MAAG Gear AG Winterthur:

New development of the MPV-59 double stage planetary gearbox

designed for 25 MW Gasturbines

1 New propulsion solutions for huge and fast yachts

1.1 Introduction

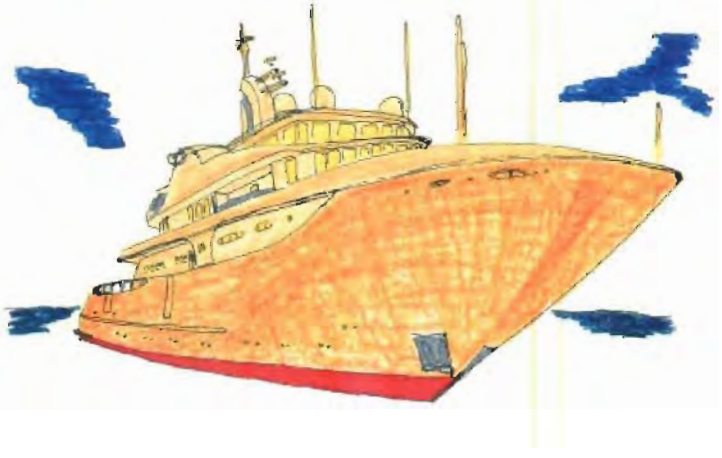
Shipbuilders of huge yachts are installing more powerful propulsion systems than ever. MAAG Gear Winterthur has developed a double staged planetary gearbox to connect the LM 2500 gas turbine with the huge water jet.
Reliability, low weight, compact shape and low noise emissions have been the main targets for this new project.

1.2 The project

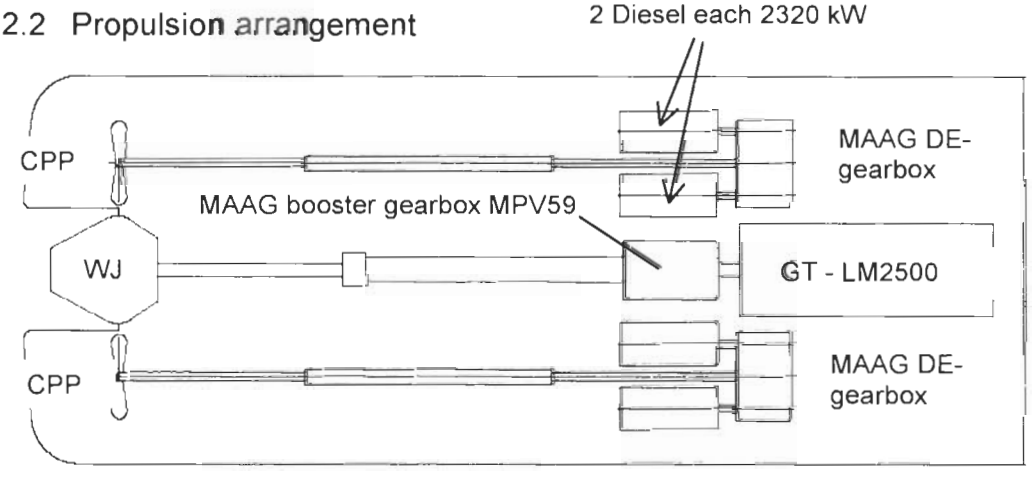
In October 2001 our customer, one of the word's most famous builder of luxury yachts ordered three gearboxes for the propulsion of an 80 meter long pleasure boat. The ship is powered by two CPP's port and starboard each driven by 2 diesel engines of 2x2320kW and a power booster which delivers 21300 kW to a waterjet located between the CPP's.

1.2.1 Technical parameters

Length overall		80m
Breadth overall		12 m
Number of decks		4
Crew		10 persons
Propulsive power		4x 2320 kW 1x 21300 kW
Propulsion diesel-mechanically onto 2 propellers		
Propulsion Gas –Turbine Onto 1 Waterjet		
Ship's speed		30 knots



