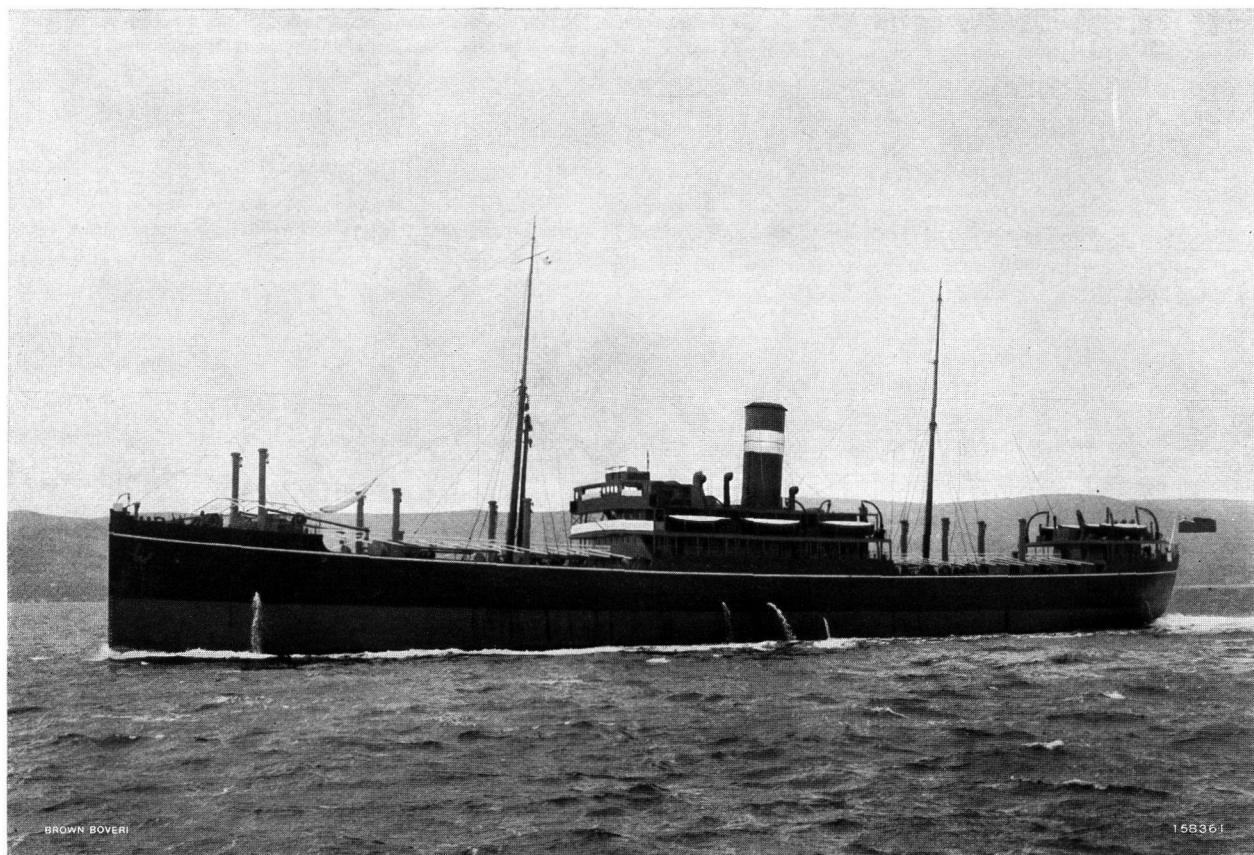


# THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



M. S. "DALGOMA" OF THE BRITISH INDIA STEAM NAVIGATION CO., LTD.

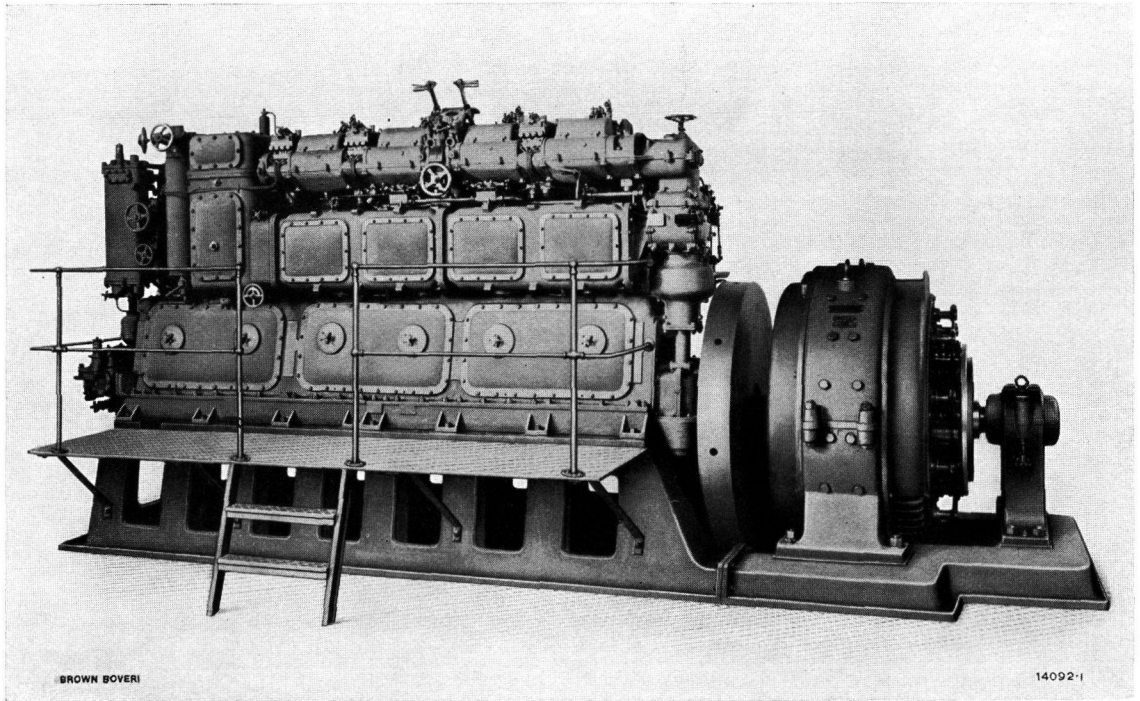
8300 tons, 12 knots, propelled by two Sulzer two-cycle Diesel engines fitted with Brown Boveri centrifugal scavenging blowers.

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# SHIPS' ELECTRICAL EQUIPMENT

CONFORMING TO LLOYD'S REGULATIONS



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300 kW, 210/330 V, 400 r. p. m., driven by a Sulzer two-cycle marine Diesel engine.

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COMPLETE ELECTRICAL EQUIPMENT OF SUBMARINES  
COMPLETE POWER AND LIGHTING INSTALLATIONS FOR SHIPS OF ANY SIZE

# THE BROWN BOVERI REVIEW

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## CENTRIFUGAL SCAVENGING BLOWERS FOR TWO-CYCLE MARINE DIESEL ENGINES.

Decimal index 621.62:621.436 + 623.824.

### I. INTRODUCTION.

Until quite recently, the scavenging of two-cycle Diesel engines was carried out exclusively by means of reciprocating pumps built on to the main engine and driven by the extended crank shaft. Such an arrangement can be seen to the right of the engine cylinders in Fig. 2, which shows a Diesel engine designed and built by Messrs. Sulzer Brothers, Winterthur, Switzerland. The large space required by the cylinder of the scavenging pump will be immediately noticed.

Although reciprocating scavenging pumps are quite satisfactory from the mechanical point of view, they considerably increase the weight and overall length of the engine, and there is also a number of disadvantages inherent to their mode of operation. Amongst these, the following may be mentioned:—

The quantity of scavenging air can only be adjusted to correspond to the prevailing load by means of throttling, except when the engine is running on full load—a method of regulating the air quantity which is by no means economical. Further, no scavenging air is available when starting up the engine, and, owing to the nature of reciprocating pumps, the flow of air is essentially

pulsating, whereas the best results are obtained with a continuous flow.

Taking into consideration all these disadvantages, the scavenging pumps were first of all separated from the main engine, and, more recently, centrifugal blowers have been adopted for supplying the scavenging air. The development of these blowers has been greatly advanced by the employment of two-cycle Diesel engines for ship propulsion, as in this case everything possible has to be done to keep down the weight and dimensions of the machinery, and this has been largely effected by the replacement of reciprocating scavenging pumps by centrifugal blowers. A saving in weight and space is obtained with centrifugal blowers, even if a complete standby set be provided.

In Fig. 1 the relative dimensions of reciprocating pumps and centrifugal blowers for scavenging are clearly

shown, and in Fig. 2 the large dimensions of the reciprocating scavenging pump compared with the remainder of the engine can be seen.

To the best of our knowledge, Messrs. Sulzer Brothers were the first engineers to introduce centrifugal blowers for scavenging purposes, and in 1915 they entrusted Brown, Boveri & Co. with their design and

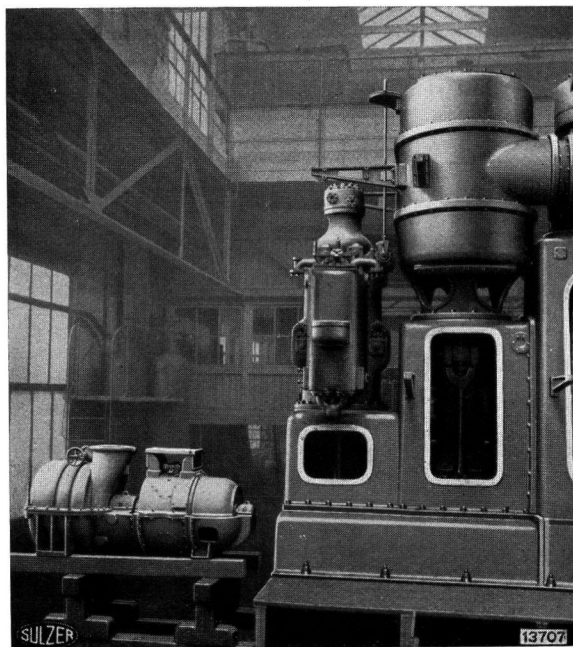


Fig. 1. — Comparison of the size of a reciprocating scavenging pump with that of a centrifugal blower of the same capacity.

manufacture. The very first design, shown in Figs. 3 and 4, gave complete satisfaction, and, up to the present, Brown, Boveri & Co. have supplied more than 60 scavenging blowers. Due to the experience

consumption of lubricating oil is small, no parts are liable to wear, and regulation of the blower over a large range is possible. Owing to the smaller amount of scavenging work necessary, the adoption of centrifugal

