Compressed Air Systems for Modern Warships

Summary:

Compressed air is used for many applications onboard modern naval ships. A centralised high-pressure system offers costs advantages in hardware and especially in software costs, as the number of different compressors installed is reduced resulting in less technical specification, less integration and less ILS work. The WP5000 and WP5500 compressors are in use in many Navies' throughout the world as an essential part of this centralised high-pressure system.

Compressed air requirements onboard naval ships

Compressed air is used for various applications on modern surface warships. Low pressure (LP) air up to 10 bar is used for general service or control air, as well as for wave-guide cooling having undergone a special air treatment process. Medium pressure (MP) up to 40 bar is used for diesel engine starting both for main engine or propulsion diesel and/or auxiliary diesel engine starting. High pressure (HP) air up to 350 bar is used for breathing air, weapon or aviation-air supply and for gas-turbine (GT) starting.

Pneumatic GT starting has the advantage of far fewer system requirements compared to hydraulic starting or starting by an auxiliary power unit (APU), as in most cases a high-pressure air system has to be installed onboard for other applications. In addition, the pneumatic power can easily be stored in high-pressure bottles and is instantly available. If more than one GT is installed, pneumatic starting allows bleed air from a GT already running to start another GT. As a result of these advantages pneumatic starting remains the preferred starting method for today's naval design.

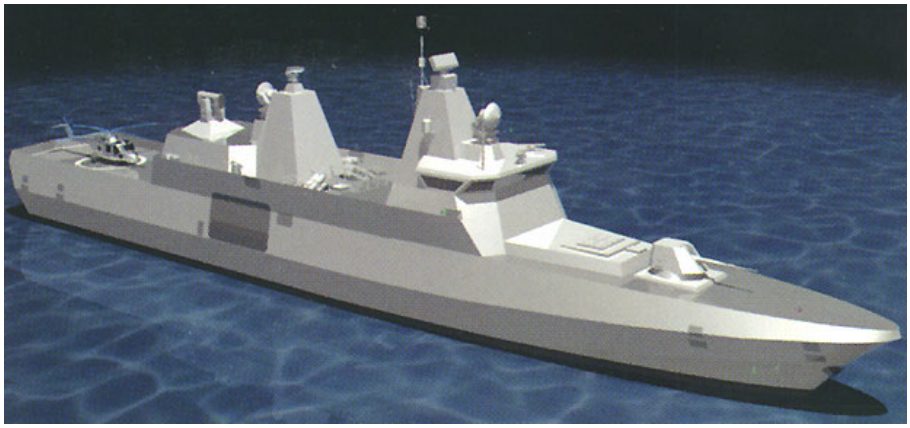
A compressed air system consists of the compressors and accessories such as filters and dryers, air receivers, regulating and control valves and the air piping system. The air system is vitally important to ensure platform survival. All equipment for the compressed air system is installed to meet full naval shock and vibration-proof requirements and provide a degree of redundancy.

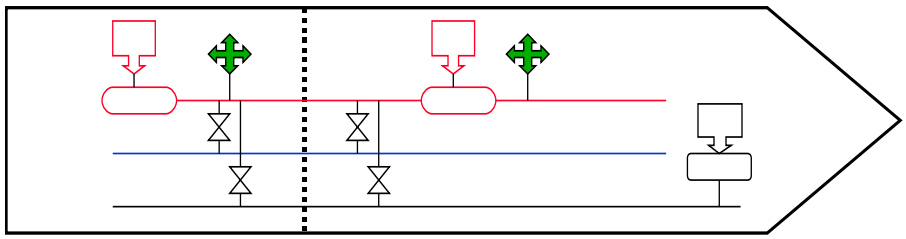
Alternatives for compressed air system onboard naval vessels

The selection of an optimal system at the initial design phase allows the yard as well as the user to save considerable cost. Basically there are two options for a compressed air system for naval surface ships:

- Air system with dedicated low, medium and high pressure air compressors
- Centralised high-pressure air system.

In a compressed air system with dedicated air compressors each requirement for low, medium and high-pressure air is analysed independently of each other and subsequently different specifications are developed for these systems. Based on these specifications the most technically acceptable and cost effective solution will be selected for each system and in some cases even from different suppliers.





Picture 1: German Corvette with Centralised High Pressure Air System consisting of 2 x HP Air Compressors with 80 m3/h @ 250 bar, 1 LP Air Compressor (screw type air cooled) of 100 m³/h @ 8 bar and local breathing air filtration stations.

In the centralised compressed air system, two fully naval shock and vibration proof type high-pressure air compressors of 250 to 350 bar final pressure are used to produce the total air requirement. Breathing air is generated by local filtration and filling stations and compressed air at lower pressures is produced using regulating and pressure reduction valves. In order to save running hours on the more sophisticated HP air compressors, it is recommended that an additional standard non-shock-proof LP air compressor is installed. In the event of a critical mission this low-pressure air compressor will be taken off-line and backed up by the full Naval type high-pressure compressor via pressure reducing valves.

