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Experiments in Noise Reduction in Ships.

READ

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CHAIRMAN: MR. R. RAINIE, M.C. (Chairman of Council).

Synopsis.

IN practically all forms of transport attention is being directed to the reduction of noise, particularly by the application of various acoustic principles during construction. Little data exists, however, in relation to ships. The present paper deals with the acoustic problems of noise (as distinct from vibration) in passenger accommodation and describes some laboratory and practical research into means of reducing this, particularly in Diesel-engined vessels.

Methods of determining the sound absorbing and sound insulating properties of materials are reviewed, with comparative figures for those used in ship construction. The measurement and interpretation of noise levels is discussed, and portable sound measuring instruments for use in practical ship tests are illustrated. Some methods of sound insulating engine-room casings and passenger accommodation are given, together with the results of large scale experiments to determine their relative effects. Sound measurements made in various Diesel ships (both with and without acoustic insulation) are tabulated and include results of application to (a) newly constructed vessels (b) those which have been in service.

In connection with new vessels, various noise precautions which may be taken during construction are reviewed, and some data is included in connection with sound deadening of fan rooms and trunking.

SECTION 1. GENERAL CONSIDERATIONS.

Noise To-day.

In practically every form of transport, attention is being directed to the reduction of noise by the application of acoustic principles during construction. Typical examples upon which research has been undertaken are railways, automobiles and aircraft. Little information exists, however, in relation to ships. The author has, therefore, endeavoured to include within the scope of this paper some general information on noise and its measurement in order that it may be available in a condensed form for marine engineers and shipbuilders.

It will be agreed that noise is very much in the public mind to-day. A number of factors have brought about this result, in particular the increasing mechanisation of the age, coupled with the faster tempo of life in general.

It is of interest to note that a parallel development has occurred in both engineering and architecture in relation to noise. This arises from the higher stressing of structural materials. In engineering we have development along the lines of higher speeds and greater powers coupled with higher stress and lower overall weight (vide marine propulsion). This makes for greater noise. In architecture and building construction we have larger buildings composed of lighter materials. These take the form of a stressed steel framework in which the walls and subdivisions are relatively light, and are not necessarily load-carrying members as in the older types of construction. The reduction in mass greatly facilitates the transmission of sound. Therefore, modern buildings are more noisy than those of the last century. In other words, we have increased noise by mechanisation and simultaneously diminished the resistance of our buildings. Caught between two fires, so to speak, the public have had noise consciousness thrust upon them. This position is being modified in two ways, firstly by the attention of the engineer to reducing sounds produced by machinery and secondly by the architect in providing a greater degree of protection against them.

The impact of these problems upon many industries has been considerable and great strides have been made. It seems apparent that an analogous situation is now coming to the notice of the shipbuilder, who, in addition to his already considerable difficulties, is faced with both the engineering and architectural aspects. During an association extending over a number of years with the acoustical difficulties of various industries, the author has observed that progress in these respects is achieved only by patient research and practical experiment. The subsequent sections of this paper, therefore, must be regarded only as a small contribution to a very considerable problem.

The Effects of Noise.

We have to-day reached a stage where excessive noise is to be regarded as anti-social and largely unnecessary. It has to be remembered that the ear is one of the warning or protective devices of the body and as such is in constant operation, i.e we can close our eyes, but not our ears. Opinion is divided upon the extent of the physiological effects on the human organism produced by exposure to noise, but all authorities are agreed that it is harmful. To quote Professor George Robertson: "The effect of noise, especially prolonged noise, on the nervous system may be in the nature of a constant drain on nervous energy and lead ultimately to exhaustion and neurasthenia". On the subject of adjusting ourselves to the exposure to noise, Lord Horder says: "It is true that our nerves have the power of adjustment, but we do not gain in any way and it is sheer waste of good stuff to make this particular adjustment".

There appears to be no method of measuring the "annoyance factor" of various sounds, since some persons find low pitched notes more irritating than high ones and vice versa. In general, however, loudness is the principal source of annoyance, though most people find impulsive and intermittent sounds (such as those produced by pneumatic drills) more irritating than continuous notes.

Noise in Relation to Ships.

The structure of a ship represents an efficient medium for the transmission of sound throughout its bulk. There are also so many sources of sound. Usually the subject is considered purely from the passengers' point of view, but it should also be borne in mind that the ship's personnel are subjected to the loudest part of it, particularly the engine-room staff. Moreover, the cabins of many of the crew are of necessity situated in noisy positions which offer no opportunity for relief.

The effects of noise are none the less serious because the sufferer may be unaware of the cause and extent of the damage.

Among the various methods of propulsion, the noise produced by internal combustion engines is of importance in view of the increasing popularity of the motorship. Whereas in earlier Diesel engines the maximum pressure in the cylinders rarely exceeded 500lb. per sq. in., in modern dual cycle engines this figure rises to 700lb. per sq. in. and in some cases even more. Coupled with this we have lighter installations of greater horse power and increased speeds of auxiliary equipment such as Diesel driven generators. Offsetting these to some extent are mechanical improvements in valve gear, more efficient silencing, etc.

The great engineer, James Watt (quoted by J. H. Marshall) wrote in describing an engine in one of the Cornish tin mines: "The velocity, violence, magnitude and horrible noise of the engine give universal satisfaction to all beholders". Fortunately noise is not regarded to-day as a measure of efficiency! The principal complaint against ship noise, however, is that it often interferes with sleep. The throbbing noise of reciprocating engines and the low pitched components of gear noise are frequently referred to by passengers.

Normally, people sleep in a background sound level which is very low and this makes ship noise seem louder at night by comparison with the higher background level normally experienced during the day. The ordinary daily activities of moving, talking, etc., all produce sounds in themselves comparable with the engine noise experienced in ships' cabins. When this activity ceases, the cabin noise is thrown into greater prominence and appears to be louder. The ordinary mechanism of hearing is assisted by "bone conduction" in which the bones of the skull play a part. The fact of laying the head on a pillow in a cabin helps to increase the efficiency with which structure-borne sounds are heard. For this reason the modern provision of cabin beds rather than bunks is advantageous, since these can be isolated by means of suitable mountings from the cabin floor upon which they rest.

Characteristics of Sound.

Sound waves are produced by vibrating bodies and consist of alternations of condensation and rarefaction in the air. They pass outwards in all directions and can be reflected, or absorbed, according to the nature of the surfaces against which they strike in their course. They also travel easily through solids as well as gases. The essential characteristics stated briefly are :—

(1) *Velocity.* This is constant for all pitches and depends upon the medium of propagation. In air v is about 1,100ft. per second and in steel 16,300ft. per second.

(2) *Amplitude.* The amplitude of the wave determines the loudness of the sound.

(3) *Frequency.* The frequency of the wave (i.e., cycles per second) determines the pitch of the note. Low notes have low frequencies and vice versa.

(4) *The wavelength* of a sound is the distance between the respective condensations.

The simple relationship is :

$$v = n\lambda$$

where

v = velocity in ft. per second.

n = the frequency in cycles per second.

λ = the wavelength in ft.

Noise may be described as "unwanted sound" but in general a noise is a mixture of sounds of various frequencies which create an unpleasing effect on the ear. For this reason some modern forms of music are pleasurable to some persons but are merely "noise" to others. Most engineers derive pleasure from the rhythm of an engine in perfect tune, particularly if they are closely associated with the design or operation of it. The same rhythm, however, may be unadulterated noise to another listener. The frequency range of the human ear extends from 16 to 20,000 cycles per second, termed "audio-frequencies". Mechanical vibration is usually distinguished from sound in that it covers the relatively low range of frequencies which can be "felt" rather than "heard", although all sound has its origin in mechanical vibration.

Some ranges of frequency are given below :—

TABLE I.

	Frequency range (cycles per sec.).
Human hearing	16 — 20,000
Pianoforte, lowest note to highest note	26·8 — 8,192
Noise of turbo generator gear 6,000/1,000 r.p.m.	100 — 5,700
Noise of 3 phase induction motor 120 h.p. 750 r.p.m. 50 c.p.s. on load	120 — 3,400
Frequency range most generally encountered in engineering practice	100 — 6,000

The following table helps to fix the pitch of various frequencies for those unaccustomed to thinking in terms of cycles per second.

TABLE II.

Notes on Pianoforte.	*Corresponding frequency (cycles per sec.).*
2 octaves below middle C	64
1 octave "	128
Middle C	256
1 octave above middle C	512
2 octaves "	1,024

It will be observed that the frequency doubles for each step of one octave.

SECTION 2. LOUDNESS AND ITS MEASUREMENT.

Noise Level.

The quantitative expression of loudness of noise is a matter of some complexity. The author includes some general information on this subject here because of its importance to engineers and because some understanding of it is a primary essential in all considerations of noise. The engineer may well ask "Why bother with instrumental measurement and complicated units when I can tell whether a sound is loud or soft merely by listening to it?" The answer lies in the fact that the foundation of research and consequently of *knowledge* is in *measurement*. To quote Churcher & King (1) "Thus, while the ear is an exceedingly sensitive and discriminating detector of sounds, it cannot yield the quantitative information required. As with other engineering qualities, it is necessary to deal with sound on a basis of measurement in terms of a definite standard rather than on the basis of the opinions of individuals. . . . This is particularly important when considering the limits for the sound it is permissible for a piece of engineering apparatus to emit". Moreover it will be found that even an experienced acoustic observer cannot recollect degrees of loudness over a period of time. We must have measurement to preserve aural memory.

What the author calls (for want of a better expression) "interest-association" also plays a part. For example, those associated with the production of a given noise will assess it less loudly than others who have to listen to it. Similarly a competitive engine is generally noisier than one's own! This occurs quite genuinely in a great many widely divergent cases in all industries. Thus, the chief engineer of a ship is the best judge of *quality* of engine noise and a less accurate judge of *loudness* of engine noise. It is necessary, therefore, to guard against psychological influences in the assessment of loudness and the annoyance factor associated with it.

One of the difficulties in numerically defining degrees of loudness lies in the enormous range of operation of the human ear. If we measure the energy of the smallest sound that can be heard (at medium frequencies), and compare it with the energy of the loudest sound, we find that one is a million-million times the other.

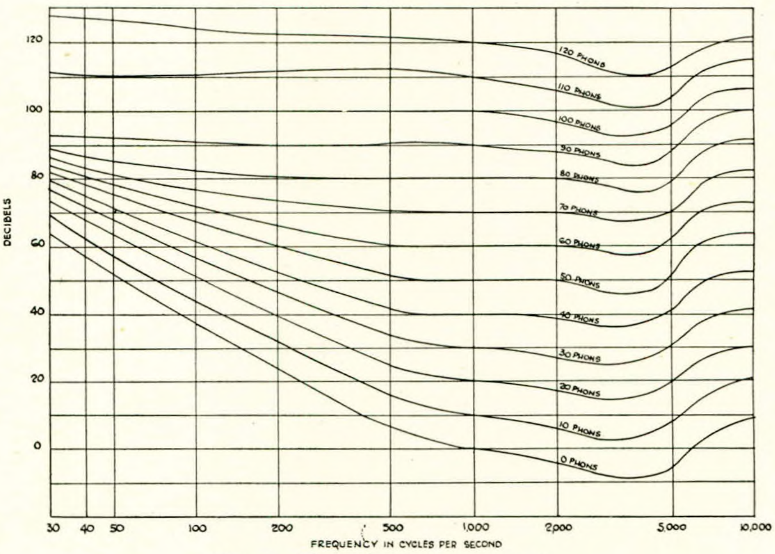

FIG. 1.—Equal loudness contours.

These two important points in connection with hearing are termed respectively "the threshold of audibility" and "the threshold of pain". A numerical scale on this basis would involve enormous and cumbersome values. Moreover, we also find that the ear reduces its response as sounds increase in loudness. In fact, it records geometric increments of sound energy as arithmetic increments. For this reason any unit adopted must be logarithmic in character. The *bel* is an amplification ratio signifying a 10-fold increase in energy, power or intensity. Two bels correspond to a 100-fold increase. In practice the *decibel* (one-tenth of a bel) is the unit more commonly used. The following table, due to A. H. Davis, shows this clearly in relation to the energy.

TABLE III.

DECIBELS (A METHOD OF EXPRESSING AMPLIFICATION RATIOS).

Amplification of energy in sound wave.	*Amplification of pressure in sound wave.*	*Intensity change in decibels.*
1,000,000,000,000-fold	1,000,000-fold	120
100,000,000	10,000	80
10,000	100	40
100	10	20
10	3·2	10
4	2	6
2	1·4	3
1·26	1·1	1

We can express the difference in loudness between two similar sounds in decibels according to the following relationship.

$$\text{Difference in intensity (decibels)} = 10 \log_{10} \frac{I_1}{I_2}$$

or

$$\text{Difference in intensity (decibels)} = 20 \log_{10} \frac{p_1}{p_2}$$

where I_1 and I_2 are the intensities of the two sounds. and p_1 and p_2 are the pressures of the two sounds. By adopting any particular standard for I_2 or p_2 we can express the loudness of a given note as so many decibels *above* this standard. It will be noted that the decibel is a ratio, and does not express "level" of sound unless used in relation to a fixed standard, usually a specified threshold of audibility.

Sounds having the same energy or pressure (i.e., intensity) do not necessarily sound equally loud if their pitch differs. Intensity, therefore, is a physical property of sound, but loudness is its effect upon the human ear, which is something quite different. Moreover when we consider noise as a complex sound composed of many frequencies, it will be seen that complications arise. For these reasons great care has to be exercised in comparing loudness figures expressed in decibels which are not of recent date. The standards previously adopted in various countries differ by some 14 db, and were usually stated without any associated reference level.

Following an international conference this matter has been remedied by the adoption of a further unit, the *phon,* which is now standard throughout the world for the expression of the loudness of sounds, the decibel being restricted to energy ratios.

The Phon.

The Phon is the British Standard unit of equivalent loudness. Its standards are a pure note of 1,000 cycles per second, and a reference level of 0·0002 dynes per sq. cm. The loudness of any sound or noise is η phons when it is equally as loud as a 1,000 cycle note of η decibels—above 0·0002 dynes per sq. cm. Phons therefore may be loosely described as "decibels at 1,000 cycles". In fact the nomenclature used in the United States is "decibels

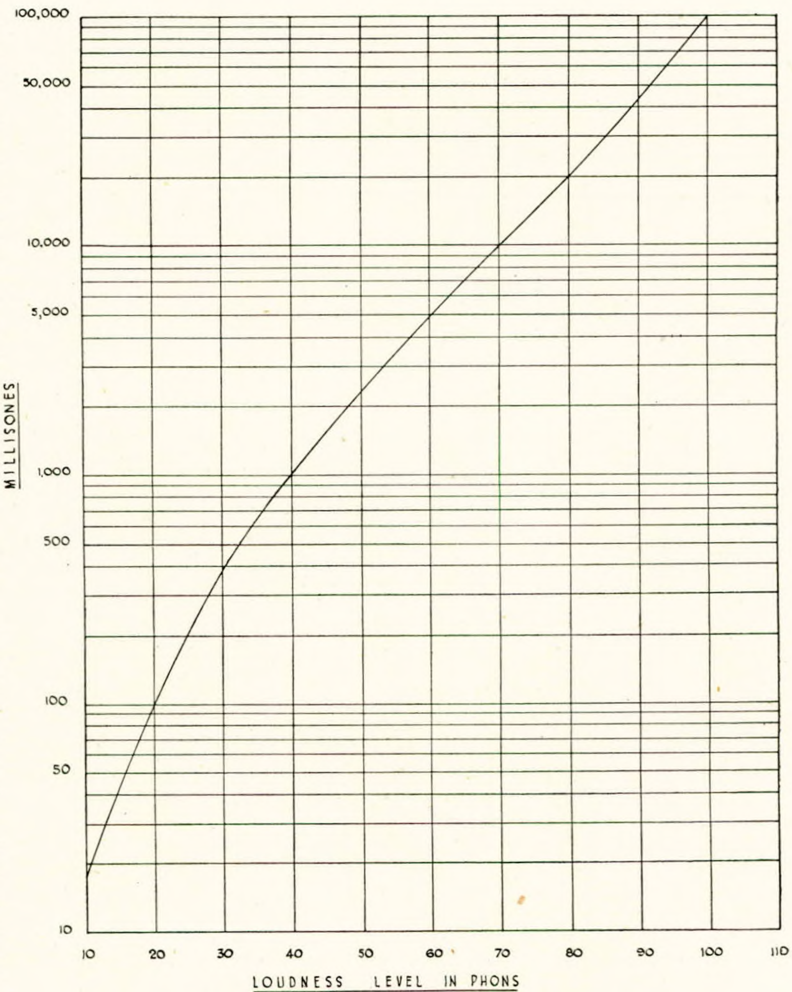

FIG. 2.—Curve of phons and millisones.

above 10^{-16} watts per sq. cm.", this being the energy corresponding to a sound pressure of 0·0002 dynes per sq. cm.

Referring to Fig. 1 a series of contours of sounds of equal loudness are plotted at various frequencies (Fletcher & Munson). It will be noted that the loudness range of the ear is covered in 120 steps from the threshold of audibility (zero phons) to the threshold of pain (120—130 phons). The range of greatest sensitivity occurs in the vicinity of 1,000 cycles per second. For convenience, one phon may be regarded as a perceptible step in loudness of which there are about 130 in the range of hearing.

The Practical Interpretation of Phons.

An unfortunate feature of these loudness units is that they require familiarity for their interpretation in every-day practice. The Author feels that it will be helpful to discuss this point at greater length because engineers so frequently ask for information concerning it.

Owing to the peculiarities of the ear these units are necessarily logarithmic in origin. For this reason we cannot compare loudness levels in the ratio of the figures concerned, i.e., if we reduce a noise from 100 phons to 90 phons the change does not sound like ten per cent. Actually it sounds nearer 50 per cent. Engineers frequently require to make this comparison, for example when considering the effect on the total noise of machinery due to a change in design. Churcher, King & Davies [2] have proposed a series of loudness numbers in which 100 phons has a loudness number of 100, the other levels being arranged on a comparative aural basis.

Another, somewhat similar, method has been proposed recently by Fletcher [3] employing a larger arbitrary number, viz., 100,000 for the "American Tentative Standard". These loudness units have been called "millisones" by Knauss [4], a terminology which avoids confusion between the terms "loudness level" and "loudness units".

A curve is shown in Fig. 2 which enables comparisons on a percentage basis to be made by converting from phons to millisones. It will be seen that a reduction in noise of 10 phons from a level of 100 phons sounds very different to a reduction of 10 phons from 30 phons. At the noise levels encountered on ships (round about 80 phons) the following table of reductions in per cent. may be useful.

TABLE IV.

AURAL REDUCTION PHONS TO PER CENT.

Noise Reduction phons.	*Noise level (phons) from*	*to*	*Equivalent percentage registered by the ear.*
5	80	75	30
10	80	70	50
15	80	65	66
20	80	60	77

It should be noted that the relation between phons and millisones is obtained from the loudness estimations of a large number of individuals and therefore represents the subjective effect of loudness upon the *average ear.*

Levels for Various Sounds in Phons.

A variety of noise levels are given in Table V. They are arranged to show conveniently how the sounds ordinarily met with on shipboard compare with the more familiar kinds of noise ashore. There is always a good deal of variation between noise levels according to the nearness or otherwise of the source. These examples represent averages and in most cases deviations above and below have been recorded.

TABLE V.

VARIOUS NOISE LEVELS WITH THEIR EQUIVALENTS ON SHIPBOARD.

Types of noise (various).	*Noise level (phons).*	*Noises associated with Ships and Shipbuilding.*
Sound is painful about	130	
Aeroplane engine (18ft. from airscrew)	125	
	114	Ship's syren
	113	Hammering on steel plate
	110	Boiler factory
Pneumatic drill	105	Engine room of Diesel ship (normal)
	104	Marine turbo-blowers
	102	Auxiliary generators
Heavy traffic in Mersey Tunnel	100	
London Underground Rly.	98	Turbine engine-room (near gear cases)
	93	Roller chain 1,000 r.p.m.
Ministry of Transport statutory limit for road vehicles	90	Engine-room of Diesel ship (sound insulated)
London traffic (very dense)	89	
	87	Machine shop
Typing office	85	Cabins near casings on Diesel ship (normal)
Automobile factory	82	
In noisy automobile at 30 m.p.h.	80	Cabins on Diesel ship (normal)
Moderate traffic in street	80	
Railway train	75	Smoke-room on Diesel ship
In quiet automobile 30 m.p.h.	70	
Ordinary conversation	65	Cabins on Diesel ship (insulated)
Quiet office	62	Cabins on large turbine driven liner
Street in suburb (no traffic)	45	
Country road (no traffic)	38	
Sitting still in quiet house	25	
In the country (very quiet)	15	
Threshold of hearing	0	

Referring to the table, it may seem surprising that a ship's engine-room may compare with a pneumatic drill (105 phons), and a ship's cabin with London traffic (89 phons) or a typing office (85 phons). The readings do show, however, the reason for the complaints sometimes made by passengers, since some of the values given approach the legal limits for noise of road vehicles of the Ministry of Transport (90 phons). Moreover these are generally agreed by the motor industry to be exceedingly tolerant, even for heavy vehicles.

It will be observed that when we get below 50 phons we have more or less passed out of the range of ship noise. At the lower noise levels the ear is extraordinarily responsive, and even when we are in conditions of comparative silence there are always minute sounds which the ear can register.

To quote Humbert Wolfe: " . . . . the little feet of rain gliding from blade to blade are almost heard". Even in very quiet surroundings in the country (15 phons) we still have the movement of leaves and the sounds of insects to create at least some slight level of loudness.

Noise Meters.

Several reliable types of noise meters are on the market at the present time, and the fact that field measurements can now be made with ease has greatly contributed to the improvements in mechanical and electrical machinery which many manufacturers have been able to effect from the standpoint of noise. During the earlier days of the author's association with acoustics, very little apparatus was commercially available and one was often driven to the expedient of having to design and construct suitable apparatus (sometimes with indifferent results) before a specified piece of research could be carried out. The investigator of to-day is in a much happier position.

Noise meters are of two types—

(1) Subjective meters, in which the instrument itself creates a tone which is equated to the noise to be measured, and

(2) Objective meters, in which the noise is directly recorded by a microphone, amplifier, and attenuator. Meters of this type have suitable electrical networks incorporated in the amplifier circuit to enable the instrument to simulate the frequency sensitivity of the ear for various loudnesses. Examples are illustrated in Figs. 3 and 4.

With the subjective type of meter, the matching of the tone depends upon the observer, and readings by different observers do not necessarily agree. The author prefers the objective type of meter because personal bias is avoided and independent observers can check the visual readings if desired. There are, however, certain limitations to their use.

In general we are concerned in engineering practice with the *effect* upon some given noise, of design modifications or acoustic treatment, and in these cases it is the *difference* before and after which matters most. For this reason a slight variation from the true aural loudness does not greatly matter, provided it remains constant for both measurements. Normally the author uses a portable objective meter designed by the National Physical Laboratory, which incorporates a condenser microphone. For ship work, however, one of the piezo-electric type is often used on account of its comparative lightness and greater portability, a matter of importance when it is necessary to secure a number of readings in different parts of a vessel in a limited time.

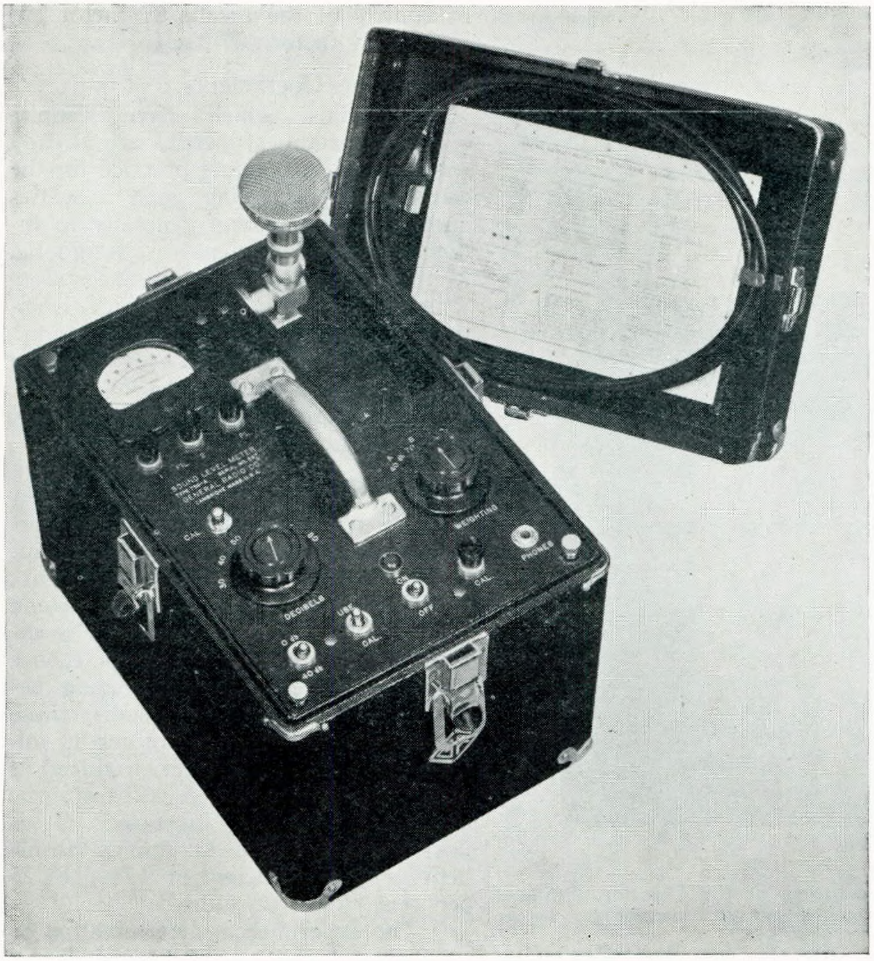

FIG. 3.—Typical sound level meter—objective type.

For further information on the subject of noise meters, the reader is referred to a paper by Dr. A. H. Davis: "An Objective Noise Meter for the Measurement of Moderate and Loud, Steady and Impulsive Noises" read before the I.E.E. (1937).

SECTION 3. THE ABSORPTION AND TRANSMISSION OF SOUND.

How Sound is transmitted in Ships.

The general structure of a ship is ideal for the propagation of sound energy. In the first place the principal sources of noise (i.e. machinery, etc.) are rigidly coupled to the structure and enable vibrations of the moving parts to be directly communicated. In the second place, steelwork is highly reflective to sound and propagates it from one surface to another with little loss of energy. We are therefore mainly concerned with the following:—

(1) Direct air-borne sound, i.e., sound energy radiated from the engines or other sources of noise. This impinges upon, and is transmitted through, the casing to the adjacent parts. It is conducted easily along alleyways, etc., by reflection from the bounding surfaces.

(2) Indirect air-borne sound, i.e., sound which impinges upon the casing and travels along (not through) it to distant parts of the ship, being radiated again as air-borne sound from the ship's plating. This is really a combination of air-borne and structure-borne sound.

(3) Structure-borne sound, in which the audio-frequencies of vibrations in the machinery are directly transmitted to the hull and radiated thence in different parts of the vessel.

If we disregard for the moment any question of reducing the sound energy at its primary source (i.e., by engine modifications), we see that there are these three paths which must be considered in any methods by which we may attempt to reduce noise.

In the case of both types of air-borne sound we can attempt to insulate against sound propagation either in the engine-room itself or in the passenger accommodation, or both. We can also attempt to reduce it by other means.

In the case of structure-borne sound we must provide mechanical isolation of the source by the use of resilient mountings, and this provides a problem of some practical difficulty on shipboard.

The succeeding sections deal with these individual lines of attack.

The Absorption of Sound.

From the work of Jaeger [5], Buckingham [6] and others, it has been shown that, for a uniform emission of sound in a room, the maximum intensity is given by

$$I_{max} = \frac{4E}{vaS.}$$

where

I_{max} = the maximum intensity (energy per unit volume).

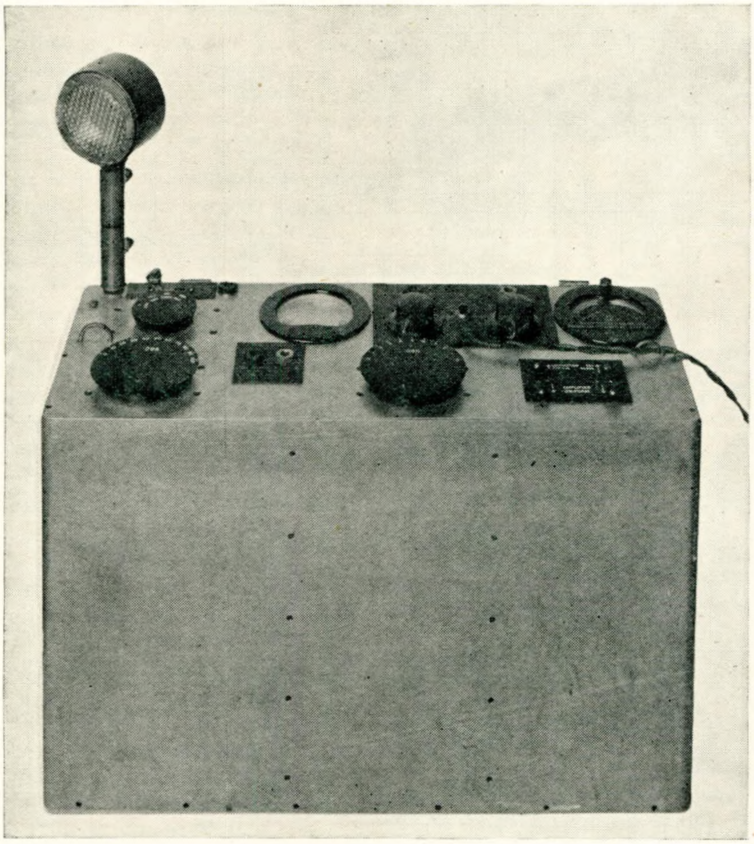

FIG. 4.—N.P.L. acoustimeter (by courtesy of the Director, National Physical Laboratory; Crown copyright reserved).

E =the rate of emission of energy from the source.
v =the Volume.
aS =the total absorbing power, i.e.
$= a_1 S_1 + a_2 S_2 —— + a_n S_n$.

To us as engineers, the important feature of this relationship is that the intensity resulting from a uniform emission of sound (e.g., an engine) depends upon the magnitude of the absorbing power of the enclosure. In other words the noise produced by a given engine depends upon *the acoustic properties of the engine-room,* as well as upon the noise emission of the machine itself. Obviously, in the practical application of this relationship, the effect reaches a maximum when the factor aS is a maximum. Therefore we can control, within limits, the noise level resulting from any given source by varying the absorbing power of the enclosure in which it is placed. There is nothing new in this principle but, so far as I am aware, its application to ships' engine-rooms on a large scale is of relatively recent origin.

The application of this principle gives us a means of partially controlling factors (1) and (2) previously discussed in connection with the propagation of sound in ships. It also gives us a measure of control of the results of factor (3) but not of factor (3) itself.

Absorption Coefficients.

Materials which have definite sound absorbing properties are already widely used in building practice for the purpose of producing good acoustics and controlling sound generally in industry. Their efficiency is designated by their coefficient of sound absorption, which expresses the proportion of incident sound absorbed by the material. The absorbing power of a given quantity of material is expressed in "absorption units" and is the product of the area and the absorption coefficient.

Since the absorption of the steelwork in a ship's engine-room is only about 1 per cent., and that of the normal protective surfaces of casing insulation from $1\frac{1}{2}$ per cent. to 2 per cent., it follows that the total absorbing power of the usual engine room is exceedingly small. Thus the noise echoes throughout the enclosure, ringing between the casings. If we modify these surfaces to be sound absorbing it follows that the noise level produced is automatically decreased as the total absorbing power is increased. It is possible in practice to employ absorbents with a coefficient of 0·75 (i.e., 75 per cent.) or even more.

The experimental determination of absorption coefficients involves a number of technical difficulties, and requires a special laboratory for the purpose. In the laboratory with which the Author is associated the "reverberation method" is used. The material to be tested is mounted as in practice in a large reverberant room, all surfaces of which consist of hard cement or similar material of low absorption, giving a reverberation period of several seconds. Sounds of pure wave form are produced by loudspeakers fed from a thermionic valve oscillator which produces a range of audio-frequencies (usually 50—10,000 cycles per sec.). The sound source is cut off and the rate of decay of intensity measured from various levels. This is effected by picking up the decaying sound on a microphone which, through its amplifier, operates a thyratron-valve relay. The relay in turn controls a phonic chronoscope which records the reverberation times obtained. This is repeated for the various frequencies under examination both with, and without, the test area installed. From the graphs so obtained the absorption coefficient of the material is calculated.

Sound Absorbing Materials.

Broadly speaking, hard materials such as steel, concrete, plaster, etc., have practically no sound absorbing capacity, in fact they are efficient reflectors of sound. On the other hand, soft fibrous materials such as felts, cushions, carpets, etc., are good sound absorbers. (Note the difference in reverberation between an empty room and a well-furnished room). The following table gives the absorption coefficients for various materials :—

TABLE VI.

Sound Absorption of Miscellaneous Materials.

Material.	*Absorption coefficient at 500 c.p.s.*
Steel plate	0·01
Plaster and cement surfaces	0·02
Glass	0·02
Wood—painted	0·03
„ unpainted	0·06
Cork tiles	0·06
Rubber carpet	0·08
Fibre boards ½in. thick (painted)	0·12
Carpets	0·15 — 0·3
Fibre boards ½in. thick (unpainted)	0·2 — 0·3
Acoustic plasters	0·2 — 0·3
Hair felt 1in. thick	0·55
High efficiency materials especially manufactured for acoustic purposes	0·6 — 0·8
Open window...	1·0

It is relatively easy to produce special materials of high sound absorption. Difficulties arise, however, when appearance, strength, application, resistance to fire and other practical properties are involved. There is a wide range of products commercially available to meet these different requirements but the majority are unsuitable in varying degrees for use on shipboard. The following is a short table of materials which to the Author's knowledge have been employed on ships. The absorption is given for various frequencies.

TABLE VII.

Sound Absorption of Materials used in Ships.

No.	*Description.*	*Absorption coefficient at various frequencies. (Cycles per second).* 250	500	1000	2000	*Mean for the range* 250-2000
1.	Asbestos fibre tiles with drilled surface, 1in. thick	0·55	0·75	0·85	0·80	0·74
2.	Cane fibre tiles with drilled surface, 1¼in. thick... ...	0·43	0·98	0·79	0·57	0·69
3.	Asbestos fibre sheets 2in. thick	0·55	0·65	0·75	0·80	0·69
4.	„ „ 1in. „	0·50	0·55	0·65	0·70	0·60
5.	Sprayed asbestos 1in. thick ...	0·45	0·70	0·70	0·75	0·65
6.	„ „ ½in. „ ...	0·30	0·35	0·50	0·60	0·44
7.	Acoustic felt surfaced with thin perforated plating, 1in. thick	0·29	0·62	0·80	0·72	0·61
8.	Flexible asbestos blanket, ½in. thick	0·20	0·60	0·65	0·70	0·54
9.	Cork slabs, 2in. thick	0·17	0·35	0·27	0·34	0·28
10.	Fibre board $\frac{7}{16}$in. thick (unpainted)	0·20	0·24	0·22	0·23	0·22

Tested by N.P.L.—Nos. 1, 3 to 6, 8.
„ Acoustical Materials Association (U.S.A.)—No. 2.
„ P. A. Sabine—No. 7.
„ F. R. Watson—No. 9.
„ several authorities (average)—No. 10.

The efficiency of all these materials, with the exception of Nos. 1, 2, and 7, is impaired by repeated painting. This loss, however, can be minimised by taking certain precautions during this operation. The asbestos products are, of course, fireproof, due to their composition. Material No. 7 can also be produced in a fireproof form. Materials Nos. 3, 4, and 8, are generally employed for sound insulation purposes behind panelling in passenger accommodation. Materials Nos. 1 and 7 would appear to be most suitable for engine-room use. Cork slab (No. 9) has been used for this purpose, but its absorption coefficient is comparatively low and the author does not regard it as a safe material owing to the risk of fire. When employed for cold storage insulation this objection does not apply as the cork is covered with cement or other non-inflammable protection.

Experiments in the Absorption of Marine Engine Noise.

The estimation of the probable reduction due to a given line of treatment is, of course, a matter of everyday practice. There are, however, various technical difficulties associated with the application of existing data to ships' engine-rooms and some practical checking appeared desirable. To this end, some practical tests were undertaken with a machine designed to simulate the noise of a large Diesel engine. This consisted of rollers rotating in a large steel drum, coupled with eccentrically set gears, and driven by an electric motor. By varying the relative speeds of the components and adjusting the sounds they emitted (by acoustic materials and damping), a fair imitation of this particular noise was produced, of the same loudness as that obtaining on ships. The machine was mounted on wheels in a large room adjusted to the acoustic conditions of a ship's engine-room. An adjacent room was treated with acoustic materials in varying quantities to produce pre-determined reductions in total noise. By moving the machine between the adjacent rooms the comparative loudness levels were measured. Noise reductions up to 15 phons were observed and it was found that good agreement with the calculated values was obtained in practice. Nothing new emerged from this work except the practical confirmation of values for the type of noise appertaining to the engines of motorships, at the same degree of loudness.

It may be mentioned here that the effect of acoustic treatment on engine noise is subtractive. That is to say, a correctly estimated reduction of 10 phons reduces a noise of 100 phons to 90. It also reduces 90 phons to 80, and so on. This is convenient in practice because it means that whatever noise level is encountered, it can definitely be reduced by a predictable amount. There is, however, a limit to the extent to which this can be done in practice because, with each increment of total absorption, the reduction in phons becomes slightly less. In general for shipwork not less than 7 phons should be attempted, and the limit is reached for engine-rooms between 12 and 15 phons, according to the area of casings, etc., available for treatment and the efficiency of the material. Incidentally, high efficiency materials are absolutely essential for ships' engine-rooms otherwise an insufficient effect is produced in relation to the cost of application. (Results for the large scale application of sound absorbents in ships' engine-rooms are given later in this paper). Although there are the practical limits referred to above, this method appears desirable in a ship because it affects the level of sound produced by the propelling machinery (or auxiliaries) in the engine-room itself, which is the source from which most of the ship's noise proceeds. Less noise here means less noise available for radiation in the passenger accommodation. Since thermal insulation of the casings in way of passenger accommodation is already a matter of general practice, the addition of sound insulation to the thermal insulation does not present any serious practical problem.

The Transmission of Sound.

Before considering this subject in relation to ships, some general information may be helpful. The transmission of sound through walls, partitions, floors, etc., has been studied by a number of investigators, in particular by the National Physical Laboratory and the Building Research Station, and a great deal of useful information is available.

The amount by which a sound is reduced in passing through a given partition is termed the Sound Reduction Factor of the partition and is usually expressed in decibels. With regard to single homogeneous partitions, such as brick walls, building block partitions, etc., the important fact has emerged that their resistance to sound transmission (i.e. resistance to sound passing through them) is a function of the logarithm of their mass. In other words, the deciding factor is weight and not the material itself. An example is shown in Fig. 5 (due to Constable) which illustrates the average sound reduction (for frequencies between 200 and 2,000 c.p.s.) of several materials when erected as single homogeneous partitions.

When considered at individual frequencies it is found that the insulation increases about 5 to 6db per octave (i.e. each time the frequency is doubled). High notes are thus easier to insulate against than low notes. Similarly by doubling the thickness, we increase the sound reduction factor by 5db. For this reason the structural weight becomes prohibitive when high insulation values are desired. When it is necessary to obtain a high degree of insulation, constructional devices have to be adopted, such as making a double partition on staggered supports, use of absorbing materials, isolating the edges, etc. In other words, materials alone are insufficient; design also must be considered, and such factors as discontinuity assume considerable magnitude.

When we attempt to apply some of these principles on shipboard many practical objections arise, such as mass, difficulty of effecting discontinuity, etc. In particular, we are up against the fact that the whole structure is in a state of forced oscillation, and any subsidiary structure has to be fixed directly to it, thus being itself set into oscillation. The ship, therefore, presents problems more complex than those encountered on land.

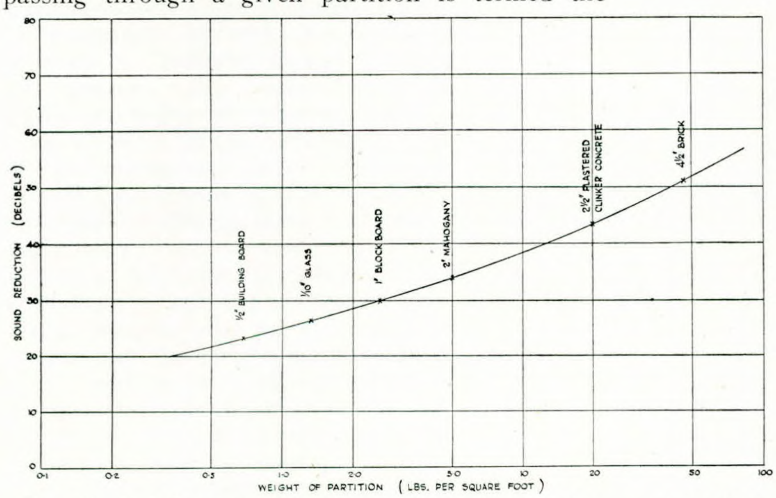

FIG. 5.—Relation between sound reduction and weight per square foot for single homogeneous partitions. (Average for 200-2,000 cycles per second.)

