T.D. special coolant circuit with regard to the hydraulic cooling requirement and to the landmode and seamode compatibility.

2.2 Air Filtration System

2.2.1 Technical Description

Air Supply System (see Attachment 1)

Air for the main engine and engine-compartment venting is through a hood, located on the top deck of the vehicle, to be defined by the vehicle designer: this hood closes in case of submersion.

To remove spray water from the air, a plenum chamber should be included in this duct.

A smaller amount of this intake air - approx. 5% of the main air flow - is required for engine compartment venting and will be drawn off by an electrically driven blower.

The connection to the engine-air filter system can be adapted to the vehicle intake system. It is proposed to use a flexible hose with a V-band connection to the engine-air filter system. This connection can be arranged either from the top or axially. A flexible connection is required in order to withstand the movements between the resiliently mounted engine and the vehicle-mounted intake duct.

Air Filter System
(Pressurized Fine-Filter System)

For the engine filter system, a new type of filter is used. The primary difference is shown in Fig. 6.

Contrary to an atmospheric system a two-stage cyclone module is used instead of a single stage, providing a higher degree of dust separation. The separation efficiency of cyclone filters has been improved recently to such an extent that the turbocharger can be supplied with pre-cleaned air. Furthermore, during landmode operation the turbocharger speed will be very low, which causes no erosion problems. During marinemode no dust concentration in the air is to be expected.

The fine filter is located downstream of the charge-air cooler, where the air density is highest. The combination of better raw air pre-cleaning, together with high air density on the filter side, allows the fine-filter dimensions to be approx. 1/4 that of an atmospheric fine filter with the same replacement intervals.

The dust capacity of the pressurized fine-filter cartridges is lower than that of an atmospheric fine filter because the particle size is smaller, resulting in quicker clogging. This was taken into consideration when determining the fine-filter size and maintenance interval.

2.2.2 Technical Data

Flow requirements

- Combustion air flow at nominal power 1100 kW, 1475 HP at 3000 rpm	1.65 kg/s	3.64 lb/sec
- Scavenge flow rate 12%	0.20 kg/s	2.44 lb/sec
- Total intake air flow	1.85 kg/s	4.08 lb/sec

Precleaner

- Design type: 2 stage-cylone with electric diven scavenge blower, one unit for each turbocharger

- Dimension:	height	370 mm	14.57 inches
	width	270 mm	10.63 inches
	length without air duct	165 mm	6.50 inches
- Pressure loss at nominal flow		2000 N/m²	8.0 inchWG
- Absorbtion efficiency		98%	98%
- Scavenge blower			
Power requirement		1.12 kW	
current		28.0 V DC	
speed		13000 rpm	
pressure	approx.	5000 N/m²	20 inchWG

- Weight per unit	25 kg	55 lb

Fine filter

- Design type: pressurized fine filter, one cartridge for each cylinder bank		
- Cartridge effective diameter	270 mm	10.63 inches
- Cartridge length	390 mm	15.35 inches
- Effective paper area per cartridge	16.3 m^2	175.0 sqft
- Pressure loss clean cartridges	600 N/m^2	2.4 inchWG
- Max. pressure increase for dust ingestion	2500 N/m^2	10.0 inchWG
- Expected time between removal for land mode operation in zero visibility environment 1 g/m^3 dust concentration	100 hrs.	
- Weight	75 kg	265.0 lb.

2.2.3 Proposed or Currently Available Hardware

- Two-stage cyclone pre-filter have been built for various test vehicles. The cyclone cells are in production at Mann & Hummel. The special size for H.W.S.T.D. must be ordered.

- The scavenge blower is a serial product for the Leo 2 powerpack.

- The fine-filter cartridges have the same diameter as used for the Leo 2, Self-Propelled Howitzer and XK1 powerpack. The length required for the H.W.S.T.D. powerpack can be furnished with serial production tools.

2.3 Cooling System

2.3.1. Technical Description

Requirements

The heat to be dissipated from the following sources must be provided for in designing the cooling system.

- Main engine (landmode, watermode)
  - coolant
  - lube oil
  - charge air
- Splitter box
  - oil
- Hycraulic drive system
  - oil

In the landmode heat must be dissipated into the ambient air via radiators; in the watermode a seawater/coolant heat exchanger dissipates the total heat of the power plant.

Operation of the vehicle on land and in the water necessitates a cooling concept which will ensure maximum efficiency for both propulsion modes as well as trouble-free transition operation at a minimum of expense and complexity. The transition phase requires safe operation under undefined cooling conditions.

For landmode operation two different engine power levels have been considered. Power level 1 assures a hydropump power requirement of 400 HP. Power level 2 is based on an engine power level of 400 HP. The landmode cooling system has to be designed so that the heat for both power levels can be dissipated to a max. ambient temperature of 38°C, 100°F, without max. power restriction.

Selected Concept for:

Landmode Operation - see Fig. 7, 8, 9 and Attachment 1

A cooling system over the engine is used to dissipate heat in landmode; it exists of two, layered, low-profile radiators with one hydrostatically-driven radial fan.

Cool air is drawn in by the fan through louvers which can be closed during watermode. The connection between the radiator system and the intake louvers is sealed by a flexible rubber seal. The cooling air is sucked through the radiator by the fan (suction-system) and then expelled through an air duct to the vehicle exit louvers, which will also be closed during watermode. The radial fan has been selected because of the insensitivety to corrosion, water ingestion and with regard to low cost and stable pressure characteristic over speed. The fan is driven by a hydromotor. Fan speed is automatically controlled to provide a constant coolant temperature at the outlet of the two cylinder banks of the engine.

The selected coolant circuit is adapted to the requirements of two temperature levels in the circuit. The lower temperature level is used for the cooling of the hydraulic-oil circuit and the charge-air circuit, the higher level is taken to cool the engine itself. Therefore, the circuit consists of two coolant branches having separate radiators and heat exchangers and one engine driven coolant pump. The individual coolant branches are brought together at the water pump inlet.

The radiator at the inlet side of the cooling-air inlet cools approx. 30% of the total coolant flow to a temperature (85.5°C, 186°F at 38°C, 100°F ambient temperature) resulting in a relatively low oil temperature of approx. 90°C, 194°F, in the hydraulic circuit during landmode.

The radiator at the fan side cools approx. 70% of the coolant flow to a higher temperature (101°C, 213.8°F at 38°C, 100°F ambient temperature) which the engine can operate with.

Cooling of the splitter-box oil and of the charge air is provided by heat exchangers cooled by the low temperature circuit. This circuit has been selected with regard to minimizing the amount of piping and valves. For watermode the smaller, low-temperature circuit is to be switched by a two-way valve only. During watermode the low-temperature circuit is cooled by a seawater heat exchanger instead of the radiator for landmode. The reasons for the selected circuit can be summarized as follows:

- Simple system

- System can be used for watermode as well as transition operation without special equipment - refer to watermode operation.

- Lower charge-air and hydrostatic-oil temperature can be achieved without influencing the temperature levels of the main radiator module and the engine coolant.

- The operating temperature of the main branch can be selected independently of the secondary branch, enabling greater efficiency (higher temperature and smaller volume).

- Pre-heating of charge air for cold starting by joining both branches upstream of the pump. This is also favourable in the land mode low power range.

- Equalization of thermal capacities by joining both branches: permits utilization of thermal capacity of total system of all subsystems.

- Integration of all subsystems' cooling requirements enables minimum dimensions because the cooling capacity of the total system is available for incidents such as the transition mode which does assure cooling capacity either from the landmode cooling system or the seamode cooling system.

Watermode operation - see Fig. 10

(Marinemode)

During travel in the water, heat from the power pack is dissipated by a water-tube heat exchanger. The lower temperature-level coolant flow (already described in landmode operation) is cooled in this heat exchanger bv seawater which is supplied by a hydromotor-driven seawater pump. The selection of the branched or mixed cooling circuit allows 30% of the total coolant flow to cool to a very low temperature (e.g. with 26.7°C, 80°F seawater temperature, 54°C, 129.2°F coolant temperature). Triggered by an electrical signal or by manual changeover of a two-way valve, coolant flow to the landmode radiator is blocked. In addition, a semi-switched position for the transition phase can be realized. The low temperature branch cools the hydraulic oil via a heat-exchanger to a favourable low temperature of approx. 62.7°C, 144°F with regard to the high power level of the hydraulic drive system for watermode.

After the hydraulic heat exchanger, the coolant flows partially through the oil-heat exchanger of the splitter box and cools then the charge air in the charge-air coolers. After leaving the charge-air cooler, the coolant is still at a relatively low temperature, low enough to cool the main coolant branch to the required engine inlet temperature.

The main engine branch - 70% of the total coolant flow - flows through the engine radiator although the radiator dissipates no heat, because the fan is cut out and the cooling-air inlet and outlet louvers are shut for water-mode.

To change from land to watermode, the following operations are required:

- Close cooling air inlet and outlet
- Change two-way valve over to watermode.
- Stop fan
- Changing the hydrosystem to the watermode automatically switches on the water-jet system and the seawater pump.

2.3.2 Technical Data

Cooling System Design Data (see 2.1.7)

total heat to be dissipated for land mode operation	
power level 1:	423 kW, 401 BTU/sec
power level 2:	321 kW, 304.3 BTU/sec
ambient temperature:	38°C, 100°F
engine speed:	2200 rpm
coolant flow:	59.4 m^3/hr, 261.6 GPM
total heat to be dissipated for water mode operation	1080.4 kW, 1024 BTU/sec
ambient temperature:	30°C, 86°F
sea water temperature:	26.7°C, 80°F
engine speed:	3000 rpm
coolant flow:	81 m^3/hr, 356.7 GPM

Components temperature/flow data see Fig. 7,8

- low temperature radiator:

- type:	plate-fin, louvered fin type
- material:	aluminium
- supplier:	Behr
- fin density:	70 fins/dm, 17.8 fins/inch
- flow:	cross counter flow

- height total:	70 mm, 2.75"
- air side area:	0.64 m², 6.9 sqft
- air core length:	60 mm, 2.36"
- coolant core length:	2 x 800 mm, 2 x 31.5"
- coolant pressure loss for:	18.33 m³/hr, 80.7 GPM 0.4 bar, 5.8 psi
- air pressure loss for:	8 kg/s, 17.6 lb/sec 1200 N/m², 4.8"WG
- heat (power level 1):	255.7 kW, 242 BTU/sec
- weight (dry):	32 kg, 70.5 lb

Engine main radiator

- type:	plate fin louvered fin type
- material:	aluminium
- supplier:	Behr
- fin density:	70 fins/dm, 17.8 fins/inch
- flow:	cross counter flow
- height total:	85 mm, 3.35"
- air side area:	0.64, 6.9 sqft
- air core length:	75 mm, 2.95"
- coolant core length:	2 x 800 mm, 2 x 31.5"
- coolant pressure loss for:	41.1 m³/hr, 180.9 GPM = 1.2 bar, 17.4 psi
- air pressure loss for:	8 kg/s, 17.6 lb/sec = 1500 N/m², 6"WG
- heat (power level 1):	167.3 kW, 158.5 BTU/sec
- weight (dry)	40 kg, 88.2 lb

Oil heat exchanger

Splitter box:

- type:	plate fine louvered fin type
- material:	aluminium
- supplier:	Behr
- flow:	single flow for coolant cross-counter flow for oil
- oil face area:	100 mm x 300 mm, 4" x 12"
- coolant face area:	100 mm x 160 mm, 4" x 6.3"
- block dimension, edges to be added:	100 mm x 160 x 300 mm 4" x 6.3" x 12"
- coolant pressure loss for land mode:	18.33 m^3/hr, 80.7 GPM 0.15 bar, 2.18 psi
for sea mode:	25 m^3/hr, 110 GPM 0.25 bar, 3.62 psi
- oil pressure loss for:	2500 l/hr, 11 GPM 0.4 bar, 5.8 psi
- heat: power level 1 water mode	18 kW, 17.06 BTU/sec 43.8 kW, 41.51 BTU/sec
- weight:	10 kg, 22 lb

Hydraulic oil heat exchanger:

- type:	plate fin, louvered fin type
- material:	aluminium
- supplier:	Behr
- flow:	single flow for oil cross-counter flow for coolant
- oil face area:	650 mm x 300 mm 25.6" x 11.8"
- coolant face area:	700 mm x 300 mm 27.6" x 11.8"
- block dimension, edges to be added:	700 mm x 650 mm x 300 mm 27.6" x 25.6" x 11.8"
- coolant pressure loss: for land mode	18.33 m^3/hr, 80.7 GPM 0.3 bar, 4.35 psi
for sea mode	25 m^3/hr, 110 GPM 0.35 bar, 5.08 psi
- weight	170 kg, 375 lb

- heat: for land mode power level 1	70 kW, 663. BTU/sec
for water mode	156.6 kW, 148.4 BTU/sec

Sea water heat exchanger (see Fig. 11)

- type:	flat pipe type
- material:	G-CuZn15Si4
- supplier:	Behr
- flow:	single path for sea water single path for coolant
- total dimension:	611 mm x 390 mm x 225 mm 24" x 15.4" x 8.9"
- sea water pressure loss for:	70 m^3/h, 308 GPM 0.75 bar, 10.9 psi
- coolant pressure loss for:	25 m^3/h, 110 GPM 0.65 bar, 9.43 psi
- heat (sea mode)	1080 kW, 1023,7 BTU/sec
- weight (dry)	60 kg, 132 lb

Charge air cooler (2)

- type:	plate fin louvered fin type
- supplier:	Behr
- material:	aluminium
- fin density air core:	80 fins/dm, 20.3 fins/inch
- air core length:	115 mm, 4.5"
- air face area:	700 mm x 150 mm, 27.5" x 5.9"
- flow:	single air path cross-counter coolant
- pressure loss (water mode)	
air:	1200 N/m^2, 4.8"WG
coolant:	0.2 bar, 2.9 psi
- heat (total)	
landmode power level 1:	10 kW, 9.5 BTU/sec
sea mode:	190 kW, 180 BTU/sec
- weight:	12 kg, 26.5 lb

Sea water pump - pump map (see Fig. 12)

- type:	radial pump
- supplier:	MTU
- max. speed:	3300 rpm
- nom. speed:	3255 rpm
- nom. pressure:	3.4 bar, 49.3 psi

