A 50-year success story

Process-gas screw compressors from MAN TURBO

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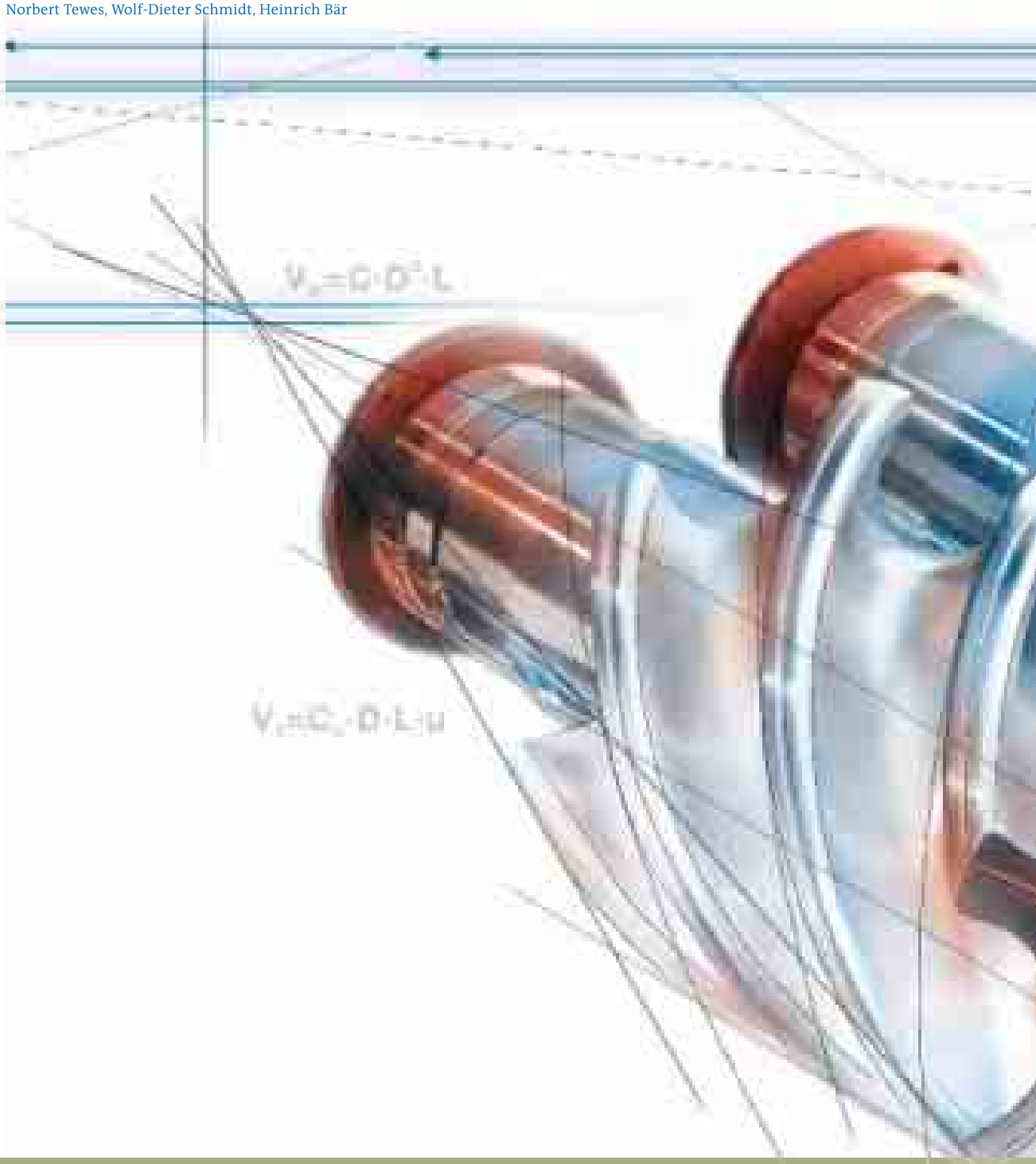


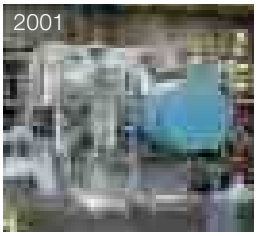
Milestones in development

MAN TURBO has been developing, manufacturing and supplying oil-free process-gas screw compressors for nearly all gases for 50 years.