1.2.2 Propulsion arrangement



1.3 Gearbox Description

1.3.1 General

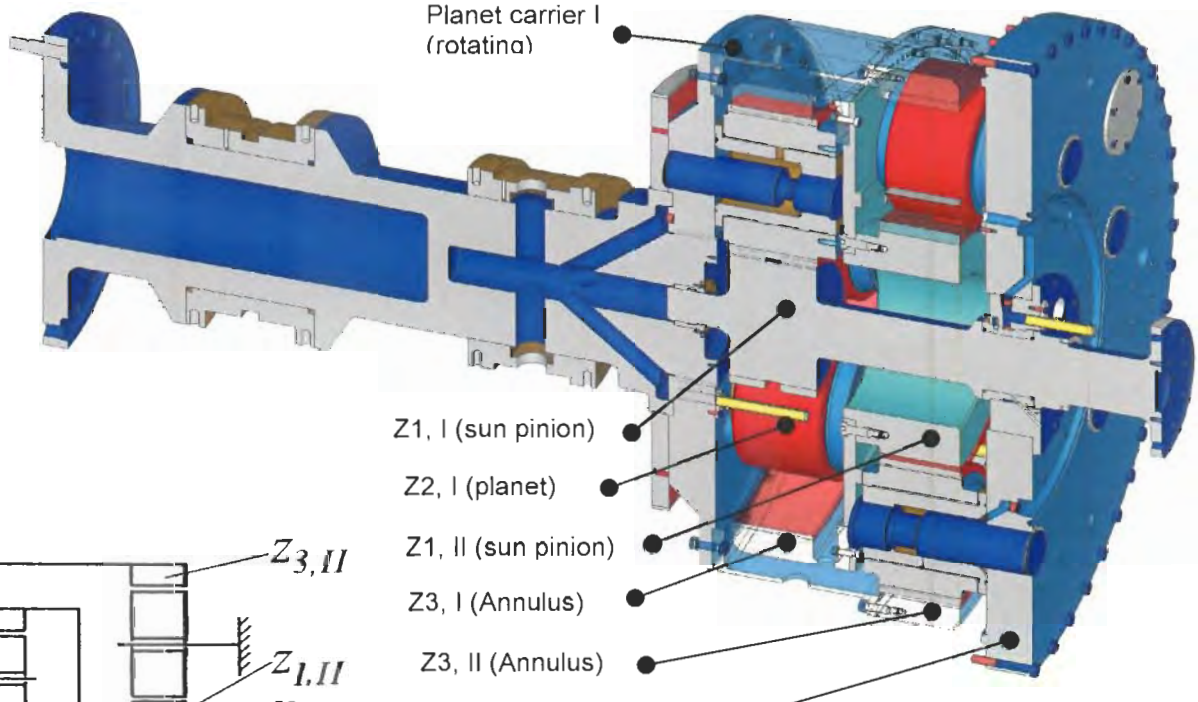
The gearbox is a two stage, epicyclic, reducing drive. The gas turbine prime mover is arranged forward driving a water jet connected through the coaxial gearbox. The gearbox is rigidly mounted.

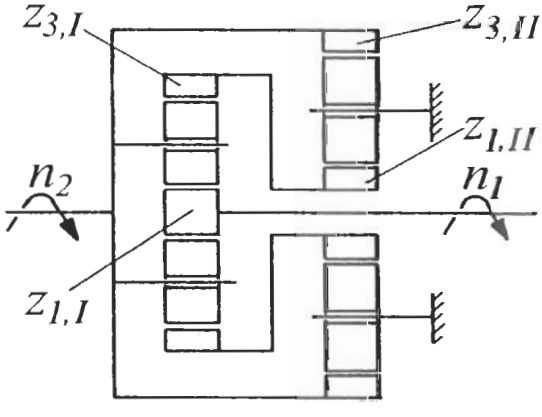
The gear is lubricated by a gear mounted lube oil system consisting of a gear driven oil pump, filter, heat exchanger, electric motor driven lube oil pump and related valves and controls. The oil sump is located within the ship's hull.

1.3.2 concept

The type of this epicyclic gear is a compound type PV with 5 planets at the first stage and 7 planets at the second stage. 39% of the power of 21300kW is translated by the 1st stage and 61% by the 2nd stage. The planet carrier of the 1st stage is rotating while planet carrier of 2nd stage is mounted rigid on the ships foundation.

1.3.3 Design and formula





$$i = \frac{n_1}{n_2} = 1 + \frac{z_{3\,I}}{z_{1\,I}}\left(1 + \frac{z_{3\,II}}{z_{1\,II}}\right)$$

1.3.4 Rotating Parts

Sun pinions and planet gears are carburized, hardened and high precision ground. The annuli are made of high tensile alloy steel and through-hardened. All gearing is provided with the necessary tip and root relief and longitudinal corrections.

