

# Turbo Magazine

*A century  
of turbocharging*



2	› <b>Turbocharging in Switzerland – A history</b>
3	Pioneering era
8	Turbocharging's triumphant march
16	The modern era begins
23	A century of progress

---

Reprinted from Turbo Magazine 2/2005

# A century of turbocharging

*The year 2005 will go down as a special year in our company's history. In addition to being one of the most successful to date, it reminds us of an important event which, exactly one hundred years ago, laid the basis for the success we enjoy today. 1905 was the year that a highly talented Swiss engineer by the name of Alfred Buechi filed the patent that would come to be looked upon as the starting point for exhaust gas turbocharging.*

*Alfred Buechi soon approached BBC in the hope of turning his "highly supercharged compound engine" into reality. Some initial reservations on the part of our company eventually, and thankfully, gave way to an agreement on collaboration. It marked the beginning of one of the most notable success stories in Switzerland's industrial history.*

*The past 100 years have brought changes to every area of life. Today, turbocharged engines play a highly influential role in many of these areas, and our fascination with them is in no way diminished. Also unchanged are the qualities – know-how, talent and staying power – that are essential to achieve the goals we see as being achievable, for our customers and for ourselves.*

*I hope you enjoy reading this short history of turbocharging and of our turbochargers. I am sure that while some of the journey may be familiar, you will, like me, also find that the story has much which is new to discover.*



*Daniel Arnet*

*President*

*ABB Turbo Systems Ltd*

# Turbocharging in Switzerland – A history

This issue of Turbo Magazine traces the history of the ABB turbocharger, from its roots in the 1905 Buechi patent through the development and progress of the VTR and RR series to the advanced TPS and TPL generations.

Baden – home of the  
ABB turbocharger.

The high-tech ABB turbocharger we know today is a far cry from the first “supercharged scavenging blower with attached exhaust gas turbine” that Brown Boveri built for

an experimental two-stroke engine in 1924. But that ground-breaking machine was also advanced for its time. And it, too, was the product of earlier invention and innovation,

inspired by an idea patented by a Swiss engineer 100 years ago and now universally recognized as the starting point for exhaust gas turbocharging.



## PIONEERING ERA

### Diesel sets the scene

The story of the exhaust gas turbocharger began in a period of phenomenal technical progress. The early years of the twentieth century were remarkable for the breakthroughs they produced (not the least of them powered flight!). Engineers and entrepreneurs alike were active in the promising field of thermal machines. Rudolf Diesel had patented the engine named after him already in 1892, and its efficiency was by now better than 30 percent. (Diesel even mentioned supercharging in an early patent claim, but later experiments did not produce the high efficiency he was seeking, so he decided to take it no further.)

The first diesel engines of MAN (Maschinenfabrik Augsburg-Nürnberg) in Germany and B&W (Burmeister & Wain) in Denmark, as well as of other companies, date from this period. Swiss machine manufacturer Sulzer also began to build diesel engines at its factory in Winterthur around 1900. And in Baden, less than 50 kilometers away, a certain electrical engineering company by the name of Brown, Boveri & Cie was celebrating its first decade in business by embarking on an exciting new venture. It was the construction of continental Europe's first steam turbine, the very branch of engineering that would later bring forth the BBC exhaust gas turbocharger.

### Buechi's 1905 patent

The Swiss engineer we have to thank for the 1905 patent is Alfred Buechi, who at the time was working with Sulzer. In it, he describes a "highly

supercharged compound engine" with a four-stroke diesel engine, multi-stage axial compressor and multi-stage axial turbine mounted on a common shaft. In a subsequent US patent Buechi went further, describing the series arrangement of the three machines in general terms in a sub-claim.

Further work by Buechi at Sulzer eventually led to publication in 1909 of his idea for a freewheeling turbocharger (it would nevertheless be some time before anyone would follow this up) and later, in 1915, to his important "scavenging patent".

It was also in 1915 that Buechi, looking for a partner, first contacted Brown Boveri in Baden. The company, which by then had already gained a great deal of experience

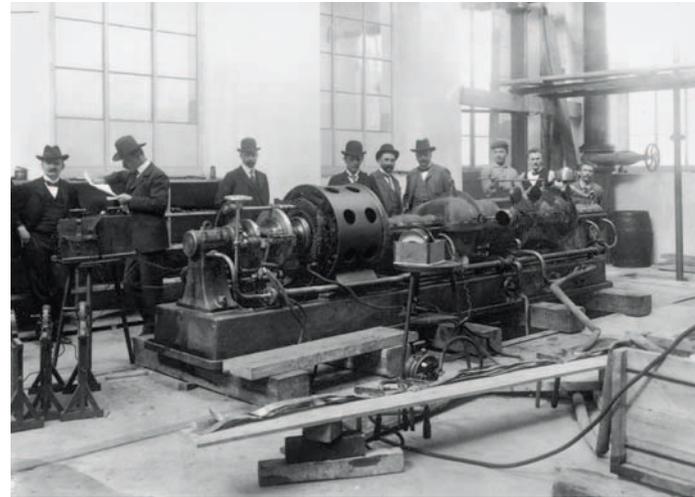
in designing and building turbomachinery, considered Buechi's proposal, but turned down the opportunity of collaboration, as it did again later in 1919, on the grounds that "the project as a whole is undesirable and uneconomical". Whatever

the reasons for this conclusion, advocates of turbocharging did exist at BBC and it would not be long before they were making a strong case for its development.

### Parallel developments

Around the same time, work on supercharging aircraft engines was going on in France under Auguste Rateau and at General Electric in the USA under Sanford Moss.

In a 1916 patent (which was not published until 1921) Rateau, who had collaborated with Brown Boveri in gas turbine development in the early



1900s, described devices for regulating a supercharging compressor driven by an exhaust gas turbine, and in 1917 manufactured and tested such a device. Aircraft with turbocharged engines were in use towards the end of and after World War I, but development was not taken any further. Alfred Buechi and others later acknowledged that Rateau should take the credit for having manufactured the first turbocharger.

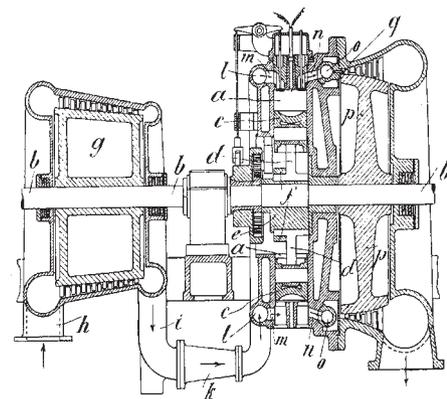
Moss was the first to manufacture turbochargers on a regular basis. Interestingly, the early GE Moss turbocharger had a manually controlled flap which, in certain flight conditions, made it possible to blow off the exhaust gases and bypass the gas turbine – something we nowadays refer to as a waste gate.

First BBC steam turbine – the branch of engineering that would later bring forth the BBC exhaust gas turbocharger.

The compound engine patented by Buechi in 1905 and recognized as the starting point for exhaust gas turbocharging.

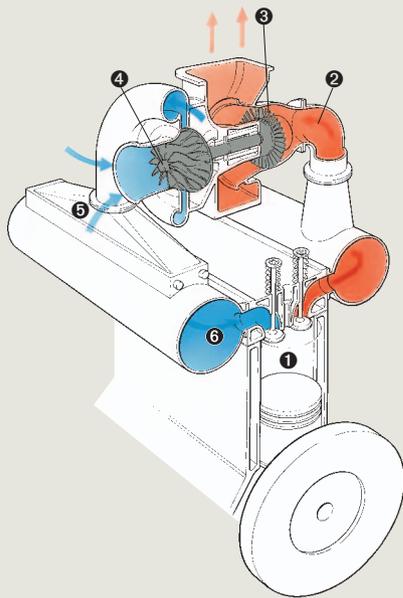


Alfred Buechi



**How turbocharging works**

The output of an internal combustion engine is determined by the amount of air and fuel that can be pressed into its cylinders ❶ and by the engine's speed. Turbochargers supply air to the engine at a high pressure, so more air is forced into the cylinders and is available for combustion.



An exhaust gas turbocharger is driven, as its name suggests, by the engine's exhaust gas ❷. This gas, at a temperature approaching 600°C, is directed at high velocity onto the blades of a turbine ❸, which drives a compressor wheel ❹ mounted on the same shaft. As it rotates, the wheel (or "impeller"), sucks in ambient air through a filter-silencer, compresses it and feeds it via an after-cooler ❺ to the engine's air receiver ❻, from where it passes to the cylinders.

Turbocharging increases engine output by up to four times. Thus, 75 percent of engine power is dependent upon the turbocharger.

**Turbocharging's potential is recognized**

The change in Brown Boveri's policy came in 1923 with the publication in Germany of a report on low-pressure supercharging trials carried out by MAN. These trials, on a 160-rpm, four-stroke engine, had shown that with a charge pressure of just 1.35 bar the engine output increased by 33% even after the power for the electrically driven blower had been subtracted. The use of exhaust gas to drive the compressor promised a further 6–8% increase in power as well as lower fuel consumption. On top of this, the operating pressure, the combustion temperatures and the heat load on the walls all remained within acceptable limits.

Brown Boveri now decided to apply the know-how it had acquired building turbines and compressors to the development of superchargers.

**First ships with turbocharged engines**

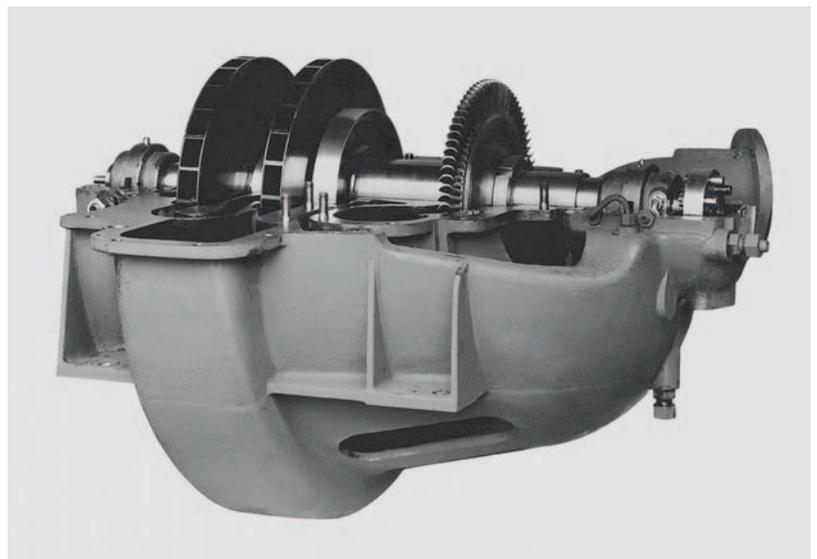
1923 was also the year that the Vulkan shipyard in Stettin received a contract to build two large passenger

ships, the *Preussen* and the *Hansestadt Danzig*, for the East Prussia Line. Each ship was to be powered by two 10-cylinder four-stroke MAN engines, built under licence and turbocharged from 1,750 to 2,500 horsepower. The engines had a common exhaust gas receiver for all cylinders, which meant that they operated under constant pressure. The turbochargers, designed and built under Buechi's supervision, were manufactured in the Vulkan works in Hanover, with BBC in Mannheim providing the compressor wheels. After being tested in May 1926, they were installed in the ships in September of the same year. These two ships were the first in maritime history to be powered by turbocharged engines.

As important as this event was, however, we have to go back three years to trace the first-ever industrial exhaust gas turbocharger.

**World's first heavy-duty turbocharger**

In 1923 Swiss Locomotive and Machine Works (SLM), like Sulzer based in Winterthur, was also seri-



World's first turbocharger for a large diesel engine. Delivered in 1924, it had external plain bearings and a two-stage compressor for a pressure ratio of 1.35.

ously considering the potential benefits of supercharging.

SLM had a two-stroke experimental engine on the test rig that year which needed bringing up to a higher power level with better fuel consumption. Brown Boveri recommended using an exhaust gas turbocharger that would feed into the scavenging blowers, and SLM subsequently placed an order for such a machine. In June 1924 turbocharger VT 402<sup>1</sup>, the world's first heavy-duty exhaust gas turbocharger, left the Baden works of Brown Boveri.

In the same year, discussions into the possibility of collaboration with Buechi began.