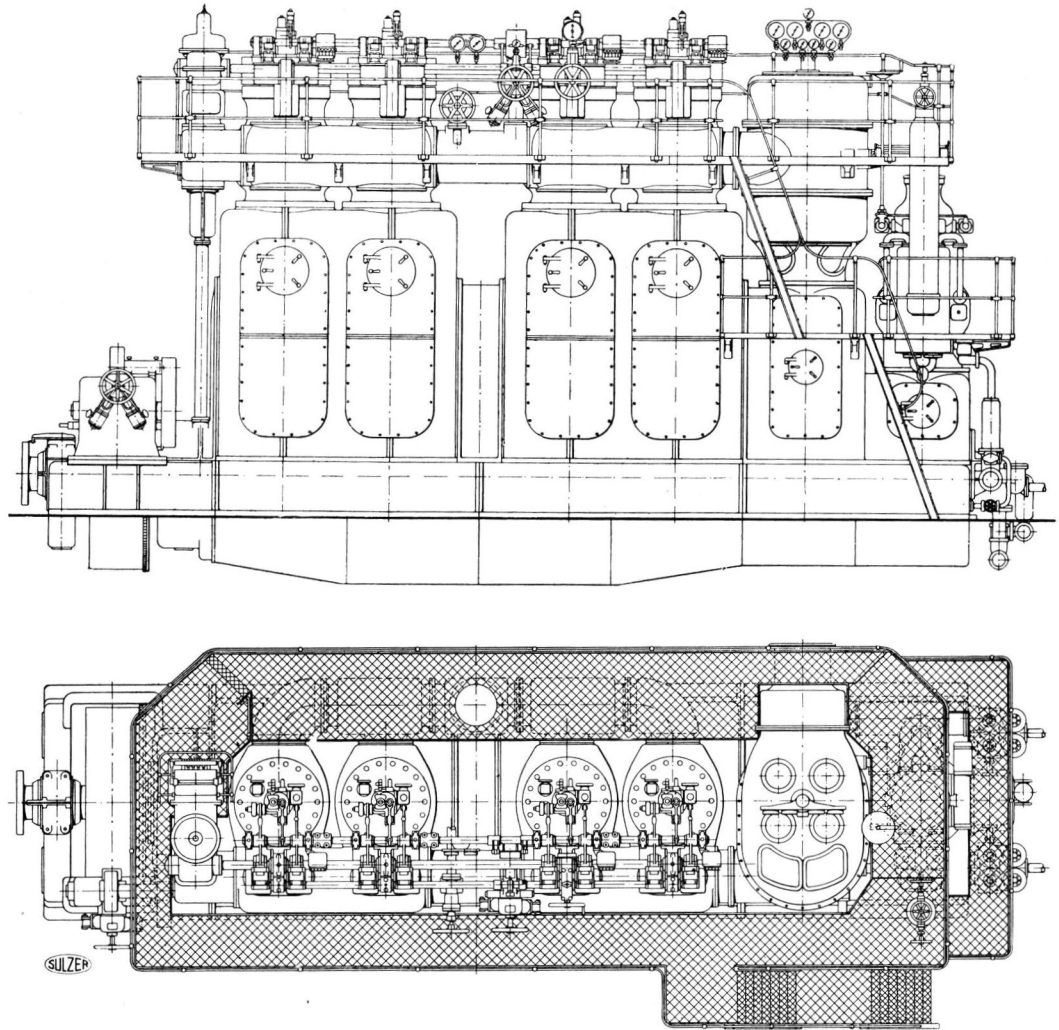


Fig. 2. — Two-cycle marine Diesel engine with built-on scavenging pump, built by Sulzer Brothers, Winterthur (Switzerland).

gained with all these sets in service, many special features have been incorporated in the design, and to-day these blowers have reached a very high degree of perfection.

## II. ADVANTAGES OF CENTRIFUGAL SCAVENGING BLOWERS.

Apart from requiring less space and being lighter than reciprocating scavenging pumps, centrifugal blowers have many other advantages, amongst which the following may be enumerated:— the air flow is free from pulsation, less supervision is required, the

blowers also entails a reduction in fuel consumption. Reciprocating scavenging pumps driven directly by the extended crank shaft require about 6% of the output of the Diesel engine, while, with the employment of separately driven scavenging blowers, this amount naturally becomes available for driving the propeller. In the case of electrically driven blowers, the necessary power is supplied by the existing ship dynamos. Despite the extra demand these dynamos have to meet in driving the blowers, they need not be of a much larger size than if required for driving

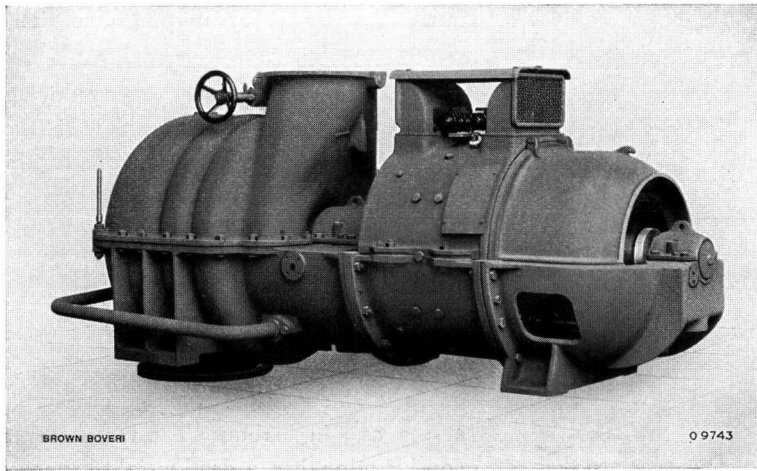


Fig. 3. — Centrifugal scavenging blower of 1915–16 designed for submarines.  
 Indrawn volume of free air 185 m<sup>3</sup>/min. Delivery pressure 1.28 kg/cm<sup>2</sup> abs.  
 Speed 3200 r. p. m.

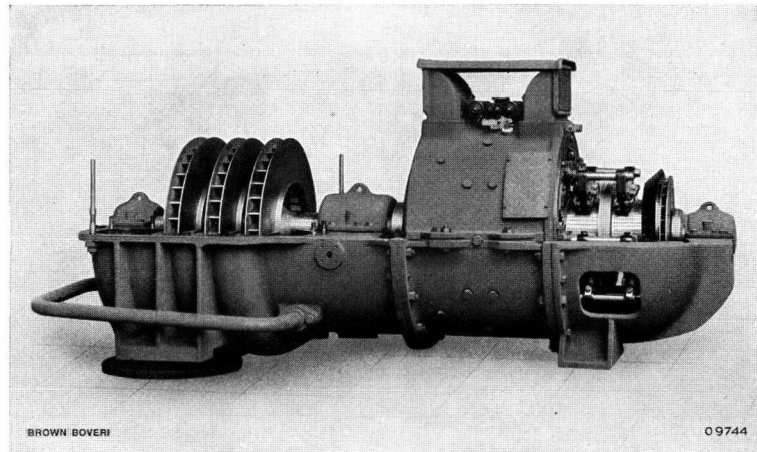


Fig. 4. — The same blower as in Fig. 3, with top half casing removed.

the remaining auxiliary machinery only. This matter is dealt with more fully later on.

Finally, another advantage worth mentioning is that starting and manœuvring are greatly facilitated by the use of independently driven scavenging blowers. This is due to the fact that an ample supply of warm scavenging air is available for the expulsion of the cold air employed for starting the Diesel engine; therefore, the compression can commence at such a temperature that the air will be sufficiently heated at the end of the compression stroke to effect a reliable ignition of the fuel.

### III. NOISE CAUSED BY CENTRIFUGAL BLOWERS.

Occasionally the question arises whether the noise caused by blowers could be a hindrance to their em-

ployment on board ship. Such fears, however, are unfounded if the necessary precautions have been taken to damp the sound. Right from the beginning, special care has been taken to avoid such trouble, and wide and valuable experience has been gained from the first sets made. The development of the Brown Boveri scavenging blower has resulted in the production of a machine which leaves nothing to be desired as regards silent operation. The small, unavoidable noise, due to the air being caught by the blade tips at the suction side of the impeller, can be made practically inaudible on merchant vessels by suitably locating the blower. Where, however, the space for such an arrangement is not available, and where the blower has to take the air directly from the engine room, — e. g. in submarines, — a specially designed silencer is adopted for damping the noise. A blower equipped in this way is shown in Fig. 5. The silencer is fitted to the blower inlet and is also combined with the inlet throttle valve in such a way as to damp the noise caused through suction throttling. (Patents applied for.)

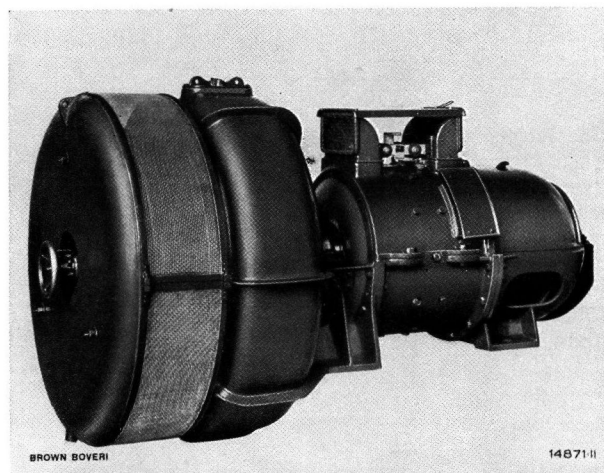


Fig. 5. — Centrifugal scavenging blower with built-on suction silencer for a submarine.  
 Indrawn volume of free air 480 m<sup>3</sup>/min.  
 Delivery pressure 1.28 kg/cm<sup>2</sup> abs. Speed 3800 r. p. m.

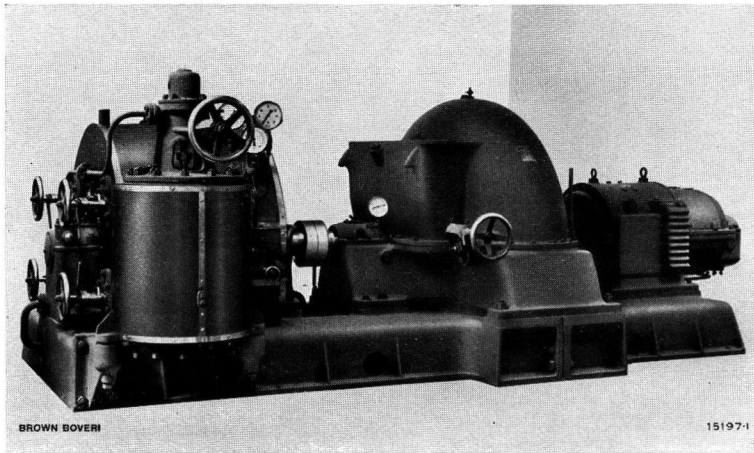


Fig. 6. — Centrifugal scavenging blower, driven by a steam turbine and a direct-current motor, for a motor ship equipped with Still engines.  
 Indrawn volume of free air 340 m<sup>3</sup>/min. Delivery pressure 1.165 kg/cm<sup>2</sup> abs.  
 Speed 3800 r. p. m.

much too large for normal conditions during voyages.

As mentioned above, by employing electrically driven scavenging blowers, the average load can be greatly increased without making it necessary to enlarge the electric generating plant to any appreciable extent. The following table is taken from a paper read by Lieut. Commander L. J. Le Mesurier, on "The Sulzer two-cycle marine engine", which shows the approximate load conditions of the auxiliaries at sea and in harbour. The vessel under consideration has a dead-weight capacity of 10'000 tons, carrying passengers and cargo. The propelling machinery has an output of 6000 S. H. P.

IV. PRIME MOVERS FOR SCAVENGING BLOWERS.

Direct-current motors are generally employed for driving scavenging blowers on board ship. Sometimes, however, steam turbines are used; such is the case where all the remaining auxiliary machinery is driven by steam, a special boiler being provided for the purpose. The steam turbine is also particularly advantageous where the waste heat is made use of as in the Still engine, which operates as a combined internal combustion and steam engine.

Fig. 6 shows a blower set equipped with both steam turbine and direct-current motor as prime movers. This set has been supplied for the first vessel equipped with Still engines. Other details and data of this interesting blower are given at the end of the article.

Wherever the auxiliary machinery is operated by electricity, electric drive of the scavenging blowers has the great advantage of maintaining a practically constant load on the ship's generating plant, which, under such conditions, runs continually in the neighbourhood of full load, and consequently at its best efficiency, both when the ship is in harbour and when at sea. The size of the dynamos is based upon the input necessary for the complete auxiliary machinery (winches, capstans, windlasses, etc.) in operation when the ship is in harbour. Once the vessel is at sea, only a small fraction of the dynamo output is taken by the auxiliaries, and therefore the dynamos are

Auxiliary machinery	At sea	In harbour
Scavenging blowers and cooling-water pumps . . . . .	400 H. P.	—
Steering gear . . . . .	30 H. P.	—
Pumps (bilge, ballast, etc.) . . . . .	50 H. P.	80 H. P.
Lighting and ventilation . . . . .	60 H. P.	50 H. P.
Winches and windlasses . . . . .	—	300 H. P.
Total	540 H. P.	430 H. P.

