The INSTITUTE of MARINE ENGINEERS
Transactions

1950, Vol. LXII, No. 7

Noise in Passenger Accommodation of Ships

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The paper first discusses the general problem of noise giving a few definitions of the more important acoustical terms concerned. The definition of the phon leads to the fundamental standard for noise measurement and the development of portable secondary meters more suitable for practical use. Attention is drawn to the shortcomings of these meters and to ways of overcoming them. The sources of noise in passenger accommodation are discussed under two headings, air-borne and structure-borne, examples of each and results of some noise measurements in cabins being quoted. Methods of reducing both types of noise at the source are indicated where practicable. Reduction in transmission is often more economic and the ways in which this can be done for air-borne sound by partitions and acoustic filters and for structure-borne sound by floating floors and resilient mountings are explained quantitatively with the help of curves. Measurements have been made of the noise in a state-room with the Diesel driven auxiliary generators resiliently and solidly mounted and a comparison shows the benefits and limitations of the method.

INTRODUCTION

Comments and complaints are sometimes heard regarding the noise in passenger cabins and other rooms in ships, such as reading rooms, where quiet is desired. This is especially the case with sleeping accommodation as it is when trying to sleep that one is most critical of noises outside one's control. Some activities are essential in a ship even at night so the problem of reducing the noise and vibration associated with these activities, and especially the noise and vibration which reach the passenger accommodation, is of considerable importance. In the past, the designers of ships have had little quantitative information on which to base their designs in order to ensure quiet conditions where they are particularly desired. As a result there has been a tendency to rely on personal opinions and vague maunfacturers' claims regarding the performance of the structural materials they have for sale. The reduction of noise and vibration has now progressed to the stage of being a moderately exact science so that it is possible to design, within the limits imposed by other considerations in ships, to ensure a reasonable degree of quiet. It is proposed to outline the problems involved and indicate some of the ways they may be tackled.

DEFINITIONS

In order to preserve a consistent treatment of the subject it is necessary to define some of the terms which have been given special acoustical meanings. The matter has been dealt with comprehensively by the B.S.I.* but attention might be drawn to a few important definitions. "Sound" covers both the physical aspect of longitudinal waves in an elastic medium and the subjective aspect of the corresponding sensation evoked in the auditory system of a hearer. "Noise" is defined as "unwanted sound" so a certain sound may be, for example, "music" or "noise" depending on the hearer and his desires at the particular time in question. "Air-borne" and "structure-borne" sounds are terms used to discriminate between the two ways by which sound is propagated from source to hearer.

MEASUREMENTS

Any systematic sustained attack on the problem of reducing noise in passenger accommodation must have a quantitative basis and this involves, necessarily, a satisfactory method of measurement. Without measurement the effect of modifications may easily be lost in the uncertainties of personal opinions and recollections over periods, which may extend to days or even months, while changes are made. However, since noise, by definition, is essentially subjective, its measurement is not an easy matter. The fundamental standard for noise measurement has been laid down by the B.S.I. and has been agreed upon internationally. The equivalent loudness, or loudness level, of a sound in phons is numerically equal to the intensity level in decibels above a reference pressure of 0·0002 dyne per sq. cm. of the tone of 1,000 cycles per sec. which appears to an average observer, listening naturally with both ears while facing the source, to be as loud as the sound. While being admirable as a laboratory ultimate standard, this method of measurement is quite unsuitable for practical use. A portable subjective meter

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* British Standards Institution 1936. "Glossary of Acoustical Terms and Definitions".

using two telephone ear pieces to achieve alternate listening to the sound and reference tone has been developed and gives readings agreeing closely with the fundamental standard. However, in many cases where sounds have to be measured, the introduction of any possibility of personal bias in the result is most undesirable and a lower standard of accuracy than that obtainable with the fundamental method would be accepted in an objective meter to avoid the personal element. While an objective meter reading in accord with the subjective standard method is therefore very desirable, it is very difficult to devise.

It is true that a simple instrument can easily be made incorporating a microphone, an amplifier and an indicating instrument and that such a meter will show an increasing deflexion as a sound is made louder. However, aural comparison of sounds which are rated by such a meter as equal in magnitude shows anomalous results as obvious differences in loudness are encountered. There are two main reasons for these differences. The first is the variation in sensitivity of the ear over the audio frequency range and the second is the complex law of summation of the ear. The response of the human ear to pure tones of different frequencies has been determined in U.S.A.* and this country† and the two sets of equal loudness contours are shown in Fig. 1. There are appreciable differences between the two families of curves and these differences have not been satisfactorily explained. The U.S.A. curves have been standardized in that country but, pending the results of further work being carried out at the N.P.L., no decision regarding standard hearing contours has yet been taken in this country. Taking one of these sets of contours, it is a straightforward matter to make weighting networks which will bring the overall response of the sound meter outlined above into line with each curve in turn for pure tones of any audio frequency. While such an instrument, by its weighting, gives the equivalent loudness of pure tones in phons, it may read as much as 20 phons low on a complex noise having many components. In spite of this possibility of error, the simplicity and reproducibility of this sound level meter, as it is called, has led to its adoption‡ by the American Standards Association. Two attempts have been made, both in this country, to remove this limitation to the use of the sound level meter. The first§ was intended mainly for steady and impulsive noises over 80 phons and embodies a "nearly-peak" output meter. The second* is more comprehensive, having both peak and r.m.s. output meters, the ratio of the two readings giving a correction to add to the sound level in db in order to give a closer approximation to the equivalent loudness in phons. This measurement of the equivalent loudness of a sound by the primary standard and suitable secondary meters is very important as it ensures that the results shall be in accord with the final arbiter, the human ear. However, the numbers of phons assigned to different sounds, while ranging them correctly in order of loudness, do not give to the average individual a suitable mental picture of their relative loudness. A better impression is given by transferring the results to a loudness scale.† A convenient approximation to this scale is given by:

$$\text{Loudness} = (\text{Phons})^5 \times 10^{-8}.$$

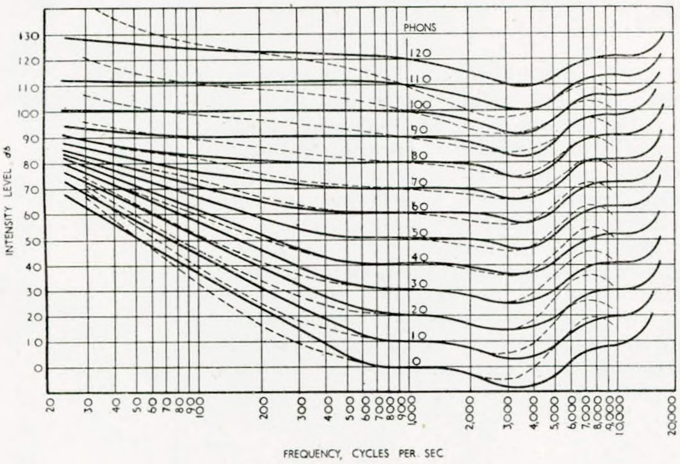

FIG. 1—*Equal loudness contours*
——— U.S.A. Standard
- - - - Churcher and King

In addition to the measurement of the overall loudness of a sound, it is very helpful,‡ in diagnosing the causes of the various component tones, to have a spectrum analysis of the sound giving the frequency and magnitude of the components. Portable instruments to make such analyses of sounds are available and their use will be apparent from the examples discussed later.

It is often better to measure sound as vibration, especially when investigating structure-borne sound. This is easily done by replacing the microphone of a noise analyser by a vibration "pick-up". The latter may respond to vibration amplitude, velocity or acceleration depending on its type but, knowing the frequency, these three bases of measurement are readily interchangeable. These methods of measurement have been described elsewhere.§

SOURCES OF NOISE IN SHIPS

Noises can be classified according to the path they follow from source to hearer as "air-borne" or "structure-borne", although in some cases both types of transmission are present in varying degrees. Air-borne sounds are those which the source radiates directly to the air and which the latter transmits as waves, possibly through walls or panels, to the hearer. Common examples in passenger cabins are the sounds from fans and leaks in air ducts and of people talking or of music in nearby cabins or passages. Structure-borne sounds are radiated as vibrations from the source to solid bodies in contact with it and these vibrations are conducted by a succession of such solid bodies in good contact, often with little attenuation, to distant surfaces, there to be radiated to the air as sound. As a result of the necessarily well-knit fabric of ships giving very good conduction of vibration, structure-borne sounds are often more important in passenger accommodation than air-borne sounds. Examples are the sounds of the engines and auxiliary machinery and also of footsteps on hard floors. Some typical noise levels in a ship's cabin are given in Table 1.