### The “Buechi syndicate”

Things were now moving fast. One year later, in 1925, Buechi took out a patent in his own name that was to make him world-famous. Referred to as the “main patent”, it detailed the advantages of pulse operation for

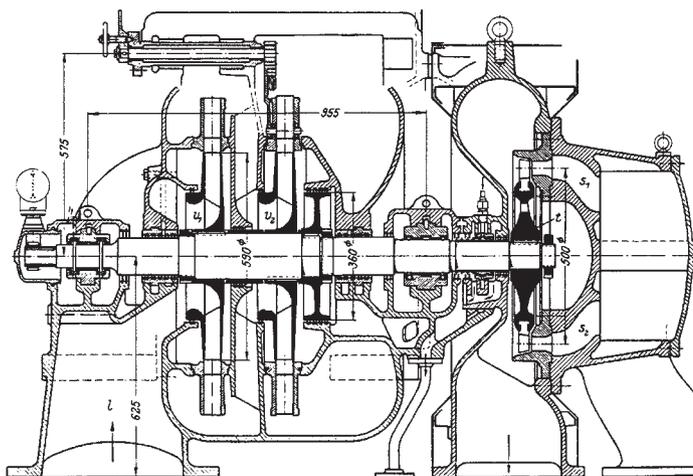
<sup>1</sup> V stands for “Verdichter”, the German word for “compressor”; T is for “turbine”; 400 was the diameter of the compressor wheel in mm; 2 says that the compressor has two stages.

low-pressure supercharging (see panel), and was, within a short time, being used all over the world. The “main patent” was the breakthrough that everyone had been waiting for.

A new company, known as the “Buechi Syndicate”, was set up the following year for the purpose of promoting the further development of the “compound combustion engine with an exhaust gas turbine and a supercharger pump”. Under the terms of the contract, Buechi was in charge of engineering and customer relations, Brown Boveri would build the turbochargers, and SLM was to provide the diesel engines for the tests and trial runs.

### Partnerships with engine builders

An improved, larger turbocharger designated VT 592 was supplied to SLM in 1927 for a second experimental engine. The results were impressive. Licensing agreements were now being concluded between the syndicate and numerous leading engine manufacturers. Other applications for turbocharging were also under investigation. First test runs on diesel-



VT 592 turbocharger for the second SLM experimental engine, supplied in 1927.

### Buechi's “main patent”

A so-called “pulse system” feeds the exhaust gases of the engine through narrow pipes to the turbocharger's turbine, thus driving the compressor. The pressure variation in the small-volume pipes allows overlapping of the inlet and exhaust, which permits the compression space in the engine cylinders to be scavenged with clean air. Cylinders that do not disturb each other's scavenging process are connected to one exhaust pipe according to the engine's firing order. Buechi's 1925 patent laid the foundation for the future success of turbocharging.

Alfred Buechi

Patent Nr. 125664

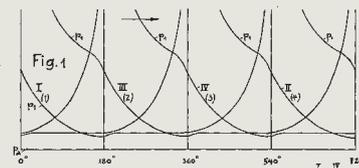


Fig. 2

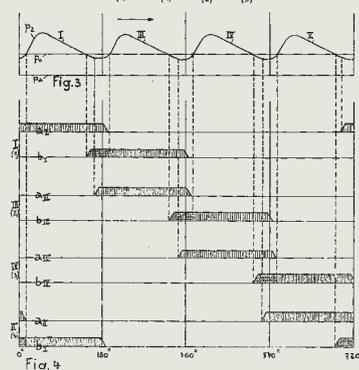


Fig. 4

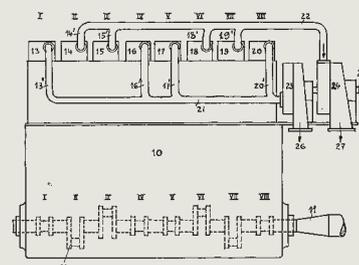
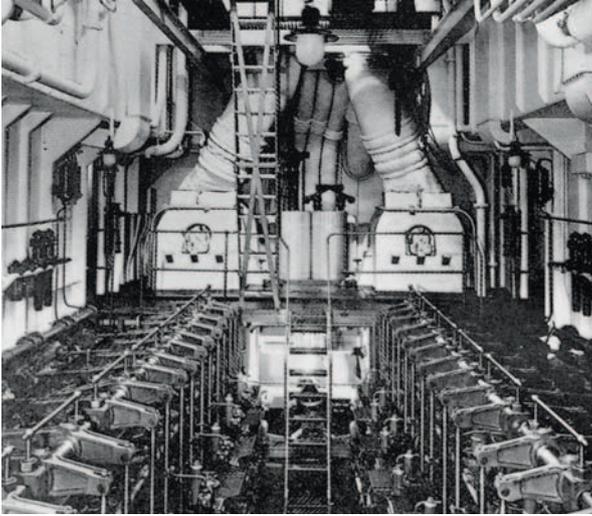
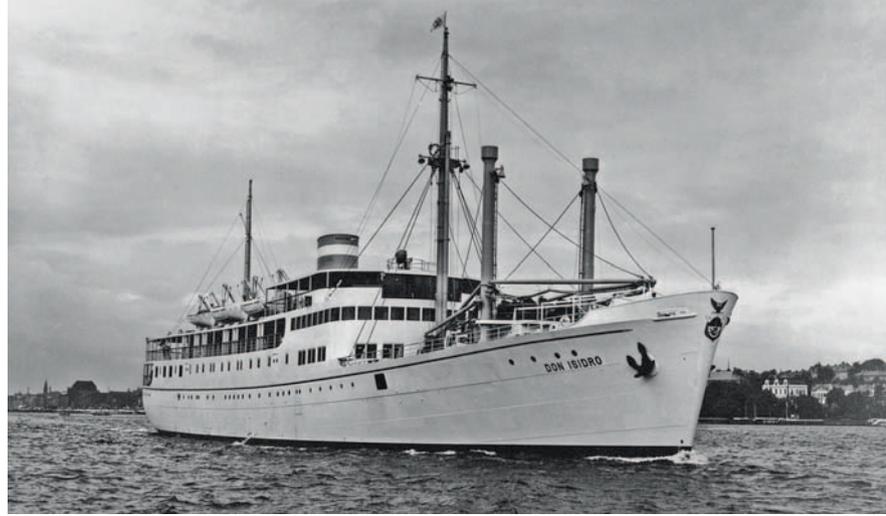


Fig. 5



View of the engine room of the *MS Don Isidro*. The VTx590 turbochargers are mounted on a platform behind the engines.



*MS Don Isidro*, sailing in the late 1920s for de la Rama S.S. Co., Manila, under the power of its two turbocharged, 9-cylinder Krupp diesel engines, each with a shaft output of 3,500 horsepower.

electric locomotives took place, while turbochargers were also recommending themselves for more economic operation of stationary diesel power plants.

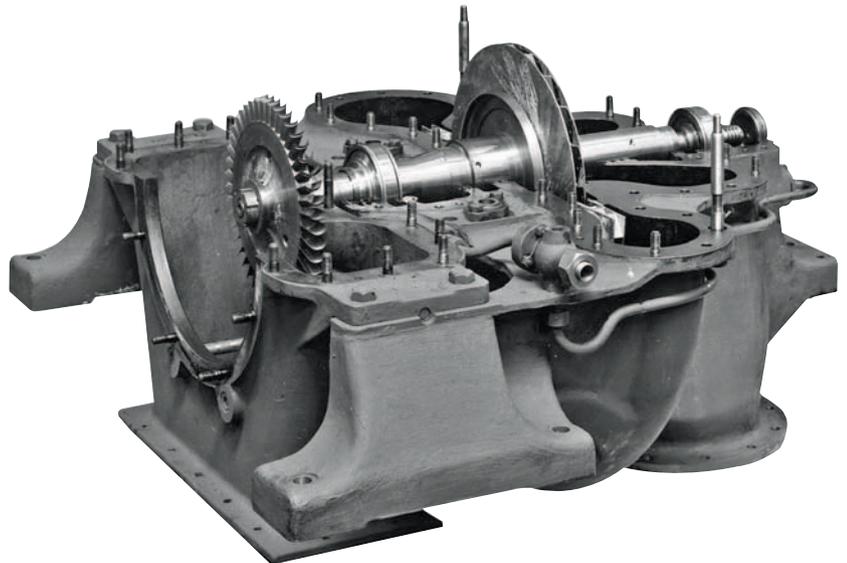
From 1928 on, the trade magazine "The Motorship" was full of reports of new vessels with turbocharged engines. Photos from that era typically show the turbochargers standing alongside and connected to the four-stroke engines by long, divided exhaust pipes. This, of course, allowed only weak pulse operation, but for the slow-running engines of the time it was sufficient.

Continuing development work was also providing new solutions. More compact installations were achieved after 1930 with vertical-axis turbochargers mounted directly on the engine. Though still "horizontally divided", the turbochargers also became simpler around this time with the introduction of a single-stage compressor and improved, turbine blades. Brown Boveri was now working with major German engine builders, including Daimler Benz, KHD (Kloekner-Humboldt-Deutz) and MAN, and outstanding results were being achieved.

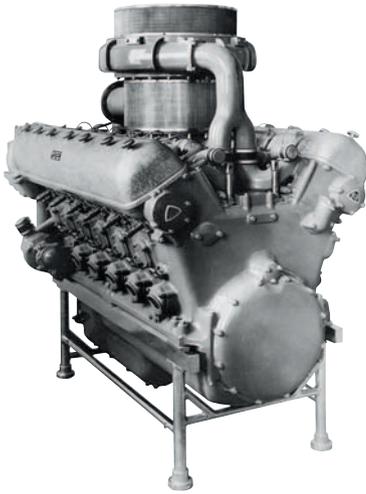
Brown Boveri's growing influence manifested itself in a special way: The company was now advising customers on how to install the turbocharger, the air and the gas pipes, and on the timing of the valves. Understanding the interaction between the engine and the turbocharger had become a key business asset.

### First standardized turbochargers

In 1932 an important design decision was made. Now that an optimal technical solution had been found, Brown Boveri's design engineers went on to formulate specifications for a standardized range of turbochargers. This offered nine sizes, corresponding to compressor diameters



BBC turbocharger with single-stage compressor and overhung gas turbine wheel, dating from the year 1930.



VTy 410 vertical-axis turbocharger mounted on a Maybach 12-cylinder, four-stroke rail traction engine.

ranging from 110 to 750 mm. Horizontal-axis units were denoted VTx and the vertical-axis machines VTy. Many of their features, such as (self-lubricated) external ball bearings, water cooling and the wide use of standard parts, were designed to make service work easier, but the decision to make the turbochargers modular was key as it meant that they could be fitted to an enormous range of engines.

The second half of the 1930s saw an upsurge in turbocharger sales. The number of licence-holders was also increasing, and the railcar business boomed (in 1938 the VTy 410, a vertical-axis model for railcars, accounted for nearly one third of all sales). A growing number of orders were also being received from the US market, one early customer being the American Locomotive Company (ALCO).

### The two-stroke engine challenge

The leap in diesel engine efficiency that had taken place in the 1920s was made possible by direct fuel injection and turbocharging. In the meantime,

largely thanks to turbocharging, the four-stroke engines had strengthened their position relative to the two-stroke machines. But two-stroke engine development had not stood still, either. MAN and Sulzer, for example, obtained interesting results with experimental two-stroke engines in the early 1930s. However, neither of these engines could really compete with the four-stroke machines.

### Developments in two-stroke turbocharging

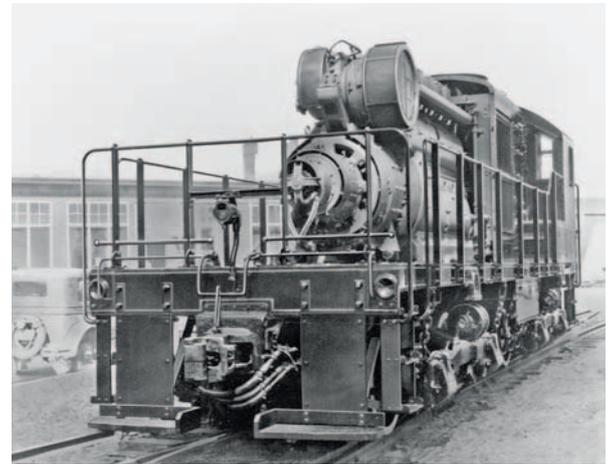
Brown Boveri had already signalled its interest in two-stroke turbocharging in 1925 with its purchase of the "Curtis" patent. This covered the so-called series arrangement, in which the turbocharger feeds air into the mechanical scavenging air blower of the two-stroke engine, thus guaranteeing start and operation at low load. As the engine output increases, the blower load is automatically reduced.

