MAXIMATOR®

Maximum Pressure.

High Pressure Technology • Testing Equipment
Hydraulics • Pneumatics

Best Practice

Highly compressed air -HCA

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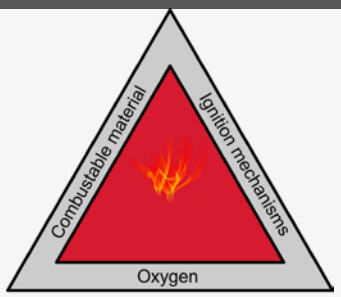
Highly compressed air
Basics

Maximator GmbH has demonstrated in tests the suitability of Maximator compressors for compressed air up to 1000 bar (14.500 psi). In the absence of reliable sources for the risk assessment of the operation of high-pressure components with highly compressed air, Maximator GmbH conducted its own trials. The set-up is essentially based on the "BAM pressure surge test for oxygen components". As a result of these tests, Maximator GmbH was able to qualify the -HCA (Highly Compressed Air) option for Maximator compressors.

Compression of oxygen-containing gas mixtures



Oxygen itself is not flammable, but it considerably accelerates the combustion reaction (also called oxidation reaction) of other flammable substances. Flammable substances can self-ignite very quickly in an oxygen environment.When pressure within a closed volume increases, such as in a piston chamber of a compressor, the temperature of the gas increases proportionally.
At this point, there is the option of going deeper into thermodynamic basics, but that is not what this paper is about.
The focus is on avoiding the undesirable event of ignition within the high-pressure system. For safety reasons, it therefore makes sense in this context to consider compressed air in a similar way to oxygen. In accordance with statutory requirements, Maximator GmbH has defined a maximum compression ratio ε of 1:4 for gases with an oxygen content of more than 21% also for the compression of compressed air. This limitation for Maximator compressors as components is based on the ignition-promoting property of oxygen and the materials of the components optimised for use in oxygen applications.

The following table shows some theoretically expected gas temperatures at different transmission ratios.

Gas	Compression from 6 bar to 100 bar (87 psi to 1450 psi)	Compression from 100 bar to 350 bar (1450 psi to 5076 psi)	Compression from 6 bar to 1000 bar (87 psi to 14.500 psi)
	ε =1:17	ε =1:3,5	ε =1:167
	Theoretically calculated temperature after compression*.	Theoretically calculated temperature after compression*.	Theoretically calculated temperature after compression*.
compressed air	187°C	90°C	402°C
Oxygen	187°C	90°C	402°C
Nitrogen	187°C	90°C	402°C

The temperature development of the three gases shown is the same, but the ignition-promoting properties differ, at least when it comes to nitrogen. As already mentioned, the presence of oxygen significantly promotes the potential ignition of flammable substances. The higher the temperature of the oxygen-containing gas and the higher the proportion of oxygen in the mixture, the higher the probability of the undesired event, the ignition effect.

The obvious consideration is: if oxygen can be compressed to up to 350 bar (5076 psi), compressed air with "only" 21% oxygen content could accordingly be compressed much higher. However, Maximator GmbH has set a limit of 1000 bar (14.500 psi) for the compression of compressed air, based on various contexts.

* The value of 22°C was assumed as the input temperature of the medium to be compressed.

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Practical basics

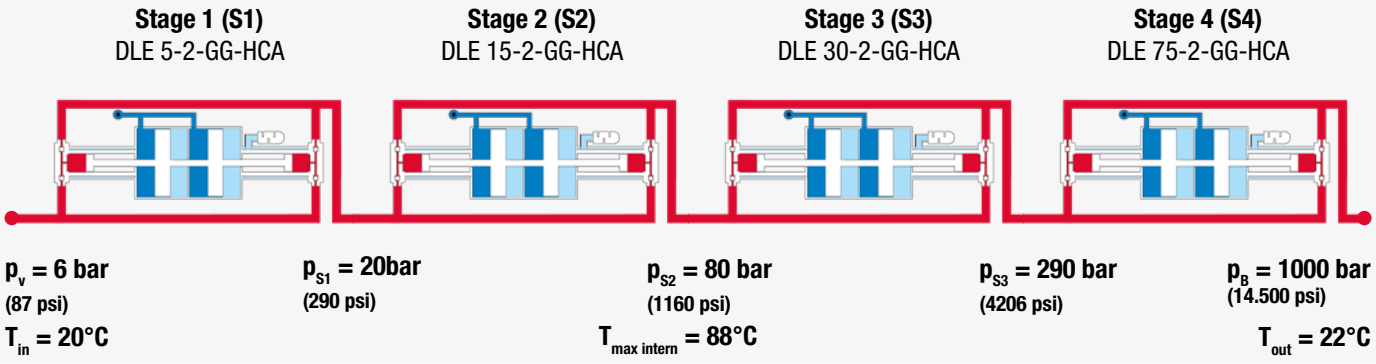
Compression of oxygen-containing gas mixtures

In a trial, the risk of ignition was to be demonstrated by testing and evaluating standard components against optimised components.