Consideration of Ships' Cabins.

Cabins are the particular location to which the attention of shipbuilders and owners is most frequently directed in searching for means of providing better acoustic conditions for the passengers. There has always existed an understandable desire for some material which is merely applied to structures to render them soundproof. Although the author has often heard that such a product was about to be produced, he has never seen it in practice! To-day we know that such a material cannot exist, and that the reduction of sound transmission is a matter of design and intelligent use of materials having diverse properties. We can illustrate this with a simple case. Assume we stop all transmission of sound from the underdeck, ship's side, etc., of a cabin and then leave large ventilating louvres open in the door; we immediately lose much of the advantage of the previous work because sound flows in through the openings. This effect may be compared to water flowing from one compartment of a tank into another until both attain the same level.

The author has found very definitely that cabin noise is influenced by the presence of adequate absorption. Therefore acoustic ceilings and luxury (soft) furnishings help considerably. Since there are several sources of noise in ships' cabins, a reduction is only effected by tackling the loudest source first, and reducing it below the level of the remaining sources. If the major noise happens to be from the ship's side, no treatment of other parts will be effective. If a sound has two components one 10db. less than the other, the smaller noise only contributes $\frac{1}{2}$ phon to the total loudness. Similarly, if there are two equal sound sources and one is completely eliminated, the total noise is only reduced by 3 phons. It is therefore possible to apply an efficient method of sound insulation to part of a structure and obtain practically no effect. This occurs, not because the insulation fails to do its job, but because it has been put in the wrong place, and the effect is drowned from some other noise source. A similar phenomenon often occurs in quieting machinery. A series of noises on an engine may be tackled correctly and produce practically no change in the overall loudness because the major source remains unaffected. This is one of the most discouraging features of machinery quietening from the engineers' standpoint, and calls for considerable perseverance on the part of those responsible for design and construction.

So far as the Author's experience goes, the source of the major component of cabin noise appears to vary with different designs of ship and the location of the particular cabins concerned. The ship's side in way of cabins is frequently assessed by marine engineers as the loudest source on certain classes of ship, and the Author undertook some experiments with a view to reducing (but not necessarily eliminating) this. These are briefly described in the succeeding paragraphs.

Experiments in Transmission Reduction.

For testing the resistance of various constructions to sound transmission, the method is to use two adjacent soundproof rooms. These have a communicating aperture usually about five feet by four feet, in which the construction is built. Sounds of varying frequency are made in one room and their loudness measured in both. The difference gives the reduction factor of the construction. In the laboratory with which the Author is associated these rooms are of double construction throughout, having an inner and outer masonry shell with an air space and sound-absorbing materials between. The walls are all built on separate foundations carried well down, so that there is no connection between them. Double soundproof doors are provided to each room in isolated frames. The doors screw up on to rubber gaskets to ensure sealing against extraneous sounds.

For these particular tests a section of ship's side complete with stiffeners was erected in the test aperture as shown in Fig. 6. In order to allow for losses at the deck a section of this was built out from the plate as shown. Transmission effects were examined both with and without this deck section in position, using loudspeakers as sources of sound and also the machine for simulating Diesel engine noise previously referred to. To reproduce practical conditions, the steel plating was vibrated directly from the machine by coupling the centre point to the machine itself by means of a steel bar. It is, of course, possible to effect large sound reductions when the machine and plate are completely separated. This, however, cannot occur in practice on shipboard, but some very interesting observations were made on the comparative effects of complete isolation and complete coupling. A number of methods were tried in the coupled con-

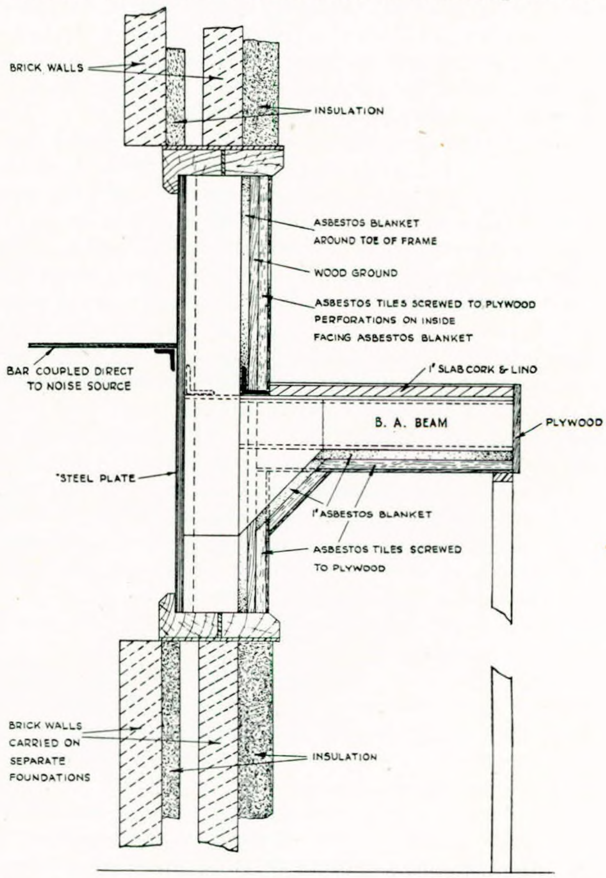

FIG. 6.—Arrangement of sound transmission tests for accommodation insulation.

dition which need not be detailed here, but that giving the best result for least complexity is shown in Fig. 6. It consisted of covering the plating with a 1in. layer of asbestos blanket and carrying the inner cabin partition on vertical studs connected only at the top and bottom. The plywood lining had a covering of asbestos fibre tiles facing inwards. The effect was as follows:—

1in. Asbestos blanket only on the ship's side and under deck increased the insulation of the bare plate by 4—5 phons.

1in. Asbestos blanket as above plus ⅜in. plywood cabin lining, with asbestos tiles facing inward, increased the insulation of the bare plate by 15 phons.

The upper deck surface was covered with compressed cork and lino in each case.

Results are given later in this paper of tests on a vessel fitted with ship's side insulation on these lines.

Structure-borne Sound and Isolated Machinery Mountings.

Having referred to the propagation of sound along the steelwork of a ship's structure as one of the paths by which it is conducted, we should consider the mechanical isolation of the ship's machinery from the hull itself. This is a matter of considerable importance from the standpoint of both vibration and noise, and one which is attracting the attention of marine engineers to-day.

Anti-vibration mountings are common enough in land practice, and have frequently been applied to auxiliary engines on shipboard, but the problem of flexibly mounting the main propelling machinery is one of great practical difficulty, particularly with large engines. It is, of course, well known that it is not merely sufficient to fix a machine on springs, rubber, or other resilient material between the bedplate and the foundations. The general principle is to produce a mounting such that its natural period of vibration is considerably lower than the frequency of any disturbance arising in the machine itself. Very careful design is necessary in relation to the frequencies involved, loading, static and dynamic stiffness of the isolating material, as well as the directions of the oscillating forces concerned. The taking up of the movement of the engine upon its supports in relation to the propeller shaft presents some difficulties from the marine engineering point of view.

We are not concerned with this particular problem here except in so far as such methods (as are to-day available) affect the noise produced by a given machine (i.e., the proportion of structure-borne noise as compared with air-borne). So far as the Author's experience goes, there is no doubt that, when applied to the main propelling machinery, the effect upon mechanical vibration is excellent. With regard to the effect upon the general noise, he is in doubt, because in some measurements he has made he has not been able to find a difference in structural sound attenuation between vessels with and without isolated mountings. In one case, however, in which considerable precautions were taken, he obtained a better figure than the normal. He attributes these variations to the great practical difficulty of isolating the many connections (other than foundations) between the engines and the ship's structure such as the propeller shafts, exhaust pipes, general service pipes, etc. Even with reasonable precautions, it appears almost impossible to eliminate the many structural paths whereby audio-frequencies may be transmitted. The Author has unexpectedly observed results in several ships comparable with those for structure-borne sound, deduced by Berg & Holtsmark [7] for certain types of buildings. The whole subject is one upon which we require much more data in connection with ships. It is undoubtedly a most important step towards the production of vibrationless motorships.

It should be noted that in using materials such as natural cork, rubber, felt, etc., in anti-vibration mountings, very high loading is usually necessary to bring the natural frequency of the material sufficiently low. Provision for easy renewal of the mounting is therefore desirable because of the high stressing of the material and consequent deterioration. Springs of suitable design provide an excellent means of mounting auxiliary machinery such as generating sets. Where these are employed, the additional provision of rubber mountings for the springs is necessary in view of the high frequency transmission through the springs themselves.

Cooling water, feed and exhaust pipes all require flexible connections to obtain the best results. It should be observed here that *short* flexible connections are insufficient; on water pipes, etc., about 3 feet appears to be necessary.

In isolating fans and similar machinery by pads of damping material it should be observed that it is necessary also to insulate the holding-down bolts where they pass through the bedplate and also the washers above the bedplate.

SECTION 4. FULL SCALE EXPERIMENTS IN MOTORSHIPS.

General Considerations.

The foregoing principles involved in the acoustic treatment of machinery spaces and passenger accommodation have been tested in practice on a number of vessels, and this section deals with matters of practical application thereto and the results obtained. These results are somewhat restricted in range in that they apply to motorships of the cross-channel type, but this is in some respects advantageous, because it enables reasonably accurate comparisons to be effected between vessels of similar size. Also, these tests involve a type of vessel in which (owing to its size) undue noise is likely to be a disturbing factor in the sleeping accommodation on night services, and a reputation for quietness or otherwise materially affects the financial side of operation.

APPLICATION OF ACOUSTIC TREATMENT TO THE ENGINE ROOM OF AN EXISTING MOTORSHIP.

Particulars of the vessel are as follows:—

Designation	Ship "A".
Type	Twin screw passenger and cargo motorship
Gross tonnage	3,800
Length	345ft.
Beam	46ft. 6in.
Propulsion	Two single acting 10 cyl. 4 str. cycle
B.h.p. (total)	6,000
R.p.m.	140 - 150
Acoustic insulation	1in. asbestos tiles to engine-room only.

The original heat insulation applied to the interior of the engine-room casing consisted of 4in. to 6in. of blue asbestos felt slabs covered with asbestos cement sheeting. The sound absorption of this surface was about 2 per cent. To reduce noise in the engine room, the interior surfaces were covered with 1in. thick asbestos tiles having a sound absorption of 75 per cent. These were applied over the existing insulation and secured with metal cover strips. The acoustic treatment was fixed to such parts of the internal surface of the engine-room and casing as were conveniently available. The auxiliary engine-room was similarly treated.

The object of the acoustic insulation was to reduce the noise at its source and thereby effect some reduction in all parts of the ship.

Apparatus.

The acoustic tests were taken with a sound level meter consisting of a piezo-electric microphone and 6-valve amplifier with the necessary attenuators. They are tabulated with the figures obtained prior to the application of acoustic insulation and are given for similar situations so that the results are comparative.

TABLE VIII.
COMPARATIVE SOUND LEVELS IN PASSENGER ACCOMMODATION.

Deck.	*Location.*	*Sound level after insulation. (Phons).*	*Sound level before insulation. (Phons).*	*Difference in sound level. (Phons).*
Boat	Smoke-room	62	71	9
A.	Lounge	61	69	8
	Inside cabins (ship's side)	68	75	7
	Alleyways	69	78	9
	Mean sound reduction	—	—	8
B.	Dining saloon ...	68	79	11
	Inside cabins adjacent to casing	71	80	9
	Alleyways:—			
	Centre of casing ...	73	82	9
	Aft of casing ...	73	82	9
	Outside cabin right for'd	62	69	7
	Mean sound reduction	—	—	8·7
C.	Inside cabins adjacent to casing	76	83	7
	Inside cabins right for'd	62	69	7
	Alleyways:—			
	Centre of casing (noisiest point in ship)	81	88	7
	For'd of casing ...	80	87	7
	Mean sound reduction	—	—	7

TABLE IX.
COMPARATIVE SOUND LEVELS IN ENGINE-ROOM.

Location.	*Sound level after insulation. (Phons).*	*Sound level before insulation. (Phons).*	*Difference in sound level. (Phons).*
Top of casing	83	95	12
Valve rocker platform	94	103	9
Control platform ...	94	102	8

TABLE X.
SOUND LEVELS BEFORE AND AFTER INSULATING.
BASED ON MEAN VALUES OF READINGS.
(The total number of readings was considerably greater than the examples shown in Tables VIII and IX).

Location	*Relative sound levels (phons). Before insulating.*	*After insulating.*	*Sound reduction as judged by the average ear (Millisones per cent.).*
Public rooms ...	74	64	51%
Cabins	80	72	44%
Engine-room ...	100	90	55%
Mean value	—	—	50%

Observations on the Results.

There was a very marked difference in the sound level in the vessel subsequently to the application of the insulation. The effect appeared to be distributed fairly evenly over the entire ship and to be of the order of 8 to 10 phons, corresponding to a reduction as heard by the average ear of about 50 per cent. Considering the extremely simple means whereby this was obtained the result is of some practical value.

The level in the Smoke Room on the Boat Deck (62 phons) was found to be very comfortable for ordinary conversational purposes. The Dining Saloon on B Deck (68 phons) was found to have improved considerably; this was previously a rather uncomfortable situation from the noise standpoint.

The worst cabins (76 phons) on "C" Deck after insulation were as good as the best cabins (75 phons) on "A" Deck before insulation.

In the Engine Room the difference was very noticeable. Under the conditions originally obtaining on the control platform (102 phons) it was practically impossible to converse even by shouting. Under the subsequent conditions intelligible conversation was easy by raising the voice (94 phons).

A number of readings (not shown) were taken in all parts of the vessel whilst running on one main engine only and also when both main engines were stopped, but auxiliaries running. The following mean values are of interest:—

(1) Stopping one main engine reduced the total noise by ... ... 3 phons
(2) Stopping both main engines reduced the total noise by ... ... 13 phons
(3) The acoustic insulation reduced total noise by ... ... 8-10 phons

The acoustic insulation, therefore, made more difference to the sound than did the stopping of one of the two main engines. In other words, the ship

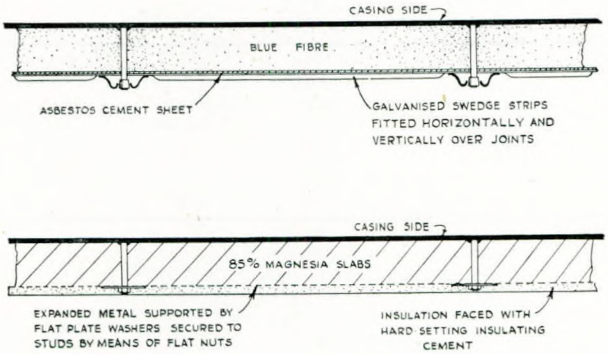

FIG 7.—Usual methods of thermal insulation of motorship casings.

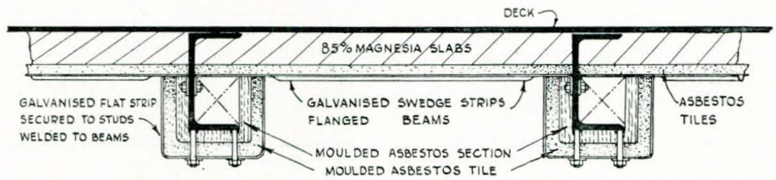

FIG. 8.—Method of combining 85 per cent. magnesia with sound insulation.

was quieter on two engines than it was before insulation on one engine.

The Design of Casing Insulation for Motorships.

The usual methods of thermal insulation for engine-room casings on motorships are on the lines of those shown in Fig. 7, and consist of either :—

(a) 85 per cent. Magnesia slabs faced with expanded metal and cement.

or (b) Asbestos fibre slabs of various kinds, covered with asbestos cement sheeting (asbestos slate).

These are applied in various thicknesses, according to the thermal requirements. Both systems have hard protective surfaces, not far removed in sound *reflecting* properties from that of bare steel (99 per cent.). By incorporating with either of these types a sound absorbing material, it is possible to :—

(1) Reduce noise throughout the ship (i.e., substitute 75 per cent. absorption for 2 per cent.).

(2) Economise in cost of sound

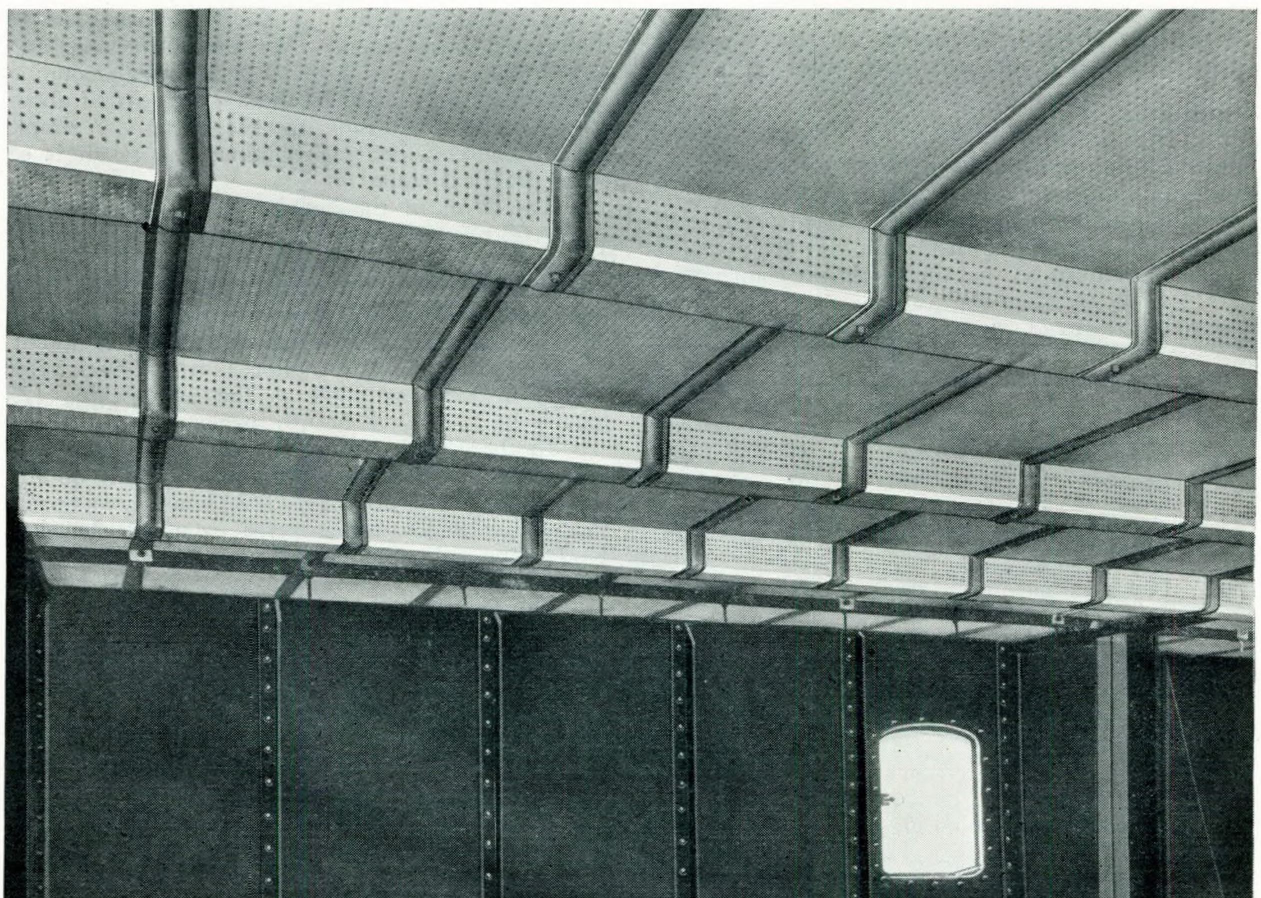

FIG. 9.—Sound insulation combined with magnesia in a liner.

insulation because the same fixings will hold both insulations.

(3) Simultaneously improve the fire resistance of the insulation by the adoption of a fireproof sound absorbent.

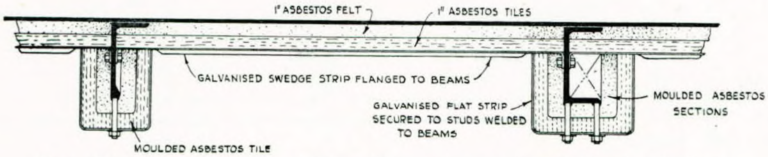

FIG. 10.—Method of combining thermal, sound and fire insulation.

Two methods which have proved successful in practice are shown in Figs. 8 and 9. In Fig. 8, the asbestos fibre tile for sound absorption is manufactured as a composite slab with the 85% Magnesia and secured to the casing by welded studs which protrude through the cover strips of sheet metal. The asbestos tile has a white surface drilled with small holes in which the absorption of sound occurs. The efficiency is not affected by repainting unless the holes are deliberately filled up. The illustration in Fig. 9 shows the appearance of the treatment in a motor-driven liner.

In Fig. 10 is shown a combination of thermal, sound and fire protection insulation. In this method a sound damping layer of asbestos felt (1in. thick) is applied to the casing and covered with a 1in. thick asbestos tile similar to that referred to above. The stiffeners are covered with a fire-protecting section of moulded asbestos, surmounted by a moulded absorbing tile. The application of this system to an engine-room is illustrated in Fig. 11. It may be observed that some sound absorbing materials have good heat insulating properties, and in the above system this is secured by the combination of the damping layer and the tile. The fire-protection period is about 2 hours.

The Author has not discussed the merits of

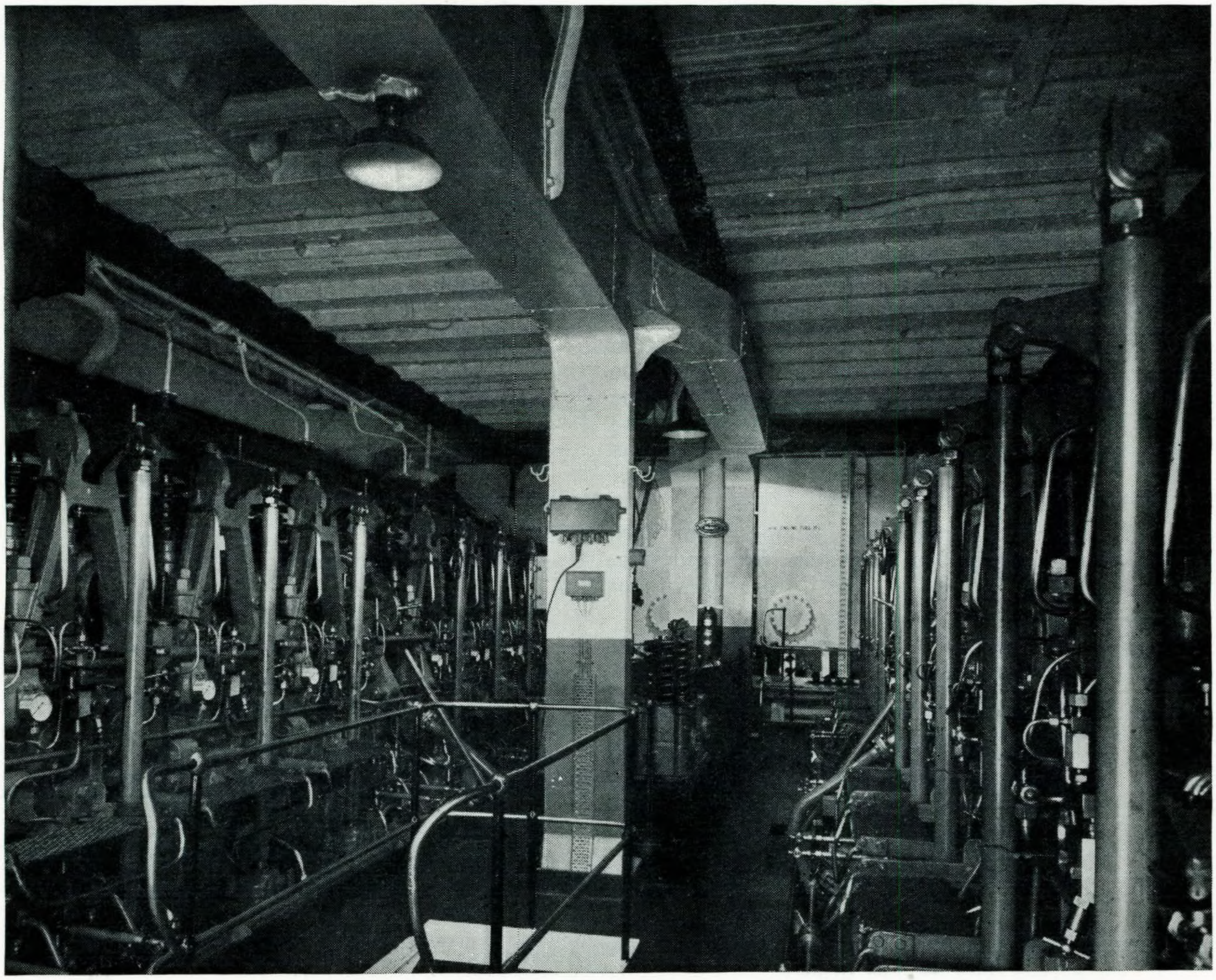

FIG. 11.—Sound insulation combined with thermal and fire insulation in engine room.

various thermal insulators in connection with casing treatment since we are mainly concerned here with sound, but the reader is referred to papers by Gard and Robinson [8] and also by Cox [9] for data on heat insulating materials.

Fire Protection of Casings.

Although the prospect of fire in the engine-rooms of motorships is happily remote, some remarks on this subject may not be out of place. Whilst making investigations in connection with oil fires in power stations, due to the explosion of switch tanks, etc., the Author was surprised to observe the relatively low resistance of stressed steel-work to the cutting properties of the flame. This effect is particularly noticeable in fires in which blazing oil is concerned, and probably applies also to motorships.

Tests on normally loaded rolled steel joists (6in. × 3in. × 12lbs.) about 14ft. long, showed that they completely collapsed within 14 minutes from *lighting* the fire beneath them, and when about 1,500° F. flame temperature was attained. Using an asbestos protection very similar to that discussed in the foregoing paragraphs, other joists remained unaffected in the same fire. In fact, the same joists with the same insulation were used for a further test in an oil fire at 2,100° F. The temperature in the steel-work did not exceed 212° F. after 90 minutes.

Sound Insulation Applied to a New Motorship

It is always preferable that sound insulation and various precautions against noise should be considered in the design stage and built into the vessel rather than applied later on. The succeeding tests refer to a motorship in which this was done. Treatment was carried out on the following lines :—

(1) The main and auxiliary engine-rooms were lined with 1in. asbestos felt and 1in. asbestos tiles on the lines shown in Fig. 10.

(2) The exterior of the engine-room casing was lined with 1in. asbestos blanket behind the panelling.

(3) The ship's side in way of cabins was treated with 1in. asbestos blanket and 1in. asbestos tiles behind the lining in the manner shown in Fig. 12, and described previously in connection with sound transmission.

(4) The main engines were mounted on rubber-lined chocks.

(5) The auxiliary generators were mounted on springs with rubber inserts.

Particulars of the vessel are as follows :—

Designation.	*Ship "B".*
Type	Twin screw passenger and cargo motorship
Length	367ft. overall
Breadth (moulded) ...	50ft.
Gross tonnage ...	4,320
Propulsion	Two single acting 2 stroke cycle 10 cyl. airless injection engines
B.h.p.(total)	5,200
R.p.m.	120
Auxiliary generators	Three 2 str. cycle 6 cyl. 300 r.p.m.

Similar tests to those previously described were carried out, and the figures are tabulated against those for Ship "A" in the *uninsulated* condition to provide a comparison with normal practice (see Table XI).

This is condensed in Table XII to give a more compact view of the comparison, whilst the engine-room figures are given in Table XIII.

TABLE XI.
COMPARATIVE SOUND LEVELS IN PASSENGER ACCOMMODATION.

Deck.	*Location.*	*Sound insulated ship "B" sound level (phons).*	*Normal ship "A" sound level (phons).*	*Difference in sound level (phons).*
Boat A.	Smoke-room	61	71	10
	Lounge	60	69	9
	Special suite	.59	73	14
	Inside cabins (ships' side)	65	75	10
	Alleyways	73	78	5
	Mean sound reduction	—	—	9·5
B.	Dining saloon ...	67	79	12
	Inside cabins adjacent to casing	70	80	10
	Alleyways adjacent to casing	74	82	8
	Mean sound reduction	—	—	10
C.	Inside cabins adjacent to casing	73	83	10
	Alleyways adjacent to casing	75	87	12
	Aft of casing... ...	62	80	18
	Mean sound reduction	—	—	13·3
D.	Inside cabins... ...	60	83	23
	Alleyways	64	87	23
	Mean sound reduction	—	—	23

TABLE XII.
DIFFERENCE BETWEEN UNINSULATED SHIP "A" AND INSULATED SHIP "B".
(Based on mean values of readings).

Location.	*Mean decrease in sound level. (phons).*	*Reduction as judged by the average ear. (Millisones per cent.).*
Public rooms ...	10·3	54
Special suites ...	14	66
Cabins	13·2	61
Alleyways	12	57
Engine-room ...	11	60
Mean throughout ...	12·1	60

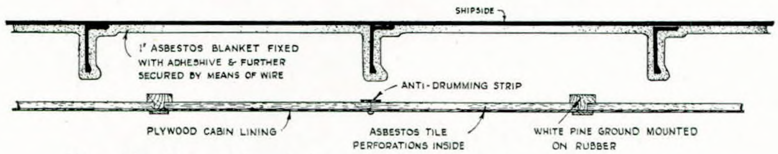

FIG. 12.—Sound insulation of ship's side in way of cabins.

TABLE XIII.

COMPARATIVE SOUND LEVELS IN ENGINE-ROOM.

Location.	*Sound insulated ship "B" sound level (phons).*	*Normal ship "A" sound level (phons).*	*Difference in sound level (phons).*
Top of casing ...	83	95	12
Valve rocker platform	91	103	12
Control platform ...	93	102	9

TABLE XIV.

AVERAGE SOUND DISTRIBUTION (SHIP "B").

Deck.	*Sound level (phons) in* *Public rooms.*	*Cabins generally.*	*Cabins near casing.*
Boat ...	61	—	—
A.	60	60	67
B.	67	63	70
C.	—	63	73
D.	—	58	60
Mean ...	63	63	67

Main engine-room (general level) 89 phons.

On an average there appears to be a difference of about 12 phons between the two vessels, or 60 per cent. as registered by the average ear. Compare the Dining Saloon (67 phons) which is equivalent to quiet conversation with that of the normal vessel (79 phons), equivalent to a typing room or street traffic. On the normal ship the voice has to be raised to overcome the background sound and it is impossible to subdue the consciousness of noise at any time. The reduction of 12 phons means that the sound has gone down to $\frac{1}{16}$ of its former intensity. The irritating effects of noise are generally in proportion to intensity, which explains why a difference of a few phons in the total noise can afford an increase in comfort out of all proportion to the numerical change. 12 phons is the difference between a residential street and a city street, or between talking and shouting. Similarly 7 phons is the difference between one motor cycle engine and five motor cycle engines running together.

Regarding Table XIV, which gives the sound distribution in the ship at normal speed, it will be seen that the Public Rooms on the Boat Deck and A. Deck are particularly quiet. At a level of 60 phons there is absolutely no interference with conversation and in fact the sound level in the Smoke Room increases by 2 phons when a number of persons are present, showing that the level of noise from the ship itself is less than that occasioned by the passengers. In other words, in the present instance two persons carrying on an ordinary conversation make more noise than that coming from the engines.

The following are figures for cabins in the *noisiest* situations in each ship, and some equivalent sound levels:

"Noisy" cabin on	*Sound level phons.*	*Equivalent*
Sound insulated ship "B"	70	Two persons conversing
Normal ship "A"	80	Typewriting room
Another ship	90	London traffic

It may be mentioned that, in the treatment of a sister ship of vessel 'B', still further improvements were made in the cabins in the noisiest situations on 'C' Deck.

Sections through Ship 'B' are shown in Fig. 13 with the sound level marked at various points in the vicinity of the casings. The figures in brackets are those for Ship 'A' in the uninsulated condition

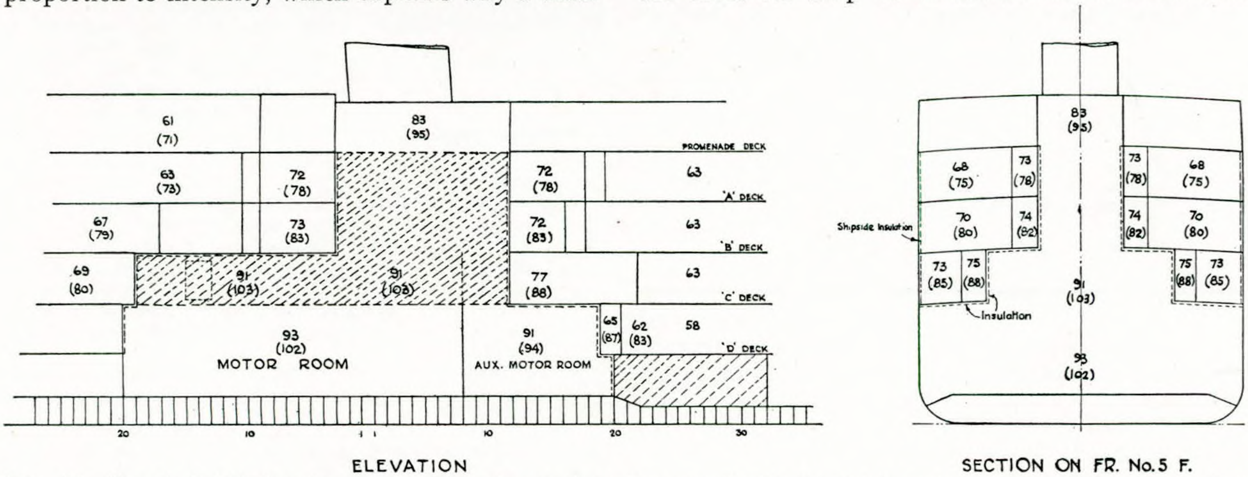

FIG. 13.—Sound distribution in vicinity of engine casings for acoustically insulated motorship. (Figures in brackets are for uninsulated ship in same locations).

and enable a visual comparison to be made between a normal and an acoustically treated vessel.

Engine-room of Ship 'B'.

Referring to Table XIII, we see that the noise reduction in the engine-room is similar to that obtained for the cabins, i.e., about 12 phons. All the values recorded are very low for a motorship, the engine-rooms of which are usually about 102-108 phons. The general level was about 89 phons, which compares with a turbine engine-room of 86 phons and is below that of turbine gears (98 phons).

It is impossible to carry on an intelligible conversation at noise levels of 100 phons and over. In Ship 'B' this was relatively easy, and is a point of importance in an emergency where difficulty of *accurate* interpretation of orders may have serious consequences.

In connection with engine-room noise, a colleague and the Author once had occasion, whilst making tests, to go directly from an insulated motor-room to an uninsulated one within the space of half an hour, whilst the aural memory still retained an accurate impression. It was a most striking experience, because otherwise we could not have appreciated the true extent of the change. Direct comparison of noises requires almost instantaneous change from one to the other. A lapse of 24 hours is sufficient to lose accurate comparison altogether.

Influence of Main Engines on Total Noise.

The auxiliaries and various other sources contribute considerably to the total noise on shipboard. One or two readings which illustrate this are grouped together in Table XV, which show that there is a relatively high residual noise level even when the main engines are not running.

TABLE XV.

VARIATION OF SOUND LEVEL IN PASSENGER ACCOMMODATION DUE TO MAIN ENGINES. (SHIP "B").

Auxiliaries running in all cases.		Sound level—phons. Main engines.		*Increase in level due to main engines.*
Deck.	*Location.*	*Stationary.*	*At 115 r.p.m.*	*phons.*
A.	Lounge	56	60	4
B.	Dining saloon ...	61	67	6
C.	Alleyway adjacent to casing	65	77	12
„	Forward b'hd. of Aux. E.R. ...	77	77	0

The importance of dealing acoustically with the auxiliary room as well as main motor room is shown by the fact that, at a point immediately forward of the auxiliary room bulkhead, there is no change in the noise level with or without the main engines. On the higher decks relative to the motor-room, the main engines contribute progressively less to the general noise.

SECTION 5. FURTHER EXAMPLES OF ACOUSTIC TREATMENT ON SHIPBOARD.

Corkboard.

Whilst this paper was in the course of preparation it was considered desirable to have some practical tests on materials differing from those upon which the previous investigations had been made. This occasioned some difficulty, because so little work appears to have been carried out with other materials. The Author therefore approached a Continental firm of shipowners who had tried Cork Slabs as a means of providing acoustic absorption in the engine-rooms of two of their vessels. The Author gratefully acknowledges the permission and facilities afforded by the Owners to make acoustic tests, especially as these motorships are of considerable interest from the technical point of view. Owing to their high speed (22-25 knots) in relation to their displacement (2,800 tons), the joint problems of vibration and noise assume considerable importance. They are also of interest in view of differences in their respective auxiliary equipment and in the method of supplying the scavenging air for the main engines. These are detailed below, and in the succeeding analysis the effect of the auxiliaries upon the sound distribution is shown.

Regarding the effect of the cork insulation in the engine-rooms, it is of course not possible to give a comparison with a similar vessel uninsulated.

An interesting comparison is afforded with ships A and B previously discussed, in that the lengths are the same, but with a smaller depth and nearly three times the horse-power.

Designation	Ships C and D.
Type	Fast passenger motorships.
Overall length ...	370ft.
Beam	46ft.
Displacement	2,800 tons.
Gross register ...	3,300 tons.
Service speed ...	$22\frac{1}{2}$ knots.
Propulsion	Two 12 cyl. single acting 2 str. engines (crosshead type).
B.h.p. (total)	15,000 at 257 r.p.m.
Engine room insulation	Cork slabs, 4in. thick, mounted on 2in. wood grounds. Face of cork exposed, and painted. Applied to ship's side, bulkheads, and casings of engine-room.

Auxiliary Equipment:—

	Ship C.	*Ship D.*
Scavenging air supply... ...	Three turbo blowers taking about 1,500 h.p. total.	One reciprocating air pump per cyl. driven by levers and links from the crossheads.
Auxiliary generators ...	Four Diesel driven, 485 kW. each at 550 r.p.m.	Three Diesel driven, 200 kW. each at 550 r.p.m.

In ship 'C,' therefore, the machinery in the auxiliary room totals about 2,500 h.p. as compared with 800 h.p. in Ship 'D'. This has the effect of altering the balance of noise between the main and auxiliary rooms in each ship, i.e., in Ship 'C' the auxiliary room is noisier than the main engine-room

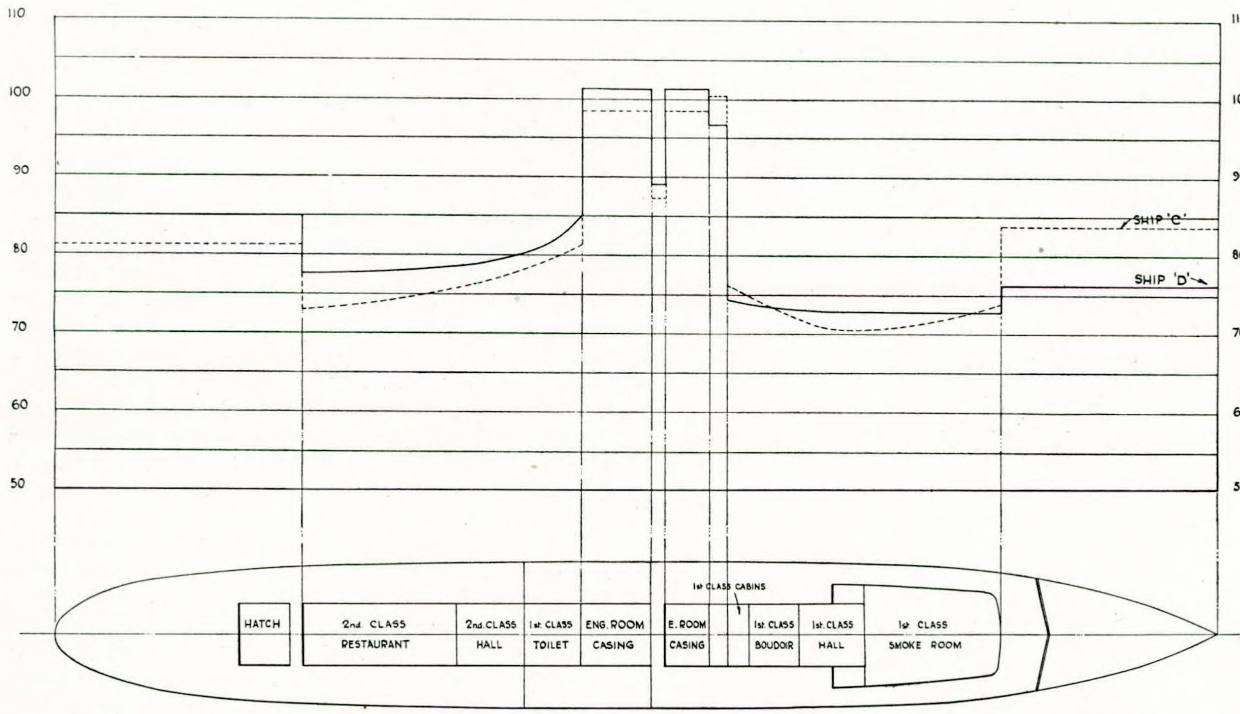

FIG. 14A.—Sound distribution diagrams for two 22-knot motorships (measured along centre line)—C deck.

and in Ship 'D' the reverse obtains.