An internal study by Brown Boveri in 1934 also dealt with the supercharging of a 5,000 horsepower Sulzer two-stroke engine. It showed that by using a turbocharger with aftercooler and pulse operation, under full load the turbocharger alone could be expected to supply enough air. Partial-load solutions, such as auxiliary blowers and supplementary drives, were also mentioned in the study.

Later, in 1940, tests were carried out with a prototype VTx 750 with radial-flow wheel on a 7,500 horsepower two-stroke Sulzer engine. The results, however, were disappointing, and further tests were halted.

Thus, until after World War II, turbocharging with exhaust-driven turbochargers was confined exclusively to four-stroke engines. The two-stroke engine, with its low exhaust-gas temperatures and dependence on a blower for the gas exchange, pre-

sented significant difficulties due to the low turbine and compressor efficiency at the time. Not until compressors and turbines with higher efficiencies were developed did turbocharging two-stroke marine engines become a practical proposition. Thereafter, the use of exhaust gas turbocharging increased rapidly, helping the two-stroke engine to achieve absolute supremacy as a direct drive, slow-running marine engine.



The ALCO 8-cylinder, 900 horsepower engine was typical of the engines being supercharged by Brown Boveri in the late 1930s (in this case with a VTx 350).

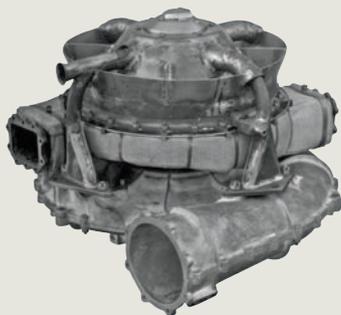


This locomotive of Swiss Federal Railways was still in service in the 1990s, more than 50 years after being shown at the 1939 Swiss National Exhibition. Its four-stroke Sulzer diesel engine, which was fitted with a VTx 350 turbocharger, could deliver 1,200 horsepower at 750 rev/min.

**Brief excursions into new areas**

In the years leading up to and during World War II, Brown Boveri, which had been looking for new markets, was also working on aircraft turbochargers. This involved some interesting issues, including, of course, the problems caused by the reduction in air pressure as altitude increases. However, despite some further work in the post-war years in the hope of a profitable leisure flying market, it was no more than a brief episode in the company's history. Large aircraft engines would, of course, anyway soon be ousted by the jet engine.

VTF 201 BBC aircraft turbocharger with a weight of only 32 kg.



In 1940 the company also turned its attention to the specialized area of wood gas turbocharging! Liquid fuels were in short supply during the war and converting diesel engines to wood gas engines was seen as a viable way to provide motive power for road vehicles. However, the converted engines were weak, to say the least, and turbocharging was put forward as a solution. This venture, too, was short-lived. Once the war was over and cheap liquid fuels became available again, interest in wood gas units quickly, and understandably, ended.

Six-ton lorry with 100 horsepower turbocharged diesel engine converted to wood gas generator (on right, behind door). The inlet for the VTx 110 turbocharger can be seen above the left mudguard.



**TURBOCHARGING'S TRIUMPHANT MARCH**

**The VTR..0 is launched**

From 1940 on Brown Boveri had a new range of turbochargers under development. Denoted VTR, these had an open radial-flow compressor (hence the R) and light rotor, flexibly mounted external roller bearings and a self-lubricating system. Component standardization allowed large-scale production, and therefore competitive pricing. The introduction of the VTR..0 series after World War II was a significant milestone in the BBC turbocharger story. With a compressor efficiency of 75% for a pressure ratio of 2, it was only the start of what was to come, but the BBC VTR..0 turbocharger marked the beginning of a new era.

It was now possible to turbocharge two-stroke engines with engine-driven scavenging air pumps. However, to eliminate the scavenging pumps and reduce fuel consumption a pulse-type turbocharging system was needed, and it would be several years before this feature would be successfully introduced (in 1951) on a B&W marine propulsion engine.

The Buechi syndicate had meanwhile been dissolved. Brown Boveri had built up its own turbocharger design department and also had its own test center and production facilities. The decisive move had been made from individual to industrial turbocharger manufacturing. First signs of a global turbocharger service network were also visible.

**The post-war boom ...**

There was intense demand for turbochargers in the post-war years, and one development in particular was driving it – the growing status of oil

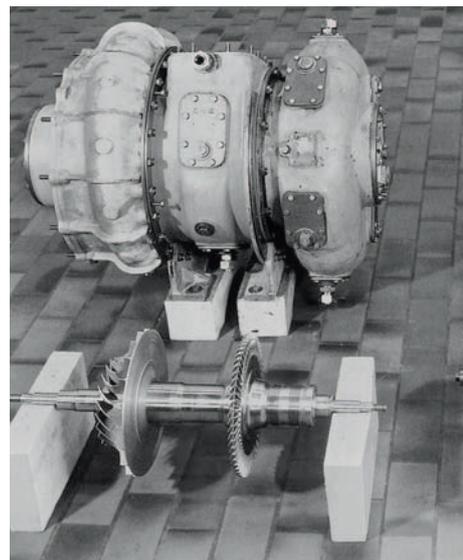


Demand for BBC turbochargers was strong in the post-war years. Numbers supplied each year (excluding units manufactured under licence).

as the preferred energy carrier. Over the next decade or so the world's merchant fleet doubled in size, with tanker capacity growing even faster. For more and more of these vessels, the power source of choice was the diesel engine.

**... and final breakthrough**

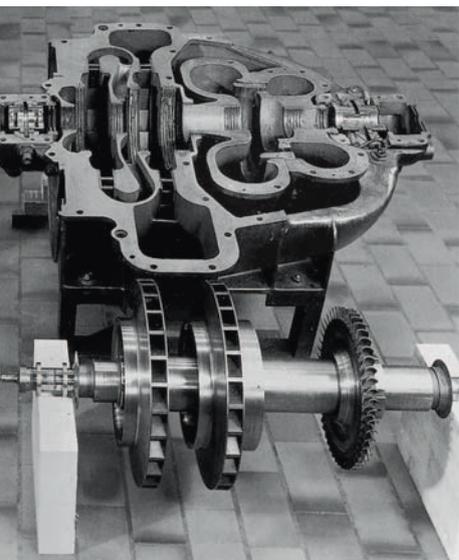
The period between 1945 and 1960 saw the final breakthrough for turbocharging, first for four-stroke engines and then, from 1951 onwards, also for two-stroke engines. Boost pressures increased slowly but steadily during this period, although sales



activities initially centered on low-pressure supercharging, i.e. pressure ratios were about 1.5. The original VTR turbochargers could be equipped with either a low-pressure or a high-pressure compressor, but the latter was hampered by a restricted volumetric flow rate. Compressor development in the following years would erase this disadvantage, pushing the pressure ratio at full load steadily towards 3.

There were several important collaborations with engine builders during this period. Some companies were also experimenting with high boost pressures. MAN, for example, developed around this time a high-pressure turbocharged four-stroke engine with an effective efficiency of 45% – a figure that would not generally be reached for some time.

These collaborations showed once again the importance of the relationship between engine builder and turbocharger supplier. The new technology had to be explained to the engine builders, who needed to know how to make the best use of the exhaust energy in pulse operation and, in many cases, even how the exhaust pipes were to be designed.



### Strategic decisions

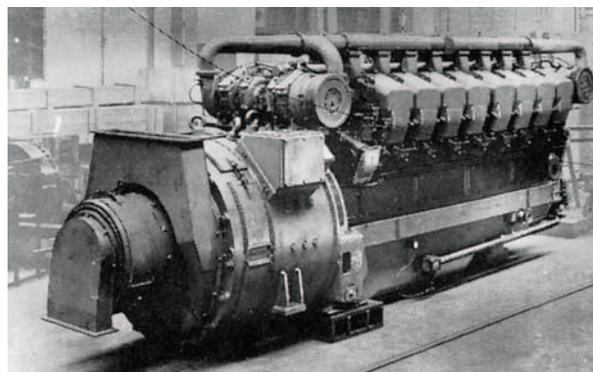
The post-war period saw several decisions taken that would set the pattern for the coming decades and which ultimately would play a key role in the worldwide market acceptance of the BBC turbocharger.

In anticipation of Buechi's main patent in the USA expiring in 1950, Brown Boveri was making a great effort around this time to establish contact with US engine-builders and gain market share. Competing with US-built low-pressure turbochargers, however, was difficult and it became clear that Brown Boveri would have to concentrate on high-pressure turbocharging, where the technical assistance it offered could tip the balance in its favour. As part of its long-term strategy for the country, Brown Boveri also began to build up its service organization in the USA.

Being in the US market had another advantage, too: The turbocharger orders for stationary gas engines provided Brown Boveri with early knowledge and experience of this important application.

In 1958 a decision was made to enter into a collaboration that would be of great strategic importance for Brown Boveri. This was the granting of a licence to Ishikawajima-Harima Heavy Industries (IHI) in Japan to manufacture BBC turbochargers. IHI, which was then building engines under licence from Sulzer, went on to expand throughout Asia, and in doing so secured a dominant position for BBC turbochargers in that region. (This collaboration led to the joint venture company Turbo Systems United (TSU) being set up in 1998 by ABB Turbo Systems and IHI.)

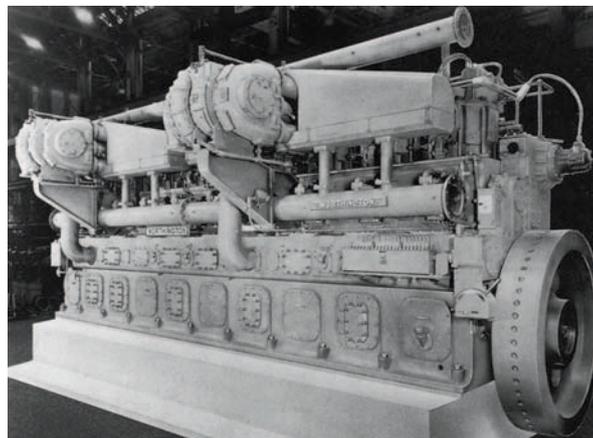
The progress of turbocharger technology from 1924 to 1945. Designed for the same engine size, the more compact VTR 320 on the left achieves a much higher boost pressure than the earlier VT 402.



There were several important collaborations with engine builders in the post-war years. One was with English Electric, whose popular four-stroke V16 engine had four VTR 200 turbochargers mounted on it.



Production in the new turbocharger plant, after 1949.



Ten-cylinder natural gas engine in the USA, turbocharged with two VTR 400 units.

ABB's "Shipowners' Conferences" and the "ABB Evening" at CIMAC Congresses both stem from this time. The importance of good customer relations had been recognized very early on, and these events were excellent opportunities for ABB to explain to the shipping and engine-building community the latest advances in turbocharger technology.

The 18,000 tonne *Dorthe Maersk* was the first ship to be powered by a turbocharged two-stroke diesel engine.



### Dorthe Maersk

Continuous refinement of turbo-charging technology had, by the early 1950s, set the stage for the next pioneering act. In October 1952, the 18,000 tonne tanker *Dorthe Maersk* was launched. Built by the Danish shipyard A. P. Møller, it was the first ship to be powered by a turbocharged two-stroke diesel engine (B&W, 6 cylinders). Two VTR630 side-mounted turbochargers raised the engine's output from 5,530 to 8,000 horsepower. *Dorthe Maersk* was the first milestone in two-stroke marine turbocharging.

### The focus shifts to Asia

The years between 1955 and 1975 were a time of tremendous upheaval for the shipbuilding industry. During this period, half of the world's shipbuilding moved to Japan's yards, while western European shipyards' share went from 80% to less than 40%.

There were other signs of change. By the mid-1950s it was not at all unusual for a Japanese firm manufacturing under licence to be the first to put a newly developed model from the licensing company on the test bench. This was the case, for example, in 1955/56 at Mitsubishi Heavy Industries in Kobe, where

MHI had the first large turbocharged two-stroke Sulzer engine, a 7-cylinder RSA 76 (760 mm bore) running with two VTR630 units.