The test specimens in the standard version showed traces of ignition after the tests were carried out. The optimised components passed all test cycles without any problems. No ignition traces were identifiable, leading to the conclusion that the optimised components can be used for the compression of compressed air up to 1000 bar (14.500 psi).

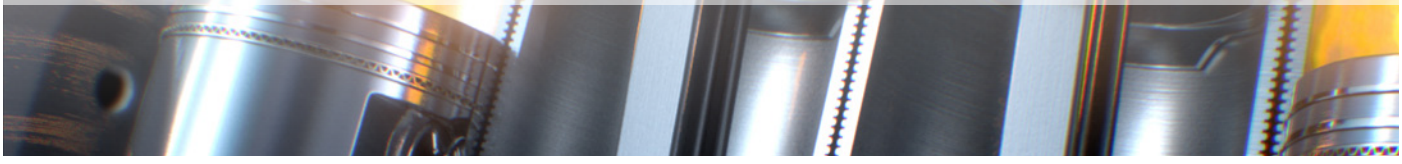
In order to be able to regulate the temperature of the highly compressed air via coolers and not to exceed the maximum compression ratio of 1:4, it may be necessary to compress compressed air in several stages.

Example: Compression from 6 bar to 1000 bar requires at least 4 single-stage or 2 two-stage compressors:



The diesel engine

An everyday illustration of the ignition potential of particles such as oils, greases or metal chips in an environment of compressed air is possible using the diesel engine.
The intake air is compressed in a cylinder by a piston to such an extent that it heats up to about 700-900 °C. This causes a small amount of injected diesel fuel to ignite in the cylinder itself. Hence the name „compression ignition“. No ignition spark is necessary to cause ignition.
The explosive combustion, which briefly produces temperatures of over 2000°C and pressures of about 150 bar (2175 psi), pushes the piston downwards. The piston then pushes the exhaust gases out of the cylinder through an exhaust valve and the process begins again.



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Overview- materials and components

Materials and components

Booster

- Cleaned for gas applications with >21% oxygen content
- O-rings: special compound for gas applications with >21% oxygen content
- Seals, valve seats, valve balls, cooling, high-pressure section: materials adapted to gas applications with >21% oxyen content
- Lubricants: lubricants for oxygen application are tested in accordance with **statutory requirements**
- Leakage measurement with nitrogen (full inspection)

Valves and fittings

- Cleaned for gas applications with >21% oxygen content
- Seal packing: special compound for gas applications with >21% oxygen content
- Lubricants: lubricants for oxygen application are tested in accordance with **statutory requirements**
- Leakage measurement with nitrogen

P_B max.: to 100 bar	P_B max.: to 1000 bar
Standard Maximator components	DLE 5-15-HCA
	DLE 5-15-2-HCA
	DLE 15-30-HCA
	DLE 15-30-2-HCA
	DLE 30-75-HCA
	DLE 30-75-2-HCA

Requirements for compressed air

CGA G 7.1 2018 Grade E Air:
gaseous hydrocarbons max. 25 ppm
oil mist max. 5 mg/m³
dew point < -52°C

Further information on the special cleaning of components for the compression of gas mixtures with an oxygen content >21% can be found in the Best Practice „Oxygen Compression“.

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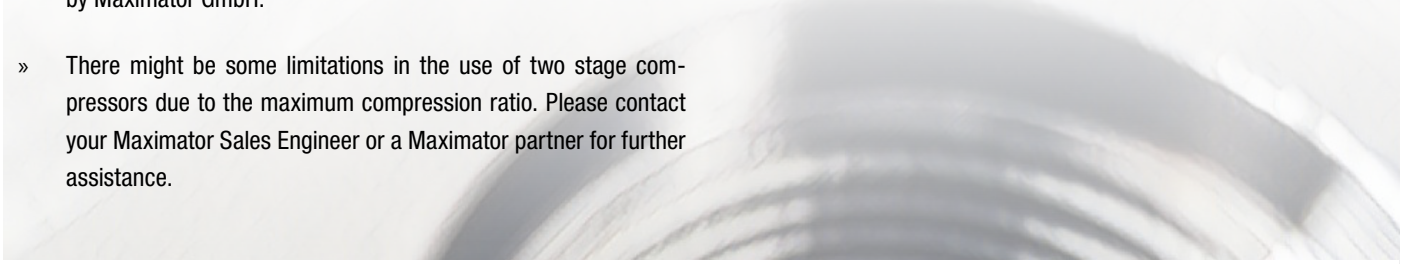
Information - Compact

Important operating information

- Maximum compression ratio: **1:4**
- Maximum working pressure: **1000 bar** (14.500 psi)
- Maximum operating temperature: **+ 60°C**
- Maximum flow velocity (flow rate): **8 m/s**
- Maximum particle size: **10 µm**
- Drive air has to be **oil- and grease-free**
- Only components that are specially cleaned for HCA service should be used for HCA applications.
- Only lubricants recommended by Maximator GmbH should be used for HCA applications.
- All details about recommended lubricants can be found on the latest drawing of the component.
- All connections to a cleaned component need to be completely oil- and grease-free or to be used with lubricants recommended by Maximator GmbH.
- There might be some limitations in the use of two stage compressors due to the maximum compression ratio. Please contact your Maximator Sales Engineer or a Maximator partner for further assistance.