Acoustic Tests.

Similar tests to those already described were carried out, using the same apparatus. These also included a series of readings made at intervals along the centre line of each deck for the full lengths of the two ships. It should be noted that these readings refer to noise only and are not concerned with vibration, except where mechanical vibration is itself a cause of noise. Also that small variations of noise level are experienced between

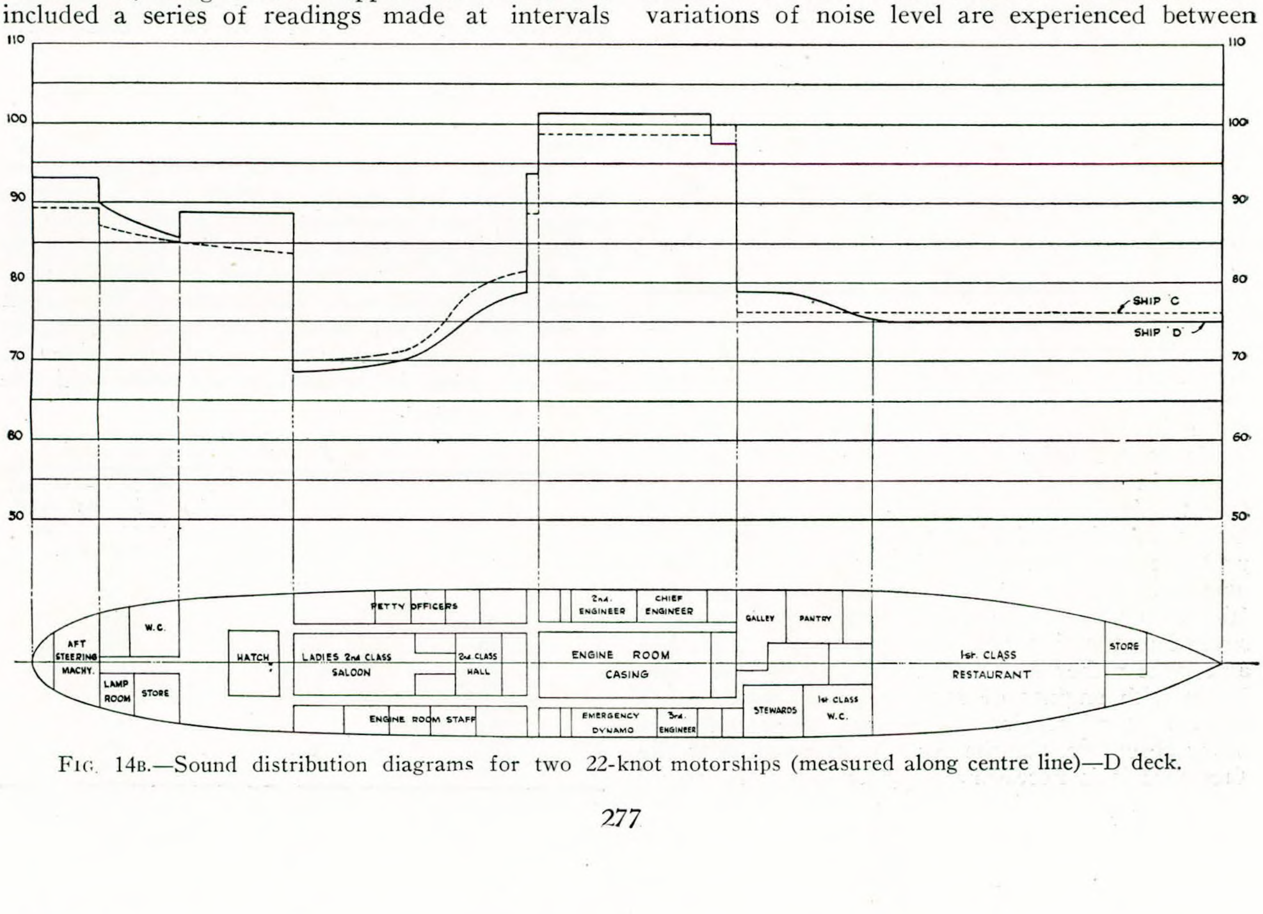

FIG. 14B.—Sound distribution diagrams for two 22-knot motorships (measured along centre line)—D deck.

readings due to extraneous noises produced by passengers, wind on deck, etc. Where time allowed, a number of records were taken to eliminate the effect of abnormal sounds. In the succeeding Tables specimen readings only are incorporated to save space.

TABLE XVI.

SOUND LEVELS IN PASSENGER ACCOMMODATION.

All readings taken as far as possible on centre line of ship. Readings for each deck given in order of location commencing forward.

Deck.	Location.	*Noise level—phons.* Ship "C".	Ship "D".
A (Boat Deck)	Alleyways	88	83
	1st class hall	77	78
	After end of "A" Deck (outside)	81	79
B Deck	1st class veranda	73	73
	1st class hall (for'd) ...	80	77
	Alleyways between E.R. casings	88	88
C Deck	1st class smoking room (for'd)	73	73
	1st class boudoir	74	74
	2nd class restaurant (aft)	73	78
	Stern (outside)	82	85
D Deck	1st class restaurant (for'd)	76	75
	Engineer's cabin (opposite main E.R. casing) ...	81	86
	Alleyway immediately aft of main E.R. casing ...	89	94
	Ladies' saloon	72	70
	Outside steering engine compartment aft ...	87	90
E Deck	1st class saloon (for'd) ...	73	74
	1st class ladies' saloon (for'd of aux. E.R. casing)	83	82
	2nd class saloon (aft of main E.R. casing) ...	79	84

TABLE XVII.

SOUND LEVELS IN ENGINE-ROOMS.

Location.	*Noise level—phons.* Ship "C".	Ship "D".
Main engine-room:		
At cylinder heads	99	102
Between main engines (control platform level	104	106
Auxiliary room:		
Centre of auxiliary generators ...	105	102

It will be agreed that, in view of the very considerable horse power employed, these figures are very creditable. Many of them are similar to those of Ship 'A' before insulation. So far as the engine-room figures are concerned (see Table XVII) the levels do not differ greatly from those of Ship 'A' before insulation. There is no doubt, therefore, that the insulation contributes towards this end. Using materials of higher sound absorption it is probable that even better figures might have been obtained. The Author has obtained figures of 102-104 phons in the uninsulated engine-rooms of several motorships of much lower power. He has also been rather surprised to find almost the same levels with engines of modern design as those of several years' service. This may be disputed by other observers, but the Author attributes it to the fact that it is necessary to bring down the sound *emission* of an engine by 50 per cent. to make a reduction of 3 phons in its total loudness. This gives an idea of the difficulties confronting an engine designer in relation to noise.

Sound Distribution.

Reverting to Ships 'C' and 'D', it will be noted that the method of supplying the scavenging air from the main engines has had the effect of increasing the main engine noise slightly, and simultaneously decreasing the auxiliary noise. This change, it is interesting to note, is generally reflected throughout the ship (though with exception in some locations). In other words, Ship 'C' tends to have slightly higher readings in positions for'd of the casings, and Ship 'D' higher readings aft of the casings. This can be observed in the sound distribution diagrams for both ships given in Fig. 14. For reasons of space those for Decks C and D only are included.

The similarity in the general distribution of sound between the two vessels will be observed; this also applied to the remaining decks. Vessels of similar type appear to exhibit comparable shapes of distribution curve. In general (though not invariably), the whole curve is elevated or depressed according to the mean loudness of the main and auxiliary machinery casings. It may also be noted that some variations occur due to the silencing arrangements on Ship 'D' which are more efficient than those on Ship 'C'. This, together with wind noise, produces some changes in the sound levels which are noticeable forward in the readings for C Deck. Mention should also be made of the fact that in respect to vibration both these vessels were good.

INFLUENCE OF REVOLUTIONS ON TOTAL NOISE.

Noise.

In connection with engine speeds, the Author has observed that engine builders are sometimes concerned with the effect of a given number of r.p.m. upon the sound produced. The following Table XVIII of readings taken on Ship 'D' may therefore be of interest. Measurements were taken at the central point between the main engines, at the control platform level. Sound level given at zero revolutions is the background noise level due to the auxiliaries.

TABLE XVIII.

VARIATION OF MAIN ENGINE NOISE WITH R.P.M.

R.p.m.		*Sound level—phons, for twin dual cycle engines totalling 15,000 b.h.p.*
0	...	80
80	...	97
100	...	100
120	...	102
140	...	103
160	...	103·5
180	...	104·5
200	...	105
220	...	106
230	...	106

It will be seen that the noise level increases fairly rapidly with the revolutions up to about 130 r.p.m. after which the curve flattens considerably and the increase in noise becomes correspondingly less as the higher revolutions are approached. The change of noise level for corresponding increments of speed naturally varies according to the design of engine.

Sprayed Asbestos.

Some interesting work has been carried out with a process for spraying asbestos fibre directly on to steelwork. The Author is not aware that it has been applied as a sound deadening material in engine-rooms, though it has been used frequently as a combined sound and thermal insulation in accommodation. The sound absorption is variable at will (according to the density, thickness and type of finished surface), between about 20 per cent. and 90 per cent. At the latter absorption, the material is too flocculent for marine use, but it is probable that 50-60 per cent. can be obtained with a density and thickness suitable for shipwork. This material was used together with asbestos blanket, throughout the passenger accommodation of one of the largest foreign passenger liners, and also in the stern and shaft tunnels. The thickness was 1in. Several foreign naval vessels have been treated on similar lines, but I know of no acoustic tests upon ships so treated. Absorption coefficients for asbestos spray are given in Table VII on page 9.

SECTION 6.

Ventilating Equipment.

Noise from ventilating equipment can be very disturbing to passengers. Fortunately, however, it is one of the simplest with which to deal in practice.

Sources of Noise in Ventilating Apparatus.

Air ducts, particularly those of the sheet metal variety, are in effect efficient speaking tubes transmitting any noise with ease along their entire length, due to the sound reflective properties of the internal surfaces. The noises are created by air eddies

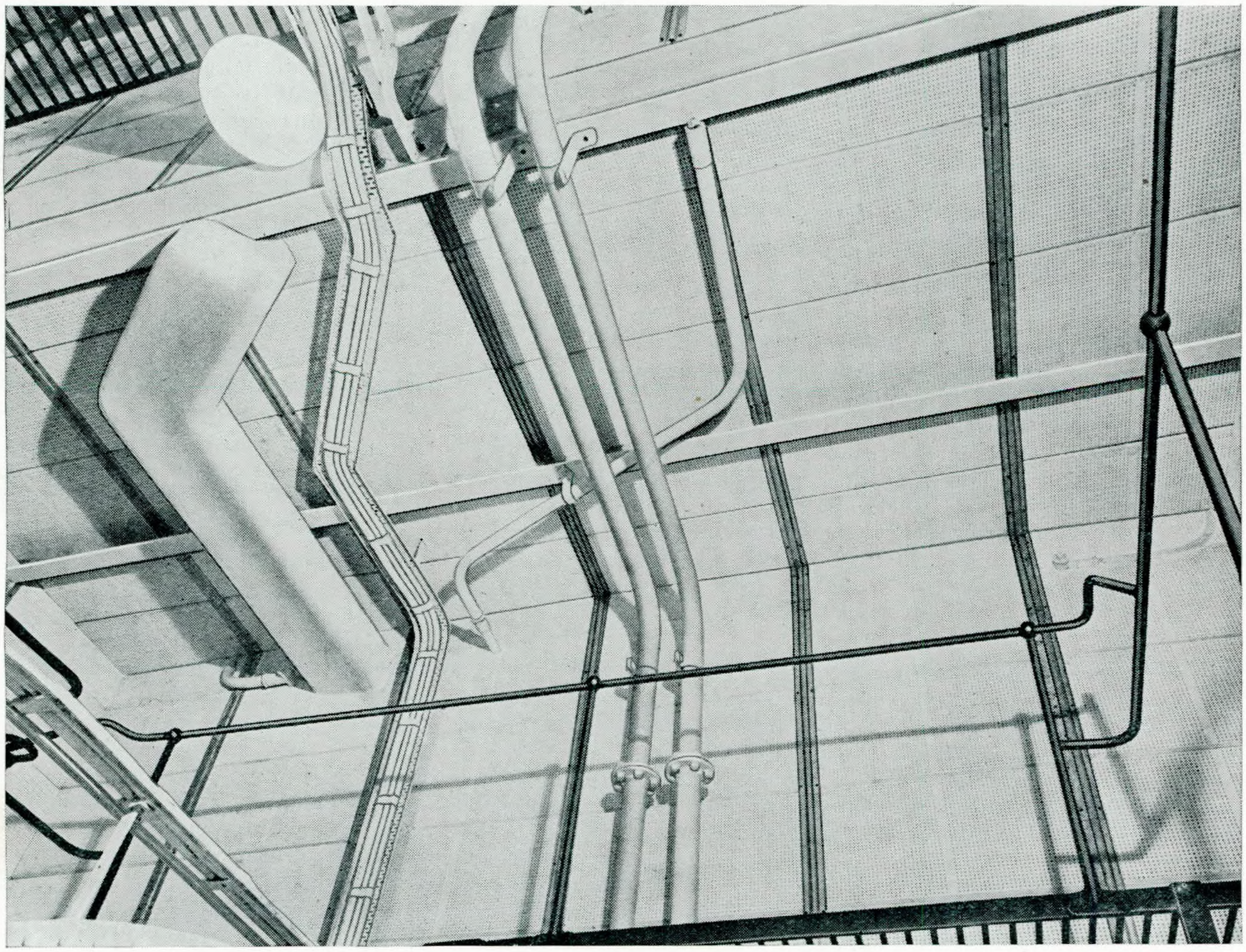

FIG. 15.—Sound absorbing treatment in fan room.

from the fan blades, the hum of the motor, bearing noises and sounds propagated by the rush of air through the ducts. All these pass with little loss through the trunking in two ways (a) through the air stream itself and (b) through the metal work of the ducts.

Limitations of space available for equipment and ducting on shipboard are one of the difficulties confronting the designer of ventilating equipment. This has an important effect on the noise produced by the equipment. When the tip speed of the blades exceeds 55ft. per second, the air eddies shed by them produce noise which rapidly increases with the speed. Blade flutter is a prolific source of sound, and rigidity here is essential.

When the velocity of the air in the ducts exceeds 20ft. per second, noises are produced by the motion of the air itself. In marine installations, the air velocity is usually much greater than in land practice and speeds of 40ft. per sec. are often used. Quiet running therefore requires low speeds coupled with large duct-work, and this increases the size of the installation beyond the limits of space usually available in ships. These difficulties can be overcome by the following provisions, adopted according to the circumstances of the case :—

(1) Where a number of fans are housed together, the general noise can be reduced by acoustic treatment of the fan room itself.

(2) Sound borne along the ducting through the air stream can be reduced to any desired extent by lining the interior of the ducting with a suitable absorbent over a proportion of its length.

(3) Sound transmitted from the fans to the ship's structure is reduced by the use of isolating pads in the mountings.

(4) Sound passing along the metalwork of the ducts themselves is reduced by inserting a flexible, non-metallic joint near the fan.

Items (1) and (2) are the most effective because they enable a predetermined control to be applied. Items (3) and (4) are desirable, but for various reasons are limited in their effectiveness on ships. Further details of items (1) and (2) are given below.

Fan Rooms.

A reasonably quiet fan room has a noise level of about 75 phons. A noisy one may be anything in excess of this. Particularly in large vessels, where several fans of considerable horse power may be grouped together, the noise is not only transmitted to distant parts of the ship via the ducting, but may be disturbing to adjacent passenger accommodation.

The use of a high efficiency acoustic material in the fan room will bring this noise down by 10 to 15 phons according to the area which can be accommodated. In general, not less than 25 per cent. of the total internal area (including deck) should be treated. Good results are obtained at 50 per cent. of the total area. This method has been successfully applied to the fan rooms of many liners. In the case of one particularly large fan room which the Author tested in a liner, the acoustic treatment consisted of 1in. asbestos tiles, fixed on wood battens and secured by metal strips (see Fig. 15). Passenger accommodation was located above and around this casing, and in the portions most liable to suffer from noise 1in. of asbestos felt was added behind the tiles. The results were as follows :—

Noise level inside the fan room ... 61 phons.
Noise level outside against casing... 52 phons.

Both these figures are remarkably low. Measurements outside other casings in the vessel varied from 66 to 80 phons. The value of 61 phons in the fan room itself may be compared with levels of 67 phons and thereabouts which the Author has encountered in *passenger accommodation* near the duct outlets.

Ducts.

Since the interior of the duct-work is highly reflective to sound (i.e., 99 per cent.) noises are propagated over long lengths with great facility. This is prevented by lining the *interior* surfaces with a sound-absorbing material. The greater the length so treated, the greater is the resulting noise reduction. The result obtained, therefore, is proportional to the amount of material installed. Several materials may be employed for this purpose, such as fibrous absorbents behind perforated sheet metal, asbestos felt sheets, or acoustic asbestos board. Building boards made of wood fibre are sometimes used, but their absorption is low and they are not fireproof. Also with low absorptive materials the cost of application is considerably increased because of the greater length of treatment required. A reasonably efficient ½in. material affords a practical solution for ship work, provided it is non-inflammable.

Length of Duct to be Treated.

The length of acoustically treated duct to reduce any given noise to a level at which it will not cause annoyance depends upon three factors :

(1) The noise from the equipment.

(2) The size of the duct.

(3) Background level of sound to be expected in the location served by the duct.

As the length to be treated is greater for large ducts than for small ones it is convenient to express this as so many times the mean diameter. Each case requires calculation on its merits, but in general a treated length equivalent to 10 to 20 mean diameters is desirable. Where the length of duct in which treatment can be applied is too short (or in the case of very large ducts), the length requiring treatment can be greatly reduced by splitting the cross section with a dividing wall composed of absorbing material.

It sometimes happens that a considerable noise reduction has to be produced within a very short length, in which case the process of sub-division may be multiplied until the cross section assumes a honeycomb appearance. This is very effective in practice, and is useful, for example, when dealing with the noise of fans on deck. Baffles are sometimes used, but they restrict the airflow, whereas an extension to the inlet with suitably constructed sub-divisions will produce a better result without interfering with the flow.

SECTION 7. MISCELLANEOUS NOISE PROBLEMS ON SHIPS.

There are a considerable number of sources of noise on a ship, and particularly on a large ship, which we are unable to consider here in detail. The following, however, are a series of notes regarding some of them with briefly indicated lines of treatment. Some of these remarks apply in particular to large liners owing to the relatively lower noise from the engines obtaining on the upper decks. When the background level is lower, the loudness of incidental noises is thrown into greater prominence.

(1) Footsteps on Deck Overhead.

This problem is one to which a good deal of attention has been directed on land in connection with blocks of flats and similar buildings. Concrete floors are similar to steel decks in that they are practically transparent to what are termed "impact" noises. A florin, balanced on edge and allowed to fall flat, can be heard through a 4in. concrete floor. Research and experience indicate that the practical solution lies in complete separation of the floor into two parts, one floating on, and isolated from, the other. This is done in building practice with a loaded wood floor mounted on rubber pads or an additional concrete floor floating on a layer of soft material. In both cases the edges of the superimposed floor have to be completely separated from the walls and skirtings. The practical difficulties in the case of buildings are considerable and when we come to consider the application of these principles to ships, the problem is infinitely more complex. Although experiments have been made on ships, the Author is not in a position to indicate the most satisfactory solution because more data are still necessary.

Where outside decks are not involved an adequate thickness of rubber carpet is very beneficial.

(2) Printing Shops, Laundries, etc.

Noise from these sources in large vessels is reduced by the use of a suitable sound-absorbing material on the underside of the deck above the noise and additionally on the sides, depending upon the anticipated loudness in the space involved. Isolated mountings for the machinery are, of course, desirable, if not essential. Further information in the section on Fan Rooms indicates the results to be obtained.

(3) Galleys.

Similar remarks to the foregoing apply here. Measurements of the sound in galleys, due to the clatter of crockery and cooking utensils, indicate that although they normally lie in the region of 65—70 phons, peak levels as high as 80 phons occur. These are sometimes sufficient to be noticeable in the adjoining Dining Saloon.

(4) Large Public Rooms.

In the larger classes of vessel, the public rooms often attain considerable dimensions. This increases reverberation and magnifies sounds created within them. The total sound absorption produced by soft furnishings offsets the effects of volume, but if the absorption is low, as may well happen with modern (as distinct from period) furnishing, the result may be very unpleasant. It is desirable for accommodation of this type to be acoustically checked beforehand. Incidentally this can be done with reasonable accuracy from drawings and other particulars, and has a considerable influence on whether a particular room is comfortable or not.

A further point concerns the use of wireless loudspeakers in accommodation. The dreadful results sometimes produced are often traceable to defective acoustic conditions rather than to the apparatus itself. The cure, of course, lies in correcting the acoustics, a relatively simple matter to-day.

(5) Ships' Cinemas.

In some large ships a special sound cinema has been constructed. There are two particular requirements involved :—

(a) That the wall facing the loudspeakers shall be sound absorbent to prevent reflection towards the front.

(b) That the period of reverberation shall be suitable for sound reproduction.

Reproduced sound requires a much shorter period than does natural sound, and in this respect the absorption of the audience itself has to be considered. The reverberation period required depends on the size of the cinema but for ship work should be about one second. Attention is also necessary to the design on shipboard of public rooms which may be used for the reproduction of talking pictures in addition to their normal purpose. It is not difficult to adjust such rooms acoustically to meet both requirements satisfactorily.

(6) Localised Noises.

Occasions sometimes arise where noise from a small unit of machinery situated in the vicinity of passenger accommodation may be disturbing. An easily-removable box lined with sound absorbing material and placed over the offending unit is a simple cure. When this is done with units involving electric motors, a small inlet and outlet air duct (acoustically lined) is necessary to allow circulation to the motor without letting the noise escape. As an example, the high pitched whine (produced in starting up) from a wireless generator was eliminated by this means.

(7) Locating Sound Absorbing Materials in the Engine-room.

Whilst this subject has been discussed in its technical aspects earlier in this paper, a practical point occurs in locating sound insulation in engine-rooms. The Author has frequently seen this specified to be applied over the same areas as the heat insulation. This is incorrect, because these areas are not necessarily co-incident in position or dimensions. It is desirable to get the absorbent well down in the vicinity of the engines themselves, particularly (in Diesel engines) near the valve gear and below. It is also desirable to present it efficiently to the sound, i.e., to avoid applying on areas which will be hidden by the proximity of large tanks, particularly the rectangular ones. In such cases it can be applied over the face of the tanks.

Difficulties naturally arise on areas where there are a multiplicity of pipes, cables, etc., but the Author's experience is that if the matter is considered in an early stage of design, the whole of the pipe clips, etc., can be increased in length by the necessary 1in. to 1½in. to enable the insulation to be accommodated. Also, it is not sufficient to apply sound absorbents only over parts where it is desired to reduce sound going *through.* The effect depends on the total area and this is different for each ship.

(8) Blowers.

Blowers often form a prolific source of noise. The Author has measured several producing levels of 106 phons. Owing to the gearing (when mounted direct on the scantlings) they are difficult to cope with. In one or two cases beneficial results have been observed to follow from enclosing them in a sheet iron case lined with asbestos tiles with an air space all round. Ample absorption in a properly designed air intake is also necessary. If the original blower noise is less than the level of the engine itself, no result will follow. If the reverse obtains, the result is beneficial. Similarly it is no use enclosing the blower itself if most noise is emitted through the air intake. Depending upon the design, radiation from the engine casing can also nullify the result. Treatment therefore depends largely upon the individual circumstances.

(9) Motor Yachts.

In common with all the smaller types of craft, motor yachts are particularly subject to noise, which forms a common cause of complaint on the part of owners. Attention has been drawn to this matter by K. M. Millar [10]. Most of the principles previously described have been successfully applied to vessels of this type.

(10) Naval Craft.

It has been the practice of the British Admiralty to employ asbestos absorbents in control rooms, wireless cabins, etc., for many years. Sprayed asbestos has been widely used in the French Navy throughout accommodation, for the joint purpose of reducing noise and providing a thermal insulation. It is understood that the German Admiralty employ a thick mattress formed of asbestos cloth which encloses a number of interwoven layers of asbestos rope. This is fixed in the engine-rooms and crews' quarters.

CONCLUSION.

The Author's thanks are due to the following:—Mr. R. Wright of the British & Irish Steam Packet Company, to whose pioneer spirit much of the work mentioned in this paper owes its inception, and whose encouragement in many difficulties is gratefully acknowledged; Messrs. Harland & Wolff, Ltd. who, by their advice and by affording facilities for experiments on ships, made a large contribution to the practical application of this work; the several Shipbuilders and Shipowners whose active co-operation enabled tests to be made in their vessels; the Directors of Newalls Insulation Company for permission to read this paper and to incorporate the results of work carried out in their research laboratories; and Mr. E. G. Cawte, B.Sc., whose collaboration throughout the experimental work was invaluable.

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Discussion.

Mr. E. F. Spanner, R.C.N.C., retd. (Member of Council), opening the discussion, said that from the point of view of the naval architect there were three main sources of noise in ships, i.e. propellers (generally accentuated when the rudder was used), the main machinery and the auxiliary machinery. The author had shown that the two latter troubles could be dealt with more or less effectively by the expenditure of a certain amount of money and acceptance of certain other disadvantages. He noticed in the sample ventilating trunk, for instance, that an appreciable percentage of the area of the trunk had to be sacrificed and possible disadvantages incurred due to increased friction, vermin, moisture, and so on. An increase in the size of ducts and weight of ducts and insulation naturally meant increased expenditure. The fact remained that main and auxiliary machinery noises could be greatly subdued if desired.

With regard to the propellers he would like them to look at the diagram on page 277. The lower diagram gave curves of noise taken on deck "D", and it would be observed that there was almost as big a crest over the stern part of the ship as over amidships. It could be assumed that this was due to the propellers only, and it was obvious that over a considerable part of the ship this was a noise which could not be got rid of by means of insulation. The trouble there was one which would always be with them, and unfortunately it affected the ship's structure as a whole. These vibrations ran right through the ship—if a noise was not heard at least a tremor was felt. The author mentioned that the dissociation of the sleeping berths from the ship's side was very important from the point of view of the passengers' comfort, since, even if steps were taken to reduce noise, there might otherwise be a tremor under one's head if one were lying in a bunk.

Before deciding to spend a lot of money on a ship to eliminate major noises, they must be certain that in doing so they would not be unduly accentuating small noises not noticed at present, but which would eventually annoy passengers. It should be remembered that the more comfortable people were made the more apt they were to grumble at the little troubles still left. The speaker quoted as an instance the fact that the tiny tap resulting from the striking of a small wooden blind tassel against the window of his bedroom frequently awakened him.

In applying noise-reducing mediums to ships, care must be taken not to get the background so low that small noises became a positive source of annoyance. People did not wish to travel in a ship so quiet that on awakening they wondered if anyone was alive. A reasonable background should be aimed at. To go beyond that would saddle the shipowner with a lot of expense and leave passengers less satisfied than now—for the reasons that they were disappointed that better results had not been obtained and that for noise had been substituted tiny annoyances.

Reverting to the subject of propellers, he wondered whether it was possible for those associated with the Kort nozzle to say whether there was any noticeable difference in vibration and in the propeller noises aft in ships before and after fitting the nozzle. The noise from an ordinary propeller was due to the impact of the water on the hull. In the case of a Kort nozzle the blows were confined within the rigid nozzle. If the Kort nozzle reduced vibration and noise it might be helpful in larger ships merely from the point of view of noise reduction.

He still hoped that someone, some day, would be bold enough to build a ship with propellers amidships. That would cut out practically all vibration and all propeller noises. To place propellers aft at the end of a long elastic structure was deliberately to ask for the maximum amount of vibration and noise from the propeller disturbances at the stern.

Several examples had been shown of the method of fixing the insulation on the bulkhead. Some time ago the speaker made reference to a system of construction (see Fig. 16) first given practical effect in America. In one form of sound insulation shown in a model the stiffener was continuously connected and the insulation boxed out around it—an expensive method of application. He wondered whether it might not be equally effective to make the insulation flush all along the side of the stiffeners. This would give a gap of perhaps 8in. between the insulation and the bulkhead. It would provide a double diaphragm which was advantageous and a plain straightforward insulation without fancywork boxing in those beams. The idea was clearly illustrated in the drawing.

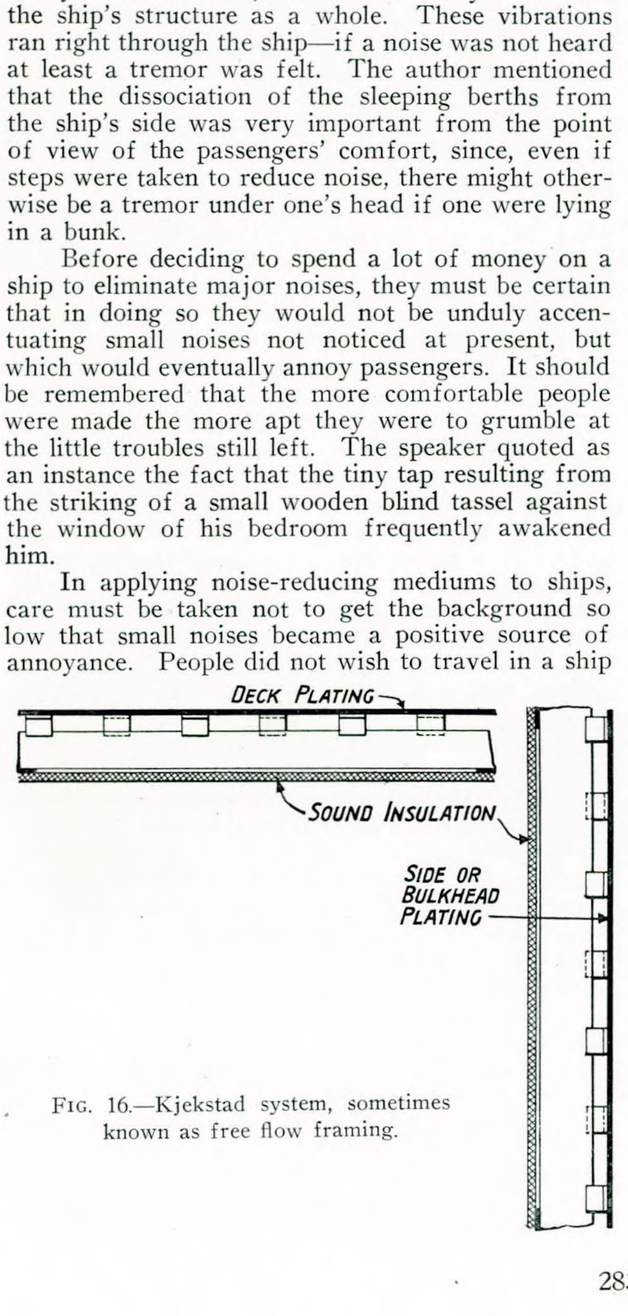


FIG. 16.—Kjekstad system, sometimes known as free flow framing.

Mr. A. C. Hutchinson (Visitor) said that there were one or two points in the introduction to the paper dealing with the theory of the subject which might be underlined. The author detailed the relation between the sensation of loudness and the phon value of a sound and gave a table showing the loudness reductions associated with different decreases in the number of phons. Taking 80 phons as a basis, the table showed how much loudness decreased with different phon reductions. A reduction, for example, of 5 phons from 80 represented a reduction of 30 per cent. in loudness. As a rough rule, one could take loudness as proportional to phons to the 5th power. It had been suggested by Churcher, King and Davies that $(\text{phons})^5/100{,}000{,}000$ should be taken as loudness numbers. Figures obtained in that way agreed very well with the figures given in the paper. It followed that for small changes, percentage changes in loudness were roughly five times percentage changes in phons.

With regard to loudness meters, it had to be pointed out that if a perfect objective meter could be made which would give loudness directly, there would be no case for the subjective meter. The disadvantage of objective meters was that although they could be made to give results similar to the human ear when dealing with single tones, they were liable to be incorrect with complex noises. For instance, an objective meter when dealing with a noise like the hum of a transformer, consisting of a fundamental tone and a train of harmonic overtones, might give a result 20 or 30 phons different from the correct value obtained with a subjective meter.

Regarding the mechanism of the transmission of noise through ships, he heartily endorsed the author's view that no-one knew very much how structure-borne noises were transmitted. He thought that the mounting of an engine, say a Diesel auxiliary, so as to prevent the noise getting into the ship's structure and reappearing in the cabins, was not at all well understood. The speaker himself had had some experience with the noises of turbine gears and Diesel auxiliary machinery. There were two schools of thought on insulated mountings. There was the heavy engineering school which held that the engine should be mounted on a wide, lightly-loaded slab of cork, the specific loading being only 15lb. per sq. in. or so, and the school represented by the motor trade, which advocated the use of a few heavily-loaded rubber elements. There was no doubt about the efficiency of the method of noise insulation in motor cars, but he was not convinced that the heavy engineering method of mounting was so good. He had tried with a stethoscope to determine the difference between the noise in the baseplate of a Diesel auxiliary engine, mounted on 2in. of felt, and the noise in the ship's seatings. There was very little difference across the felt, indicating that there was more to be learned on this subject.

He would point out, too, that in mounting an engine in a ship on an anti-vibration mounting, there was one great difficulty which did not occur when mounting a land engine, i.e. that the engine had to be seated on a relatively jelly-like support which had at the same time to control the engine movement in a seaway. When the ship was rolling the loading in the springs on one side might double while on the other side it became nothing. This presented a difficult mechanical problem.

The only definite general idea about the mechanical transmission of sound he had come to was that the transmission of sound through structures did not take place as in air by compression and expansion waves, but was a process of transverse vibrations. Following on that, he felt that the author's statement that noise could be transmitted down a propeller shaft was open to question because a stiff shaft like a propeller shaft had very little chance of transmitting noise by transverse vibrations.

Mr. A. H. Ledger (Member) observed that the author had stated that little data existed in relation to ships on the subject of sound insulation, and the author would agree that much less data was available twelve years ago when he, the speaker, was confronted with a very difficult sound absorption problem. At that time the company with which he was associated built a very large cable steamer. Fitted to this ship was an echo-sounding machine, not for navigation purposes in shallow water but for recording the depths of the deepest waters of the ocean. Now to be able to emit an audible sound wave under perfect control and of sufficient intensity to reach the bottom of the oceanic depths was one thing, but to so damp that sound wave that it was, as it were, instantaneous, and then to be able clearly to hear the return wave or echo was quite another. For a long time it was not possible to do either, and to get the transmitter to function satisfactorily took months. It was found, for instance, that the slightest trace of moisture interfered with the hard metallic blow that was essential, and that the very best mild steel snapped due entirely to percussive effects. Eventually the transmitter was made reliable, but the problem remained of enabling the observer on the navigation bridge to hear the echo distinctly. The echo-receiving instrument, or hydrophone, was fixed in the forward end of the ship and consisted, briefly, of a steel diaphragm which the echo wave had to set in motion and a microphone for conveying that vibration electrically to the observer on the bridge. Unfortunately, this instrument was situated inside one of the bays of a 500-ton double-bottom tank immediately on top of which was another ballast tank 27ft. in depth. To overhaul or examine the instrument at sea was therefore a practical impossibility and, moreover, the speaker had become convinced that, even had it been possible to isolate the mechanism for easier accessibility, the surrounding noises of the ship and of the sea itself would still smother the faint returning echo, unless by some means of sound absorption they could be eliminated. The speaker then related his experiences in trying to obtain a suitable material. First he tried asbestos sheeting, but this proved unsuitable—flexibility was essential. Eventually he had been led to try eel-grass, a commodity about which he obtained information and supplies only with great difficulty. Eel-grass was a particular kind of sea-weed obtained from Nova Scotia, but with a texture much more like brown grass than sea-weed. (He understood, incidentally, that settlers' huts, still in good condition, had been found insulated from the heat and cold with this material). The material was made up like an old-fashioned quilt with tough paper on one side and a woven fabric on the other; it was supplied in rolls and, of course, was quite flexible.

By the use of this material a bay in the double-bottom tank was made thoroughly sound-proof. No attachments to the ship's structure were permitted through the insulation; a dummy door, and that also insulated, was fixed inside the door opening into the bay itself. Inside, with the door closed, it was like being in a tomb, even with men chipping and scaling in the tank overhead.

The sequel to this was as follows. The ship was on her way home from Venezuela when orders were received to proceed to a position off Newfoundland and take soundings from there to another position off Ireland. Formerly, a ship would have to stop for an hour or an hour and a half at each deep-water sounding, with all the consequent delays and handicap to keeping a good course—one ship was away nine months sounding for the first Pacific cable. The Atlantic soundings were taken literally in the ship's stride at an average speed of $11\frac{1}{4}$ knots in truly boisterous weather, a couple of blows on the transmitter being sufficient at almost every sounding even in deepest water. Unless the ship was over particularly uneven ground such as a cluster of submarine hills —an absence of a clear echo was soon taken as an indication of uneven ground, as proved by ordinary soundings—failure to obtain soundings never occurred no matter what the depth of the ocean. That result was very largely made possible by means of sound absorption.

Mr. W. J. Robinson (Visitor) said that he had been struck by the fact that although, in vessel "B", a large number of additional provisions against noise had been made compared with vessel "A" *e.g.* mounting the engine on rubber chocks, mounting the auxiliary generators on springs, the addition of asbestos blankets, etc., little additional improvement had been obtained.

The author had mentioned that in using materials such as natural cork, rubber, felt, etc., in anti-vibration mountings, very high loading was usually necessary to bring the natural frequency of the system sufficiently low. Such low natural frequencies were also often associated with excessive movements of the machine due to pitching and rolling of the ship, and limitations were thereby imposed. Was that the reason that sound insulating the machinery in ship "B" had resulted in so little improvement over ship "A" where, apparently, no such insulation had been provided?

Another interesting point was the fact that there was roughly only the same order of phon reduction in the engine room as compared with the various cabins. Could the author account for that, because he (the speaker) was doubtful about the result and was inclined to suspect that the instrument was not giving the correct answer? Mr. Hutchinson had raised the question of the reliability of objective meters, and the speaker could not help wondering whether, in view of the impulsive nature of noises in the engine room, reliable results were there being obtained. The noise in the engine room would be "peaky" and therefore rich in harmonics of a high frequency character. Unless the instrument was a "peak meter", the noise level recorded would not have been as high as the ear actually heard it. The sound absorbent would probably have reduced the relative intensity of the peaks of noise in the engine-room, but—unless an accurate noise instrument had been used—the full benefit of sound insulation in the engine-room would not have been registered. This might be the explanation for the small difference between the reduction of engine-room and cabin noise levels.

A point of interest to marine engineers was the additional weight per sq. ft. of the sound insulating panels, over and above the heat insulation, to give the results obtained. Would the author please give particulars.

Was there a full theoretical explanation for the reduction in noise which was obtained throughout the ship? Was it due to the reduction of reverberation or to the additional weight of the panels in the engine-room?

On the second page of the paper the author mentioned that "the throbbing noise of reciprocating engines and the low-pitched components of gear noise are frequently referred to by passengers". The speaker had not personally experienced any prevalent low frequency noises associated with marine gearboxes, but on one occasion he investigated a case (alleged to be a gear noise) which turned out to be a steam pipe noise. He wondered whether the author had met any cases of steam pipe noise and if there was any known cure?

On the proposal of **Mr. A. F. C. Timpson, M.B.E.** (Vice-Chairman of Council) a vote of thanks to the author for his particularly valuable paper was accorded with acclamation.

By Correspondence.

Mr. R. Kahrs and **Mr. J. D. Behrens** (Det Bergenske Dampskibsellskab, Bergen) wrote that the author had made some very interesting comparisons regarding the insulation and sound absorption of engine rooms in motor ships. Especially interesting was the comparison between the ship "A" before and after the insulation, as this gave exact values. An improvement of an average of 9 phons should be sufficient on any passenger ship and seemed very satisfactory.

A direct comparison between the ship "A" before insulation and the ship "B" after insulation could not in their opinion be made, as the ships were not identical in either machinery or size. "A" was a smaller ship of 3,800 tons with larger machinery, 6,000 b.h.p., and higher revolutions than ship "B", which had a gross tonnage of 4,320 and a b.h.p. of 5,200 at 120 r.p.m. This in itself, in their opinion, should make ship "B" a very much quieter vessel, but besides this ship "A" had two four-stroke cycle engines while ship "B" had two two-stroke cycle engines. This, they were afraid, accounted fully for the improvement of about 3 phons from ship "A" insulated to ship "B" insulated.

