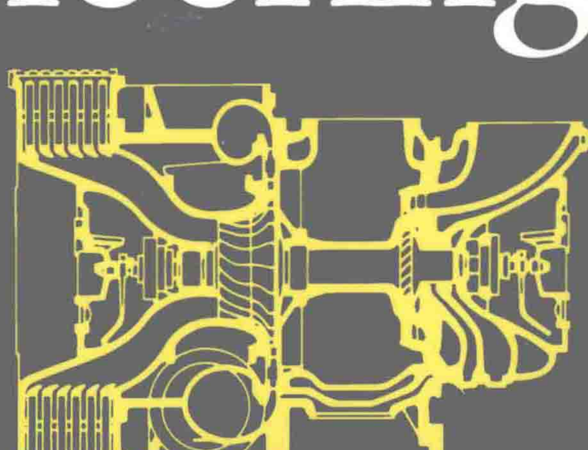
D A Taylor

introduction to

Marine Engineering



REVISED SECOND EDITION

Second Edition

Introduction to Marine Engineering

D. A. Taylor, *MSc, BSc, CENG, FIMarE, FRINA*
Marine Consultant, Harbour Craft Services Ltd, Hong Kong
Formerly Senior Lecturer in Marine Technology, Hong Kong Polytechnic University

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Introduction to Marine Engineering

Preface to second edition

Progress has been made in many areas of marine engineering since the first edition of this book was published. A greater emphasis is now being placed on the cost-effective operation of ships. This has meant more fuel-efficient engines, less time in port and the need for greater equipment reliability, fewer engineers and more use of automatically operated machinery.

The marine engineer is still, however, required to understand the working principles, construction and operation of all the machinery items in a ship. The need for correct and safe operating procedures is as great as ever. There is considerably more legislation which must be understood and complied with, for example in relation to the discharging of oil, sewage and even black smoke from the funnel. Engineers must now be more environmentally aware of the results of their activities and new material is included in this revised edition dealing with exhaust emissions, environmentally friendly refrigerants and fire extinguishants.

The aim of this book is to simply explain the operation of all the ship's machinery to an Engineer Cadet or Junior Engineer who is embarking on a career at sea. The emphasis is always upon correct, safe operating procedures and practices at all times.

The content has been maintained at a level to cover the syllabuses of the Class 4 and Class 3 Engineer's Certificates of Competency and the first two years of the Engineer Cadet Training Scheme. Additional material is included to cover the Engineering knowledge syllabus of the Master's Certificate.

Anyone with an interest in ships' machinery or a professional involvement in the shipping business should find this book informative and useful.

D.A. Taylor

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Chapter 1
Ships and machinery

As an introduction to marine engineering, we might reasonably begin by taking an overall look at the ship. The various duties of a marine engineer all relate to the operation of the ship in a safe, reliable, efficient and economic manner. The main propulsion machinery installed will influence the machinery layout and determine the equipment and auxiliaries installed. This will further determine the operational and maintenance requirements for the ship and thus the knowledge required and the duties to be performed by the marine engineer.

Ships

Ships are large, complex vehicles which must be self-sustaining in their environment for long periods with a high degree of reliability. A ship is the product of two main areas of skill, those of the naval architect and the marine engineer. The naval architect is concerned with the hull, its construction, form, habitability and ability to endure its environment. The marine engineer is responsible for the various systems which propel and operate the ship. More specifically, this means the machinery required for propulsion, steering, anchoring and ship securing, cargo handling, air conditioning, power generation and its distribution. Some overlap in responsibilities occurs between naval architects and marine engineers in areas such as propeller design, the reduction of noise and vibration in the ship's structure, and engineering services provided to considerable areas of the ship.

A ship might reasonably be divided into three distinct areas: the cargo-carrying holds or tanks, the accommodation and the machinery space. Depending upon the type each ship will assume varying proportions and functions. An oil tanker, for instance, will have the cargo-carrying region divided into tanks by two longitudinal bulkheads and several transverse bulkheads. There will be considerable quantities of cargo piping both above and below decks. The general cargo ship will have various cargo holds which are usually the full width of the vessel and formed by transverse bulkheads along the ship's length. Cargo-handling equipment will be arranged on deck and there will be large hatch openings closed with steel hatch covers. The accommodation areas in each of these ship types will be sufficient to meet the requirements for the ship's crew, provide a navigating bridge area and a communications centre. The machinery space size will be decided by the particular machinery installed and the auxiliary equipment necessary. A passenger ship, however, would have a large accommodation area, since this might be considered the 'cargo space'. Machinery space requirements will probably be larger because of air conditioning equipment, stabilisers and other passenger related equipment.