This system of making use of the same generating plant both for supplying the current to the blower motors when the ship is at sea and for driving

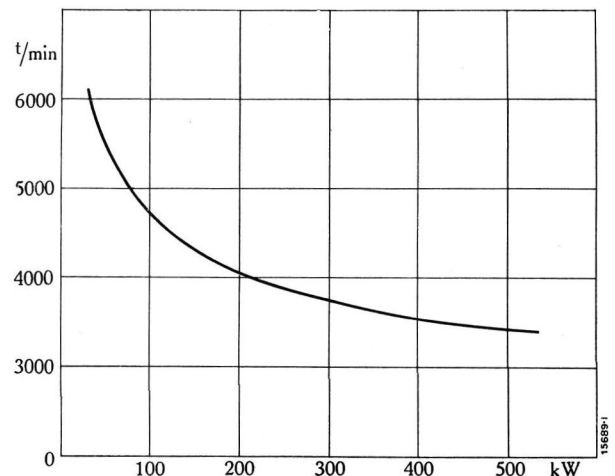


Fig. 7. — Normal speeds of Brown Boveri high-speed, direct-current motors for 220 V.

the auxiliaries, such as winches, etc., which only come into operation in harbour, i. e. when the main engines are not running, has been patented by Messrs. Sulzer Brothers, Winterthur, Switzerland.

According to the pressure and volume conditions, speeds between 2500 and 4500 r. p. m. are used for centrifugal scavenging blowers. Although such speeds are quite common for steam turbines, they can only be obtained from direct-current motors of special design. A geared drive is not desirable, since such an arrangement is not only more expensive but also adds considerably to the space and weight of the blower set. The development of centrifugal scavenging blowers has

been materially improved by the progress achieved with Brown Boveri high-speed direct-current motors. The normal speeds obtained at a pressure of 220 volts—which is almost universal in marine installations—by high-speed direct-current motors built by Brown, Boveri & Co. are shown in Fig. 7. Further particulars are given later of the notable features incorporated in the design of these machines.

V. ARRANGEMENT OF CENTRIFUGAL SCAVENGING BLOWERS ON BOARD SHIP.

The number and arrangement of centrifugal scavenging blowers on board ship is generally chosen in such

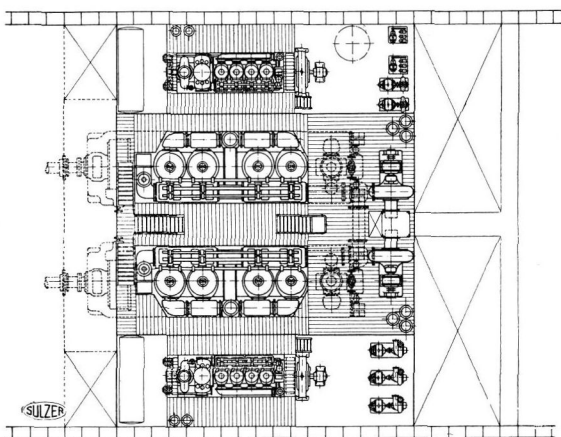
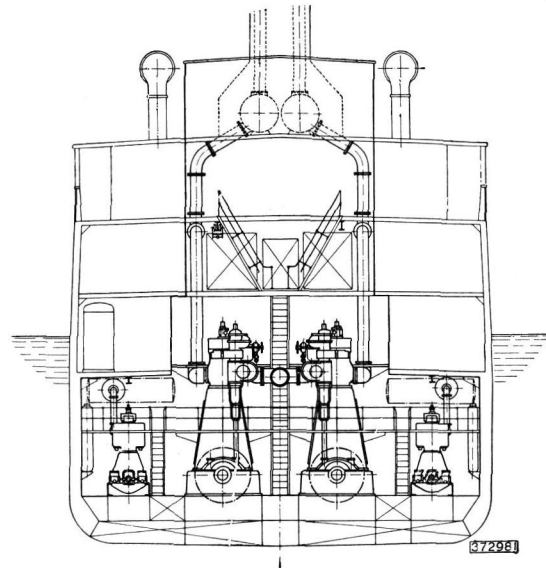
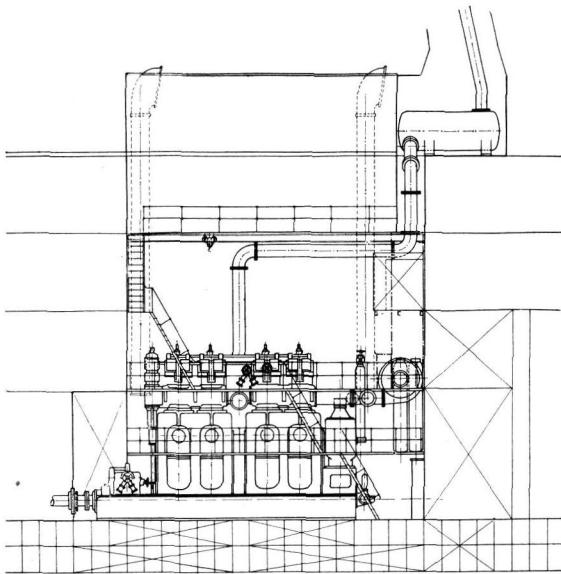


Fig. 8. — Arrangement of a Sulzer two-cycle marine Diesel-engine plant with centrifugal scavenging blowers.

a way that one complete set always forms a standby. For instance, in the case of a twin-screw vessel with two main propelling engines, two blowers are installed, each being designed to supply the necessary quantity of scavenging air to both Diesel engines, so that, whilst one blower set is in operation, the other one forms a reserve. Fig. 8 shows such a twin-screw plant designed by Messrs. Sulzer Brothers.

The blowers are placed at the same level as the scavenging manifold of the cylinders, as in this way the scavenging air is led directly to the cylinders without having to flow through tortuous passages.

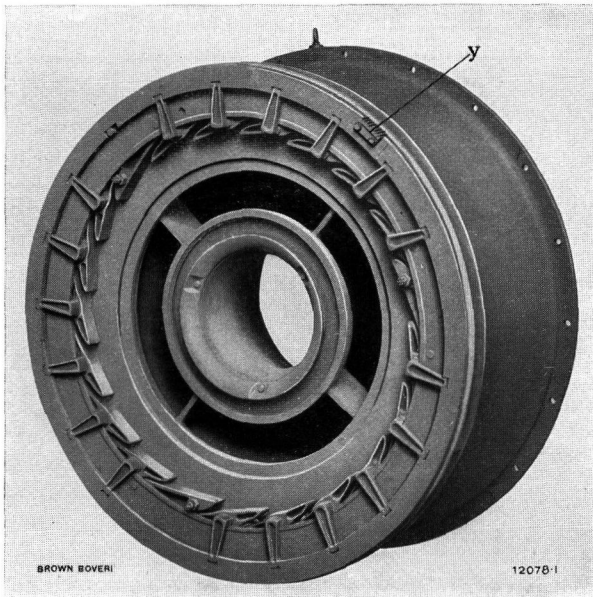


Fig. 9. — Intake of a centrifugal scavenging blower, showing movable diffuser.

"y" indicates the toothed segment for operating the diffuser adjusting gear.

### VI. OPERATION OF CENTRIFUGAL SCAVENGING BLOWERS IN CONJUNCTION WITH DIESEL ENGINES.

#### *Scavenging-air demand characteristic and regulation of the blower.*

The use of centrifugal blowers for supplying the scavenging air to Diesel engines adds no appreciable complication to the plant. Moreover, the operation of the blowers entails no extra work for the engine-room staff, either when the ship is at sea or when it is manœuvring in shallow waters or in harbour. The blower is adjusted to the normal load conditions of the Diesel engine once and for all, either on the test bed, or during the trial trip of the vessel. The adjustment of the blower is greatly facilitated by means of movable diffusers (Fig. 9), a feature patented by Brown, Boveri & Co. The regulation with these movable diffusers permits of the adaptation of the blower to fulfil the requirements of the Diesel engine in the most efficient manner.

This arrangement is particularly valuable where considerable discrepancies occur between the quantity of scavenging air estimated by the engine builder and that which the engine actually requires. After the necessary adjustments have been made the diffuser vanes are fixed definitely. Should permanently adjustable diffuser

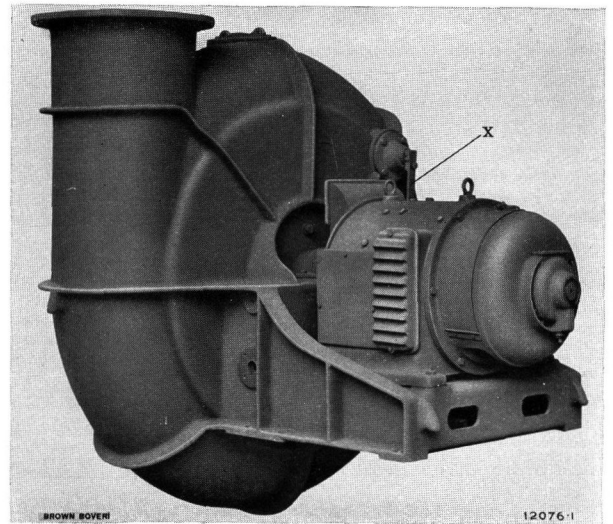


Fig. 10. — Centrifugal scavenging blower for a motor ship.

Indrawn volume of free air 500 m<sup>3</sup>/min.

Delivery pressure 1.15 kg/cm<sup>2</sup> abs. Speed 3100 r. p. m.

The blower has movable diffusers, which are adjusted by means of the lever "x".

vanes be desirable, however, they can be supplied. They are operated by means of a lever or hand wheel, as shown in Figs. 6 and 10. This is of special value when the engine load is greatly reduced, or when one or more of the engines is temporarily shut down.

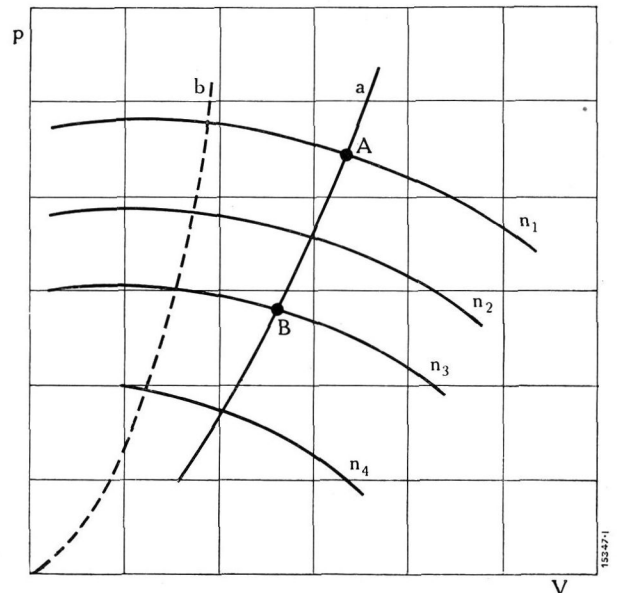


Fig. 11. — Characteristic curves of the scavenging air required by a two-cycle Diesel engine.

$n_1$ — $n_4$ . Pressure-volume curves of the blower at different speeds.

a. Back-pressure-volume characteristic for the scavenging air with different loads.

b. Pumping-limit locus of the blower.

A. Normal delivery point of the blower.

B. Partial load of the blower.

Under such conditions, the blower can work satisfactorily when delivering only small quantities of air, pumping being entirely prevented.

Furthermore, combined diffuser and speed regulation results in a better efficiency than if speed regulation alone were employed. (More details on this subject are published in an article entitled "Movable diffuser vanes for turbo-blowers and compressors" which appeared in The Brown Boveri Review, 1922, No. 2, p. 35.) When the vessel has to sail for considerable periods at reduced speed, owing to fog, or when navigating in narrow or shallow waters, the regulation of the blower by means of movable diffusers becomes of real economical importance.