The writers were concerned in fact with two similar ships, probably running in a service similar to "A" and "B". The gross tonnages were rather different owing to a larger superstructure on the largest one, but the main dimensions were not really very different. The smaller ship had a gross tonnage of 5,400 and a b.h.p. of 9,000 with two ten-cylinder four-stroke engines running at 153 r.p.m.; the larger ship had a gross tonnage of 7,300 and developed 11,000 b.h.p. from two ten-cylinder two-stroke cycle engines running at 137 r.p.m. The arrangement and size of the engine rooms were practically identical, but the ship with the two-cycle engines had a very much quieter engine room and was also very much quieter in the accommodation. They regretted that exact data could not be given as the different measurements had not been made. The difference in insulation could hardly account for these results, the larger ship being partly insulated in the engine-room side with magnesia covered with 1mm. lead sheets and partly with litosilo, the engine-room of the smaller ship being insulated with cork slabs covered with galvanized iron plates. Consequently they considered that the improvement of 3 phons in ship "A" compared with ship "B" was very difficult to explain. It was, in their opinion, due to the panels being fixed directly to the steelwork instead of being applied elastically. As stated by the author, this latter point was a rather difficult one, but it was posible to do it and they had tried it in a small part of the ship with the four-cycle engine.

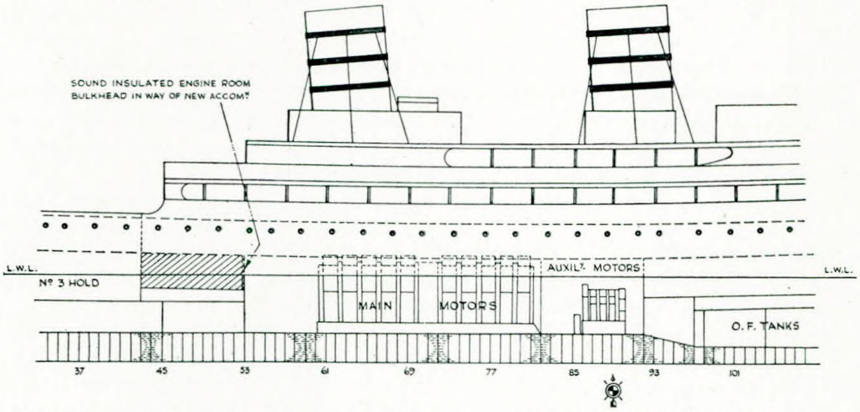


FIG. 17.—Arrangement showing position of sound insulated bulkhead in way of new accommodation.

After experiments carried out in co-operation with the author some years ago, they arrived at the conclusion that one of the main points was to have the panels fixed elastically to the steel work. They had to convert a part of the after 'tween deck of the four-cycle ship to passenger accommodation. This part was situated at the after engine-room bulkhead where a noise level 3ft. from the bulkhead was found which was considerably above the noise level of the passenger accommodation above. The insulation was carried out in this way:—Vertical wooden battens were screwed to the bulkhead stiffeners. Two layers of asbestos blanket were applied, one very near to the bulkhead and one at a distance of two-thirds of the depth of stiffeners, and carried around the edges of these. Four horizontal wooden battens were screwed to the vertical battens at equal distances, and a vertical batten was screwed to these in the centreline between the stiffeners. To these battens a horizontal cleading of $\frac{3}{4}$in. tongued and grooved boards was fixed, and the actual outer cleading of vertical profiled boards was applied to this with a layer of insulating paper between. The space between the cleading and the horizontal (spring) battens was filled with $1\frac{1}{2}$in. Paxfelt. It was carefully observed that the cleading was in no place in direct contact

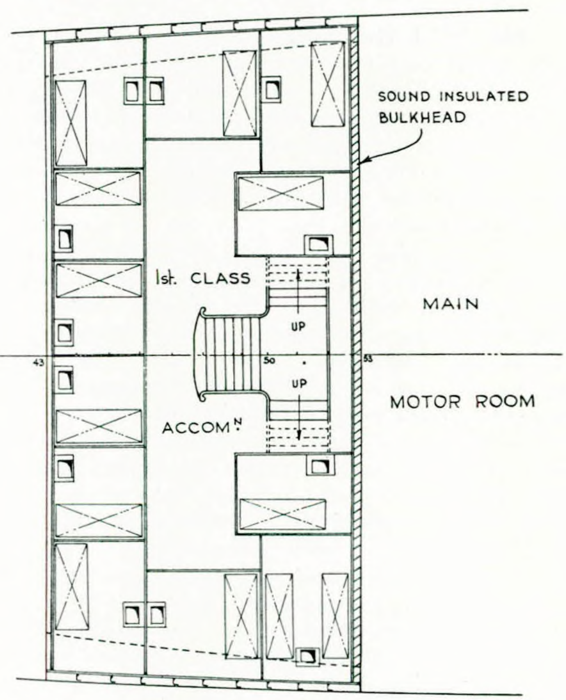


FIG. 18.—Arrangement of new first-class accommodation, showing position of sound insulated bulkhead.

with deck, beams or beam knees.

The result of this insulation was very good. As a matter of fact the cabins near to this wall were much quieter than the cabins at the after end of the compartment against the cargo hold where no sound insulating had been carried out.

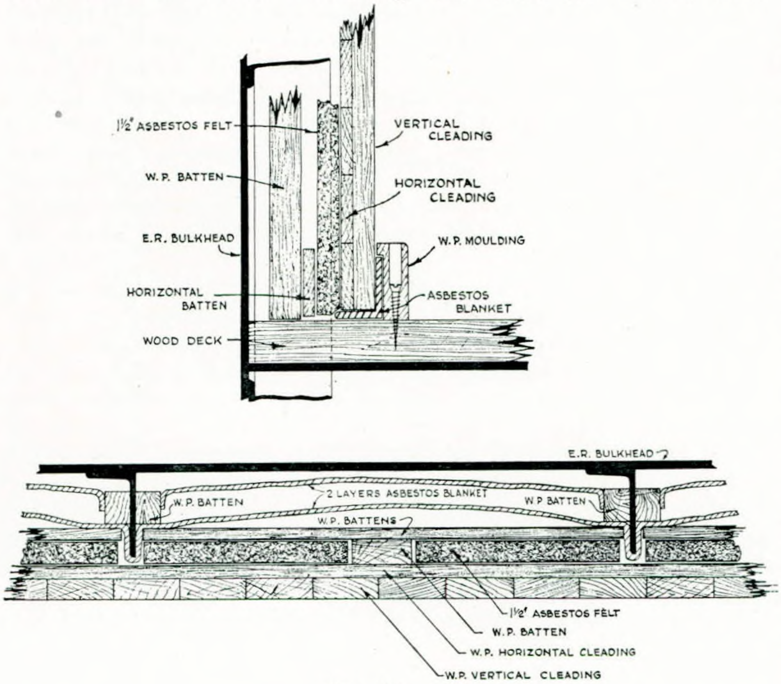


FIG. 19.

It appeared, however, from the author's results, that the simplest way to reduce the noise level was to fix a sufficient amount of absorption materials in the engine-room itself; their only objection to this was that the material used by the author would be difficult to keep clean, and they were afraid that the perforations would in time give smaller effect due to the fact that they might get blocked up with oil and dust. The casing of an engine-room ought to have a plain surface which could easily be kept clean.

Another point which ought to be studied was the insulation against high notes as compared with that against low notes. In the writers' opinion it was not quite sufficient to obtain a certain amount of sound reduction if this was mainly obtained by reducing the high frequencies, the low frequencies remaining almost unaltered. It would be very interesting to know whether the author had made any experiments in this respect, as the writers had the impression that most passengers found the low-pitched sounds the most annoying.

Dr. E. G. Richardson (King's College, Newcastle-on-Tyne) wrote that he considered the results would be of still greater value if the author had shown how the sound reduction in various pitch regions was affected by the introduction of insulation, since the extent to which a noise was "unwanted" by listeners depended on pitch as well as intensity. The writer desired this information especially in regard to the effect of engine revolutions shown in Table XVIII. He had always understood that good sound insulators were good heat insulators, and he was rather surprised that it was necessary to consider the thermal and acoustical amelioration separately. Could the author quote the thermal conductivities of the substances listed in Table VII?

Mr. W. West (Post Office Research Station) wrote that for practical reasons it was usual to place materials for absorbing sound directly against a reflecting surface, such as a ceiling or wall of a room. Most of the highly absorbing materials relied for their absorption properties on porosity and for such materials it had been demonstrated that the absorbing power was greatest when the material was placed in a region where the movement of air particles was greatest (see, for example, the Post Office Electrical Engineers Journal, Vol. 20, p. 128).

It was generally to be expected that the air particles situated at a distance from a hard, reflecting surface were more free to vibrate than those close to the surface. An absorbing material was therefore not being used to its best advantage when it was applied directly against the reflecting surface. This applied in particular to sounds at the lower frequencies, for which the wavelengths were longer and it applied only to surfaces where the dimensions were large by comparison with the wavelength of the sound.

Although it was not usual that practical considerations permitted the placing of special materials for absorbing sound anywhere but against a reflecting surface, exceptions did sometimes arise. For example, ceilings could in some cases be treated by suspending the absorbing material to form a false ceiling a foot or so below the reflecting surface (i.e., the real ceiling) as conveniently as by direct attachment to the reflecting surface.

Author's Reply to the Discussion.

The point raised by Mr. Spanner regarding the reduction of cross-sectional area of a ventilating duct by the introduction of a sound absorbing material was of importance in a ship, in view of the already limited space available for duct work. In fact the author understood that this was one of the reasons for the adoption of high air speeds in marine work as compared with land work.

The small duct shown in the demonstration was lined with 1in. asbestos felt, this being the thickness normally used. On this duct the absorbing material did take up a proportion of the cross-sectional area, but in a normal sized duct this proportion was relatively much less. It was also possible to obtain satisfactory results in many cases with ½in. material. Moreover, it was not necessary to line the whole of a duct. Treatment for a 1ft. duct varied between 10 and 20 linear feet and it was usually possible to accommodate the insulation over this length without great difficulty.

So far as moisture and vermin were concerned, the author had never experienced trouble due to these sources. Moisture did not affect asbestos at all—it just dried out again. Also, the anti-verminous property of asbestos was one of the reasons why it was so widely used. It did not attract vermin since it was a mineral, as opposed to a vegetable, substance.

He agreed with all Mr. Spanner's remarks regarding propeller noise. This was definitely a design problem, in the solution of which acoustic materials could only play an auxiliary part.

With reference to the accentuation of incidental background noises due to the reduction of the major sources, Mr. Spanner quoted the tapping sound produced by a window blind. The author encountered this identical problem on railways with fast acoustically treated trains. He thought, however, there was scope for much more improvement in ships before these background noises became of importance. Even so, the rattling of doors and various fittings was often disturbing, particularly if vibration was present.

So far as the Kjekstad system was concerned, the provision of the airspace would be advantageous, but probably the accessibility of cables and pipework would be lessened in accommodating them behind the sound insulation.

An example of flush finish across the face of the stiffeners was shown in Fig. 15 (*See* also reply to Mr. W. West).

In reply to Mr. Ledger, eel-grass quilt had been used for a number of years on land for incorporation in sound-proofing constructions. It was frequently employed for example in blocks of flats, but the author had not previously heard of its use in ships, probably owing to its vegetable origin and consequent lack of fire-resistance.

The design used by Mr. Ledger was important in that he completely isolated the enclosure from the ship's structure and employed a double door construction. It was in this matter of *effective* isolation that so many practical difficulties arose on ships. (Mr. Kahrs and Mr. Behrens also referred to this same principle).

Coming from one who had himself carried out research in engineering noise problems, Mr. Hutchinson's remarks were of particular interest.

He quoted a simple approximate method of converting from changes in phons to percentage changes in loudness, which was very useful.

With regard to the measurement of complex sound, the author was in agreement with Mr. Hutchinson's views, and in fact had experienced the same difficulty mentioned in connection with transformer noise in his own work on that subject.

The peculiarities of the ear presented considerable difficulty in reproducing them satisfactorily in an instrument; moreover the energy of quite loud noises was very minute. The shouting of a whole Cup Final crowd at Wembley only produced enough energy (when converted into heat) to boil a cup of tea.

As mentioned in the paper, there were certain limitations to the use of objective meters. For certain types of noise the subjective meter was better. The author was biased in practical work, however, in favour of the objective meter, because other interested parties could themselves see results as they were recorded. This obviated any suspicion of rigging a result, which might conceivably occur with the subjective meter, where the matching of the sounds depended entirely upon the investigator himself.

With regard to isolated mountings and structural transmission, Mr. Hutchinson had drawn attention to a number of salient points. The example of the auxiliary engine mounted on felt contrasted with a case within the author's experience. This concerned an engine mounted on heavily-loaded elements in which observations with a stethoscope showed a very marked decrease across the mounting. In spite of this, however, the noise was still apparent in the hull. In both these cases the sound still reached the hull, but by apparently different structural paths.

Mr. W. J. Robinson raised the question of the additional precautions on vessel "B" and why they did not produce a better result compared with vessel "A", the relative aural reductions being 50 per cent. for "A", and 60 per cent. for "B". He also mentioned the possible low frequency limitations of the engine mounting as a contributory cause. The author agreed with this up to a point, but thought the major reason lay in the fact that each successive increment of sound reduction was harder to obtain in practice. For example, the first 5 phons were easy to get; 5 to 10 phons involved much more trouble, and 10 to 15 phons were difficult.

It would be remembered that they heard sounds according to the logarithm of their energy, and it was the reduction of energy with which they were concerned in their practical endeavours to reduce it. A high energy reduction (*i.e.* a high efficiency of acoustic insulation) was necessary to produce even a moderate change in loudness. Thus, in ship "A", the energy had to be cut down to 1/10th of its original value to produce 10 phons loudness reduction, and on ship "B" to 1/16th to produce 12 phons. In other words the energy of sound in ship "B" was actually 40 per cent. lower than in "A".

The same speaker asked why there was roughly the same order of reduction in the engine room as in the cabins. This did not occur for individual locations, but was more apparent when averaging results over the whole ship. The author was himself rather surprised that this was so, but he had also observed it on other ships. The author did not think they had yet reached the stage where a full theoretical explanation could be made concerning the way in which sound was transmitted in ships, and he was endeavouring to collect more data on this subject.

Regarding the relative effects of reverberation reduction and the mass law, the author had found the former to be more effective on ships. He had tried applications of the mass law to casings, without much practical result. Some tests on a heavily-armoured battleship should help to elucidate this point further.

With reference to Mr. Robinson's remarks concerning peaks in engine room noise and the measurement difficulties they involved, the author guarded against this as far as possible by suitable calibration of the instruments. Nevertheless, in view of the difficulties involved in the measurement of impulsive noises, it was possible that the sound reduction in the engine room of ship "B" might have been somewhat greater than the figures suggested.

In connection with the measurement of noise generally, mention might be made here of the important investigations which had been made at Teddington by the National Physical Laboratory.

The question of weight was important. In applying sound insulation in conjunction with the normal heat insulation there was actually a *saving* in weight. This is due to the fact that the asbestos tiles referred to replaced the normal protective coating of the heat insulation which was generally asbestos cement sheeting, sheet metal or ½in. cement on expanded metal. The latter weighed 3·9lb. per sq. ft. plus 0·2lb. per sq. ft. for the reinforcement. The asbestos tile weighed 1·5lb. per sq. ft. giving a saving of 2·6lb. per sq. ft.

So far as steam pipe noise was concerned, the author had not carried out any work on this particular subject.

Mr. Kahrs and Mr. Behrens had made some observations of considerable interest, particularly with reference to the comparative acoustic merits of two-stroke and four-stroke cycle engines.

The author had carried out some comparative tests on two-stroke and four-stroke cycle engines of the same horse power, and, in the particular examples concerned, he found that the noise measured at the position of the controls was the same in each case. At the level of the valve gear, however, there was a difference in favour of the two-stroke cycle type and this was also noticeable in parts of the accommodation, but *only in parts*.

In the two cases mentioned by Mr. Kahrs and Mr. Behrens he agreed with their observations and that the difference was not due to the two types of engine room insulation.

With reference to the elastic mounting of the sound insulation shown in the drawings, there was no doubt that this was of importance, particularly in achieving specially good results. As they pointed out, it was difficult from the practical standpoint and also expensive. The author's opinion was that this type of treatment had to be done thoroughly and carefully, or not at all. He attributed the results obtained in this case not so much to the insulation itself, but to the way in which they worked a series of acoustic principles into the practical design. This was more difficult on shipboard than it would appear at first sight.

The contributors had been good enough to refer to experiments made in collaboration with the author, but he felt obliged to point out that these formed only part of a series of acoustic investigations of great technical interest and utility which they themselves undertook.

Regarding the effect of oil and dirt in the engine-room upon drilled asbestos tiles, this was anticipated in marine work by employing a larger perforation than was common in land work, and no difficulty had been experienced on this score over a number of installations.

With reference to low frequency absorption he would refer the writers to the reply to Dr. E. G. Richardson.

With regard to Dr. Richardson's remarks, the author had examined the noise reduction in the various pitch regions under laboratory conditions with the system of insulation referred to, but not in its effect on shipboard. Mr. Kahrs and Mr. Behrens also referred to the fact that pitch was important as well as intensity reduction. This was an important subject upon which further investigation might well be carried out. In obtaining very high absorption at low frequencies, a considerable thickness of material in a mechanically resilient (or soft) condition was desirable, and this might have practical disadvantages in an engine-room.

Dr. Richardson pointed out that most sound absorbing materials were also good heat insulators. It had only been found necessary to consider the heat and sound insulation separately so far as *location* was concerned. In a motorship it seemed desirable to get some of the acoustic material at lower levels in the engine-room than was general for the heat insulation. The respective insulations did, however, overlap on a large proportion of their area and as Dr. Richardson rightly suggested, the thermal insulation of the acoustic treatment should be taken into account. This was in fact done in the case of ship "B", and should be allowed for ir thermal calculations where the type of construction shown in Fig. 8 was employed.

The thermal conductivities of the materials given in Table VII were as follows:—

Thermal Conductivity in B.Th.U./sq. ft./hr./°F./in. for mean temperatures usually encountered on engine-room casings.

1.	Asbestos tiles with drilled surface ...	0·71
2.	Cane fibres tiles	0·33
3 & 4.	Asbestos fibre sheets	0·37
5 & 6.	Asbestos spray	0·37
8.	Asbestos blanket	0·49
9.	Cork slabs	0·28
10.	Fibre boards	0·33-0·53

Generally speaking it was advantageous to apply absorbents with an air-space behind as Mr. West had pointed out. This was sometimes done in cabin insulation, but the author had not tried it in engine-rooms, largely because of the practical restrictions involved. These included space (usually limited on shipboard) and fixing, together with the limitations incurred due to the pipework.

In large fan rooms, on the other hand, the author had found it convenient to utilize this principle and an example was shown in Fig. 15 in which the absorbent was applied flush with the face of the stiffeners, and had an air space behind.

Annual Conversazione.

To the Convener (Mr. A. Robertson) and Members of the Social Events Committee must be credited another memorable achievement in that the continued increase in popularity of the Annual Conversazione resulted in an attendance of 1,050 members and guests at this year's function, which was held in the Great Hall at Grosvenor House on Friday, the 25th November, this number slightly exceeding last year's record attendance. The Committee regret that it was again impossible to accommodate everyone who wished to attend.

The President, Sir E. Julian Foley, C.B., and Mrs. R. Rainie, received the members and guests from 7.15 to 7.45 p.m. Immediately afterwards dinner was served, during the course of which Mr. R. Rainie, M.C., Chairman of Council, submitted the toast of the President in the following terms:—

"Ladies and Gentlemen,

Again this year I am privileged, as Chairman of Council of The Institute, to put a proposition before you. The basic principle upon which this party is organized is that those who attend it should eat, drink and be merry; in other words, they should do things that give them joy. The proposition I have to make to you will not depart one iota from that basic principle; it is that we will drink a toast to the very good health of our President.

Members of The Institute can congratulate themselves on two facts—that they have drawn in front of that curtain behind which even our most prominent Civil Servants function a delightful character and outstanding personality to be our President, and that in one of the most important and busiest years in the annals of The Institute he has represented us so ably. My proposition cannot help, therefore, but appeal to the members of The Institute. Our guests I am sure will be only too ready to respond to it also, realizing that the man I will ask you to honour controls and directs with such success the great Department of Government of which he is the head.

Ladies and Gentlemen, I ask you to rise and drink to the health, prosperity and happiness of the President—Sir Julian Foley".

The toast was enthusiastically accorded with musical honours and loud and prolonged applause, which the President acknowledged in a witty response.

THE RECEPTION BY SIR JULIAN FOLEY AND MRS. R. RAINIE.

THE ANNUAL CONVERSAZIONE.

THE PRESIDENT'S TABLE.

The Chairman of Council's table. Mr. Rainie is on the far side, third from right-hand end.

SOME OF THE 1,050 MEMBERS AND GUESTS.

The first part of the cabaret was staged immediately after dinner, the second part providing a delightful interlude from 11.30 p.m. to 12.15 a.m. The artistes included Duane and Leslie (in new dances), the Two Equillos, Paul Oscard's Adorables, Bower and Ravel, the Bavera Trio, the Three Jokers, the Three Admirals, and Joanne Carpenter. Sydney Jerome and his orchestra rendered orchestral and dance music throughout the evening, the proceedings terminating at 2 a.m. with a grand rally for "Auld Lang Syne".

A CONVERSATION PIECE DURING THE COUNCIL RECEPTION. MR. LEE WOOD (a Vice-President for Liverpool) and (right) Eng. Com'r. W. A. GRAHAM (Vice-President, Southampton).

ELECTION OF MEMBERS.

List of those elected at Council Meeting held on Monday, 5th December, 1938.

Members.

Thomas Albert Cambourn, 90, Boundary Road, Carlisle.

Francis John Anthony Coleby, Com'r. (E.), R.N., The British Embassy, Washington, D.C., U.S.A.

George Kenneth Coltar, c/o Huilever S.A. (Div. H.C.B.), Leopoldville, Belgian Congo.

Duncan Corbett, 18, Church Lane, Merton Park, S.W.19.

Albert Henry Payne, 154, Cranbrook Road, Redland, Bristol.

Herbert Edwin Shaw, 12, Kynaston Close, Harrow Weald, Middlesex.

Walter Smith, 43, North Way, Queensbury, Edgware, Middlesex.

Associates.

Gerald Gower Elder, 92, Gainsborough Road, Wavertree, Liverpool.

John Guthrie, Earlsferry, 8, Prideaux Road, Eastbourne.

Douglas Blacow Thompson, 56, Aynam Road, Kendal, Westmorland.

Student.

Arthur Glen Hunt, 62, Clemence Street, Burdett Road, E.14.

Transfer from Associate Member to Member.

Edmund Carlton Garratt, Crows-nest, Pear Tree Lane, Shorne, Kent.

Transfer from Student to Associate.

John Robertson Batey, 10, Woodhead Road, Walker-Gate, Newcastle-on-Tyne.

John Buckley, 36, Wandle Road, Wandsworth, S.W.17.

ADDITIONS TO THE LIBRARY.

Purchased.

The Running and Maintenance of the Marine Diesel Engine. By John Lamb. C. Griffin & Co., 4th edn., 18s. net.

Presented by the Publishers.

The British Engine Boiler and Electrical Insurance Co., Ltd. Technical Report for 1937.

Statutory Rules and Orders, 1938, No. 1375. Merchant Shipping. Life-Saving Appliances. H.M. Stationery Office, 9d. net.

The following British Standard Specifications:—

No. 587-1938. Motor Starters and Controllers and Resistors Employed Therewith (excluding Liquid Starters and Controllers and Single-phase A.C. Models).

No. 813-1938. Chemical Symbols and Abbreviations.

No. 21-1938. Pipe Threads (Part I—Basic Sizes and Tolerances).

Proceedings of The Institution of Mechanical Engineers, Vol. 139, containing the following papers :—

"Some Problems in the Transmission of Power by Fluid Couplings", by Sinclair.

"Engineering Problems Associated with the Improvement of the Temperature and Humidity Conditions of the Atmosphere in Mines at Great Depths", by Dobson and Walker.

"The Design and Operation of a Modern Blooming Mill", by Cartwright.

"The Transmission of Superheated Steam over Long Distances", by Genève.

"Practical Problems in Spring Design", by Berry.

"Aerial Ropeway Transport", by Taylor.

"Some Developments in Engineering Practice Relative to the Steel Industry", by Roebuck.

"The Birth and Growth of Engineering in the West Country", by de Soyres.

Transactions of The Institution of Naval Architects, 1938, containing the following papers :—

"Alternative Firing of British Men-of-War", by Acworth.

"Destroyer Turning Circles", by Cole.

"The Reheated Reciprocating Marine Steam Engine", by Hunter.

"An Alternating-Current Power System for Diesel-engined Ships", by Belsey.

"Further Experiments in Smooth and Rough Water with a Model of a High-speed Ship", by Kent and Cutland.

"Further Resistance and Propeller Experiments with Models of Coasters", by Todd and Weedon.

"Structural Stress in an Oil Tanker Under Service Conditions", by Bridge.

"Vibration in Ships", by Constantini.

"Launch of the Twin-screw Turbine Steamer 'Nieuw Amsterdam'," by Chambers.

"Aluminium and its Alloys with particular reference to their Use in Warships", by Hughes.

"Trends in Shipbuilding", by Montgomerie.

"Effect of New Safety Regulations in Senate Report No. 184 on the Design of Merchant Ships", by Vickery.

"The Present Trend in Marine Engineering in the United States of America", by Burkhardt.

"Marine Engineering Problems of To-day", by Freeman.

"Experimental Methods to Determine the Strength of Materials in relation to Shipbuilding", by de Leiris.

"Whirl of Diesel Engine Crankshafts", by Lugt.

"Ocean Waves, Freeboard and Strength of Ships", by Schnadel.

"Some Contributions to the Theory of Rolling", by Watanabe.

Autographic Indicators for Internal Combustion Engines. By J. Okill, M.Eng. Edward Arnold & Co., 88 pp., 62 illus., 5s. net.

The author, owing to his long association with the teaching of motive power engineering at Liverpool University, is well qualified to write this monograph on the subject of indicators. He has only considered indicators of the combined piston, spring and pencil lever type, which has limited his descriptions to those types which are suitable for engine speeds up to 500 r.p.m.

The opening chapter briefly deals with the history and development of the indicator from the first steam engine indicator invented by James Watt in 1790 to the modern Dobbie-McInnes external spring type for use with internal-combustion engines. Chapter II deals with piston friction and the author emphasizes the care which must be taken in order to obtain good cards. Tests made by the author show that the grooves in an indicator piston do not form a labyrinth packing and hence the leakage is less for a plain piston than for one fitted with three grooves. He also states that leakage is of lesser importance than piston friction. The errors due to inertia and spring vibration are thoroughly dealt with in Chapter III, which also includes descriptions of types of drum operating gear as used on opposed-piston oil engines. Some useful information on the testing of indicators at their working speeds and pressures is given in Chapter IV. The uses of the maximum pressure indicator, first designed by the author in 1907, are described, and the special features of the 1919 instrument are illustrated by clear diagrams. Chapter V deals principally with the effect on the shape of the diagrams of connecting the indicator to the cylinder by means of a connection having either a plug-cock, a right-angle screw down valve or a straight-through valve. The author in Chapter VI stresses the importance of making greater use of the indicator by taking out-of-phase diagrams, ignition and injection timing diagrams, and various gadgets for obtaining these special diagrams. The final chapter illustrates and draws attention to some of the special features of designs of indicators which have given satisfactory service and concludes with some excellent practical tips on the taking of diagrams.

The book is clearly printed and well illustrated and the information therein will be very acceptable to all engineers who are concerned with the taking of indicator diagrams. There is only one criticism that might be made and that is directed against the publishers and not against the author. If the book had been published at 3s. 6d. instead of at 5s., it would have had a bigger sale among junior engineers.

Theory of Mechanical Refrigeration. By N. R. Sparks. McGraw-Hill Publishing Co., 225 pp., 55 illus., 18s. net.

This work may be regarded primarily as a survey of the thermodynamic aspects of the principal refrigerating cycles. The author deals exhaustively with the basic principles of the behaviour of gases under the conditions obtaining in refrigerating plants and also with the simple and compound compression cycles. In addition, the work contains a good deal of information about the manufacture of solid CO_2 and the absorption and water-vapour systems.

The author has also dealt with one application of mechanical refrigeration, namely, air conditioning and ventilating. In the opinion of the reviewer, it is a pity to depart from the main theme of the work to deal with one application of refrigeration—admittedly an important application, but by no means the most general one. The data given on air conditioning is of considerable interest and comprises much useful information. Some space is also given to the use of refrigerating plant working on the reverse cycle for heating in buildings.

As regards the compression cycles, the author deals exclusively with those using ammonia and CO_2. In view of the fact that many low-pressure refrigerants are commonly employed nowadays and their use is on the increase, it seems a pity that some space is not devoted to them. These low-pressure gases obey the same laws as those for NH3 and CO_2 but, having different physical properties, require in practice a somewhat different treatment in some cases. The reviewer considers that a short chapter on these low-pressure gases and some tables of their physical properties would greatly increase the value of the book.

The book is written for persons with a fairly high standard of knowledge of physics, and anyone who thoroughly understands this work can consider himself as having a good general idea of the principles of the refrigerating cycles in common use at the present time.

Accumulator Charging, Maintenance and Repair. By W. S. Ibbetson, B.Sc. Sir Isaac Pitman & Sons, Ltd., 6th edn., 165 pp., 42 illus., 4s. 6d. net.

Although only a very short time has elapsed since the publication of the fifth edition of this handbook on accumulator charging and maintenance, no efforts have been spared to make this new issue meet the latest requirements of all who are concerned with the operation of secondary batteries. Additional information has been included with regard to the charging of batteries for electric vehicles, and included in the appendix are the latest questions set in the City and Guilds of London examinations for candidates taking the Motor Vehicle Electrician's Course dealing with batteries. Although improved methods of construction and greater demands for batteries are enabling manufacturers to give better guarantees for their products, the principles underlying the operation and management of accumulators remain the same. It has always been the author's aim to explain and make as clear as possible these principles and their application and, wherever possible, additional attention has been paid to this important aspect of the subject, both in the text and by means of diagrams. The rapidity with which the successive editions of this work have been exhausted is the most convincing evidence that he succeeds in his object.

The contents of the book include, following an introductory, chapters on electrical power, production of electrical energy, the effects of charge and discharge, capacity, modern accumulators, battery charging, generator methods of charging, diseases and their treatment, repairs and workshop, alkaline cells, and country house and private plants.

Elementary Technical Electricity. By R. W. Hutchinson, M.Sc. University Tutorial Press, 392 pp., 402 illus., 5s. 6d. net.

The author's "Junior Technical Electricity" is well known and appreciated by both teachers and students of the subject. The present volume replaces it under a new title. It has been practically rewritten, new and up-to-date matter is included, and it has been greatly extended.

The reviewer has several times recently drawn attention to incorrect explanations of electrical engineering phenomena, introduced through ignorance and included to meet the requirements of some particular examination syllabus for pupils who have in very many cases little opportunity of verifying the principles involved. This fact the author also draws attention to in his preface :—"It leads to a logical development of the subject, its units, sound theory and definition, and eliminates excessive 'make-shift' explanations to be corrected or discarded later". There is no excuse or room in the teaching of any subject for the inclusion of matter which is incorrect or has to be unlearned later. The author wisely introduces modern explanations *from the beginning*. He achieves his object "to give a clear and *accurate* insight into the necessary electrical theory, a training in experimental work and observation, and a thorough acquaintance with the elements of practical electrical engineering". The book does actually combine scientific principles with engineering practice. About two-thirds of the volume deals thoroughly in detail with the principles of elementary electricity and magnetism. The ground covered is all that is necessary for the object of the book and involves numerous calculations, examples and laboratory experiments. The remainder of the book treats more generally of electrical engineering principles and practice. Lamps, testing, transmission, d.c. and a.c. generators and motors, wireless, television, etc., are all discussed briefly but usefully and accurately.

Exercises and test questions on the several chapters appear at the end with answers to the arithmetical problems. The book is cheap, sound and practical. It is an excellent first-year course in the subject and will no doubt gain well-merited popularity.

Diesel Engineering. By J. W. Anderson. McGraw-Hill Publishing Co., Ltd., 269 pp., 149 illus., 18s. net.

The general description, construction and application of the different types of Diesel engines have already been given in the author's companion book. In this volume the dynamic and thermodynamic problems relating to design are discussed in detail. A knowledge of the fundamentals of mechanics and thermodynamics is presumed but as the development of the Diesel engine has presented new problems to designers, builders and operators the author analyses the research work done in finding the solution to these difficulties and lays down the fundamental principles on which future development must be based.

After a preliminary chapter on the thermodynamic cycles, some excellent curves are given illustrating the relation between thermal efficiency, strength of mixture of fuel and air and compression ratio. Later, the shape of combustion chamber required together with fuel injection is discussed in relation to time lag in combustion, and the effect of this time lag. A further section deals with the oil pressure for airless-injection engines, the flow of the oil in pump and pipeline, the form of spray and their general effect on penetration, the whole series forming a very complete analysis of what is required to give maximum efficiency under the best running conditions.

Other sections include fuels, cooling, lubrication and design of engine parts. This book should be useful to engineering students specialising in the design of Diesel engines.

The "Cassel" Heat-treatment and Casehardening Handbook. Imperial Chemical Industries, Ltd., 127 pp., illus., no published price.

This small handbook exemplifies the great progress that has been made in recent years in the processes of heat-treating and casehardening of steel and iron.

Those who remember the days when casehardening was effected by packing finished steel products in crushed bones, charcoal, charred leather or other carbonaceous material and heating to an unknown temperature for an indefinite time, will be glad to find that the production of a satisfactory "case" is now no longer a matter of experiment and uncertainty but one of positive and calculable result.

The "Cassel" products described in this booklet include sodium cyanide for carbonising up to 0·025in., "Rapideep" which penetrates to 0·09in. and various tempering and heat treatment salts. The uses of these products are fully explained with special reference to their employment on medium carbon and alloy steels and malleable cast iron. A brief glossary of metallurgical terms is included and space is found for some excellent micrographic illustrations and a number of informative tables and steel specifications.

Although under the heading of "Safety Instructions" it is stated that there are no recorded cases of accidental poisoning by "Cassel" heat-treatment salts, it is recognised that injury may occur through careless handling of the salts and thus several pages are devoted to safety measures and methods to be adopted in the event of mishap.

This handbook should be studied by all production engineers who are concerned with hardening or heat-treatment problems and it should efficiently dispose of the misgivings of those who still view casehardening as a speculative process.

The Superheater in Modern Power Plant. By Dipl. Ing. D. W. Rudolf. Sir Isaac Pitman & Sons, 293 pp., 157 illus., 21s. net.

This work is probably the first text-book dealing exclusively with superheaters, and a study of it leads to the conclusion that the subject certainly justifies a special book in lieu of the chapter or so usually devoted to it.

The book deals entirely with present-day practice, and the omission of any historical record may be open to criticism in a work which should have a good circulation amongst others than superheater specialists; indeed there is much matter of interest to anyone dealing with problems of heat transfer.

On page 4 the author assesses the economy in heat consumption of a turbine at 1 per cent. for 18° F. superheat; this is greater than is usually reckoned, and indeed the author's Fig. 2 gives approximately 1 per cent. reduction for 35 to 40° F. Although the work is confined to land superheaters, exception might be taken to the author's remark on page 2 that "reciprocating steam engines, with a few occasional exceptions are nowadays used only in small generating and industrial plants". As is well known, very many marine reciprocating engines of up to several thousand horse power each continue to be built, and indeed the survival of the type for marine purposes is in large measure due to the adoption of superheat, and more recently of reheating. To many, a definition of the author's use of "boiler load" and "boiler rating" would be helpful —for instance on page 50, Fig. 31, we have "boiler loads" from ¼ to 1, and on the same page Fig. 32 gives "boiler ratings" from 0 up to 400 per cent. It would also be helpful if the author could group his symbols and definitions together to facilitate reference.

Altogether, however, the book is highly creditable and should find a place on the bookshelf of anyone connected with superheaters and similar heat transfer problems.

Mechanics of Materials. By P. G. Laurson, M.S. and W. J. Cox, C.E. Chapman & Hall, Ltd., 408 pp., 467 illus., 18s. 6d. net.

Under the unusual title of "Mechanics of Materials" the authors, who are associated with the School of Engineering of Yale University, have made a very useful contribution to the study of the strength of materials. The subject has been covered extensively by many previous people, and the present book offers very little in the way of original treatment. The calculus has been freely resorted to throughout and much of the matter assumes a good mathematical standard.

The particular feature upon which the authors are to be congratulated, however, is the excellent quality of the examples illustrating the text. In most cases these have been chosen with great originality. More than 500 carefully designed problems have been included, many of which are based on actual well-known engineering structures and machines. Well executed sketches with an occasional photograph relieve the text.

Several worked examples are included in each chapter, and the relevant problems at the end of each section are supplied, in most instances, with the answers. A great deal of space is devoted to the question of beams, with an unusual addition of a very interesting chapter on the design of beams. The question of deflection has been generously treated, both by the double integration of the elastic curve, and the area moment method, again with a number of unusual applications.

Encastre, propped and continuous beams are very fully developed with a special chapter devoted to beams of different materials, including reinforced concrete, and "flitched" beams.

The theory of columns is followed by a chapter on the design of columns with examples in steel, cast-iron, aluminium alloys, and timber. The book concludes with a group of "comprehensive problems", the solutions requiring in each case a number of principles drawn from different parts of the text. The appendix includes a very complete set of tables of American steel sections, obviating the use of a steel handbook in the solutions of the problems throughout the book.

This very comprehensive survey of the subject will make its appeal to teacher and student alike.

JUNIOR SECTION.

Lecture on Steering Gears.

The annual joint meeting of the Junior Section with the Students of the L.C.C. School of Engineering and Navigation, Poplar, took place on Thursday, November 17th, 1938, at 7 p.m., when Mr. G. Buchanan, B.Sc., delivered a most instructive lecture on the subject of "Steering Gears". Mr. J. Paley Yorke, O.B.E., M.Sc. (Principal of the School) again honoured the occasion by occupying the Chair.

Mr. Buchanan had obviously exercised a great deal of care and judgment in the preparation of his lecture and in the selection of the slides with which he illustrated his remarks, and consequently he held the close attention and interest of the audience until the end of his lecture. The lecturer's reply to the many questions which followed terminated a very successful meeting.

On the proposal of Mr. T. A. Bennett, B.Sc. (Head of the School's Marine Engineering Department and Member of Council of The Institute) Mr. Buchanan was warmly thanked for his excellent lecture, while Mr. E. F. Spanner, R.C.N.C., ret. (Member of Council) voiced the thanks of The Institute to Mr. Paley Yorke and the Staff of the School for their co-operation.

CORRESPONDENCE.

To the Editor of the TRANSACTIONS.

Dear Sir,

"Gas Engines for Small Craft".

I am sorry that through an oversight on my part an error has occurred in the report of my contribution to the discussion on Mr. Gibbons' paper (*see* Vol. L. of TRANSACTIONS, Part 10, November, 1938, p. 241). The word "coking", which occurs twice, should be read as "caking". Please allow me the opportunity of correcting this error by publishing the present letter in the next issue of the TRANSACTIONS.—Yours faithfully,

C. H. NOTON.

ABSTRACTS OF THE TECHNICAL PRESS.

The Motorship "Wilhelm Gustloff".

The motorship "Wilhelm Gustloff" is the first ship to be specially constructed for the Deutsche Arbeitsfront, and is to be used to bring sea-cruising within reach of the German working classes. The ship was built by Messrs. Blohm & Voss, and the principal particulars are: Length B.P. 639·75ft.; breadth moulded 77ft.; depth moulded to lower-promenade deck (strength deck) 56·6ft.; draught loaded, forward 19·7ft., aft 23ft.; deadweight 5,660 tons; gross tonnage 25,484; engine b.h.p. 9,500; speed 15·5 knots; total number of passengers 1,465; total number of crew 426. The unusual service for which the ship is designed has occasioned the introduction of many original features. The absence of need for cargo holds, hatchways, etc., has permitted extensive clear deck spaces, and on the sun deck there is an uncovered area for games and assembling purposes, which is large enough for a gathering of 4,000 persons.

There are eight main decks and a captain's bridge; the eight decks are of steel, and seven of them are passenger decks. The cellular double bottom, about 55in. deep, extends from the collision bulkhead to the after peak and can contain 1,175 tons of fresh water, 735 tons of oil fuel, 80 tons of lubricating oil, and a large quantity of water ballast. There are 12 watertight bulkheads, and many of the lower spaces are used for the carriage of about 2,450 tons of fresh water. Deep tanks at the ends and the fore and after peaks carry about 1,470 tons of water ballast, and the main portion of the oil fuel, about 815 tons, is carried in 8 deep tanks at the sides of the auxiliary-machinery room. The oil tanks are separated from other tanks and spaces by cofferdams, and the total oil-fuel capacity is 1,550 tons—sufficient for a voyage of roughly 12,000 miles. Except for the machinery spaces only one compartment below E deck is not taken up by tanks; this compartment houses all the cold storerooms of the ship.

Only the exposed decks have any camber, all the interior decks being flat; this is even so on the promenade decks, the central parts within the deck-houses being flat and the exposed parts at the sides being slightly cambered.