TABLE 1. TYPICAL NOISE LEVELS IN A CABIN.

		Phons
(1)	Ship stationary in dock, main engines not running, window and air vents closed. Auxiliary generators and fans running.	53
(2)	As (1) but with air vents open.	57
(3)	As (1) but ship at sea with main engines running.	60
(4)	As (3) but with air vents open.	63
(5)	As (4) but with window open (strong breeze).	70–75

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* "Proposed Standards for Noise Measurement". A.S.A. Committee on Acoustical Measurements and Terminology, J. Acoustical Soc. America, October 1933, Vol. 5, p. 109.

† CHURCHER, B. G. and KING, A. J. 1937. J.I.E.E., Vol. 81, No. 487, p. 57, "The Performance of Noise Meters in Terms of the Primary Standard".

‡ American Standards Association. 1936. Z.24.3.

§ DAVIS, A. H. 1938. J.I.E.E., Vol. 83, p. 249, "An Objective Noise Meter for the Measurement of Moderate and Loud Steady and Impulsive Noises".

* KING, A. J. *et al.* 1941. J.I.E.E., Part II, Vol. 88, No. 3, p. 163, "An Objective Noise Meter Reading in Phons for Steady Noises".

† CHURCHER, B. G., KING, A. J., and DAVIES, H. 1934. J.I.E.E., Vol. 75, p. 401, "The Measurement of Noise . . ."

‡ CHURCHER, B. G., KING, A. J. 1930. J.I.E.E., Vol. 68, p. 97, "The Analysis and Measurement of the Noise Emitted by Machinery".

§ KING, A. J. 1946. J.I.E.E., Vol. 93, Part II, No. 35, p. 435, "The Analysis of Vibration Problems".

These noise readings show that the contributions of the main engines, auxiliary machinery and ventilation are of the same order of magnitude and that they can all be eclipsed by the noise of the wind when the window is opened. A noise level of 60 phons is quite usual in the home during the day and levels of 70 to 80 phons are often found when listening to radio programmes. However, during the night the noise level in a bedroom will usually be 40 phons or less, although in some cases the ticking of clocks giving a noise of 60 phons is not only tolerated in a bedroom but actually preferred to silence. The human ear is very adaptable and most passengers soon get accustomed to the steady background of sound in a cabin but they do not like outstanding noises such as a hum conducted along the ventilating trunking from a motor-driven fan. It is, therefore, important to eliminate such outstanding noises as far as possible.

REDUCTION OF NOISE AT SOURCE

It is obviously desirable that all necessary measures to reduce noise should be taken before equipment is installed in a ship. However, it often happens that the importance of a noise is not appreciated until it is heard in a quiet cabin as opposed to the noisy test department of a works.

In some cases it is possible to reduce a noise at its source by adjustments or modifications on site, in other cases it is necessary to take the source away to be dealt with in a workshop or laboratory, and in a few cases it is not possible or economic to effect any reduction at the source. A common source of air-borne noise in a cabin is the ventilation system. When the air control is turned off, any leaks in the air director outlet or the trunking cause whistling noises which are sometimes very annoying. These leaks call for individual attention, pasting on a sheet of strong paper over leaking duct joints being one effective treatment. When the control is turned on, the issuing air may be accompanied by noise of air turbulence at the outlet and the fan hum. Turbulence can be reduced by avoiding sharp corners and by fitting guide vanes. In some cases both the turbulence and the associated noise can be reduced by using "splitters" as guide vanes at the outlet. Splitters consist of sheets of sound absorbent material in perforated metal containers, usually 1-inch to 3-inch thick, used to sub-divide the air stream in a duct into a number of parallel passages in order to increase the attenuation of sound along the duct compared with that which can be obtained by simply lining the duct with absorbent material. Typical attenuation curves for cases where the splitters reduce the duct cross-section by 50 per cent are given in Fig. 2. These curves apply for particular widths of air passages to both splitters and duct linings, the former being twice as thick as the latter. Noises due to turbulence at outlets are usually mainly high pitched so advantage can be taken of the high attenuation that can be obtained in a short length of small-spacing-and-thickness splitters, such as 1-inch spacings and 1-inch splitters or $\frac{1}{2}$-inch linings. The splitters should have rounded leading edges and tailed trailing edges to avoid further turbulence and vortices. The source of hum heard in the air stream can be investigated by a noise analyser which gives the frequency and intensity of the component tones. The frequency of the fundamental will usually be found to coincide with the number of blades on the fan multiplied by its revolutions per second so confirming the fan as the source. Modifications to the fan to reduce its noise are best done by the manufacturer who may be able to make a satisfactory compromise between air quantity and noise. A reduction in diameter of the blades is sometimes effective if a reduced air quantity can be tolerated.

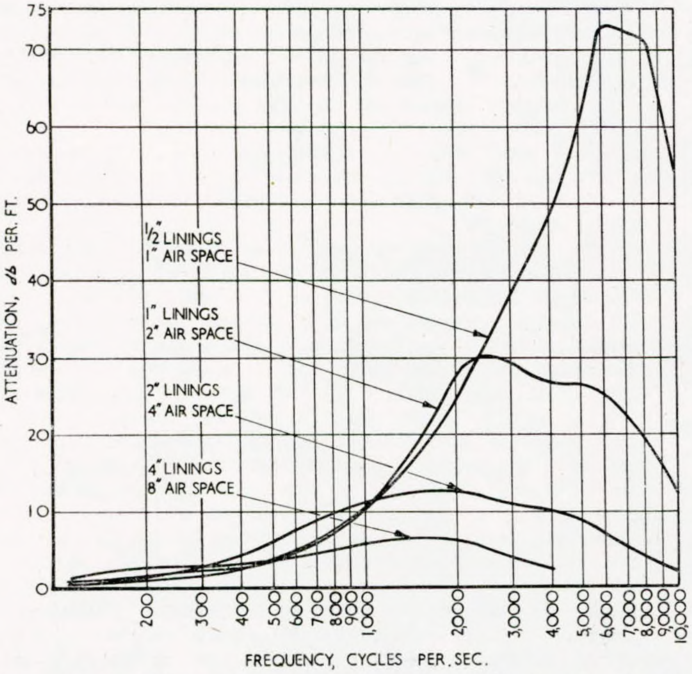

FIG. 2—*Variation of attenuation with thickness of porous linings for ducts in which air space is 50 per cent of total duct width*

Rock wool linings (13·7lb. per cu. ft.)

The sound of talking or of music in adjoining cabins is difficult to reduce at the source apart from asking passengers to exercise restraint. Some reduction can be obtained by introducing soft furnishings, carpets and sound absorbent linings to the cabins, but it is an expensive way of obtaining a small improvement in noise, as doubling the absorption in a cabin reduces the noise only 3 db.

The most important sources of structure-borne noise are usually the propellers, main and auxiliary engines and gears although a hum conducted along metal ventilating trunking can be very annoying. As regards the main engines, little can be done to reduce the noise of either turbines or Diesels once they are installed. The importance of a high degree of dynamic balance in turbines to reduce vibrations of rotational frequency and harmonics is realized by manufacturers and electronic methods have been devised to facilitate balancing and to keep a check on it. In Diesels the firing frequency and its harmonics cause most disturbance owing to the discontinuous impulses which are inevitable to the Diesel system. A more continuous burning process, such as that in a gas turbine, would avoid these discontinuous impulses but would no doubt have other drawbacks. Other sources of structure-borne noise are Diesel-driven generators, motor-driven pumps, refrigerators and, in some cases, steering gear. The importance of reducing the vibration on all these auxiliaries should be stressed to the respective manufacturers when ordering. In the case of electric motors, the most common source of structure-borne noise is the "magnetic note" or vibration of the frame due to the impulses associated with armature teeth leaving pole tips. These impulses, which may get conducted along ventilating trunking to the cabins, can be reduced by lowering the flux density in the teeth, skewing the armature or pole tips in d.c. machines and grading the air gap. Such changes make for a somewhat larger and more expensive machine but they are often justified by the reduction achieved.