2.3.3 Performance Prediction

- land mode power level 1 400 HP pump input for ambient temperature of 38°C, 100°F

  power balance: see Fig. 7,9

engine power at 2200 rpm		404.0 kW		542.0 HP
electric power		5.0 kW		6.7 HP
engine output		399.0 kW		535.3 HP
power loss splitter box		18.0 kW		24.1 HP
charge pump power		3.0 kW		4.0 HP
pump input power	2 x	189.0 kW	2 x	253.5 HP
power loss hydr. (heat)		70.0 kW		93.9 HP
line loss hydr.		5.3 kW		7.1 HP
leakage loss approx. 2%		6.7 kW		9.0 HP
hydromotor output power		296.0 kW		397.0 HP
cooling fan power		68.0 kW		91.2 HP
land mode drive motor output (total)		228.0 kW		305.8 HP

- land mode power level 2 400 HP engine power for ambient temperature of 38°C, 100°F

  power balance: see Fig. 8,9

engine power at 2200 rpm		298.0 kW		400.0 HP
electric power		5.0 kW		6.7 HP
engine output		293.0 kW		393.0 HP
power loss splitter box		17.0 kW		22.8 HP
charge pump power		3.0 kW		4.0 HP
pump input power	2 x	136.5 kW	2 x	183.1 HP
power loss hydrost. (heat)		50.0 kW		67.1 HP
line loss hydrost.		4.8 kW		6.4 HP
leakage loss approx. 2%		4.7 kW		6.3 HP
hydromotor output power		213.5 kW		286.4 HP
cooling fan power		45.5 kW		61.0 HP
land mode drive motor output (total)		168.0 kW		225.0 HP

- Sea mode power for seawater temperature of 26.7°C, 80°F and 30°C, 86°F ambient temperature

  power balance: see Fig. 10

engine power at 3000 rpm	1100.0 kW	1475.3 HP
electric power	5.0 kW	6.7 HP
engine output	1095.0 kW	1468.6 HP
power loss splitter box $\eta = 0.96$	43.8 kW	58.7 HP
charge pump power	7.5 kW	10.0 HP
pump input power	1x280 kW, 2x378.1kW	1x375HP, 2x507 HP
power loss hydrost. (heat) $\eta = 0.85$	156.6 kW	210.0 HP
line loss hydrost.	7.5 kW	10.0 HP
leakage loss	30.2 kW	40.5 HP
hydromotor output power	849.4 kW	1139.0 HP
power seawater pump	12.4 kW	16.6 HP
seamode hydrojet pump input (total)	837.0 kW	1122.6 HP

2.3.4 Proposed or Currently Avialable Hardware

Radiator:

Radiator type normally used for MTU-power packs size must be specially procured for H.W.S.T.D. p.p. Tools are available at Behr.

Similar turnable coolant connection used for M48 power pack. Applied mixed circuit used for several MTU-power packs. Similar hydrostatic cooling arrangement has been applied for special German Mine Remover.

Sea Water Heat Exchanger:

In production for MTU ship propulsion systems.

Hydraulic Oil Heat Exchanger:

Similar size used for Mine Remover.

Sea Water Pump:

Used for MTU ship propulsion system. Must be modified for hydromotor drive.

2.4 Cooling Fan Drive System

2.4.1 Description

With respect to the location of the cooling system above the engine and the hydrostatic propulsion system for landmode and watermode, a hydrostatic fan drive system has been chosen. The selected radial fan rotates at a maximum speed of 4850 rpm, altering use of a direct fan drive.

Because the cooling systems have to be cooled at full engine landmode output up to an ambient temperature of 38°C, 100°F, and since only minor fan performance is required with less severe climatic conditions, the fan speed - and therefore power control - is recommended from a fuel and power economy point of view.

The possibilities of fan-speed control have been considered:

1. Use the fixed displacement pump at the splitter box for the fan-drive system during landmode. Control the fan speed via the bypass valve in the circuit. The result is that fan power is reduced by the square of the speed respectively heat based on constant ambient temperature.

2. Change the fixed displacment pump to a variable displacement pump and control the fan speed by the angle of the pump. The fan power is then reduced by the cube of the speed respectively heat based on constant ambient temperature. This is a primary controlled fan-speed system.

3. Use a variable displacement motor which is supplied with constant pressure from the two displacement pumps at the splitter box. That means, these two pumps are primarily supplying oil for the landmode drive system and a small oil flow for the fan drive. Fan speed is controlled by the angle of the hydromotor. This is a secondary controlled fan-speed system. The power/speed respectively heat relation is the same as for option 2. In this case a "Stromag" coupling disengages the constant hydropump from the splitter box, switching from seamode to landmode.

Presently, the hydraulic supplier, "von Roll" is favouriz-ing option 3 with regard to the total power pack weight. For the final decision, the advantages and dis-advantages of the 3 options should be further considered in detail when the efficiency of the systems, for all displacement angles, are available and the weight of the different systems can be compared.

As parameter for the fan-speed control, the engine outlet temperature, which is limited to 107°C, 225°F as starting point for power reduction has been chosen. The max. allowable coolant temperature is 110°C, 230°F - see Fig. 13.

The fan-speed control is so adjusted that the max. fan speed is at approx. 103°C, 217°F. The fan starts to operate at approx. 98°C, 208°F.

The hydraulic-oil circuit is cooled by the cooling branch of the coolant through a heat exchanger. The heat dissipation and allowable hydraulic-oil temperature is therefore assured for all operating conditions.

2.4.2 Technical Data

Cooling Fan

Dimension:		
max. diameter	581 mm	22.9"
intake diameter	460 mm	18.1"
max. height	175 mm	6.9"
Nom. speed:	4850 rpm	
Air pressure loss:		
inlet	500 N/m^2	2.0"W.G.
radiator 1	1200 N/m^2	4.8"W.G.
radiator 2	1500 N/m^2	6.0"W.G.
fan inlet	1000 N/m^2	4.0"W.G.
fan outlet casing	500 N/m^2	2.0"W.G.
exit	500 N/m^2	2.0"W.G.
total	5200 N/m^2	20.9"W.G.
Fan inlet under-pressure:	4200 N/m^2	16.9"W.G.
Fan outlet back-pressure:	1000 N/m^2	4.0"W.G.
Fan power requirement for nom. speed, sea level $\eta = 0.67$:	68 kW	91.2 HP
Fan weight:	20 kg	44.0 lb

Fan Motor

Option 1:		fixed displacement motor	
Type:	14/40	32 cm^3/rev.	1.9 $inch^3$/rev.
Supplier:		Behr, Hydromatik	
Oil flow:		162 l/min	42.8 GPM
Speed:		4850 rpm	
Differential pressure:		290 bar	4206.0 psi
Weight:		10 kg	22.0 lb

Option 2 and 3:	variable displacement motor
Type:	A6VM-28
Supplier:	von Roll, Rexroth
Differential pressure:	depending on selected circuit pressure
Weight:	22.7 kg 50.0 lb
Fan drive efficiency:	combined sprocket drive, fan drive system η_{TOT} = 0.783 (power level 1) η_{TOT} = 0.782 (power level 2)

2.4.3 Fan Speed Control (see Fig. 13 and 2.4.1)

Fan speed is controlled by variable displacement fan motor for option 2 and 3.

Fan speed is controlled by bypass valve for option 1.

Control parameter is engine coolant outlet temperature.

For over 103°C, 217°F fan speed is 100%. Fan speed is then linearly reduced as a function of the coolant outlet temperature up to zero for approx. 98°C, 208°F coolant temperature.

The relation between heat capacity fan power, fan speed and ambient temperature is shown in Fig.

2.4.4 Proposed or Currently Available Hardware

- The proposed cooling fan is in serie-production for the Leopard 2 power pack and AMX 30 repowering kit. Some few modifications have to be made for the direct connection of the hydromotor and fan flange.
- Hydrostatic units are standard components of Rexroth respect. Hydromatic.
- Coolant sensors can be taken from MTU power packs in serie-production.
- Piping and valve should be ordered after finalized detailed design.

2.5 Engine Compartment Venting System

2.5.1 Concept Evaluation

The main reason for venting the engine compartment is not to cool engine parts because the liquid-cooled engine does not really need cooling. The venting air is mainly required in order to avoid unventilated, respectively over-heated areas, that can damage peripheral power pack components such as electronic systems, hoses or sensors.

The air flow requirement is therefore very low. A flow of approx. 0.4 kg/s is enough in MTU-experience if a good flow distribution can be reached.

The engine compartment must be ventilated during water and landmode operation. Theoretically, air supply could be achieved by the cooling fan during landmode operation via a bypass duct at the fan suction side or casing. This possibility has often been used for MTU-power packs. During watermode, the cooling fan must be shut-down and the intake and exhaust louvers closed. A second source of ventilation is therefore required with a fording hood intake and exit which hinders water entering the engine compartment.

These fording components normally result in quite high pressure losses for the intake and exit air. The design of the inlet and exit hood has to be made by the vehicle designer.

It can be estimated that the total required air pressure should be approx. 500 mmWG, 20.0"WG.

The drive system for the blower can be an electric motor or a hydromotor. The electric motor is advantageous for engine shutdown. To avoid heat soak the electrically driven blower can be operated some minutes after engine shut down. The total efficiency of the electric or hydro-motor drive will be nearly equal.

2.5.2 Technical Data

Required venting air flow		0.4 kg/s	9 lb/sec
Required total pressure	approx.	500 mmWG	20"WG
Location of inlet and outlet:			
Recommended inlet:		over power pack electronic box	
exit:		approx. over splitter box at both sides of the top deck	

2.5.3 Proposed and Currently Available Hardware

It is recommended to use commercial or military components which are in production. Recommended is an electric driven blower but even an hydraulic driven is applicable.

German blower sources:

Hydraulic driven blower:

used in personal carrier "Marder"

Technical data:

blower power:	3.34 kW	4.5 HP
blower type:	2-stage axial	
air flow:	20 - 24 m^3/min	53.0 lb/min
air pressure:	700 mmWG	27.0"WG
hydraulic flow:	30 l/min	7.9 GPM
hydraulic pressure:	80 bar	1160.0 psi
total weight:	approx. 30 kg	66.0 lb
stock No.:	BWB 23111290200	

Electric driven blower;

Technical data:

supplier:	Fa. Piller, Osterode	
blower power:	5.0 kW	6.7 HP
blower type:	axial part No. 93614ANM0270	
air pressure:	2900 N/m^2	11.6"WG
air flow:	66.0 m^3/min	174.0 lb/min
total weight: approx.	49.0 kg	108.0 lb
dimensions: max. DIA	330.0 mm	13.0"
max. length	470.0 mm	18.5"

2.6 Vehicle/Power Pack Interface

2.6.1 Connectors, Couplings
(see also installation drawing No. 657 900) Attachment 1

Electronic connectors and electronic supply: Located at both sides of electronic box over fine filter.

Coolant: Quick-disconnects below left pre-filter for:

- coolant to sea water heat exchanger 45 mm, 1.8"min DIA, max. flow 25 m³/hr, 110 GPM, max. pressure 5 bar, 72.5 psi
- coolant to hydraulic heat exchanger 38 mm, 1.5"min DIA, max. flow 18.3 m³/hr, 80 GPM, max. pressure 5 bar, 72.5 psi
- coolant from splitter box heat exchanger, 45 mm, 1.8"min DIA, max. flow 25 m³/hr, 110 GPM, max. pressure 5 bar, 72.5 psi
- coolant venting from heat exchangers 13 mm, 0.5 m³/hr, 2.2 GPM, max. pressure atmospheric

Hydraulic oil: Quick disconnects below right pre-filter for:

- oil to hydromotor for fan 25 mm, 1"min DIA, max. flow 162 l/min,43 GPM 350 bar, 5000 psia
- oil from hydromotor to hydraulic circuit, 25 mm, 1"min DIA, max. flow 162 l/min, 42.8 GPM, max. pressure 30 bar, 435 psia
- oil leakage flow from hydromotor 8 mm, 0.3"min DIA, max. flow approx. 2 l/min, 0.5 GPM, max. pressure: atmospheric

Fuel: Quick disconnect location can be adapted on vehicle provision recommended location: front of engine below fine filter and front engine cover.

- fuel from tank system 16 mm, 0.63"min DIA, female connector, max. flow approx. 800 l/hr, 3115 GPM, max./min. pressure.6 bar, 9 psia
- fuel to tank system, 16 mm, 0.63"min DIA, male connector, max. flow approx. 800 l/hr, 3.5 GPM pressure 0.5 bar, 7.0 psia

2.6.2 Mounting Requirements

The power pack has three mounting locations at the length coordinate of the vehicle (see installation drawing 657 900), Attachment 1.

The rear splitter box mount is the length determinating mounting. It consists of two prestressed elastomeric conical elements for both sides. Simple screw threads must be provided in the hull bracket. The engine flexible mount at the output is an auxiliary mount used for disassembling the engine and taking vertical shocks in one direction didn't need any provision. A simple flat machined surface is needed at the hull basement.

The forward engine mount consists of flat rubber elements to take vertical shocks in both directions. This shock mount is relatively soft compared with the splitter box mounting system. The length misalignment and thermal expansion of the power pack will therefore be compensated by the forward rubber elements. One screw thread on each side is required to fix the power pack. The forward and rear basement of the engine mounting system must allow to move the engine horizontally approx. 2" in forward direction.

2.6.3 Inlet and Exhaust Grill and Sealing Requirements

For the cooling system an inlet and outlet grill with closeable louvers have to be provided by the vehicle manufacturer.

The following technical data for the cooling system design must be reflected for the grill design:

Inlet grill:

max. cooling air flow	8.0 kg/s 6.7 m^3/s	17.6 lb/sec 235.0 cuft/sec
grill inlet area	800x880 mm	31"x35"
inlet sealing flange breadth required (machined surface):	approx. 30.0 mm	1.2"
max. pressure loss	500.0 N/m^2	2.0"WG

Outlet grill:

max. cooling outlet flow:	8.0 kg/s 8.55 m^3/s	17.6 lb/sec 301.0 cuft/sec
grill exit area	400 x 940 mm	15.7" x 37"
exit sealing flange breadth required (machined surface): approx.	30.0 mm	1.2"
max. pressure loss:	500 N/m^2	2.0"WG

For the inlet grill an protection screen against large particles is recommended. This grill should be removable or easy cleanable. Screen size recommended approx. 2.5 mm x 2.5 mm, 0.1 " x 0.1 ".