The pressure-volume characteristic of the scavenging air required by a two-cycle marine Diesel engine driving a propeller is approximately a parabola (Fig. 11, curve a). This curve shows the pressure corresponding to any volume of scavenging air required. The pressure is merely that necessary to overcome the resistance to the air after it is discharged from the blower until it exhausts to the atmosphere. These different service conditions, which are illustrated by

the parabolic curve a, can be obtained simply by regulating the speed of the blower, as the pressure-volume characteristic of a centrifugal blower at various speeds is also a parabolic curve. Hence, the efficiency does not vary appreciably within a certain volume range. Should point A (Fig. 11), for instance, be the normal output of the blower, the normal speed being  $n_1$ , and should point B correspond to the scavenging air required at a partial load of the Diesel engine, this point B can be arrived at simply by reducing the speed from  $n_1$  to  $n_3$ , and, under certain circumstances as mentioned above, diffuser regulation can be added for the purpose of improving the blower efficiency.

With direct-current motor drive, the speed can be adjusted most simply by shunt-field regulation. As a rule, the conditions occurring in practice have proved that a range of speed regulation of about 25% is sufficient. Speed regulation over too wide a range entails unnecessarily large and expensive motors.

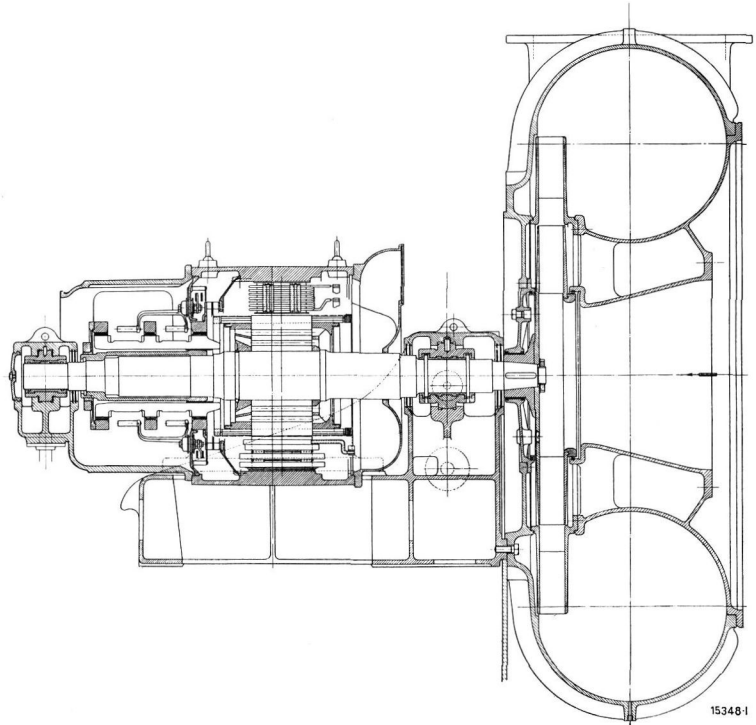


Fig. 13. — Longitudinal section through a direct-current motor and scavenging blower for a merchant vessel.

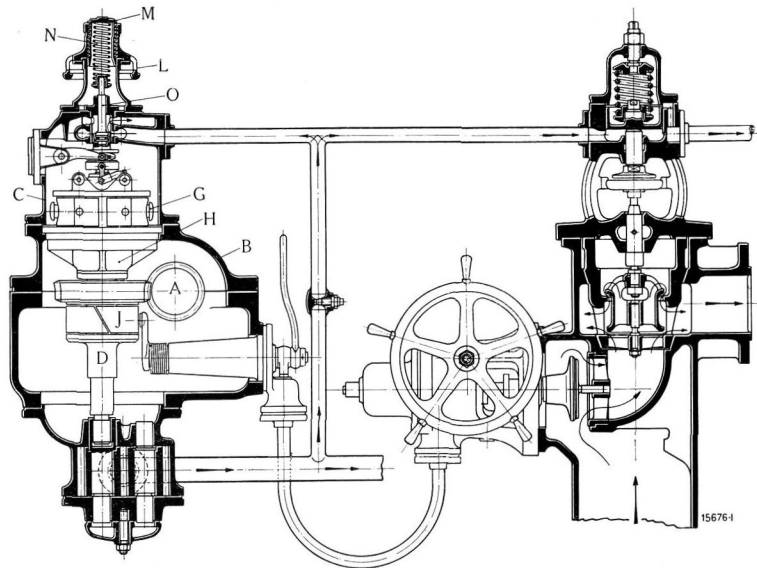


Fig. 12. — Brown Boveri steam-turbine governing gear for an extensive speed range.

- |  |   |
|--|---|
| A—J. Components of the normal Brown Boveri governing gear. | M. Internally threaded liner.           |
| L. Handwheel for speed adjustments.                        | N. Supplementary spring.                |
|  | O. Support of N on the governor sleeve. |

Where steam turbines are used, speed regulation is made possible by means of a special governing gear, as shown in Fig. 12, or by means of hand regulation.

When manœuvring, which generally only lasts a short time, it is not necessary to alter the blower speed. During such periods, the blower set can quite well be run at full speed, as an excess of scavenging air has no bad effects. Speed regulation is only required if the engines have to run at reduced speed for a considerable time.

From the above, it will be seen that the use of centrifugal scavenging blowers causes no additional work for the engine-room staff, and in no way interferes with the manœuvring of the vessel.

## VII. THE DESIGN OF BROWN BOVERI CENTRIFUGAL SCAVENGING BLOWERS.

The centrifugal scavenging blowers built by Brown, Boveri & Co. are either of the single or two-stage type according to the delivery pressure required. For merchant vessels, the single-stage type with overhung impeller is generally used. This type, compared with the blower design incorporating two bearings, has very simple air passages and consequently a higher efficiency. This latter fact is of considerable importance, in view of the continuous service which is required on board merchant ships. For larger air quantities, impellers of the double-suction type are

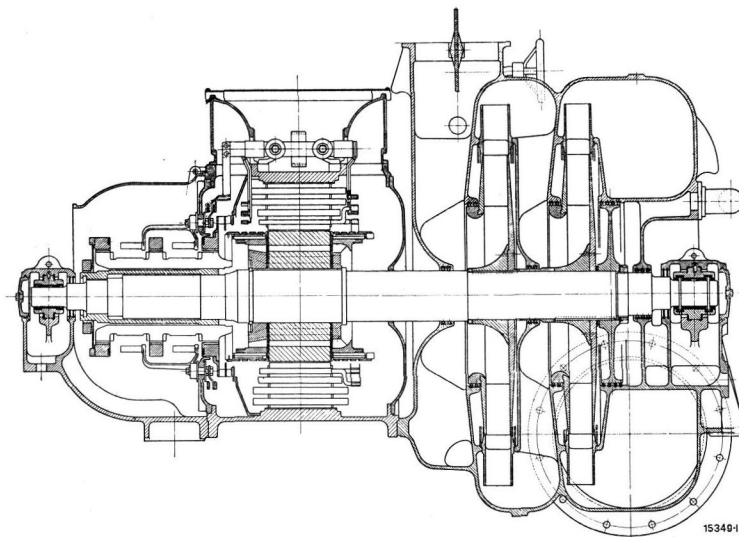


Fig. 14. — Longitudinal section through a direct-current motor and scavenging blower for a submarine.

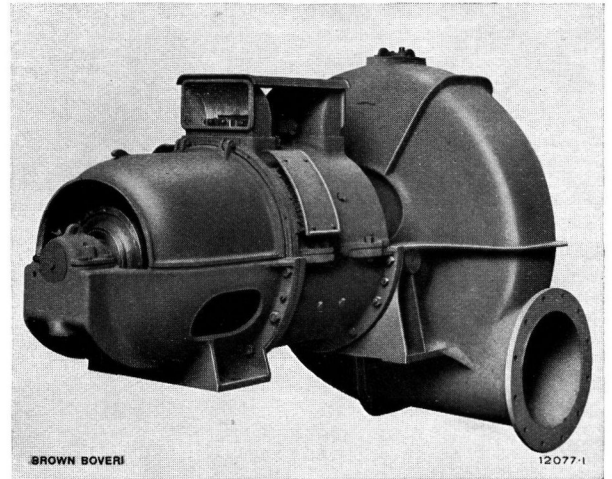


Fig. 15. — Single-stage centrifugal scavenging blower for a submarine.

Indrawn volume of free air 480 m<sup>3</sup>/min.

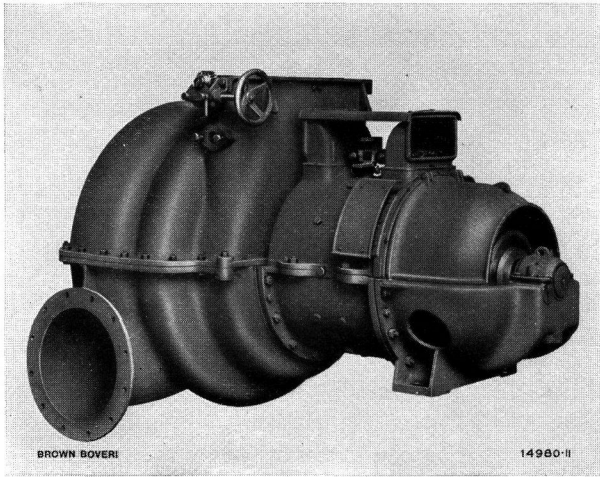
Delivery pressure 1.28 kg/cm<sup>2</sup> abs.

Speed 3800 r. p. m.

also employed, and here an outboard bearing is necessary for supporting the shaft. Figs. 13 and 14 illustrate the designs of Brown Boveri scavenging blowers. Fig. 13 represents a blower used for merchant vessels, and Fig. 14 shows a blower of the submarine type, where special consideration had to be given to the economy of space and weight. Figs. 6 and 10 illustrate other blowers supplied for merchant vessels whereas those shown in figs. 3, 4, 5, 15, 16 and 17 are for use in submarines.

All motor-driven blower sets have the rotors of both machines mounted on a common shaft supported in two bearings only. The bearings, which are lined with white metal, are arranged for forced lubrication, the oil being supplied by the lubricating system of the main engines. If specially required, however, the blower bearings can be arranged for independent lubrication, and, for this purpose, one or several oil pumps can be supplied.

The impellers are made of high-grade steel. Before despatch from the works, these impellers, as well as the rotors of the prime movers are subjected to an over-speed test, in which the normal speed is exceeded by about 30%, so that every guarantee can be given with regard to the reliability of the materials used.



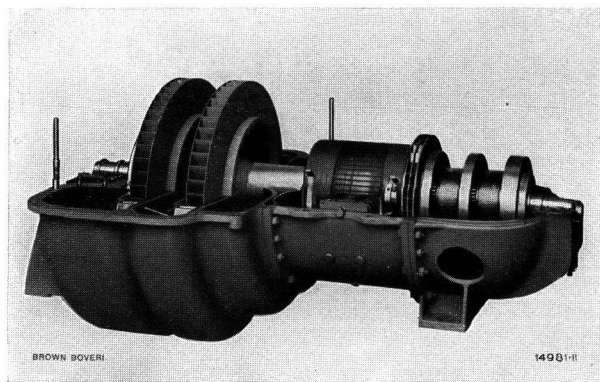
**Fig. 16. — Two-stage centrifugal scavenging blower for a submarine.**  
 Indrawn volume of free air 500 m<sup>3</sup>/min.  
 Delivery pressure 1.28 kg/cm<sup>2</sup> abs.      Speed 3000 r. p. m.

Fig. 18 shows part of the equipment which has been specially installed for carrying out these over-speed tests.

The blower casings are made of special cast iron, and, in order to obtain a high efficiency, they are liberally dimensioned. The casings of single-stage blowers with overhung impellers are bolted to the motor bracket, with which the bearing housing is also incorporated. This arrangement makes it possible for the delivery branch to be placed at any angle suitable to the particular conditions on board ship.