Cost savings using a centralised high pressure system

The compressed air system with dedicated air compressors for low, medium and high-pressure air may seem more advantageous at first glance. Such a system selection avoids air being compressed to HP and then later reduced to MP and even to LP air. Additionally, an optimal technical solution can be selected for each pressure, since only the actual requirement for high, medium and low-pressure has to be considered, which can lead to smaller compressors for each air system.

However, considering the overall picture for such an air system, there are considerable disadvantages compared to a centralised compressed air system. An evaluation of a ship's system should take into consideration not only hardware costs but also increasing software costs associated with integration, provisioning, installation, ILS and maintenance costs when a variety of compressed air systems are required.

Unlike a compressed air system with dedicated compressors for LP, MP and HP demanding 3 or 4 types of compressors to be integrated, the number of compressors can be reduced to 2 or even 1 if a centralised high-pressure air system is selected. This leads to fewer compressor types, which will result in an expected 50% saving in software costs for integration, provisioning, installation and ILS by:

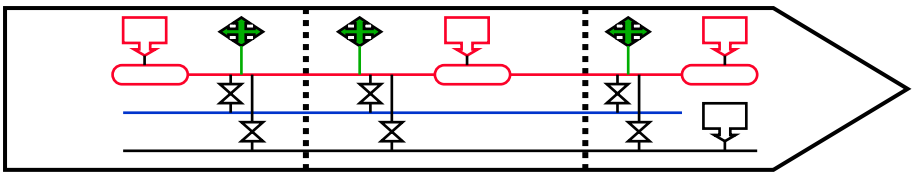
- A reduction in the number of technical specifications
- Reduced interfaces with the ship system
- Fewer purchasing processes
- Less work for ILS such as:

- Spare parts for onboard and depot
- Training requirements
- Number of manuals and documentation

Even greater cost savings can be expected with a centralised compressed air system since it can be purchased from a single supplier. Additionally, overall weight and space is less with a centralised high-pressure system.

Examples of costs effective centralised HP air systems

The following 2 examples describe a centralised high-pressure air system for the latest ship designs.



Picture 2: Type 45 “Darling Class Destroyer of the Royal British Navy with Centralised High Pressure system consisting out of 3 water cooled HP Air Compressors WP5500 with 60 m3/h@ 276 bar, 1 LP Air Compressor (piston type water cooled) with 170 m³/h @ 8 bar and local breathing air filtration stations.

The new German corvette of the type K130 requires HP air of breathing air quality, MP air for diesel engine starting and L P air for working and control air. The total air requirement was analysed and the optimal solution was selected with two water cooled full navy type HP air compressors, each 80 m^3/h @ 250 bar. Each is installed in the one of the safety area of the ship and combined by a cross connection. High-pressure lines feed two breathing air stations in the front and aft part of the corvette. Breathing air is produced locally with the use of already dehumidified air and the HP air receiver acts as a buffer for high-pressure air. This reduces the requirements for breathing air filtration, leading to longer maintenance intervals. For working and control air a simple standard screw type compressor is installed, which is backed up by the HP air compressors in the event of a critical mission.

For the Type 45 “Darling Class” destroyers, under construction at BAE Systems in Yarrow for the Royal British Navy, a centralised HP air system with Sauer Navy Compressors has been selected. The major factor which influenced this selection was that BAE System is not only responsible for the design and construction of the platform, but also has to provide ILS and through lifetime support for the destroyers. Consequently the yard took a very keen look at the overall cost picture for the system and equipment to be selected. In addition to providing breathing quality air, HP air is needed on the Type 45 destroyer for aviation and weapon air, medium pressure air for diesel engine starting and again LP air for working and control air as well as wave-guide cooling.

Three water cooled full navy type HP air compressors WP5500 of J.P. Sauer & Sohn with 53 m^3/h at 276 bar, each installed in one safety area on the ship, joined by a common connection, have been selected. High-pressure lines feed the breathing air system that is produced locally in each safety area. To satisfy the need for working and control air, a water-cooled piston type compressor is installed at 170 m^3/h, 8 bar, backed up by the HP air compressors in the event of a critical mission.