The advantages of this type of compressor were recognized as long ago as 1952. The acquisition of a licence from Svenska Rotor Maskiner AB signalled the start of a successful business. In taking the decision to go down this road, MAN TURBO joined the pioneers who advanced this concept, which had long been familiar in theory, to the stage of industrial utilization.

Following a period of development lasting just over a year, the first screw compressor developed and constructed by MAN TURBO was unveiled to the public in 1954. After that, the number of machines produced increased year by year as the screw compressor secured its place anew, even in new industrial applications.

Today solutions featuring a process-gas screw compressor exist worldwide for a host of processes. Below we list a few of the milestones in the development of process-gas screw compressors by MAN TURBO:



1954 Commissioning of the first screw compressor installation

1959 The first process-gas screw compressor complete with steam turbine drive comes off the production line in Oberhausen, Germany.

1963 The miracle of Lengede: a process-gas screw compressor is taken out of routine production to provide the compressed air necessary to drill down and rescue 11 miners trapped underground. The men were brought to the surface unharmed after being entombed for 14 days.

1964 The first process-gas screw compressor in the world with a discharge pressure of 40 bar is constructed for a customer in Belgium.

1970 The market acceptance of the process-gas screw compressor is proven by the sale of 1,000 machines.

1977 Linde AG, Germany, confirms 100,000 hours of operation without any replacement parts for a process-gas screw compressor.

1981 Two screw compressors are supplied for the recondensation of gases from a low-temperature storage facility (gas temperature -103°C) – the first low-temperature application of process-gas screw compressors worldwide.

1987 The first offshore screw compressor for recompressing associated flash gas is commissioned on an oil platform in the North Sea.

1993 Efforts to limit hydrocarbon emissions into the atmosphere result in the use of dry gas seals in a process-gas screw compressor.

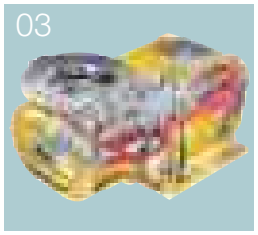
1996 The first three directly driven process-gas screw compressors with a high-frequency drive motor leave the production shops, destined for a soda ash plant.

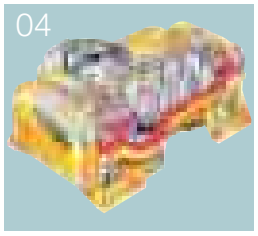
2001 MAN TURBO is the first manufacturer worldwide to launch an oil-free process-gas screw compressor with a discharge pressure of 50 bar onto the market.

Thanks to their robust, low-maintenance design, process-gas screw compressors are preferred in applications where heavily contaminated gases and gas mixtures would curtail the life of other compressors. They are used for the compression of all technical gases and gas mixtures with the exception of pure oxygen.

The modular design of the MAN TURBO process-gas screw compressor facilitates an individual, optimized configuration for different applications, offering every client a made-to-measure solution for his process. Application-specific adaptation of plant engineering components and control systems yields further scope for realizing the client's requirements and wishes to best advantage.

01 One of the first screw compressor installations





02 Comparison of the smallest set of rotors with a large set
03 CP series
04 SKUEL series

Product range

MAN TURBO offers the world's most comprehensive range of process-gas screw compressors, covering volume flows from 200 m³/h up to approx. 100,000 m³/h and discharge pressures up to and beyond 50 bar. Rotor diameters range from 102 mm on the smallest compressor to 816 mm for the largest model.