Electric welding has been widely used; it has been used exclusively for tank top plating, inner bottom, steel bulkheads, and machinery seatings, and has replaced riveting to a considerable extent on the shell. It is estimated that welding has effected a saving in weight of about 1,300 tons.

The passenger accommodation comprises 221 double-berth, 239 four-berth and 6 ten-berth rooms. Every cabin has a sidelight giving natural light and air, and the light and air passages to the inner cabins are unusually wide, a little over 4ft. There are 127 bathrooms and shower baths and 150 toilets. The baths have hot and cold salt water and the showers hot and cold fresh water. Hot water heating is employed, and 109 motors, totalling 500 h.p., provide mechanical ventilation. The system has been subdivided into a number of units, each in a fireproof compartment, and each unit can be stopped by means of a switch on the navigating bridge. The crew accommodation is to the same standard as the passenger accommodation.

There are two CO_2 compressor sets, each rated at 60,000 cal. per hour, and the cold storage spaces aggregate 32,000 cu. ft.; 100 reversals of air per hour are arranged for the meat room, and 50 reversals per hour for the vegetable and egg rooms. The temperatures to which the various rooms can be refrigerated vary from plus four degrees Cent. to minus 18 to 20 degrees Cent.—*"The Shipbuilder", No. 349, Vol. XLV, pp. 608-615, November, 1938.*

High-Pressure High-Temperature Installations.

The editorial quotes papers read before learned societies by GUY in 1926 and 1929. BAUMANN in 1930 (on future developments), MELLANBY AND KERR, in which the expert authors were substantially in agreement as to the relative advantages of moderate (against high) temperatures and pressures, although recently there has been a tendency abroad to favour the latter. It points out that replacement of existing plant by more up-to-date units must be considered from time to time and normally new developments are then incorporated as, in the case of power station equipment, higher pressures and temperatures, regenerative feed-heating, improvements at the low-pressure end of the turbines and in the condensing plant. But unless depreciation allowance has been generous, interest charges will offset increased thermal efficiency and it is seldom desirable to scrap plant still in good working order. Two solutions are suggested. (1) new high-pressure high-temperature plant with full expansion, (2) a "topping" plant consisting of a back-pressure turbine taking h.-p. h.-t. steam and delivering its exhaust (suitably reheated) to the original equipment at the designed pressure; this involves h.-p. boilers which can frequently take the space of those existing. Total heat to generate 1lb. of steam does not vary greatly with pressure—at 2,000lb./in.^{2} and 850° F. 1,380 B.Th.U., at 400lb./in.^{2} and 750° F. 1,393 B.Th.U.; the adiabatic heat drop between these conditions is

176 B.Th.U., and further to 29in. vacuum 498 B.Th.U.; allowing a little for the lower efficiency of the h.-p. turbine one obtains an increase in capacity of 30 per cent. by this "topping" from 750° to 850° F. In addition the old plant still operating efficiently can be retained. Obviously the rate of interest and the price of fuel will influence the decision. Figures given by ORROCK at the 1938 Glasgow International Engineering Congress are discussed, in reference to the development of the central electricity station in U.S.A. In the discussion reported in *Trans. American Society of Mechanical Engineers, July, 1938,* the difficulties encountered are reported:—creep, boiler troubles due to slag accumulation, defective circulation in cooling tubes, superheater joints, superheat variation, and deposit of solids on h.-p. temperature blading. These troubles are due mainly to high furnace temperature and high steam density, and attention must be given to damper control, desuperheating, steam/water separation, and use of soft water for make up. According to MARGUERRE [*"Engineering", Vol. 132, 1931, p. 241*] there is no fundamental connection between high pressure and corrosion. The editorial concludes that under suitable economic conditions there is no serious practical objection to extension of capacity by either method.—*Leader, "Engineering", Vol. 146, 14th Oct., 1938, pp. 451-452.*

Efficiency of High-Pressure High-Temperature Installations.

In reference to the leading article [*see* preceding Abstract "High-Pressure High-Temperature Installations", p. 193], it appears that no account has been taken of the energy of reheating the exhaust of the superposed turbine; although the steam has done work in the latter the total heat is greater on the figures quoted. The correct relation would appear to be—Assuming adiabatic expansion and boiler feed at the vacuum temperature (29in). heat input at total temperature of 850° F. and 2,000lb./in.^{2} is 1,331·5 B.Th.U./lb. Heat input in reheater is 179·5 B.Th.U., and total heat after expansion to 400lb. (gauge) 1,212·5. Adiabatic heat drop is 166 and 498 B.Th.U. in the superposed and low-pressure turbines respectively, giving a total of 664 B.Th.U./lb. *i.e.* about 44% availability.

Without "topping", the heat input to produce steam at 400lb. (gauge) at total temperature of 750° C. is 1,345 B.Th.U. and adiabatic heat drop in the low pressure turbine 498. *i.e.* about 37 per cent. availability, the increase by topping is therefore about 19 per cent. of the capacity.

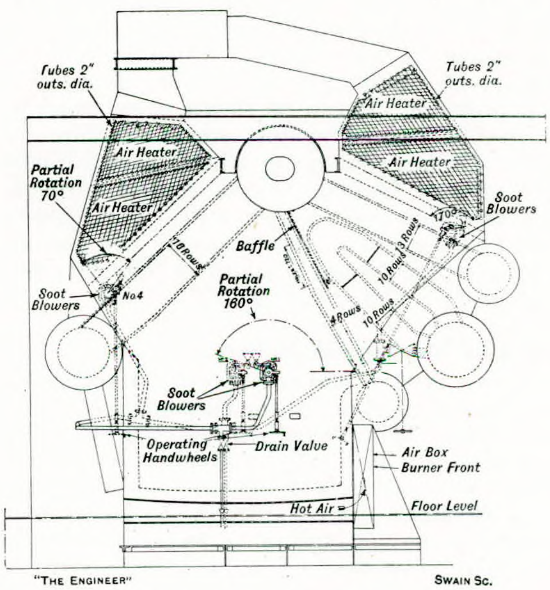
If reheating were not used, adiabatic heat available in the superposed and low-pressure turbines would be 577·5 B.Th.U., giving 43·4 per cent. availability and an increase in capacity of 17 per cent., but in any case it would be necessary otherwise the steam would be too wet for use at low pressure. The editor accepts the criticism, agreeing that the 30 per cent. increase in capacity originally mentioned is obtained at the expense of a fuel consumption increase of 10 per cent.—*L. C. Hookins, "Engineering", Vol. 146, 28th October, 1938, pp. 505-506.*

Twin-Screw P. & O. Liner "Canton".

The vessel sailed from London on a maiden voyage to the far East without a vacant berth, on 7th Oct., 1938. Her particulars are—

Length overall	562ft.
Beam	73ft.
Depth to "D" deck	46ft.
Gross tonnage	15,784
Nett tonnage	9,255
Deadweight carrying capacity	10,320
Draft loaded	29ft. 6in.
Cargo capacity	7,700 tons including 700 tons refrigerated.
Service speed	about 19 knots.

She carries two sets of 3 turbines with designed s.h.p. of 18,500 at 125 r.p.m. propeller speed, supplied from 4 Yarrow 5-drum side-fired oil-fuel



Yarrow water-tube boiler.

boilers at 435lb./in.^{2} and 725° F. Each boiler has its own electrically-driven forced-draft fan above the side fuel tank, and induced-draft fan at the base of the funnel, and is supplied with Clyde soot-blowers [see following Abstract]. An alarm cuts off oil fuel if water level should fall too low. Fuel temperature is thermostatically controlled, pumping and heating units being arranged in a passage between the boilers. Electricity is generated from four 450-kW. turbo-generator sets with closed feed. A 60-kW. Diesel-driven emergency set is also provided. Her complement is 260 firsts, 220 seconds and 370 operating staff.—*"The Engineer", Vol. 166, 14th Oct., 1938, p. 419.*

Soot Blower Equipment.

The blower is so placed that it can deliver high-velocity steam jets through all the tubes in a nest, from a single nozzle, a wall box being provided so that it can protrude into the combustion chamber during the operation. It is operated for 30 seconds at full boiler pressure, at intervals depending on the rate of soot deposition, as frequently as once or twice in 8 hrs. or as rarely as once or twice a week. A drop in the exit gas temperature of as much as 150° F. (83° C.) often follows as a result of blowing and has been noted even after two days' easy steaming. It is claimed that the action is not affected by the heat of the flue gases, and all mechanism is totally enclosed for protection from dust. It is operated by turning the hand-wheel about three turns, first forward and then back. The nozzle is thus advanced and steam admitted through a self-contained sleeve valve, semi-rotary movement being transmitted to the nozzle. After use, the wheel is rotated back to the "off" position retracting the nozzle from the flue gases. After each operation the boiler stop-valve must be closed; drainage is automatic, a special valve, which remains open while the blower is out of use, being closed by the steam pressure. It can be closed in no other way but may be opened against steam pressure by a handle. On large boilers or where space behind the boiler is very limited, remote control through a single extension rod can be fitted. The apparatus is fitted to the new vessel "Canton" and shown at the Empire Exhibition, Glasgow.—*"The Engineer", Vol. 166, 14th Oct., 1938, p. 413.*

Exhibit of Mechanical Stokers.

A new type of stoker employs a standard steel plate furnace front and firing doors, and the air- or water-cooled hollow panel is supported by this, but not fixed to it. In this way difficulties of alignment common with cast iron fronts are avoided and cooling is efficient; drive is by a $\frac{1}{2}$-$\frac{3}{4}$-h.p. motor mounted on the flue wall or on an inclined bracket, with a tensioning device for the V-belt. Gear box mechanism comprises a combination of worm reduction and bevel drive completely enclosed in an oil bath. The worm, running at 700 r.p.m., is coupled directly to the fuel impellers which rotate continuously at this speed with the stoker casings. Measurement is by feed rotors mounted on the base of the hoppers, regulated at 5 rates by a totally enclosed silent ratchet which can be operated while the stoker is in operation. Only a single fireman is needed to adjust the fuel control lever; the deflector parts are arranged inside the casing and the control handles can be locked to suit any particular length of grate. While the equipment has been primarily designed to burn graded fuels, very successful results are claimed for washed gum with a special hopper design to prevent sticking. Very large firing doors can be used if required, and provision is made to prevent jamming of the mechanism by lumps, but for double nut fuel an additional feed regulator is fitted to each casing. It is claimed that the stoker maintains a level fire without trimming, up to 8ft. long and 4ft. wide per stoker. The equipment is exhibited at the Glasgow Empire Exhibition.—*"The Engineer", Vol. 166, 21st October, 1938, p. 440.*

Launch of the "Robert Ley".

The hull of this fifth largest German mercantile ship, of length 669ft., water line breadth 78ft. 8in. and height of sports deck 96ft. 2in., to carry 1,770 cruising passengers, was launched in March, 1938. From launching data, a favourable keel inclination was deduced to be 1 : 20, that of the slipway used was actually 1/18. On the assumptions (*a*) a rigid slip, (*b*) an elastic hull, (*c*) trapezoidal stress distribution on the runners, ground and bottom pressures from the ship's weight and displacement were calculated for the whole course of the launch, and plotted against water depth. Maximum pressure was found by calculation to occur about 260ft. from the forward perpendicular and a limit of 1,500 tons for ground loading was laid down. From tidal records a high water deficiency of 40 cm. (16in.) might be expected in very unfavourable conditions and from intersection of these values on the graph a limiting weight of 11,000 tons was shown, entailing close control. Measurements on the freely floating ship later confirmed the weight and metacentric point. Owing to a submerged obstruction anchors could not be let go until 250-300m. (825-990ft.) had been traversed; it was therefore decided to install a temporary wooden brake at the stern of surface 440 sq. ft. This should cause a resistance ($\rho S v^2 k/2g$), where $k = 1{\cdot}1 - 1{\cdot}4$ for a partly submerged surface according to Engels and Gebers (*Schiffbau, Vol. 9, 107, p. 201 and 243*); in the launch of "Bahia Blanca" a mean value of 1·5 was reached according to Commentz (*ibid, Vol. 13, 1912, p. 429*). Launching velocity according to

$$v^2 = 2\int\left(\frac{\{g(m - w_x)(\sin\alpha - \mu\cos\alpha)/m\}\, e^{2\int P\,dx}}{e^{2\int P\,dx}}\right)dx$$

agreed satisfactorily with observed values ($P = \rho k S/2m$ and w_x the momentary displacement). A total weight of anchors of 47 tons was used against the theoretical 25 and let go beyond the obstruction. An 18 second roll was observed and the ship halted 66ft. before the expected position. The following data were applicable:—

Length of launching way ... ... 760ft.
Distance from aft cradle to aft perpendicular ... ... 129ft.
Distance from slipway axis to ship axis ...12ft. 8in.
Slip surface ... ...4,800ft.^{2}

Launching weight		10,900 tons
Initial pressure on the lubricant ...		1·54 tons/in.^{2}
Total pressure on the forward cradle at floating		2,400 tons
Distance to floating		517ft.
Minimum moment against tilting ...		498,000 tons
μ		0·028
Apportionment of resistance	Slipway friction	62%
	Brake and ship	24%
	Anchor	14%

—*A. Klehn, "Zeitschrift V.D.I.", Vol. 82, 1st Oct., 1938, pp. 1172-1175.*

Development of German Whaling.

From the time of the Phoenicians the whale has been hunted, and on the coasts of Flanders as recently as the 9th century. Hanseatic participation began in 1643-1644 and developed rapidly to a peak between 1665 and 1730, but in the intense competition which followed the Hansa Towns felt the lack of a strong national backing enjoyed by Danish, Dutch and British vessels. An attempt at revival by the equipment of a large number of whalers by Frederick the Great in 1768 failed and the introduction of steam in British and Norwegian vessels completed the decline. Holland took the lead to the Western Arctic in the 18th century and was quickly followed by Scandinavia, U.S.A. and Britain; the explosive harpoon was developed by Germans; the Antarctic grounds were exploited later, mainly by Norwegians and British, by the use of whale factories independent of shore bases, but this was first taken up by Germany in 1936. The development of whaling technique to the present stage of one depot ship with 6-10 hunter ships, is described. To avoid total destruction of the species, the "Geneva agreement" of 1932 was signed by nine countries in London in June, 1937; it sets limits on the period and place of operating, and the size of the whales to be caught. The "Jan Wellem" and two chartered Norwegian ships, brought back together 40,000 tons of oil in 1936. In 1937, three German-built ships, one bought and two chartered as before, brought back 90,000 tons and a large quantity of whale meal. In 1938 another whale factory "Wickingen" has been built and enlarged, so that in the coming winter a total exploitation of about 115,000 tons may be anticipated, against a home consumption of about 200,000 tons in margarine manufacture. By-products, *e.g.*, whalebone, whale meal, and medicaments, are discussed.—*C. Keysler, "Zeitschrift V.D.I.", Vol. 82, 1st October, 1938, pp. 1161-1163.*

The Whale Factory "Jan Wellem".

In the conversion of a cargo vessel into a whale-factory with oil-tight bulkheads, special equipment, and accommodation for a complement of 270, considerable steel stiffening was required. It was therefore resolved to widen the ship by 4m. (13ft.) over a distance of 215ft. and to build a new slaughter deck 5m. (16ft. 5in.) above that existing; this led to an increase in tonnage from 11,200 to 14,500. The blubber boilers are completely circulating and electrical power is used throughout. Every attention is given to efficiency of working, the factory being installed on the slaughter deck on which the whale is hauled by two winches. Aft are placed three fat and three bone boilers with ancillary separation and storage apparatus; forward are four bone boilers, one meat boiler and two equipments for meat treatment as well as by-product recovery apparatus. The 12,000m.^{3} (430,000 cu. ft.) tanks occupy the former holds and are used as fuel bunkers on the outward voyage. Blubber chunks $\frac{3}{8}$in. thick and 18in. square are simply thrown into the cylindrical perforated drum, and as the cooker can be sealed against internal pressure no special supervision is necessary. Bone boilers, fat cutter, and separators are described in detail. In view of its high protein content whale meal is a valuable cattle fodder. After chopping, the meat is divested of its small quantity of adhering fat in a 5 minute boil, partially de-watered and de-oiled by passing through a spiral at 90° C. (194° F.) and water, oil and slime are separated. More water is removed from the meat under pressure, the cake is then shredded and transferred to be dried on a steam heated surface over which flow currents of warm air sucked through the factory ventilators. Temperature and moisture content are automatically controlled before the meal is loaded into sacks, 2 tons being produced in about 25 min. From the wash water, etc., $1\frac{1}{2}$ tons of solids are recovered per hr. Blubber sinews are salted down and brought back home for use as substitute raw-material. For control of pharmaceutical products there is a well fitted-out laboratory. As the original four boilers each with 3,000m.^{2} (33,000ft.^{2}) of heating surface, were insufficient, two new La Mont boilers each of capacity 5 tons/hr., were installed with two of the original cylindrical boilers to act as collecting drums. In this way a capacity up to 35 tons/hr. was attained at the cost of little extra space. Three 220-kW. and one 440-kW. Diesel generators are installed to meet the unusually high demand, there being 180 motors in the factory alone; despite this, steam loss is high and a 250 tons/day distillation plant was installed. Two heaters handle $7\frac{1}{2}$ tons of fouled wash water/hr., the steam being returned to the cookers at 4 atm., the condensate at 3 atm., and 130° C. (266° F.) being used for feed make-up. 350m.^{3} (12,500 cu. ft.) of refrigerated space is intended for storage of edible whale meat, the refrigerators having a capacity of 75,000 k.Cal. (297,000 B.Th.U.)/hr. The reconstruction of the ship was carried out in the short space of 8 months, and although many of the devices were new and untried, she has worked well without any disturbance worth noting. From the 1,800-2,000 tons of carcass worked daily on the slaughter deck, 300-350 tons of oil are recovered.—*F. Berg, "Zeitschrift V.D.I.", Vol. 82, 1st October, 1938, pp. 1164-1168.*

12-cylinder "Sea Lion" Marine Engine.

The engine, exhibited in the marine section of the Earl's Court Motor Show, has a designed output of 500 b.h.p. at 2,300 r.p.m. Its twelve cylinders are arranged in three branks at 60°, and have bore 5½in. and stroke 5⅛in., and its weight without reverse gear and auxiliary equipment is only 952lb., with petrol consumption 0·558lb./b.h.p. hr. During the makers' bench trials a lubricating oil consumption of 12½ pints per hour at 2,350 r.p.m. was recorded; it is claimed that this diminishes in use. The motor differs from its Napier aircraft parent in having no reduction gear, a crankshaft redesigned and extended to take a clutch and reverse mechanism, a new crank case, and modified lubrication system with additional filters. A special auxiliary shaft with flanged extension operates the auxiliaries; the induction system has been remodelled with three carburettors per engine, after much experimental work. A low compression ratio of 5·3 is used, so that No. 1 petrol (minimum octane 71) can be employed without detonation. Exhaust and cylinder-valve-seats are faced with Stellite giving almost negligible wear. Specially strengthened connecting rods are used, and the steel shells lined with lead-bronze in the big-end bushes are three times the thickness of those in the aircraft engine. Combined ball-roller bearings are fitted to the driving end of the crankshaft, and a non-locating roller bearing to the other. Water jackets of twice the thickness are used with a new circulating system. and a new carburettor and magneto control is installed. The reverse gear incorporates a bevel wheel reduction with needle bearings.—*"The Engineer", Vol. 166, 28th Oct., 1938, p. 465.*

B.S.I. Specification 302-1938—Wire Ropes for Cranes.

This is a revised 1927 specification for round strand steel wire lifting ropes of types 4 × 37, 6 × 19, 6 × 24, 6 × 37 and 6 × 61. Recommendations for use and modifications of drum and pulley diameters are the result of consideration by the Wire Ropes Research Committee of the Institution of Mechanical Engineers. Further, suggestions for storage, uncoiling and handling, installation and maintenance are included. The wire of tensile range 115 - 125 tons/in.^{2} has been deleted, and tensile specifications are now arranged to specify a definite tenacity for each grade of wire. Aggregate breaking loads no longer appear and the section on galvanised wire testing has been brought up to date. —*"The Engineer", Vol. 166, 4th November, 1938, p. 511.*

Isotta-Fraschini 950 s.h.p. Marine Petrol Engine.

This A.S.M. 183 motor with designed output of 950 s.h.p. at 1,800 r.p.m. and maximum output at full throttle of 1,150 s.h.p. at 2,000 r.p.m. is shown at the Earl's Court Motor Show, Marine Section. The 18 cylinders of bore 130mm. (5·1in.) and stroke 180mm. (7·1in.) with total swept volume of 57·25 litres, are arranged in 3 banks. Dual ignition is by two Marelli magnetos with automatic advance and a small starting magneto. Each cylinder has two sparking plugs with fire prevention device, and starting may be by electric motor or compressed air. Fuel and oil consumptions are 223gm. and 14gm. per s.h.p./hr. respectively (0·492 and 0·031lb.). Total weight of the dry engines is about 1·2 tons and fresh water cooling is used. A reverse gear gives an astern power of 200 s.h.p. The units are being fitted in naval torpedo boats.—*"The Engineer", Vol. 166, 4th November, 1938, pp. 498-499.*

Reconditioning of Worn Metal Surfaces by Oxy-Acetylene Welding.

A French process for reconditioning worn rail-ends has now been extended to machine and engine components, it being claimed that the deposited metal is harder and therefore wears better than the original [*see "Engineering", Vol. 144, 1937, p. 496*]. Badly-worn rolling mill wobblers and pinions of medium steel have been successfully built up with 1-1·2 per cent. C. rod. After preheating in a portable furnace the article receives successive deposits in a reducing flame, the process being conducted under cover and away from draughts. Each layer is subjected to forging with a light hammer at red heat. With the aid of a template the work is gradually brought to specified dimensions, the deposited metal having a hardness of 200 - 250 against 130 - 150 for the original. 50 chain links each receiving two deposits of air-hardening steel totalling 60gm. per link, were treated in an 8-hr. day; other examples are stelliting of valve seats and seating rings of high power engine exhaust valves, deposition of tungsten carbide on cutting tools, and repair of worn bearings, slides and runner blades of cast-steel water turbines, which are often pitted or perforated by cavitation, by depositing Tobin bronze or nickel-silver.—*"Engineering", Vol. 146, 21st October, 1938, pp. 490-491.*

The New M.A.N. Two-Cycle Trunk Piston Diesel Motor, Type GZ 52/90.

Owing to its high rate of revolution the M.A.N. two-cycle trunk-piston Diesel motor GZ 52/70 was specially adapted for geared or Diesel-electric marine installations. For the direct drive the M.A.N. has now developed a similar long-stroke engine type GZ 52/90 of 520mm. cylinder diameter × 900mm. stroke which is built in sets of five to ten cylinders each developing 340 b.h.p. at about 175 r.p.m. Scavenging is effected on the well-known M.A.N. return-flow system, the scavenge air being admitted through ports situated below the exhaust ports on the same side of the cylinder and governed by the piston itself. It is supplied by a positive type blower driven from the crankshaft through gearing. The starting and safety valves are arranged in the lower part of the cylinder cover on the exhaust side and the fuel injection valves are of the needle type, each cylinder being fitted with a separate fuel pump, operated by means of a camshaft with a chain drive from the intermediate wheel of the fan drive. The lower part of the cast-iron cylinder cover, which surrounds the combustion space, is water-cooled. The lower part of the piston, which is air-cooled, is made of cast-iron and carries two oil control rings in addition to four lead bronze guide rings which facilitate the running in of the piston, while the main piston rings are fitted to the upper part which is made of steel. The cylinder liner and the crown of the cylinder cover are sea-water-cooled, while either fresh-water or oil cooling may be adopted for the needle valves. In reversing, a piston operated by compressed air displaces the camshaft in such a manner that the rollers of the fuel pump drive engage with the ahead or astern cams as required, while flaps in the scavenge air blower which are mechanically connected with the reversing gear open or shut the delivery ducts in the sense desired. On the test bed a fuel consumption of 160g. (·354lb.) per b.h.p. per hour was obtained at full load with an eight-cylinder engine of this type, the ignition pressure being 45 atm. and mean indicated pressure 5 - 6kg./cm. (71 - 85lb.), and with a total lubricating oil consumption of 1·1g. (·0024lb.) per b.h.p. per hour recorded in service, the engine was only slightly inferior to a crosshead type engine.—*"Schiffbau", Vol. 39, No. 21, 1st November, 1938, p. 407.*

The Coal-Dust Engine.

While the invention of the coal-dust engine is attributed to the Frenchman Montgolfier (1740-1810) and the earliest definite proposal for such a prime mover is contained in an American patent of 1851, Dr. Diesel, so far as is known, appears to have been the first to attempt the development of a coal-dust engine on the basis of laboratory research in 1899. Since then, German technicians, notably R. Pawlikowski of Goerlitz, one of Diesel's assistants, have so far overcome the difficulties associated with the design of such an engine that to-day no doubt exists about its technical practicability. Extensive tests were carried out between 1925 and 1930 by the I.G. Farbenindustrie A.G. at Oppau on several coal-dust engines of various types and sizes including a four-cylinder 450 b.h.p. set of 420mm. bore by 650mm. stroke, running at 215 r.p.m., but these tests were ultimately abandoned because no satisfactory solution of the wear problem could be found. Since 1933, however, economic conditions in Germany have resulted in further endeavours to perfect this type. Thus, through the medium of the German Research Association an order was placed with the firm F. Schichau, G.m.b.H. of Elbing for a single-cylinder four-stroke unit of 160 b.h.p. On this engine many tests were carried out covering questions of coal feed, control, reliability, lubrication, piston rod packing, airless injection, life of cylinder liners and piston rings, exhaust valves, ante-chamber nozzles, etc., particulars of which were presented to the Augsburg Engine and Fuel Conference of the VDI, and as a result the firm of Schichau has received an order for a 600 b.h.p. coal-dust engine intended to be put on the market.—*"Gas and Oil Power", October, 1938, p. 249.*

Heat Balance Calculations for Marine Steam Plants.

The authors present a brief description of the use and principles involved in heat balance calculations for marine steam turbine plants and develop a method of preparing such calculations on the basis of the information and data usually available in the design stage. The basis of this method is the development of a single equation of the first degree equating the total brake horsepower developed by the turbine unit to the sum of the horsepowers developed between the various terminals and extraction points. The latter are expressed in terms of the steamflow and of the actual water rates between these points. For example, in an installation with steam extracted from the main unit at three points let:

P = total horsepower to be developed,
E = total actual evaporation,
G = steam flow to auxiliaries from boilers,
A, B, C = extraction steam quantities at third, second, and first stage bleeder points respectively.
a, b, c, d = actual section water rates between throttle and third stage, third and second, second and first stage bleeder points, and from first stage to condenser,

then

$$P = \frac{E-G}{a} + \frac{E-G-A}{b} + \frac{E-G-A-B}{c} + \frac{E-G-A-B-C}{d}$$

The values a, b, c, and d are taken from the Mollier chart and from a condition curve of the main turbine which is developed from the Rankine efficiency ratio and the isentropic heat drops; G is estimated from the respective duties of the auxiliaries; A, B, C, and D being definite fractions of the as yet unknown evaporation E are expressed in terms of E. The consumption of the other auxiliaries requiring extraction steam is calculated and the solution of the basic equation, which contains only one unknown, viz. E, then yields the total evaporation for the given power. The extraction flows to the heaters are then readily obtained. The author demonstrates the principle outlined by giving the full calculation for a single-screw double-reduction geared turbine set developing 8,000 s.h.p. with oil-burning water-tube boilers fitted with economisers supplying steam of 400lb. per sq. in. pressure and 750° F. temperature, both at the superheated outlet. To afford a comparison between the example described and other types of installations particulars of several other designs for the same shaft horsepower are tabulated. These designs represent modifications with respect to the pressures and temperatures, the type of boiler and turbine auxiliaries and of the feed system, and the final comparison on the basis of fuel per s.h.p. indicates a range from ·622lb. for 400lb. pressure, 750° F. temperature, for boilers fitted with economisers, part electric turbine auxiliaries and one-stage direct-contact feed heating, to ·521lb. per s.h.p. for 1,200lb. pressure, 950° F. temperature, boilers fitted with air-heaters and economisers, all electric auxiliaries, and four-stage closed-feed heating. In an appendix, the authors give empirical allowances for the purpose of estimating generator loads, consumption of air ejectors, make-up feed, and domestic steam.—*A. S. Thaeler and D. C. MacMillan, Trans. of American Soc. of Naval Architects and Marine Engineers, December, 1938.*

A New Oil Fuel Burner.

The author observes that although the design of the present-day pressure atomiser has reached an extremely high state of development as regards the quality of atomisation, it has one serious drawback, namely a very limited operating range without recourse to a manual change of the atomiser orifice. This is due to the fact that the quantity of liquid passing through an atomiser orifice varies as the square root of the inlet pressure, so that to double the capacity of an atomiser delivering 400lb. of oil per hour at 300lb. per sq. in. oil delivery pressure, a pressure increase to 1,200lb. per sq. in. would be required, which is not practicable. If on the other hand the capacity was to be halved the same atomiser would have to be operated at 75lb. per sq. in., which is too low to produce a fine quality of atomisation. In practice, this deficiency is at present overcome by the use of multiple burners, so that individual burners can be cut in and out of service manually for substantial load changes, but the author claims that this feature can be elminated by means of the variable capacity atomiser which he describes in detail. This consists structurally of the same members as the ordinary atomiser except that an additional passage to return unused oil and a separate atomiser orifice plate are provided. The sprayer and orifice plates are centred in the burner nut, the orifices being of the same diameter and alignment. The return passage is made by placing a large tube on the outside of the supply tube, and the orifice plate is made dome-like so that it provides an annular space in the orifice through which part of the oil supplied can be bye-passed to the return passage, the quantity so returned being a function of the return pressure which is adjusted by means of a valve. This atomiser functions as follows: Oil under pressure enters the whirling chamber through slots tangent to its side walls, individual particles describing spiral paths as they progress towards the outlet orifices. On entering these the pressure parallel to the axis of the sprayer plate has been converted into velocity in the same direction by the Venturi action of the chamber and orifice. At the same time a definite centrifugal pressure perpendicular to the axis of the sprayer plate has been set up, under the influence of which the outer portions of the rotating mass will be diverted into the return annulus. Tests with this atomiser have shown that its capacity range is expectionally large; thus a 1,300lb. per hour unit has been operated continuously and satisfactorily at 17lb. per hour, viz. a range of 76 to 1, the quality of atomisation being constant over the whole range.—*George P. Haynes, Trans. of the American Soc. of Naval Architects and Marine Engineers, December, 1938.*

Cunard-White Star Quadruple-Screw Liner "Queen Elizabeth".

The vessel whose keel was laid in December, 1936 and which was launched on 27th September, 1938, by the Queen, incorporates in hull and machinery the far reaching progress of recent years. A striking difference from the sister ship "Queen Mary" is that she has only two funnels; uptakes are arranged centrally, but there is a more generous allowance of clear deck space, promenades and passenger accommodation. The bridge is streamlined and a bow anchor has been fitted to facilitate anchoring at Southampton and New York, to allow a clear fall an increased length of 10ft. and bow raking has been adopted. In all there are 14 decks with spacious accommodation for all classes, both in the open air and under cover, 29 public rooms, some with controlled weather, a verandah grill on the sun deck, theatre, garden and observation lounges, library, studio, writing room and nursery. Tourist accommodation includes smoking room, cocktail bar, drawing room, library, nursery and lounge on the promenade deck and main deck. In the third class hot and cold running water and modern ventilation will be provided in all state rooms. Ready assembled cabins are stored adjoining the slipway for rapid installation. The finished vessel will be painted white on upper deck and superstructure, funnels red with black tops and three black bands. Her particulars are:

Length	1,030 ft.
Length of promenade deck ...	724 ft.
Breadth	118 ft.
Height to top of lounge ...	120 ft.
Approx. gross tonnage ...	85,000 tons

Her propelling machinery consists of quadruple-screw Parsons reaction single-reduction geared turbines—four in each set—developing a total s.h.p. of 180,000, and supplied with steam from 12 Yarrow side-fired oil-burning boilers at 750° F. and 425lb./in.^{2}. Four 2,200-kW. 225-volt geared turbo-dynamos running at 4,500/600 r.p.m. on steam at 730° F. and 390lb./in.^{2} are installed as auxiliaries. For emergency, two 6-cylinder 133 b.h.p. oil engines at 900 r.p.m. drive 75-kW. 220-volt generators. In hull design the possibility of very bad weather was continually in mind and 7,000 tank experiments on numerous models included investigations of hull form, propellers, steering, rolling, and bilge keels. As a result of the service performance of the "Queen Mary" a still more economical form has been developed. The main deck runs clear fore to aft, with cruiser stern, there are 15 transverse watertight bulkheads and the double bottom contains over 50 main compartments, giving a total of 140 below the bulkhead deck. Forty-nine hydraulic watertight doors are fitted, 12 sliding vertically and 37 horizontally, each designed to withstand 36 tons; these are operated at 700lb./in.^{2} and should all be shut within a minute, including 7 seconds warning, but may be opened locally (and closed automatically) if desired. The inner boundary of the bunker tanks confers considerable longitudinal stiffening. To avoid over-stressing the upper structure, 5 expansion joints have been fitted; double plating and high tensile steel have also been used extensively; the massive scale of the frames, beams, and structural work generally is apparent on inspection. Castings for stem, four propeller shaft brackets, stern post, rudder stock and frame, and bow hawspipe together weigh 600 tons, the rudder itself 140 tons; facilities for inspection within the latter are provided. Each propeller weighs 30½ tons, three railway engines could run abreast in a funnel. Each boiler has 20,500ft.^{2} for heating, 10,100ft.^{2} for superheating and 27,300ft.^{2} for air heating. Machinery and boiler arrangement was influenced to a great extent by water-tight subdivisions. A forced-draft closed-stokehold system is used, giving simplified layout, controllable combustion and pleasant working conditions. Eight pumps, driven by 12-h.p. 1,500 - 750 r.p.m. motors through worm gearing, deliver 20,000lb. oil fuel/hr. at 270 r.p.m. against 175lb./in.^{2} and 3 rotary displacement pumps delivering 100 tons/hr. are also fitted. The oil fuel is carried in side bunkers and double bottom tanks, and filling is carried out in 8hrs. via 5 hoses. A westerly passage from Cherbourg to New York may be possible in 4 days and "turn round" in 12hrs. under favourable conditions. Closed circuit feed is used for turbines and auxiliaries and condensate temperature will be within 2° F. of the corresponding vacuum temperature; main and auxiliary condensate, ejector and feed systems are described in full; steam bled from the main turbine at 230lb. (absolute) raises the temperature from 320° to 370° F.; 24 regulators are installed and feed varies with steam demand. A low water alarm operates a steam whistle and cuts off the fuel supply. In Pt. III the precautions necessary in launching this 40,000-ton 1,031ft. monster, are described; 2,300 tons of drag chain was used and the whole operation took 90sec. The navigating equipment is of the latest type. Three 16-ton anchors each carrying 990ft. of cable (total weight of cable 225 tons) will be used. Most of the 26 lifeboats carry 145 persons each and are propelled by oil engines at 6·7 knots. CO_2 fire extinction is fitted and much of the timber has been fireproofed. Hydraulic oil steering, from pumps driven by 4h.p. servo motors, is fitted. Two vertical CO_2 machines serve insulated food chambers of capacity 43,000 cu. ft., five holds of capacity 19,000 cu. ft. and a domestic load; there are no less than 12 artificial weather plants. The two power stations are independent but interconnected and of the four generating units there will usually be one idle, each watertight section of the ship has its own switchboard, so that piercing of bulkheads is avoided. Every precaution has been taken to ensure continuous current under the most abnormal conditions; sixty 1in.^{2} Cu. cables, specially insulated, are required to feed the ring main for hotel service and 126 for machinery. There are approximately 650 motors from ¼ to 360 h.p., totalling 16,500 h.p., and about 30,000 lamps. Electrical regulations of Lloyd's Register, I.E.E., and B.O.T. have been more than covered, and *in fine* it seems that nothing which can contribute to the comfort or safety of passengers has been omitted. The article is illustrated with 16 photographs and 1 plate.—*"The Engineer", Vol. 166, 23rd and 30th September and 7th October, 1938, pp. 340-341, 357-360, 393-395.*

Non-magnetic Anchor.

An anchor in high-tensile aluminium bronze, for the research vessel H.M.S. "Research" [*see* ABSTRACTS, *Vol. 1, September, 1938, p. 131*], built to the requirements of the Admiralty by a Dartmouth firm is shown at the Empire Exhibition, Glasgow. It is claimed that this is the only bronze anchor of any size made for Admiralty service. It has length of 6ft. 3in., width 4ft., weight 5½ cwt.; the anchor itself is a sand casting chilled at important points, while the stock is forged, and the whole has passed Lloyd's standard tests for steel anchors. The chain cable is made of similar cast links.—*"The Engineer", Vol. 166, 28th October, 1938, p. 470.*

Fusion-welded Boiler Drums.

The stand of a Wolverhampton company and affiliates at the Empire Exhibition, Glasgow, shows examples of fusion-welded boiler drums, as supplied to many power stations at home and abroad. This type is now constructed for pressures up to 1,000lb./in.^{2} and X-ray equipment is available for examination, the firm's products being approved as Class I by Lloyd's Register and insurance companies. Models are also shown of the forced circulation system of the La Mont boiler, and of the complete installation [*see* p. 201] which a subsidiary is now manufacturing under license.—*"The Engineer", Vol. 166, 28th October, 1938, pp. 469-470.*

La Mont Boiler Installation.

In order to obtain practical experience of a high-pressure forced-circulation type of plant, particularly with circulating pumps, it was decided by Messrs. Weir to install a La Mont boiler capable of generating 22·3 tons of steam/hr. at a maximum pressure of 1,000lb./in.^{2}. This is claimed to be the highest in the country. Elasticity was essential since the demand for test steam may fall to zero not infrequently; existing plant consisted of two water-tube boilers and one Stirling boiler operating at 350lb., and a topping 700kW., 1,500 r.p.m. turbo generator at 850lb./in.^{2} was therefore selected; further, space was limited and returned condensate is small. In the new plant water is circulated by a pump operating at 30 - 40lb./in.^{2}; each tube has its own nozzle to prevent over-heating, and can thus be made long and narrow and designed to fit an awkward space. One set forms water walls surrounding the combustion chamber on all sides and is continued to form an evaporator; another set is led up the centre division wall and forms a second evaporator. Drum separation is used, and fusion welding was employed whenever practicable in fabrication of boiler and drum, at favourable cost over a forging. It is 15ft. 5in. long, 3ft. 3in. internal diameter, 2½in. thick and weighs 8½ tons, as much as 2 cwt. of weld metal being deposited. Vertical tubes and a simple water-cooled door are used, and even with volatile Scottish coals excellent combustion is achieved. A new system of "inert gas circulation" for steam temperature control will be watched with interest. Two motor-driven centrifugal pumps are installed with one turbine as standby, and balanced draft is used. Heating surface of boiler and walls is 3 050ft.^{2}, of economiser 5,380ft.^{2}, of superheater 1,750ft.^{2}; stoker grate area is 144ft.^{2}, and it was estimated that the gases leaving the economiser at 330° F. (165° C.) will contain 12·5 per cent. CO_2, giving a feed temperature of 216° F. (102° C.) and overall efficiency 81 per cent., all at n.e.r. In practice 82·92 per cent. was attained, equivalent to 8lb. steam per lb. coal; with lower grade fuel lower costs resulted. The daily de-aerator oxygen readings vary from 0·04 c./litre to zero. The instrument control board consists of 5 panels, for h.p., i.p. and l.p. turbines, condenser and feed; welded joints were everywhere used for h.p. mains.—*"The Engineer", Vol. 166, 30th September and 7th October, 1938, pp. 367-370 and 395-396.*

Aircraft Carriers.

The new aircraft carrier construction programme seems to show that these vessels are becoming more appreciated, while fears of their vulnerability are diminishing. The correspondent cannot understand why such moving aerodromes have not been developed for pure military purposes. The effective range of a bomber is shortened by anti-bombing devices, and it would be very awkward to be at war with an enemy with territory partly or completely out of range of our own or colonial aerodromes. Large high-speed vessels would be the most suitable and the possibilities of converting the "Queens" might be considered. A 40-knot vessel suitable for Atlantic service might also be used; electric propulsion might or might not prove essential for such a ship, but in any case, this should prove no obstacle to the marine engineer.—*G.U.N.S., "The Engineer", Vol. 166, 21st October, 1938, p. 450.*

Old and New Diesel Engines.