State of the art compressor design

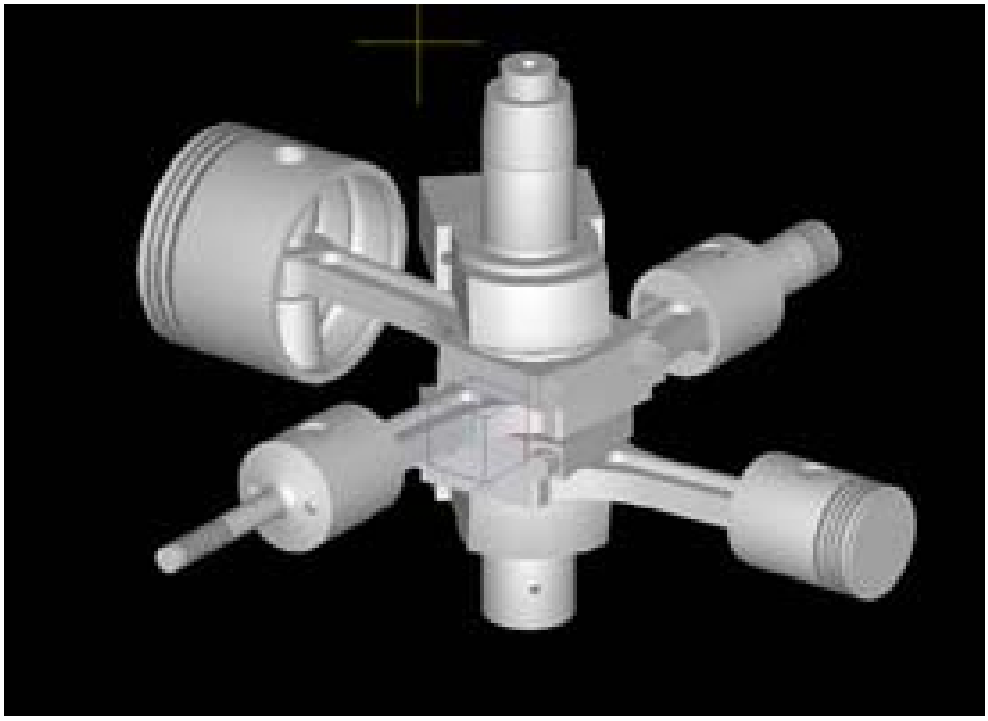
A centralised HP air system, however, is only as good as the equipment used in the system. While the advantages of centralised high pressure systems have always been recognised by Navy’s; high-pressure air compressors were in the past considered both unreliable and expensive.

Picture 3: High Pressure Air Compressor WP5000 with Integrated Membrane Dehydrator as installed in the US Navy Carrier Fleet with 160 m³/h at 350 bar.

The WP5000 and WP5500 water-cooled High Pressure Air Compressors by J.P. Sauer & Sohn have proved to be the most up-to-date and most competitive Naval compressors in the world. The design philosophy behind the continued development of these ‘special’ Naval compressors is that Naval vessels deserve technical solutions not normally provided for industrial or merchant marine applications. However, to ensure this compressor technology can be offered at an affordable cost, and a short lead time, it is necessary to use as many common parts and knowledge gained from more than 1,000 commercial units delivered by J.P.Sauer & Sohn each year.

The key feature of the WP5000 and WP5500 is the vertical crankshaft with the 4 cylinders radially displaced around it. This unique arrangement of the running gear – fully balanced - free of all inertia forces - ensures low vibration, low air and structure borne noise values. Dry liners and hermetic separation of the oil, water and air spaces, together material selection to avoid electrochemically

dissimilar materials in the seawater cooling water system, are just some of the features to guarantee the highest reliability. The WP5000 and WP5500 are maintenance free for at least 1,000 hours of operation.



Picture 4: The unique feature of the WP5000 and WP5500 is the vertical crankshaft with 4 cylinders radially arranged around it – basis for lowest structure borne noise values.

Type testing for these compressors has been performed by the German, French, Royal British, as well as by US Navy, and all known Navy standards for shock and vibration can be fulfilled without problem. Since the first delivery to the Hydra Class Meko Frigate to the Hellenic Navy in 1990, more than 120 units are on order or have been delivered to submarines and naval surface vessels around the world. These compressors are in service with the F123 and F124 of the German Navy, F100 and F310 by IZAR for the Spanish and Royal Norwegian Navy, and the Type 45 “Darling Class” destroyer of the Royal British Navy, as well as the US Navy Air Craft Carrier fleet.

Development of compressed air accessories

In addition to state-of-the-art HP air compressors; it is also important that latest developments in the area of compressed air accessories are taken into consideration.

The Interstage Membrane Dehydrator (IMD) uses the principle of semi-permeable membranes to eliminate the water vapour from the compressed air. Due to pressure limitations, IMD's are installed between the 3rd and 4th stage of the compressors and with appropriate filtration, oil-free and dry air is delivered at the outlet from the compressor, avoiding the need for additional filtration to protect the more maintenance intensive desiccant dryers. IMD's require no maintenance, no electrical energy and no control. The WP5000 with IMD's have proven to be successful in service with the US Navy and have been selected for the Hellenic Navy U214 submarines under construction at HDW.

Compressed air receivers for high-pressure air have been another constraint of many Navies' owing to their high cost, long lead-time and susceptibility to corrosion. Modern alternatives are standard high pressure 50 litre air receivers, arranged in bottle racks to achieve the required total air capacity, which can easily be replaced or the use of corrosion resistant carbon fibre reinforced plastic air receivers which are available up to 100 litres.

About the Author:

Dipl.-Ing. Harald Schulz was borne in 1959. He holds a degree in Mechanical Engineering and Business Administration. He joined J.P. Sauer & Sohn in 1985 as a mechanical engineer and in 1990 was promoted to Sales Director responsible for all Sauer compressor products including the world's Naval market. In addition he is Director of the subsidiaries Girodin-Sauer in France and Sauer Compressors USA Inc.