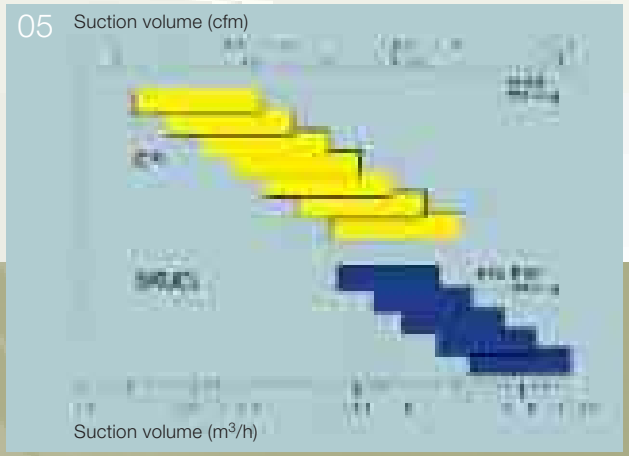
Two compressor series are available: the CP series for high discharge pressures and the SKUEL range for high volumetric flowrates.

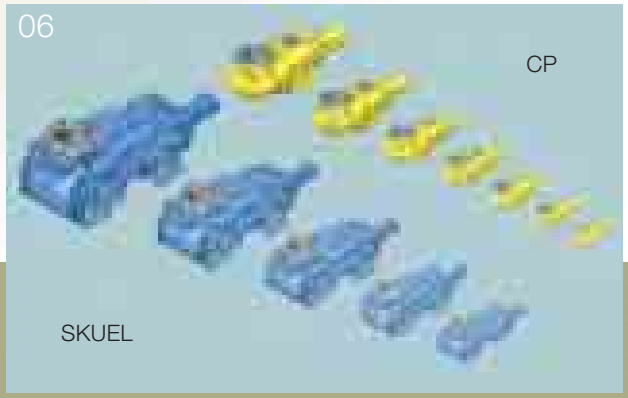
With 7 different rotor diameters and 3 different length/diameter ratios, the CP models are rated for volume flows from 200 up to 20,000 m³/h. The barrel-type casing design with a vertical split joint permits discharge pressures of over 50 bar.
The SKUEL types, featuring 5 different rotor diameters and 2 different length/diameter ratios, cover a volume flow range of 4,000 to 100,000 m³/h at a discharge pressure of up to 16 bar.

Apart from their broad application spectrum, process-gas screw compressors have a number of other convincing features:

– a low number of wearing parts, no high-maintenance valves
– no oscillating masses, i.e. good vibration characteristics
– suitable for dirty, dust- or droplet-laden gases
– optional liquid injection to reduce the discharge temperature or to wash the gas
– superb part-load characteristics with variable-speed drives (50 % speed ≈ 50 % suction volume ≈ 50 % power consumption)
– subcritical operation (first lateral critical speed is above the operating speed)
– no "surging", i.e. no unstable operating characteristics
– steep characteristic curve, i.e. scarcely any change in volume flow when the discharge pressure changes

A high level of availability is one of the many advantages of this compressor type.





05 Selection diagram
06 Relative sizes of CP and SKUEL variants

01_Compressor type SKUEL 408

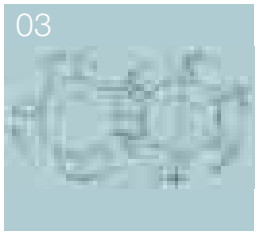
Mode of operation

The screw compressor is a positive displacement machine, i.e. the pressure ratio attainable is basically independent of the speed. Thanks to the intermeshing, screw-shaped geometry of the two rotor profiles, closed chambers are formed between the rotors and casing that become larger or smaller cyclically as the rotors turn. The screw compressor is thus also referred to as a "rotary piston compressor". This mode of operation is illustrated in Fig. 04 in diagrams a to e.