2.6.4 Power Pack Removal Provisions

With regard to the large hydraulic piping connections at the splitter box mounted pumps a possibility of the disassembling the engine from the splitter box in the engine compartment has been foreseen. The following procedure for the removal of the engine with peripherical equipment as cooling, air filter is required.

- Disengage the engine splitter box power connection via the movable spline shaft, which engages at the engine side in the spline of the Geislinger coupling and on the other end in the center gear of the splitter box. For that purpose the splitter box small rear cover must be removed.
- Loose the both forward mounting screws.
- Open the three quick-disconnect clamps of the flanges between engine and splitter box.
- Detach the quick-disconnect self sealing coupling at the engine for coolant and hydraulic oil of the fan drive system.
- Detach electrical connectors at the engine control box.
- Detach the quick-disconnect couplings for fuel at the forward engine end.
- Remove the engine horizontally for approx. 2" until the forward single guide pin attachs the guiding rail.
- Lift the engine out at the three lifting eyes (two at the forward engine end, one near the engine output).

2.6.5 Maintenance Access Openings

The maintenance locations are listed and shown in the installation drawing 657 900, Attachment 1.

Maintenance access is required at the forward engine top side for engine oil filling cap, dipstick and coolant filling cap. The fine filter cartridges can be replaced from the engine compartment at the forward engine side. The engine oil filters can be replaced at the left engine side, either in installed or removed position. The engine oil filters are replaced every second year or after 200 operating hours.

The vehicle designer could provide either a large opening at the forward top cover area or single small maintenance access openings.

2.7 Monitoring and Control System

2.7.1 Overview

The control and diagnostic system planned for the H.W.S.T.D. engine will be a standardized system as presently in development and hardware available in 1987, which is used for all power packs with 880 engines planned or in production. The system has the possibility to address the special requirement of the H.W.S.T.D. power pack. As for the H.W.S.T.D. engine specified, the monitoring and control system will control the engine power corresponding to the signal from the on-board computer. It will also reflect the power map limitation for water and land mode operation as shown in Fig. 2,3. In addition the power pack Monitoring and Control System will be provide an engine speed signal for the vehicle computer control system. For the indication of land or water mode a signal from the on-board computer must be transferred.

2.7.2 Description

The block diagram for the Control and Diagnostic System and the external units are shown in Fig. 14 . The power pack mounted system is the Control and Diagnostic System (CDS), which consists of the Engine Control System (ECS) and the Power Pack Control System (PCS). In addition in the CDS is an Integrated Test System ITS, which has the function of CDS self-control and failure, loud profil memory and life-time indication.

The external units allow to collect data and transmit data and give the possibility to communicate with other system outside or inside of the vehicle.

The individual system has the following functions:

- Engine Control System (ECS):

  Engine governor to control

  - idle speed
  - rated speed (2) (land and water mode)
  - full load characteristic (2) with coolant temperature limitation
  - droop
  - fuel injection timing

Engine monitoring system to check

- coolant circulation
- coolant level (2 switch points)
- coolant temperature
- oil pressure
- oil temperature

• Integrated Test System (ICS):
  - continuous fault detection (self-testing) of sensors, transmitters and electronics
  - recording of operating profile
  - indication of time until maintenance

• Fleet Data System (FDS)

  Data Base

  - collects, stores and displays upon request fleet data transmitted from CDS and/or additional sensors
  - transmits data to AI

  Artificial Intelligence (AI)

  - process, analyses and assesses the data transmitted from FDS
  - displays proposals for corrective actions

• Dialog Unit (DU)
  - non-volatile storage of operating parameters
  - short-term storage of measured and computed data
  - up-dating or modification of operating parameters
  - display of measured and computed data
  - initiation of test routines
  - display of test results

• Vehicle Interfaces
  - CDS receives power requirements form the on-board computer controller
  - CDS receives land or water mode signal
  - PCS indicates max. power limitation
  - PCS gives engine speed signal

2.7.3 Dimension and Weight

The rough dimension is shown in the installation drawing. This has been taken from a existing ECS/PCS system for the MT 883 engine as to be installed in a Leopard 2 chassis.

Weight and dimension are therefore rough estimation, because the hardware is just in development.

Dimension:	300 x 250 x 500 mm 11.8" x 10.0" x 20.0"
Weight:	approx. 25kg, 55 lb

2.8 Performance

2.8.1 Degradation of performance due to power derating.

Water mode operation: max. power see Fig. 5

For the maximum defined sea water temperature of 26.7°C, 80°F and ambient temperature of 30°C, 86°F no power derating is effective because the cooling system is designed for and the max. engine power of a charge-air cooled engine relies mainly on the charge-air temperature after the charge air cooler for the sea mode application.

The following power degradation is effective if the fuel temperature is above 30°C, 86°F.

2.5% per 10°C, 18°F fuel temp. increase.

If the coolant temperature at the engine outlet is above 107°C, 224.6°F for the case of failure in the sea mode coolant system an automatic power degradiation system will be effective. In the first approximation the automatic power degradation gives 100% power up to 107°C, 224.6°F max. and 70% power min. at 112°C, 233°F.

Land mode operation:

The max. power during land mode operation is limited by the design point of the cooling system, see Fig. 3
The power derating is shown in Fig. 4 for the max. land mode power of 404 kW, 542 HP respect. 298 kW, 400 HP pump input power. It is about 20% power degradation for 10°C, 18°F above the cooling system design point effective for full throttle position steady-state operation.

2.8.2 Projected vehicle performance

To be provided by vehicle designer based on 2.8.3

2.8.3 Max. Available Net Power

The projected drive-line performance is shown in the power/heat balance for 2 power levels of land mode operation and the water mode operation see Fig. 7,8.

For 404 kW, 542 HP engine power (power level 1) the power at the drive motor output is total 228 kW, 306 HP equivalent to a total drive line efficiency of 56.4%.

For 298 kW, 400 HP engine power (power level 2) the power at the drive motor output is total 168 kW, 225 HP equivalent to a total drive line efficiency of 56.4%.

For 1100 kW, 1475 HP engine power (water mode) the power at the water jets input is total 837 kW, 1122.6 HP equivalent to a total drive line efficiency of 76.1%, see Fig. 10.

2.9 Fuel Consumption

The engine fuel consumption map is shown in Fig. 3 for land mode operation and in Fig. 2 for sea mode operation.

With respect to the required cooling fan power for max. land mode power (power level 1) the following fuel consumption is estimated:

- for 404 kW, 542 HP engine power at 30.0°C, 100°F
  sfc = 218 g/kWH, 0.36 lb/HPhr, 228 kW 306 HP

drive line output	88.0 kg/hr	194.0 lb/hr
	106.1 l/hr	28.0 GPhr
specific fuel consumption output related	386.0 g/kWhr	0.63 lb/HPhr

- for 418 kW, 566 HP engine power at 21.1°C, 70°F,
  sfc = 218 g/kWh, 0.36 lb/HPhr, 252 kW, 338 HP

drive line output	91.0 kg/hr	200.0 lb/hr
	110.0 l/hr	29.0 GPhr
specific fuel consumption output related	360.0 g/kWhr	0.59 lb/HPhr

For water mode operation the following fuel consumption is estimated

- for 1100 kW, 1475 HP specified water mode condition
  sfc = 220 g/kWhr, 0.36 lb/HPhr, 837 kW, 1123 HP

drive line output	242.0 kg/hr	533.0 lb/hr
	291.0 l/hr	77.0 GPhr
specific fuel consumption output related	289.0 g/kWhr	0.47 lb/HPhr

2.10 Fuel, Oils and Coolant Requirements

2.10.1 Engine Lubrication

0-236 according MIL-K-2104D (SAE 30) as year round lubricant for outside air temperature up to -10°C, 14°F
0-239 according MIL-L-2104D (SAE 40) for outside air temperature down to +10°C, 50°F

These lubricants can be used at lower outside air temperature after preheating to an oil temperature after preheating to an oil temperature as above mentioned outside air temperature limits.

2.10.2 Fuel

Diesel Fuel according DIN 51 601 or Diesel Fuel F54 according VV-F800C GRADE DF2
or Jet Fuel F34 according MIL-T83133A, Am2
or Jet Fuel F40 according MIL-T5624L, Am2 GrJP4

F40 pure only for emergency operation. Jet Fuel as F40 as supplied by Mineral Oil Industry has cetan rating of 30 or above.

Mixtures of all these fuels can be used.

Min. fuel supply to the engine:	14 l/min	3.7 GPM
Min. fuel pressure:	.6 bar	8.7 psia

2.10.3 Coolant

As year round coolant used at outside air temperatures to -40°C, -40°F a mixture of drinkable water and antifreeze in the ratio 1:1 by volume. Admitted antifreeze agents are listed in spec. TK6-03-010/2.

In areas with outside air temperatures above 0°C, 32°F a mixture of 98% up to 98.5% of drinking water and 1.5% up to 2% by volume of corrosion preventive soluble oil. Admitted corrosion preventive soluble oil manufacturer are listed in:

MTU-Fluid and Lubricants Specification
MO 01061/11 E addition 0185

2.10.4 Filling Quantities

- Lube oil:	engine	80.0 kg	176.4 lb
		96.0 l	25.0 gallons
	splitter box	10.0 kg	22.0 lb
		12.0 l	3.2 gallons
- Fuel:	as required, fuel hour range see 2.9		
- Coolant:		120.0 kg	264.5 lb
		120.0 l	32.0 gallons

2.11 Weight Estimates

		(kg)		(lb)
Basic engine dry incl. starter		1650		3637.6
Peripheral equipment as wiring, connection parts, mounting brackets, 20 kW-generator, coolant expansion tank and piping		300		661.4
Air filter system:				
2 x prefilter with scavenge blower	50		110.2	
2 x fine filter	75		165.3	
Total		125		275.5
Cooling system (engine mounted)				
Air duct casing	85		187.4	
Cooling fan	20		44.1	
Hydromotor	20		44.1	
Piping with quick-disconnect self-sealing coupling	10		22.0	
2 radiator with mounting equipment	150		333.7	
Total		285		628.0
Exhaust system with silencer		60		132.3
Splitter box with mounting and heat exchanger		200		440.9
2 hydraulic pumps 4 V250		381		840.0
1 hydraulic pump 2 F355		137		303.0
1 hydraulic pump QC-200		75		165.3
Total powerpack dry weight with hydr. pumps		3213		7083.3
Filling quantities (hydraulic excluded)		75		165.3
Engine oil	80		176.4	
Coolant	120		264.5	
Splitter box	10		22.0	
Total		210		463.0
Operation weight (wet)		3423		6459.5

2.12 Cost and Schedule Estimate

The Time and Cost Schedule is shown in Fig. 15. In order to avoid delay for the planned availability of the power pack, it is recommended to order at least the long-lead items before the main contract signing. This "pre-procurement" will save 5 months before the main contract must be placed. In this 5 months' period the interface should have been also clarified so that detailed designing can start after main contract award.

In addition to the Scope of Work specified for the Conceptual Design Study, the subcontractor has added the development cost and hardware cost for the splitter box, which can be furnished by the subcontractor in collaboration with the German firm, "Zahnradfabrik Friedrichshafen" (ZF). This is a proposed option with regard to saving interface problems and additional shipment cost. The decision hereto will be made by the main contractor, respectively the Marine Corps Program Office.

After design effort has been carried out on the to-be-modified engine parts for the H.W.S.T.D., such as the charge air cooler, air ducts, piping, assembly parts and brackets for peripheral components, the two basic engines will be assembled with hardware available 12 months after the "pre-contract" or main contract signing. Both engines are to undergoe an acceptance test on the MTU test stand. The contractor is invited to these tests. The peripheral components are available for powerpack assembly 8 months after main contract signing. After assembly the powerpack will first undergoe functional tests. A vibration test with the splitter box, without hydropump loads, will verify the vibration analysis: No load is expected to be the worst case of all operating conditions. After a full-load test with simulated brake power but without the splitter box, the power pack will finally undergoe an acceptance test.

The subcontractor will also assist with the power pack installation, with a check of the engine compartment approx. one month before installation and with an installation check prior to starting vehicle tests. It is planned to have a test-service man available for the time of the 8 months test and engineering support for approx. 4 months.

With the delivery of the power pack and spare engine, an Operation Instruction Manual for power pack maintenance and failure identification will be provided.