Machinery

Arrangement

Three principal types of machinery installation are to be found at sea today. Their individual merits change with technological advances and improvements and economic factors such as the change in oil prices. It is intended therefore only to describe the layouts from an engineering point of view. The three layouts involve the use of direct-coupled slow-speed diesel engines, medium-speed diesels with a gearbox, and the steam turbine with a gearbox drive to the propeller.

A propeller, in order to operate efficiently, must rotate at a relatively low speed. Thus, regardless of the rotational speed of the prime mover, the propeller shaft must rotate at about 80 to 100 rev/min. The slow-speed diesel engine rotates at this low speed and the crankshaft is thus directly coupled to the propeller shafting. The medium-speed diesel engine operates in the range 250–750 rev/min and cannot therefore be directly coupled to the propeller shaft. A gearbox is used to provide a low-speed drive for the propeller shaft. The steam turbine rotates at a very high speed, in the order of 6000 rev/min. Again, a gearbox must be used to provide a low-speed drive for the propeller shaft.

Slow-speed diesel

A cutaway drawing of a complete ship is shown in Figure 1.1. Here, in addition to the machinery space, can be seen the structure of the hull, the cargo tank areas together with the cargo piping and the deck machinery. The compact, complicated nature of the machinery installation can clearly be seen, with the two major items being the main engine and the cargo heating boiler.