Ball and roller bearings constitute another cause of structure-borne noise, this time with a distributed spectrum. Minute irregularities, less than 10^{-4} inch, are sufficient at medium and high frequencies to generate a fairly loud sound, e.g., a motor shaft, without any armature, running in ball or roller bearings will generate a sound of 60 to 70 phons whereas a similar shaft running in journal bearings on an oil film will usually be inaudible. The oil film is essential to quiet running as then there is no metal to metal contact and imperfections in machining of the bearing surfaces are accommodated by the oil film without any appreciable disturbance. The disadvantages of journal bearings are the periodical attention they require and the necessity to provide for taking any end thrust such as that from a fan runner.

The characteristic whine of gears usually has a frequency corresponding to the teeth contacts per second and is then due to incorrect profile of the teeth so that if one member rotates with a constant angular velocity the other has superimposed on its average velocity a ripple of contact frequency. The angular acceleration to give the ripple involves an oscillatory torque and pulsating reaction forces at the bearings. The oscillatory component transmitted through the bearings vibrates the gear case at contact frequency and the "gear note" is radiated. In hobbed gears the profile can be improved by careful checking of the hob and in important cases this checking is done by the N.P.L. Some improvement can usually be made by scraping the high spots on the teeth but this calls for experience and care. Another note, the "phantom gear" note, is sometimes heard from a precision cut gear. This is due to incorrect machining of the worm drive to the table on which the gear was cut. These two notes can be distinguished by their frequency. If the frequency of the gear note is obtained by a sound or vibration analyser and is divided by the revolutions per second of the gear wheel, the contact note will give the number of teeth on the wheel and the "phantom" note the number of teeth on the cutting table. The phantom note calls for attention to the worm drive of the cutting table although some improvement can often be achieved by running the gear fed with glass powder. This must be done very carefully as too much grinding spoils the profile and increases the contact note. By keeping a check with an analyser after successive grinding runs an optimum for the two notes has been achieved.

ATTENUATION OF SOUND AND VIBRATION IN TRANSMISSION

The attenuation of the air-borne sound entering a closed cabin is determined very largely by the mass of the walls, the relation between mass per sq. ft. and attenuation over the audio frequency range being given by the curves of Fig. 3. This relation is very much simplified and applies only when the wall is sealed, i.e., not porous, and is not resonant at one of its natural modes of vibration. The necessity of a heavy wall for high attenuation at low frequencies is unfortunate for the shipbuilder who naturally wishes to keep unnecessary weight to a minimum. The problem of increasing the attenuation without increasing mass has received much attention, especially in the aircraft industry. There is an instinctive tendency on the part of many engineers to rely on light porous materials for sound proofing. Fig. 4 gives the results of some tests on the attenuation of sound through rock wool of 10lb. per cu. ft. For comparison, the straight line gives the attenuation of a solid partition of 10lb. per sq. ft., i.e., of the same mass as a layer of the rock wool 1-foot thick. It is seen that even with a 1-foot layer, which is seldom used, the solid partition is better up to 600 cycles per sec. For a porous layer half as thick the attenuation in db is halved whereas for a solid partition of half the thickness and mass the attenuation is only 6 db less. A combination which is sometimes adopted is to use two sheets of non-porous material with a layer of porous material between them. If the porous material is 3 inch thick or more, this construction can give a somewhat higher attenuation at frequencies above 1,000 cycles per sec. than that given by a solid partition of the same total mass. However, as most of the noises heard in ships' cabins are of medium and low frequencies, the extra attenuation attainable in this way at higher frequencies may be unnecessary. It is important to avoid any sharp resonances of partitions as at these natural frequencies the attenuation is very much reduced. The underlying principle is to arrange that flexing of the partition will introduce viscous or friction forces which will give the necessary damping to prevent any sharp resonance. Such damping is often inherent to a composite partition but a simple panel, such as a single sheet of aluminium, will have many sharp resonances. Damping can be introduced to such a panel by using two similar sheets riveted or spot welded together at a few points, with a sheet of paper between if desired. Any flexing causes the two sheets of metal to rub on each other, or on the paper, and so damps the vibration. Dissimilar sheets may be used so long as one is not so weak compared with the other as to move with it and not introduce adequate damping either by relative movement or by internal hysteresis. A good example of a material possessing this property of internal hysteresis in a marked degree is lead. One possible "dead" construction would, therefore, consist of two sheets of aluminium with a sheet of lead between. Composite panels can obviously be made with many other constituents depending on the materials available and any other considerations, such as structural, thermal or condensation, but bearing in mind the essential points outlined above.

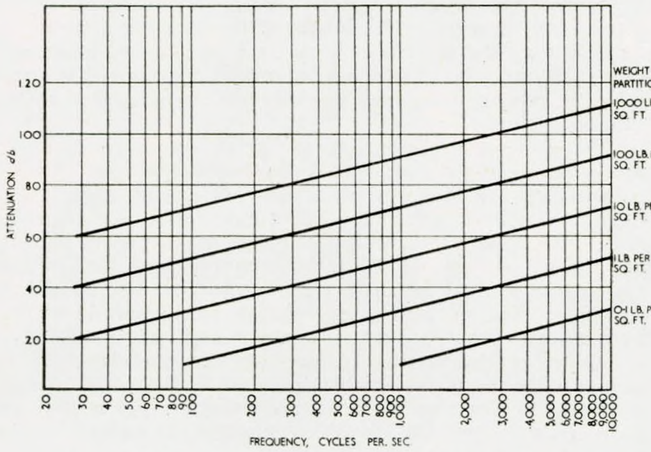

FIG. 3—*Attenuation of sound by partitions*

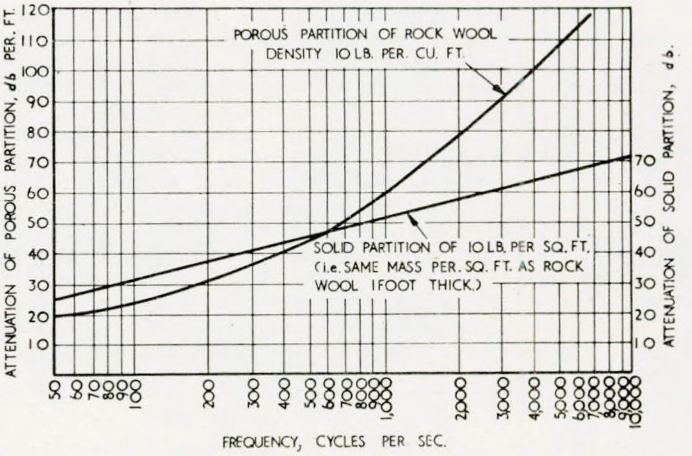

FIG. 4—*Sound attenuation of partitions*

The method of attenuating sound in air ducts by absorbent linings and splitters has already been given in connexion with reducing the noise of air turbulence at outlets into rooms. The main difference between this case and that of attenuating the fan-hum carried along the ducts is one of degree due to the lower frequency of the hum. Fig. 2 shows that in order to obtain a useful attenuation per foot at a medium frequency, linings 1-inch to 2-inch thick or splitters 2-inch to 4-inch thick should be used. Even then the attenuation is not so great as with thinner layers at higher frequencies. As an example of the use of Fig. 2, if a noise analyser shows that the fan-hum in a cabin is of 500 cycles per sec. and to make it bearable the intensity should be reduced by 15 db then the curves show that 2-feet length of 4-inch air space with 2-inch thick linings of porous material such as rock wool would be suitable. If a single air passage 4-inch wide is insufficient, a wider duct can be sub-divided by 4-inch splitters into the required number of 4-inch passages, leaving either 2-inch linings or 2-inch air space at the sides. If there are other component tones present the choice of length and size of splitters or linings may have to be a compromise. An easily remembered rule to find the thickness of lining and width of air space to give good attenuation to a particular tone is that the minimum lining thickness should be approximately 1/12th of a wavelength, i.e., take the wavelength in feet and call it inches. The thickness of splitters and width of air spaces should then be twice as much. The upper-limit of frequency for good attenuation is fixed by the width of the air spaces which must not be greater than twice the wavelength. The latter in feet is obtained by dividing the velocity, 1,100ft. per sec., by the frequency in cycles per sec.