1.3.5 Gear Accuracy

Close tolerances are selected according to our extended experience in the design and manufacture of marine gears. They are accompanied by MAAG gear grinders of recent design, operated by experienced personnel.

1.3.6 Tooth profile and longitudinal corrections

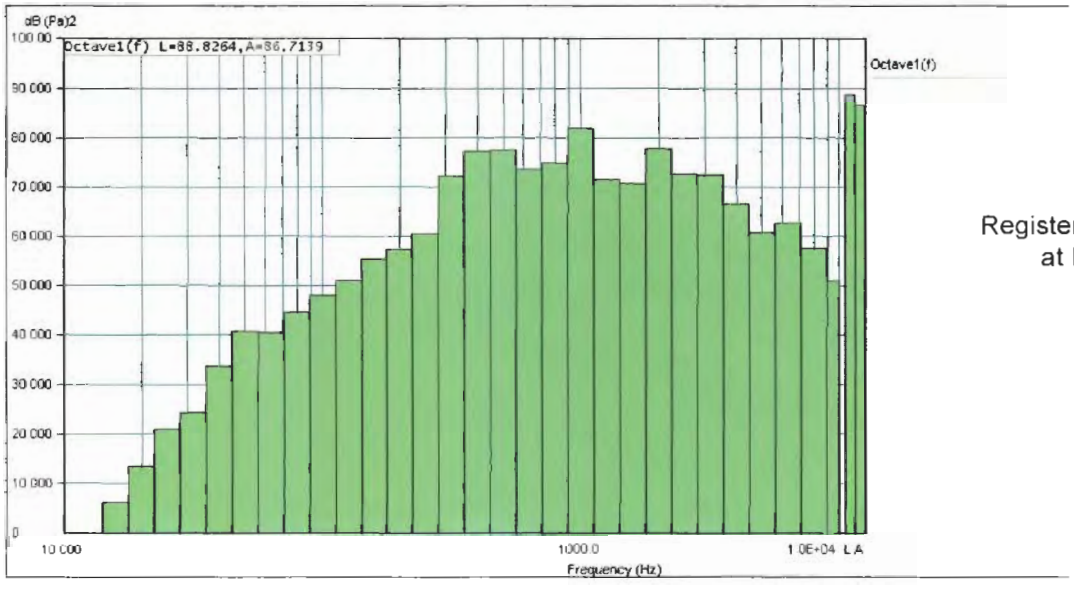
When tooth pairs of loaded uncorrected gear-drives move at elevated speed into mesh, shocks arise, which cause fluctuation in angular velocities and produce noise, even if the teeth manufactured are as near the theoretical involute-form as possible. Such shocks are partly due to the elastic deflection of the teeth, which depends on their strength related to the actual load being transmitted. To avoid these engagement shocks the involute tooth profile has to be modified (corrected).
Well designed and accurately produced **longitudinal corrections** have important and beneficial effect on the running behaviour gears. Although the main object of longitudinal correction is to obtain uniform load distribution across the facewidth under load, i.e. to counteract those various influences detrimental to good tooth bearing condition.
A balanced combination between profile correction and longitudinal corrections will give adequate bearing under load, and meshing at a **low noise level**.

MAAG gear grinding machines have built-in tooth flank correction devices, designed to meet the various requirements of the shape, degree and accuracy of the prescribed corrections.
These corrections can be controlled accurately, and the relieved areas are blended smoothly into the remaining true – involute areas. They are, once set dependably repeated.

1.3.7 Dynamic balancing

All rotating components are dynamically balanced. In order to reach a high degree of accuracy, the balancing machines are carefully selected with regard to size and weight of the work piece. The quality grade attained normally is Q1 in accordance with ISO 1940.

1.3.8 Noise



Registered noise at FAT

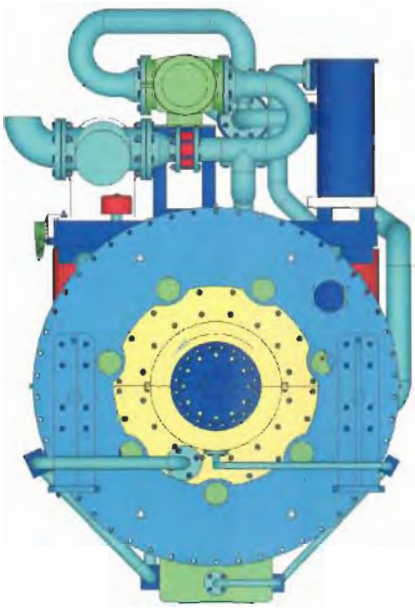
Airborne noise was expected not to exceed 85 dBA. Structure borne noise level is extremely low due to the application of high accurate gears.