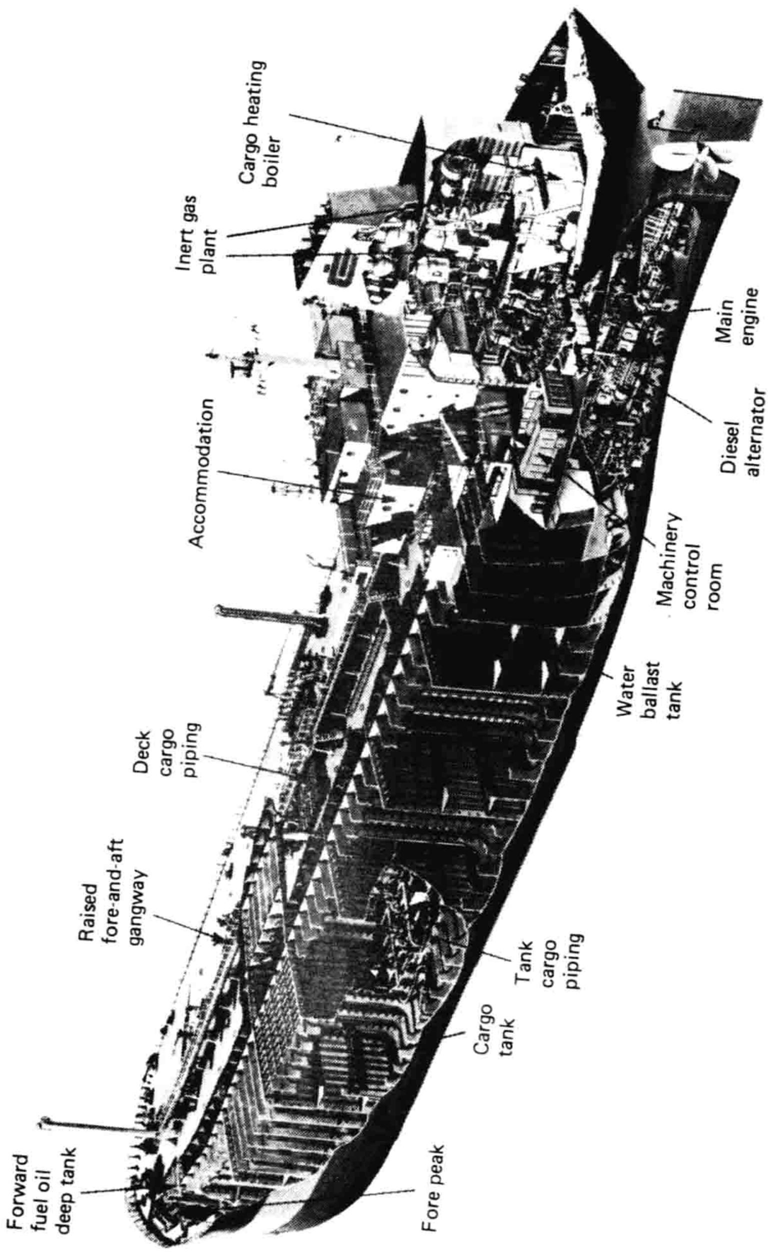


Figure 1.1 Cutaway drawing of a ship

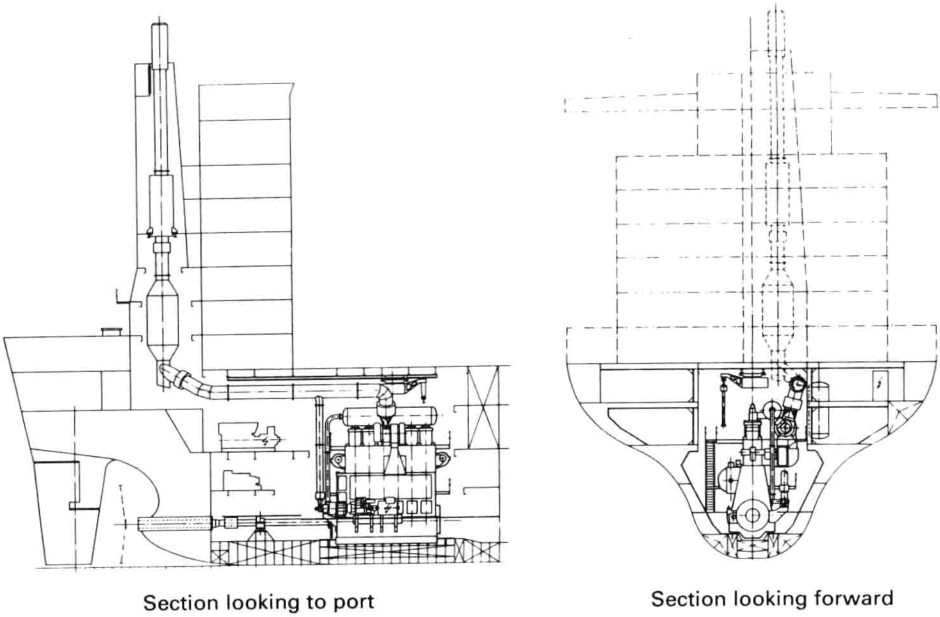


Figure 1.2 Slow-speed diesel machinery arrangement

The more usual plan and elevation drawings of a typical slow-speed diesel installation are shown in Figure 1.2.

A six-cylinder direct-drive diesel engine is shown in this machinery arrangement. The only auxiliaries visible are a diesel generator on the upper flat and an air compressor below. Other auxiliaries within the machinery space would include additional generators, an oily-water separator, an evaporator, numerous pumps and heat exchangers. An auxiliary boiler and an exhaust gas heat exchanger would be located in the uptake region leading to the funnel. Various workshops and stores and the machinery control room will also be found on the upper flats.

Geared medium-speed diesel

Four medium-speed (500 rev/min) diesels are used in the machinery layout of the rail ferry shown in Figure 1.3. The gear units provide a twin-screw drive at 170 rev/min to controllable-pitch propellers. The gear units also power take-offs for shaft-driven generators which provide all power requirements while at sea.

The various pumps and other auxiliaries are arranged at floor plate level in this minimum-height machinery space. The exhaust gas boilers and uptakes are located port and starboard against the side shell plating.