Since structure-borne sound is transmitted as vibration, the problem of reducing it is that of reducing the transmission of vibration from the source to the vicinity of the hearer. The most effective way of doing this is by interposing resilient mountings between the source of the vibration and the structure, in the present case, of the ship. The softer the resilient mountings the smaller the oscillatory forces brought into play by a vibration of given amplitude and the larger the compression of the mountings due to the weight of the source. Put mathematically, if h is the elastic compression in inches of the resilient mountings due to the weight of the source, the vertical natural frequency (f_0) of the source is given by $f_0 = \sqrt{\frac{10}{h}}$ and, at a frequency f greater than $3f_0$, the attenuation of vibration between the source and solid foundations is $(f/f_0)^2$ times. If the resilient mountings are not perfectly elastic and the dynamic stiffness s_d is k times the static stiffness s_s, then $f_0 = \sqrt{\frac{10k}{h}}$. The attenuation of vibration is then $\frac{f^2h}{10k}$ times or 20 log $\left(\frac{f^2h}{10k}\right)$ decibels.

The dependence of the attenuation on frequency and compression for perfectly elastic mountings, i.e., $k = 1$, is shown in Fig. 5. For mountings with k greater than unity the actual compression required to give a certain attenuation must be that shown in the curves multiplied by k. The important of this point has not been appreciated in the past principally because it was usually assumed that static compression tests were sufficient to define the stiffness to vibration, i.e., that $k = 1$. In practice the value of k ranges from unity for steel springs, 1·5 to 2·0 for rubber, 2-5 for cork, and up to 20 or more for felt. If a material is overloaded the value of k can be considerably increased and the attenuation correspondingly reduced.

The above simple theory applies only to vertical vibrations but these are the ones which usually give trouble and have to be reduced. There are actually six ways in which a supported body can vibrate and unless the centre of gravity of the body is in the plane of the supports, the vertical and rocking modes are coupled together. However, the vertical natural frequency is in most cases the highest so if it can be arranged to be one-third or less of the lowest exciting vibration frequency then the attenuation of the other modes will be automatically higher than that of the vertical mode.

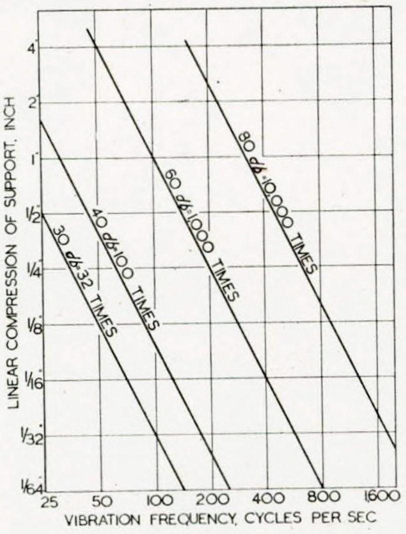

FIG. 5—*Variation of vibration attenuation with frequency and linear compression of support*

If a machine is self-contained on a rigid bed, resilient mountings can be placed under the bed and the whole flexibly supported. This is the case with Diesel electric generators and motor-driven auxiliaries and appliances. Care must be taken to see that all connexions, such as cables and pipes, to the suspended machine are more flexible than the supports. A difficulty arises when it is necessary to attenuate low frequencies in that large elastic compressions are required. Objections are raised to such large compressions on board ship owing to uncertainty as to their behaviour in rough weather. This uncertainty is largely removed if the supports are arranged to include the centre of gravity of the machine and its bed in their plane and the lateral stiffness of the supports in both horizontal directions is the same as the vertical. Proprietary mountings which permit this are commercially available. If the machine is not self-contained but is connected by a belt or shaft to another machine or to the main propeller, provision must be made to accommodate relative vibration and yet to take the reaction forces of the drive.

In the case of main propulsion drives the provision of a really flexible coupling to the propeller shaft is very difficult, particularly in large sizes. As an example of the benefits and difficulties of resilient mountings, some results may be quoted of an investigation of structure-borne sound in the cabins of a liner while in dock. The auxiliary generators of this ship are Diesel driven, one set having a 5-cylinder engine mounted on resilient pads and the other an 8-cylinder engine solidly mounted.

The noise in a typical cabin was measured and analysed for each auxiliary set operating in turn and the results are given in Table 2.

TABLE 2. NOISE IN CABIN.

Overall noise	Resiliently mounted set	59 phons
	Solidly mounted set	64 phons

Noise Analysis

f, cycles per sec.	Intensity level, db	Equivalent loudness, phons	Source
Resiliently mounted set			
16	50	—	Fundamental firing frequency
21	53	—	
32	56	—	2nd harmonic firing frequency
80	52	23	5th harmonic firing frequency
410	35	31	
Solidly mounted set			
32	65	—	
104	54	33	4th harmonic firing frequency
150 250	47	37	Band of components

The vibrations of the cabin floors in the two cases were also analysed and the results are given in Table 3.

TABLE 3. VIBRATION ANALYSIS ON CABIN FLOOR.

f, cycles per sec.	Amplitude, inch $\times 10^{-3}$	Source
Resiliently mounted set		
16	0·06	Fundamental firing frequency
32	0·016	2nd harmonic firing frequency
80	0·006	5th harmonic firing frequency
240	0·0006	15th harmonic firing frequency
340	0·0004	
Solidly mounted set		
26	0·16	Fundamental firing frequency
400	0·0005	

Since the two sets are not identical, having different numbers of cylinders, and therefore different explosion frequencies, it would be dangerous to deduce too much from these results. However, vibration measurements on the engines showed that the resiliently mounted 5-cylinder engine had several times the amplitude of vibration of the solidly mounted 8-cylinder engine, as would be expected, yet in spite of this, the noise and vibration in the cabin was appreciably less in the resiliently mounted case.

Still further reductions in the transmitted vibration would be possible if more flexible mountings were permitted. In choosing these mountings it is important to choose materials with a low value of k operating under conditions which will ensure that this low value is operative and is maintained over a reasonable life. Steel coil springs have the merits of $k = 1$ and little creep if not overloaded but they have a succession of sharp resonances at which they become stiff. The trouble is largely avoided by using leaf springs in which damping is provided by interlaminar friction between adjacent leaves. The natural frequencies are then not so pronounced.

The conduction of vibration from motor-driven fans along metal ventilating trunking to the cabins has been mentioned because it has caused trouble in the past. It is now realized that in addition to resiliently mounting the motor, the connexion between the fan and ducting should be flexible. The requirements in regard to magnetic vibration of the motor can then be relaxed somewhat.

Another way in which resilience can be used on board ship and elsewhere is to reduce footstep noises and other impact noises from the floor above. A layer of carpet on the floor reduces both the noise in the same room as the walker or floor impact and that in the room below. Where this is not permissible or is unable to reduce the transmitted impulses sufficiently, another and more effective method can be used. The method is to create on the normal floor a floating floor consisting of any convenient floor construction, such as a boarded floor, resting on a sheet of resilient material, such as glass wool. A loading of about 1lb. per sq. in. gives a compression of about 50 per cent so, as k for glass wool is quite low, a very good attenuation of structure-borne footstep and other floor impact noises is obtainable with a layer of glass wool only ½-inch or so thick.

It has not been possible in the paper to deal exhaustively with the subject of noise in passenger accommodation as many more surveys of different sizes and types of ships would be necessary to ensure that all the offending sources of noise had been identified and measures evolved to reduce them satisfactorily. However, it is hoped that the ground that has been covered will be helpful to shipbuilders and the manufacturers of machinery for installation in ships.

The author's thanks are due to Mr. A. S. Ennis for carrying out noise surveys in ships and to Mr. L. Baker, Marine Superintendent, Messrs. Alfred Holt and Co., for so kindly permitting him to quote the results of tests on the Blue Funnel liners. He also records his thanks to Sir Arthur P. M. Fleming, C.B.E., D.Eng., Director, and Mr. B. G. Churcher, M.Sc., Manager Research Department, Metropolitan-Vickers Electrical Co., Ltd., for permission to publish this paper.