1.4 Technical equipment

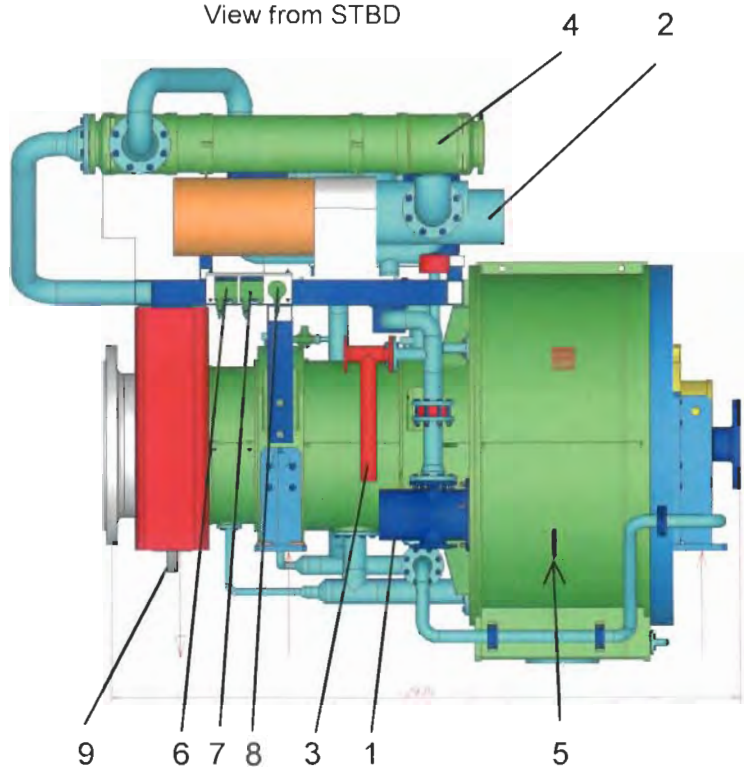
The equipment listed hereafter is included in the propulsion gear unit

1. gear driven L.O. pump (3 bar pressure)
2. electric motor driven L.O. pump (3 bar pressure)
3. pressure regulating valve (2.2 bar adjusted)
4. heat exchanger (for 500 kW power loss)
5. speed sensor (2 proximity switches)
6. Pressure Transmitter, oil inlet & alarm
7. Pressure Transmitter, oil inlet shutdown
8. Local gauge, gearbox inlet
9. Output shaft brake (prevents tailing if equipment not in use)

View from GT to flange



View from STBD



10.Output shaft locking device for trailing water jet condition

11.Hand operated turning gear

12.gear driven sea water pump

13.duplex oil filter

14.temperature control valve

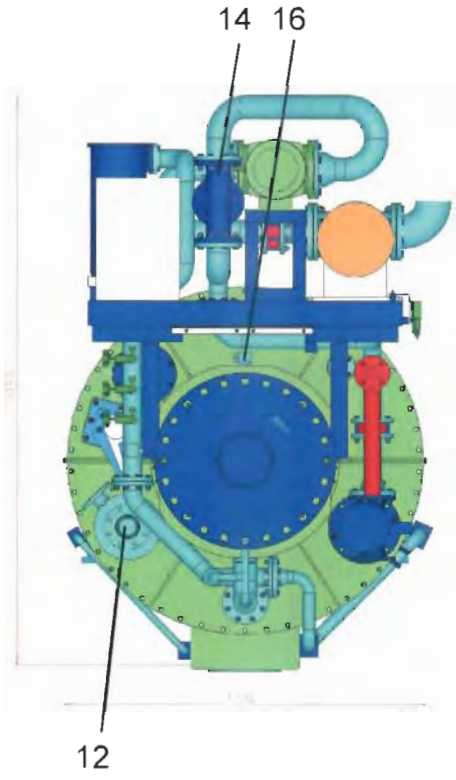
15.Temperature sensor at gearbox oil inlet