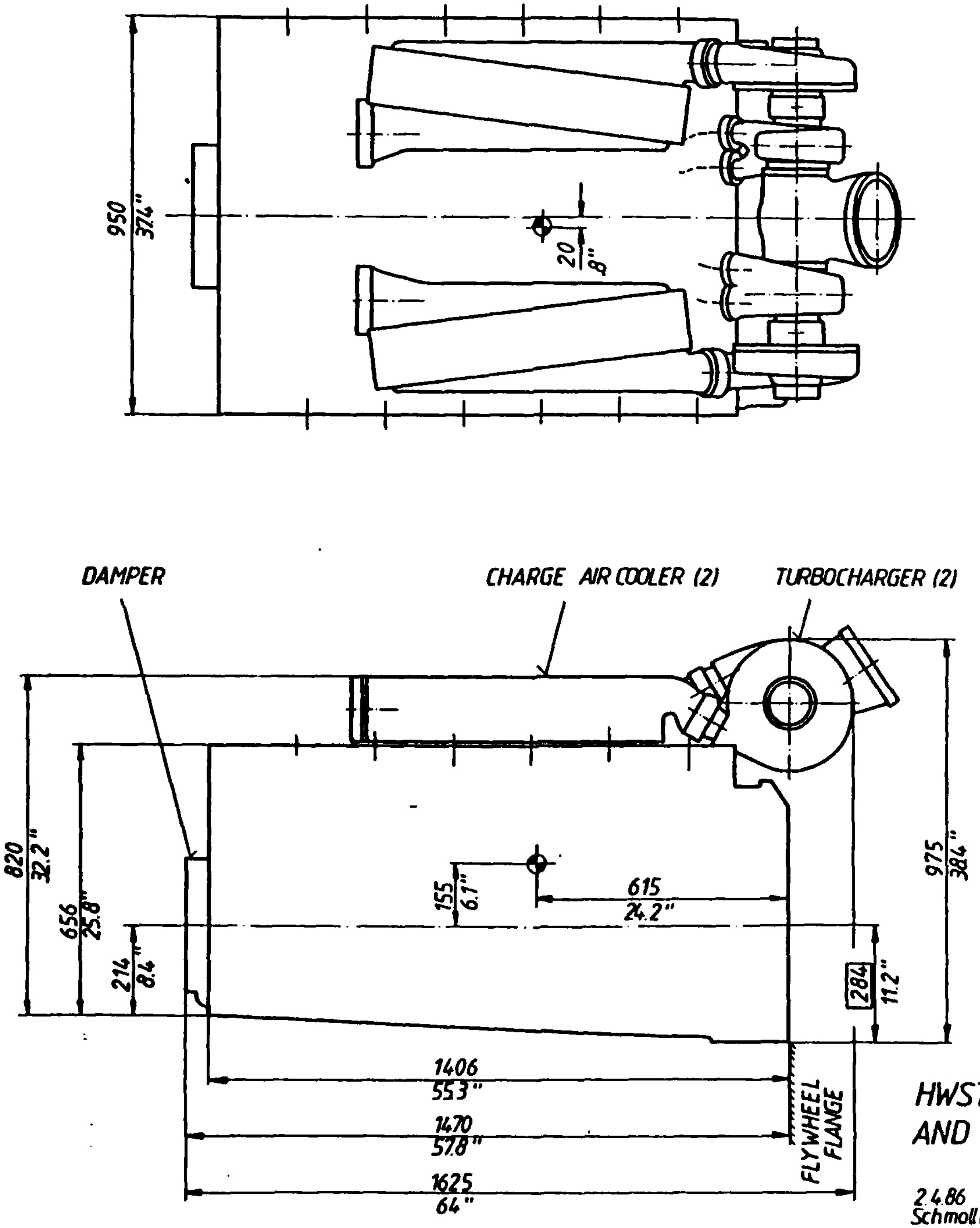


FIG. 1

HWSTD-BASIC ENGINE DIMENSIONS
AND CENTRE OF GRAVITY

2.4.86
Schmollinger

657 883

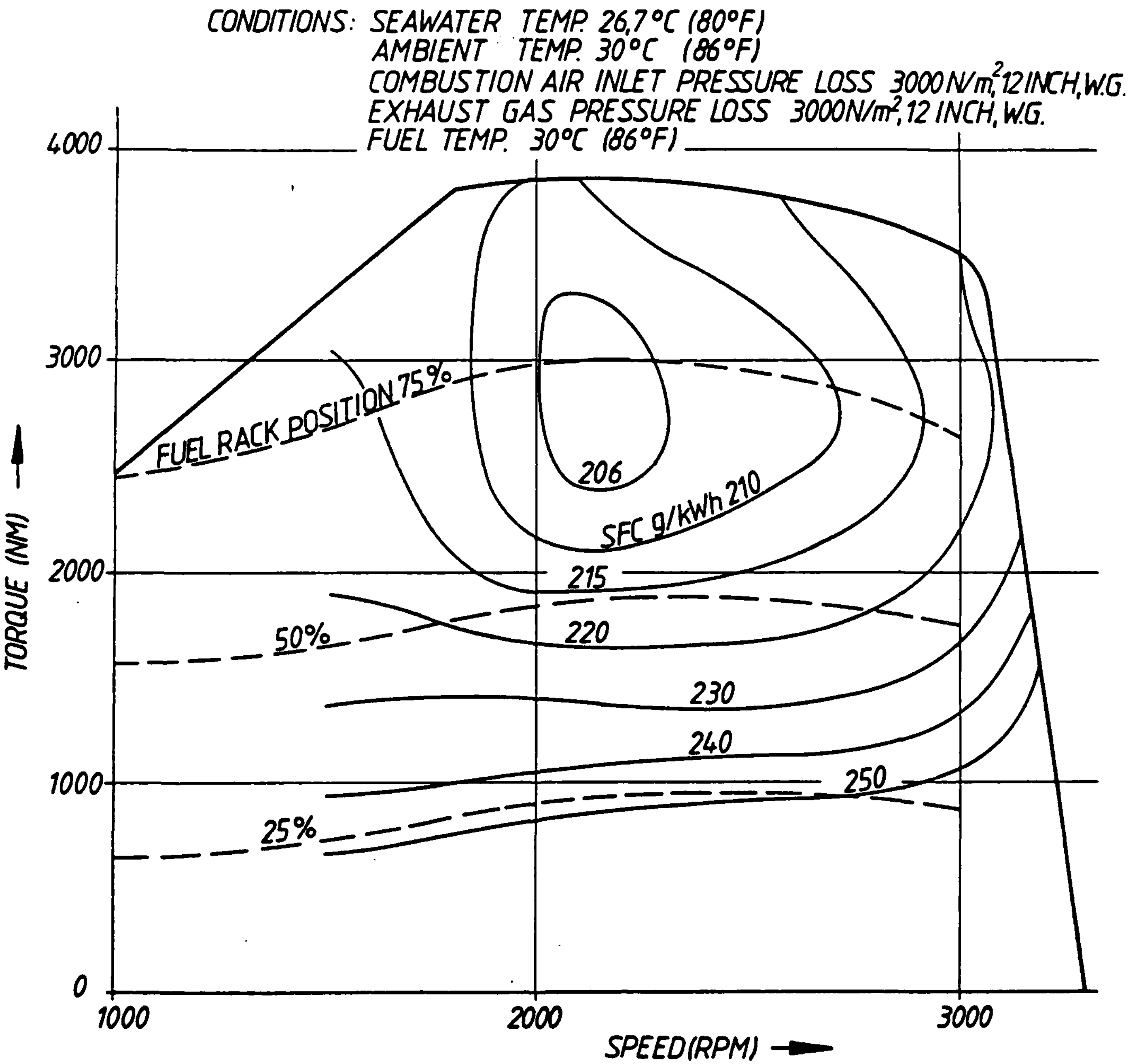
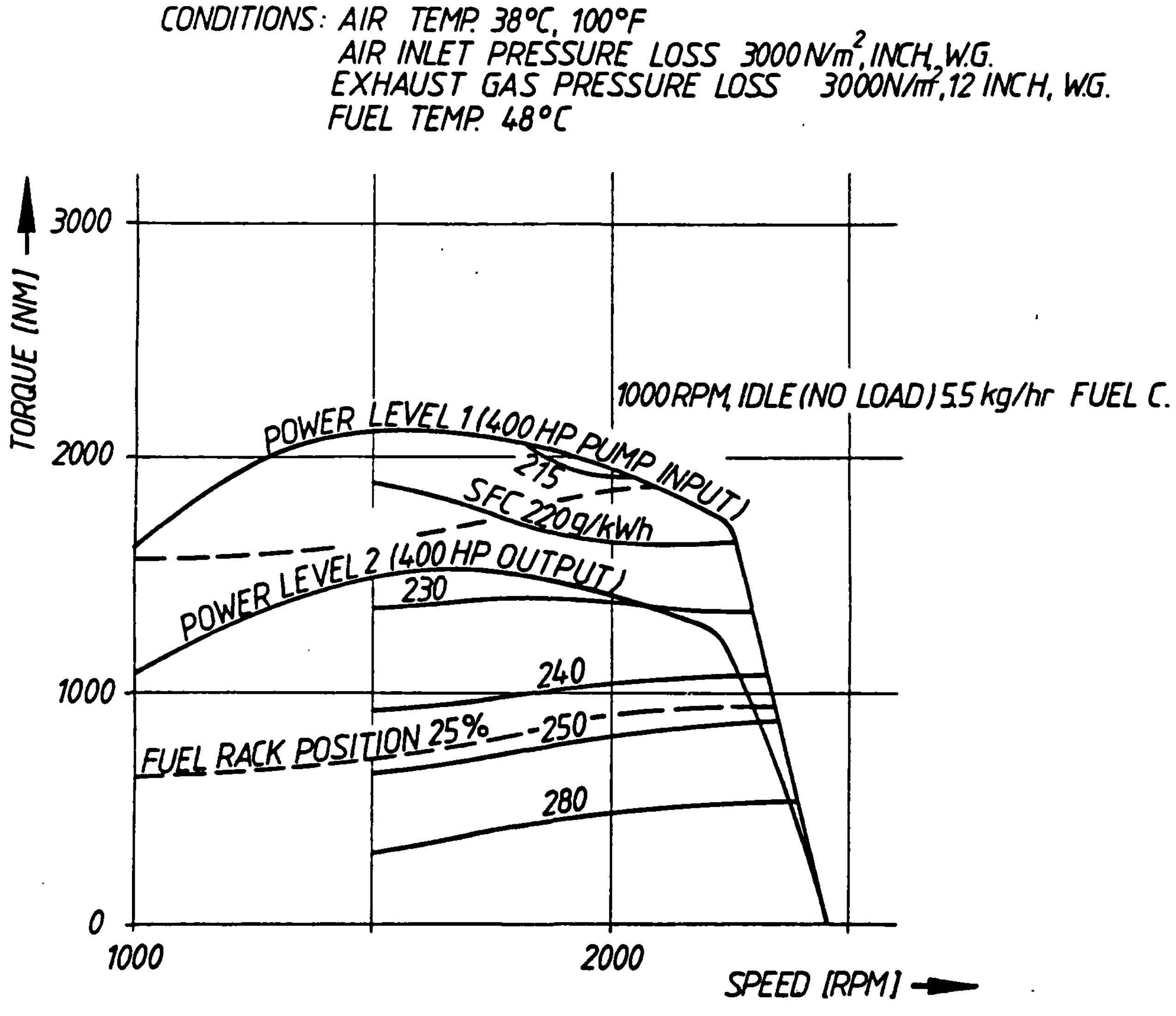


FIG. 2

PREL. ENGINE PERFORMANCE MAP (WATERMODE)

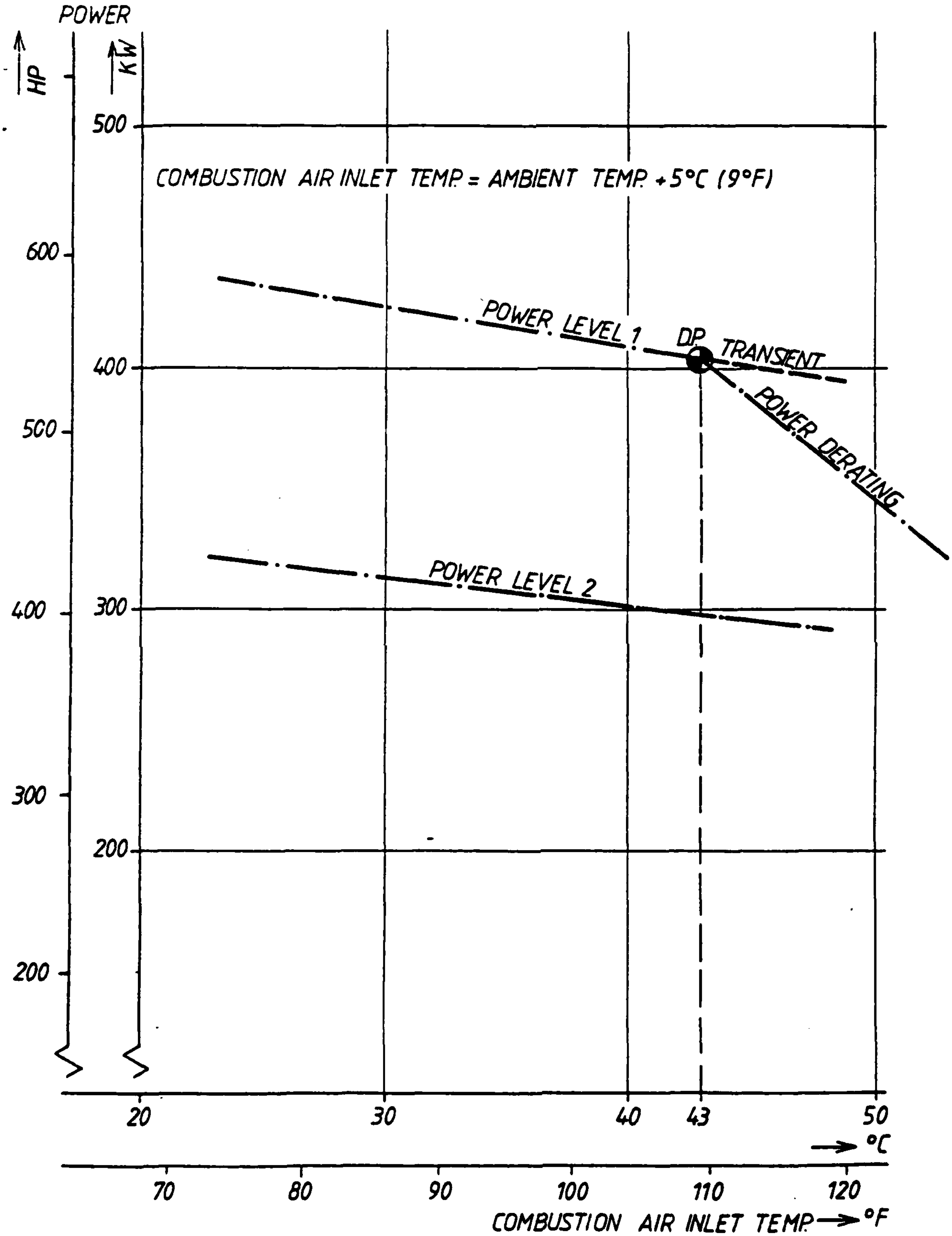
EPF 3.4.86 657 893



PREL. ENGINE PERFORMANCE MAP
(PROPOSED LANDMODE POWER)