Discussion

MR. L. BAKER, D.S.C. (Member of Council) said that the author had described what might be expressed as the scientific side of noise, but there was also a less scientific factor which was unfortunately in many cases the predominant one. This was the psychological aspect. Many would well know of psychological tests being carried out where various research workers had succeeded in proving the opposite of each other. The result depended very largely upon the personal factor, and also, unfortunately, upon the individual person's training. If he might quote an example for which neither the author nor the engineers were responsible, in the working of a ship the technically trained man would be glad when he heard the grunts and groans coming from the hull because it would tell him the stress was being relieved satisfactorily and he need not worry. The passenger, on the other hand, might complain bitterly. He, however, was interested in noise in the engineering sense in that it did indicate inefficiency. It might not be a major factor, but it was nevertheless a factor. It was not known at present just how much noise affected the human element—the engineers on watch: that was under active research. He was hoping that the results, when they came forward, would be of as much value as many other psychological tests had been—properly conducted tests, that was to say.

It had been the practice in his company to use "Paxmarine" for sound insulation of the engine room or boiler house. He believed this was originally done for fear that the noise in motor ships would be transmitted through the hull and keep the crew and passengers awake. It was interesting to see from Fig. 4 that as good a result might have been obtained by putting another ⅛ or ¼ inch on the thickness of the bulkheads. Fortunately the practice justified itself from another and entirely different aspect, and that was heat. "Paxmarine" was, in addition to being sound insulating, also heat insulating, and the effect of the insulating material had had a very comforting effect on the accommodation generally.

He was somewhat surprised that there was no note in the paper on the subject of the motor gun-boat No. 2009. The silencing of the compressor inlet was a very convincing demonstration of what could be achieved. As originally built, the gun-boat was uninhabitable on deck on account of compressor noise. After the author had remedied this defect, it was a pleasure to be on deck so far as the compressor was concerned, but the funnel was then found to be making just as much noise on a different frequency, and that was not quite so easy to tackle.

So far as cargo liners were concerned, the main sources of noise were, he thought, unquestionably fans for the ventilation system and the Diesel engines for auxiliary purposes. The fans were, he thought, relatively easy to deal with, but the Diesel engines produced vibrations rather than sounds in frequencies that were objectionable, and they presented a very serious problem. It might be straining after a gnat to seek perfection in this field, but the subject was of interest not so much from the comfort angle as from the effect of these vibrations on the seatings over a period of years. One of the expenses which had to be met after some twenty or so years in service was virtually complete reconstruction of the engine seatings, and it was hoped by attention to resilient mountings to avoid this.

MR. J. K. W. MACVICAR (Associate) said the author had referred to the need for introducing instruments for measuring sounds, and such instruments were, of course, of undoubted value in making comparisons between different types of noise-producing equipment and also in establishing to what extent noise emanating from any particular component had been produced by the introduction of sound traps or other measures.

It was some years since he had had the opportunity of utilizing such an instrument, but it was undoubtedly true that any analytical approach to this problem involved the use of a suitable measuring instrument. He felt, however, that where complaint of noise had been made, say, in a passenger cabin once the ship was at sea, the person making the complaint was not particularly interested in the intensity of the noise as measured in phons or decibels, nor was he concerned with any reduction of this noise as shown by the instruments if the noise itself continued to be objectionable. In such a case—and this was the usual approach on board ship—it would be agreed that the human ear formed the only criterion as to whether or not the noise in question was in fact objectionable.

He felt sure the author would agree that frequently the background noises were of considerable importance. One might take, for example, the case of the much maligned ventilation system with its accompanying noises and make a comparison between the ship at rest with the ventilation on at full speed and the same condition when the ship was under way at sea. The intensity of the noise from the ventilation system was, of course, not altered to any degree, but the introduction of the usual ship background noises in many cases completely masked the ventilation note.

Then again there were many kinds of noises, and he liked the author's suggestion that noise was "unwanted sound". For example, the noise from a ventilation system in a relatively cold climate might be most objectionable, but the same noise became almost a welcome sound in the extreme conditions encountered in the tropics.

While very little of the noise emanating from a ventilation system was due to the fan itself, particularly where well-designed centrifugal fans were used, it was undoubtedly true that where the indiscriminate use of standard fans designed for all purposes was adopted, then the fan noise was really quite important. This was very obvious during the war on troop ships and on naval vessels where all-purposes fans had to be installed. Similarly, if axial flow fans were used for accommodation ventilation, as had been suggested in some quarters trouble was bound to follow, as even the best of axial flow fans could not compare with a well-designed centrifugal fan from a quiet-running point of view.

The author's remarks on the introduction of some form of acoustic lining in the duct work were, of course, true; but in his own experience the lining of ducts for a relatively short length off the fan was of the greatest value in as much as it tended to stop the resonance of the metal ducts, and from this point of view it was probably of greater value than sound filtering in the form of splitters. A combination of both was, of course, valuable.

The author's suggestion of trunks having air-spacing equal to the cross-sectional area of the sound-absorbing material was not easily accommodated on board ship, where the ventilation engineer was always in difficulties in any case. Experience and it was the kind of noise that could be cured by sound insulation, to put half inch of suitable material covered with, say, perforated plate. This almost invariably stopped the noise and certainly stopped the resonance of the duct work. A combination of splitters and lining would be of value, but there again the space problem arose.

The author also mentioned the possibility of isolating the duct work from the fan by means of a flexible connexion between the fan and the ducting, and this was adopted in many cases; but in his own experience it was of very little value.

The author had commented on whistling noises caused by air leakage, and naturally on any first-class installation these leaks would be sealed before the ship was handed over. He did not like the suggestion of curing this trouble by pasting pieces of paper over the leaky joints, but it could easily be overcome by means of a suitable compound.

Noise from the air terminals could, of course, be very annoying when pressure was high, as everyone knew who had had experience at sea, but again this objectionable noise became a welcome sound in hot weather, and since all the louvres were usually open in hot weather complaint was seldom made.

He was also interested in the author's comments on the use of ball bearings associated with fan motors, and he agreed that ring-oil journal bearings were infinitely superior. The amount of attention these bearings required was not great, nor was it found in practice that the end thrust bearing, which was necessary for a fan, ever constituted any major source of trouble.

The introduction of flexible mountings on board ship was not very easily accomplished in the positions fans and motors were normally fitted, and he would hesitate to utilize them as a general method of avoiding noise transmission except in very special circumstances. The main point with ventilation was to ensure that the motors driving the fans were entirely free of magnetic hum, and he could not accept the author's suggestion that if the motor and fan were resiliently mounted and the connexion between the fan and ducting was flexible, the requirements in regard to magnetic vibration could be somewhat relaxed. He contended that this was a very dangerous suggestion. His own experience with this class of work had convinced him that only super-silent machines should be fitted, as in the early days it was no uncommon experience to find the fan motor running comparatively quietly and apparently satisfactorily, but three decks down the magnetic hum from a particular machine created almost unbearable conditions.

Mr. Baker, in his remarks, had mentioned the question of bearable noise and how much noise was actually bearable. As a matter of interest, before the war a foreign Navy, in building battleships, had decided to have enclosed stokeholds with a stokehold pressure of up to 18 inch. They had used turbine-driven axial flow fans for creating draught. The noise level was extremely high, and the length of the period a man could remain on watch was governed by his physical endurance of the noise of the fan and not by the actual work he was doing.

MR. V. L. FARTHING (Member) said before dealing with noise it would be desirable to consider the source of the noise. Was it, for instance, structure-borne or air-borne, or both? Was it to be dealt with by sound absorbent or solid structure methods to prevent the passage of noise, or by a combination of both? Then there was the question of economics. A Diesel engine power station had recently been treated with sound absorbing material but instruments had shown very little real reduction in noise level. The reduction was quite enough, however, to make a noticeable difference, and the people concerned were convinced that although they had spent a lot of money, it was worth it.

With regard to the splitter, if one used this method one did not need to use so great a thickness in lining the fan ducting. Contrary to the experience of Mr. MacVicar, it must be about twelve years since noise had been quietened in fan ductings by splitters and also by using either leather or canvas between the fan and the ducting and so interrupting the had been found to be very successful.