Spare parts and Maintenace

- Only spare parts according to **Maximator specifications** are allowed. These spare parts are not cleaned for HCA applications and need to be cleaned specially before usage. A list of available spare parts, spare part kits and reusables can be found at the latest drawing of the component, which is supplied with the products.
- In case of spare part orders, a serial number / revision of the system is required.
- Attention should be paid to the maximum storage time for **seals.**
- Inspection of all movable parts is necessary. In case of scratches or damages, these parts need to be replaced.
- A special cleaning of all parts is needed.
- Personnel must be especially trained for the handling of high pressure HCA components.
- Maintenance intervals for preventive maintenance depend on the application and need to be defined by the user. Maximator GmbH recommends maintenance **once a year** as a minimum for components used in HCA applications.



At this point, however, it should be mentioned that when compressing oxygen-containing gases, one is always moving in an unstable system in which ignition effects can also occur below the specified limit values. The aspects mentioned are to be regarded as inhibiting, not as preventing measures.

Further information on the special cleaning of components for the compression of gas mixtures with an oxygen content >21% can be found in the Best Practice „Oxygen Compression“.

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How to control the uncontrolable?

With sophisticated solutions for highly compressed air.

- Generous and comprehensive assessment of all safety factors
- Regular internal tests and hydrocarbon residue analysis through independent laboratories (certificates available on request)
- Alignment with regulations from official councils and committees
- Competent advisors through the whole product lifecycle
- Maximization of appropriate materials (ignition/ combustion resistant or a low potential therefore)
- Minimization of ignition potential through control mechanisms which prevent ignition or dirt contamination of the system

Your benefits

Safety
Higher safety level for operators and commissioning experts; Prevention of accidents with personal injuries or material damage

Raise of availability
Reduction of loss of turnover caused by system downtime

Predictability
Long-term predictable maintenance expenses

Easy integration
Facilitation of risk assessment with regards to Maximator GmbH components

Service
Operating instructions for assembly, operation and maintenance released by competent and experienced advisors

Know-how
Experienced application specialists/ application expertise

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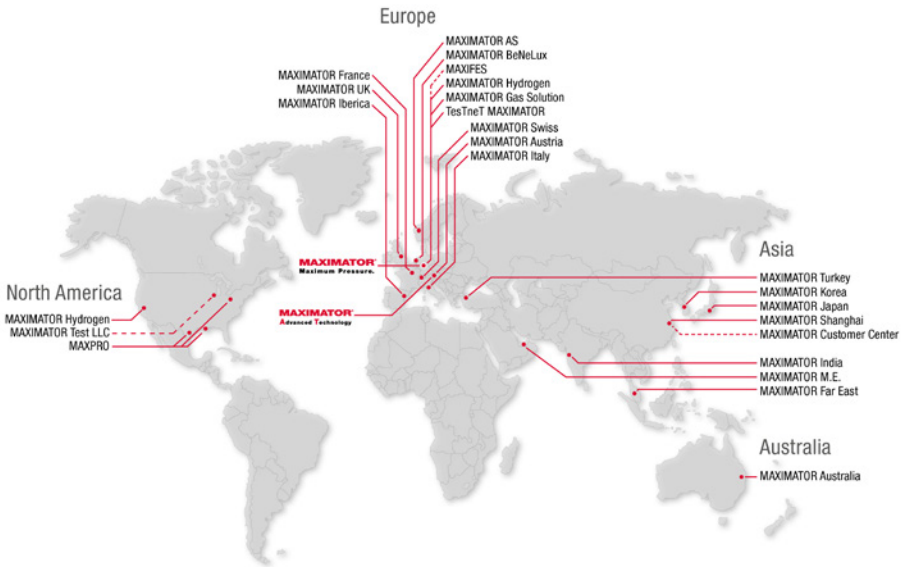
On your side everywhere

Maximator is one of the leading companies providing high pressure equipment up to 25,000 bar. The standard air driven Maximator boosters have been used in hydrogen applications for over 20 years.

Maximator GmbH, with its company headquarter in Nordhausen, has been extremely successful worldwide for more than five decades.

With our products and innovative system solutions, we are the long-standing partner of companies of repute in the automotive and supplier industry, as well as the life sience, chemical and mechanical engineering, energy, oil and gas industry sectors.

With our international partner companies, experienced experts in high-pressure technology are always ready to assist you. We have compiled detailed contact information for our international partners which you can find on our website at:
www.maximator.de/worldwide+distribution



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