16.Temp. sensors at radial bearings

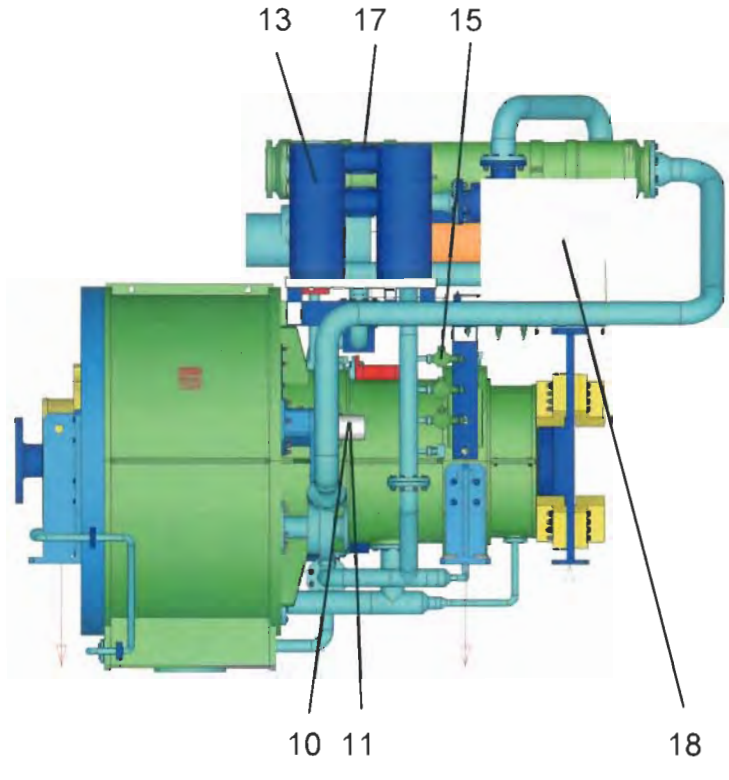
17.Differential pressure switch across filter

18.Brake hydraulic system

View from waterjet to GB flange



View from PORT



1.4.1 Technical Data

Engine Power and Speed

Type MPV-59	Power kW	Turbine Speed rpm	Water Jet Speed rpm
LM2500 gas turbine	21300	3600 + 5% overspeed	330-331

1.4.2 Journal bearings

The planet bearings are one piece, white metal layered type, while the input and output bearings consist of white metal layered steel rings in two halves. The shaft journals are case hardened and high precision ground. Special attention is given to the bearing journals which are ground to a high degree of accuracy in roundness and diameter. The position of the bearing joints, in the case of the split bearings, depends on the direction of the bearing load vector and the sense of rotation. Each bearing is held in its proper position by an anti –rotating key which also prevents faulty assembly.

1.4.3 Thrust bearings

The thrust due to the coupling at the input shaft is carried by a taper land bearing. No thrust bearing is required at the output shaft.

1.4.4 Gear case

The gear case consists of lower and upper sections and end plates with various covers. Inspection openings are strategically located to permit inspection of the gear teeth.

All major sections are of welded steel design. Ribbing of the walls have been designed to give adequate rigidity. In particular, the casing structure is designed to avoid that any distortion from the ship structure will not affect bearing locations eventually causing gearing overload. This design aspect necessary for optimised weight for ship applications and is achieved by proper arrangement of ribs and stiffeners.

The oil sump is located in the ship's hull. An oil pan is fitted around the lower part of the second stage annulus to prevent it from immersing into gear entrained lube oil to minimise gear losses.

The lube oil system consists primarily of gear mounted components (heat exchanger, filter and E-motor pump. The gearbox has pipes leading to the bearings and spray nozzles for gear tooth lubrication are flanged to a main leader pipe and an orifice at each pipe connection adjusts the oil flow to the specified quantity.