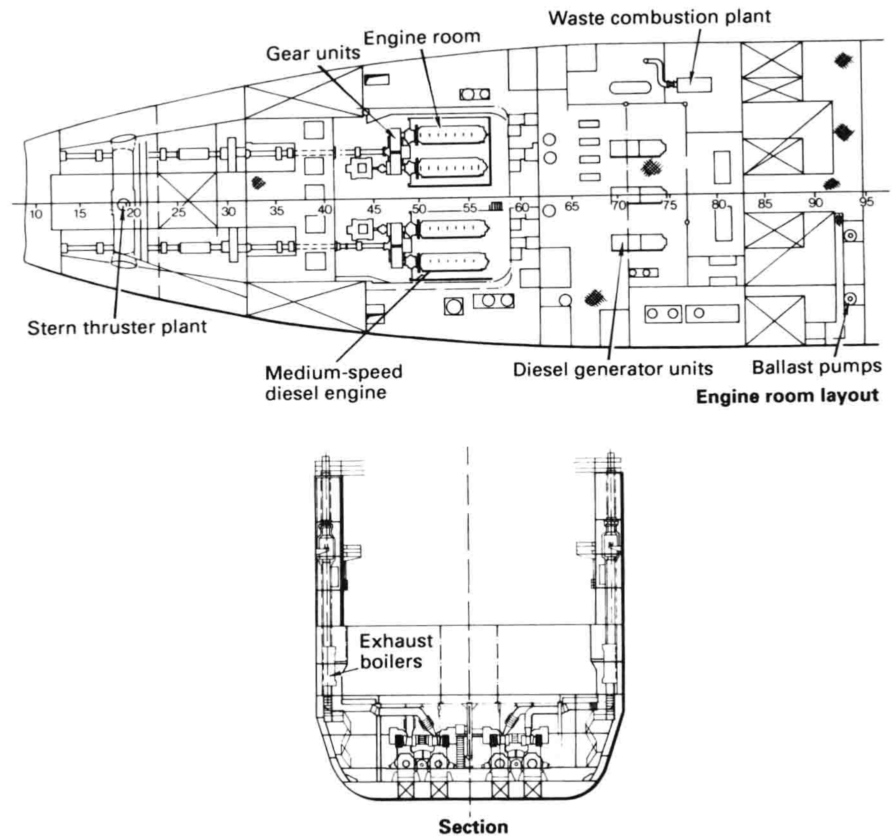
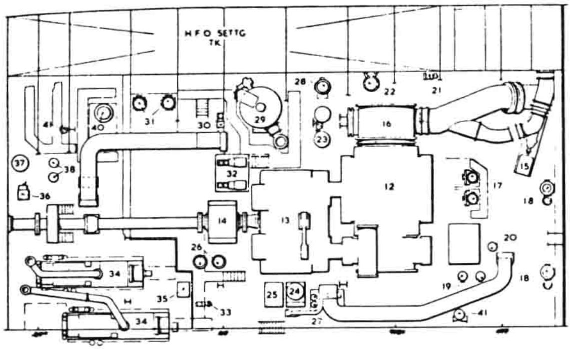


Figure 1.3 Medium-speed diesel machinery arrangement

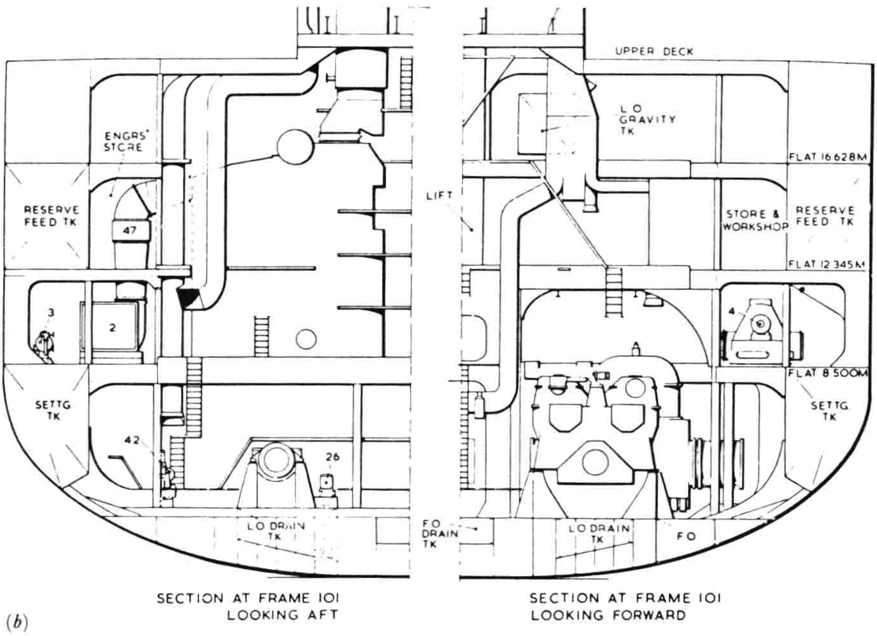
A separate generator room houses three diesel generator units, a waste combustion plant and other auxiliaries. The machinery control room is at the forward end of this room.