One question that had not been commented on in the discussion was the noise heard in cabins due to people walking along decks. The author did mention that this could be overcome by putting some suitable absorbent on the deck or by carpets or something of that kind. There had been developed recently, however, a system for affixing to the undersides of the staterooms a material which tended to prevent sound. The difficulty previously had been a method of attachment to prevent the transmission of structure-borne sound vibration.

He agreed with the last speaker that axial flow fans, while they might be very efficient, did need treatment. Flexible mountings required a great deal of thought, and one or two materials were on the market, but he did not think there was a really satisfactory material yet which would maintain resilience but he was presently investigating a new material.

MR. R. S. DADSON said that the paper was largely concerned with the fundamental problems of noise measurement and noise reduction, and it was extremely important that this work should be supplemented by information on the manner in which sound was transmitted from place to place in particular classes of ships. So far very little information was available on this subject.

The author had referred to the distinction between air-borne and structure-borne sound. Before remedies could be tackled effectively, the different ways in which noise could be transmitted from the source to points in the accommodation must be understood. In some cases, such as ventilation noise, this was likely to be fairly obvious, and there would be little difficulty in knowing what sort of measures to apply. In other cases very careful examination might be necessary before a decision could be reached. He might mention one example. Suppose a power unit in the engine-room was giving rise to unwanted noise in the accommodation. One had to distinguish immediately between two possibilities: firstly, the structural vibration from the power unit might be transmitted from its supports to the structure of the ship and in this case straight away to distant parts of the accommodation; but there was another possibility, and that was that the machines might emit air-borne noise into the engine-room which air-borne noise would fall on the bounding surfaces of the engine-room, setting them into vibration, which would be transmitted to the accommodation. Clearly the methods of dealing with noise were quite different in the two cases. In the first case one had to consider such measures as resilient mounting, flexible connexions and other means for damping the transmission of vibration through the structure of the ship to the distant points. In the second case it was possible the appropriate measure would be to put absorbing material in the engine-room itself, such as was done in some cases. But frequently quite elaborate experimental work on a ship or on a particular class of ship was necessary before one could be sure which of these methods one must adopt.

The author remarked that some of the measurements obtained indicated that the contributions of the main engines, auxiliary machinery and ventilation were of the same order of magnitude. That might be true in one class of ship but he did not think it was by any means generally true. He had come across a case, for example, in which the main machinery was responsible almost entirely for the noise reaching the accommodation, and other cases in which auxiliary equipment might be more prominent.

With regard to the effects of resilient mountings, if it was shown that in a particular case the noise from a power unit was structure-borne, then the first thing which would occur to one would, of course, be to mount it on resilient mountings or to improve the mountings. He thought it desirable that one should get information by direct measurements on the effect of such mountings. Measurements should be made on power units, or engines, before and after they were mounted, and there seemed to be very little information of that kind in published form. The author had given some results in Table 2, although actually the two engines concerned were not the same, one being a five cylinder and the other eight-cylinder. In the same connexion, there was no doubt that it was most important to ensure that any beneficial effects from resilient mountings were not nullified by rigid piping or other incidental rigid fixings.

He would like, in conclusion, to stress that one did not know enough about this problem yet to generalize as between different classes of ships. What was really needed was a great deal more experimental evidence on the methods of transmission of noise in ships and the relative importance of different sources.

MR. A. F. EVANS (Member) speaking from the passenger's point of view, said that he did not see how noise could be calibrated by instrumentation, except as a direct comparison.

On a sailing ship on a breezy night, making ten or twelve knots there was a great deal of noise. If this was recorded it would be found to be very complex and of considerable magnitude. One could, however, go to sleep in that noise. If, unfortunately, there be a door in the alley-way, loose on its hook, sleep might be out of the question.

The working of a ship could be pleasant though he never felt quite happy when the noise was from the relative movement of the woodwork, the cabin paneling for instance, and the steel structure. Why could not this woodwork be mounted on some form of rubber buffer?

One might have an inaudible steam engine. It was pleasant in the engine room but it was not the same for the passengers and the noise differed in various parts of the ship.

He had had a number of trips in some small vessels engined with a pair of eight-cylinder, 800 r.p.m. 500 h.p. engines. Outside the engine room one could not hear them running, one could hear the propellers but not the engines.

Inside the engine room it was an unbearable scream, no other noise could be produced that was audible.

How could one measure that?

With regard to auxiliaries, he had been on a turbine ship recently and one could not hear the propelling machinery at all. She had three fairly large auxiliaries, two always in operation. They made a considerable noise with one running but with both together as they came into synchronization and out again repeatedly, at long and short intervals, the ship was really uncomfortable.

Some time ago an American had a yacht built with twin screws. He objected to this disconcerting and unessential effect and he had synchronizing gear fitted consisting of an alternator on each engine with their armatures electrically coupled and a controlled exciter circuit. This was cut in automatically at the right phase. The improvement that this made was startling.

If a ship was provided with alternating current this could no doubt be easily arranged.

The subject of resilient mountings was interesting but whatever one did one would get rebound. In a motor car where this was pronounced they fitted dampers or dashpots. If the engine were mounted on heavy springs and provided with dashpots it might be effective if suitable radius rods were employed.

MR. J. W. COULTHARD, D.S.C. (Member) said he had great admiration for getting down to mathematical certainty in the manner undertaken by the author to investigate this noise problem. He had first experienced the practical side of the question in the year 1936 when he had charge of a small ship of the cross-Channel passenger type, powered by trunk piston Diesel engines of 3,000 b.h.p. The noise in the engine room was tremendous, and the vibration was quite severe in the machinery space. Much of the noise and vibration was noticeable throughout the ship; often the vibration was blamed for sea-sickness amongst the passengers. Incidentally, research on industrial ailments had indicated that vibration from buffing machines tended to promote a high sickness rate in female operators. So, possibly, there was something in the excuse made by lady passengers when a rough crossing caused sea-sickness.

Anticipating the building of a new ship, he set down in writing to the owners a few suggestions for their consideration. One of these ideas was to line the engine room casing with absorbent material, also all static metal parts to absorb noise vibrations. The ship was built in the following year with this idea incorporated, the casing and deck-head being lined with a proprietary brand of asbestos slabs. For this vessel it was also suggested that some form of mounting for the Diesel generators which would reduce the vibration should be fitted. It had been observed that the general vibration throughout the vessel was due to the auxiliaries as much as the main engines. Whilst little could be envisaged for reducing the main engine vibrations it was thought possible to do something with the auxiliaries.

In due course when the second ship was built he had gone to the builders for trials, etc., and asked what they were doing to reduce generator vibration. They had replied "That is all right, we have fitted one inch thick rubber slabs under the bed-plates". At this time little had been done to develop what later became known as resilient mountings so these engines were bolted hard down; no flexible pipes were fitted. During the subsequent trials the holding-down bolts fractured; even chrome-nickel bolts were tried without avail. Finally, realizing that bolting hard down on rubber gave a live load it was decided to remove the rubber and fit normal cast iron chocks.

In the third ship, built in 1939, the generators were fitted with resilient mountings which consisted of one inch thick pads made of rubber and cork composition bound in steel. The h.d. bolts were also fitted with pads above and below the bed-plate so that the engine floated. The bolts had to be tightened by hand only, using a six-inch leverage. All attachments, pipes, etc., were made as flexible as possible; the pipes, of the copper coil type, started to leak after two weeks service. Bands of black tape eventually gave way to ordinary rubber tubing for the water services, the copper pipes being discarded.

Since that time he had been associated with flexible pipes on high speed engines which were of the hose type fitted with a patent joint. If that joint leaked one could do nothing about it, so it was necessary to carry a stock of spare pipes.

That was some indication of what one was up against in those early days of efforts to overcome the noise and vibration problem. These efforts did much to lessen the noise. One further improvement might have been to install a noise-lock to the engine room entrances, rather in the manner of an air-lock.

To deviate a little from that to discuss the physical aspect of noise and its effect on human beings, he had been working for twenty years with Diesels before 1936 without experiencing really severe noise. In 1943 he had attended a London hospital where he was told he was tone deaf to the lower frequencies due to prolonged contact with noise. He had also noticed when serving in these vessels that until accustomed to the noise, watch-keeping was unusually tiring.