The chambers that are increasing in size are connected to the suction side by control apertures in the end face. They are under suction pressure and extend on the top side of the rotors across the entire profile length as far as the opposing discharge side, although they have no connection as yet to the discharge nozzle (Fig. a). Once the interlobal chambers filled with fresh gas have been isolated from the suction side (Fig. b) they are transported to the underside of the rotor pair by rotation of the rotors. This is where the actual compression now commences due to the intermeshing of the rotor teeth, the gas being compressed in the shrinking chamber and at the same time displaced in an axial direction towards the discharge side (Fig. c), where it is ejected into the discharge nozzle, likewise via control apertures (Figs. d and e).

Depending on the pressure distribution in the interlobal chambers, forces are exerted on the radial and axial rotor bearings and torques are generated around the rotor axes that have to be produced by the prime mover. It should be emphasized that, owing to the pressure difference between the top and bottom side of the rotors, the radial and axial bearings are loaded proportionately to the pressure difference between the suction and discharge pressure. The principal share of the torques resulting from the gas forces is concentrated on the main rotor, which is characterized by a convex tooth shape and takes up around 95 % of the drive power. The so-called female rotor, with a concave tooth shape, primarily assumes only a guide function for forming closed interlobal chambers, and thus acts purely as a seal.

02_Assembly of SKUEL643 process-gas screw compressor



03_Asymmetrical 4/6 rotor profile

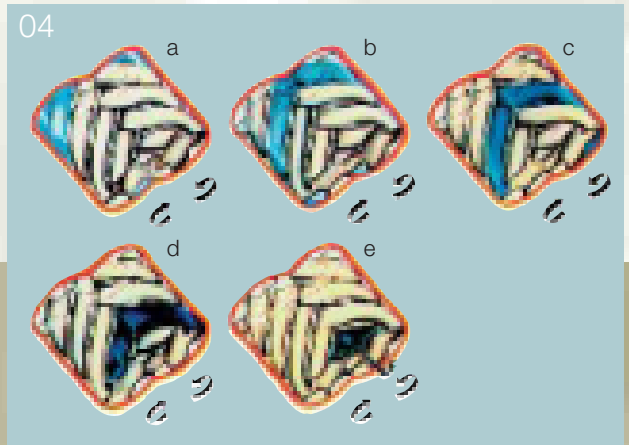
The profile shape used by MAN TURBO in most cases for process gas applications is the asymmetrical 4/6 profile. Here the male rotor has four teeth and the female rotor six teeth, so that the female rotor speed is 2/3 of the male rotor speed. This profile offers a good combination of a large interlobal volume, small internal leakages and a high level of bending stiffness. The high bending stiffness permits operation at great pressure differences and results in a high 1st lateral critical speed. This rotor profile can be used in the vacuum to high-pressure range without any problem and has a high efficiency rating.

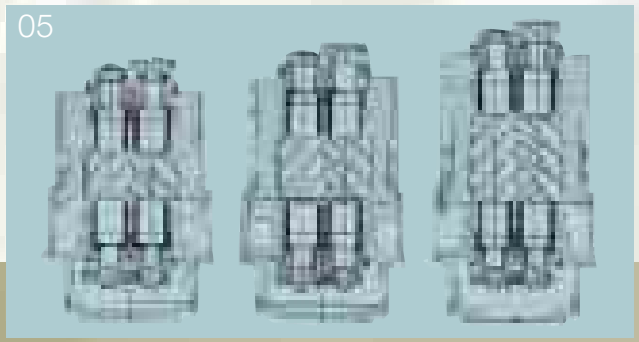
The level of efficiency is basically determined by the tightness; due to the asymmetrical shape of the profile teeth, geometrically unavoidable leakage points, so-called blow holes, are minimized on the discharge side of the rotor pair. This is particularly effective on this side, as it is here that the highest pressure differences occur between the interlobal chambers too. Apart from the blow holes, leaks occur through gaps between the profiles and the casing and between the two profiles themselves. These gaps are intended to ensure contact-free movement of the rotors and must therefore take account of all position- and shape-changing influences such as bearing play, bending, torsion and thermal expansion. The aim is to make these gaps as small as possible to achieve optimum efficiency, but as large as necessary to ensure safe operation.