The diffusers are fitted into the blower casing. Either of the following types can be supplied:—

- (1) Cast diffusers, which permit of no adjustment.



**Fig. 17. — Two-stage centrifugal scavenging blower for a submarine, top half casing removed.**  
 Indrawn volume of free air 500 m<sup>3</sup>/min.  
 Delivery pressure 1.28 kg/cm<sup>2</sup> abs.      Speed 3000 r. p. m.

- (2) Movable diffusers, of which there are two designs as follows:—

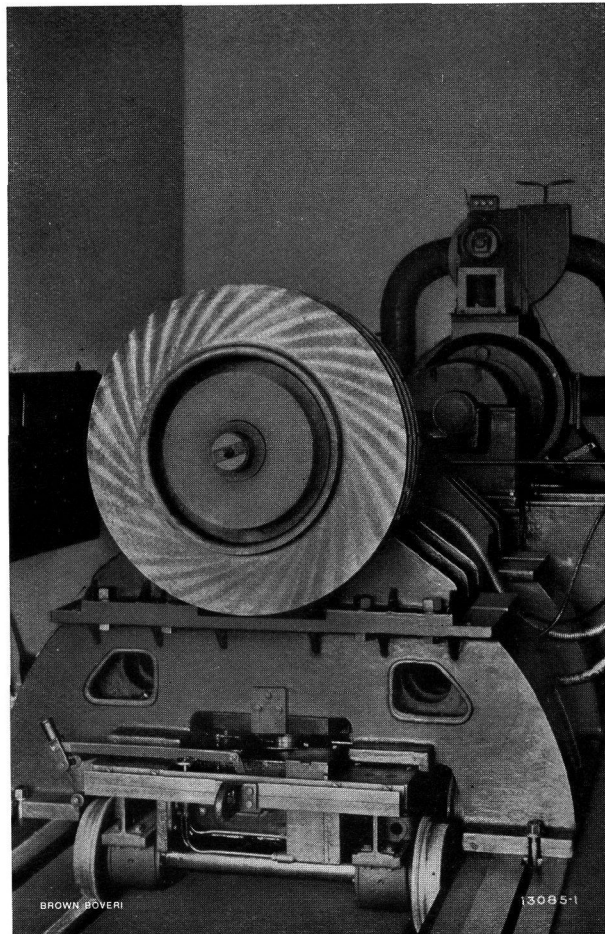
- (a) Diffuser vanes which are definitely set and fixed to the diffuser plate in the best position when the tests with the Diesel engine have been completed.

- (b) Permanently adjustable diffusers, operated by means of either a lever or a hand wheel.

The type of diffuser to be chosen depends on the prevailing conditions, and no hard and fast rule can be laid down as to what constitutes the best solution.

### VIII. THE BROWN BOVERI HIGH-SPEED DIRECT-CURRENT MOTOR FOR DRIVING CENTRIFUGAL BLOWERS.

It will not be out of place to describe here the Brown Boveri high-speed direct-current motor, used for driving centrifugal blowers. The steam turbines



**Fig. 18. — Blower impeller on the overspeed test-bed.**

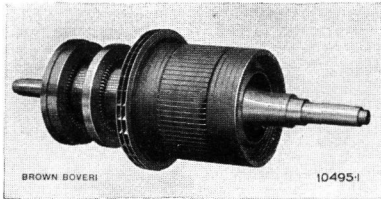


Fig. 19. — Armature of a Brown Boveri high-speed direct-current motor.

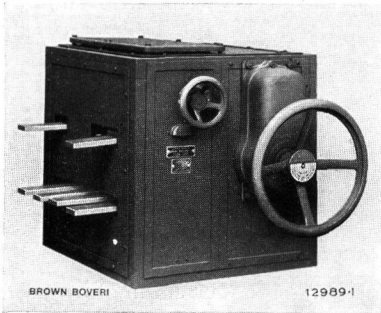


Fig. 20. — Starter for direct-current centrifugal-scavenging-blower motor (1500 A, 220 V) with combined speed controller. (Submarine type.)

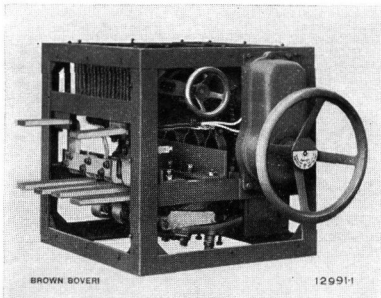


Fig. 21. — The same starter as Fig. 20, but with casing removed.

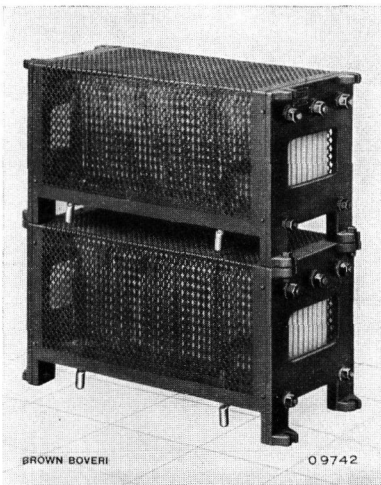


Fig. 22. — Air-cooled starting resistance.

employed for this purpose are of standard design and have been dealt with more fully in brochures such as No. 748 E, "Brown Boveri Steam Turbines", etc.

The outstanding features of the direct-current motors are their simple, compact design and small overall length, which ensures perfectly smooth running without any signs of vibration, despite the high speeds. The small size has been attained by adopting special methods of design, both from the magnetic and electric points of view, together with very efficient ventilation.

The armature winding is of a design particularly conducive to the uniform distribution of the current and to the effective dispersal of heat. The winding is held in the slots by keys, and a substantial wire binding keeps the coil ends in pos-

ition. A double fan draws the cooling air through the axial ventilation ducts of the armature, and also through the stationary field coils. Special arrangements are provided for keeping the surface of the commutator cool, the ends of the commutator segments being spread out fanwise (Fig. 19), thus giving rise to a flow of cooling air over the commutator surface. With high-speed motors, dovetail joints are unsuitable for securing the commutator segments to the commutator bushing, and shrink rings have to be employed for this purpose. The end of the commutator nearer the armature is shrunk on to the shaft, whereas the other end is supported by a flexible diaphragm

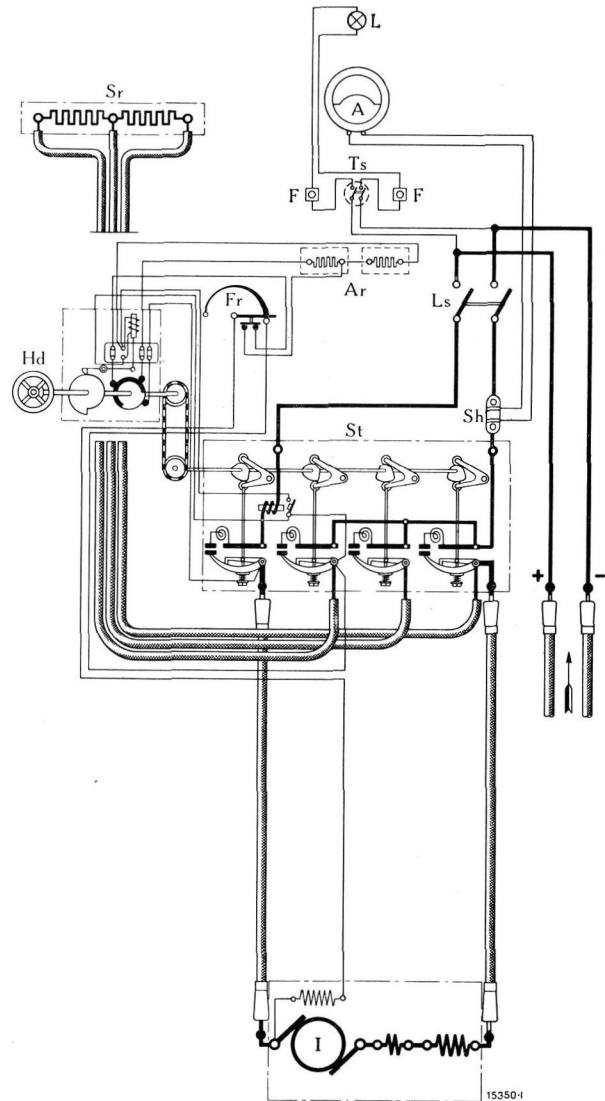


Fig. 23. — Diagram of connections of the switch cubicle shown in Figs. 24 and 25.

which allows of axial expansion due to the temperature rise. The commutator operates sparklessly under all conditions, without adjustment of the brushes being necessary.

Besides the shunt winding, the stator is provided with a compound winding, which imparts to the motor a speed drop with increasing load, and thereby protects the blower from excessive speeds and from overloads.

The magnet frame is split in order to facilitate dismantling on board ship. The outside bearing is usually incorporated in the end shield, and is lubricated by oil under pressure, as already stated.

The motors are either of the drip-proof or of the enclosed-ventilated type (Figs. 10 and 27), the latter being preferred for marine purposes. The motors

comply with the underwriters specification (Lloyd's Register, Bureau Veritas, etc.) as regards temperature rise and general design. Patent rights have been taken out by the firm, protecting the most important features.

IX. CONTROL DEVICES OF DIRECT-CURRENT MOTORS FOR SCAVENGING-BLOWER DRIVE.

Special starting and regulating apparatus has been evolved for direct-current motors driving scavenging blowers. Figs. 20 and 21 show a starter with built-on speed regulator as used in submarines. The starting resistances (Fig. 22) are, in this case, separate, and the resistance elements are of special rustless cast iron, the whole being protected from accidental contact by an expanded metal cover. The starter is provided with overload and no-volt releases. The

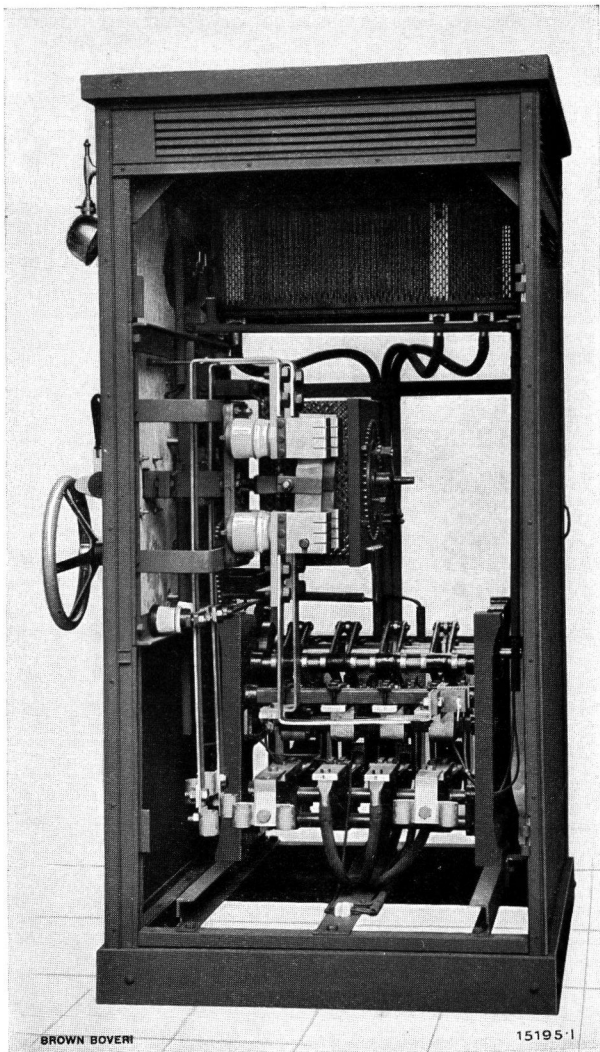


Fig. 24. — Switch cubicle shown in Fig. 25, with side panels removed.