Two years ago he had visited a factory where high speed Diesel engines were being tested in the same shop wherein they were erected. Since some six were on test at the same time something had to be done to reduce noise. This was achieved by wheeling a steel hood, lined with sound absorbing substance, over the whole engine. Possibly something on these lines could be attempted, that was, confine the noise at the source.

Author's Reply

DR. KING wrote in reply that the discussion had been very useful as many interesting points of practical importance had been mentioned. Mr. Baker referred to the psychological factor which was so dependent on the point of view of the hearer. An example somewhat similar to the one quoted occurred during the war when the noise of testing aero-engines lulled the works manager to sleep but kept all the other nearby residents awake. When, through some defect, the engines stopped the manager awoke wondering what was wrong, while the other residents heaved a thankful sigh of relief and went to sleep. It was obviously impossible for noise meters to take account of such factors although the point was covered by the definition of noise at the beginning of the paper. As shown by Fig. 4 heavy solid partitions usually had higher acoustic attenuations than light porous ones although thermally the position was reversed. He and his colleagues had carried out many investigations on warships but the results could not be quoted. However, it could be said that the marked reduction in the compressor noise of M.G.B. No. 2009, noted by Mr. Baker, was effected by applying the data of Fig. 2. The importance of resilient mountings for Diesel driven auxiliaries could not be stressed too much and Mr. Baker was well advised to make them as flexible as sea-going conditions permitted.

Background noise, mentioned by Mr. MacVicar, was very important as it was only in so far as a particular sound obtruded above the background that it was noticed. Usually a sound had to be 10 or more phons louder than the background to be obtrusive although it might be detected when 20 phons less. It was true that space considerations in ships might make it impossible to use 50 per cent. space factors in ventilating ducts. If less space was allotted to linings or splitters, longer treated lengths were required but were usually permissible. It was a matter for careful design after analysing the noise in question. Fig. 2 showed that ½-inch thick linings gave good attenuation only at high frequencies but the damping effect on duct walls might be effective at lower frequencies. Other ways of increasing the damping of panels were given on p. 260. Resilient mountings which would attenuate the magnetic vibration of a motor by 20db or more were readily available. It was, therefore, a question of economics whether it was better to use a standard and relatively cheap electric motor on resilient mountings or a specially designed and, therefore, dearer motor with solid mounting. Questions of delivery and stocks of spares must also be borne in mind. Although axial flow fans were usually noisy, appreciable reductions in the fan blade components had been achieved by fitting a shroud to the blade tips.

Mr. Farthing's experience in lining a Diesel engine power station confirmed the statement in the paper that the reduction resulting from an expensive lining might be indicated by measurements to be only a few phons. However, the sounds were localized and this gave an apparent improvement which was important in large factories such as cotton mills.

He was in complete agreement with Mr. Dadson on the necessity for careful individual study in order to determine the mechanism by which sound was transmitted from source to hearer in any particular ship. He also agreed that much more experimental evidence on different kinds of ships was very desirable and would be necessary before it would be possible to ensure quiet cabins at the design stage instead of having to make costly alterations later.

In reply to Mr. Evans, the standard method of measuring noise was by aural comparison with a standard reference tone. Noise meters should give the same answer as the aural comparison method but, unfortunately, many of them read somewhat low. The real difficulty in the case mentioned was in comparing a more or less steady windage noise with the intermittent noise of a rattling door. The latter was difficult to measure objectively but a rough measurement could be made subjectively. It might be dangerous to stop the creaking noises of timbered ships as the strength and performance in rough weather might be affected. The synchronization of engines was a useful way of reducing their nuisance effect and was utilized in aircraft during the war. Usually resilient mountings had sufficient inherent damping as they did not operate for any length of time at resonance. Steel springs, however, had very low damping and were sometimes fitted with friction shock absorbers, as on cars, where there was excitation at the natural frequency either during running up and down in speed or by impulses. Under normal steady conditions, resilient mountings were better without damping.

There was some evidence that Mr. Coulthard might be right in associating a very loud noise with sea-sickness. A person without ears could not be made sea-sick. Many engineers fitted sheets of rubber or cork of quite arbitrary thickness and area as resilient mountings and then bolted down solidly. The thickness and area of resilient material should be calculated for the desired attenuation from the frequencies present and the weight of the machine and all holding down bolts must be fitted with resilient washers and bushes. Similarly all pipes and other connexions from the machine to the ship must be made flexible. Mr. Coulthard's partial deafness through loud noises could have been avoided if he had worn good ear defenders. These had been found very beneficial where they had been used consistently and not left off as was often the case.

The use of a suitably designed hood over a machine on test in a works provided an effective and convenient way of reducing the noise in the works from a noisy machine, but it also enabled a quiet machine to be tested in a noisy shop.

Crankcase Explosions*

Mr. G. E. Windeler (Member, I.Mar.E.) who opened the discussion said that he was very interested to note that the title of this discussion was the very open one of "Crankcase Explosions"; it was not qualified in any way to indicate that it referred only to internal combustion engines. He had known several cases of crank chamber explosions on steam engines of the enclosed pressure-lubricated type. It was not implied that there had been a very great number of explosions in either Diesel engines or steam engines, and indeed, there had not been a great many; but the results of some of those that had occurred had been unfortunate, for they had been fatal. Naturally, such cases had had a good deal of publicity.

As engineers they wanted to know, first, what were the causes of these explosions, and secondly, what they could do to prevent them. They were not just looking for a cure, but for means of prevention.

Among the possibilities which would lead to explosions there was an enclosed chamber in which a number of parts were revolving and reciprocating. In the main, the engines were single-acting; therefore, there was a good deal of displacement in the crankcase, due to the pistons descending and rising again, a displacement of the air, mist and anything else that was there.

In the very early days of Diesel engines he had a two-cylinder engine, of 24 inch stroke, having the unfortunate feature that it would exhaust the air through the aperture provided for ventilation, carrying with it a good deal of oil, which was blown all over the place. He put a valve on to the aperture with a view to dealing with the trouble.

When the engines were started up, and if they blew some of the contents of the crankcases out through the openings, some people might well assume that there had been an explosion or, as some called it, a "blob" or a "puff". At any rate, they knew that there was displacement, and probably such displacements had occurred on a great number of engines, giving rise to the assumption that they would cause explosions or were associated with explosions.

The running parts of an engine were very susceptible to seizure. He had known bad seizures of pistons to occur owing to the gap in the piston ring being too small. As the piston ring warmed up, it could only partially get rid of its heat through the piston body, and there was an oil film between the ring and the cylinder wall; so that it could reach a fairly high temperature. As the piston expanded, and if the ring gap was small, the ring could buckle and could seize the piston. He had seen one or two rather bad cases of such happenings where the gaps in the piston rings had been only about one-third as large as they should be; when the gaps had been increased, the trouble had ceased.

A point which was very vulnerable was the piston pin, which was fixed in the piston with a fairly tight fit. If it was too tight, it distorted the body of the piston; if it was too easy, it would hammer when the piston warmed up. If the top piston bearings got hot and began to expand, it forced the piston out at the point where the bosses that retained it joined up with the body of the piston. That was a very vulnerable change of section, and investigation of piston seizures had shown that very wide bands of seize marks occurred opposite those particular points, generally at about four places on the piston circumference. Quite high temperatures could be attained; indeed, where a 22-inch diameter piston had seized, he had noticed that the metal had reached the plastic condition, so that it rippled as the piston moved up the cylinder walls. Examination of the liner showed displacements and little surface cracks, due to the pull when the piston moved. The fact that the metal was in the plastic condition meant that it was at least of blood red colour, probably 500 or 600 deg. F. When that occurred, pistons were distorted and the liners had been known to crack in cases where that part of the liner had not been water-cooled. He could not say that he had ever seen a liner cracked right through, due to the seizure of the piston, but where liners were not cooled they would crack. Obviously, if they cracked there was very severe distortion, and in his opinion it was dangerous to run a piston that had seized and cooled again until it was taken out, examined and gauged, to ensure that it was of the size that it ought to be, because once it had seized, it did not subsequently push itself back to its original round shape, but formed an octagonal or other undesirable shape, so that there would be an intense pressure on the bearings which would again cause seizure.