Modular design for customized solutions

Standard components enable costs to be streamlined and the model range to be harmonized as well as permitting development of the compressor in stages with a view to increasing its availability and efficiency. Above all, standardization encompasses:

– the rotor pair, comprising the male and female rotors. Depending on the level of mechanical loading, these are provided with “normal” or “reinforced” bearing journals. The normal diameter of one size is equal in this case to the reinforced diameter of the next size down.
– the compressor casing
– the synchronization gear for preventing the two rotors from coming into contact
– the radial and axial bearings
– liquid- or gas-lubricated shaft sealing systems for the relevant application to minimize gas leakage





04_Mode of compressor operation (pictures a — e)
05_L / D variations on the type CP

To take up the radial stresses, rotors for MAN TURBO screw compressors are single-piece forgings. Depending on the requirements of the respective application, standard journal, bearing and profile section components are used to construct the rotors. It makes sense to standardize the journal geometry of the rotors, as the length of the shaft seals and the width of the radial bearings only vary slightly across a wide range of applications. In addition, the length of the profiled part of the rotor has the greatest influence on the rotor deflection and bearing forces. Consequently, screw compressors are constructed according to the operating differential pressure with a different ratio of the profile length L to the profile diameter D. Normal designs have a length / diameter ratio (L / D) of 1.65. In the high pressure range, profiles with an L / D ratio of 1.2 to 0.9 are used. In the low-pressure range, the profiles are extended up to a L / D of 2.0. Longer or shorter profiles than these are in most cases ineffective for thermodynamic reasons.

Standard components of this kind are used for the casing design, thus lowering costs. The compressor casings are designed completely as castings. The smaller casings for the CP series are of the barrel-type design, i.e. they have a vertical split joint and are suitable for high pressures. The larger casings of the SKUEL series are split horizontally and are easy to maintain. The bearing housings are integrated into the compressor casing. The standard design has the gas inlet connection on the top and the gas outlet connection on the bottom of the casing, an arrangement that enables liquids for cooling or washing the gas to be injected easily.

Broad application range and typical applications

MAN TURBO screw compressors are used in single- or multistage compressor installations in a wide variety of industrial sectors and processes. When it comes to compressing dust-laden gases or gases with a tendency to polymerization, this compressor type all but replaced other compressor types decades ago thanks to the possibility of continuous liquid injection. This includes the off-gas compressors used in the vacuum range in styrene plants as well as compressors for coke oven and lime kiln gas. Reciprocating compressors, which require more maintenance, are also being replaced increasingly by screw compressors for the compression of gases that are subject to a continuous change in the gas composition and thus also in the gas density as a result of the process conditions.

01 2 x SKUEL643 / SKUEL408 compressors in steel production, 41,000 m³/h of coke oven gas, 1 to 11 bar
02 SKUEL643 in styrene monomer production, 56,000 m³/h of off-gas, 0.3 to 1.6 bar
03 4 x CP100 in power generation, 1,000 m³/h fuel gas, 15.3 to 28 bar

Growing environmental awareness and a perennial interest in optimizing energy utilization mean that new process engineering applications are constantly being developed. This has resulted in the use of screw compressors in the manufacture of environmentally compatible detergents in new Linear Alkyl Benzene (LAB) plants or in the production of reduced-sulphur petrol and diesel fuels in refineries.

As displacement machines, screw compressors ideally complement the classic turbo-compressor range of MAN TURBO.
Continuous product development should help MAN TURBO to retain its leading global position in this market segment in the future too.