### Shipbuilding booms

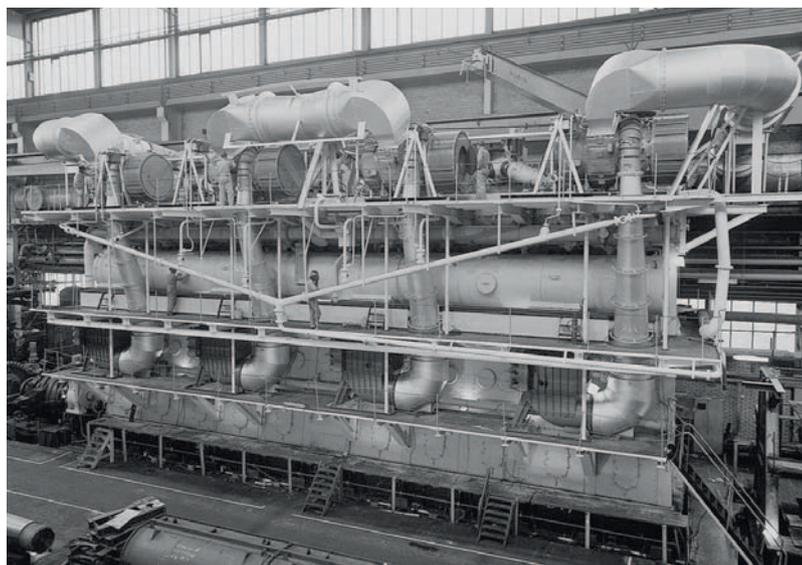
IHI wasn't the only foreign company manufacturing BBC turbochargers at this time. In the period from 1955 to 1975, Brown Boveri signed several significant licence agreements – a strategy that would continue into the late 1970s and 1980s with agreements between BBC and firms in China, India and South Korea, among other countries. Shipbuilding

was at a record level, and the ships being built were becoming bigger and faster. Crude oil prices were low; fuel costs had become insignificant; the diesel engine industry was booming.

The VTR..0 was in its heyday, with overall turbocharger efficiency around 56%. Engines with BBC turbochargers were continually breaking records for output and efficiency.

### Two-stroke market developments

It is worth considering at this point the background to the next major

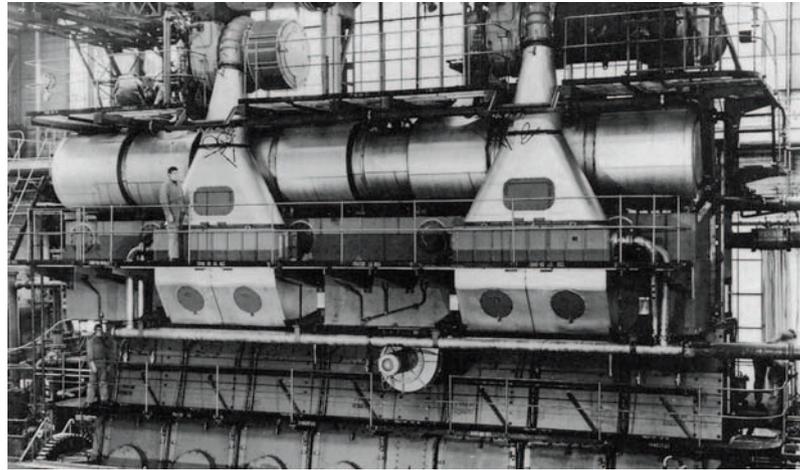


Eriksberg B&W engine of type 10K98FF, rated 38,000 bhp, 27,950 kW, at 103 rev/min, fitted with four VTR750 units.

advance in two-stroke engine turbocharging. The pulse system introduced in 1951 by B&W had the advantage that a mechanical system was not needed at any point in the engine load range to guarantee the air supply. This was partly due to the very high mechanical efficiency of the VTR turbochargers made possible by their anti-friction bearings. The required exhaust gas energy was obtained by opening the exhaust valve early, although this also reduced the effective expansion stroke.

An engine with scavenging pumps and with constant pressure turbocharging can make do with a much later opening point for the exhaust valve, but it takes some of the energy for the air supply from the crankshaft. Thus, the engine drives its own scavenging pumps, with the result that fuel consumption is essentially the same as for the B&W engine with pulse system.

The obvious way to improve fuel consumption was therefore to use constant pressure turbocharging and eliminate the scavenging pumps. The problem was, of course, that this would require turbochargers with a higher efficiency, and for the moment they were not available.



Two VTR631 turbochargers on a Sulzer 7 RND 90 two-stroke diesel engine under test in 1971.

### Enter the VTR..1

New compressors with higher efficiencies and pressure ratios as well as increased throughflows were developed through the 1950s and 1960s. Higher pressure ratios meant higher speeds and increased axial thrust, for which improved bearing designs were necessary. Mountings were also reinforced. In 1970, compressors with an even higher throughflow were introduced and the gas outlet housing was enlarged. The turbine intake was also reworked.

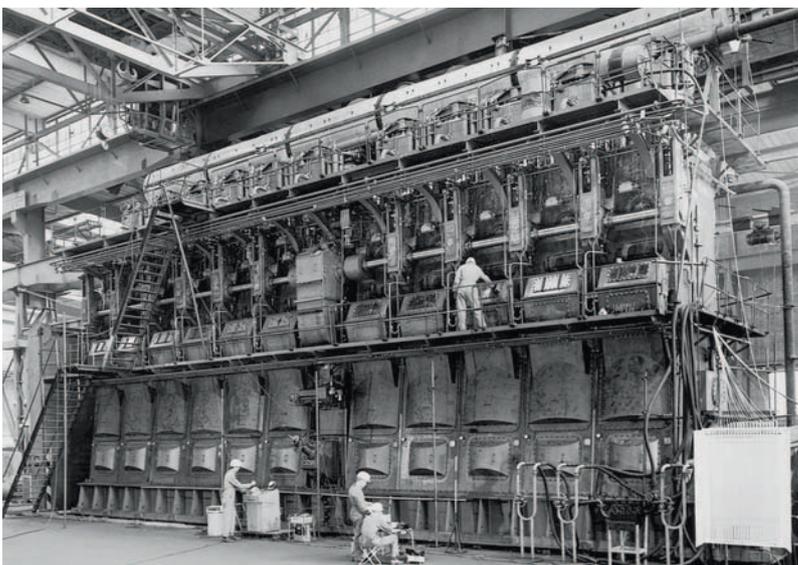
All of these improvements were incorporated in 1971 in a new series

– the VTR..1. From now on, Brown Boveri could offer turbochargers with an overall efficiency of almost 60% for a wide range of applications. In the past, efficiency had risen steadily but slowly. This was the first big leap.

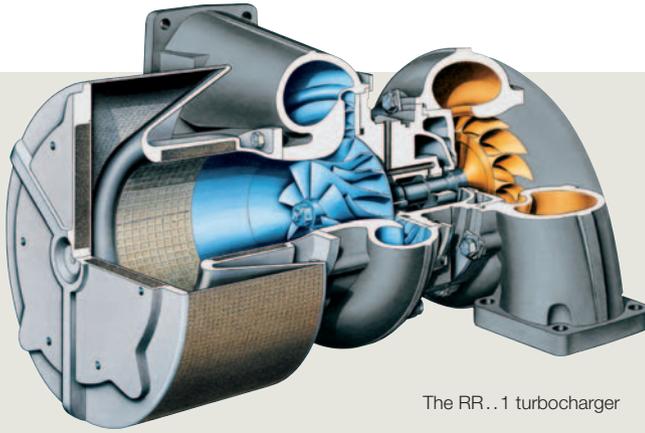
### RR buttresses the lower end of the range

In 1968, three years before the launch of the VTR..1, Brown Boveri brought a new series of small turbochargers onto the market. Named RR due to its radial turbine and radial compressor, it was developed for applications at and below the lower end of the VTR power range.

The introduction of the RR series fulfilled a market need that had been evolving for some time. By the mid-1960s many firms were building turbochargers that competed for market share with the smallest VTR. Smaller, lighter turbochargers were in demand for the then modern, fast-running diesel engines in the lower power range. Designed with plain bearings for heavy duty, the RR150 had a compressor pressure ratio of up to 3.0 at full load. Brown Boveri had developed small turbochargers during and after World War II, but the RR150 was the first real small, series turbocharger to be built by the company.



Three VTR630 turbochargers were installed on this Götaverken engine of type VGS 11U, rated at 26,400 bhp, 19,000 kW, at 119 rev/min.

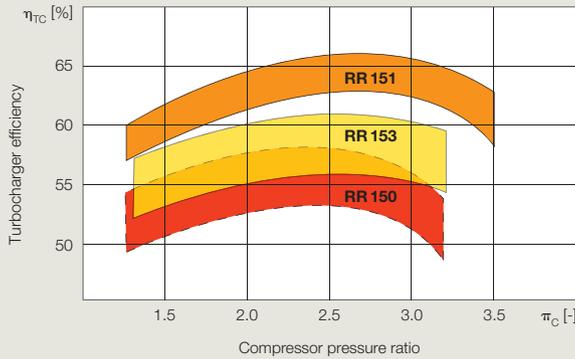


The RR..1 turbocharger

### RR turbochargers

The RR turbochargers were intended mainly for use with high-speed four-stroke engines. These engines progressed enormously throughout the 1970s, making further development

completely new and set new standards of efficiency for such small units, mainly as a result of their innovative mixed flow turbine. In the years that followed, the RR..1



Increase in RR turbocharger efficiency



RR 153 turbocharger compressor wheel, with backswept blades.

necessary. In 1981, Brown Boveri introduced the RR 153. This had fewer components than the RR 150, was 20% lighter, and featured a 25% increase in airflow plus higher efficiency. The turbine had a profiled nozzle ring, but was otherwise practically unaltered. The RR 153's new compressor wheel, with backswept blades, represented a major step forward.

The introduction of the RR..1 generation in 1985 marked another breakthrough. These turbochargers were

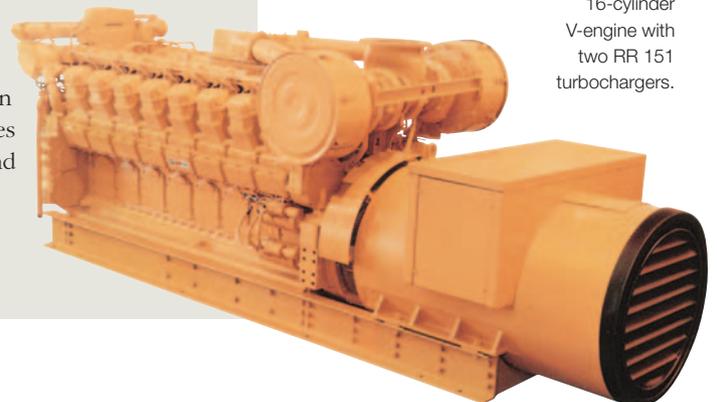
contributed to the popularity of the high-speed engine in applications ranging from emergency gensets through marine propulsion to off-highway vehicles. Designed for an engine output range of about 500 to 1,800 kW, the RR..1 can also take much of the credit for the widespread use of turbochargers on gas engines in Europe and in the USA.

### Shipbuilding crises

The boom in the turbocharger business was still holding firm in the early 1970s, thanks mainly to the strong performance of the market for main and auxiliary marine diesel engines. Then, in 1973, oil prices per barrel quadrupled and shipbuilding collapsed. Within a short space of time, whole fleets of ships were being mothballed.

Economic forecasts in the mid-1970s were speculative, to say the least. Oil prices continued to rise and fluctuations in international exchange rates took their toll. Nevertheless, by 1980 world trade had begun to recover and since fewer new vessels were being built each year most of the laid-up vessels were being returned to service. It was not to last. An economic downturn at the beginning of the 1980s reversed the trend. "Three years worth" of ships had to be laid up again.

Japan and several newly developed countries like South Korea, Singapore and Taiwan not only managed to avoid the downturn, their economies actually boomed at this time. Western Europe's share of the shipbuilding industry was shrinking again just as the Asian shipbuilders', particularly South Korea's, was increasing. One consolation for the European shipyards was that they were building mainly high-value, specialized vessels with stronger engines.



Caterpillar 3500  
16-cylinder  
V-engine with  
two RR 151  
turbochargers.



This Silja Line ferry was typical of the specialized vessels being built by European shipyards after mid-1970. Its four Wärtsilä-Pielstick 12 PC and three Wärtsilä-Vasa 6R32 diesel engines were fitted with VTR 321 and VTR 251 turbochargers, respectively.