1.4.5 Shaft brake

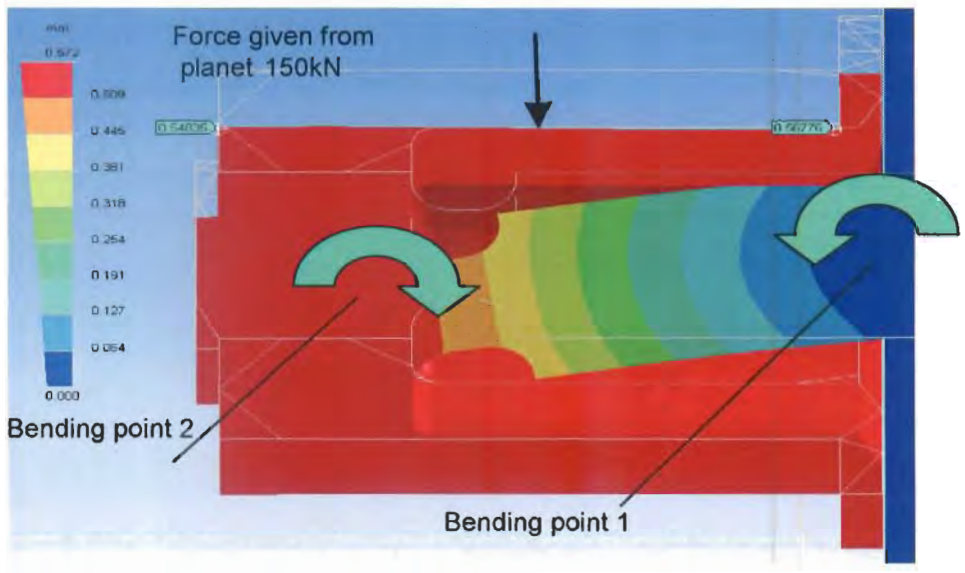
A calliper type disc brake is installed at the output shaft of the gearbox. It has been designed to have a capacity to stop the rotor string (GT power turbine, gearbox and WJ shafting) based upon the following conditions:

- Load torque, GT : 44 kNm
- Total Rotor Inertia: 54200 kgm^2
- Maximum Shaft Speed: 65 rpm
- Stopping time base on above: 14.3 sec.
- Design Brake Torque, dry brake: 71 kNm

This brake is hydraulically operating via an hydraulic power pack mounted on gear. The power pack has the following features:

- An accumulator tank to ensure the brake is applied for up to 24 hours in case of power failure. If power failure occurs while the brake is not applied, the brake will remain in the non-applied condition.
- Hand operated pump for emergency brake application in case of power failure. The power required for the intermittently operating hydraulic pump is 2.2 kW

1.4.6 Flexpin



A flexpin is a flexible axle which allows parallel self-adjustment of the bearing. Wearing of all planets and its teeth is optimised and guaranteed. It is one of the secrets of a quiet planetary gearbox. MPV-59 gearbox is fully equipped with the patented flexpin.

1.4.7 Lubrication System

The oil flow is provided by an electric / gear driven pump system. The required lube oil quantity at start up and at low speeds is covered by simultaneous operation of the electric pump and the gear driven pump. The output speed of the electric pump is to be controlled by a variable frequency electric motor. This provides a nearly constant flow to the required flow for the gear system. Please refer to the oil flow schematic, appendix 5.6, for details. The control system shall be designed to select the proper electric motor frequency for the flow requirement. In the case of a gear driven pump failure, the electric pump must supply sufficient flow to gearbox. In the case of an electric motor driven pump failure, the gear driven pump supply will be insufficient for the gear operation, and therefore the gas turbine propulsion operation must be shut down. The gear driven pump will however supply sufficient oil for the the run-down from shut down. Non-return valves prevent oil flow into the other supply piping in the case of single pump operation. The nominal oil pressure (1.8 to 2.2 bar) is adjusted by the pressure regulating valve.

The duplex filters include a 39 micron filter inserts (approx. 27 microns nominal absorption capacity). They are equipped with contacts for optical and acoustical alarm indication.

The oil coolers are rated to absorb the lube oil heat dissipation up to a max. seawater inlet temperature of 32 °C.

The cold start temperature is 4 °C.

1.4.8 Monitoring

The gear unit is equipped with various instruments for control, monitoring and interlock interfaces. Temperature and pressure of the lube oil flow is controlled at various points of the circuit by switches and transmitters.