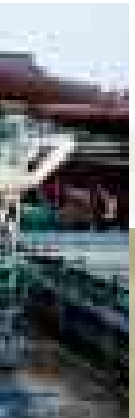
Service aspects

Compared with other types of machines, service activities on process-gas screw compressors are entrusted more frequently directly to the machinery manufacturer, resulting in continuous contact with the operators over the entire lifetime of the installation. MAN TURBO Service thus looks after a large number of screw compressor installations that were commissioned over 30 years ago.

Customer training courses, both in Oberhausen and on the client's premises, often constitute the initial contact with the operator's staff. The aim then is to build up a long-term relationship with the operators via service contracts, which are modular in structure and can thus be adapted optimally to the specific requirements of the respective operator (figure 01, page 78).

Using modern remote data transmission technology it is now possible to monitor the operating data of the machines continuously and provide the operator not only with assessments in the form of reports but also with facts regarding the life of the machine, and to offer cost-saving preventive service measures (figure 02, page 78).

The planning and execution of maintenance and overhauls together with the production and delivery of replacement parts over the entire life of the installation are a matter of course.



02

03

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Service contracts
Selection criteria: Scope of service
MAN TURBO offers service contracts based on the following modular concept:

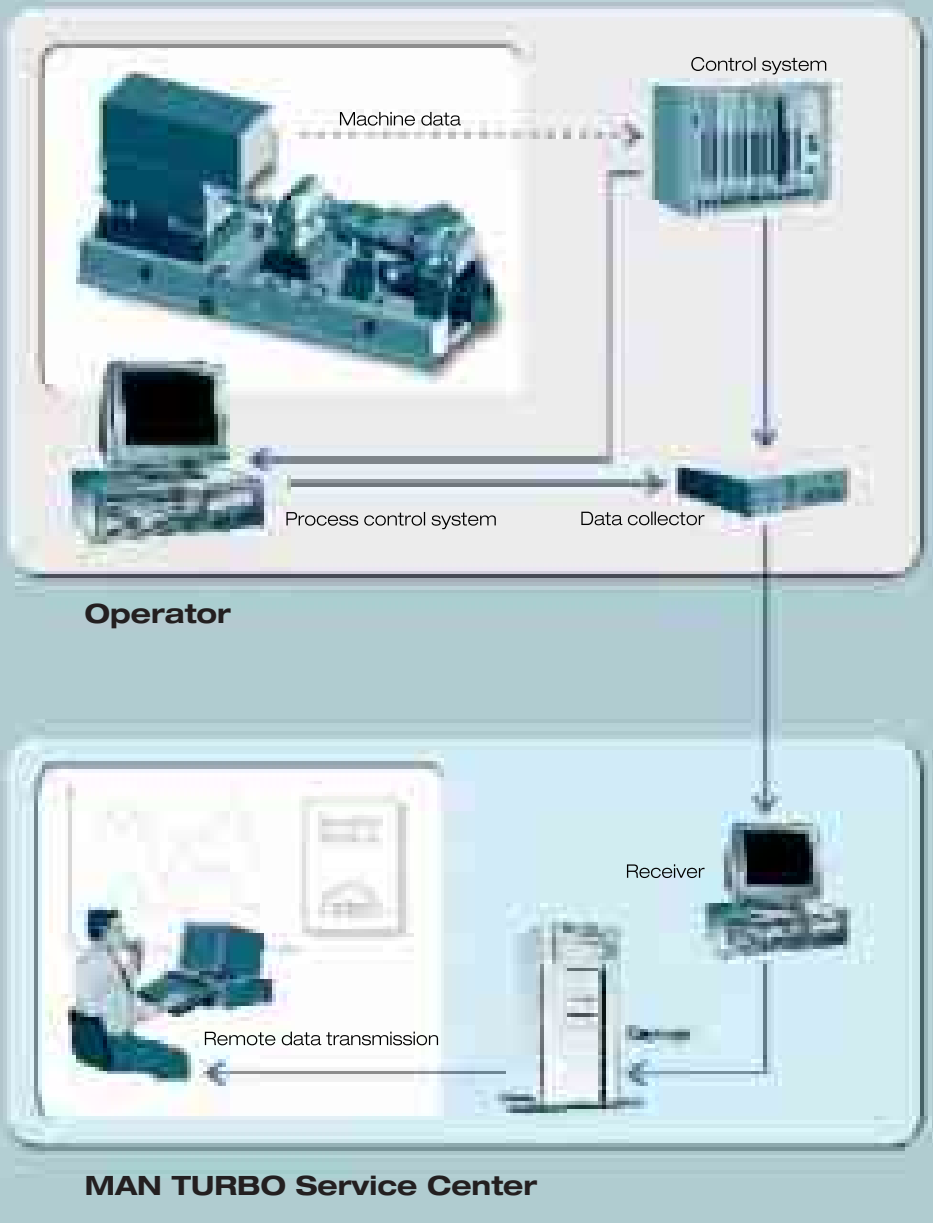
Full service contract
Spare parts storage and logistics (optional) at the customer s site
Unscheduled activities/maintenance