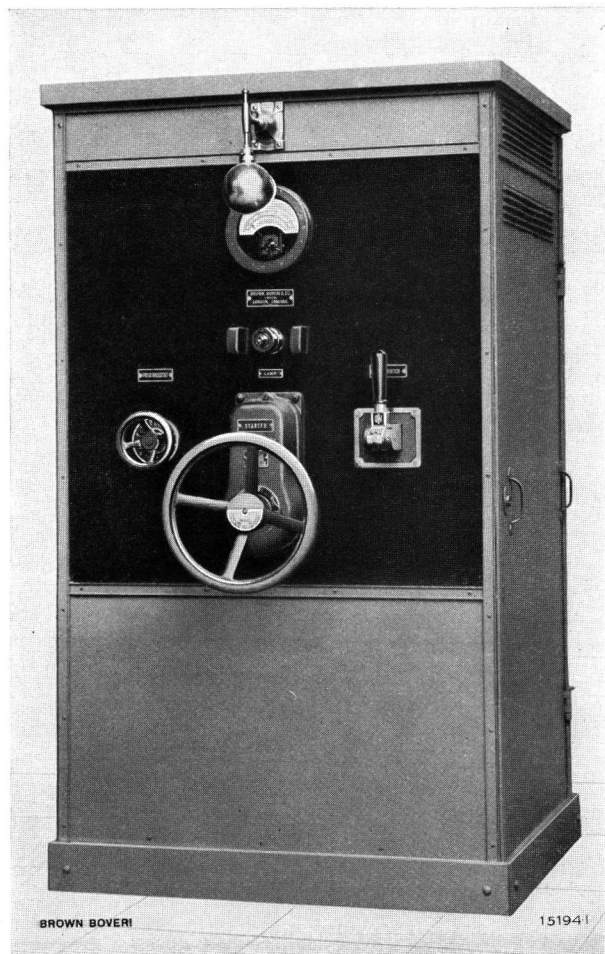


Fig. 25. — Switch cubicle containing starting gear for centrifugal scavenging blower on a merchant vessel.

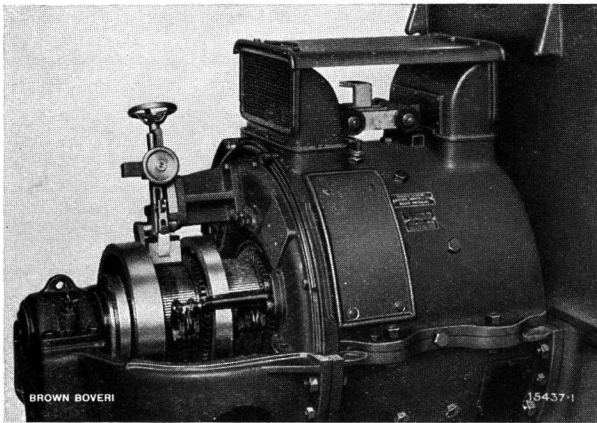


Fig. 26. — Commutator grinder fitted to the direct-current motor driving a centrifugal scavenging blower.

shunt-field rheostat is interlocked with the starter in such a way that the motor can only be started up with the full field—i. e., that corresponding to the slowest speed.

On merchant vessels, where more space is available than in submarines, a combined switch cubicle is preferred, so that the apparatus for the motor is more accessible. Figs. 24 and 25 show a switch cubicle of this description. In addition to the starter, the shunt field rheostat, and the starting resistances, the details of which do not differ from those illustrated in Figs. 20, 21 and 22, the switchboard generally contains a main switch, measuring instruments, etc., according to the requirements of the ship owners. Fig. 23 shows a diagram of connections of such a control-panel equipment as well as the general design of the starters used for these blower sets. The starter has an "off" position, two starting positions, and one running position. The connections are made to each position by means of contacts, which are operated mechanically by a series of cams. Each switch has sparking contacts, which are easily interchangeable. The hand drive of the starter is provided with a free-return clutch, which, if necessary, automatically switches off, although the hand wheel may be held.

#### X. RELIABILITY AND MAINTENANCE OF HIGH-SPEED DIRECT-CURRENT MOTORS FOR SCAVENGING-BLOWER DRIVE.

All the Brown Boveri scavenging-blower sets which have been supplied, are running satisfactorily in every respect. The fears, at one time entertained, that the commutator and brushes would be subjected to heavy wear on account of the high speed, have proved to be unfounded. The following example will serve to substantiate this statement.

At the time of writing, the motor ship "Handicap" has been in service for more than two years, and, although the blower motors were running almost continuously, the commutator shows no appreciable wear. Another feature welcomed by the engine-room staff is that not the slightest overhaul or adjustment of the blower sets was necessary either during or after voyages.

Here attention may be called to the fact that the maintenance of the commutator is greatly facilitated if a grinding device, similar to that shown in Fig. 26, be employed. A suitable bracket, carrying the grinder itself, is bolted to the motor casing, then the motor is started up, thereby grinding the commutator without a small auxiliary-motor being necessary.

#### XI. SCAVENGING-BLOWER SETS SUPPLIED BY BROWN, BOVERI & CO.

A considerable number of scavenging-blower sets have been supplied for submarines of various navies, and, apart from this, many blowers have been built

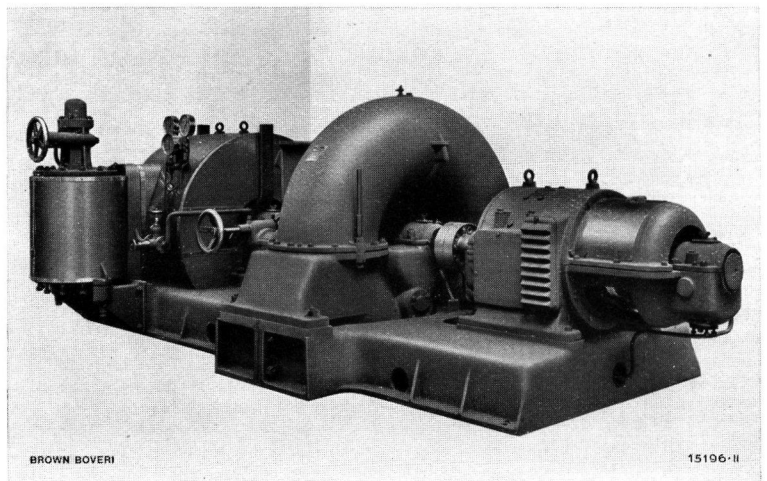


Fig. 27. — Centrifugal scavenging-blower set for a Still-engine plant.

for use on merchant vessels. Among the latter the following are of special interest:

(1) *M. S. "Handicap"* (9000 tons dead-weight capacity, 10.5 knots).

Builders: A. S. Rosenberg, Mekaniske Vaerksted, Stavanger.

Owners: Bruusgaard & Kjøsterud, Drammen (Norway).

This vessel (Fig. 28) was the first to be provided with Sulzer two-cycle Diesel engines scavenged by centrifugal blowers. For this purpose, two Brown Boveri blower sets are installed, each capable of delivering  $340 \text{ m}^3$  of free air per minute against a delivery pressure of 1.15 at. abs. The maximum speed is about 3100 r. p. m. This ship was put into commission in

December, 1921, and, as already stated, the performance of the scavenging blowers has been most satisfactory. The blowers are provided with permanently movable diffusers (Fig. 10).

(2) *M. S. "Camranh"* (11,700 tons dead-weight capacity, 11.5 knots).

Builders: Ateliers et Chantiers de la Loire, Nantes.

Owners: Chargeurs Réunis.

The two centrifugal scavenging blowers of this vessel are each designed for  $500 \text{ m}^3$  of free air per minute delivered against a pressure of 1.18 at. abs., the normal blower speed being 2750 r. p. m. The Diesel engines of this ship were built at the works of Messrs. Sulzer Brothers in Winterthur, Switzerland.

(3) *M. S. "Dalgoma"* (8300 tons dead-weight capacity, 12 knots).

Builders: Alexander Stephen & Sons, Ltd., Lint-house (Glasgow).

Owners: British India Steam Navigation Co., Ltd., London.

The vessel is driven by two Stephen-Sulzer Diesel engines, and the scavenging blower set supplied by Brown, Boveri & Co. is designed for the same output and speed as the blowers supplied for *M. S. "Camranh"*.

(4) *M. S. "Dolius"*. Under construction at the time of writing.

Builders: Scotts Shipbuilding & Engineering Co., Ltd., Greenock.

Owners: Alfred Holt & Co.

This vessel is the first to be equipped with Still engines, and is provided with a scavenging blower driven at one end by an exhaust steam turbine, and at the other by a high-speed direct-current motor (Figs. 6 and 27). The maximum output which the blower can

deliver is  $340 \text{ m}^3$  of free air per minute at a pressure of 1.165 at. abs., the speed being 3800 r. p. m.

The turbine driving the blower utilises the exhaust steam available from the Still engine. Under normal circumstances the inlet pressure of the exhaust steam to the turbine is 0.42 at. abs., but the turbine had to be designed to run the blower at the above

output when supplied with steam having any inlet pressure between 0.21 and 1.05 at. abs. Accordingly, the turbine is fitted with four hand-operated nozzle valves, to enable it to deal with the various steam conditions occurring.

The blower is started up by the direct-current motor. As soon as exhaust steam from the Still engine is available, the turbine takes over the duties of the motor either partly or completely. Under all conditions, the motor remains connected to the current supply. If the steam quantity exhausted by the Still engine is greater than that required by the turbine to drive the blower alone, the motor acts as a generator and delivers current to the supply system of the vessel. If, for any reason, the steam supply is cut

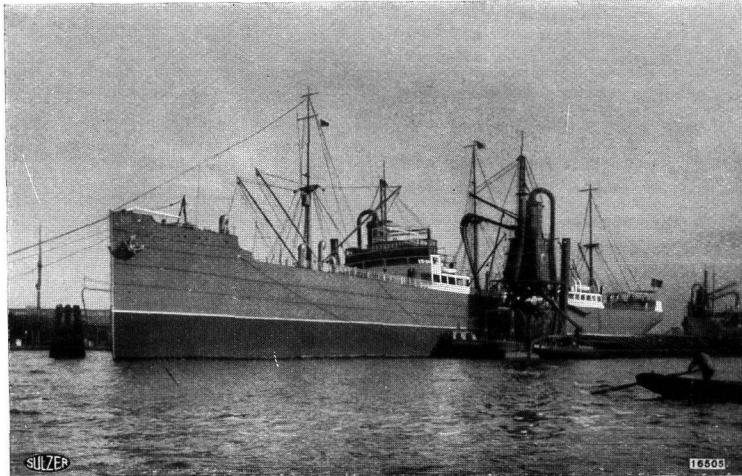


Fig. 28. — *M. S. "Handicap"* discharging grain at Hamburg. The first motor ship to be equipped with centrifugal scavenging blowers.

off, the motor immediately comes into operation again as prime mover.

The blower is fitted with hand-operated permanently movable diffusers. The bearings have both forced and ring lubrication. A special oil pump supplies the necessary lubricating oil under pressure. For the starting-up period, and also in the event of the oil pump breaking down, the ring lubrication is sufficient.

(5) *M. S. "Aorangi"* (at present under construction, 22'000 tons).

Builders: Fairfield Shipbuilding & Engineering Co., Ltd., Govan (Glasgow).

Owners: Union Steamship Co., Ltd.

The vessel is at present the largest motor ship ordered. The four Diesel engines of the Sulzer type will have a total capacity of 13'000 S. H. P. The three scavenging-blower sets, the order for which has been placed with Brown, Boveri & Co., will be motor driven, and each is to be capable of delivering 960 m<sup>3</sup> of free air per minute against a pressure of 1.16 at. abs. when running at a speed of 3200 r. p. m.

(6) *M. S. "Phæbus"*.

Builders: Howaldtswerke, Kiel.