FIG. 3

EPF 7.4.86 657 898

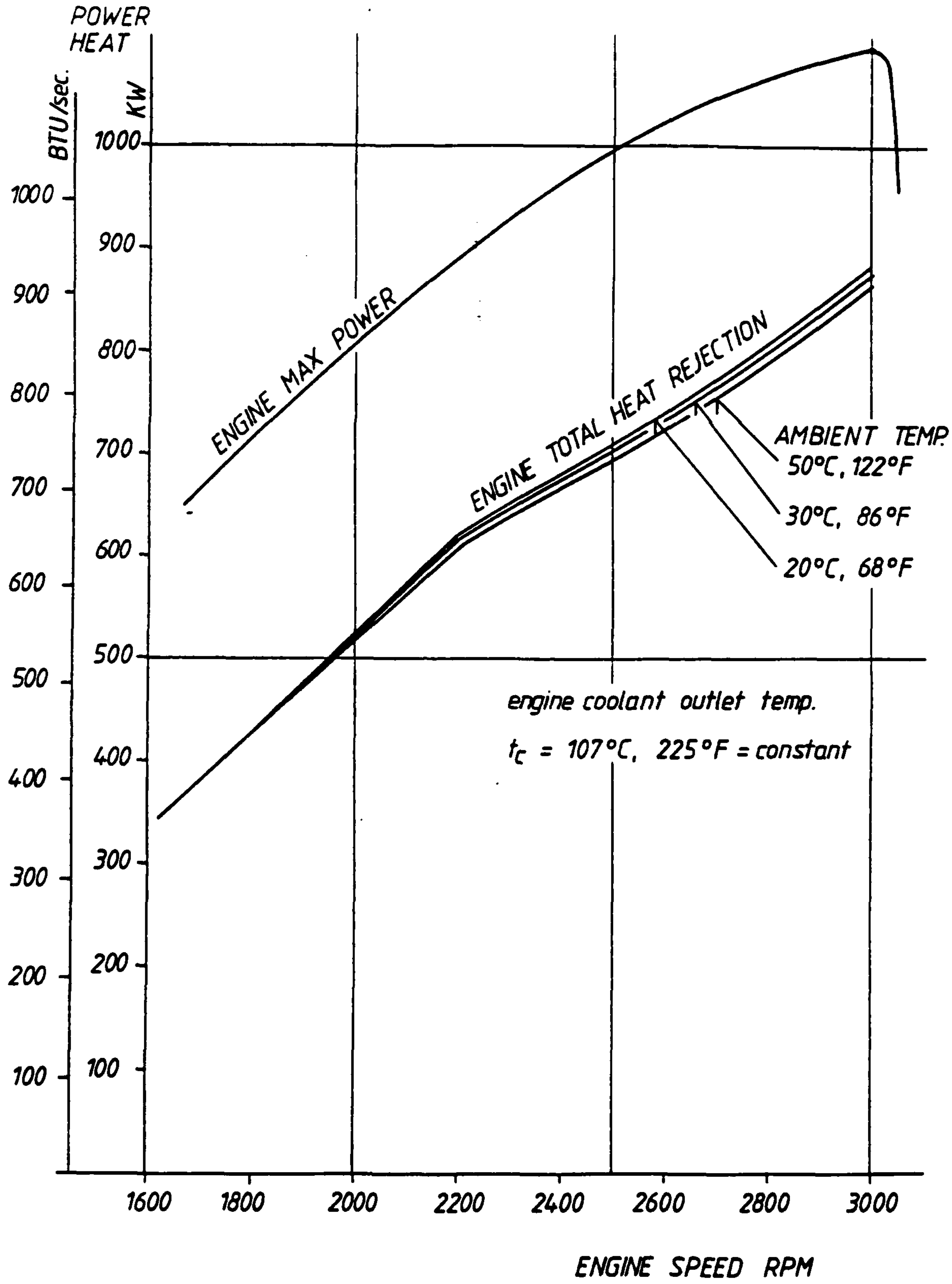


MAX POWER LANDMODE

EPF 3.4.80

657 894

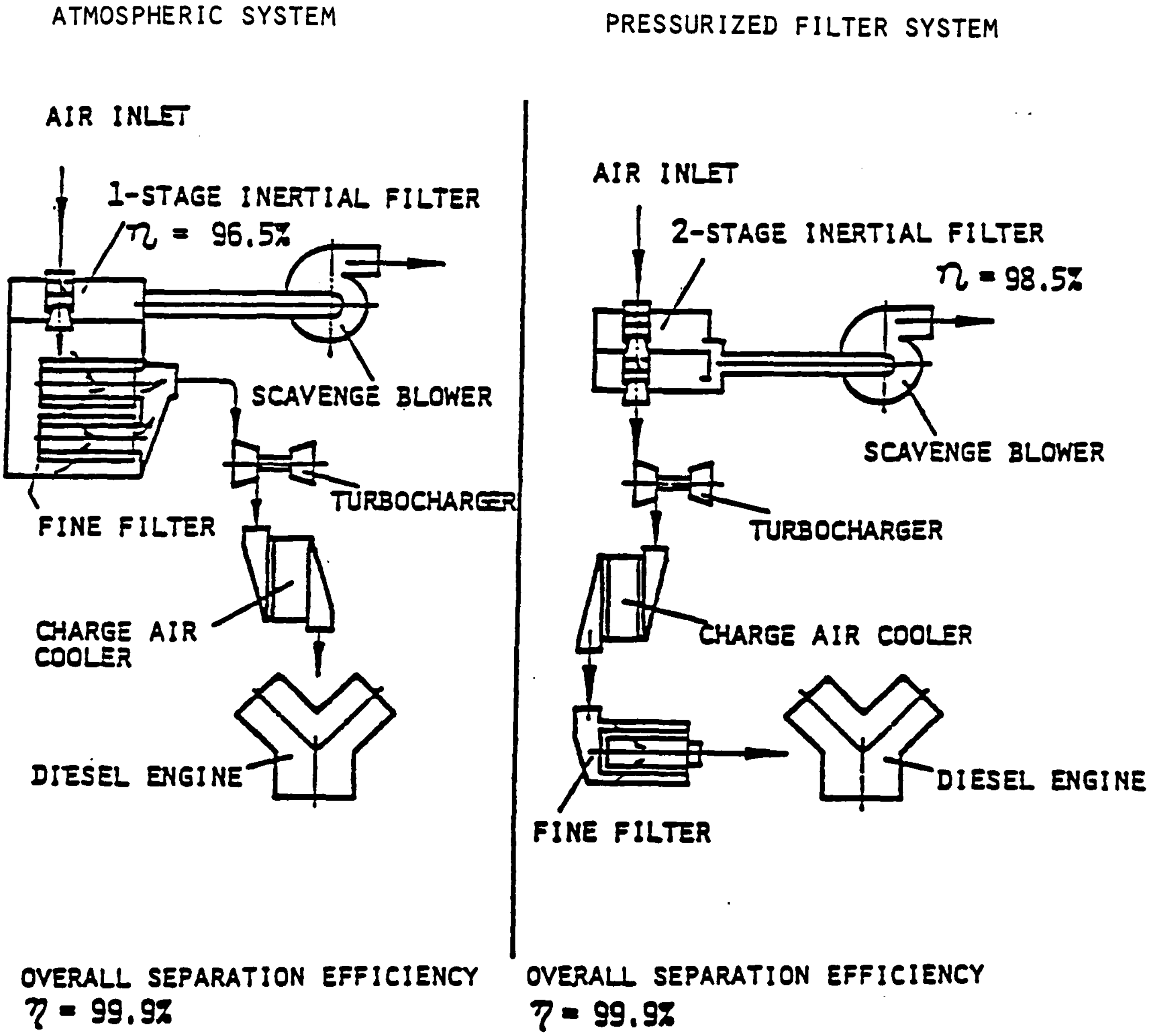
FIG. 4



HWSTD ENGINE HEAT REJECTION (WATERMODE)

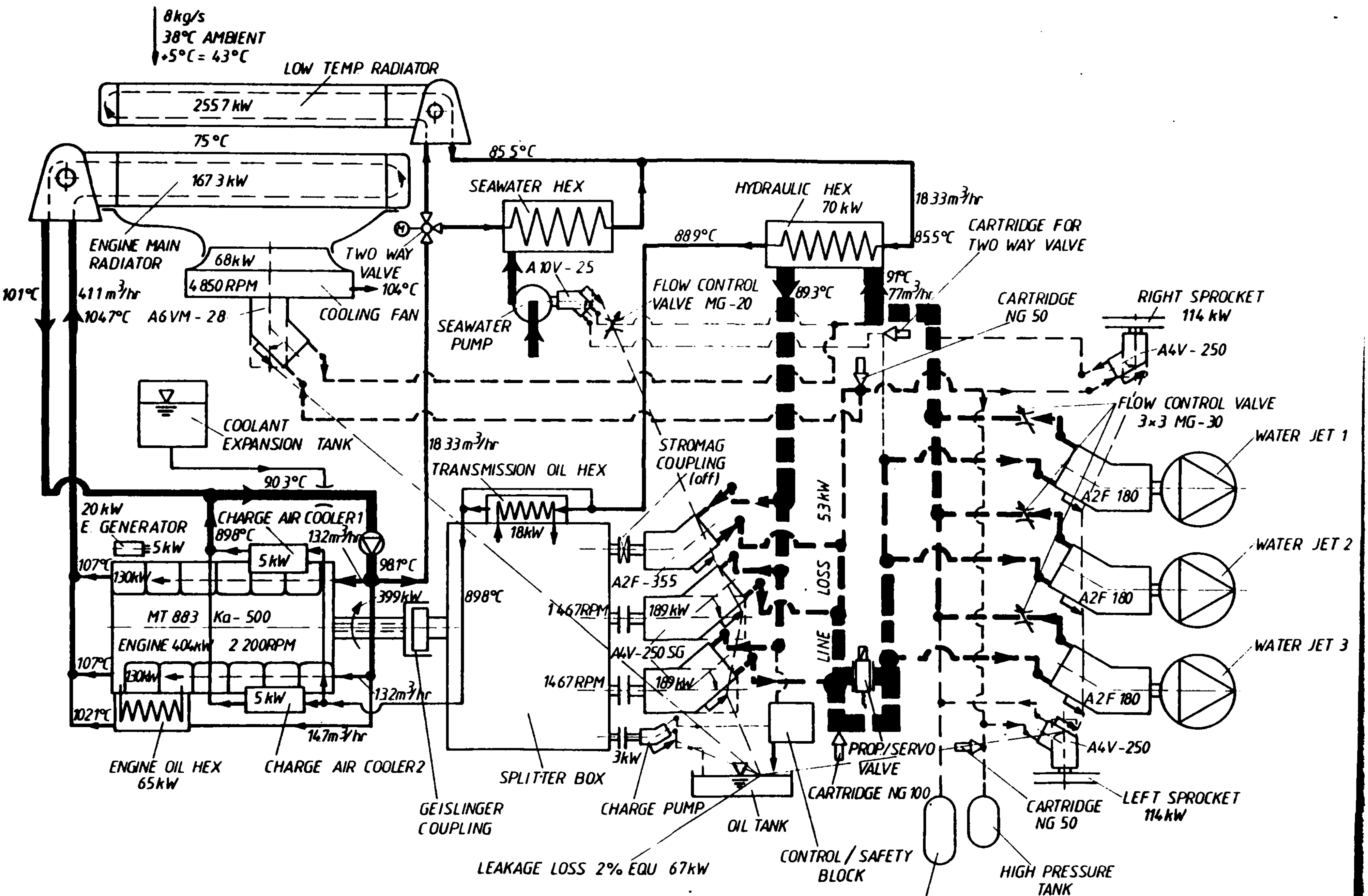
EPF 4.4.86 657 887

FIG. 5



COMPARISON OF ATMOSPHERIC AND PRESSURIZED FILTER SYSTEM

FIG. 6

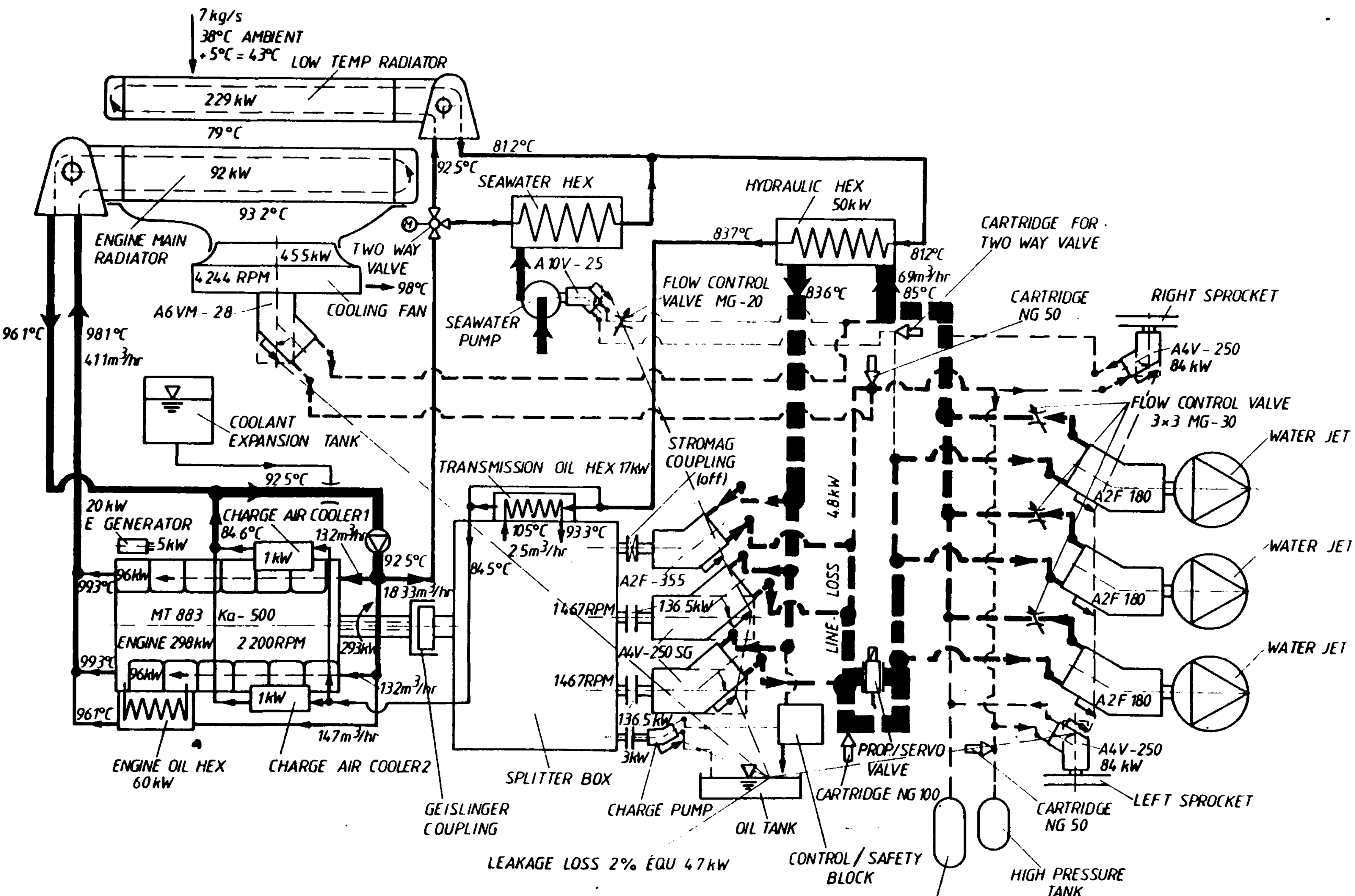


HWSTD COOLANT/HYDRAULIC CIRCUIT LANDMODE
POWER/HEAT BALANCE (298kW (400HP) PUMP INPUT))