Steam turbine

Twin cross-compounded steam turbines are used in the machinery layout of the container ship, shown in Figure 1.4. Only part plans and sections are given since there is a considerable degree of symmetry in the layout. Each turbine set drives, through a double reduction gearbox with separate thrust block, its own fixed-pitch propeller. The condensers are located beneath each low-pressure turbine and are arranged for scoop circulation at full power operation and axial pump circulation when manœuvring.



(*a*) *Part plan at floorplate level*



(*b*)

Figure 1.4 Steam turbine machinery arrangement

1 Main boiler
2 FD fan
3 Main feed pump
4 Turbo-alternator
7 SW-cooled evaporator
10 Hot water calorifier
11 FW pressure tank
12 Main turbines
13 Main gearbox
14 Thrust block
15 Main SW circ pump
16 Main condenser
17 Main extraction pump
18 Bilge/ballast pump
19 Drains tank extraction pumps
21 Turbo alternator pump
22 LO cooler
24 LO bypass filter and pumps
26 LO pumps
28 Fire pump
29 Auxiliary boiler
30 Auxiliary boiler feed heater
31 HFO transfer pump module
32 HFO service pumps
33 Diesel oil transfer pump
34 Diesel alternator
35 Diesel alternator controls
40 Condensate de-oiler
41 Refrigerant circulation pump
42 Oily bilge pump
43 Steam/air heater

At the floorplate level around the main machinery are located various main engine and ship's services pumps, an auxiliary oil-fired boiler and a sewage plant. Three diesel alternators are located aft behind an acoustic screen.

The 8.5 m flat houses a turbo-alternator each side and also the forced-draught fans for the main boilers. The main boiler feed pumps and other feed system equipment are also located around this flat. The two main boilers occupy the after end of this flat and are arranged for roof firing. Two distillation plants are located forward and the domestic water supply units are located aft.

The control room is located forward of the 12.3 m flat and contains the main and auxiliary machinery consoles. The main switchboard and group starter boards are located forward of the console, which faces into the machinery space.

On the 16.2 m flat is the combustion control equipment for each boiler with a local display panel, although control is from the main control room. The boiler fuel heating and pumping module is also located here. The de-aerator is located high up in the casing and silencers for the diesel alternators are in the funnel casing.

Operation and maintenance

The responsibilities of the marine engineer are rarely confined to the machinery space. Different companies have different practices, but usually all shipboard machinery, with the exception of radio equipment, is maintained by the marine engineer. Electrical engineers may be carried on very large ships, but if not, the electrical equipment is also maintained by the engineer.

A broad-based theoretical and practical training is therefore necessary for a marine engineer. He must be a mechanical, electrical, air conditioning, ventilation and refrigeration engineer, as the need arises. Unlike his shore-based opposite number in these occupations, he must also deal with the specialised requirements of a floating platform in a most corrosive environment. Furthermore he must be self sufficient and capable of getting the job done with the facilities at his disposal.

The modern ship is a complex collection of self-sustaining machinery providing the facilities to support a small community for a considerable period of time. To simplify the understanding of all this equipment is the purpose of this book. This equipment is dealt with either as a complete system comprising small items or individual larger items. In the latter case, especially, the choices are often considerable. A knowledge of machinery and equipment operation provides the basis for effective maintenance, and the two are considered in turn in the following chapters.

Chapter 2
Diesel engines

The diesel engine is a type of internal combustion engine which ignites the fuel by injecting it into hot, high-pressure air in a combustion chamber. In common with all internal combustion engines the diesel engine operates with a fixed sequence of events, which may be achieved either in four strokes or two, a stroke being the travel of the piston between its extreme points. Each stroke is accomplished in half a revolution of the crankshaft.

Four-stroke cycle

The four-stroke cycle is completed in four strokes of the piston, or two revolutions of the crankshaft. In order to operate this cycle the engine requires a mechanism to open and close the inlet and exhaust valves.