This oil tanker is fitted with two scavenging blowers, each built for the following duty:—

Maximum air quantity 520 m<sup>3</sup> per minute, maximum delivery pressure 1.2 at. abs., speed 3500 r. p. m.

(7) *M. S. "Fulda"*.

Builders: Weserwerft, Bremen.

Owners: North German Lloyd, Bremen.

The two blowers of this motor ship, which is a passenger liner, are designed to deliver 680 m<sup>3</sup> per minute against a delivery pressure of 1.2 at. abs., the speed being 2750 r. p. m.

The engines of both this vessel and that mentioned under No. 6 are of the Sulzer type and were manufactured in the works of Messrs. Sulzer Brothers at Ludwigshafen on Rhine.

(8) *M. S. (Unnamed.)* At present under construction (10'000 tons dead-weight capacity, 12.5 knots).

Builders: Lithgows, Ltd., Port Glasgow.

Owners: Nippon Yusen Kaisha.

This boat will be provided with two scavenging blowers of the same type as supplied to the *M. S. "Camranh"* described under No. 2. The two engines of the Sulzer type are capable of delivering 4000 S. H. P.

(9) *M. S. "Wajang"* (15'000 tons dead-weight capacity, 15 knots).

Builders: Kon. Mij. "DeSchelde", Flushing (Holland).

Owners: Rotterdam Lloyd.

This twin-screw vessel is equipped with two-cycle Sulzer engines, having a total capacity of 7000 S. H. P.; two scavenging blowers are installed, each designed for dealing with a free-air volume of 960 m<sup>3</sup> per minute delivered against a pressure of 1.113 at. abs., the speed of the blower being 2900 r. p. m.

(10) *M. S. "Turbinia"*.

Owners: Rotterdam Lloyd.

This vessel is at present being converted into a motor ship, a Sulzer Diesel engine of 1160 S. H. P. at 85 r. p. m. being fitted. Two scavenging blowers were supplied, one as reserve. At 3400 r. p. m., each is capable of delivering 170 m<sup>3</sup> of free air per minute at 1.15 at. abs.

(MS 238)

*E. Klingelfuss (D. M.).*

## NOTES.

### The machinery of the passenger and cargo steamers "Thuringia" and "Westphalia".

Decimal index 623. 824 (43).

IN January and May of last year, two sister ships, *S. S. "Thuringia"* and *S. S. "Westphalia"* (Fig. 1), both intended for passenger service as well as cargo, were handed over to the Hamburg-America Line by the builders, the Howaldtswerke in Kiel, after the trials had been successfully carried out. These two vessels are employed on the Hamburg-New York route and have, at the time of writing, completed a large number of entirely satisfactory trips in direct succession.

The Brown Boveri Review 1922, No. 7, contains on pages 148—50 a short account of the propelling machinery

constructed by Brown, Boveri & Co. for these two vessels (see also Brochure 755 E). The following description deals at greater length with the plant in question.

The chief particulars of the vessels are as follows:—

Length between perpendiculars . . . . .	144 m
Beam . . . . .	18.44 m
Draught . . . . .	8.53 m
Displacement . . . . .	18'100 tons
Number of first-class passengers . . . . .	150
Number of third-class passengers . . . . .	650

#### *I. Main machinery installation.*

(See Fig. 2.)

The power required for propelling the ship at the normal speed of 13 knots is about 5000 S. H. P. The high-pressure turbine runs at about 3000 r. p. m. and the low-pressure turbine at about 2300 r. p. m., these speeds being

lowered by double reduction gearing to 85 r. p. m. for the propeller shafts. The h. p. ahead turbine is of the combined type with a two-stage impulse wheel and a drum carrying reaction blading; the h. p. astern turbine has a two-stage impulse wheel only; the l. p. ahead and the l. p. astern turbines are of the pure drum reaction type. The h. p. ahead and astern turbines are in one single casing and the l. p. in another. The construction of the turbines is in accordance with the Brown Boveri standard design. Each turbine is provided with an emergency governor to cut off the steam supply automatically when the speed reaches a predetermined value about 10% higher than the regular maximum running speed. There is, in addition, a speed governor fitted on one of the intermediate gear shafts, which regulates the speed within a small range that can be adjusted as required; this governor ensures a relatively constant propeller speed even in a heavy sea. For the diagram of the control arrangements as well as constructional details of this plant, the reader is referred to the above-mentioned article, including Figs. 57 and 61, in the Brown Boveri Review 1922, No. 7.

The pinions of the large reduction gear are placed well above the centre of the main spur wheel, and the pinions of the smaller reduction gears are situated vertically above the spur wheels they drive, so as to give sufficient head room for the condenser, which is placed directly below the low-pressure turbine, and also to obtain the necessary fall to the suction end of the turbine-driven condensate pump without having to keep the propeller shaft high. The turbines are connected to their respective pinion shafts by means of claw couplings; the connection between the spur-wheel shafts of these first reduction gears

and the pinion shafts of the second reduction gear is made in each case by means of a flexible intermediate shaft passing freely through the centre of the pinion, and by a pin coupling that permits axial movement. The main particulars of the gears, which have helical teeth, are as follows:—

	First reduction		Second reduction
	h. p. turb.	l. p. turb.	h. p. and l. p. turb.
Diameter of pinion . . . . .	199 mm	255 mm	493 mm
Diameter of spur wheel . . . . .	1186 mm	1141 mm	2910 mm
Breadth of tooth . . . . .	2 × 340 mm		2 × 500 mm
Number of teeth on pinion . . . . .	53	68	61
Number of teeth on spur wheel . . . . .	316	304	360
Normal pitch . . . . .	3.25 π		7 π
Spiral angle of teeth . . . . .	30°		30°

The control platform is situated in front of the turbines and permits easy access to all the more important parts of the engines and gears. The main handwheels for operating the manœuvring and other valves, the revolution indicator, the more important pressure gauges and thermometers for the boilers and turbines, as well as other numerous indicating and measuring instruments, are mounted in the most suitable manner on a special instrument board.

The steam pipes leading to the turbines and from one turbine to another, and the valves in the piping, are so arranged that, in the event of one turbine being put

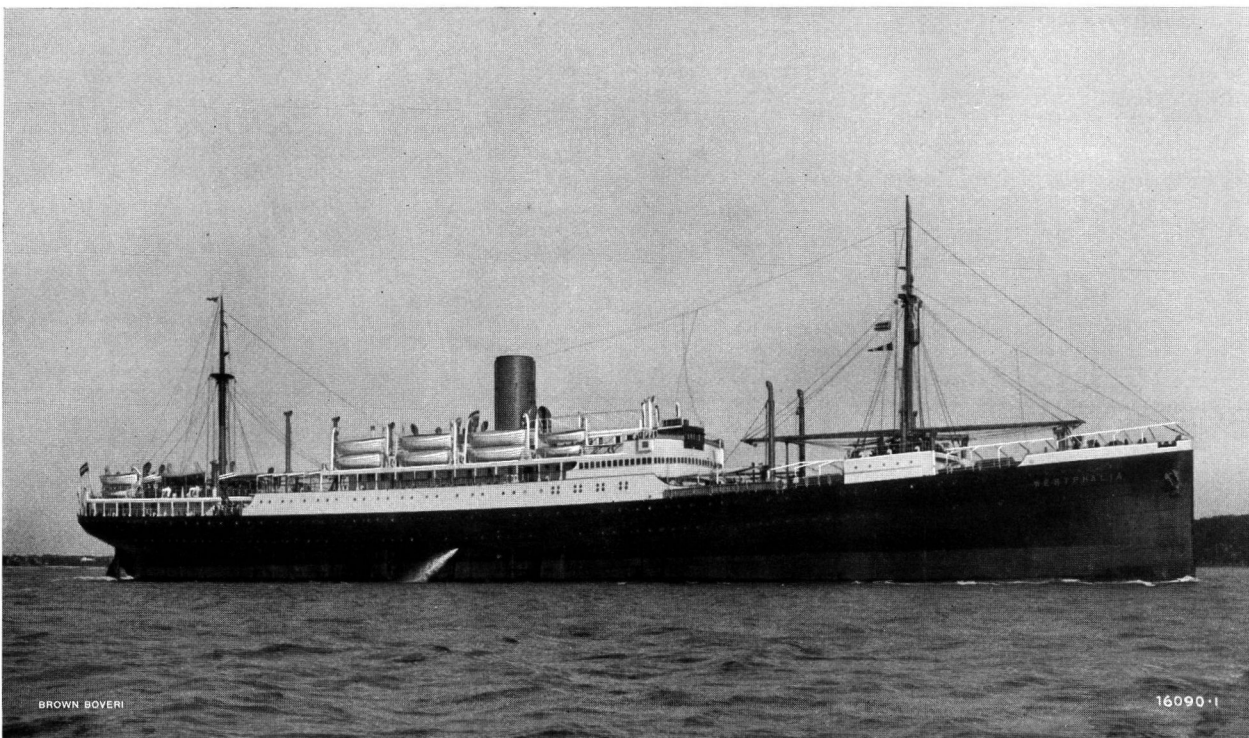


Fig. 1. — S. S. "Westphalia" constructed by the Howaldtswerke, Kiel, and equipped with Brown Boveri turbines.

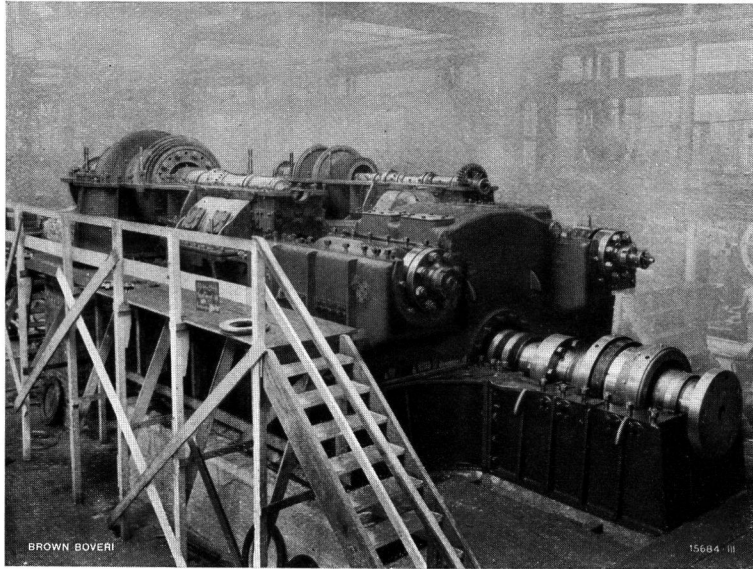


Fig. 2. — Propelling machinery of the "Thuringia" on the test-bed.

out of commission, the vessel can proceed on about half power with the remaining turbine, that is, with one ahead and one astern turbine.

The main condenser, which is of the Brown Boveri OV type with a cooling surface of 590 m<sup>2</sup>, is situated immediately below the turbine and rests on a support so constructed that it yields to allow of expansion or contraction due to changes of temperature. A detailed description of the type of condenser in question is to be found in Brochure 772 E.

For the lubrication of all the bearings and of the gear-wheel teeth a gravity system is provided, the oil being returned to the gravity tank by an oil pump after it has passed through a filter and a cooler. The oil pressure in the distribution chamber situated on the housing of the reduction gears corresponds to the gravitational head and amounts to about 1 kg per cm<sup>2</sup>; this is reduced to 0.3—0.5 kg per cm<sup>2</sup> by suitable diaphragms at the various lubricating points. In view of the importance of reliable lubrication, all the parts such as oil pump, filter, cooler, reservoir, etc., are provided in duplicate and connected in such a way that it is possible to change over from one system to another at a moment's notice. Further, the quantity of oil normally contained in the reservoir, which can be checked by a gauge glass on the instrument board, is sufficient to supply the regular lubrication for a period of several minutes. The lubrication of the gear-wheel teeth is carried out by means of special nozzles, which can be inspected singly and, if necessary, removed for cleaning while running.

