EC FUNDED RESEARCH (1990 – 2010) ON LARGE MARINE DIESEL ENGINES as background to the R&D programme HERCULES

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INTRODUCTION

The large engines have an efficiency advantage over smaller engines, purely because of size. Large cylinder diameters, larger volume/surface ratios, high excess air, low speeds, lead to lower values of heat transfer, gas flow, flame speed, sliding friction. Also, the size makes exhaust energy recovery economically viable.

99% of all ships worldwide are powered by diesel engines. These engines can produce power up to 80MW (2010) can be very large, 30m length, 14m height, 2300tons weight and expensive, reaching 15 Million USD. They are unit products and can be individually tailored for each application.

Engine design changes are introduced in steps, with new technologies leading to increases in engine operational parameters. Subsequently, the new designs are revised and consolidated to restore reliability. There are no prototypes, all engines produced are sold.
Many "innovations" introduced today in engines have been used in the (distant) past, but were not successful, usually because of materials, manufacturing or control problems. For example, Vickers used common rail injection in submarine engines in 1917. Also Doxford opposed piston marine slow speed diesel (1920-1988) used a type of common rail for heavy fuel. Variable valve timing was already used in steam engines in the 19th century (Stephenson links).
The main issues in marine engine design and operation have always been Reliability, Fuel economy and (since 2000) Emissions. Nowadays, emissions is a forcing term in the development process. With the ongoing R&D efforts, the issue of emissions will be completely resolved in the coming years, albeit with somewhat complex technology and combinations of aftertreatment, combustion techniques and control systems.
Operational optimization, health monitoring and adaptive control over the lifetime of the powerplant, are further issues to ensure lifelong reliability and economy.

FROM FP3 TO FP7

The sequence of European Commission (EC) supported R&D projects on large (marine) engines from Framework Programme 3 (FP3) to FP7, reflects to a large extend the technological needs of the respective time period.

One large engine project funded within FP3, was DEFOS (Diesel Engine operation on Variable Quality Fuels), with a consortium of 30 partners, engine manufacturers (MAN-B&W, Ruston, SULZER, WARTSILA), oil companies (BP, ELF, SHELL, MOBIL, TOTAL), component suppliers, universities, led by Lloyd's Register. The objective was to optimize engine operation to reduce fuel consumption, accounting for combustion performance deviations, due to fuel quality variations in successive refuellings of a ship.

The single most important development in large engines in the past 20 years was the deployment of electronics, allowing the use of servo-mechanisms providing independence of flow exchange events and combustion inside the engine. This allows increased flexibility in manipulating the engine process, leading to the so called “Intelligent” electronic engines with improved economy & emissions.
The aim of remote fault diagnosis and intervention onto the electronic engine were subjects of some projects on shore support of ships, using satellite communications. Such projects were funded within FP3 and FP4 (e.g. MARIN-ABC and MOEBIUS, where WARTSILA participated together with many industrial and university partners)

In the 1990’s, the European marine engine makers and sub-suppliers enjoyed success and were strong financially, unlike the European shipyards which had difficulties. After a period of consolidation with company takeovers, mergers and acquisitions, two groups emerged, MAN and WARTSILA, which today hold 90% of the world’s market in marine engines. The competition between the groups and the good economic results meant that they could own-fund R&D and would not readily consider external (e.g. E.C) funding within collaborative projects – as was commonplace in the European automotive or aerospace industry - .

Occasionally, the engine makers would participate in collaborative R&D projects on the behest of the “customers”.
In 1998 the project ACME (Adaptive control of Marine Engines) was funded within FP5. It was led by shipping company DANAOS that had suffered a severe engine related damage, which resulted almost in total ship loss in extreme weather in the Pacific.
MAN-B&W, ABB, universities and research institutes joined to examine the behavior of very large powerful engines in heavy weather and propose improved control techniques.

By the year 2000 the emissions issue was becoming important, in anticipation of pending worldwide legislation. Already in mid 1990s all engine manufacturers had ongoing research programs for low emissions diesel engines and there were some installations of aftertreatment systems onboard ships (e.g. AURORA ferry Sweden). The project LIFETIME (Low in Fuel and Emissions Two-stroke Intelligent Marine Engine), funded within FP5, involved MAN-B&W, ABB, shipping companies, universities. The objective was to establish correlations between performance, emissions and the engine operating parameters and optimize engine performance, with emissions as constraint.

In FP3, 4 and 5 there was no formal slot in the EC R&D Workprogrammes for large engines, since there was no common large engine industry position and related expression of interest or lobbying.
In 1998 the EC established an External Expert Advisory Group (EAG) in Land Transport & Marine Technologies (Chaired by G. Michellone of FIAT) to advise on the R&D priorities of the sector. The final report of the group, later included in a Commission White Paper on Transport Policy, recognized the strategic importance of European large engine industry and paved the way for inclusion of the related R&D in the FP6 Workprogramme. In FP6, the new concept of Integrated Projects having large size and complexity and receiving substantial funding was introduced. This was also instrumental in providing a sensible framework for handling the complex interrelated R&D needs of large engine development.

In 2002, high-level discussions started between MAN & WARTSILA with a view of establishing a common thematic set, for a joint R&D programme on large engine technologies.
In the year 2003, having surpassed the initial discomfort of co-working, the seeming contradiction of competitor partnership and the complexities of apparent market dominance of the ensuing grouping, a common long-term R&D program was put forward of 10 years duration and 100MEUR budget ,to develop new technologies for marine engines:

- To increase engine efficiency, thus reduce fuel consumption and CO_2 emissions.
- To reduce gaseous & particulate emissions.
- To increase engine reliability

In the year 2004, the Integrated project I.P.HERCULES (High Efficiency Engine R&D on Combustion with Ultra Low Emissions for Ships) was funded within FP6, with MAN and WARTSILA and 40 other industrial & university partners. It was the 1st phase of the HERCULES programme. The I.P. HERCULES (A) was broad in the coverage of the various R&D topics and considered a range of options and technologies. Several cutting-edge test arrangements were designed and manufactured.

HERCULES- B was the Phase II of the original Programme concept and runs from 2008 to 2011 with 32 participant organisations and 26 M€ budget. The general targets for emissions and fuel consumption were retained in HERCULES-B. However, based on the developed know-how and results of I.P. HERCULES (A), it was possible to narrow down the search area, to focus on potential breakthrough research and to further develop the most promising techniques for reduction in specific fuel consumption (and CO2 emissions) and ultra-low gaseous and particulate emissions.

For taking marine engine technology a step further towards improved sustainability in energy production and total energy economy, an extensive integration of the multitude of new technologies identified in Phase I and Phase II is required.
The proposed HERCULES-C project (2012-2015)is the Phase III of the HERCULES programme and addresses this challenge by adopting a combinatory approach for engine thermal processes optimization, system integration, as well as engine reliability and lifetime.