The third engine of its type manufactured under Diesel's patents is shown at the Glasgow Empire Exhibition, still running after 40 years' service. The same firm exhibits a recent 4-stroke 6-cylinder model with bore 8in. and stroke 12in., developing 360 b.h.p. at 900 r.p.m. The cylinder-block is of close-grained cast iron, with heat-resisting steel for certain portions such as the hot throat; it is possible to remove the cylinder head without disturbing pipes. Heat-resisting steel exhaust valves, the mechanism being lubricated by forced feed and protected by an oil-tight Al cover, and an Al piston-alloy with lower expansion than normal are used. Fully floating ground nitrided alloy steel gudgeon pins are fitted. A chilled phosphor bronze bush is "frozen" into the forged and machined Ni-steel connecting rods and a special type of big-end bearing is made possible by the built-up crankshaft—a floating white-metalled bush rotating on the crankpin and inside a nitralloy steel bush, *i.e.* between two hardened surfaces, with resulting reduction in surface speed. To secure the crankpins, the webs are split and tightened on by a high tensile steel bolt. The overhead valves are driven by push rods from the gear driven camshaft with hardened profiles. In the interests of strength, the very deep I-box column is bolted to the bedplate with large Al doors for inspection; if desired an Al bedplate can be supplied instead of cast iron. Main bearings are lined with white metal centrifugally cast, and the centrally located fuel pump is crankshaft-driven via gears. Single-hole injection nozzles with case-hardened and ground moving parts are used; since the injector does not penetrate any water joint it can be removed with impunity. Pressure lubrication of dry-sump type, gear operated from the crankshaft is fitted, with valves for relief and regulation of pressure. Hand priming, scavenging pumping and lubricant cooling are also incorporated. Compressed air without heater plugs is used for starting; "stop-start" handle, speed control and tachometer are grouped at one end.—*"Engineering", Vol. 146, 28th October, 1935, p. 515.*

Steam and Electric Cargo Winches.

In the steam winch the moving parts run in oil, and it is particularly silent in operation and therefore suitable for passenger ships; it is made to carry 2, 3, or 5 tons. The electric winch is made in 1, 1½, 2, 3, and 5 ton sizes, self-contained and ready for connecting to the ship's mains. Both mechanical and electrical gear are enclosed in water-tight casings. Speed control varies automatically with the load, with quick return of the light hook. Electrical control equipment consisting of motor, controller and resistances, and load discriminator, is specially designed for deck use. The series motor at 220v. has shunt-limiting windings for d.c. supply; it has a shaft of special steel and large machined cast-iron commutator covers; armature or coils can be removed without dismantling the winch. The rating should allow cargo to be worked continuously through the day. The contactor-controller is completely enclosed in the bedplate, with cast-iron inspection door, and by automatic timing damage cannot be caused by changing rapidly from full lower to full hoist. An overload and broken circuit relay is fitted, and the handwheel must be brought back to "off" before restarting. Rustless resistances, phosphor-bronze worm wheel engaging a steel forged worm shaft, are fitted. An electro magnetic disc-brake, mechanical foot-brake working on the barrell and centrifugal speed limiting brake are installed, the first and third being enclosed in water-tight casings. The footbrake is for emergency or to obtain a creeping speed and is interlocked with a switch to prevent electrical damage. The equipment is shown at the Empire Exhibition.—*"Engineering", Vol. 146, 28th October, 1938, p. 515.*

Clark-Troller Outboard Motor.

This engine, 21in. long and with a weight of 10½lb., output of 1·2 h.p. at 2,650 r.p.m., bore and stroke 1⅜in., and capacity 0·0433 litres was shown at the Marine Section of the Earl's Court Motor Show. Crankshaft, cylinder and piston are arranged immediately behind the propeller, the whole being thus water-cooled without the usual driven pump. The quart fuel tank above the engine is fitted with a simple mixing valve with needle and throttle controls; the exhaust passes to a small silencer and is finally rejected under water. Dry battery ignition is used, coil, mixing-valve and air inlet being protected by a shield. A two-bladed propeller, with notched pulley for the starting-cord, is fitted; its diameter is 6½in. and pitch 8in. The whole engine, in a corrosion-resisting light alloy, is attractive in design and appearance; it is supplied with simple fitting brackets, and in a larger (24in.) model a variable pitch propeller can be used.—*"Engineering", Vol. 146, 4th November, 1938, pp. 499-500.*

Silentbloc Marine Exhibit.

At one stand in the Marine Section of the Earl's Court Motor Show, specimens of three manufacturers' marine engines, all mounted on anti-vibration bearings are shown. An interesting technical exhibit is the Andre-Hutton pump for sandy and gritty fluids driven by a ¼-b.h.p. motor, rated for 500 gall./hr. against a head of 25ft. with suction lift of 14ft. It is of opposed-piston reciprocating type, self-priming and needs no foot valve. Bore and pistons are concave in section, so that an annulus of varying thickness exists between them; in this a rubber ring is placed, which rolls between the two surfaces. The makers claim that wear is negligible and a water-tight joint is effected without glands. Rubber mushroom inlet and outlet valves are used, being returned to position by the tension in their stems, the face being reinforced by a thin plate below the surface; in this way grit particles, even when large, are passed without damage. Rubber-sealed pipe unions are also used. No oil or grease comes in contact with the liquid, and by using synthetic rubber for rings and valves, oil and other liquids may be handled without seriously affecting the life of the pump.—*"The Engineer", Vol. 166, 4th November, 1938, p. 499.*

The Gas Engine Afloat.

The gas engine for ship propulsion has repeatedly attracted attention without adventitious encouragement; indeed it has never been quite moribund in U.S.A., Britain or the Continent. WHITE, 30 years ago, expressed his faith in the project and MCKECHNIE actually drew up plans for a 16,000 h.p. battleship. In his paper before the I.M.E.-I.N.A. International Conference in London in 1938 [*see Abstracts, Vol. 1, July, 1938, pp. 82-86*] FREEMAN suggested that the time was now ripe for reconsideration of gas-engine propulsion and GIBBONS has now discussed its application to small craft of 300-1 500 h.p. [*see November, 1938, Transactions*]. In 1906 a scheme for a 7,000 tons cargo steamer was prepared, in 1913 CHORLTON designed a gas steam plant of 5,500 b.h.p. suitable for cross-channel passenger service. The athwartship engines, geared to the paddle shaft, were to be assisted by uniflow steam cylinders supplied from waste-heat boilers for manœuvring. Certain of GIBBONS' statements *re* "Holzapfel I" are controverted. To enable high-speed engines to be used and to avoid reversal, a *Föttinger* transmitter was used. More recently units up to 1,000 h.p. have been built in various countries; in the Rhine tug "Harpen I" two 8-cylinder single-acting 4-stroke 350-b.h.p. engines running at 160-400 r.p.m. drive twin-screws through mechanical reverse gears. A *Deutz* producer is used, with alternative oil fuel, and compressed air starting is employed. In Britain non-development was almost entirely due to economic causes, but to-day much experience is to hand from continental road vehicles burning charcoal, apart from the advantage of using a home-produced fuel. No excessively severe technical problems have arisen with the installation of gas producers in ships and a plea is made for concerted attention to GIBBONS' suggestions by old established gas-engine manufacturers who now appear to be concentrating their attention on the oil engine.—*Editorial, "Engineering", Vol. 146, 4th November, 1938, pp. 537-538.* [*See also* ABSTRACTS, *Vol. 1, July, 1938, pp. 78-79; Gas Producer Plant*].

Stability in Aircraft.

The low-wing monoplane presents problems completely soluble only by lengthy researches, and the rapid succession of new designs is not the least of the difficulties faced at the aerodynamics department. Recently low-wing monoplanes have been found to have lower longitudinal stability than was anticipated. From analysis of field data supplied by manufacturing firms and correlation with somewhat meagre wind-tunnel results, it appears that the de-stabilising effect of nacelles is much greater than was thought, so that tail surfaces are too small and c.g. too far astern; this displacement may be as much as 10 per cent. of wind chord. Further, slipstream and slipstream modification by other features can be either favourable or unfavourable to stability. A research is in progress on a typical monoplane model with one or two screws projecting from wing nacelles, landing flap effect, and the effect of the proximity of the ground on trim and stability. Mathematically it has been shown that a model suspended at the end of a long rod can show the lateral stability characteristics of free flight under certain correlation of mass, aerodynamic lift, and degrees of freedom. This method gives much quicker results than the laborious measurement of derivatives hitherto used by which a single engine high-wing monoplane with propeller running had already been investigated. On a ¼-size model it appears that yaw is affected not only by down-wind slipstream speed but by rotation at the tail, *i.e.* on efficiency of the airscrew as well as its thrust. With sideslip and rudder setting both zero the sign varies according to the direction of rotation and the position of the axis of the propeller. In a certain aircraft the loss of rolling moment with a highly tapered (4·4) wing was traced to body-wing interaction when the latter were in the low position, loss of stability not being due to the high taper as was thought at first. Wing-tip design to reduce undesirable rolling near stalling incidence is proving a difficult subject, wind tunnel research being very susceptible to scale effect in this instance. Slots are an effective remedy against wind dropping but a design is being attempted which does not include them.—*Report on N.P.L. Research, "Engineering", Vol. 146, 4th November, 1938, pp. 527-528.*

Oil-Driven Twin-Screw Launch and Motor Boat Engines.

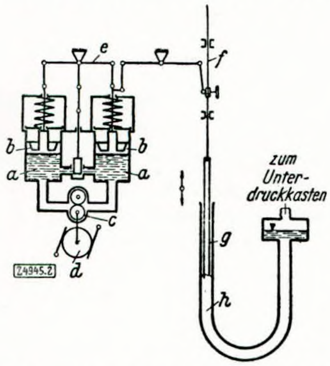
A 50ft. oil-engined twin-screw launch designed for work in the equatorial conditions of the Persian Gulf is exhibited at the Earl's Court Motor Show. The two 6-cylinder engines, with designed output 95-145 s.h.p., will give a speed of 20 m.p.h. Engines similar to those fitted in the lifeboats of "Queen Mary" and "Queen Elizabeth" are also shown, as well as a new compression-ignition type with bore 4in. stroke 6in. and displacement 3·7 litres. Another new exhibit is the twin-cylinder "Handybilly" now adapted to the Hesselman principle with heavy oil fuel. This has bore 3½in., stroke 4½in. giving a rated output of 9 b.h.p. at 1,100 r.p.m., the propeller speed being reduced to 700 r.p.m. by a combined reducing-reversing gear. The carburettor is replaced by a simple fuel pump which injects the fuel about the point of maximum compression, this being so thoroughly vaporised that it can be ignited by a sparking plug. The quart of petrol carried in a separate tank is enough for about 30 starts.—*"The Engineer", Vol. 166, 4th November, 1938, pp. 499-500.*

Research on Steel Castings.

The *"Third Report of the Steel Castings Research Committee"* is divided into 6 sections. From work at Sheffield, Professor T. H. ANDREW deduces that temperature is the all-important factor and composition of the metal plays a minor part; when the temperature for a fluidity value of 12in. is plotted against composition the plots follow the liquidi very closely. An investigation of the RUFF method (*see Carnegie Scholarship Memoirs, Vol. 25, 1936*) shows it to have the necessary simplicity and convenience for industrial use and yet to give a good indication of fluidity. From the Research Dept., Woolwich M. ALEXANDER reports that Cu is a valuable alloying element in steel castings; with low C (to avoid temper brittleness) valuable mechanical properties may be obtained which Cu in low alloy steels by temper-hardening. Further, H. F. HALL describes tensile tests on 8 simultaneously-cast test-pieces at various times after solidification, with special attention to the effects of Mu and S; a hot-tearing test is also described. The Moulding Materials Sub-Committee deals with standardization of test methods, and points out the economic advantage of using domestic sands where possible A bibliography of 84 pages is included.—*"Engineering", Vol. 146, 4th November, 1938, p. 548.*

Automatic Sub-atmospheric Pressure Regulator for Cavitation Investigation.

In cavitation tests not only must model dimensions but also in- and out-flow, and in the case of water turbines, suction conditions must conform to the similarity principle. In a 1/10 model to obtain cavitation the water must flow at less than atmospheric pressure. This can be obtained either by closed circulation or by having a hanging column of water attached. Methods of regulation used in various German hydraulic laboratories are indicated. In the apparatus described a gear wheel pump circulates oil between two connected cylinders closed by spring pistons linked to a double-arm lever which operates a valve in the circulating system. The pump motor is controlled by a weak current relay operated by a weak current passing between one or two steel rods and a mercury column the level of which is affected by the (sub-atmospheric) pressure in a water reservoir attached to the cavitation apparatus. Hand adjustment of the cross section allows a suitable relation between the alteration of



(*a*) oil cylinder; (*b*) piston; (*c*) gearwheel pump; (*d*) back-drive motor; (*e*) double lever; (*f*) back-drive rod; (*g*) steel point; (*h*) mercury manometer. (Zum Unterdrukkasten = to low-pressure reservoir.

r.p.m. and of the velocity to be attained. Accurate and trouble-free regulation without hunting is possible down to about 0·15 atm. absolute, and stable suction characteristics necessary for accurate work are obtainable with a propeller pump. About 0·12 cu. ft./sec. per cu. ft. of water used, of (air + water vapour) is found to separate and this must be removed from the system.—*K. Strauss, "Zeitschrift V.D.I.", Vol. 82, 29th October, 1938, pp. 1284-1285.*

Determining the Characteristics of Electric Steering Gears of the Ward-Leonard Type.

The initial data for calculating the characteristics of an electric steering gear are usually the following:—

T = the given time for putting the rudder from hard over to hard over, in seconds.

$\alpha^\circ_{max.}$ = the maximum angle of helm.

$M_\beta = f(\alpha^\circ)$ = the relative moment of resistance on the rudder head in kg./m. at the angle of helm.

K = ratio of gearing of the steering gear.

η = efficiency of the steering gear.

For ascertaining the moment on the rudder head the Joessel formula is usually adopted in the U.S.S.R. In calculating $M_\beta = f(\alpha^\circ)$ by the Joessel formula for balanced and semi-balanced rudders, the moment on the rudder head may have a negative value within the limits of 0° to $+\alpha_1^\circ$, after which at greater angles it acquires positive values. With an ordinary rudder a diagram of $M_\beta = f(\alpha^\circ)$ increases from zero to $M_{\beta max.}$ by a curve which nearly approaches a straight line. The selection of the characteristics of an electric steering gear should be based on two cases when putting the rudder from hard over to hard over, the first case being when the vessel is proceeding at full speed ahead, and the second at full speed astern. The basic calculation for the characteristics is the relation of the moment of resistance of the shaft of the electric motor to the angle of the helm $M = f(\alpha^\circ)$. The initial data for the construction of these characteristics is the dependence $M = f(\alpha^\circ)$ for two stages in the position of the rudder, the first stage being when putting the rudder over from $-\alpha^\circ_{max.}$ to 0° and the second stage from 0° to $+\alpha^\circ_{max.}$ In the above stages the turning moment is transmitted from the rudder head to the shaft of the electric motor mainly when putting the rudder from hard over to amidships and transmitting the turning moment from the shaft of the electric motor to the rudder head when turning the rudder from midships to hard over. Steering gears are generally self-braking and fitted with a worm transmission. This necessitates the shaft of the motor having a positive turning moment for rotating the self-braking worm gear, notwithstanding that at certain angles of helm there are negative turning moments on the rudder head. Taking the foregoing into consideration it may be assumed that the moment of resistance on the motor shaft at the ahead speed of the vessel for all angles of helm (within the limits of $-\alpha^\circ_{max.}$ to 0° in the case of an ordinary rudder, and from $-\alpha^\circ_{max.}$ to $+\alpha^\circ_1$ for balanced and semi-balanced rudders) is constant and equal to the moment on the motor shaft when running with no-load M_o, which takes place upon the rudder when passing through the amidships position. By putting the rudder over from 0° to $+\alpha^\circ_{max.}$ in the case of ordinary rudders, and from $+\alpha_1^\circ$ to $+\alpha^\circ_{max.}$ in balanced or semi-balanced rudders, the modification of the moment of resistance on the

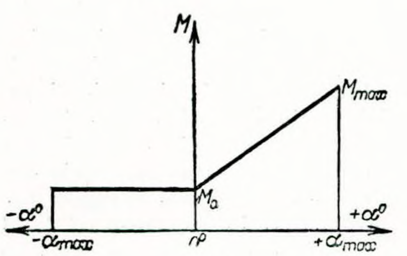


Fig. 1.

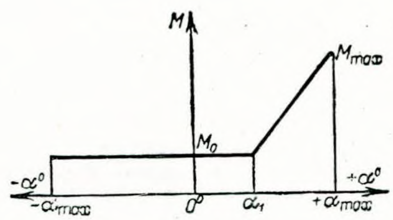


Fig. 2.

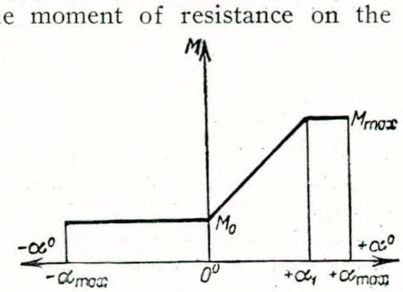


Fig. 3.

shaft of the electric motor from the value M_o to the value $M_{max.}$ may be taken as varying linearly with the angle of inclination of the rubber. The value of the maximum moment on the motor shaft $M_{max.}$ may be determined from the expression :—

$$M_{max.} = \frac{M_{e\,max.}}{K \cdot \eta} \qquad (1)$$

The value of the moment of the gear when running free is very difficult to determine; in practice it is assumed as a percent. ratio of $M_{max.}$:—
and $M_o = 0{\cdot}1$ to $0{\cdot}2$ $M_{max.}$ for ordinary rudders.
$M_o = 0{\cdot}2$ to $0{\cdot}4$ $M_{max.}$ for balanced rudders.

Taking the above into consideration, the variation of the moment of resistance on the motor shaft from the angle of helm $M_c = f(\alpha°)$ may be represented for ordinary rudders by Fig. 1 and for balanced and semi-balanced rudders by Fig. 2. In some cases it may be necessary to guarantee the time for putting the helm hard over to hard over when going astern; it may happen that this condition may determine the characteristics of the gear. In the case under consideration, by means of the relation $M_\beta = f(\alpha°)$ the moment of resistance $M_c = f(\alpha°)$ may be obtained, as shown in Fig. 3. By accepting the above assumptions for the moment of resistance the following equation is obtained :—

$$M_c = M_o + b\alpha \qquad (2)$$

where b = the angle coefficient of the straight line,
α = the radial angle of inclination.

The working of the steering gear and the necessary characteristics may be calculated in the case where an ordinary rudder is put over on a straight course (Fig. 1). Deductions for other cases may be analogically examined. Formulæ for those cases arising from the calculation are given below. The time for putting the helm over may be divided into two parts, viz. t_1 and t_2. The first period t_1 corresponds to putting the helm over from $-\alpha°_{max.}$ to 0°. For this part the moment of resistance M_o is constant in value. The second period t_2 corresponds to putting the rudder over from 0° to $+\alpha_{max.}$ For this stage the moment of resistance has the relation as given in formula (2). The value of the angle coefficient b may be obtained from the final condition by $\alpha = \alpha_{max.}$ and $M_c = M_{max.}$, whence

$$b = \frac{M_{max.} - M_o}{\alpha_{max.}}$$

The expression for the moment of resistance will take the final form of :—

$$M_o = M_o + \frac{M_{max.} - M_o}{\alpha_{max.}}\alpha \qquad (3)$$

Separate sections are set forth in the article containing various formulæ and detailed methods for determining the moment of motive power of the electric motor, turning moment of the rudder at constant and varying speeds, total time for putting the rudder hard over and the characteristics of the electric motor, the power and selection of the type of the electric motor, and selecting the generator and the electric motor transmitter for the transformer. Tabulated particulars are furnished of electric motors manufactured in the U.S.S.R. and suitable for electric steering gears.

Summary.

The suggested methods for determining the characteristics of the electric motor equipment for steering gears permit, on the basis of catalogue particulars of electric machines, the selection in general of the type of machine and consequently the weight characteristics of the electric installation. The assumptions indicated in the calculations permit the conditions guaranteeing the time for putting the rudder from hard over to hard over being handed to the manufacturers. The conclusions as described in the foregoing determine the particulars of the electric equipment for the steering arrangement, from which the manufacturers are enabled to make the necessary calculations for the electric motors. The suggested calculations and conclusions serve the purpose of presenting to shipbuilders methods by which the determination of the characteristics of the steering arrangement may be ascertained in the preliminary stages of the design under consideration. On the basis of the suggested methods an example is worked out in detail for obtaining the particulars of an electric equipment for an electric steering gear of the Ward-Leonard system. The basic particulars of the example are as follows: Maximum moment on the rudder head at full speed ahead $M_{e\,max.} = 6\,000$ kg./m.; maximum angle of helm $= \pm 35°$; efficiency of the steering gear from the rudder head to the motor shaft $\eta = 0{\cdot}32$; ratio of the gearing $K = 1{,}535$; total time for putting the rudder from hard over to hard over $T_a = 30$ secs.—*"Soudostroienie", No. 3, 1938.*

Direct Transmission of Heat from Furnaces of Marine Return-tube Boilers.

The absence of any sufficiently accurate methods of determining the transmission of heat from furnaces of marine boilers is often the cause of a great divergence between the projected characteristics of a boiler and those obtained under service conditions. Under the direction of the Central Research Institute of Water Transport, U.S.S.R., investigations were instituted to devise a method of determining the emission of heat from furnaces of marine return-tube boilers. Heat exchange in furnaces represents a difficult and complex process which so far cannot be dealt with by theoretical calculations. Simultaneously with the process of exchange of heat in a furnace, intensive reactions take place by the burning of the fuel, which add to the difficulty of the investigations. Thus the analytical investigation of heat exchange processes in furnaces may only be determined very approximately in existing circumstances. This explains the wide use made of empirical formulæ for determining heat production in furnaces of land boilers; as a basis for these formulæ definite theoretical considerations are taken which more or less correspond to the present view of the nature of the exchange of heat in furnaces. At the present time there appears to be no method for determining the direct emission of heat in furnaces of marine boilers; the reason of this, no doubt, is the lack of reliable experimental data. In order to procure such data, the experiments should be conducted in such a manner as to secure the possibility of ascertaining the temperature of the gases at least in one section of the gas flow between the furnace and the convection heating surface (boiler tubes). For this purpose the temperature of the gases should be measured by means of a suction pyrometer (this method has not yet been adopted by the Water Transport Dept.). Ascertaining the temperature of the upper layer of fuel and the furnace space by an optical pyrometer, cannot be done with sufficient accuracy owing to the limited dimensions of the furnace surrounded by a cold heating surface and the pecularities of the optical pyrometer (based on the principles of black radiation); the readings always show the mean temperature between the measuring point and the temperature of the heating surface. The same also applies to taking the temperature of gases in the combustion chamber; an optical pyrometer should therefore not be used in measuring the temperature in furnaces of marine boilers. Making use of all the available material, the following method for calculating the direct emission of heat from furnaces may be employed. When testing marine boilers, the temperature of the gases is usually measured at one spot, viz. at the exit end of the boiler tubes. The temperature of the flue gases in marine boilers generally corresponds with the temperature of the gases when leaving the tubes. It is considered advisable first of all to determine the temperature of the gases on their entry into the tubes and consequently the quantity of heat transmitted to the tubes. The next characteristic is the temperature of the gases when leaving the furnace, i.e. at the throat of the furnace. It should be pointed out that measuring the temperature of the gases directly they issue from the furnace presents considerable difficulties on account of the unequal distribution of the temperatures over the section of the furnace throat, which necessitates taking the temperatures at a number of points in this section; on this account the determining of the direct emission of heat from the furnace is actually limited to ascertaining the total heat absorption of the radiation heating surface of the boiler (furnace and combustion chamber). The pyrometer readings will usually be lower than the actual value of the temperature of the flue gases; the correction should be in the region of 30° (at a temperature 300° to 400°). It is also necessary to make a correction for air-leakage which may be taken approximately as 0·1; introducing this correction we obtain a coefficient of air excess at the smokebox which, owing to the absence of leakage in the gas passage of marine boilers, is numerically equal to the coefficient of air excess in the furnace. In view of the above the calculation should be based on the following formulæ:—

$$T_r''' = (T_k + 30)\,\frac{\Sigma m\cdot c}{\Sigma m_1\cdot c_1}\,[^\circ\mathrm{C}],$$

Where T_r''' = the calculated temperature of the gases in the smokebox (in °C.);

T_k = the measured temperature of the gases in the smokebox (in ° C.);

$\Sigma m\cdot c$ = the specific heat of the gases in the smokebox per 1kg. of fuel, taking into account the air leakage (cal/kg/deg.);

$\Sigma m_1\cdot c_1$ = the specific heat per 1kg. of fuel, (cal/kg/deg).

On account of the introduction of corrections in the value of the temperature of the gases and the coefficient of air excess in the smokebox, the loss of heat with the flue gases should also be determined by the Welter-Bertai method. The value of the specific heat and the heat content of the gases were calculated by the Welter-Bertai method with corrections for mechanical non-combustion. The temperature of the gases on their entry into the boiler tubes was ascertained by the Retenbacher formula. The mean layers of the gases in the combustion chamber are determined by the formula:—

$$S = \frac{4\cdot F}{P}\ \text{(metres)},$$

in which F = the section in square metres,

and P = the perimeter of the combustion chamber in metres.

The section and perimeter are ascertained in the horizontal plane at about the middle of the height of the combustion chamber. The coefficient of the heat transmission by convection, on account of the low velocity and high temperature of the gases in the combustion chamber, should be taken as a constant of approximately 8 cal./m.² p.h. deg. The effect of soot and dirt on the heating surface is taken at about 15 per cent. The amount of heat transmitted by the gases in the combustion chamber per 1kg. of fuel at the exit temperature from the furnace is determined by the formula:—

$$\Delta Q = \frac{H_{OK}\,.K\,(T_G^{CP} - t_c}{B}\ \text{(cal./kg.)},$$

Where H_{ok} = the heating surface of the combustion chamber in m²;

K = coefficient of the heat transmission in the combustion chamber, taking into account radiation (cal.² p.h.°C.);

T_G^{CP} = mean temperature of the gases in the combustion chamber (°C.);

t_c = temperature of the sides (°C.);

B = consumption of fuel per hour (kg./p.h.).

The value of ΔQ for each value of the temperature of the exhaust gases as they issue from the furnace is plotted on a graph* (Fig. 1) which illustrates the above method. The heat transmitted

* Tables and illustrations are not reproduced.

to the furnace relative to the lower calorific value of the fuel is determined by the formula :—

$$\sigma=\frac{\Delta Q}{Q^{P}_{H}}$$

The ratio of the amount of heat transmitted to the furnace to the total volume of heat produced in the furnace, is obtained by the formula :—

$$\mu=\frac{\sigma}{\eta'_{T}},$$

where η'_{T}=the efficiency of the furnace determined by the formula :—

$$\eta'_{T}=1-\frac{q_3+q_4+q^{T}_{5}}{100}+\frac{L_o+a_T+C_B\cdot t_B}{Q^{P}_{H}}\cdot\frac{100-q_4}{100},$$

Where q_3=chemical loss due to incomplete combustion (in %);
q_4=mechanical loss due to incomplete combustion (in %);
q^{T}_{5}=loss from the furnace to the surrounding space (in %);
L_o=theoretical quantity of air per 1kg. of fuel (kg./kg.);
a_T=coefficient of excess of air in furnace;
t_B=temperature of the air entering the furnace (°C);
C_B=Mean specific heat of the air (cal./kg./deg.);

The loss of heat from the furnace to the surrounding space may be taken as a constant of 0·5 per cent. *Results of tests carried out*: In accordance with the described methods, tests were carried out on 40 marine boilers. When studying the data derived from the tests it was found that the information regarding the constructional data of a number of the boilers did not correspond with the actual results obtained. Ten results were selected as representing the most reliable. These are given in Table I, in which full particulars and all the principal characteristics are indicated for each boiler. Coal was used as fuel in carrying out all the tests. The whole of the boilers were of the return-tube type, with heating surface varying from 55 to 157m.² The ratio of the heating surface of the separate gas passages to the total heating surface of the boiler varied within the following limits :—

Furnaces	3·7 to 8·1%
Combustion chambers	6·0 to 21·0%
Radiating heating surface ...	11·7 to 24·7%
Convection heating surface ...	72·5 to 84·0%

The ratio of the heating surface to the grate area varied from 27·4 to 41·5. The low values observed of the fuel consumption per unit of grate area and the mean velocity of the gases in the tubes (2·1 to 4·9 m./sec.) demonstrated the fact that marine boilers generally have a considerable amount of reserve. The amount of heat transmitted in the separate gas passages in relation to the total amount of heat transmitted is given in lines 33 to 36 in Table I. From the table it can be seen that a considerable volume of heat is transmitted in the furnace, from 59 to 84 per cent. The corresponding heat absorption of the radiation heating surface was from 77·6 to 89·8 per cent. The convection heating surface of the boiler was found to work under small heat loads, absorbing only from 10·2 to 22·4 per cent. of the total amount of the heat transmitted. In determining the effect of the characteristics of the furnace process on the values of direct transmission from the furnace, the results were arranged in several groups, after which a number of graphs were drawn (see Fig. 2). The most satisfactory results were obtained in cases which agreed with the following formula :—

$$\mu=f\left(L_o\cdot a^{T}\,\frac{100-q_4}{100}\sqrt{\frac{B}{R}Q^{P}_{H}\cdot\eta'_{T}}\right)$$

Where μ=the heat transmitted from the furnace relative to the total amount of heat produced in the furnace;
R=the grate area, m².

The character of this relationship is on the whole analogous to those accepted by Orrock, with the exception of the radiating surface, which is replaced by the grate area. The values of μ depending on the characteristics of the furnace process obtained from the data indicated in Table I are given in Fig. 2.—*"Soudostroienie", No. 3, 1938.*

Electric Transmission for Propulsion.

The practical application of electric transmission for propulsion has greatly increased in foreign vessels, the reason being that electric transmission has a number of advantages as compared with Diesel or turbine installations. The article discusses the advantages and disadvantages of electric transmission and indicates in which cases this method of gearing should be adopted, and in conclusion gives a short description of several marine installations with electric propulsion. The principle of applying electric transmission for propulsion consists of a generator worked by a Diesel engine or turbine, which feeds an electric motor connected with the propeller. The connection with the propeller shafting may be achieved either direct or by means of geared transmission. In both cases either direct or alternating currents may be utilized. In addition to all-electric propulsion, there exists also a combined transmission, working together or separately; with this system the electric transmission is generally employed for auxiliary purposes, viz. for obtaining low speeds. A great advantage in the use of electric transmission is that the engine and generators may be fitted in any part of the vessel; this permits a more rational arrangement of cargo spaces and of gun turrets in the case of war vessels. Electric transmission simplifies the construction of the machinery installation, there being no necessity for astern turbines or reversing mechanism; the number of compressors and air receivers is reduced; the propeller may be controlled direct from the bridge or other navigational posts, which is a great advantage in tugs, river vessels and other special craft. Electric transmission also permits of a wide range of power, with a maximum high speed. It is also possible to reduce to a steady low speed of 3 to 4 knots; this in certain classes of vessels is a great advantage. There is also a number of other advantages, such as the reduction of noise and vibration, the possibility of effecting repairs while under way, etc. The disadvantages of electric transmission may be stated to be: the double conversion of energy, which naturally leads to an increase in the loss of power; this is illustrated by graphs in *Fig. 1 which shows a loss of about 5 - 7 per cent. in efficiency when compared with direct drive by means of mechanical gearing. This of course does not mean that the economy of an installation with electric transmission will be less than in the case of one with geared mechanical transmission. Utilizing a non-reversing turbine by electric transmission permits a design with a higher pressure and superheating and also permits a minimum clearance for the blades; this reduces the difference in economy between mechanical and electric transmission. The weight of a turbo-electric installation is about 20 - 40 per cent. greater than the present marine turbine with mechanical transmission; this increase in weight does not necessarily mean an increase in cost. Where the increase in weight does not exceed 30 per cent. electric transmission costs about the same as mechanical transmission. With powers of 3,000 - 4,000kW. and above, the cost of an electric drive is about 10 - 20 per cent. greater than a turbine installation. As regards the space occupied by the installations, this is about the same in both cases. The losses of transmission with direct current are greater than with alternating current. The propeller installation is heavier and more costly, and because of the commutator the maintenance of machinery with direct current is more complicated. Therefore, with a high power it is more economical to utilize alternating current. Detailed particulars are given of the electrically-propelled vessels "Americo Vespucci" and the "Wuppertal", also sketches showing the schemes of the installations (Figs. 2, 3, and 4). Particulars are also given of a Diesel-electric floating crane. *Conclusions:* In cases where the installation is also intended for charging accumulator batteries, and for salvage, towing and other special work, the application of electric transmission to propellers must definitely be considered as advantageous. Electric propulsion in such vessels permits the main machinery to be used not only for propulsion, but also for the special work. In those vessels where the installation is required for a reduced speed, say of about 3 to 4 knots as well as the maximum speed, the composite method of propulsion should be installed. The electric installation mentioned in the above vessels should be of the direct-current type with a Ward-Leonard motor for propeller control. The scheme of the electric propulsion should provide for the possibility of the main generator being utilized for the auxiliary electric machines, also for the auxiliary machines being used for driving the propeller. In certain classes of vessels it is necessary to have in view a simultaneous working of the propeller motor and motors for auxiliary equipment, viz. for windlass, cranes, capstans, fire pumps, etc. The use of electric propulsion in cargo and passenger vessels and the choice of either a direct or alternating current must be decided for each separate case.—*"Soudostroienie", No. 3, 1938.*

* None of the illustrations is reproduced.

Efficiency of the Propeller Nozzle Navigating in Ice.

The Lower-Volga Steamship Co., when proposing to adopt the (Kort) nozzle system for propellers, found that there was a great lack of information regarding the efficiency of this system of propulsion under ice conditions. The service conditions in the lower reaches of the Volga require vessels to work during two periods of the year, spring and autumn, when the river is entirely frozen over. The most suitable and practical class of vessels to be fitted with nozzles was considered to be tugs of the ice-breaker type. For the purpose of ascertaining the service value of such vessels, a small steam tug of 50 h.p. was fitted with a nozzle enclosing the propeller. The experiment was carried out for the purpose of determining the following conditions:

(1) The ice-breaking properties of the vessel;
(2) The protection afforded to the propeller by the nozzle;
(3) The effect on the nozzle when working ahead and astern;
(4) The possibility of the propeller being jammed in the nozzle.

The tug, which was not of the ice-breaker type, was placed in service just before the time the thickness of the ice would have prevented the movement of the vessel. In the course of several days, after working in very difficult ice conditions for the size of the tug, it was possible to make the following observations: The ice-breaking properties of the vessel were greatly increased. According to a statement made by the captain, the vessel could not work in ice before the nozzle was fitted, but after it was installed the tug could easily move ahead through the ice without interruption. During the trials, after the installation of the nozzle, the following improvements were noted:—

(*a*) The pull on the towing hook was increased 46 per cent.;
(*b*) The towing power at a speed of 1·7 to 2·1 m./sec. was increased 35 per cent.;
(*c*) The speed when not towing was increased 2·5 per cent.

No damage was observed either to the nozzle or to the cast-iron propeller. The propeller did not get jammed in the nozzle either when working in ice, or when in clear water. Resulting from the trials, the following conclusions were arrived at: The installing of guiding nozzles in screw steamers for river service working occasionally in heavy ice conditions is without doubt very desirable on account of the increased working power of the vessel. The protection given to the propeller by the nozzle enables a cast-iron propeller to be used, which is much cheaper than cast steel.—*"Soudostroienie", No. 3, 1938.*

Diesel Engines for Use with Alternate Fuel.

It is stated in this article that a large number of river craft in the U.S.S.R. are now fitted with engines worked by gas from a gas producer plant; a number of engines have been converted from paraffin and petrol types. It has now been found possible by certain modifications to convert Diesel engines so that they may work with either oil or gas produced from coal or wood; this is found to be very profitable for craft plying on the inland waters of the U.S.S.R.—*"Soudostroienie", No. 3, 1938.*

The Welding of Cast Steel, Cast Iron and Malleable Cast Iron.

CAST STEEL.—In general, limits for welding without special precautions, may be put at C 0·25 per cent., Mn 0·75 per cent., Si 0·25 - 0·4 per cent., S and P 0·06 per cent., Cu 2 per cent.; tears generally occur during cooling below 650° C; for most materials rods of the same composition should be chosen, with thick coatings for arc work. All cracks, inclusions, pores, etc., must be removed, especially in castings; polishing and etching have even been recommended. With careful cleaning, low alloy steels may be electrically welded without preheating; with castings containing 0·3 - 0·4 per cent. C, hardening of the underlying material can be avoided only by multi-layer welding. Too high current density increases liability to shrinkage-tears and a smaller electrode should be used with castings than with rolled steel. Castings with 0·3 per cent. C or less can advantageously be warmed to 100 - 200° C, even higher when alloying elements or higher carbon are present; subsequent annealing at 500 - 600° and slow cooling to 100° C is desirable. Oxy-hydrogen welding is only suitable up to 6mm. thickness; preheating to redness is advisable with acetylene welding; thermit welding causes no difficulties, and the arc (15mm. rods at 400A) can be used for patching. With heat-treatment above AC3 followed by slow cooling, contraction stresses need not exceed 3·5kg./mm.^{2} ((2·2 tons/in.^{2}); mechanical properties of the welds are not markedly different from those in rolled steel; where cast and rolled steel are welded together the weld should show properties lying between them.

ALLOY STEEL AND IRON CASTINGS.—A neutral or reducing flame is used with borax as flux and the liquid state should not be maintained longer than is required. By use of a rod with (14 per cent. Mn + 5 per cent. Ni) heat treatment is obviated; (18 per cent. Cr + 8 per cent. Ni) rod prevents tearing and is used without flux. In arc-welding, electrodes with 0·7 - 0·9 per cent. C, 11 - 13·5 per cent. Mn, and 2·5 - 5 per cent. Ni are used with short arc; with Mn-steel a V-joint at 90° should be used. Hammering is desirable after welding lengths of 2 - 3ft.; special precautions are necessary in joining Mn and straight steels. Hard cast Mn steel can be flame-cut without preheating. Weld rot is due to slow heating or cooling in the region 425° - 800° C, is attributed to precipitation of carbon, and may be inhibited by quenching from temperatures at which it is in solution. A second type of brittleness probably originates in the liquidus-solidus interval; it is claimed that 5 per cent. Ni diminishes both these effects. Stainless steels (Cr + Ni) are discussed in detail; with acid-resisting ferro-silicon a flux of equal parts of borax and sodium bisulphate is recommended; alloy cast irons can be handled with difficulty.

CAST IRON.—In view of its usefulness in machine construction the joining of cast iron to worked steel is being actively investigated. Cast iron welding is usually by oxy-acetylene with or without preheating with the flame or *en masse* at 300° - 800° C, a charcoal fire being frequently used; with cylinder blocks special methods must be used. The only apparent difference with the oxidising, neutral, or reducing flame is in graphite take up—this may be advantageous in some cases. Rapid working is essential, as a *via media* between hard spots and slag inclusions, the rod is maintained near the flame and rubbed on the surface, the blue cone being 5 - 20mm. (0·2 - 0·8in.) from the work. Slow cooling in the fire, a furnace, or for small pieces in sand, is desirable. The chemistry of various fluxes is treated. In arc welding, preheating to 500° - 700° C is usual, and electrodes similar to those for gas-welding are used; cold welding is usually carried out with mild steel electrodes for pieces which are not too large and do not need subsequent working. Care in avoiding overheating and in removal of oxides, does not usually prevent hard spots; layer welding and hammering are desirable. A suitable cover is 40 - 60 per cent. graphite, 1 per cent. $BaCO_2$, remainder SiC, the electrodes being negative; a recent electrode steel contains 1 - 4 per cent. Ti with a little Al. In thermite welding with a mixture Fe_2O_3, Al powder, a very little ferro-silicon and 20 per cent. of small mild steel nodules, the weld metal is stronger than the basis. Arc-atomic welding has been tried, but resistance welding is unsuccessful; brazing is described in detail, graphite and coarse grained structures are undesirable; Monel electrodes can also be used. Since molten cast iron can remain covered with solid FeO, a flux is called for. Si and Mn increase welding difficulty, but Ni, Ti, and Mo reduce it. "Grown" cast iron can be welded with a reducing oxy-acetylene flame, but not in the arc. The various conditions which affect weld structure are discussed with special reference to the occurrence of graphite, martensite, sorbite, grain size and phosphorous eutectic distribution. Good welds show practically the properties of the basis metal, but the metal-arc weld shows only a fraction of the tensile strength; various tests are described. In repeated impact testing gas weld metal approaches the values of the basis material.

MALLEABLE CAST IRON.—The processes of brazing, acetylene, metal-arc, and resistance welding are described for malleable (black heart) cast iron, and usually the process is uneconomic even when practicable. Mn is favourable up to 0·5 per cent. and coated electrodes should be used, for surface hardening rapid heating and quenching are practicable; a martensite case is thus formed. The impact value of the welded material is 20 - 30 per cent. below the original.

An excellent bibliography, surveying worldwide work within the last 20 years, is included.—*W. Spraragen and G. E. Clausen, "Journal of the American Welding Society", Supplement to Vol. 16, Nos. 3, 4, 6, 1937;* summarized by *H. Cornelius, "Zeitschrift V.D.I.", Vol. 82, 10th September, 1937, pp. 1079-1088.* [*See* also following abstract].

Influence of Carbon and Manganese on the Weldability of Steel.