### The effect on the two-stroke market ...

The oil crisis created an entirely new situation in the two-stroke market. Suddenly, fuel costs made up 30%, and no longer just 10%, of a ship's total running costs. Overall propulsion efficiency became as important as engine efficiency, and highly supercharged, slow-running two-stroke engines were seen as the solution. The market, rejecting cross-scavenged engines, turned to uniflow scavenging. Two-stroke engine efficiency increased dramatically.

### ... and in the four-stroke sector

There were parallel developments in the field of four-stroke medium-speed engines. Although these are not so dependent on high turbocharger efficiency, highly turbocharged four-stroke engines still offered some decisive economic

advantages. One major breakthrough was that they could now be built for use with heavy fuel oil. The greater importance of technology in this business also meant that Brown Boveri continued to collaborate closely with the four-stroke engine-builders.

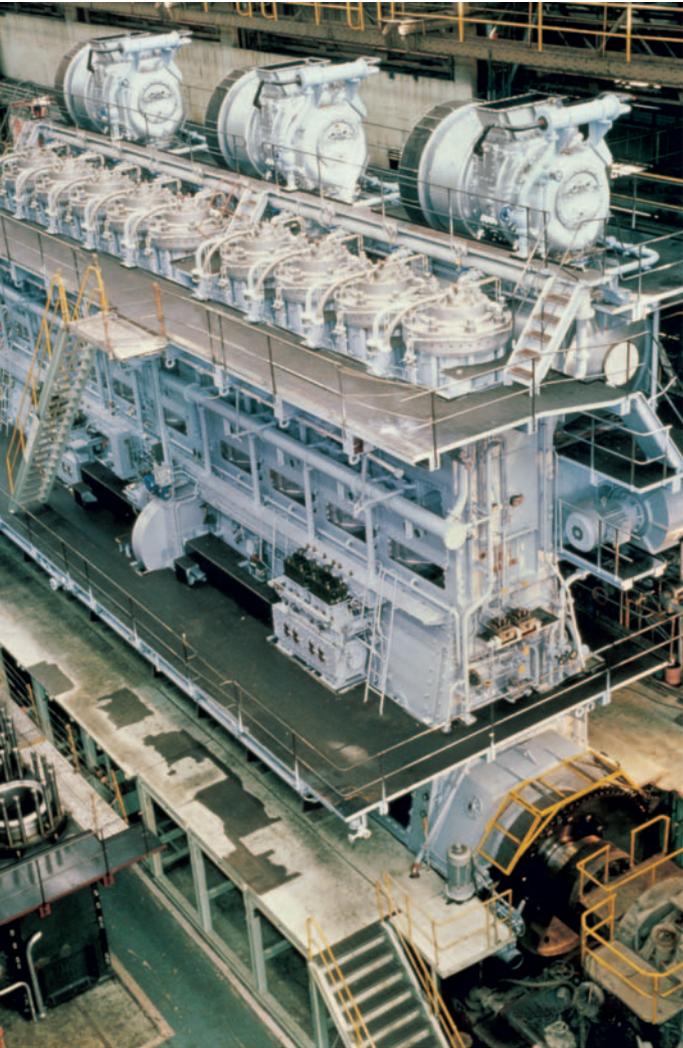
### The VTR/VTC...4

By the mid-1970s the VTR..1 had taken the original VTR concept as far as it could go. A new turbocharger range with completely re-designed components was on the drawing board. Freed from the constraints imposed by the first VTR, the VTR..4 ramped up efficiency by five percent and more, and increased the peak compressor pressure ratio to over 4. Following prototype tests on a Sulzer four-stroke engine, the VTR..4 was introduced to the trade press in November 1978 and launched on the market the year after.

### NTC power turbine

The NTC power turbine was developed in the 1980s to take advantage of the high efficiency of the VTR..4 turbochargers. Surplus exhaust gas (about 10%) was diverted to the turbine, which was coupled through an integral "power take-off" gear to the engine crankshaft. Sulzer adopted the power turbine for its RTA series of two-stroke engines; later SEMT was the first company to use it on a four-stroke engine (SEMT-Pielstick 4PC4.2).

By 1996, the power turbine was no longer being offered. Turbocharger performance was meanwhile being utilized more fully within the engines themselves due to the rise in mean effective and maximum cylinder pressures.



Sulzer 32,400 horsepower 9 RLA90 two-stroke diesel engine with three VTR 714 turbochargers, manufactured by IHI, Tokyo.

Introduction of the VTR..4 provided the impetus for new developments in diesel engine construction. By raising the overall efficiency of turbochargers used with two-stroke engines from 60–62% to 65–68%, it contributed to the spectacular rise in thermal full-load efficiency of large engines at this time from 38–40% to peak values of 44–46%.

In 1980 a compact version featuring many of the VTR..4 turbocharger's components (however with internal plain bearings) came onto the market. Denoted VTC..4, it paved the way for Brown Boveri's collaboration with Caterpillar in the USA and also helped the company become a supplier to British Rail at the end of the 1980s.

In 1984 the efficiency of the VTR..4 was raised again. The VTR..4A managed peaks of 70 percent, largely thanks to improvements to the inducer wheel made possible by "three-dimensional" manufacturing.

#### Uncooled VTR..4 turbochargers

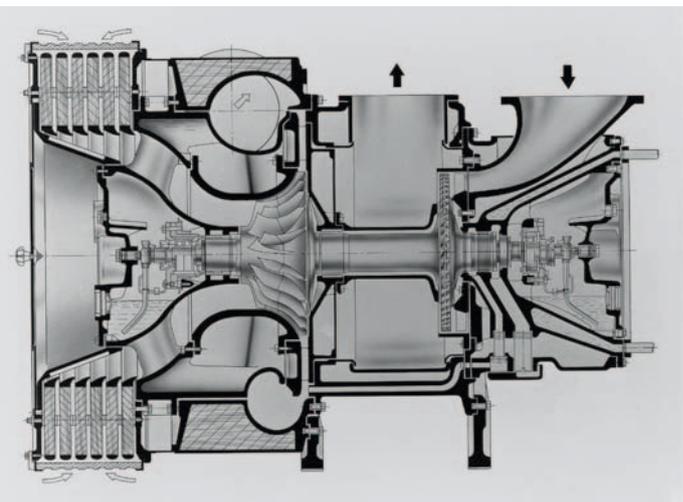
The original VTR..4 had been designed with a traditional water-cooled gas housing. All the old problems with gas housing corrosion

#### VTC..4 turbochargers

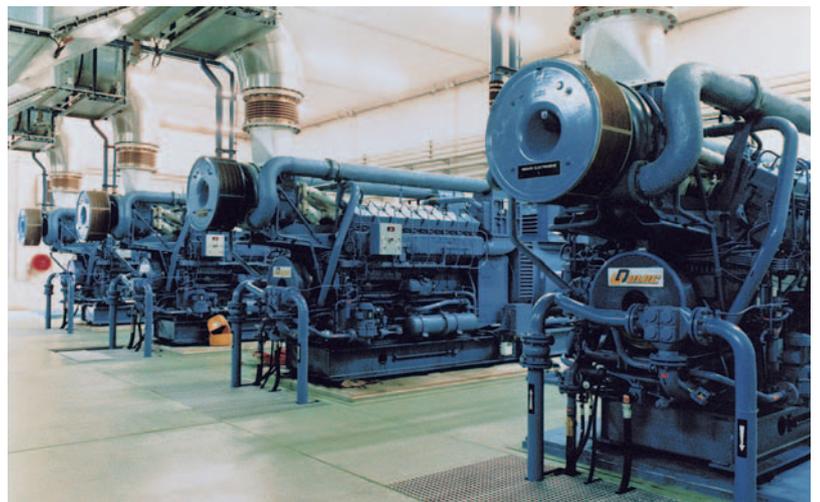
VTC..4 turbochargers were successfully introduced to the market in the 1980s, with the VTC 254, launched in 1985, quickly becoming the standard choice for Caterpillar's then new 3600 diesel and gas engines.

The VTC..4 was also in demand in the Indian railway market in the second half of the 1980s, when the VTC304 was successfully tested on an ALCO 16-cylinder 251 engine. More recently, Dalian Locomotive & Rolling Stock Works (DLRW) of China ordered VTC 254 turbochargers in 2003 for its DF11G high-speed diesel locomotives.

had meanwhile been solved, partly due to the rise in two-stroke engine output, which had pushed up the exhaust gas temperatures. When the oil crisis hit in the mid-1970s, however, ships reduced their speed, so that engine outputs and exhaust gas temperatures fell sharply. Housing corrosion became a potential problem again, especially as poorer, high-



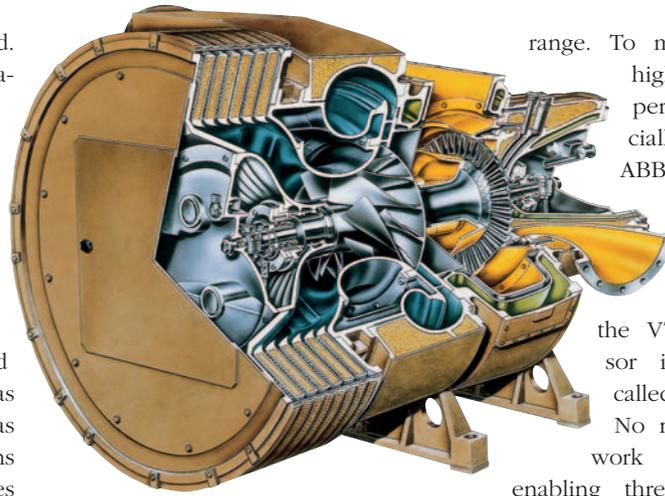
Section through an uncooled VTR..4 turbocharger.



VTC..4 turbochargers on four-stroke engines in a stationary power plant.

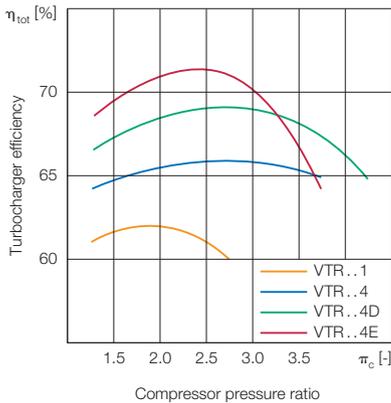
sulphur fuels were also being used. The reduced turbine outlet temperature was also a cause for concern. The market began once again to show an interest in “uncooled” turbochargers.

Brown Boveri initiated a development project that neatly solved the problem of separating the external, supporting gas housing (which had to remain cool) from the hot gas channels. This solution, which was also suitable for the applications planned for four-stroke engines (with higher exhaust gas temperatures), was retained in later versions of the VTR, such as the VTR..4E.



High-efficiency VTR..4E turbocharger, with external bearings.

range. To meet demand for higher turbocharger performance, especially by MAN B&W, ABB decided to combine the high-efficiency turbine of the VTR..4E with the VTR..4P compressor in a new type called the VTR..4D. No new development work was necessary, enabling three sizes of the VTR..4D to be launched on the market in 1994 and 1995.



Rise in peak efficiency of BBC turbochargers.

reduced so much that pressure ratios of up to 4.7 could be obtained with an aluminium alloy impeller. Thanks to the high boost pressures achieved with this turbocharger (4.5 at full load and 5 at overload), four-stroke, medium-speed engines could utilize their potential for higher mean effective pressures with a single-stage turbocharging system.

It was becoming clear in the early 1990s that development of the present turbocharger generation was reaching its limits, and that it would not always be possible to fulfil the market requirements with the current



One of the first series-produced VTR304P turbochargers was fitted to a type BR6 engine from Ulstein Bergen.

## The VTR..4E/4P/4D

Further development of the VTR..4 turbocharger continued well into the 1990s, producing peak efficiencies close to 75% with the VTR..4E, launched in 1989, and pressure ratios of more than 4 with the VTR..4P, that went onto the market in 1991.