FIG.7

EPF

657 886

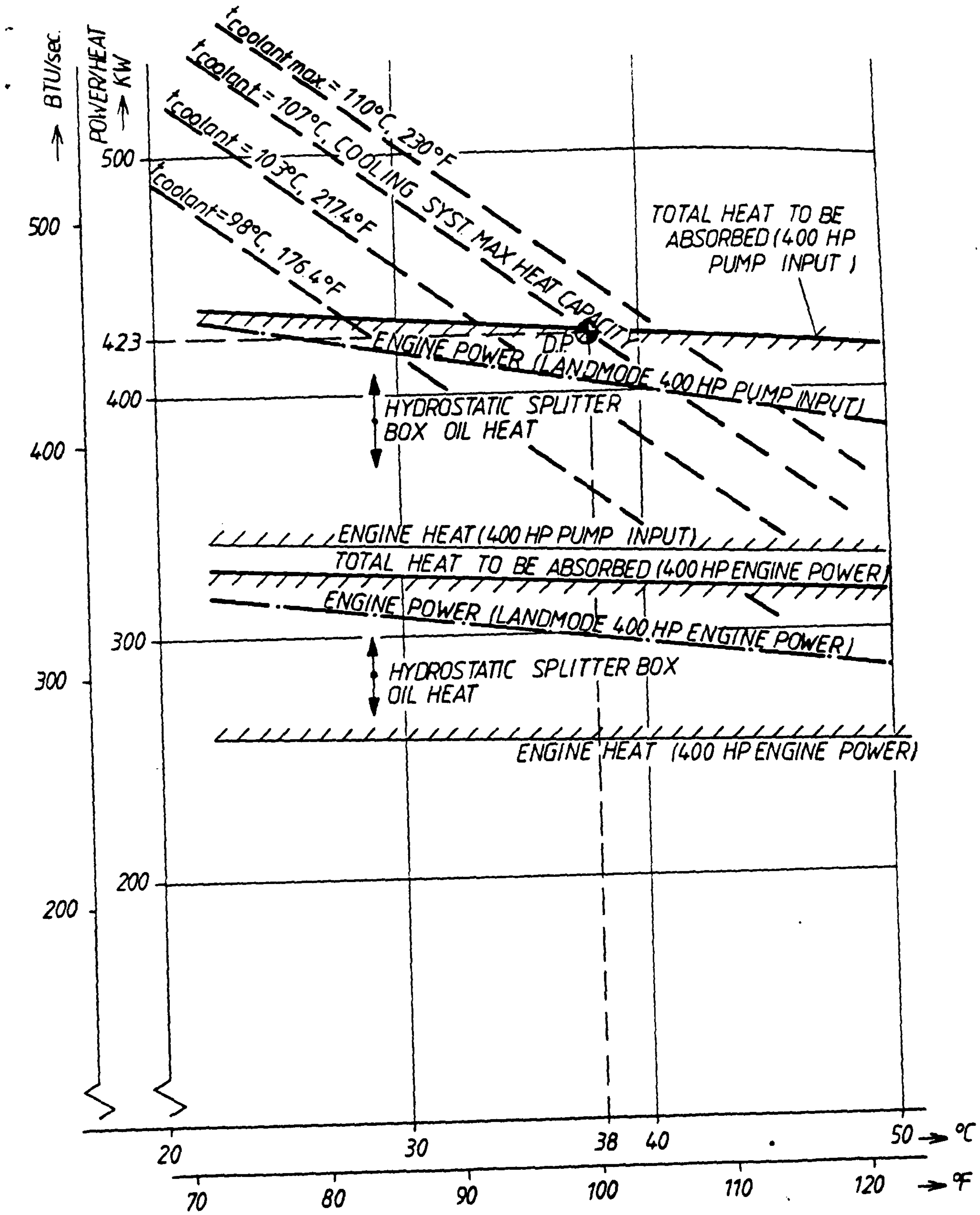


HWSTD COOLANT/HYDRAULIC CIRCUIT LANDMODE
POWER/HEAT BALANCE (298kW (400HP) ENGINE POWER)

FIG. 8

EPF 34 86

657 884

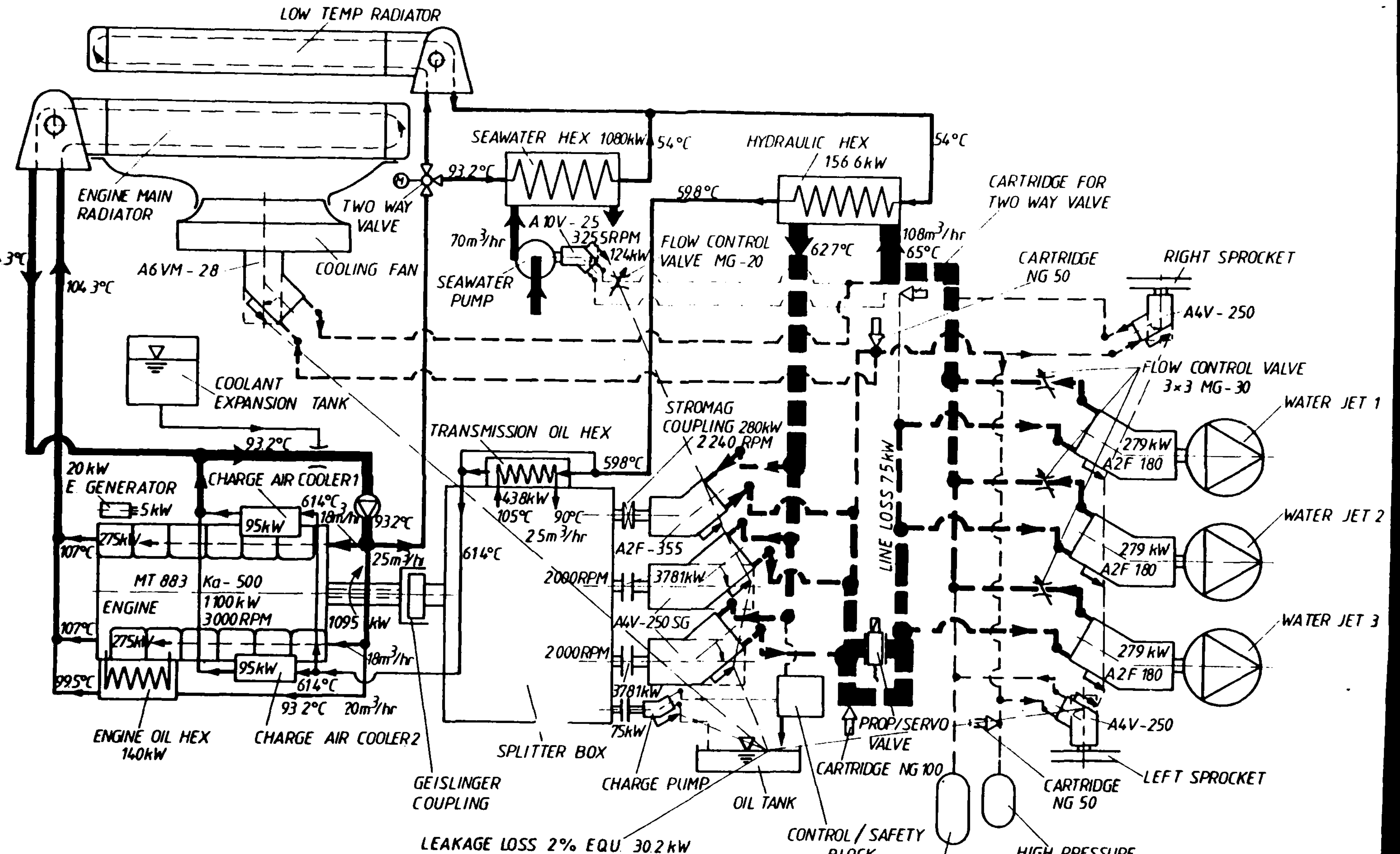


HWSTD PROP.SYSTEM HEAT CAPACITY/HEAT REJECTED

EPF 3.4.86

657 889

FIG. 9

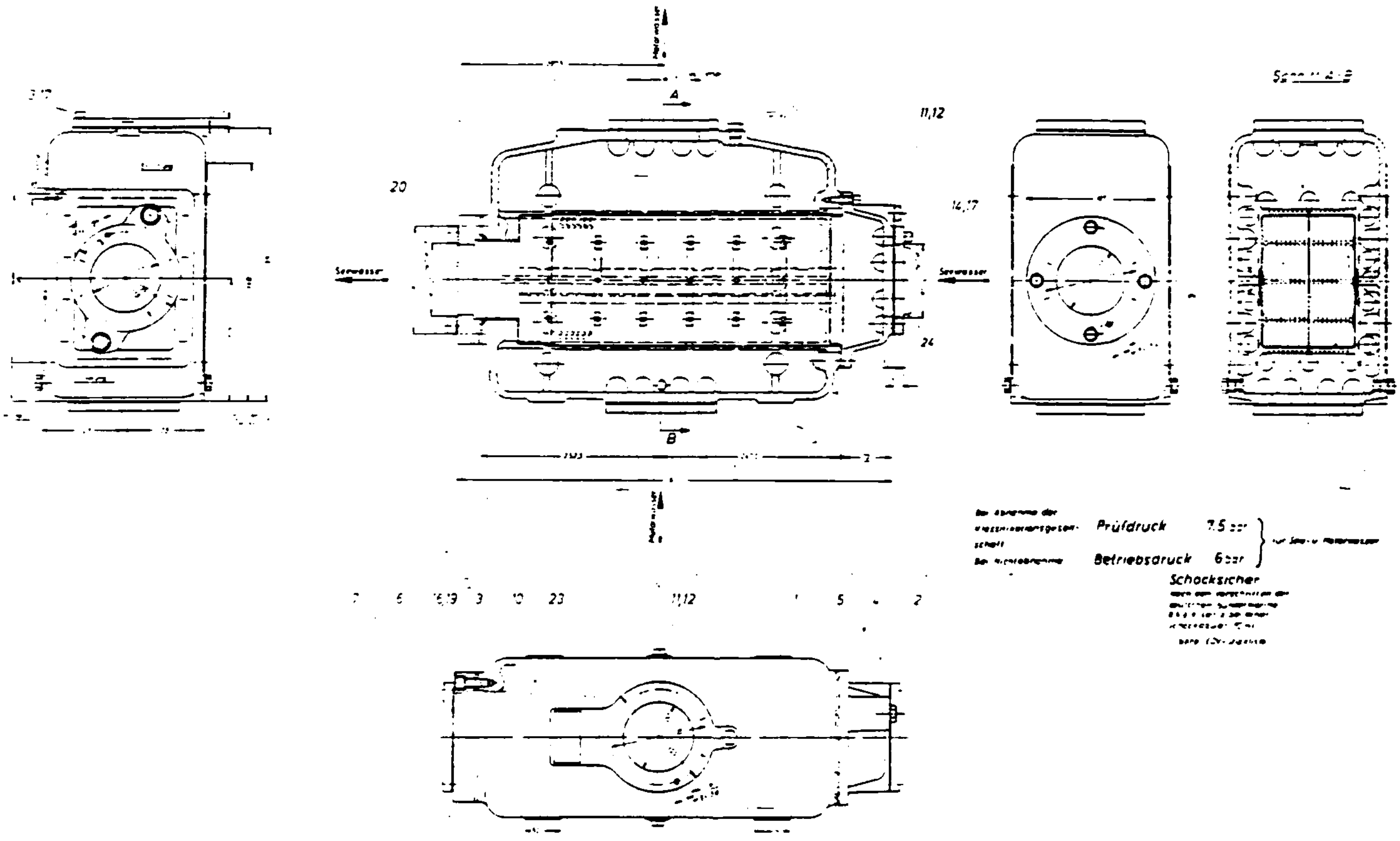


HWSTD COOLANT/HYDRAULIC CIRCUIT
POWER/HEAT BALANCE (SEA MODE)

EPF 34 86

FIG. 10

657 885

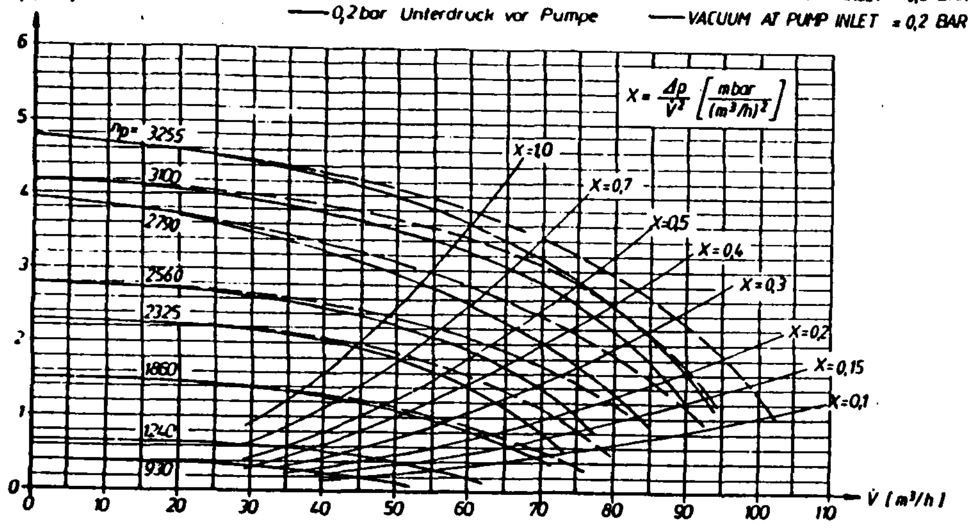


SEA WATER HEAT EXCHANGER

FIG. 11

Fördervolumenstrom
Wassertemperatur = 35 °C
- - - 0,2 bar Überdruck vor Pumpe
—— 0,2 bar Unterdruck vor Pumpe