The American authors review developments reported during the last ten years; particular attention has been paid to the effect on transformation points, the austenite transformation, grain size, and mechanical properties, of Mn additions to Fe-C alloys, which are *not* recapitulated. For steels with C up to 0·4 per cent. and Mn up to 3 per cent., it does not appear possible to lay down any definite rules regarding the Mn/C ratio at which air-hardening and brittleness become excessive, and results must be compared with caution owing to wide variations in welding conditions amongst different experiments. A table of published figures between the limits C 0·054 - 0·42 per cent., Mn 0·32 - 2·25 per cent., is given for plate thickness from 2·5 to 21mm. (0·1 - 0·8in.), the index (Mn per cent. + C per cent.) lying between 0·46 and 0·018; it is pointed out that the existence of Cu (about 0·6 per cent.), Cr (about 0·3 per cent.) and Si (0 - 1·2 per cent.), does not allow strict comparison of the results. The Mn per cent. × C per cent.) gives approximately the same order as the index (C per cent. + $^1/_7$ Mn per cent.) deduced from the fact that the effect of C in lowering the critical point is seven times that of Mn; no clear correlation with the strength of joint is found, but in most cases it cannot be determined whether fracture occurred in weld or basis metal. It would be anticipated that the welded metal would be the stronger, but the authors conclude that differences in technique are greater than the effect of Mn and C contents on the mechanical properties. This holds for electric and gas welds. Maximum weld hardness increases with increasing Mn and C contents and with the rate of welding; a table summarizes the effect of speed of working (4, 8, 18in./min.) on microstructure and hardness of the weld metal. The hardening tendency in weld metal and heated zone is influenced 5 - 7 times as much by an increase in C as by a similar increase in Mn. No trustworthy information regarding the mechanical properties of a joint can be deduced from a sample weld, but the method can be used to determine limits for rates of working and for the plate thickness that can be welded satisfactorily; hardening can, however, be markedly reduced by multi-layer welding without intermittent cooling. With C content below 0·25 per cent., Mn exercises no marked effect below 1 per cent.; above this, and especially with simultaneous higher C, the inclination to martensite formation must be combated by pre-heating. With 0·15 - 0·2 per cent. C, 1 - 1·5 per cent. Mn, 0·15-0·25 per cent. Si, welding is no more difficult than with ordinary steel; with 0·15 per cent. C and 3 - 5 per cent., liability to weld-tears is diminished; with lower Mn contents the evidence is contradictory. Mn does no markedly affect nitrogen take-up, and in a steel containing 0·1 per cent. C and 0·1 per cent. Si, was found to diminish porosity on increasing between 0·3 and 1·7 per cent. Flame cutting causes no difficulties in Mn steel. A valuable bibliography of 66 references is included.—*W. Spraragen and G. E. Glausius, "Journal of the American Welding Society", supplement to Vol. 16, No. 9, 1937;* summarized by *H. Cornelius, "Zeitschrift V.D.I.", Vol. 82, 1937, 8th October, 1938, pp. 1200-1203.*

Structure and Mechanical Properties of Heat-treated Acetylene Welds.

Work carried out by MATTING and OTTE on the following welding methods is discussed: (1) High value (*hochwertige*) gas welding; (2) Bare electrode welding; (3) Normalised gas welding; (4) Unhammered backwood welding. In No. 1, to obtain fine grain without a reheating furnace, vertical welding is carried out by one welder on either side working simultaneously from centre to edge, after 30 - 50cm. (12-20in.) according to plate thickness is completed, the weld is hammered lightly and a further 12-20in. is welded; the former hammered part is then reheated to about 800° C and thoroughly dressed with compressed air hammers on both sides. The plate is then reversed and the treatment repeated on the other half of the weld. In folding tests there seems to be no difference between gas and electric welds after such treatment. All types except No. 4 gave satisfactory results in the tensile test on specimens with a rounded notch (DVM/A120); nevertheless with No. 1 tenacity decreases with increasing plate thickness and this should be countered by using a rod of higher C content. Low extension figures may possibly be due to the *form* of the test-piece. The method should not be used for plates over 20mm. (0·4in.) thick owing to deterioration of mechanical properties. To similate boiler conditions, test-pieces were aged by quenching and heating; this caused marked diminution of Izod values which was least with arc welds.

Prolonged bending tests on the *Schenck* machine showed the effect of the welding process when plain specimens were used, but not with notched specimens, *i.e.* the effect of *shape* predominates over the effect of welding method. In prolonged tensile tests, the value for double vertical gas welds approaches nearest to that of the original structural steel at 19·3 and 25·9kg./mm.^{2} (12·2 and 16·4 tons/in.^{2}) respectively. With double vertical acetylene welding it is probable that optimum properties of the weld metal have not yet been reached, and the excess in the cost over bare electrode welding might be reduced.—*H. le Comte, "Zeitschrift V.D.I.", Vol. 82, 8th October, 1938, pp. 1204-1205.*

Whalers of the Whale Factory "Jan Wellem".

The ship is equipped with six launches, for which specially stringent requirements in regard to stability, manœuvrability, and resistance to Antarctic weather were laid down. Equipment is being developed continually, *e.g.* in electrical killing, and in newer launches further improvements have been installed. Relevant particulars are :—

	"Jan Wellem" Boats.	*New Boats.*
Length on deck	136ft.	146ft.
Length between perpendiculars...	120ft.	122ft. 3in.
Maximum beam on deck...	26ft.	26ft.
Maximum beam at C.W.L.	25ft. 8in.	25ft. 8in.
Height to main deck ...	16ft. 6in.	16ft. 6in.
Burden		
Fuel oil	4,900 cu. ft.	5,042 cu. ft.
Gas oil	132 cu. ft.	199 cu. ft.
Feed water ...	1,178 cu. ft.	1,740 cu. ft.
Drinking water	178 cu. ft.	302 cu. ft.
Cruising radius at 10 knots	2,500 sea miles	2,570 sea miles
Gross tonnage	346	350
Net tonnage	113	121

They are classified 100 A4/E+ according to the German Lloyd, with through-going deck and five water-tight bulkheads, the crew being comfortably housed, with shower baths heated by waste steam, running water, l.p. steam radiators and electric light. To reduce noise from cavitation the 4-bladed propeller was subjected to preliminary investigation; it is driven by a triple-expansion steam engine, the pistons being displaced at 120° intervals in the interests of easy handling. In the new boats the engines are completely sealed; this leads to reduction of oil consumption and noise, and ability to sustain an overload in pack ice or in the hunt; by means of flexible transparent panels and internal lighting, periodical inspection is possible and access when required. At a distance of 40 - 50m. (130 - 165ft.) the harpoon is shot at the end of an 11 ton cable; after penetration the shell at its tip explodes, driving the 4 claws outwards; by means of a spring and pulley tackle the beast is then allowed to waste his energy during flight. For electrical slaughter a copper wire accompanying the harpoon cable carries d.c. causing paralysis in 4 - 7 min., but special precautions are required, and coloured indicator lamps are fitted on the bridge. Each whaler can tow back two whales, tail first, on each side, but 6 - 8 can be handled if necessary. Care must be taken that the carcases do not sink, to avoid this the density, which exceeds unity, is reduced by inflation with compressed air at 7 atm., and the orifice stuffed with seaweed; each launch carries a compressor rated at 1,350 cu. ft./hr. Engine output, helm response, and stability are carefully correlated both for smooth and for rough water and the whalers have given satisfaction in use.—*E. Gramoll, "Zeitschrift V.D.I.", Vol. 82, 1st October, 1938, pp. 1169-1171.*

Rustless Chrome Copper Steel.

On account of the readiness with which Cu separates from steel on cooling, the structure consists of chromiferous and cupriferous deposits in a matrix of ferrite, *i.e.* it is *not* austenitic like most stainless steels; it melts at about 1090° C, and is already plastic at 1040° C; rolling can be carried out at lower temperature than with pure Cr Steels, but there is some tendency to hot shortness after a heavy pinch. It is only slightly more rapidly corroded than the common 18/8, Cr/Ni steel; only with boiling acetic and nitric acids is the difference marked; on the other hand it is less damaged by intercrystalline corrosion, being ferritic. The mechanical properties of two steels with 8-10 per cent. Cu, and with 18 per cent. Cr and 15 per cent. Cr respectively, in the air-cooled and tempered condition, are as follow: tenacity 67 - 74 and 91 - 127 kg./mm.^{2}, yield point 51 and 77 - 84kg./mm.^{2}, extension on 2in. 29 per cent. and 21 - 22 per cent., Izod value 66 and 51 - 120ft./lb., Brinell hardness 250 - 260 and 300 - 315; despite the heterogenous structure the Izod value is good. The steels draw well, their weldability is favourably influenced by the ferrite ground mass without danger of weld-rot, and the Cu prevents undesirable grain growth near the weld. Its use for turbines and brewery installations is suggested; for Pelton wheels it has been found satisfactory, and in view of the substitution of Ni by the much cheaper Cu, it seems worth investigation. Much of the development work has been carried out in Great Britain.—*T. W. Lippert, "Iron Age", Vol. 140, 1937, p. 54;* summarized by *E. H. Klein, "Zeitschrift V.D.I.", Vol. 82, 8th October, 1938, pp. 1025-1026.* [Note: 1kg./mm.^{2} =0·635 tons/in.^{2}.].

Accuracy of Brinell Impression Measurements.

Accuracy of measurement improves with increasing magnification but not in proportion, *e.g.* at ×25, ×50, ×100, and ×200 spreads of 2·5, 1·2, 0·83, and 0·67Mμ were obtained, representing not even a doubled accuracy by fourfold increase in magnification, so that in view of the increased costs it does not seem worth while exceeding ×50. Bright ground illumination, as a result of the raised rim surrounding the impression, inevitably leads to errors which in extreme cases may reach 10 per cent. By surrounding the tube with another which is illuminated from a small bulb the impression may be illuminated by rays from one direction only, and appears bright on a dark background. 550 measurements were carried out by 5 observers with a special arrangement of two scales in place of the customary cross hairs, one being placed in register with the apparent l.h. side of the impression, and the other with the r.h. side. Actual diameter could then be read off accurately on a screw gauge. In this way measurements accurate to $\pm 0{\cdot}7\mu$ could be obtained with polished surfaces, to $\pm 2\mu$ with finely ground surfaces for Brinell or Vickers impressions. Personal error varies according to the temperament and experience of the observer from $\pm 0{\cdot}3$ to $\pm 5\mu$, on an average $\pm 2{\cdot}7\mu$. For finely ground surfaces the average error is therefore $\pm\sqrt{2^2+2{\cdot}7^2}\mu=$ $\pm 3{\cdot}3\mu$, independent of the diameter, *i.e.* low hardness can be measured relatively more accurately than high.—*K. Sporkert, "Zeitschrift für Metallkunde", Vol. 29, 1937, p. 168; Vol. 30, 1938, p. 199;* summarized in *"Zeitschrift V.D.I.", Vol. 82, 1938, 8th October, 1938, pp. 1206-1207.*

Chinese Junks at the Science Museum.

Disappearance of sailing vessels is not confined to Europe; even in conservative China power vessels are ousting the characteristic native craft, and war is accelerating the disappearance of types that have been established for centuries. On 27th October, 1938, H.E. the Chinese Ambassador inaugurated the *Maze* collection of ten models, assembled and presented by the Inspector-General of the Chinese Maritime Customs. They are on a $^1/_5$ to $^1/_{24}$ scale and range from a Hong Kong sampan and Canton "slipper boat", to a trading junk of the Upper Yangtse and South China seas, and the lorcha. The largest model is over 10ft. long. a $^1/_{12}$ replica of sea-going Foochow junk; others are Amoy and Swatow fishing junks, a Hainan sea-going junk and a Shantung 5-masted junk no longer constructed. All are complete with full equipment, some of which (*e.g.* windlasses) is now obsolete in the West, while other forms (*e.g.* the long sweeps or yulohs and the anchors) are peculiar to China. The coastal and river craft section of the Science Museum has been greatly extended in recent years.—*"Engineering", Vol. 146, 11th November, 1938, p. 566.*

Ignition Measurement in Diesel Fuel Testing.

Ignitibility can be deduced to some degree from physical properties but actual measurement is very desirable [*see W. Wilke, "Zeitschrift V.D.I.", Vol. 82, 1938, p. 1135*]. Determination of the short intervals at high speed is usually carried out by oscillograph, but a new apparatus has been devised by T. B. Hetzel [*Bulletin 45 of the Engg. Exptl. Station of Pensylvania State College 1936*] using two electromagnetic circuits, one connected to the valve needle the other to the cylinder wall. These are switched as desired into a mica relay (iontron) which discharges a condenser at a particular voltage, causing a brief glow in a glow lamp mounted on a wheel. The relation between the lighting up and the valve opening can be read off on a scale, directly; lattice voltage of the mica relay must be so chosen that it does not operate at compression but only on explosion. The compression ratio is determined at which the fuel investigated ignites exactly at the dead point, with definite injection point. It is claimed that this method gives better results than determination at constant compression ratio, at which good and poor fuels give too short and too long ignition times respectively, compared with behaviour in service. Further, the effect of testing conditions—r.p.m., injection point, ignition process, air temperature and pressure, water temperature—on cetene number, is much less marked than in determination of the octane number for petrol motors.—*K. Zinner, "Zeitschrift V.D.I.", Vol. 82, 29th October, 1938, p. 1285.*

Test-piece for Triaxial Stress.

To obtain approximately equal stresses in all directions and even distribution, Haigh has proposed a very short and deeply notched tensile test-piece [*see "Engineering", Vol. 144, 1937, pp. 519, 537 and 595*]. The actual portion tested is then so short as to act as a thin plate, and radial stresses are accentuated; since a brittle fracture is obtained even with deformable materials and the breaking load can be determined accurately, he suggests that this should replace the Izod test. Kuntze does not agree since internal strength and tenacity can be correlated by a fairly simple mathematical expression [*see "Stahlbau, Vol. 9, 1936, p. 121;* and *Vol. 10, 1937, p. 177*], while impact (bending) value is a measure of how great a volume can be deformed under a sudden blow. Notching of the test-piece does not segregate the three types of stress—static, oscillating, and impact—since these are inter-related mechanically, *e.g.* under triaxial tensile stress static strength is greater while alternating and impact strengths are less. He emphasises the value of a study of the interaction of multi-axial stress distribution with simultaneous peak stresses, and the resulting effect of shape, in connection with the above three types. It is not generally known that a peak stress causes local increase in yield point or tenacity if other conditions determine a plastic behaviour of the material, so that overall tenacity is hardly affected by peak stress. Bu if distortion is prevented by triaxial stress distribution, a peak stress will diminish overall tenacity; to overcome this notches causing unequal stress distribution will be required. Apparently, therefore, a knowledge of stress distribution is necessary even with multi-axial stress testing, and the author would limit its use to determine the conditions of transfer from plastic to brittle characteristics, and the change in strength accompanying.—*W. Kuntze, "Zeitschrift V.D.I.", Vol. 82, 15th October, 1938, pp. 1229-1230.*

Effect of Nut Size on the Strength of Bolted Joints.

In general, height and diameter of nuts are made greater than is really necessary, and the extent to which reduction without loss of strength is possible is investigated with the object of saving weight and material. The new standardization of small nuts for aircraft DIN 9004 - 9009 will be based on the author's conclusions. Commercial steel with 0·48 per cent. C, 0·09 per cent. Cr, 1·00 per cent. Mn was used for the bolts, it showed a tenacity of 51-57 tons/in.^{2}, extension 21 per cent., 0·2 per cent. yield at 81 per cent. of tenacity, and strengthening effect of the thread 15 per cent. A drawn steel, and heat-treated V-Cr-Mo alloy steel with tenacities of about 44 and 54 tons/in.^{2} respectively, were used for nuts. It appears that the nut diameters laid down in DIN/Kr571 can be reduced to the size next below without danger of stripping, loss of endurance, or frettage under ordinary conditions. Equal strength in shaft and thread can be obtained from the following relation between nut height m, pitch h, and thread diameter d,

$$m/d = 0{\cdot}165 d/h^{0\cdot68}$$

for such nuts. Below M14 × 1·5, m/d may be reduced to 0·8 of hitherto standardized values; above this a value of 0·7 - 0·8 may be used and 25 - 35 per cent. of the cross-section removed by boring. Actually the full cross-section is no longer required since permanent changes of axial length occur at relatively low loads. At diameters exceeding 14 - 16mm. (0·55 - 0·63in.), therefore, the shaft material is not fully exploited, since the maximum load is only 56 per cent. of the yield value. Ratios of the strength of bolt and nut materials should not be less than 1·1 for M10 to 1·25 for M24. Endurance of the six-sided screwed joints investigated falls with increasing thread diameter, and is not affected by small longitudinal borings; with larger ones it is even increased.

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—*B. Haas, "Zeitschrift V.D.I.", Vol. 82, 29th October, 1938, pp. 1269-1274.*

Airscrews and Autogiro Blades.

Current work is concerned with the calculation of take-off thrust of moderately high pitch propellers, the performance of which, alone, has been determined for a family with a wide range of pitch, shape and number of blades. This model work is being correlated with full scale tests in the R.A.E. 24ft. wind tunnel, the conclusions being of great academic interest as well as of practical value. Interference of engine, cowling and nacelle are also being determined. Thick wings, which are strong and provide stowage space, are being increasingly used for engine mounting and it becomes important to know the smallest propeller that can be mounted a short distance ahead of a thick wing without marked loss of efficiency. Investigations on thick wooden models will shortly be extended to thin variable-pitch metal airscrews in full scale and in models. For relative valuation of alternative designs small-scale tests are adequate, quicker, and much cheaper, as shown by research into the adverse effects of cylindrical roots in the Hamilton variable-pitch type. Screw efficiency and engine-cooling flow are now being investigated, but there is no wind tunnel in the country big enough to test even model screws at the high tip speeds and forward velocities of modern aircraft; for this purpose a graphical method has been found to give good results in prediction. This is also being used in applying test work results to 3-bladed airscrews and to dimensions and speeds other than those covered directly. In contrast to torsion, it appears that bending of autogiro blades affects performance only slightly. Further work on stability is however necessary.—*Report on N.P.I. Research, "Engineering", Vol. 146, 11th November, 1938, p. 552.*

Shipbuilders, Shipowners and International Trade.

In his *Presidential Address to the N.E. Coast Institution of Engineers and Shipbuilders,* MAJOR CAIRNS traces the historical development of the Tyne from the coal workings of the Ancient Britons to a peak export of 21½ million tons in 1923, falling to 13 in 1937. He discusses shipbuilding progress from builder's, operator's and owner's standpoints; the new ship to-day is much more attractive commercially than her equivalent 20 years ago. AYRE once expressed the view that trade improvement would encourage repetition work rather than technical progress, but a corps of engineers always striving for something better, is of value in good times and bad. In shipping a poor technical job may sometimes earn good profits, but every owner should strive to maintain initially good ships up-to-date, and adopt developments as soon as practicable. Valuable information on the effects of weather, wear and tear, wastage, and relative merits of different types, is accumulated by managing firms over periods of years; he regards it desirable that the owner should exercise some influence on the design of new tonnage, and deprecates mass production in shipbuilding. Even allowing for the effect of war conditions, past experience with these was not encouraging, and initial errors might persist through a long list. Big technical improvements usually originate with builders and are accepted on the responsibility of the owners' technical advisers, the ideal ship shows a minimum of (capital and running) costs, the latter including fuel, wages, stores, insurance and maintenance. More attention should be paid to depreciation in quoting minimum freight rates, the modern steel ship rarely exceeds 30 years' life and may become obsolescent much sooner as a result of rapid technical progress. This is all the more distressing when the vessel is still in good working trim and adequate depreciation has not been allowed. The so-called tramp "boom" of 1937 was in reality only a year of normal prosperity. When a comparable basis is adopted for comparison of maritime wages Britain stands second, slightly inferior to one European country; in one extreme case wages are only 25 per cent. as high. The author refutes attacks on manning conditions, citing the recently established officers' pension fund; he discusses the reasons for a recent dearth of engineers and the widespread tendency to amalgamation. The increase of one-fifth in world population compared with pre-war days, would lead to considerable expansion in trade in the absence of autarchic policies. Expansion or contraction is, however, now more localised; in the interests of shipping, further trade pacts and greater freedom are earnestly to be desired. Recovery from the 1929 slump has made greatest progress in Germany and U.K., less in U.S.A., and France still lags behind at the 1932 level. British exports have the following difficulties to face: (1) obstructive nationalistic trade policies; (2) subsidized competition; (3) competitor's low living-standards. Trade restriction hits us hard owing to Britain's large share of world tonnage, which in 1937 contributed £130 millions of invisible exports; ancillary services and coal mining are also affected. The author would not willingly prophesy the gloomy possibility that all trade will be divided into strictly national preserves, bureaucratically administered.—*T. R. Cairns, "The Engineer", Vol. 166, 28th October, 1938, pp. 483-484.*

Journal Friction.

Various requirements for efficient lubrication are discussed; the more general use of substitute bearing materials [in Germany] has led to closer attention to exact requirements. GÜMBEL assumes a cosine relation for pressure; DENNISON assumes a parabola but decides that this is valid only for relatively slack and well run-in bearings. No exact mathematical solution has yet been attained. The question of flow in the areas where calculation shows a negative pressure to exist, affects boundary conditions and is of importance in considering the properties of oils. The expressions—oiliness, lubricating value, lubricity, etc.—merely beg the question without theoretical or practical meaning, but are very useful for assessment of working properties. According to VOGELPOHL [*V.D.I. Forschungsheft 386, see also* ABSTRACTS, *Vol. L, October, 1938, p. 142*] a pressure distribution results, such that frictional loss is a minimum. The old method of considering only viscosity [*Zähigkeit*] is sufficient for low loads and velocities, but otherwise total loss of energy must be considered; for this purpose the *Navier-Stokes* equations are accurate enough, even for variable viscosity. The heat developed, corresponding to the energy consumed, is given by a relatively simple integral

$$Q = v^2 \int_0^a \eta \left(\frac{4}{h} - \frac{6h_o}{h^2} + \frac{3h_o}{h^3} \right) \mathrm{d}x$$

in which h is film thickness, h_o the thickness at the point of maximum pressure, and v the r.p.m. The *Reynolds* law is extended to pressure partition and energy ratios of the film in mechanical and thermal relations. By means of a steel shaft and transparent glass bearing he is able to follow the flow, pressure ratios being previously obtained from the *Ritz* expression. Results are given as plots of $p\psi^2/\eta\omega$ against ϕ for $z/l = o$, 1/12, 1/6, 1/4, 1/3, 5/12, 1/2, with $l = 1{\cdot}25d$ and eccentricity $= 0{\cdot}2$; the distribution of pressure at various points ($\phi_p = 99{\cdot}5°$) projected on a single plane, is also given. VOGELPOHL'S assumption of a pressure development from the narrowest to the widest portion of the film (180°) would, however, be in contradiction to established lubrication practice; the author prefers DENNISON'S assumption of an interval between 14° and 160°. The model clearly shows longitudinal flow and it is assumed that frothing is a sign of cavitation. Tests with badly lubricated couplings show oscillating μ between 0·05 and 0·15, and the absorption of oil by the surfaces can be increased by suitable prehandling. Where hydrodynamic and molecular phenomena occur simultaneously, a different temperature relation naturally exists, and the beginning of boundary lubrication deduced from the curve $\mu = f(p_m)$ according to T. RANOW (*Dissertation, Berlin Polytechnic, 1937*) is in good agreement with results from flow measurements.—*E. von Ende, "Zeitschrift V.D.I.", Vol. 82, 29th October, 1938, pp. 1282-1283.*

Transporting the Grain Harvests of the World.

Of the 2,000 million people in the world, bread is the staple food of a large proportion; at no time have communications been more favourable to mutual exchange of natural resources, but natural hazards of crop failure are intensified by economic nationalism. Of a total cereal production of 400 million tons, 370 million is consumed domestically, while 30 million tons (about 7½ per cent.) requires ocean transport. Almost *all* grain is transported a considerable distance, and Britain is the largest single importer of every cereal except rye. Canada with 5½ per cent. of the world's production of wheat, nevertheless supplies nearly half the exports; Argentina with 8½ per cent. of the world's maize production, supplies nearly three-fourths of the exports. All three grain producing countries possess enormous unexploited reserves of production, and the change from bag to bulk handling is slow. In Canada and U.S.A. 2-ton units are generally used for collection and 40 - 50 ton covered waggons in railway transport; similar systems are being developed in South Africa and Argentina; some river barges carry 2,000 tons, and Great Lakes coal or ore ships as much as 14,000 tons, but their working season is short. In ocean transport special grain ships are unknown, despite the need for maintaining it in good condition, especially in voyages of 6-10 weeks, and bulk storage is still suspect. [*See S. J. Duly, Royal Society of Arts Lecture, 26th January, 1938*]. Gallery loading is described; in Europe discharging has been very thoroughly developed and the pneumatic elevator (*7·15d./ton*) is rapidly displacing the bucket type (10·01*d*). Silos up to 100ft. deep are the principal connecting link between farmer and miller; various installations in the Empire are discussed. In recent years the tendency is to build silo and mill adjoining a deep-water berth, as in various British ports. The author pleads for removal of dust which is costly to transport, unpleasant and sometimes dangerous; it may be as much as 5 per cent. in wheat and 20 per cent. in barley. He points out the precautions required in preventing infection by pests and the need for sterilisation of infected waggons, bins, ships, etc. In 1931, with depressed prices transport from a Canadian farm accounted for 48 per cent. of the Liverpool price, in 1929 about 35 per cent.; attention is drawn to the relatively high cost of short railway hauls in Britain.—*C. Bentham, paper read before the Institute of Transport, 18th October, 1938; reproduced in "Engineering", Vol. 146, 11th November, 1938, pp. 571-572.*

The Vienna Tank.

Since 1924 tanks have been constructed to Vienna specification in Japan (2), Moscow, Holland, Madrid, Rome and Spezia—others are under construction in Trondhjem and Gotenborg—despite the fact that Austria became an inland country after the war. Following its annexation by Germany it is hoped that the old Imperial subsidy of 100,000 marks may again be granted. Most of the model testing was done for Germany and Sweden, but orders have also been received from Belgium, Hungary, Czechoslovakia. Since the civil war, work from Spain has ceased entirely, and Italy's considerable former commissions have now ceased, except at the express requirement of foreign customers. The laboratory does not itself design hulls or propellers, but modifies and improves customers' data and drawings as a result of its model testing; results are regarded as confidential and the property of the particular firm. Representatives however frequently develop the design in conjunction with the staff, and drawings for a large French experimental type were recently finished. Hydrodynamic instrument calibration is also undertaken. Owing to restricted means scientific research is limited; recent investigation include the frictional resistance of rectangular duralumin plates cut to 45° and 30° and towed point first, and the efficiency of propellers when running astern. [No results are given]. The tank is 180m. (590ft.) long, 10m. (33ft.) wide, and 5m. (16·5ft.) deep, and was the first in the world to be fitted with adjustible false bottom. Wooden or wax models 16·5 - 23ft. long are used, propellers being cast in light alloy.—*H. Reif, "Engineering", Vol. 146, 11th November, 1938, pp. 575-576.*

Aerofoils in Cascade.

Work carried out in connection with return flow wind-tunnels in which the air is turned 4 times through a right angle, shows that a sharp right angled bend in conjunction with a cascade of deflecting vanes can show surprisingly low loss. Careful attention must be given to the shape and positions of the bends and a design is reproduced which has been found most satisfactory in terms of direction, loss of pressure, and general steadiness. The tail is thin and both tangents are at right angles to the incident stream. In this arrangement proposed, only a very slight constriction occurs in the air passing between the aerofoils, the mean change of direction being within 1° of 90° and total loss of head being 9 per cent. The conclusions drawn may be of value in duct ventilation.—*Report on N.P.L. Research, "Engineering", Vol. 166, 11th November, 1938, p. 553.*

Fluid Motion Research.

Mathematical investigation leads to a comparison of fluid friction over a rough surface with the deformation of a flexible panel clamped at opposite edges by rough and smooth members. For simplification, roughness is represented by sinusoidal ripples of various amplitudes and wave lengths. The deflection along a horizontal line is affected to an extent which decreases at increasing distance from the rough edge, *i.e.* the corrugations fade out. Boundary flow can be studied in this way at leisure. In investigation of air flow the proportion of turbulent energy at high frequencies increases with the velocity, *e.g.* limiting frequencies are 600 at 15ft./sec., and 2,500 at 35ft./sec. An instrument with thermocouple mounted behind a heated wire $^{1}/_{1000}$in. thick and a fraction of an inch long has been devised; for this anemometer stainless steel is found to be better than platinum.—*Report on N.P.L. Research, "Engineering", Vol. 166, 11th November, 1938, pp. 550-551.*

R.A.F. Long Distance Flight.

On November 5th - 7th, 1938, two Vickers-Wellesley geodetic cantilever monoplanes regained the world's long distance record from Russia by flying from Ismailia, Egypt, to Port Darwin, a great circle distance of 7,162 miles at an average ground speed of 149 m.p.h. The route chosen lay via Jask, Hyderabad, the Bay of Bengal, Andaman Islands and Timor, since a true great-circle course would include high mountains and open sea; as a result a longer distance was covered than the record implies. A third machine landed for fuel at Koepang. Standard R.A.F. machines were used, apart from the fitting of extra full tanks in the wings and widening of the fuselage forward, a single variable-pitch airscrew being fitted. Wing span is 74ft. 4in., length 39ft. 5in., height 12ft. 4in., maximum speed 210 and cruising speed about 180 m.p.h. The most economical speed, which was naturally employed during the flight, appears to be nearly 150 m.p.h. Pilot, second pilot and navigator, and a wireless operator-mechanic were carried, 3 in all. The article pays a tribute to the long-range development unit and the designers and constructors.—*"Engineering", Vol. 146, 11th November, 1938, pp. 565E566.*

Flutter and Buffeting.

As a result of the rise in aircraft speeds, the question of flutter, especially in monoplane wings, is becoming urgent, since the proportionality assumed between force and deformation is no longer adequate for safe design. The design of mechanical aids to shorten the laborious solution of differential equations is almost a research in itself. Instantaneous air forces acting on an oscillating horizontal wing, mounted on bearings and operated electrically from outside the wind tunnel, are measured by the magnetostriction of a pair of Ni tubes included in the tapes which convey the oscillations. Inertia effects are eliminated from the oscillograph by means of a second wing similarly treated but mounted outside the tunnel, only the difference being measured. The buffeting effect of the vortex tailing system on tail planes will be investigated in the same way, with particular reference to the result when tail flaps are used to control driving speed. Interest has recently reawakened in irreversible control mechanisms, theoretical conclusions on the effect of flexural stiffness on the flexure-torsion of a monoplane wing are also being tested in the wind tunnel. In this work a new technique consists of the use of tapered-plan flexible wings of 4ft. 6in. span, built up of square steel tube spars with low density balsa wood ribs.—*Report on N.P.L. Research, "Engineering", Vol. 146, 11th November, 1938, pp. 552-553.*

Safety in Operation [of Diesel Engines].

Two schools of thought exist, one relying on signal or alarm devices on the theory that faults rarely develop without warning, and the other believing in cut-off methods. One speed control depends on the action of a plunger and trip lever, which is operated by a weight when speed exceeds 700 r.p.m., the fuel supply being thus cut off. If lubricant pressure fails the fuel passage may be blocked by a plunger, or a heavy weighted lever swinging under gravity may be used to cut off the fuel supply. Another centrifugal speed governor independent of the fuel supply has fly-weights which strike the spindle of the trip gear; air is thus admitted to a cylinder controlling the decompression gear. Oil and water pressure controls have been known for years; diaphragms are compressed against springs and if the pressure falls below a predetermined figure a trip-lever is released which is connected by linkage to the fuel supply; the lever must be reset before starting up. For shafts rotating in a horizontal plane a spring-restrained weight may be used; at excessive speed centrifugal force overcomes the tension and the weight strikes a plunger. In a high-speed engine oil under pressure is introduced above a spring-loaded piston with the fulcrum pin through the fork of the governor lever operating in a specially-shaped slot; when the oil-pressure falls, the spring-loaded piston lifts the trip bracket and releases the pump control. An emergency speed governor on the same principle can be fitted, both these devices must be reset before restarting. Electrical methods include the closing of a relay circuit if oil-supported plungers drop and make contact; a similar device can be used in conjunction with a centrifugal speed governor or to indicate excessive bearing temperatures. Another mechanical device consists of oil- and water-operated pistons which hold the fuel-control plunger open against the thrust of a spring. Various causes of oil failure and over-speed, and the advantages of the different methods used to combat them are discussed critically; the article regards the cylinder-decompression method as most satisfactory and points out that no manufacturer has yet adopted the method of interrupting the air by a throttle valve in the intake manifold. This would require very little energy to start it closing after being released, but the manifold itself would require to be airtight.—*"The Oil Engine", Vol. 6, October, 1938, pp. 189-190.*

EXTRACTS.

The Council are indebted to the respective Journals for permission to reprint the following extracts and for the loan of the various blocks.

Wetness in Steam Turbines.

"Shipbuilding and Shipping Record", 27th October, 1938.

While the latest practice in the design and operation of steam turbines does unquestionably yield an increase in the overall efficiency of the installation, this is, unfortunately, accompanied by a corresponding increase in the wetness of the steam as it passes through the low-pressure stages. In particular, as can be so readily demonstrated on the entropy diagram, the increase in the vacuum due to the use of improved condensing apparatus leads to a substantial increase in the moisture content of the steam and, paradoxically enough, any improvement in the efficiency of the turbine itself also means a lower dryness fraction in the low-pressure steam, and it is these factors, coupled with the use of higher blade speeds, which have tended to make the problem of wetness in the steam of considerable importance in recent years. Thus, the turbine designer is faced with the problem of finding ways and means of combating the erosive effect of the moisture on the low-pressure blading, while the operating engineer knows that if from any cause this moisture should accumulate in the casing, the result may be a blade strip or possibly something worse.

Among turbine engineers, there are two schools of thought regarding the best manner in which this problem of wetness in steam can be solved. The first comprises those who adopt the method of prevention, while the second is represented by those who seek to cure its evil effects. The prevention of moisture can be effected by the process of superheating the steam, but, unfortunately, it is quite impracticable to give a sufficiently high degree of superheat to the steam before it enters the turbine to ensure that it will still be dry when it has expanded down to condenser pressure. Hence, some form of re-heating between the different stages of the expansion must be employed. In large installations, where the high-pressure, intermediate-pressure and low-pressure turbines are housed in separate casings, this is not very difficult to accomplish, but for low powers, where a single casing only is required, the problem becomes much more difficult of solution. But in any case, the adoption of the principle of reheating adds considerably to the complication of the pipe system, particularly if, as is sometimes practised, the reheating is effected in some part of the boilers by means of the flue gases. If, on the other hand, the reheating is effected by means of live steam, then the installation is simplified, but the temperature attainable is reduced and more than one stage of reheating may be necessary. It should be realised, however, that by reheating between the different stages of the expansion it is possible to ensure that the steam shall remain perfectly dry during its entire passage from boiler to condenser.

And in addition to the elimination of the evil effects of the moisture, a substantial increase in thermal efficiency is obtained.

Where, however, it is considered undesirable to employ reheating either because of the greater complexity of the installation or the higher capital outlay or both, then means can be taken to reduce the evil effects of the moisture to a minimum. We saw recently in the house journal of one of the leading turbine manufacturing firms in this country an interesting article in which the author (after dealing with the possibilities of reheating and explaining the reasons why it is not a common feature on turbine plant), discussed the behaviour of the moisture as it forms in the low-pressure stages, until as drops of water it passes from blade to blade with the erosive effect which plays such havoc with the blades unless they are specially designed to resist it. The impact of these drops of water, it has been found, can be met by the provision of specially-shaped shields on the leading edges of the moving blades, and because, in addition to being carried along with the steam, the drops of water tend to move outward as a result of the centrifugal force acting upon them, it is only necessary to protect the outer half of the leading edge of the blade. For this purpose, a shield of tungsten-steel is brazed on to the blade, the shape of the shield being itself somewhat similar in section to a small turbine blade. Further, since some of the drops of water are thrown clear of the blades on to the casing, specially-designed water catchers are cut circumferentially around the casing, from which the entrapped water can be led away to a drain tank or to the condenser. It may be noted that the adoption of these methods has effectively eliminated the evil effects of moisture as represented by erosion of the low-pressure blading.

Compression Adjustment in Diesel Engines.

By W. M. Wiley and F. E. Hancs*

"Gas and Oil Power", October, 1938.

One of the essential features in maintaining Diesel engine efficiency is the proper adjustment of the compression pressure. The range of variance for optimum results is relatively narrow. A compression pressure much below this range results in poor combustion and hard starting while a pressure above this range raises the firing pressure, thus placing undue stress on the engine structure. In either case the engine will not run smoothly.

*Mechanical engineers, The Texas Pipe Line Co., Houston, Texas.

The engine should be in good mechanical condition before any compression adjustments are made. In this connection the following items should be given attention :—

- Valves should be checked for timing and condition of seats.
- Rings should be free in grooves and not badly worn.
- Liners should not be excessively worn or scored.
- Bearings should have the proper clearance.
- All gaskets should be tight.
- Cylinder head studs should be drawn to proper tension.

Especial attention should be given old liners with shoulders as it is necessary that they be relieved to prevent the piston rings striking them in case shims are added to the foot of the connecting rod in raising the compression. After adjustment and before starting, it is always advisable to bar an engine over by hand to make certain that it turns freely. In many Diesel plants there is little or no stand-by equipment, hence shut-down time must be reduced to a minimum. Trial and error methods or long-drawn-out computations to determine the required amount of shimming, for the desired compression pressure, require considerable time. To obviate this, a chart of curves has been developed which permits approximating the shim thickness required. A discussion of the manner in which these curves are derived may be of interest.

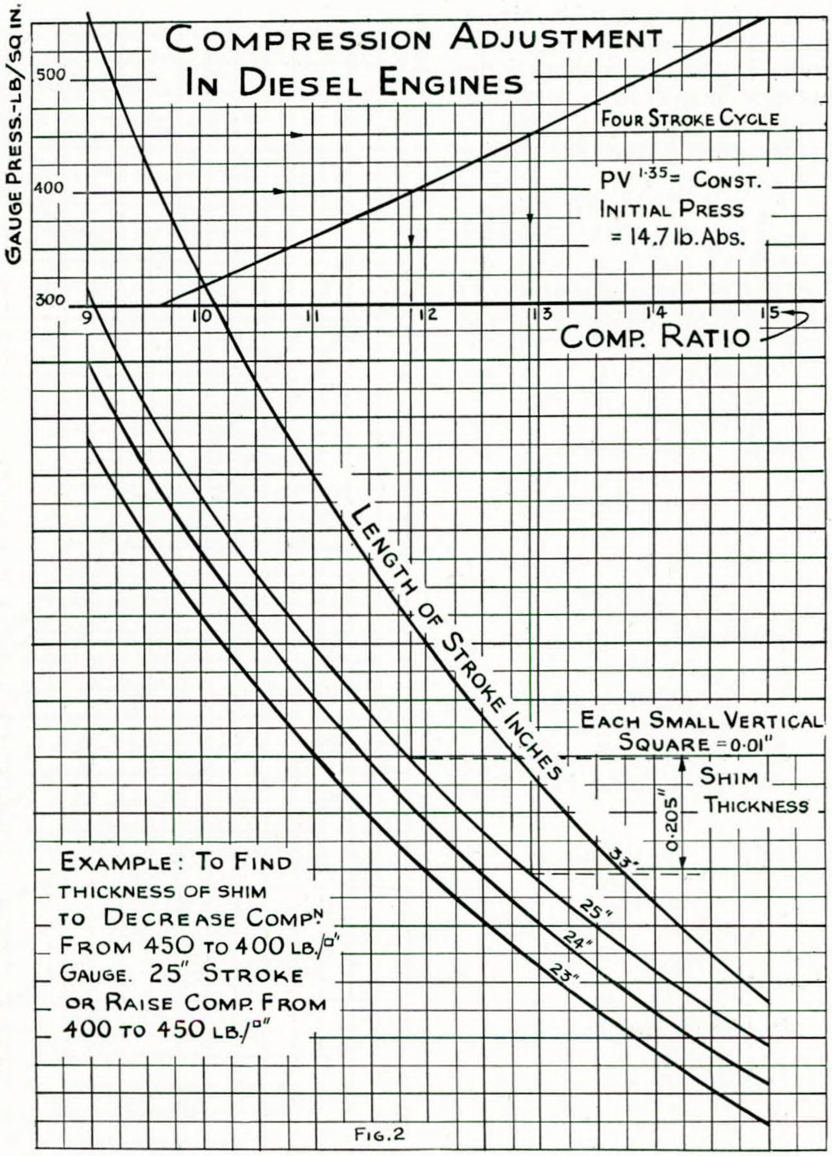

FIG. 2

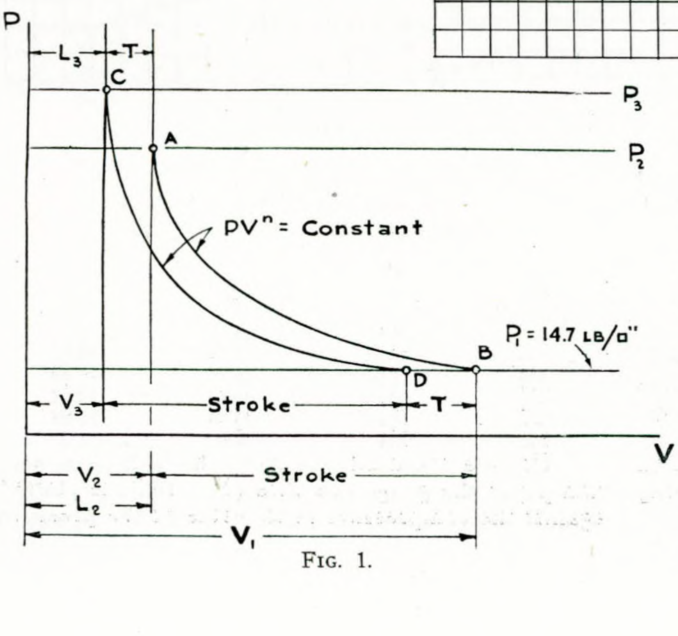

FIG. 1.