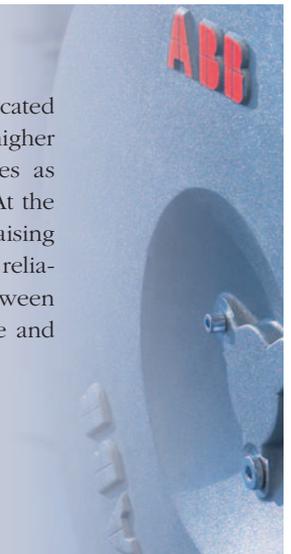
In each case, the compressor played a key role in the improved performance. Five-axis milling now made it possible to machine large compressor wheels in one piece and also to optimize their three-dimensional shape. The stresses in the compressor wheel of the VTR..4P were

## Change of name

In 1988 ASEA and BBC merged to form ABB. In accordance with the new company's policy of decentralization, ABB Turbo Systems Ltd was set up in the following year to handle the turbocharger business. The worldwide reputation of the BBC turbocharger passed to the ABB turbocharger.

This reputation was soon to be enhanced with a completely new range of turbochargers. Advanced engines were under development

that required more sophisticated turbochargers capable of higher pressure ratios and flow rates as well as increased efficiency. At the same time, end-users were raising their expectations of high reliability, with longer times between overhauls, easier maintenance and an extended lifetime.



## THE MODERN ERA BEGINS

### The TPS/TPL generation leap

In the early 1990s ABB began to develop a new generation of more compact, lighter high-performance turbochargers as successors to the VTR, VTC and RR. Two new families, the TPS for engine ratings from 500 to 3,000 kW, and the TPL for engine applications with outputs from 2,500 kW up to the highest in the business, were designed from the ground up.

Extensive market studies in the mid-1980s had shown that new, benchmark turbochargers would be needed in all the main areas of business. The markets were also changing. The engine-building industry was consolidating. Fewer, but stronger and more innovative companies were developing new generations of diesel and gas engines. For these engines, new standards of turbocharger performance and reliability were essential.

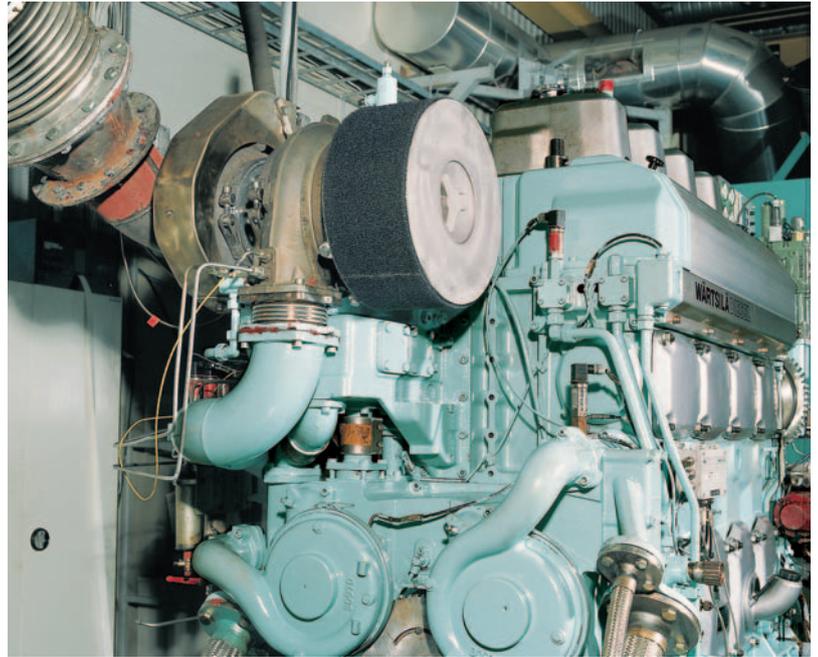
### TPS turbochargers

Since the launch of the first RR turbochargers in 1968, the high- and medium-speed diesel and gas engine market had been changing fast. ABB



TPS...-E compressor and turbine.

therefore set about developing the TPS – an entirely new generation of small heavy-duty turbochargers that would cater to the foreseeable needs of future engines in the ranges currently covered by the small VTR, VTC and RR turbochargers.



TPS 48 qualification test on a Wärtsilä 4L20B engine.

### New compressors and a new turbine

Fast-changing market conditions and compressor design potential dictated a fast pace for development work around the mid-1990s. It was concluded that the demands of the advanced engines being built at the time would best be met by two different compressors. The decision was therefore taken to introduce the TPS turbocharger with the new D-compressor for pressure ratios up to 4.2 at maximum continuous rating, and the equally new E-compressor for pressure ratios up to 4.5. These compressors have splitter bladed impellers for high airflow rates and backswept blades at the exit for a wide compressor map. Peak compressor efficiencies of more than 84% can be achieved.

For the TPS range, ABB developed a new mixed flow turbine and nozzle ring with different areas per trim for part-load and full-load optimization. The turbine concept is suitable for constant pressure as well as pulse turbocharging. A specially

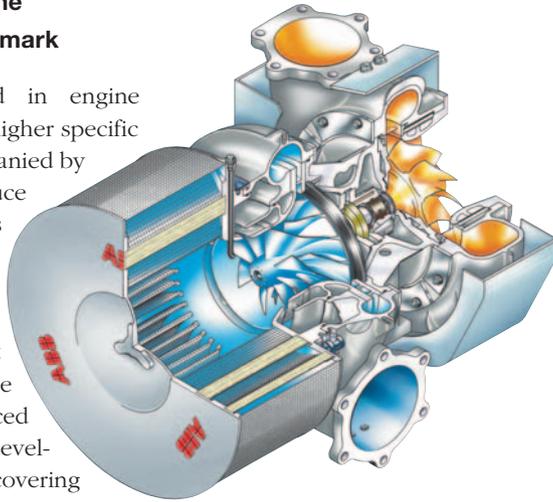
coated version of the nozzle ring is available for applications in which low-quality fuel is used. The TPS also has a new oil-cooled bearing casing, enabling it to be used for applications with turbine inlet temperatures of up to 680 °C at constant load.

Testing and prototype trials of the four TPS sizes – TPS 48, 52, 57 and 61 – took place on various customers' engines. Testing of the larger TPS 61D, for example, included trial runs in 1997 on an LH41LA diesel engine from Hanshin rated at 3,500 horsepower and 235 rev/min. Hanshin had designed this six-cylinder, four-stroke engine for installation on feeder ships in the Japanese merchant marine, where it would mostly run on heavy fuel.

## The TPS...-F raises the pressure ratio benchmark

The continuing trend in engine development towards higher specific power is being accompanied by an urgent need to reduce emissions, and this has led to most modern engines having some version of the Miller cycle incorporated in it (see panel). For these and future advanced engines, ABB has developed three new series covering the engine power range of 500 to 3,300 kW. The first, denoted TPS...-F33, was introduced to the market in 2000/2001, followed two years later by TPS...-F32, and in 2004 by TPS...-F31. Based on the TPS...-D/E platform, they achieve full-load pressure ratios of up to 4.75, 5.0 and 5.2, respectively, with an aluminium-alloy compressor wheel.

The new compressors developed for the TPS...-F series allow a 15% increase in the flow rates that can be covered by a given impeller size. This was achieved by adopting the same approach to the compressor's design as for the TPL. Instead of conventional "trimming", whereby the blade size is adjusted to obtain the required flow rates, the volume flow area for each turbocharger was



TPS...-F turbocharger

divided into three so-called design areas. Different, individual performance targets were then formulated for these areas to ensure an optimal compressor design within the physical limits of each one.

The TPS...-F was also the first ABB turbocharger to feature recirculation technology – a bleed slot around the compressor wheel which, by improving the flow field, increases the surge margin. The effect of this slot is to enlarge the map width without compromising the compressor's high efficiency.

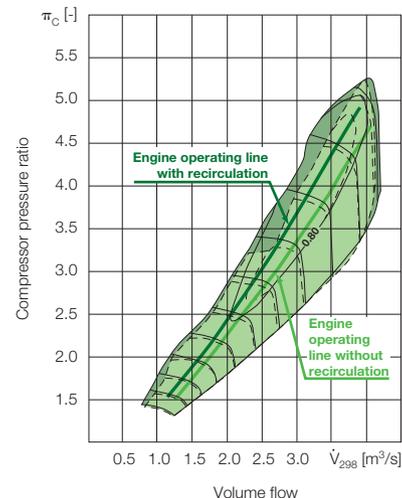
## Engine emissions and Miller timing

Diesel engine development in the first years of the new millennium has focused on higher brake mean effective pressures and lower fuel consumption. Engine builders and end-users alike are, however, also having to consider the ramifications of new emissions regulations that are on the way. To comply with the tougher legislation, turbochargers offering even higher compressor pressure ratios will be needed.

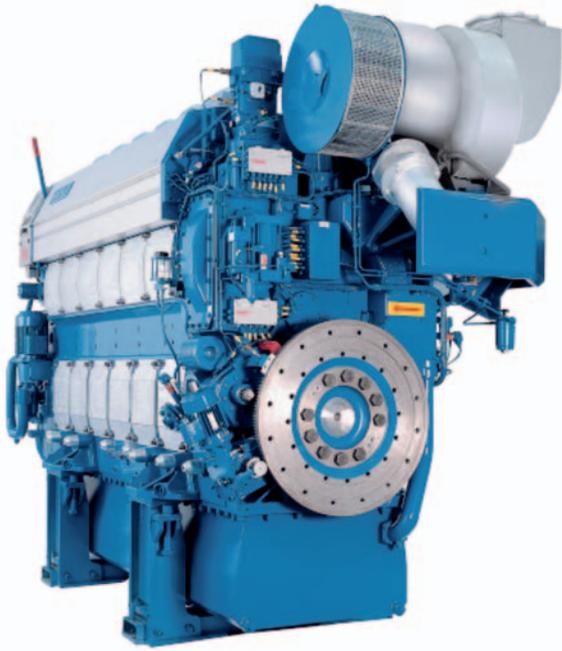
An issue that is inseparable from the industry's efforts to reduce engine emissions is "Miller timing", i. e. early or late closing of the inlet valve. Providing the engine output and boost pressure are constant, the cylinder filling is then reduced and the pressure and temperature in the cylinders remain lower throughout the process. This is one of the few measures that can be applied in an internal combustion engine to simultaneously reduce  $\text{NO}_x$  emissions and fuel consumption. A considerably higher boost pressure is, however, needed to reduce the temperature in the engine's cylinders during the Miller process.



TPS...-F33 compressor wheel with bleed slot in the wall insert for flow recirculation.



Improved compressor map achieved with flow recirculation.



TPS 57-F33 turbocharger on a Wärtsilä W6L26 diesel engine.

**TPS with variable turbine geometry**

Developments in the diesel and gas engine markets also led in the mid-1990s to a version of the TPS with variable turbine geometry (VTG).

One reason was the increasing popularity of single-pipe exhaust systems for diesel engines. When conventional turbochargers are used with these, part-load operation tends to be difficult, load response is poor and smoke and particle emissions can be high.

Gas engine performance had also been progressing impressively due to increased efficiency and bmep, high altitude capability and controlled air-to-fuel ratios. However, it was not possible to simply use conventional turbochargers with these engines, either. Solutions ranged from installing a waste gate or throttle mechanism to special matching of the turbocharger, but each had its drawbacks. Demand for a turbocharger that would solve the problem was especially strong in the 1,000 kW to 3,000 kW market segment.

An “adjustable” turbocharger was seen to be the ideal solution for both types of engine. Apart from eliminating the losses occurring with a waste gate, a turbocharger with VTG is more flexible in applications with changing operating or ambient conditions. Precise control of the air-to-

fuel ratio, so-called “lambda regulation”, is achieved with an innovative nozzle ring that enables the effective turbine area to be varied without any significant drop in turbine efficiency. The clearances for the movable nozzle blades are reduced almost to zero by springs that push the blades against the opposing casing wall.