PUMP DISCHARGE RATE
WATER TEMPERATURE = 35 °C
- - - PRESSURE AT PUMP INLET = 0,2 BAR (POS)
—— VACUUM AT PUMP INLET = 0,2 BAR (NEG)



Δp = Druckdifferenz / PRESSURE DIFFERENCE (bar)

$\dot{V}$ = Volumenstrom / PUMP DISCHARGE RATE (m³/h)

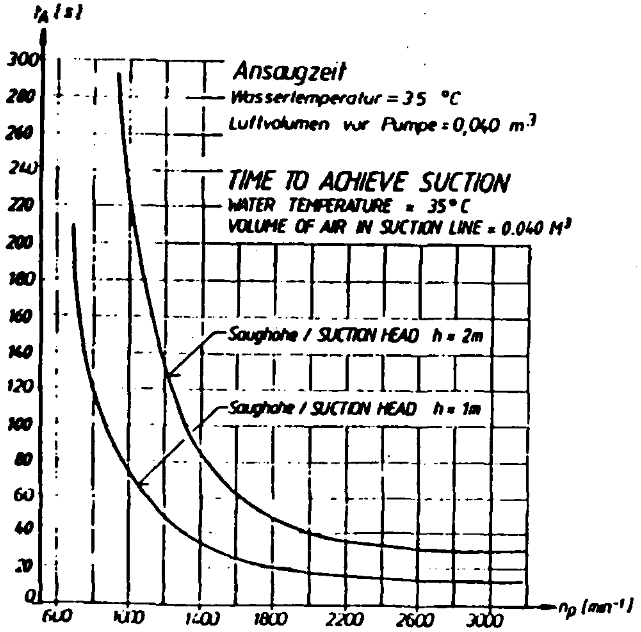
t_A = Ansaugzeit / TIME TO ACHIEVE SUCTION (s)

n_p = Pumpendrehzahl / PUMP SPEED (min⁻¹ = RPM)

OPERATING CONDITIONS:
- MAX VACUUM AT PUMP INLET = 0.2 BAR (NEG)
- MAX PUMP SPEED n_p = 3300 RPM

DRIVE:
- PUMP SPEED n_p = 1.55 × ENGINE SPEED

Die dargestellten Kennfelddaten sind Nennwerte gültig für
THE DATA SHOWN ARE RATED VALUES FOR 555 200 15 01



Ansaugzeit
Wassertemperatur = 35 °C
Luftvolumen vor Pumpe = 0,040 m³

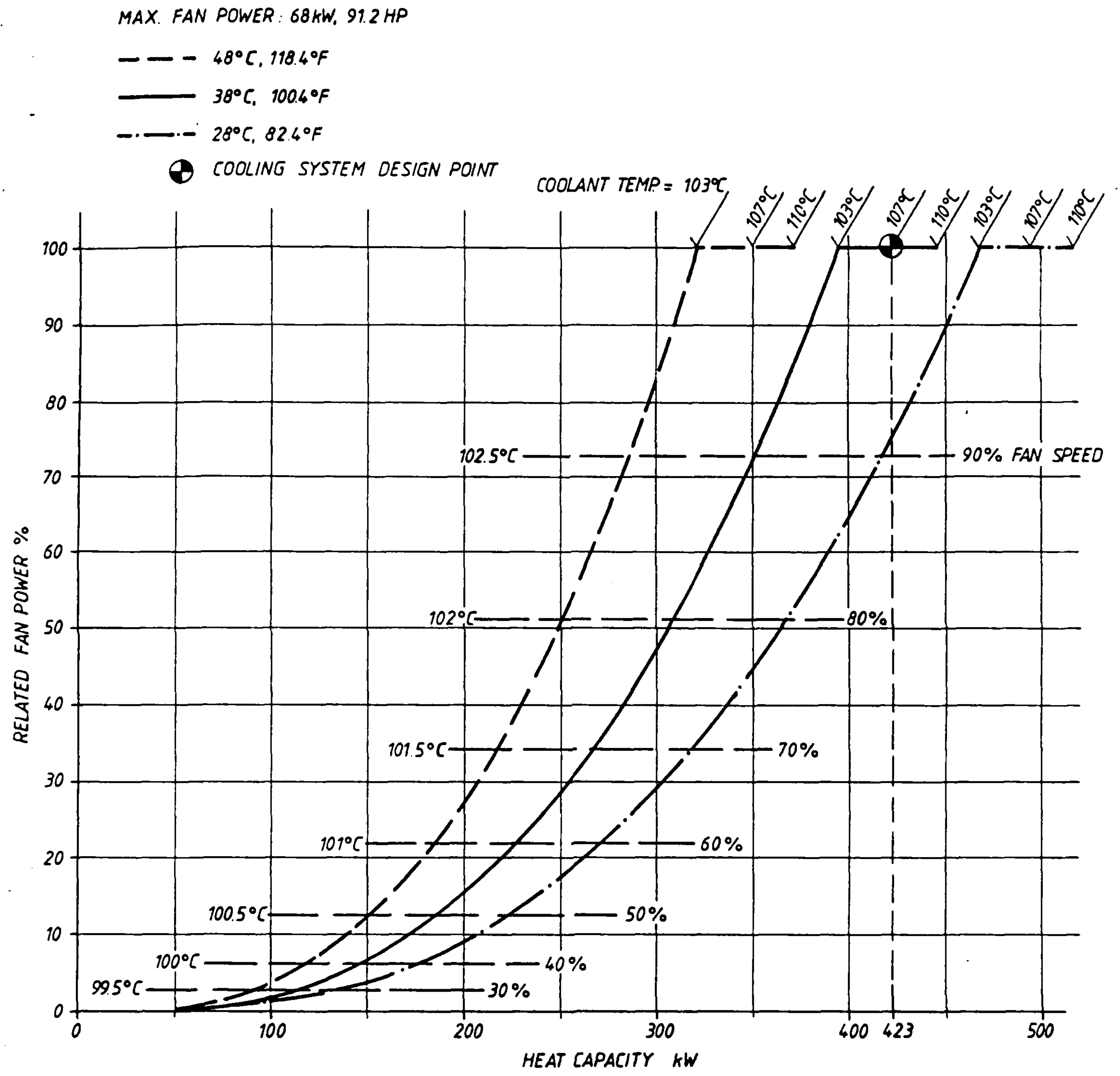
TIME TO ACHIEVE SUCTION
WATER TEMPERATURE = 35 °C
VOLUME OF AIR IN SUCTION LINE = 0.040 M³

Betriebsbedingungen:
- max zulässiger Unterdruck vor Pumpe = 0,2 bar
- max zulässige Pumpendrehzahl = 3300 min-1

20. 8. 85

FIG. 12

6-8V396	20
Datum	01.08.85
Name	Steinb
	EPS
Benennung	PUMP CHARACTERISTICS SMALL SEAWATER PUMP
	Pumpen-Kennfeld kleine Seewasserpumpe
	mtu FRIEDRICHSHAFEN
Zeichnung Nr.	5-599 230
	555 000 18 99
	C

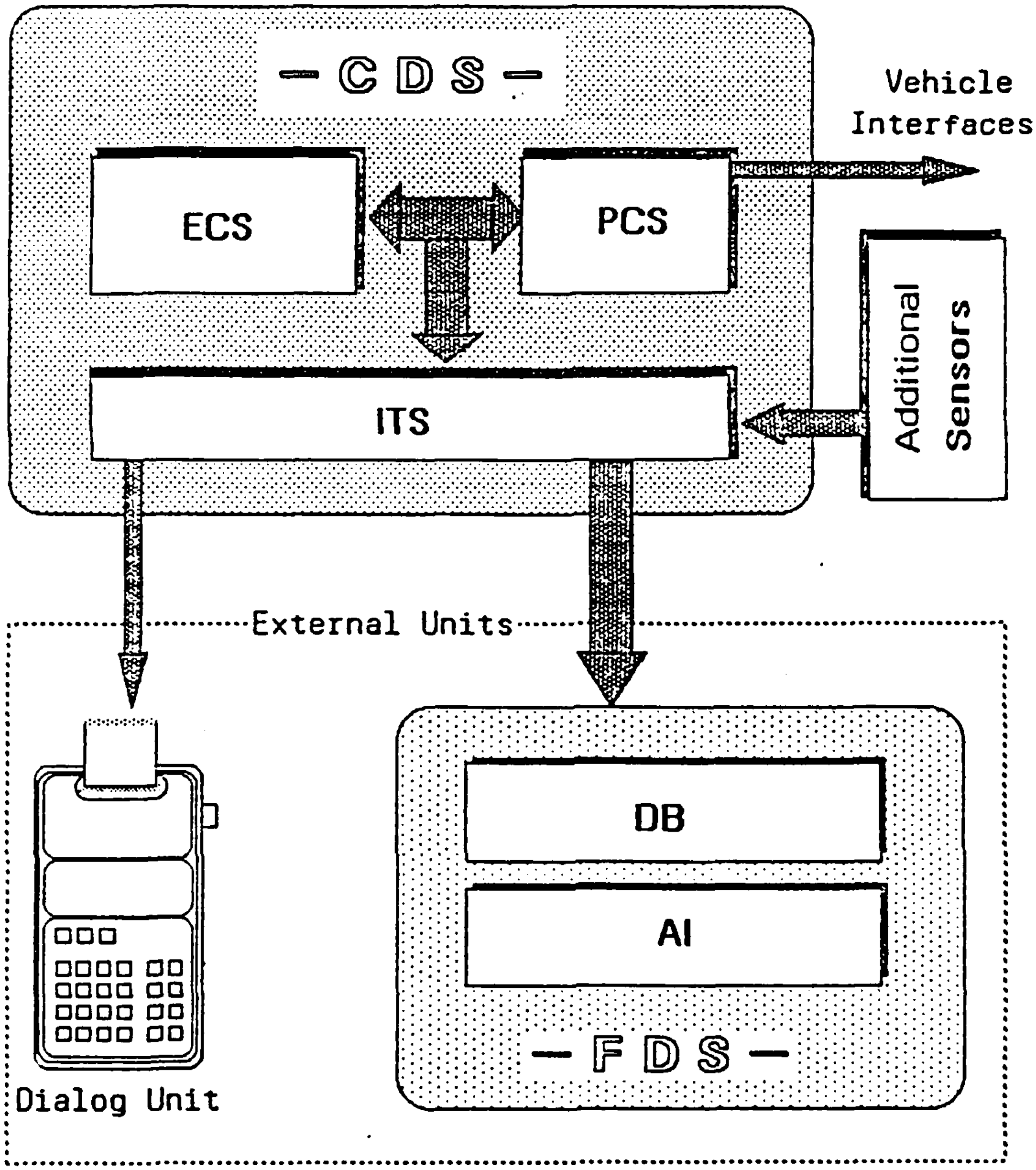


HWSTD FAN SPEED CONTROL MAP

FIG. 13

657 925

21.4.86 EPF



CDS: CONTROL AND DIAGNOSTIC SYSTEM
ECS: ENGINE CONTROL SYSTEM
PCS: POWER PACK CONTROL SYSTEM
ITS: INTEGRATED TEST SYSTEM
FDS: FLEET DATA SYSTEM
AI: ARTIFICIAL INTELLIGENCE
DB: DATA BASE

CONTROL & DIAGNOSTIC SYSTEM
AND ITS CONNECTION TO EXTERNAL USE

FIG. 14

657 906
10.4.86 Zoller

TIME / COST SCHEDULE HWSTD POWERPACK

MONTHS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

MILESTONES

▼ MAIN CONTRACTOR ACTION
▽ MTU-ACTION

- ▼ MAIN CONTRACT OR ▼ CONTRACT FOR LONG LEAD ITEMS
- ▼ MAIN CONTRACT
- ▽ CHARGE AIR COOLER DEFINED
- ▽ LLI POWERPACK DEFINED
- ▼ INTERFACE
- ▽ CONCEPT DEFINED
- ▽ LONG LEAD ITEMS BASIC ENGINE AVAIL
- ▽ 1st ▽ 2nd BASIC ENGINE ACC TEST
- ▽ POWERPACK COMP AVAIL
- ▼ HYDRO-UNIT TO MTU
- ▽ POWERPACK ACC TEST
- ▽ SHIPMENT
- ▽ POWERPACK INSTALLED

		COST BREAKDOWN THOUSAND DM
ENGINEERING – DESIGN	ADAPTION BASIC ENGINE	500
ENGINEERING – DESIGN	POWERPACK COMP AIR FILTER, COOLING SYSTEM, MOUNTING, PIPING	600
ENGINEERING – DESIGN	SPLITTER BOX (ZF SUPPLY)	50
ENGINEERING – ORG + DOC	INTERFACE CLARIFIC / DOCUMENT (OP INSTR MANUAL)	200 + 50
HARDWARE	PROC LLI CRANKCASE, OIL PAD, CRANKSHAFT, CAMSHAFT, CONNECTING ROAD, INJECTION SYSTEM, EL CONTROL, TURBOCH, GENERATOR	320
HARDWARE	PROC MODIF ENGINE PARTS PIPING, EXP TANK, OIL/WATER FILLING NACK, MOUNTING BRACKETS, CHARGE AIR COOLER	740
HARDWARE	PROC POWERPACK PARTS RADIATOR, TRANSM OIL HEAT EXCH, FILTER, ASSEMBLY PARTS, AIR DUCT CASING PIPING, COUPLINGS, SPARE PARTS	267
HARDWARE	PROC SPLITTER BOX ZF SUPPLY	120
TEST ASSEMBLY	BASIC ENGINE ASSEMBLY (1st, 2nd)	325
TEST ASSEMBLY	BASIC ENGINE TEST (ACC TEST 2nd)	
TEST ASSEMBLY	POWERPACK ASSEMBLY	100
TEST ASSEMBLY	POWERPACK TEST (SYSTEM TEST, VIBRAT. TEST)	
TEST SUPPORT INCL SPARE PARTS	INSTALLATION REQUIR CHECK	420
TEST SUPPORT INCL SPARE PARTS	INSTALLATION SUPPORT AND CHECK	
TEST SUPPORT INCL SPARE PARTS	TEST TRIALS SUPPORT (8 MONTHS)	
TEST SUPPORT INCL SPARE PARTS	TECHNICAL ENGEN ASSISTANCE (4 MONTHS)	