In Fig. I we have represented two theoretical Diesel engine compression curves. AB represents a compression curve from atmospheric pressure 14·7 pounds to some pressure P_2. CD is a similar curve with the same stroke but with shims of thickness T inserted at the foot of the connecting rod. The addition of these shims raises the compression pressure to P_3. The value of the exponent for both of these curves is assumed as 1·35. This is taken as a practical working value since it was not deemed necessary to introduce modifications for the change of exponent at the higher pressures. Engine design also results in some variation of the exponent but from a practical viewpoint this is too slight to justify other than the figure used.

L_2 and L_3 represent hypothetical lengths of the clearance volumes V_2 and V_3. While not strictly true this is equivalent to saying that the clearance volume is an extension of the cylinder. We are interested in the values of L_2 and L_3 only in so far as their difference is T the shim thickness. The increase or decrease of clearance volume is always T times the cross sectional area of the cylinder.

From Fig. I we see that :—
L_2 is proportional to V_2 and
L_3 is proportional to V_3 also
(L_2 plus stroke) is proportional to V_1.

Let R_1 = Compression ratio at the initial conditions, then

R_2 = Compression ratio after shims of T thickness have been added.

$$R_1 = \frac{V_1}{V_2} \text{ by Definition}$$

$$= \frac{L_2 + \text{Stroke}}{L_2}, \text{ from which}$$

$$L_2 = \frac{\text{Stroke}}{R_1 - I}$$

In like manner :—

$$L_3 = \frac{\text{Stroke}}{R_2 - I}$$

We may now set up an expression for the thickness of the required shims :—

$$L_2 - L_3 = T = \frac{\text{Stroke}}{R_1 - I} - \frac{\text{Stroke}}{R_2 - I}$$

A relation between the pressures P_2 and P_3 and the compression ratio R must now be established.

$P_1V_1^n = P_2V_2^n$ Then

$$R_1 = \left(\frac{V_1}{V_2}\right) \text{or} \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

Setting the initial pressure P_1 at atmospheric pressure or 14·7 psi and assuming various values within the usual range for P_2 it is possible to determine a relation between the compression ratio R_1 and the pressure at the end of the compression stroke. These values are shown in the following table :—

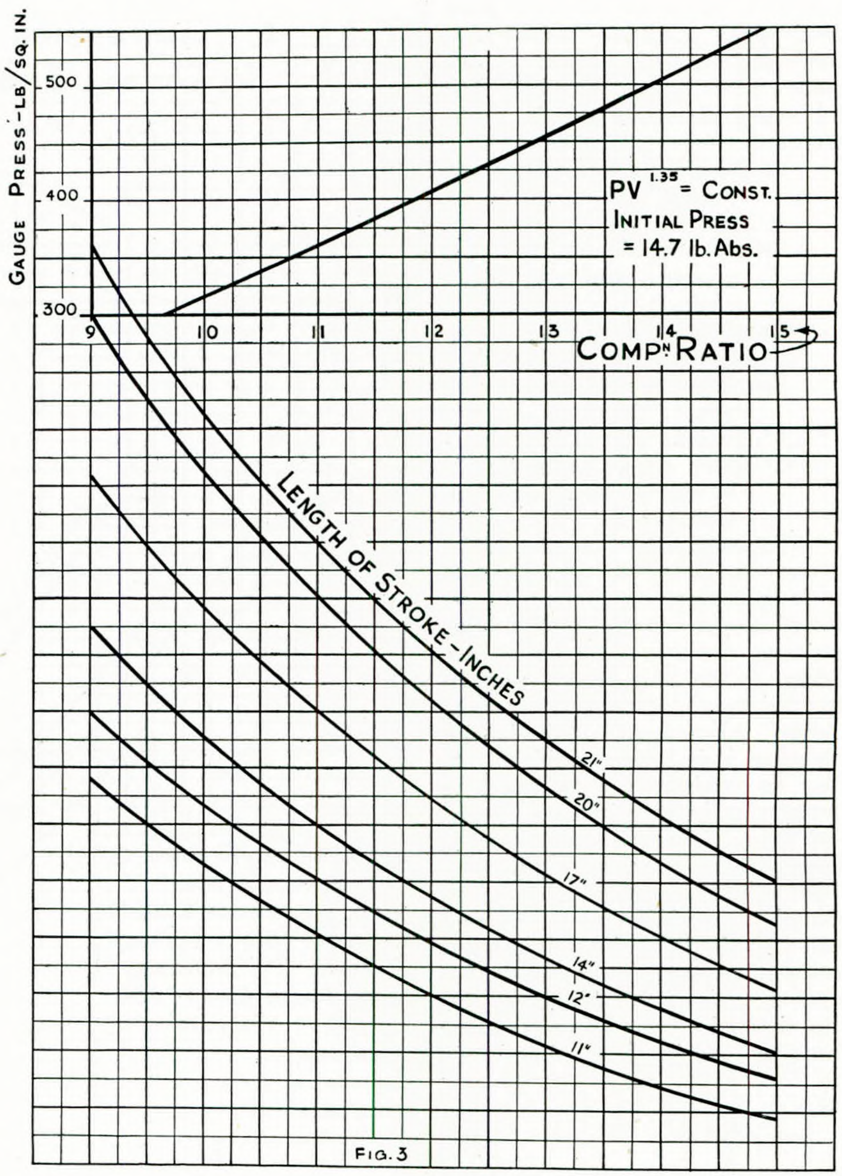

FIG. 3

TABLE I.

$$R = \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$$

Where n = 1·35, $\frac{1}{n}$ = 0·741, P_1 = 14·7

Gauge Pr. (P_2 − 14·7)	Abs. Pr. P_2	$\frac{P_2}{P_1}$	R
300	314·7	21·41	9·68
350	364·7	24·81	10·80
400	414·7	28·21	11·88
450	464·7	31·61	12·92
500	514·7	35·01	13·94
550	564·7	38·42	14·93

Using a standard 20 × 20 to the inch cross section paper the gauge pressure (P_2 − 14·7) is plotted against the compression ratio, value of the pressure

TABLE II.

Values of L_2 for various strokes and compression ratios. $L_2 = \frac{\text{Stroke}}{R-1}$ (inches)

R	R-1	33	25	24	23	21	20	17	14	12	11
9	8	4·125	3·125	3·000	2·875	2·625	2·500	2·125	1·750	1·500	1·375
10	9	3·666	2·777	2·666	2·555	2·333	2·222	1·888	1·555	1·333	1·222
11	10	3·300	2·500	2·400	2·300	2·100	2·000	1·700	1·400	1·200	1·100
12	11	2·999	2·273	2·182	2·090	1·909	1·818	1·545	1·273	1·091	·999
13	12	2·750	2·084	2·000	1·917	1·750	1·657	1·417	1·167	1·000	·917
14	13	2·538	1·923	1·846	1·769	1·615	1·538	1·307	1·076	0·923	·846
15	14	2·357	1·786	1·714	1·643	1·500	1·429	1·214	1·000	0·857	·786

being used as ordinates and the ratios as abscissae.

The formula $L_2 = \frac{\text{Stroke}}{R_1 - 1}$ gives a relation between the hypothetical length L_2, the stroke and the compression ratio. Using this relation it is possible to build up a table giving values of L_2 for the desired strokes and compression ratios. Such a table is given at the top of this page.

With this information a family of curves may be plotted for different strokes. The values of L_2 are used as ordinates with the previously plotted values of R_1 as abscissae. These curves are drawn on the same sheet below the curve giving the relationship between the gauge pressures and the compression ratio. See Fig. II. The values of L_2 are not marked on the chart as they are not required in its use. To obviate this and to permit fitting the curves on one sheet the scale of ordinates for L_2 (one small division = 0·01″) is shifted vertically as required.

To use the completed chart, Figs. 2 and 3, enter the diagram at the two points: the existing compression pressure and the desired compression pressure; carry over horizontally until the two lines intersect the curve showing the compression—compression ratio relationship. From these intersections drop down to the curve of the desired stroke. Measuring the value of the ordinate between these two new intersections gives the required shim thickness.

The curves in the form shown are suitable for use with four stroke engines. The adjustment may be made with shims under the foot of the connecting rod. Smaller short stroke engines may not have this means of adjustment, but of course the values will hold for any other adjustment provided. The curves have been used in practice with considerable success on slow speed heavy duty engines as well as on relatively high speed units. Conventional Diesel indicators are used to measure pressures.

Curves of this same type may be constructed for two stroke engines. It is only necessary that the value P_1 be known in order to complete the calculations. This is also true of four stroke engines having supercharges. The authors wish to acknowledge the helpful suggestions of Mr. L. F. Scherer, assistant chief engineer.

Lubrication Problems.

"Shipbuilding and Shipping Record", 6th October, 1938.

Despite the vast amount of research work which has been carried out in the study of the lubrication of bearings, it cannot yet be claimed that the problem has been solved. This may, perhaps, be due to the fact that the developments which are continually being made in the design of engines and machinery call incidentally for the design of better bearings. Thus, higher bearing pressures may have to be resisted or higher rubbing speeds may be employed, while as regards the bearings for all types of marine engines, the use of highly superheated steam or the adoption of the two-stroke cycle or the double-acting principle in the Diesel engine may mean that the bearings are running at higher average temperatures than hitherto. A study of the recent report of the National Physical Laboratory reveals the interesting fact that a number of problems in connection with the design of bearings have been under investigation during the past year, and while in many cases the research is proceeding, some valuable data have already been obtained from which definite conclusions can be drawn.

One of the most comprehensive of the various investigations undertaken was that dealing with the influence of speed, load, clearance and lubricant on the performance of what are termed complete-clearance bearings, that is, bearings in which there is no actual metallic contact between the shaft journal and the bush which surrounds it. An experimental bearing was constructed in which a series of bronze bushes were employed, each 2in. diameter, the diametral clearances ranging from 0·001in. up to 0·016in., relative to the steel journal, the latter being 2in. diameter and 3·5in. long, formed with a generous fillet on the end of a 4in. diameter shaft mounted in two roller bearings and driven by a belt from a variable speed electric motor. Six types of oil were tested at speeds ranging from 10 to 1,300 r.p.m., and at loads varying from 180 to 2,500lb. per sq. in. of projected area. A special apparatus was designed so that the frictional torque could be continuously and accurately measured under all conditions of running. As regards the results obtained and the conclusions drawn therefrom, while it was found impossible, on account of the effects of running in, to formulate any single relationship between the friction of the bearing and the variables under consideration, it is probable that the minimum coefficient of friction, which occurs between the stage of complete fluid film lubrication and seizure, is independent of the oil, the clearance and the load.

It is apparent that the temperature at which the bearing is run must have a profound effect upon the friction, and to investigate this problem, the journal was made hollow and means were provided for heating the bearing by means of coal gas in such a manner that close temperature control was obtainable and uniform heating of the bearing was achieved. The temperature was measured by means of a thermocouple inserted to within 0·02in. of the running surface at the point of maximum pressure. In these experiments it was found that the seizing temperature at all clearances tested was found to rise with the increase of speed and to fall with the increase of load. Generally, too, the seizing temperature was higher for lubricants of higher viscosity, such as castor oil or heavy mineral oils. In certain cases, however, some improvement was found to occur after a succession of seizures and it became apparent that a modification of the form and surface finish of the bush due to this running-in process was raising the seizing temperature. It was also evident that the seizing temperature was not entirely dependent on the viscosity of the lubricant, but was partly governed by what is usually termed its "oiliness". Somewhat akin to the above was the investigation undertaken with the idea of determining to what extent the improvement in performance that has been found to follow the prolonged running of a journal bearing in oxidising conditions is due actually to the oxidation of the lubricant. For this purpose, while the tests were in progress, hot air at a temperature of 160° C. (320° F.) was bubbled into the oil, and it was found in the course of a 30-hour test started on a new bush that successive seizures led to an increase in the seizing temperature from 200° C. to 300° C. (392° F. to 572° F.) and corresponding to this a decrease in the minimum coefficient of friction from 0·0008 to 0·00055. When, however, fresh unoxidised oil was used in a bearing which had already been run-in, it was found that the higher value of the seizing temperature on the lower value of the minimum friction was realised at once. The conclusion is reached, therefore. that the improvement is not due to oxidation, but to changes caused by the running-in process.

Cross-Channel Ships and Cylinder Wear.

"The Motor Ship", October, 1938.

It is a generally agreed theory that wear on internal-combustion-engine cylinders depends, to a considerable extent. upon the number of times the engine is started. This applies, naturally, to motor-car engines more than to those used in ships where, in many cases, they operate for two or even three weeks on end without any manœuvring. With cross-Channel vessels, however, the conditions are different, and the number of manœuvres is very much greater than those in a normal cargo or passenger vessel. It is a fact that in some cross-Channel ships the wear on the liners of the Diesel machinery has been found to be greater than that in vessels equipped with similar engines, but operating under long voyage conditions. In order partly to overcome this disability it is suggested that the cooling of the cylinder jackets and pistons should be carried out in closed circuits so that the water or oil may be heated before starting.

Elimination of Piston Rings.

"The Shipping World", 23rd November, 1938.

Certain problems and certain mechanical parts have always exercised a greater attraction for the inventive engineer than other possible avenues of development. The first illustration of the truth of this statement which comes to mind is, of course, the screw propeller, while another favourite field of invention is the piston ring. Numerous patented types of piston ring, calculated to improve the sealing qualities and reduce the wear in reciprocating prime movers, pumps, etc., have been evolved from time to time, and, of course, many of these have been exploited with great commercial success. Endeavour in this field has, if anything, been intensified with the rise of the Diesel engine, for here is a type of prime mover which is not particularly easy on piston rings. The designer's efforts have rightly been directed towards a reduction in the number of rings per piston, and at the same time a better seal between the piston and liner without increasing wear or friction. From Germany there now comes the startling proposal to eliminate piston rings altogether. It is true, of course, that the use of water grooves without any form of ring has been successfully exploited for many years in certain types of pumps, but much more ambitious applications are under contemplation.

Labyrinth Packing.

Briefly, it is the endeavour of the German experimenters to adapt the well-known labyrinth type of packing, such as is used in steam turbines, to the skirt of an engine, compressor, or pump piston, as well as in modified form to the stems of certain types of valves, etc. Experiments have shown that with a well-designed labyrinth gap packing the flow resistance is good, despite the fact that at first sight it would not appear to be so good as the true labyrinth packing, such as is used with non-reciprocating parts. It is, of course, too early to say that these revolutionary proposals are going to succeed, but from the published results it would seem that there is every likelihood of promising results. If so, interesting prospects are opened up. for there will be immediately a great reduction in piston friction. with a consequent improvement in mechanical efficiency, reduction in wear, and an increase in allowable piston speeds. First costs and maintenance costs should thus be reduced. At the same time, that very difficult problem, the coal dust internal-combustion engine, should come nearer to solution for the labyrinth gap packing could replace the special piston rings with compressed air jets behind them, etc., such as are now used. In any case, the development is one which will be watched with interest by marine engineers.

Examination of Bearing Surfaces.

"Shipbuilding and Shipping World", 20th October, 1938.

The properties of a bearing surface are known to depend upon the nature and the arrangement of the component atoms, and one of the most delicate methods available for determining the arrangement of these atoms is by the recording photographically of the diffraction pattern of a stream of electrons impinging on the surface. An idea of the practical application of this method can be obtained from the account, recently published in a contemporary, of an investigation into the nature of bearing surfaces which had been lubricated with oils containing colloidal graphite. Having obtained a photograph of the diffraction pattern from a polished layer of colloidal graphite, photographs were taken of mild steel and other metallic surfaces before and after they had been run in with oil containing colloidal graphite. These photographs showed that after running in, the surface possessed an undoubted graphoidal layer. More remarkable still was the fact that even after the surface had been rubbed with fine emery cloth the graphite pattern persisted, indicating that the graphite particles had actually penetrated the surface of the metal, although the mechanism of that penetration is not explained. The results of this experiment account for the fact that graphite-lubricated surfaces can be run dry for a considerable time without seizure.

The Study of Wear and Lubrication by Electron Diffraction.

By Professor G. I. Finch and Dr. F. D. Zahoorbux

"Gas and Oil Power" (Annual Technical Review Number), 1938.

When de Broglie's prediction of the wave character of electrons was confirmed by Thomson and Reid, and by Davisson and Germer, a new instrument for research was placed in the hands of those investigating wear and lubrication in engines. Called the electron diffraction camera, its function is to shoot a beam of high-speed electrons at approximately half the velocity of light on to the surface of a material and record on a photographic plate the pattern resulting from the diffraction of the beam by the atoms of the material. Electrons moving at high speed are more useful for surface examination, because they do not, unlike X-rays, penetrate to more than a few molecules below the surface, and so they provide complementary information to the latter.

If a surface is composed of crystals arranged at random the resulting diffraction pattern is a series of concentric rings. A film of orientated crystals on a surface gives rise usually to a series of spots on the photographic plate, the spots being symmetrically arranged, while complete atomic disorder as would be the case in a liquid surface, yields diffuse haloes. The diffraction patterns thus supply information about the structure of a surface down to atomic details and it is in this respect that electron diffraction is valuable to the engineer.

The effects of grinding as opposed to honing on a metal surface such as an engine cylinder liner or sleeve can be studied. It would appear that when a metallic surface is smoothed by abrasive methods the metal retains its crystalline structure. Smoothing by burnishing and other means where abrasion is largely absent results in the formation of an amorphous or glass-like skin on the metal. During the process high superficial temperatures are reached which cause localized melting of projections. The latter then run and congeal into amorphous metal at unstressed regions. In effect the surface is smoothed without the removal of metal by abrasion.

Examination of the face of a new bearing finished in the usual way shows it to be composed of a series of microscopic hills and valleys. Even when such a bearing is run-in under light load the bearing stresses, localized at the tops of the "high spots", cause undue pressure which melts the high spots. The metal runs down the sides of the high spots and "freezes" into an amorphous condition, so filling up the valleys referred to above. If this process is carried to completion running-in produces a smooth tough skin of "flowed" metal, referred to as a Beilby layer.

It will be seen that a necessity during running-in is protective lubrication to guard the opposite rubbing faces against abrasive wear. The good bearing qualities of cast iron are due to the protection afforded by the occluded graphite which is brought to the surface on rubbing, to provide a slippery film. Being limited in supply, the graphite can be augmented externally by means of colloidal graphite in the lubricating oil.

Not only does the graphoid layer formed on a metallic face protect the latter from abrasive wear but it averts seizure or pick-up between high spots during running-in. Consequently a deep Beilby layer is allowed to form; that is to say, the smoothing of a bearing face during running-in can be accomplished without the removal of undue metal. The graphite particles provide planes of shear between opposite rubbing faces when they press out the oilfilm and attempt to make contact. The authors conclude their paper, which is illustrated with diffraction patterns of different surfaces, by describing an experiment that showed how a bearing previously lubricated with oil containing colloidal graphite could run for a much longer period

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*Summary of a paper read at the symposium on lubrication and lubricants sponsored by the Institution of Mechanical Engineers.

without lubricant and in a dry condition than one previously lubricated with plain oil.

Piston Rings and Cylinder Wear.*

By HARTE COOKE†

"Gas and Oil Power" (Annual Technical Review Number), 1938.

A peculiar case of piston-ring and liner wear came up on the high-pressure cylinder of the injection-air compressor on a marine Diesel engine. The trouble was with the port engine of a twin-screw ship; the high-pressure piston rings would wear out each trip, and the high-pressure liner would have to be renewed about every fourth trip. The trouble was all with the port engine; the compressor on the starboard engine gave no trouble. While the ship was at the shipyard for some work, we were called in so they could demonstrate to us the difficulty with the compressor—that it was improperly constructed—out-of-line, etc. We told them that always when there was cylinder wear, it was laid to lack of alignment; but in all cases when this had been checked, lack of alignment had never been found to exist. However, a very careful investigation was made of the compressor.

The high-pressure rings were worn out, corroded and mostly gone. The liner was badly worn and rusty. A considerable deposit of material from the high-pressure rings was found on top of the low-pressure piston. The compressor was of the stepped-piston type, the low- and high-pressure cylinders being on top and the intermediate-pressure cylinder was the annular space below the low-pressure piston. Careful inspection showed no mis-alignment; the corroded rings and the deposit, however, seemed peculiar. The deposit, when analysed in the laboratory, was discovered to be about 40 per cent. sulphur.

The next problem was to find where the sulphur came from, as so much could not have come from the lubricating oil. The vessel was burning a fuel having about 3·5 per cent. sulphur. It was found that the sulphur fumes were bad in the engine room and that they came from leaky joints in the exhaust manifold. Further investigation showed a very leaky expansion joint right next to the air intake for the port air compressor. On the starboard side this corresponding joint was tight. This showed the source of the sulphur, but how did it show up only in the high pressure cylinder? An investigation of the three-stage compressor showed that in the low-intermediate-pressure stages the temperature was high in relation to the pressure, so that operation was above the dew point. With the high pressure, however, the pressure was high in relation to the temperature, so the cylinder walls were below the dew point, causing the moisture present to pick up any sulphur dioxide gas that got by the intercoolers. This sulphurous acid condition destroyed the lubrication and caused the corrosion.

When all this had been found the remedy was simple. The compressor intakes were piped to the gangway outside the engine room, and the excessive high-pressure piston-ring and liner wear disappeared. In this case the wear was due to a lack of lubrication, caused by the moisture present absorbing the corrosive gases and destroying the oil film.

*Extract of a paper delivered at the Eleventh National Oil and Gas Power Meeting of the American Society of Mechanical Engineers, held at Dallas, Texas, in June, 1938.

†Of the American Locomotive Company, Auburn, N.Y.

The Combustion Process in the Compression-ignition Engine.*

By J. W. DRINKWATER, B.Sc., D.Phil., G.I.Mech.E.,** and Professor A. C. EGERTON, M.A.†

"Gas and Oil Power" (Annual Technical Review Number), 1938.

During previous experiments on a petrol engine‡, the combustion process was followed by sampling the gases at various points in the cycle. Combustion products other than carbon dioxide and carbon monoxide were detected and found to have a bearing on the phenomena of engine "knock". The present investigation by a somewhat similar method applied to the compression-ignition engine was carried out in order to discover whether similar active intermediate compounds were formed during combustion, although the method of introducing the fuel into the cylinder differs from that of the petrol engine. The nature of the combustion process was also investigated by means of the volumetric analysis of the cylinder gases sampled at various points in the cycle.

A Crossley-Ricardo engine fitted with a Comet type of combustion chamber was used for the investigation. The gases were sampled during the later stages of the compression stroke and early stages of the expansion stroke. The sampling valve was placed (*a*) in the Comet chamber and (*b*) in the cylinder. The results are shown in the paper as a series of curves giving the percentage volume of carbon dioxide, oxygen, and carbon monoxide at various crankshaft angles. An attempt was made to determine the concentration of aldehydes in the gases; the quantity, however, was much smaller than anticipated. Oxides of nitrogen were detected in measurable quantities.

The results of the experiments show that: (1) the sampling method is suitable for investigating the chemical changes taking place during the combustion process in an internal combustion engine; (2) that combustion continues during the expansion stroke both in the Comet chamber and the cylinder; (3) that the gas expanding through the throat into

*Brief summary of a paper read on 4th April, 1938, before the Internal-combustion Engine Group of the Institution of Mechanical Engineers.

**Lecturer, Mechanical Engineering Department, The University, Birmingham.

†Professor of Chemical Technology, Imperial College of Science and Technology.

‡"Phil. Trans. Roy. Soc.", 1935, Vol. 234.

the cylinder influences the combustion; (4) that the ignition of the charge in this type of engine appears to take place near the centre of the Comet chamber; (5) the rate of combustion is greater near the centre than at the sides; and (6) the presence of nitrogen oxides is significant from the point of view of cylinder corrosion.

The experiments are fairly complete in respect of the conditions under which the engine was run, but there is scope for development of the investigation to other conditions and fuels.

The Atom and the Strength of Materials.

"The Shipping World", 16th November, 1938.

The seventh Andrew Laing Lecture, which will be of wide interest not only to the shipbuilding and marine engineering industries, but to the whole of the scientific world, was delivered before the North-East Coast Institution of Engineers and Shipbuilders last week, by Sir William Bragg, O.M., President of the Royal Society. His subject was "The Molecular Basis of the Strength of Materials", and he showed how the phenomena covered by the engineer's term "the strength of materials", was dependent on the atomic and molecular arrangements. These arrangements can now be studied by the use of X-rays, and it was with the knowledge which had been gained by these methods—through which "an enormous field of inquiry is opened up"—that Sir William Bragg was mainly concerned. After dealing with the carbon atom and with various structures in which it enters as the dominant factor, including paraffin, oils, graphite, cotton and cellulose fibre and silicon, he passed on to a consideration of the relations between structure and properties in the case of metals and alloys; as his son, W. L. Bragg, had said, "in no other field has X-ray analysis afforded results which are of such theoretical and technical interest, and of such service in elucidating a maze of hitherto unrelated data as in the investigation of metals and alloys". The atoms in this case, the lecturer explained, are packed together into the solid form on principles that differ entirely from those that are followed in organic compounds. For the most part the atoms pack together like spheres: the binding forces are due to electric attractions between those electrons which, in the solid, are easily torn away from the atoms, and positively charged atomic remainders. The structures are usually simple, the most common being one or other of the two forms in which spheres can be closely packed into a pile and a third form in which each sphere lies at the centre of a cube, the eight corners of which are occupied by similar spheres.

Among the phenomena in regard to the working of metals which Sir William dealt with were "creep" and "fatigue". Much light, he said, had undoubtedly been thrown on these important questions by the new methods of analysis. Creep, he explained, was simply the slow movement that took place when the atoms sought to arrange themselves in a new order, so relieving themselves of strain, and in general tending to a crystalline state. When all internal movement was difficult, the metal was hard, and such movements could be prevented by the incorporation of a proportion of foreign atoms, as when carbon was added to iron to make steel. In the case of iron, the permeability was in some way bound up with the freedom of movement. The nature of "fatigue" which appeared when an alloy had been subjected to a long succession of repeated stresses had been studied by Gough and his colleagues at the National Physical Laboratory. A metal specimen, Sir William said, was a conglomerate of small crystals or crystallites; it was very rarely a single crystal. Cyclic stresses tended to break up the crystallites, stopping short at a point when sufficient freedom had been obtained to permit the strain to follow the stress to an extent which could be observed by X-ray methods, but could not yet be fully explained. If the stress was increased a point was reached when no further break up into smaller crystallites was of any avail, and a break followed. It is interesting to note that the X-ray method of observing the molecular structure of materials was introduced 25 years ago. The waves of X radiation are some ten thousand times finer than those of light. It has often been recognised that in the further progress of shipbuilding and marine engineering, and particularly the latter, metallurgy will play the most important part. The explanation of present phenomena provides a sound basis for new discoveries by both the scientist and the engineer.

BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examinations for certificates of competency as Sea-Going Engineers under the provisions of the Merchant Shipping Acts.

Name.	Grade.	Port of Examination.
For week ended 3rd November, 1938:—		
Smith, James F. ...	1.C.M.	Newcastle
Johnson, Thomas F. E.	1.C.S.E.	"
Leonard, Alexander...	1.C.M.E.	"
Miller, Robert ...	1.C.M.E.	"
Stephenson, John ...	1.C.M.E.	"
Whitfield, William L.	1.C.M.E.	"
Robinson, John G. ...	1.C.S.E.	"
Preston, Samuel ...	1.C.M.E.	Liverpool
Dodd, John E. ...	1.C.M.E.	"
Haddock, Leonard G.	1.C.S.E.	"
Bell, Harvey	1.C.	"
Carson, Robert W. ...	1.C.	"
Reaveley, Alexander F.	1.C.M.	"
Clark, Royston H. ...	1.C.S.M.	"
Paton, William M. ...	1.C.M.	Leith
Boylan, John F. ...	1.C.	Dublin
Adams, Samuel ...	1.C.M.E.	Belfast
Hutchinson, Thomas G.	1.C.M.E.	Hull
Annan, Leslie G. ...	1.C.M.E.	Cardiff
Arthur, John B. ...	1.C.M.E.	"
Page, Joseph ...	1.C.	"
Leslie, Paton L. ...	1.C.	Glasgow
Taylor, William A. H.	1.C.	"
Thomson, Alexander	1.C.	"

Name.	Grade.	Port of Examination.
Commins, Albert E. ...	1.C.S.E.	Glasgow
Burton, William C.	1.C.M.E.	,,
Dowle, Harold	1.C.	London
Greenfield, Eric	1.C.	,,
Hill, Frederick C.	1.C.	,,
Woods, Edwin F. J. ...	1.C.	,,
Perry, Sydney	1.C.S.M.	,,
Walls, Thomas M. ...	1.C.S.M.	,,
Davison, Benjamin H. ...	1.C.M.E.	,,
Dawson, Herbert A. ...	1.C.M.E.	,,
Mackenzie, Fred A. ...	1.C.	Newcastle
Scott, Harold C. N. ...	1.C.	,,
Smith, Ronald	1.C.	,,

For week ended 10th November, 1938 :—

Turnbull, Robert W. ...	2.C.M.E.	Newcastle

For week ended 17th November, 1938 :—

Cuthill, Barry S.	2.C.	Glasgow
Forret, Andrew	2.C.	,,
Walker, David H.	2.C.	,,
Barrie, John D.	2.C.M.	,,
Faichney, Duncan	2.C.M.	,,
Peebles, John R.	2.C.M.	,,
Huxley, James I.	2.C.	Liverpool
Keogan, Stuart	2.C.	,,
Lloyd, Humphrey	2.C.	,,
Pullen, George	2.C.	,,
Roberts, Cadwaladr E. ...	2.C.	,,
Stephens, Clarence F. ...	2.C.	,,
Williams, John O.	2.C.	,,
McArdle, James J. ...	2.C.M.	,,
Haslin, Christopher ...	2.C.	London
Neilson, Cuthbert B. ...	2.C.	,,
Thomson, Charles W. ...	2.C.	,,
Avery, John H.	2.C.	Newcastle
Matthews, John	2.C.	,,
Nash, Frederick F.	2.C.	,,
Robinson, George W. ...	2.C.	,,
Thompson, James A. ...	2.C.	,,
Turner, James	2.C.	,,
Jeffers, Joseph	2.C.M.	,,
Tulip, John B.	2.C.M.	,,

For week ended 24th November, 1938 :—

Watson, James N.	1.C.M.E.	Newcastle
Putt, Ronald C.	1.C.	London
Braithwaite, Edward A. V.	1.C.M.E.	,,
Gibbons, Frederick L. ...	1.C.M.E.	,,
Hill, Frederick C.	1.C.M.E	,,
Turvey, William G.... ...	1.C.M.E.	,,
Venn, Cecil A.	1.C.M.E.	,,
Young, Frederick	1.C.M.E.	,,

Name.	Grade.	Port of Examination.
Clarke, James	1.C.	Glasgow
Coleman, Archibald B. Mac.D.	1.C.	,,
Johnstone, Alexander T. ...	1.C.	,,
Smith, James A. B.... ...	1.C.	,,
Dickson, John	1.C.M.E.	,,
Hamilton, Thomas	1.C.M.E.	,,
Carter, George E.	1.C.	Liverpool
Hoole, Samuel	1.C.	,,
Leahy, William J.	1.C.	,,
Morris, Patrick C.	1.C.	,,
Whieldon, Leonard	1.C.	,,
Dunn, Robert J.	1.C.M.	,,
Elordieta, Vincent	1.C.M.	,,
Bolger, James F.	1.C.M.E.	,,
Johnson, Thomas	1.C.M.E.	,,
Spence, Arthur R.	1.C.M.E.	,,
Cutter, Lancelot G.	1.C.	Newcastle
Tweddle, Robinson ...	1.C.	,,
Hultgren, Robert E.... ...	1.C.M.	,,
Wolfe, Arnold	1.C.M.	,,
Brady, Wilfrid	1.C.S.E.	,,
Holme, John	1.C.S.E.	,,
Nairne, David H.	1.C.M.E.	Glasgow

For week ended 1st December, 1938 :—

Bilbe, Walter J.	2.C.M.	Hull
Buckley, John R.	2.C.	London
Cable, Frank C.	2.C.	,,
Cain, Thomas R.	2.C.	,,
Fallon, Peter J.	2.C.	,,
Knight, Frank A.	2.C.	,,
Shaw, Donald B.	2.C.	,,
Coleman, Edward J. ...	2.C.M.	,,
Stanton, Roy J.	2.C.M.	,,
Towler, Geoffrey F. ...	2.C.M.	,,
Davies, Hugh W.	2.C.	Liverpool
Alderdice, Alexander S. M.	2.C.M.	,,
Burden, John	2.C.M.	,,
Mattson, William E.... ...	2.C.	Cardiff
Allen, Basin R.	2.C.M.	,,
Brand, James A.	2.C.	Newcastle
Lee, Henry F.	2.C.	,,
Newham, James G.	2.C.	,,
Simpson, Stanley V.	2.C.	,,
Baker, William B.	2.C.M.	,,
Nicholson, James W. ...	2.C.M.	,,
Clarkson, George	2.C.	Glasgow
Johnston, Andrew W. ...	2.C.	,,
Robb, David K.	2.C.	,,
Bate, James	2.C.M.	,,
Sneddon, Gabriel A. ...	2.C.	Leith

The late Mr. GEORGE ADAMS.

Portrait by] *[H. J. Whitlock & Sons, Ltd.*

OBITUARY.

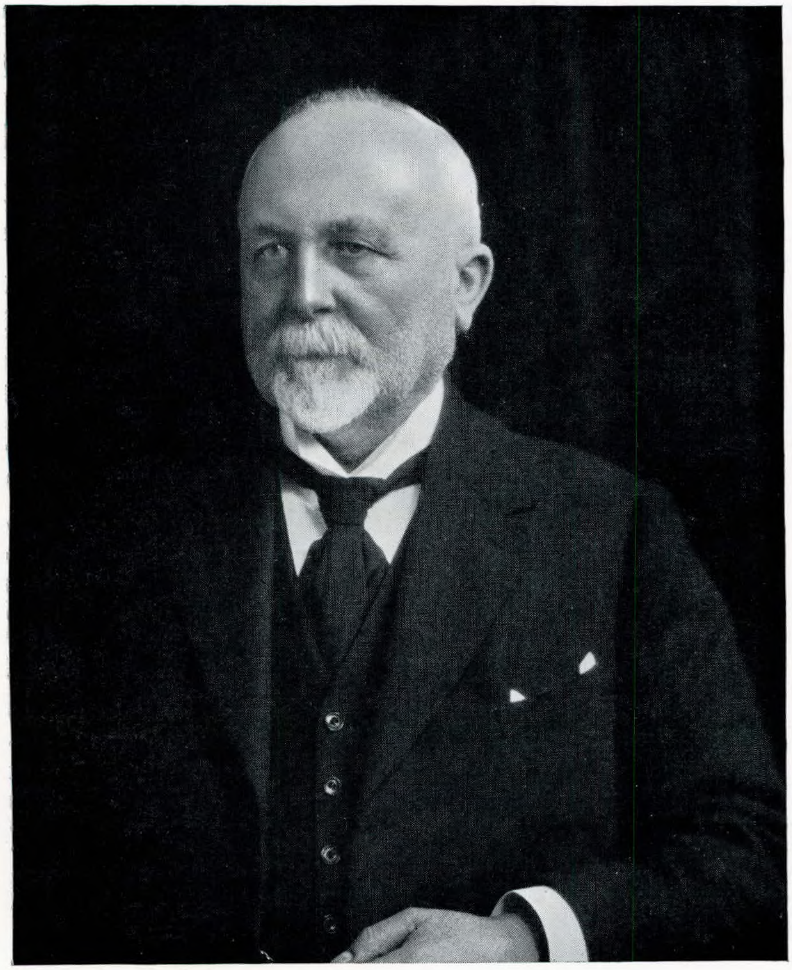
Mr. George Adams

With the deepest regret we record the death of Mr. George Adams, Vice-President, which occurred at Leytonstone on Thursday, 16th December, 1938, after some ten weeks' illness.

Mr. Adams was born at St. Albans in 1861. He served his apprenticeship with J. H. Spencer & Co., millwrights and engineers, Southwark, and began his seafaring career in the Leyland Line as fourth engineer in the "Illyrian". He afterwards served in various vessels of the National Company until, in 1887, he was appointed engineer in the steamer "Arawa" belonging to the Shaw, Savill & Albion Co., Ltd. In 1898 he became assistant to the superintendent engineer and in 1900 superintendent engineer. He was also the London superintendent for the White Star Line vessels running in the New Zealand trade under the management of Shaw, Savill & Albion Co. He retired in January, 1934, after 47 years' continuous service with his company as chief and superintendent engineer, the respect, esteem and appreciation in which he was held by the managers and staff being marked by their presenting him with a gold hunter watch and chain, with a gold thimble and a gold brooch for Mrs. Adams.

Mr. Adams was actively associated with The Institute throughout practically the whole of his shore career, from his election as a Member in 1900 till his last illness in September, 1938. He was a Member of Council in 1907, and Chairman in 1915, the eventful year during which the Council presented a testimonial to the late Admiral Lord Fisher, in recognition of his part in the conferring of military status upon the Engineering Branch of the Royal Navy, which was unfortunately withdrawn by a later Board of Admiralty. Mr. Adams was elected a Vice-President in 1916. He gave unstintingly of his time and attention to the work of various standing and special committees, particularly those in charge of Finance, Social Events, and the Benevolent Fund. When the latter became merged into The Institute of Marine Engineers Guild of Benevolence in 1934, he was unanimously elected as Chairman of the General Committee, to which office he gave loyal devotion to the last. His was a personality which inspired the affection of all with whom he became associated, whether in the course of his business, of his work for The Institute, or of his various public and private philanthropic activities.

We regret to record that Mrs. Adams survived him by only three weeks, after a protracted illness. They left no family.



The late Mr. ROBERT LESLIE, O.B.E., R.N.R. (ret.).

OBITUARY.

Mr. Robert Leslie, O.B.E., R.N.R. (ret.).

We regret to record the death of Mr. Robert Leslie, O.B.E., R.N.R. (ret.), Honorary Vice-President, which occurred at his residence, Holyrood, Burnham-on-Crouch, on Monday, 26th December, 1938, at the age of 84 years, after a month's illness.

Mr. Leslie was a native of Sanda, Orkney Islands, where he was born in April 1854. He was educated at Kirkwall Grammar School and at the Edinburgh High School, and was afterwards apprenticed to Messrs. John Scott & Son, engineers, of Inverkeithing. In 1874 he joined the Peninsular and Oriental Steam Ship Co. as fifth engineer of the "Surat", and within two years he became chief engineer, while serving in the "Brindisi". Altogether he sailed in twenty-one of the Company's steamers, the last being the "Britannia", when she made the then record voyage from London to Australia in 34 days. In 1888 he was appointed the Company's manager of works at the Albert Docks, a position he held for nearly 15 years, during which time he fitted out and equipped several of the Company's vessels as hospital ships and transports for the Admiralty, and he received the thanks of the Lords of the Admiralty for the excellent manner in which the work had been carried out. In 1903 he was appointed chief superintending engineer, and since then had seen considerable extensions to the fleet of steamers, with the additional berthing accommodation at Tilbury Docks. He retired from active service with the Company just before the war, but, on the outbreak, he was recalled to assist in a consultative capacity, and his services were then so highly appreciated by the authorities that he was awarded the O.B.E.

Mr. Leslie's death is a great loss to Burnham and district, where his generous aid had always been forthcoming for all local religious, charitable, and sporting institutions. A man of broad sympathy, church and chapel were alike to him when financial assistance was required, and it was the same with the many charitable associations which he supported. He was also anxious at all times to promote healthy sport, and took a great interest in the welfare of the younger generation. He was particularly interested in the Boy Scout movement and was chairman of the Maldon District Boy Scouts' Association. The Burnham Golf Club practically owes its existence to him and he had held the position of president since its formation. He was also a founder and president of the Burnham Constitutional Club, president of the Burnham Ramblers Football Club, a founder of the Royal Burnham Lodge of Freemasons, a member of the Royal Burnham and other yacht clubs, and of many other associations.

Mr. Leslie's connection with The Institute dates from the inaugural meeting of engineers at the Albert Docks in 1888 which resulted in the foundation of The Institute on 2nd February, 1889, and he was the last survivor of the Members who signed the original Articles of Association. He was No. 7 on the Membership Roll, and he subsequently held the office of Honorary Treasurer for eight years. Later, in 1903, he was elected a Vice-President, and was made an Honorary Vice-President in 1935. He was also a Member of the Institution of Naval Architects and of the Institute of Metals. He leaves a widow, Mrs. Bertha Leslie, J.P., with whom much sympathy is felt among the wide circle of Mr. Leslie's friends.