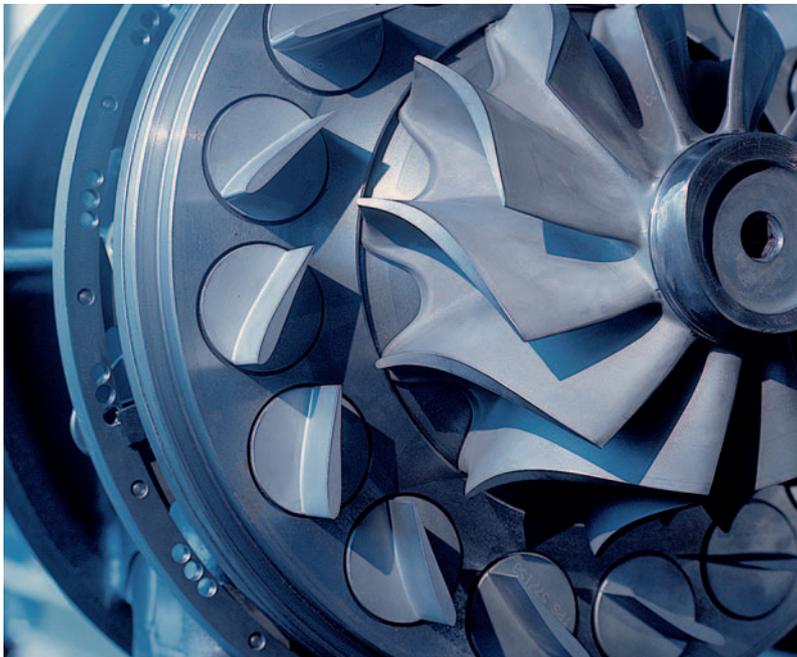
A turbocharger with VTG was successfully tested on a three-cylinder experimental gas engine at Ulstein Bergen in Norway at the end of 1996, followed some months later by first field tests with a TPS 57D-VTG on a gas engine operating in a commercial power plant. These field tests showed a significant gain in engine efficiency, as a result of which 26 TPS 57-VTG units were delivered to two Spanish power plants with 18-cylinder Ulstein Bergen engines in 1999.

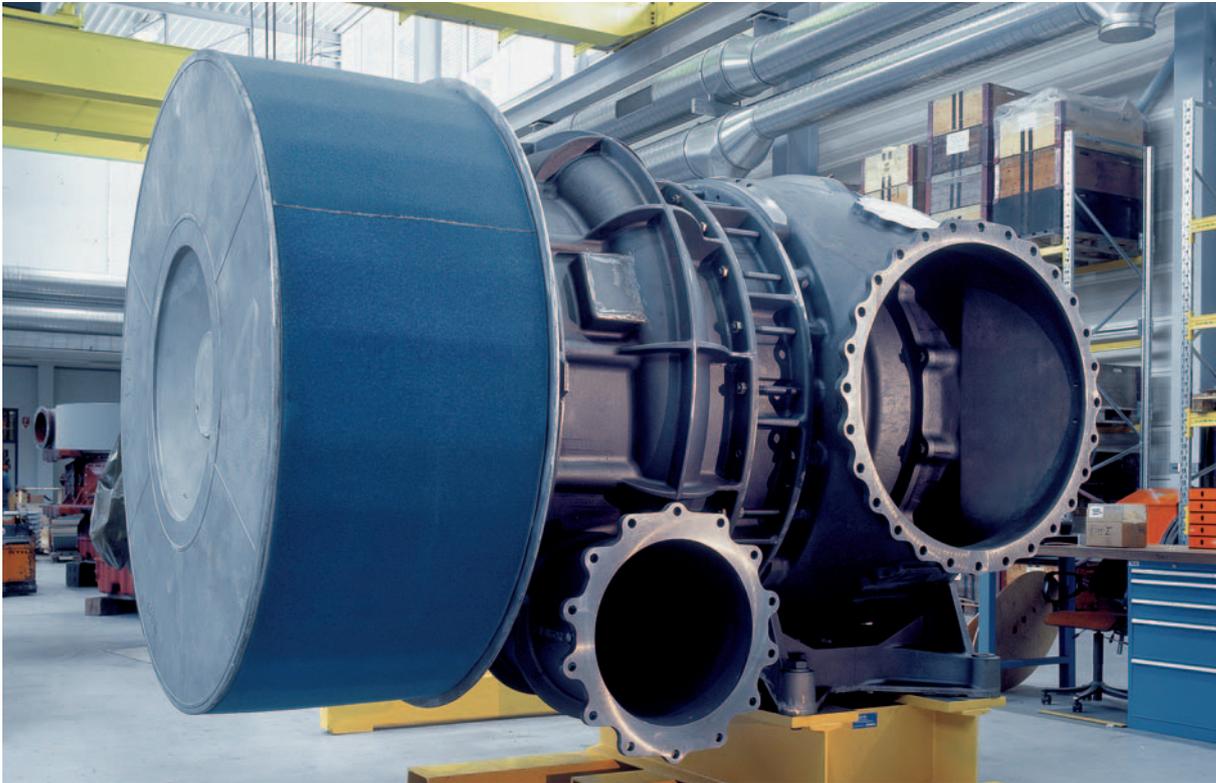
**The TPL debuts**

The TPL concept was developed as a platform for large modern diesel and gas engines with outputs from 2,500 kW upwards. For this family, ABB’s engineers designed a new axial turbine family with the blade lengths and stagger angles needed to cover the entire volume flow range. The bearing assembly is also new. Its axial thrust bearing has a free-floating disc with profiles on both sides, rotating at about half the rotor speed. The thick oil films this produces provide extra-high resistance to wear. The non-rotating bearing bushes are centered in a squeeze oil damper. As a result of this new technology the bearing lifetime has been doubled.

Two new, different centrifugal compressor stages were also developed to ensure the full range of pressure ratios required by modern turbocharged engines. The design of the TPL compressor wheel, like that of the TPS wheel, is aerodynamically optimized, with a splitter bladed

Variable nozzle ring of a TPS 57 VTG turbocharger.





TPL80 turbocharger

impeller for high airflow rates as well as backswept blades at the impeller exit for a wide compressor map. New F-generation compressor stages were developed for the TPL that allow the efficiency, maximum pressure ratio and specific swallowing capacity to all be significantly increased, the latter by as much as 15% for a pressure ratio of 4.5. A large range of turbine inlet casings, including optional waste gate connections, was also developed to enable the TPL to be used with all turbocharging systems currently in use.

### First TPL prototypes and field tests

A very extensive qualification program and performance measurements in the labs provided hard evidence of the TPL's capabilities, but experience with the new series still had to be gained in actual engine operation. Between 1996 and 1999, TPL turbochargers were subse-

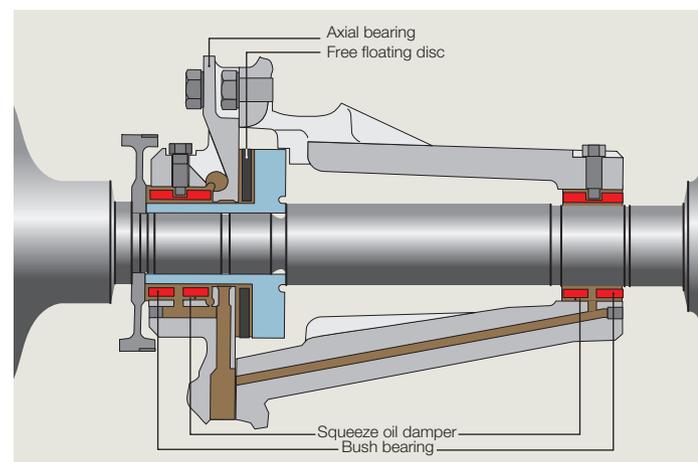
quently installed on various engines, including the Wärtsilä 12V38 and Caterpillar MaK 16M32. A special highlight was the turbocharging of the then world's most powerful four-stroke medium-speed engine, the Wärtsilä 6L64, with the first TPL80-A to be produced. Experimental runs on established engines also took place during this period, as did field tests in four- and two-stroke marine applications on board different vessels.

In addition to these engine tests, field tests with the TPL were started towards the end of 1996. On the ferry *MS Polonia* the original VTR354 on the Wärtsilä 6L38 engine was replaced by a TPL69 to gain long-term experience and provide a statistical base for component lifetime predictions. Further field tests, for example with two TPL73 units in a four-stroke marine application and with the larger frame sizes in several two-stroke applications, took place throughout 1997 and 1998.

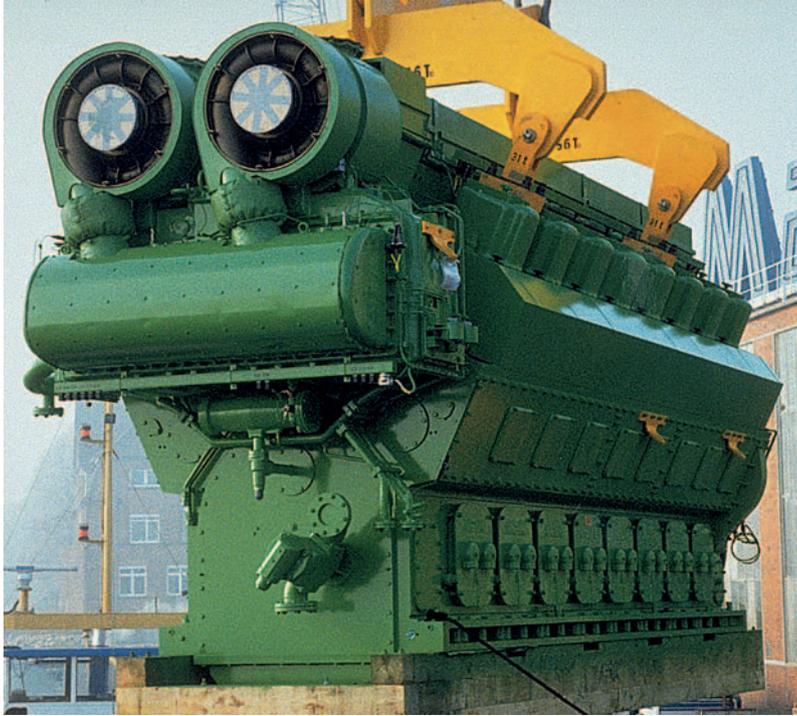
### The TPL...-A is launched

The first of the new-generation TPL turbochargers to be introduced to the market was the TPL...-A. This series was developed for modern medium-to-large four-stroke diesel and gas engines and became a runaway success soon after its market launch in 1996. Applications range from main and auxiliary engines for small and large vessels, respectively, to

TPL bearing assembly



Caterpillar MaK 16M32 diesel engine with two TPL 65-D turbochargers.



stationary diesel and gas power plants.

Two compressor designs are available. One offers a pressure ratio of 4.2 with high specific flow capacities and high efficiencies; the other is for applications requiring pressure ratios up to 4.5. Peak turbocharger efficiencies of 68% and higher can be achieved.

The larger TPL...-A turbines have lacing wire through their blading to damp the vibration produced by the pulse turbocharging systems of many of the four-stroke engines in use today. For the smaller sizes, ABB developed a single-piece, integral turbine.

In 1999, the TPL...-A played a key role in, among other projects, the

development of ALSTOM Engines Mirrlees Blackstone's 18-cylinder MB430M engine, at the time one of the largest four-stroke diesel engines ever built in the UK. The two TPL 77-A30 units for the engine were also the largest frame sizes to be utilized up until that time. ABB also provided Mirrlees Blackstone with engineering support in the form of predictive engine performance simulation results for this application.

Five frame sizes of the TPL...-A are in series production, covering the requirements of modern four-stroke diesel and gas engines with outputs of 2,500 kW to 12,500 kW.

### The TPL...-B takes on the two-stroke market

Launched in 1999, the TPL...-B turbochargers were developed primarily for large, modern two-stroke marine diesel engines with outputs from 5,000 to 25,000 kW per turbocharger. Worldwide demand for larger ocean-going vessels was strong and new, more powerful engines for them were under development.

Since the constant-pressure turbocharging systems used by two-stroke engines produce only weak exhaust pulses, inlet conditions for the TPL...-B turbine are constant. There is therefore no need for damping wire – a feature that contributes two to three percentage points to the already high turbine efficiency. Robustness is nevertheless ensured by the turbine's "wide chord" design with fewer, but stronger blades.

To further increase the volume flow and allow optimized matching to the engine applications, ABB's engineers enlarged the diameter of the TPL...-B's compressors. Thanks to the splitter bladed impeller design and backswept blades, peak efficiencies of more than 87% are obtainable.

Buquebus Line's fast ferry Catalonia, with eight TPL 65-A turbochargers on its four Caterpillar 3618 engines, broke the record for the quickest surface transatlantic crossing in 1998.