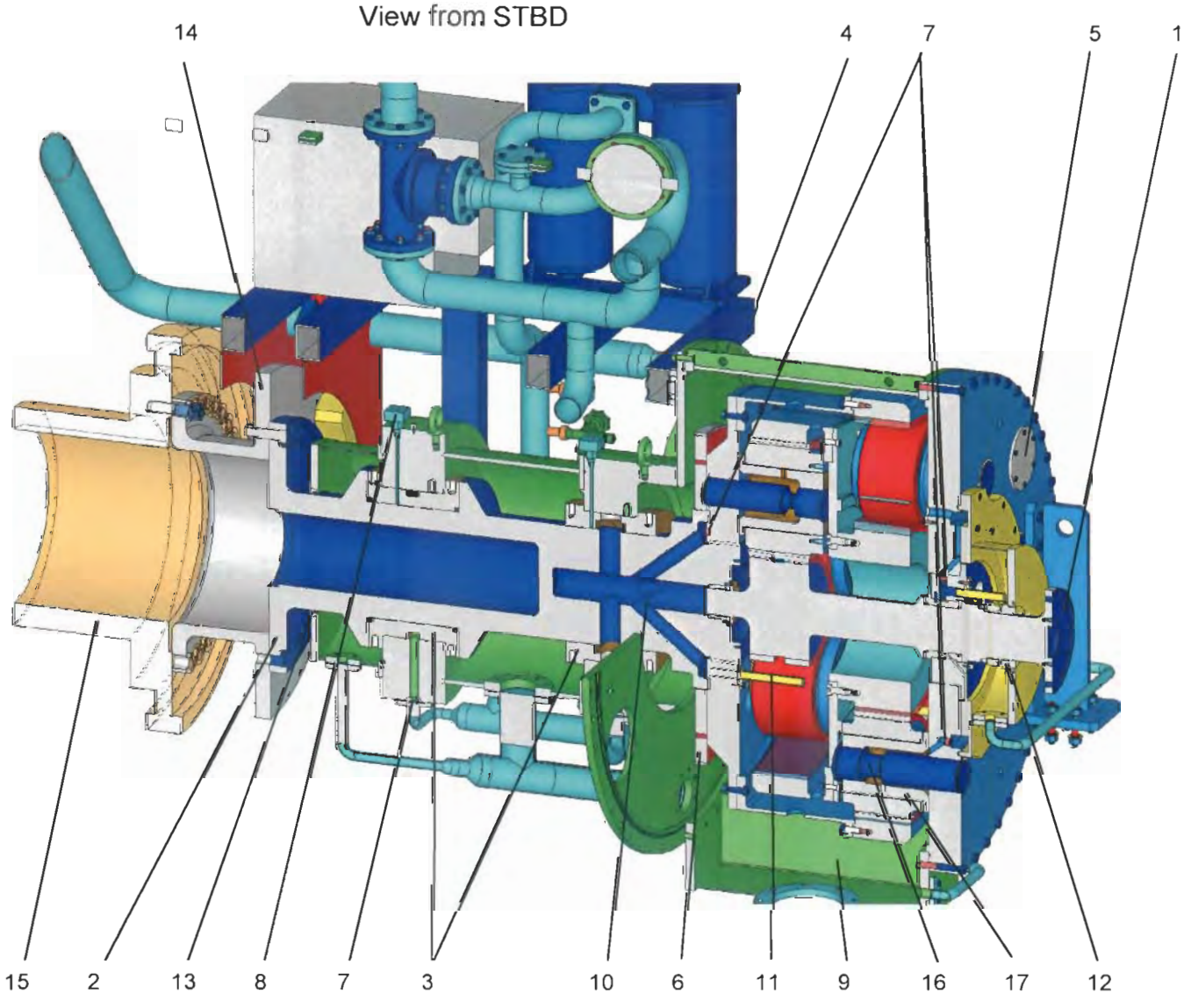
1.4.9 Approved by Lloyds Register

All design has been made following LRS design rules. After some minor modifications of flange thickness the Lloyds Register of Shipping did sign all the papers and gave us the approval.

1.4.10 Section view of gearbox

The following section view shows you the inner life of the complete gearbox:

1. Input flange (from Gas turbine)
2. Output flange (to waterjet)
3. Journal bearing (plain bearing)
4. Support frame
5. Inspection cover
6. Auxiliary gearing
7. Orifice
8. Temperature sensor
9. Oil pan to collect the luboil
10. Oil supply through bearing
11. Lubrication gearing
12. Rotating carbon sealing
13. Rubber sealing
14. Brake disc
15. Carbon shaft
16. Flexpin
17. Planet bearing



1.5 Conclusion

The new MAAG booster planetary gear will cover a range of applications with gear ratio around 1:10 and high performances from 15 MW up to 30 MW.
It can be in combination with a SSS clutch at the inlet and drives waterjets as well as propellers. It can be delivered with or without output shaft brake.
Low weight, small shape and high power transmission combined with high reliability and low noise emission are the benefits of this gearbox.

Picture1 open gearbox. Left: planet carrier II, middle: planet carrier I, right: annulus I with sun pinion II

Picture 2: View from GT side STBD