Scheduled maintenance
Scheduled inspections and condition-dependent repair of components

Diagnosis
Plant inspection, borescopic examinations, lube oil and vibration analyses, minor repairs

Teleservice
Operating data transmission (regular, event-induced, manual) rend evaluation, recommendation of measures, reporting

02



01_From teleservice to MAN TURBO full service package
02_Use of remote data transmission

Owing to process modifications initiated by the customer, there is a growing need for engineering studies to be produced regarding revamps, capacity adjustments, modernization or even complete relocations of entire compressor systems. Together with its agents and local service shops all over the world, MAN TURBO is able to meet the client's requirements in this respect. The frequent request for an increase in flow rate can often be realized in a screw compressor installation with few modifications. If the power reserves of the drive are suitable, flow increases can be achieved through an increase in speed alone, with a modified gear train.

Regular service bulletins inform operators of possible modernization and optimization options.

Outlook

In the last 50 years, the oil-free process-gas screw compressor has become firmly established in many applications in the chemical, petrochemical and other industries.

The characteristics described will open up new applications for the process-gas screw compressor in future new processes necessitated by more stringent environmental requirements, for example. The ongoing optimization of process-gas screw compressors, especially with regard to greater suction flow rates and higher discharge pressures, will enable this machine type to be used in the future with major benefits for the customer in sectors that were previously the preserve of other compressor types.

MAN TURBO Products and Services

From single machines to total train capability

Axial compressors
- Suction flow rates up to 1.25 Mio m^3/h
- Discharge pressure 20 bar

Centrifugal compressors
- Suction flow rates up to 325,000 m^3/h
- Max. discharge pressure 850 bar
- HOFIM – high-speed oil-free compressor

Pipeline compressors
- Gas transmission up to 30 MW
- Outlet pressure 130 bar
- Gas turbine or electric motor drive

Isotherm compressors
- Suction flow rates up to 600,000 m^3/h

Gear type compressors
- Suction flow rates up to 300,000 m^3/h
- Max. discharge pressure 220 bar

Expanders
- Single- and multistage design
- Power output up to 30 MW
- Max. inlet temperature 760 °C
- Max. inlet pressure 20 bar

Process-gas screw compressors
- Suction flow rates up to 100,000 m^3/h
- Max. discharge pressure 50 bar

Turbair® vacuum blowers
- Suction flow rates up to 200,000 m^3/h
- Vacuum level up to 0.2 bar

Industrial steam turbines
- Generator and mechanical drive
- Live steam up to 130 bar and 570 °C
- Power output up to 120 MW

Industrial gas turbines
- Generator and mechanical drive
- Power outputs up to 12 MW (THM), 26 MW (FT8) and 52 MW (TwinPac)

Control system
- turbolog®

After Sales Service for compressors und turbines
- Remote diagnostic system ***irds®***