### TPR – a new railroad turbocharger

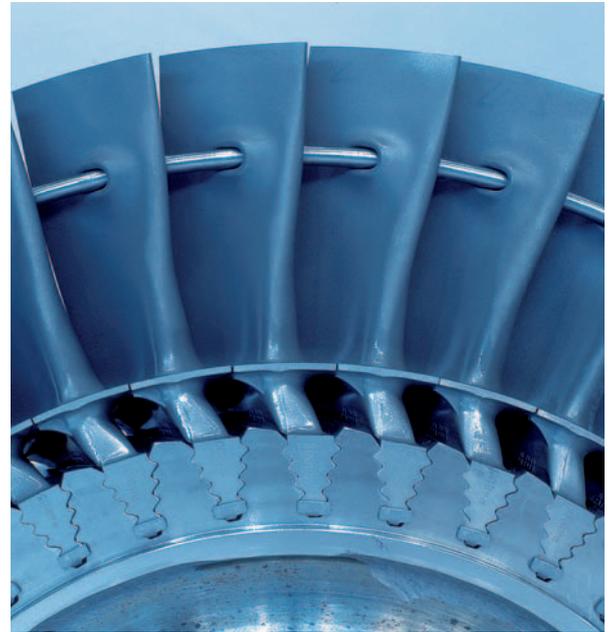
A new railroad turbocharger, the TPR, was launched in 2002 to meet demand for extra power and robustness as well as better environmental performance in traction applications. Based on the TPL design, it features an integral high-efficiency turbine without lacing wire, an improved single-entry gas inlet casing and unique foot fixation. Release of this turbocharger was preceded by 50,000 hours of

field tests, carried out by Indian Railways with ten TPR61 units between 2001 and 2002.

Considerable interest in the TPR61 has also been shown by China's Dalian Locomotive & Rolling Stock Works (DLRW), after earlier successful testing by DLRW of the TPL61-A turbocharger on its 16-cylinder V240ZJE and 12-cylinder V280ZJ engines.

Maintenance and service considerations were also high on the agenda during development of the TPL...-B. Special attention was paid, for

example, to the dismantling of the bearings, rotor, nozzle ring and turbine diffuser, all of which can be removed from the compressor side.



TPL...-A turbine blading with lacing wire.

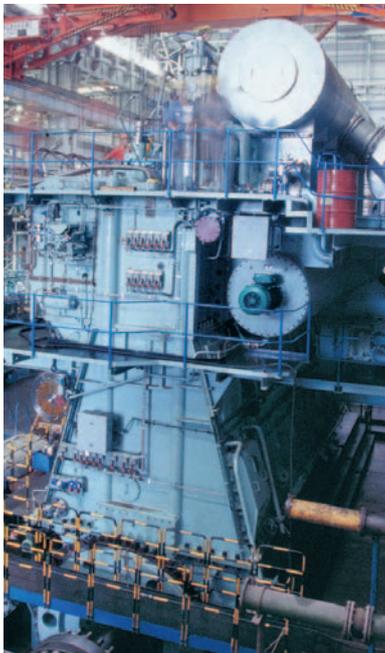


TPL...-B turbochargers were mainly developed for powerful, modern two-stroke engines on large container ships.

TPL91-B turbocharger



Test run with a TPL85-B on a MAN B&W 6S70MC engine built under licence by HHM (Hudong Heavy Machinery Co.) of China.



Initially, four frame sizes were considered to be enough to satisfy the needs of the market in the medium term. The decision to develop a fifth, even more powerful turbocharger (TPL91) took account of shipbuilders' plans towards the end of the millennium to build post-Panamax container vessels. ABB's engineers were challenged once more: The turbocharger was to be designed for use on engines with power outputs in excess of 100,000 brake horsepower and yet still be compact. This was achieved by designing a new, shorter rotor and a new constant-pressure turbine and diffuser. Mounting of the engine was also made easier by integrating the oil tank and the venting pipe connection. In November 2004, three TPL91-B units were installed on the

world's most powerful electronically controlled 12K98ME MAN B&W engine at Hyundai Heavy Industries in Korea for official testing under full load (93,360 brake horsepower).

**TPL...-C – catering to future four-stroke applications**

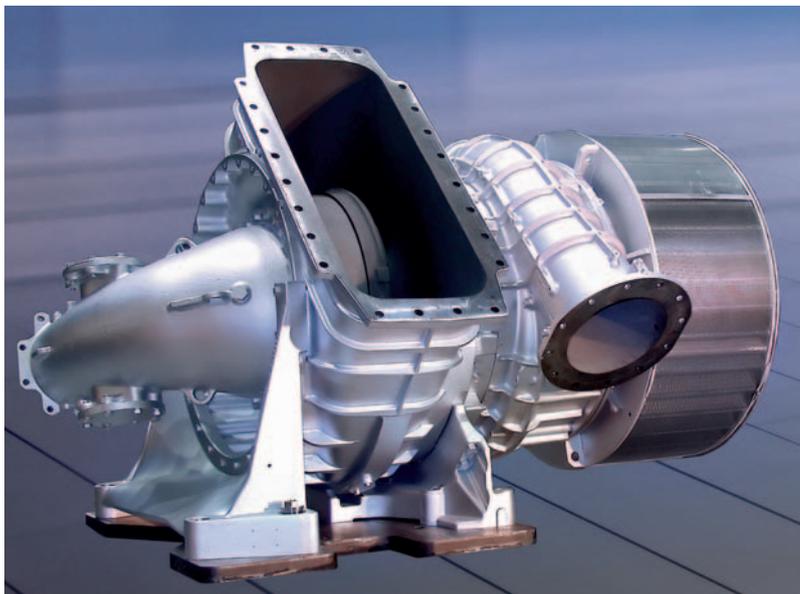
While the TPL...-A/B turbochargers meet the requirements of most engine applications, the four-stroke market continues to push for more output and lower emissions. ABB has made use of the TPL's modular platform to introduce new components and innovative technologies in a new series – the TPL...-C – that caters especially to this future market. The factors driving the develop-

ment of this brand-new turbocharger were therefore, besides economic and operational considerations, the rules set by bodies such as the International Maritime Organization (IMO) and World Bank calling for a reduction in  $\text{NO}_x$  and particulate emissions. Optimization of the combustion process and the turbocharging system is crucial to this end.

The characteristics of the TPL...-C turbocharger are aligned with the demands of future four-stroke, medium-speed diesel and gas engines in the power range of 3,000 to 10,000 kW per turbocharger. As a result of a market analysis that was carried out, the turbine of the two smaller sizes (TPL67-C and TPL71-C) is designed for quasi-constant pressure as well as pulse-charging systems, and that of the larger TPL76-C for quasi-constant pressure systems. The former turbine therefore has a damping wire, while the latter features ABB's wide chord design. The two compressor stages available for TPL...-C turbochargers are of the same basic design as those for the TPS...-F series, but take full account of the different TPL boundary conditions.

The TPL...-C compressors also feature the same recirculation technology as the TPS...-F compressors. By avoiding strong secondary flows and separations, this also helps to reduce compressor noise, especially at part load. Optional compressor cooling is another special feature of the TPL...-C. This extends the field of application for aluminium alloy wheels, offering an economic alternative to titanium impellers when higher pressure ratios are required.

The TPL...-C booked an early success with Caterpillar's decision in 2004 to install the TPL71-C on the new C version of its German-built MaK M43 six-cylinder, long-stroke, medium-speed engine. Caterpillar has also written TPL...-C turbochargers into the specification for the seven-, eight- and nine-cylinder models.



TPL 76-C turbocharger

## A CENTURY OF PROGRESS

### Looking back

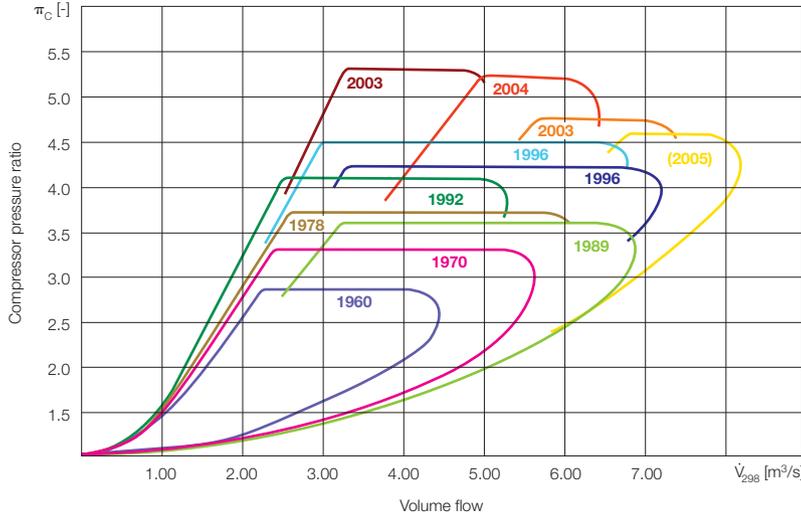
In the 100 years since Buechi's famous first patent, the exhaust gas turbocharger has become indispensable to the diesel and gas engine industry. Investment in research and development over the decades has brought quantum leaps in technology and design. Engineers from different disciplines have brought their innovative genius to bear on the problems that arose, and found solutions that have taken turbocharging steadily forward.

ABB Turbo Systems, through Brown Boveri, was fortunate to have been part of the Buechi Syndicate. Early contact with engine builders all over the world enabled our company to provide engineering support that has been to the general benefit of the industry. And the learning curve has been mutual: Often, it was the field experience reported by customers that spurred our development engineers to redesign and improve key components and processes. Nevertheless, the main driving force has always been the market. Nothing documents this better than the progress demanded, and achieved, in turbocharger performance over the years. Could Alfred Buechi ever have imagined efficiencies of 70% and more, or compressor pressure ratios in excess of 5.2?

### Looking ahead

A proud past is worth nothing if it does not stimulate to do better. It was the commitment to doing better that made first the VTR...0, then the VTR...1, the VTR...4 and the RR such a success. And it is what has made the new TPS and TPL generations their worthy successors. Ever since

Progress in the compressor performance of ABB turbochargers since 1960 (full load, with an aluminium compressor).



high compressor ratios for future high-speed gas engines.

The price of oil, at a level not seen for years, is focusing attention once again on the turbocharger's traditional role as a fuel saver. Market demand for higher boost pressures and efficiencies, plus the need to reduce the environmental impact of marine traffic, will require advanced turbochargers. With its state-of-the-art development, test and production facilities, ABB Turbo Systems is well placed to supply them. One hundred years on, Alfred Buechi's legacy is in good hands.

that very first VT 402 left our Baden factory in 1924, BBC/ABB turbochargers have continued to define the state of the art.

The steady improvement in turbocharger and engine efficiency over the years has always relied on close cooperation between ABB and the leading engine-builders. It is this cooperation that sets the development goals and which will, in all probability, become closer as the demands made on the "turbocharging system", and not just the turbocharger as a component, increase. Adjustable turbocharger components or multi-stage turbocharging are two of the possibilities here.

**New products for a new era**

ABB Turbo Systems is set on continuing the tradition of collaboration with customers and on being the market leader. With products for tomorrow's markets like the TPL65VA – the world's first series turbocharger with axial turbine and variable turbine geometry – or the next generation of the successful TPL...-B series. Also under development is a larger TPL...-C turbocharger and new turbochargers with very

**Note:** The main source of information for the first two sections of this article, "Pioneering era" and "Turbocharging's triumphant march", was "The BBC Turbocharger – A Swiss Success Story" by Ernst Jenny. Sources for the other sections include Turbo Magazine 1990 – 2005, BBC/ABB Review and scientific papers published by CIMAC, ASME and ISME, among others. The author would especially like to thank Esko Laustela, Hansruedi Born and Peter Spengler for reviewing the manuscript.



ABB Turbo Systems' headquarters in Baden.

---

Publisher:  
ABB Turbo Systems Ltd  
Hanspeter Zingg (HZ)

Editor:  
Malcolm Summers

Address:  
P.O. Box  
CH-5401 Baden/Switzerland  
Phone: +41 58 585 77 77  
Fax: +41 58 585 51 44  
[www.abb.com/turbocharging](http://www.abb.com/turbocharging)  
e-mail: [turbomagazine@ch.abb.com](mailto:turbomagazine@ch.abb.com)

Domino Style & Type AG:  
layout, typesetting and electronic publishing

Cover photo:  
Michael Reinhard, Herrliberg, Switzerland

Reprints are permitted subject  
to full acknowledgement.

© 2008 ABB Turbo Systems Ltd, Baden/Switzerland  
All rights reserved

---



**ABB Turbo Systems Ltd**

Bruggerstrasse 71 a

CH-5401 Baden / Switzerland

Phone: +41 58 585 77 77

Fax: +41 58 585 51 44

[www.abb.com/turbocharging](http://www.abb.com/turbocharging)

e-mail: [turbocharging@ch.abb.com](mailto:turbocharging@ch.abb.com)