COMMENT HARDWARE PRICE FOR BASIC ENGINE PARTS ARE BASED ON PARALLEL HARDWARE PROCUREMENT FOR MVO- CONTRACT ENGINES

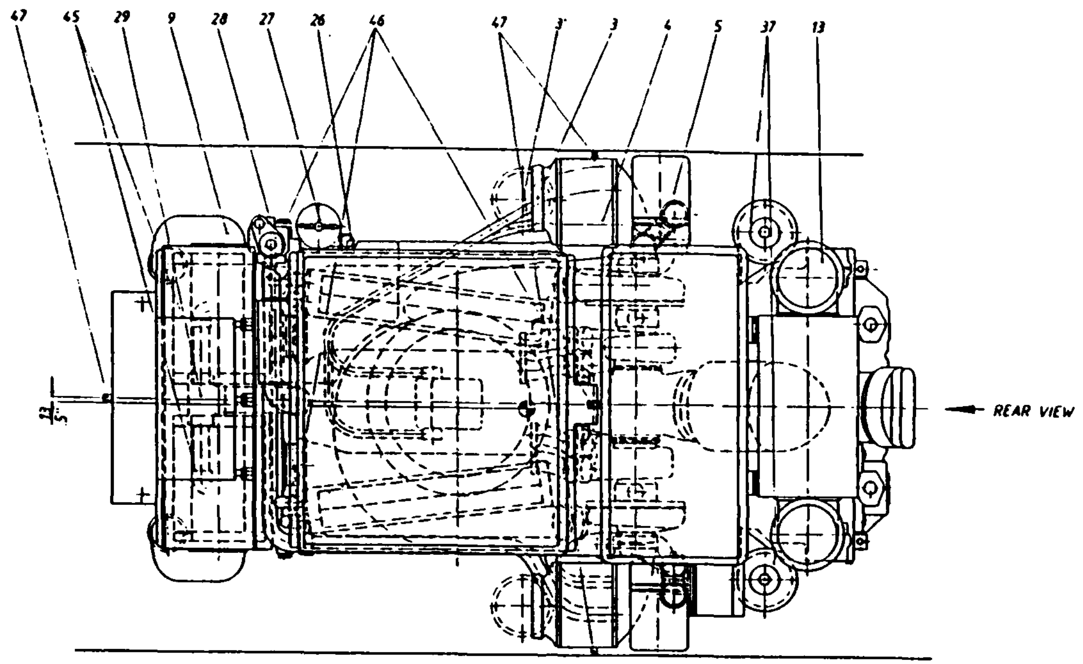
FIG. 15

Attachment 1

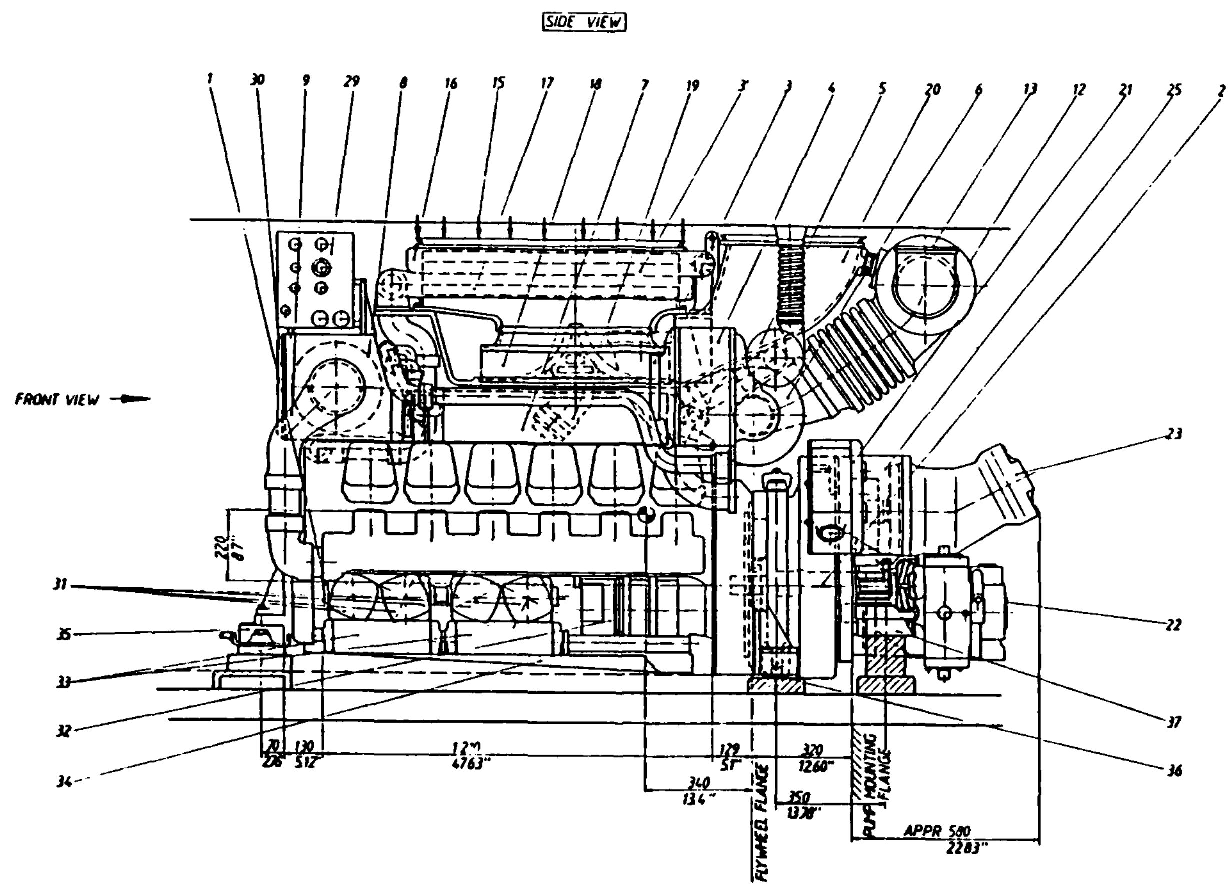
H.W.S.T.D. Installation Drawing

- side view
- top view
- front view
- rear view
- legend

TOP VIEW

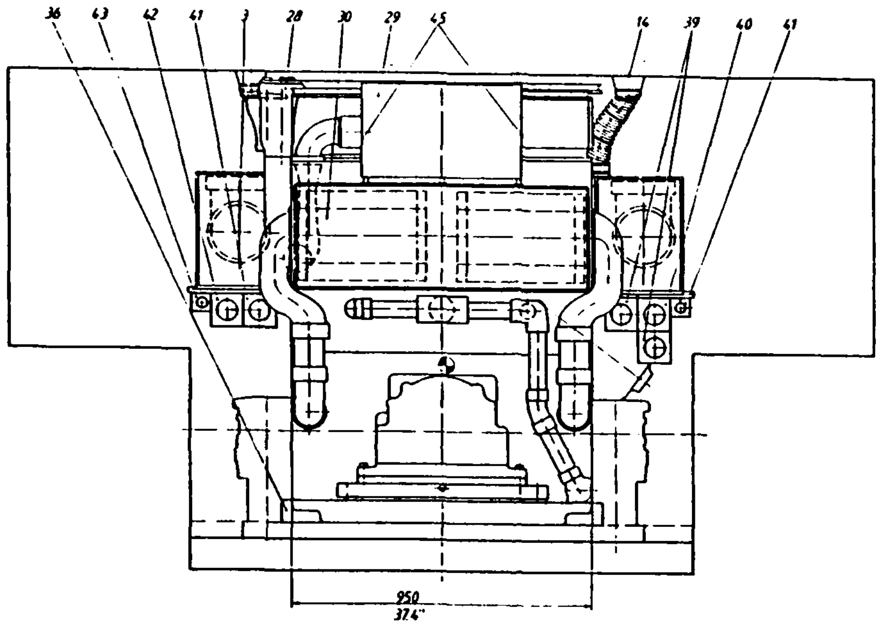


HWSTD POWERPACK (PRELIMINARY DESIGN)
1/8 SCALE
657 900



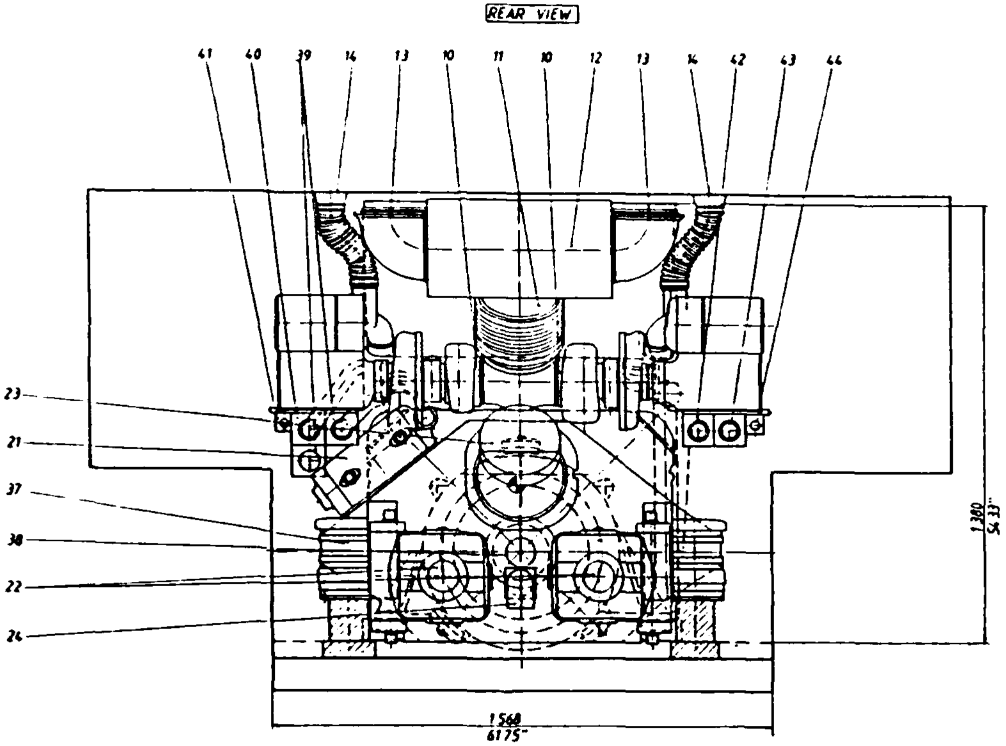
HWSTD POWERPACK (PRELIMINARY DESIGN)
1/8 SCALE
657 900

FRONT VIEW



CENTER OF GRAVITY
TOTAL DRY WEIGHT
APPR 3213 kg, 7083 Lb

HWSTD POWERPACK (PRELIMINARY DESIGN)
1/8 SCALE
657 900



HWSTD POWERPACK (PRELIMINARY DESIGN)
1/8 SCALE
657 900

LEGEND

1 MTU MT883 Ka-500 12 CYL DIESEL ENGINE

2 ZF SPLITTER BOX

ENGINE AIR INLET

3 COMBUSTION AIR INLET (VEHICLE AIR DUCT CONNECTION)

3' OPTIONAL COMBUSTION AIR INLET

4 TWO STAGE PREFILTER (CYCLON)

5 SCAVENGE BLOWER

6 TURBOCHARGER

7 CHARGE AIR COOLER

8 FINE FILTER (PRESSURIZED)

9 COMBUSTION CLEAN AIR DUCT TO ENGINE MANIFOLD

ENGINE EXHAUST

10 TURBOCHARGER-TURBINE OUTLET

11 EXHAUST GAS OUTLET

12 SILENCER

13 FLANGE FOR EXHAUST FORDING HOOD

14 SCAVENGE AIR OUTLET

COOLING SYSTEM

15 COOLING AIR INLET

16 RADIATOR FOR HYDRAULIC CIRCUIT (TURNABLE)

17 RADIATOR FOR ENGINE COOLANT (TURNABLE)

18 COOLING FAN (RADIAL)

19 HYDROMOTOR (COOLING FAN)

20 COOLING AIR OUTLET DUCT

21 TRANSMISSION OIL HEAT EXCHANGER

HYDROPUMP SYSTEM

22 VARIABLE DISPLACEMENT HYDROPUMP A4V-250 SG (2)

23 FIXED DISPLACEMENT HYDROPUMP A2F-355

24 CHARGE PUMP

25 STROMAG COUPLING

ENGINE MAINTENANCE

26 ENGINE OIL DIP STICK

27 ENGINE OIL FILLING CAP

28 ENGINE COOLANT FILLING CAP

29 ENGINE POWERPACK CONTROL SYSTEM

30 FINE FILTER ACCESS COVER FOR REPLACEMENT

BASIC ENG COMPONENTS

31 ENGINE OIL FILTERS

32 20 kW EL GENERATOR

33 ENGINE OIL HEAT EXCHANGER

34 ENGINE OIL TANK

POWERPACK/VEHICLE INTERFACES

35 FORWARD ENGINE MOUNT

36 REAR ENGINE MOUNT

37 SPLITTER BOX MOUNT

38 ACCESS COVER FOR SPLINE SHAFT REMOVAL

39 COOLANT SUPPLY QUICK DISCONNECT COUPLING FOR HYDRAULIC OIL HEX OR SEAWATER HEAT EXCH (2)

40 COOLANT RETURN QUICK DISCONNECT COUPLING FROM SPLITTER BOX OIL-/HYDRAULIC OIL HEX

41 COOLANT VENTING QUICK DISCONNECT COUPLING

42 FAN HYDRAULIC RETURN QUICK DISCONNECT COUPLING

43 FAN HYDRAULIC SUPPLY QUICK DISCONNECT COUPLING

44 FAN HYDRAULIC LEACKAGE QUICK DISCONNECT COUPLING

45 ELECTR CONNECTORS FOR POWERPACK/VEHICLE INTERFACE AND ELECTR POWER SUPPLY

46 LIFTING EYE

47 LIFTING GUIDE PINS FOR ENGINE REMOVAL

HWSTD POWERPACK (PRELIMINARY DESIGN)
1/8 SCALE
657 900