Consider the piston at the top of its stroke, a position known as top dead centre (TDC). The inlet valve opens and fresh air is drawn in as the piston moves down (Figure 2.1(a)). At the bottom of the stroke, i.e. bottom dead centre (BDC), the inlet valve closes and the air in the cylinder is compressed (and consequently raised in temperature) as the piston rises (Figure 2.1(b)). Fuel is injected as the piston reaches top dead centre and combustion takes place, producing very high pressure in the gases (Figure 2.1(c)). The piston is now forced down by these gases and at bottom dead centre the exhaust valve opens. The final stroke is the exhausting of the burnt gases as the piston rises to top dead centre to complete the cycle (Figure 2.1(d)). The four distinct strokes are known as 'inlet' (or suction), 'compression', 'power' (or working stroke) and 'exhaust'.

These events are shown diagrammatically on a timing diagram (Figure 2.2). The angle of the crank at which each operation takes place is shown as well as the period of the operation in degrees. This diagram is more correctly representative of the actual cycle than the simplified explanation given in describing the four-stroke cycle. For different engine designs the different angles will vary, but the diagram is typical.

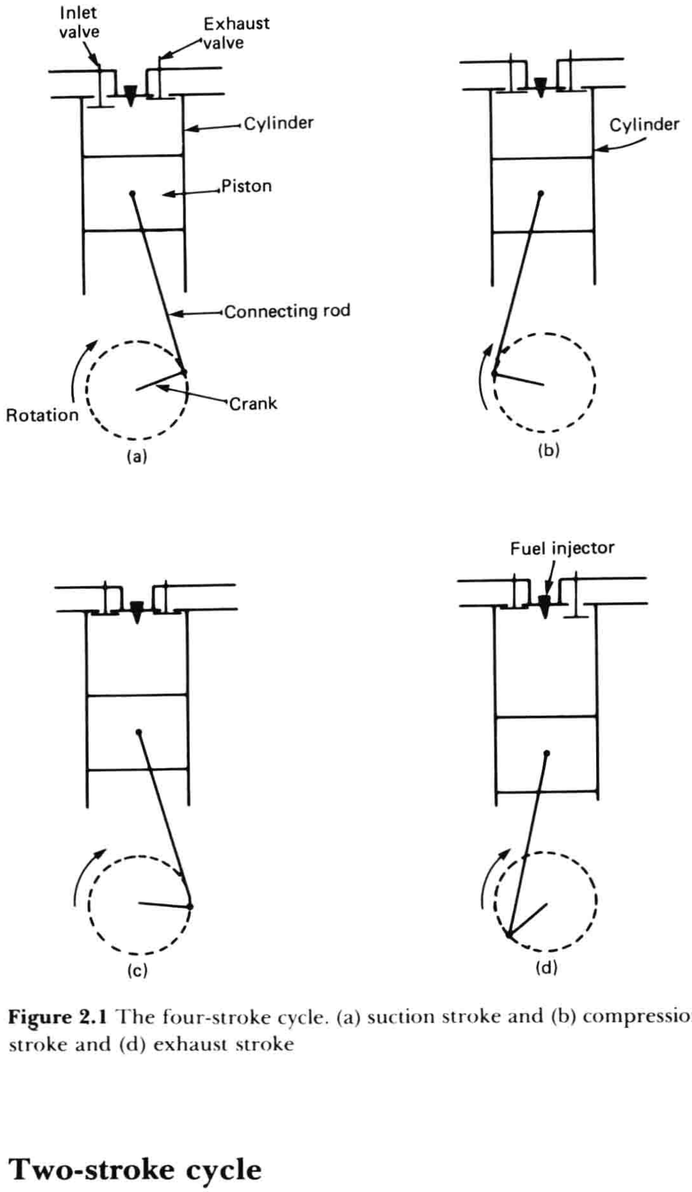


Figure 2.1 The four-stroke cycle. (a) suction stroke and (b) compression stroke. (c) power stroke and (d) exhaust stroke

Two-stroke cycle

The two-stroke cycle is completed in two strokes of the piston or one revolution of the crankshaft. In order to operate this cycle where each event is accomplished in a very short time, the engine requires a number of special arrangements. First, the fresh air must be forced in under pressure. The incoming air is used to clean out or scavenge the exhaust