## II. Auxiliary Machinery and Equipment.

The auxiliary machinery necessary in connection with the main plant, as well as the equipment for recuperating the heat in the exhaust steam and for providing make-up

water, etc., is built on the lines of that employed in large modern power stations, which is a departure from usual marine practice. The following auxiliary plant was supplied by Brown, Boveri & Co.:—

1. 1 pump set for the condenser, etc.
2. 1 spare condensate pump with electric drive.
3. 1 turbine-driven boiler feed pump.
4. 1 float regulating device.
5. 2 steam air ejectors.
6. 3 turbo-dynamos for each vessel, and the complete switchgear and wiring for the "Westphalia".

1. *Pump set.* The pump set illustrated in Fig. 3 comprises a small turbine, Type DA 4, of Brown Boveri design, running at about 4000 r.p.m., provided with speed and emergency governors, and driving the following pumps:—

(a) A main circulating pump for about 1600 m<sup>3</sup>/h against a head of 6.8 m. It is driven through gearing which gives it a speed of about 520 r.p.m.

(b) A main condensate pump designed for a maximum delivery of 43 m<sup>3</sup>/h with a head of 20 m. It is mounted on the extended pinion shaft of the above gearing and consequently runs at about 4000 r.p.m.

(c) A single-stage main oil pump for the lubricating system of the main machinery with a capacity of 50 m<sup>3</sup>/h against 30 m head.

(d) A pump for fire extinguishing and deck washing with a capacity of 50 m<sup>3</sup>/h against 40 m head. The pumps (c) and (d) are driven at a speed of about 4000 r.p.m. by the shaft of a second pinion gearing with the spur wheel.

(e) A small oil pump for the lubrication of the bearings and gearing of the whole pump set. It is driven by an extension of the spur-wheel shaft at the side remote from pump (a) and supplies the oil, which it draws from a reservoir formed by the baseplate, through a filter and a cooler to the various points of lubrication. The cooling water for the oil cooler is obtained from the main circulating pump. The

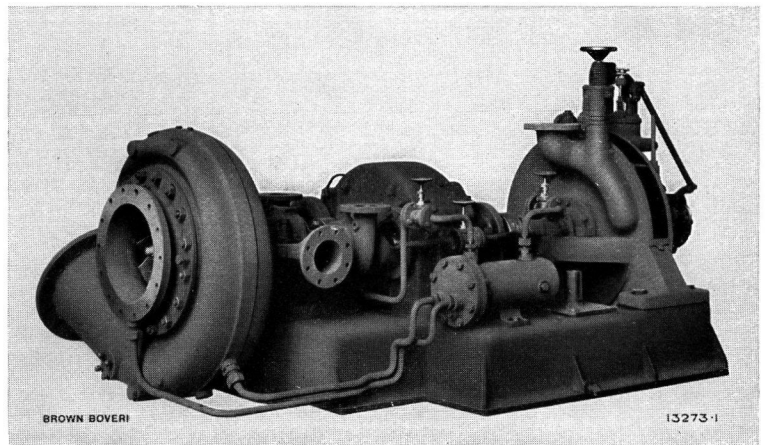


Fig. 3. — Pump set of the "Thuringia".

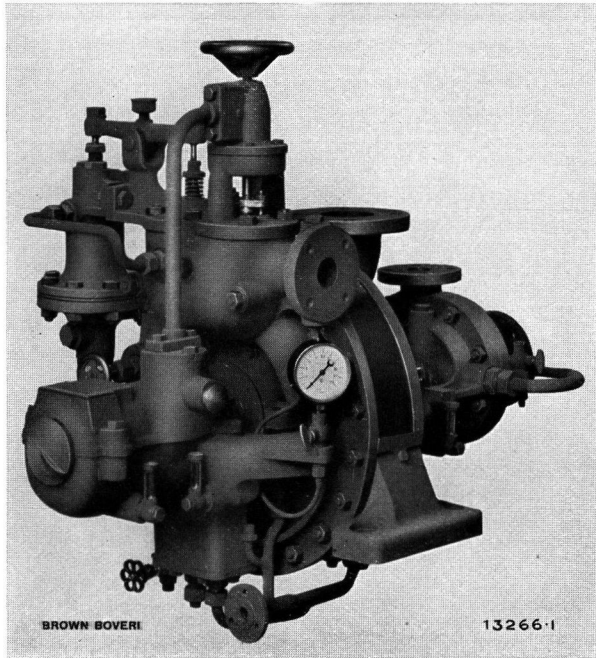


Fig. 4. — Turbine-driven boiler feed pump of the "Thuringia".

above pump set consequently forms a completely independent unit, the operation of which makes no special demands on the engine-room staff.

2. *Spare condensate pump.* In accordance with the regulations for vessels of the kind in question, a reserve for the main condensate pump is provided in the form of a spare condensate pump driven by a direct-coupled electric motor.

3. *Turbine-driven boiler feed pump.* Fig. 4 shows the main feed pump installed in each of the vessels. A small turbine, Type DA 2, running at about 6000 r.p.m., drives a single-stage boiler feed pump, Type Sp 180/7, mounted overhanging on an extension of the turbine shaft. The maximum delivery of this pump is 43 m<sup>3</sup>/h against a head of about 180 m. The steam supply to the turbine is regulated by a pressure governor influenced by the pressure of the steam and the delivery pressure of the pump, the adjustment being such that the pump pressure always exceeds the steam pressure by a certain adjustable amount; this ensures economical operating conditions. If the speed rises to about 10% above that corresponding to the maximum discharge pressure of the pump, the steam supply to the turbine is cut off by an emergency governor. The axial thrust in the pump is balanced automatically. As reserve a vertical reciprocating steam pump (Weir pump) is provided.

4. *Float regulating device.* With a view to obtaining a good vacuum and also to avoiding corrosion in the boilers and steam piping by reason of the oxygen contained in the feed water, it is desirable to have the condensate as free of air as possible. On this account, the condensate on these vessels is kept in a closed system all the way from the condenser through the condensate pump to the turbine-

driven feed pump, and from the latter to the boilers. The unavoidable discrepancies met with during operation between the actual amount of water present in the system and the quantity required at any instant by the boilers, is allowed for by an equalising tank in connection with the condenser, provided with a float regulating device which keeps the water level on the suction side of the pump constant. If the boilers require more feed water than the amount of condensate coming from the turbines, the float regulator causes water to flow from the equalising tank to the condenser, where the air present in the make-up water is removed; when the boilers require less than the quantity of water available, the float regulator passes the excess to the tank. A fuller description of this arrangement, which is patented by Brown, Boveri & Co., will be given at a later date.

5. *Steam air ejectors.* To extract the air from the main condenser two double-stage steam air ejectors, sizes IV and V, of standard design with preliminary air nozzle, are employed. They can be operated either singly or in parallel. The steam leaving the ejectors is led, along with the air extracted, to the heater of an evaporator for sea water, or to the auxiliary condenser. Particulars of Brown Boveri steam air ejectors are contained in Brochure 772 E.

6. *Turbo-dynamos.* On each vessel are installed three turbo-dynamo sets, each having an output of about 75 kW, at 110 volts, and 3500 r. p. m. The turbines are of the two-stage impulse type.

For S.S. "Westphalia", Brown, Boveri & Co. also supplied the switchgear installation and the complete wiring system.

Further particulars of the machine-room equipment of these vessels are to be found in Brochure 815 E.

(MS 290)

J. Baasch. (J. F. L.)

### The development of hydro-electric power stations in Italy since 1915.

Decimal index 621. 312. 134 (45).

In continuation of the notes on this subject published in the Brown Boveri Review, 1923, No. 8, we give the following details of an interesting order, received in November, 1923 by the Tecnomasio Italiano Brown Boveri, Milan, for two 30'000-kVA three-phase alternators.

These machines, which are the most powerful constructed in Europe up to date, are intended for Mese hydro-electric station near Chiavenna on the Liro, belonging to the Stà. Idroelettrica Cisalpina, Milan. Their principal dimensions are as follows:

Continuous output	30'000 kVA at 0.75 power factor
Power input . . . . .	32'000 H. P. (approximately)
Speed . . . . .	420/500 r. p. m.
Frequency . . . . .	42/50 cycles per second
Voltage . . . . .	8000 V ± 5% for the two frequencies
Run-away speed . . . . .	900 r. p. m.

The machines are totally enclosed, the quantity of cooling air required being 45 m<sup>3</sup>/sec. They are fitted with built-on exciters and have horizontal shafts, carried in two bearings and arranged for coupling to hydraulic turbines built by Costruzioni Meccaniche Riva, Milan.

Heaviest weight to be erected (rotor and shaft) =	100'000 kg.
Heaviest weight to be transported (one quarter of the stator without winding) =	25'000 kg.
Total weight of each alternator with its exciter . . . . .	= 240'000 kg.

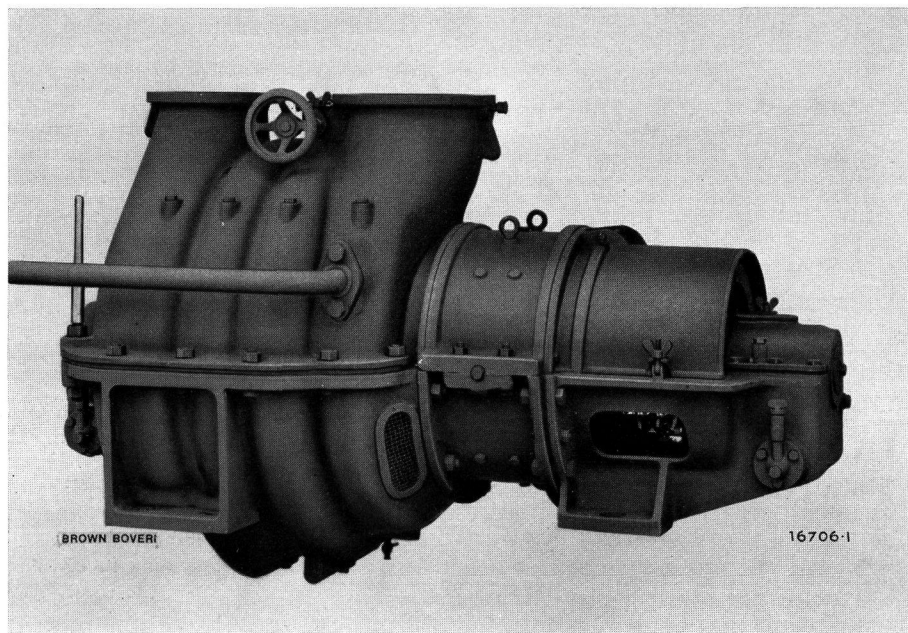
(MS 295)

F. Regard. (G. T. S.)

# BROWN, BOVERI & COMPANY LIMITED

BADEN (SWITZERLAND)

WORKS: BADEN AND MUNCHENSTEIN (SWITZERLAND)



CENTRIFUGAL BLOWER DRIVEN BY D. C. MOTOR  
for blowing out the diving tanks of a submarine. Volume of free air delivered:  $60 \text{ m}^3/\text{sec}$ ,  $p_1/p_2: 1.0/1.55$  at. abs.,  
speed: 5600 r. p. m.

## CENTRIFUGAL SCAVENGING BLOWERS

WITH D. C. MOTOR OR STEAM-TURBINE DRIVE, FOR TWO-CYCLE MARINE  
DIESEL ENGINES

## CENTRIFUGAL SUPERCHARGING BLOWERS

DRIVEN BY HIGH-SPEED D. C. MOTORS, STEAM TURBINES, OR EXHAUST-  
GAS TURBINES, FOR INCREASING THE OUTPUT OF FOUR-CYCLE MARINE  
DIESEL ENGINES

## CENTRIFUGAL DIVING-TANK BLOWERS

FOR SUBMARINES

## FORCED-DRAUGHT FANS

FOR MARINE BOILERS (HOWDEN AND CLOSED-STOKEHOLD SYSTEMS)