If such parts became hot they would constitute a danger, for there was a good deal of oil splashed about the crankcase. The crankcase contents were in a state of considerable turbulence, due to the disturbance from the piston, and so on; there was a good deal of splashing, and the air in the crankcase was mixed with any liquid which was being thrown about. Oil from the piston pin was quite a large source; oil came down in quite a stream from the inside of the piston. In cases where a piston had been allowed to run with very hot surfaces he had seen the portion at the bottom light up and the oil there actually burning—feebly, he agreed, but nevertheless burning.

He investigated two cases of trouble in steam engines, crosshead engines, with forced lubrication. At a power station many years ago the engineer on watch had taken a spanner and had taken off the door. The moment he did that and let in the air, there was an explosion, and he was killed. That had occurred on more than one occasion, fortunately not on the type of engine now common, but nevertheless it had occurred in the past. He thought it was a good idea that the D.E.U.A. and the Institute of Marine Engineers had got together on this matter, for they were both concerned with Diesel engines and probably they had a great deal more experience of those engines than had the makers, experience of what actually happened. He was sure they all agreed that it was their duty to find out all they could about preventing these troubles, and that the information should be broadly publicised so that others might profit by it also. They did not want any statutory regulations telling them how many times the piston must be swilled with oil, or anything of that kind; they knew all that, but the users and the makers of engines in particular wanted to ensure that something should be done to prevent these occurrences.

Mr. Windeler said that in 1901 he had a Diesel engine, a crosshead engine, with a piston rod and a comparatively narrow piston, and it had piston rings $\frac{3}{4}$-inch wide. After all, they did not want anything more there than just something which would carry an oil film. However, he found out what was the trouble with it and why the owners did not continue to run it. After putting it right, he ran it in order to find out what load it would take. It was interesting to note that, as the load was

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* Report of a discussion at a joint meeting of the Diesel Engine Users' Association with the Institute, held on 3rd November 1949. Mr. W. Howes (President of the Diesel Engine Users' Association) was in the Chair.

raised beyond that at which the engine was supposed to be rated, the piston head began to get red; from the under side he could see it showing change of colour. He put on a little more load, and the colour of the head became a little brighter. He then put on a little more still—the engine was of about 800 h.p., at 130 r.p.m.—and the head became fairly bright; then, without warning, blow-by occurred past the piston rings, and sheets of flame started to blow. He had by him a bucket-full of lubricating oil; he took a chance and poured some fuel oil into it, and squirted the mixture on to the cylinder walls. After he had done that three times, the blow-by stopped, the flame disappeared. But the labourer who was helping him felt that he ought to do it, and he bumped his elbow accidentally, with the result that oil was squirted on to the hot part of the piston. A flame about 12 feet long came out. He was very fortunate not to be burned seriously. However, the experience indicated to him that, if an engine were overloaded to an extent that the piston reached a really high temperature, it was dangerous to splash oil on it.

Open type engines were then built, with comparatively long stroke, so that there was a chance for the heat to be dispersed from the body of the piston on to the cylinder walls. If there was a piston of fairly large diameter it would be appreciated that the crown would become increasingly hot as heat was applied, because that heat could not be got away, so that a fin or circular rib was used in order to transfer the heat down to a point below the piston rings, to carry away the heat under safe conditions. He had known such engines in those days having pistons of 12-inch diameter and a stroke of some 18¼ inch developing the "enormous" power of 50 h.p. per cylinder. There was a time when the power drifted down to 35 h.p. per cylinder.

In one engine the speed was increased from the 100 r.p.m. for which it was designed to 200, then to 230 and a *pro rata* increase of power was obtained. It was then increased to 300 r.p.m. and the engine developed 60 h.p. per cylinder. It was found that if the m.e.p. was kept right the speed was just run up and the governor was set to suit.

When that engine was converted to the enclosed type, the story was rather different. It was then found possible to get very considerable accumulations of vapour in the crankcase; and on the end of the bed plate there was a large door which was opened in order to take out the strainer for cleaning. On one occasion, when they were trying to determine how much could be got out of the engine and it had become rather hot, there was a "blob" of about 3 inch coming out to the air, showing that there was too much pressure in the crankcase. The air was drawn away through the air induction pipe in order to change the atmosphere in the crankcase. Whether or not that was a good thing to do he did not know, but it seemed to him to be safer that way than to have a lot of air going in and constantly mixing with vapour, so that the least inflammation would set it off.

At the end of the first world war quite a lot of submarines and submarine engines were taken from the Germans; three of the engines were sent to them so that they could look over them and find out what were the interesting and novel features about them, and report to the authorities. They noticed that one of the engines had on the door which gave access to the crankcase a small circular door made of perforated metal, with a disk of what he would call Wattman drawing paper on the front of it and a ring with two or three setscrews to keep it on. When he saw it he felt that the paper, if blown off at very high velocity, could quite easily do injury to a man. The second engine, he noticed, had a similar fitting, but it was secured by four or five bars of very small round-section material standing out perhaps ½ inch or ¾ inch from the door; they were placed horizontally across the front, obviously to prevent it flying off. So that he assumed the Germans must have had some bother with the arrangement on the first engine, and that in the second engine, which was of a later type as shown by the number, they had tried to remedy the trouble.

He was not at all sure that he would regard that method as being the right one to prevent the pressure rising in the crankcase. If such doors could be blown out, they would be just as damaging to personnel as would any other type. However, something had to be tried.

It might be asked whether, apart from the piston and the piston pin, any other parts of engines gave trouble. He knew of an engine in which a crankshaft was running on bronze bushes and where, as the result of the failure of the lubrication, two of the bushes seized; that caused rise of pressure in the crankcase and a violent detonation occurred. Fortunately, no-one was hurt, but the experience showed that the danger was not limited to the piston, piston pin and top end bearing. Anything that was hot, so that it could raise the temperature of the vaporized fuel oil and render it volatile and likely to detonate, gave the possibility of trouble.

When a piston pin expanded it caused a lot of damage, for not only did it destroy the piston, but also the liner. On one occasion, therefore, they tried a floating pin. As the piston crown and body were separate parts, he conceived the idea of using a square ended piston pin in the round hole in the round body, so that it could float. Turning the matter over in his mind, he concluded that, if it did seize in the piston body, the square would open out the hole and the situation would be worse than it would be normally; so that he did not follow that line.

At about that time he told Mr. (now Sir Harry) Ricardo about this problem, and indicated what he had thought of doing. He said he was terrified because if it did seize in the piston part of the bearing it would push the piston out of shape, and possibly the result would be worse than ever. Some days after that he wrote and suggested making it round all the way through. That was how the floating pin came about; they brought it into being and, cautiously, they decided to fit it in their shop engine.

At that time he had arrived at another opinion, that all piston pins were far too long in the bearings, so that under combustion pressure the pins bent. It might seem strange that that should be so, but he did apply a static pressure equal to the combustion load and found that the pin did bend. Then he shortened the pin, and the result was that bending did not occur. They put in three pistons, one with the floating pin and no bolts in the connecting rod (a new connecting rod), and that did away with the bolt trouble. There had always been the potential danger that a bolt would break. They ran the engine fitted with the floating pin for six or eight months, and the amount of wear on the piston pin was practically negligible. But the curious thing was that they could hear the engine start up and come on to load; then the noise would die down, and about every half hour or so there would be a repetition of rapping noise, which would quickly die down again. Nothing else happened. One day, however, he decided to put a brake on the flywheel in order to stop the engine quickly and to find out what had happened. He put the engine on to load and, as soon as he heard a couple of raps, he threw the load off, jammed on the brake to pull up the engine as soon as possible, and then took out the piston. He found that the lubricating hole they had put into the pin, with nicely rounded edges, and so on, for delivering oil to the centre of the pin, had worked round to the top of the piston, and the oil was not getting into the bearings. Subsequently it inched itself round and began to empty oil into the bearing again, and the trouble ceased temporarily. Therefore, he drilled three holes, and that cured the trouble. In his opinion the floating pin cured all possibilties of piston seizure, except where there was scale on the liner, where there were overloads, and factors of that sort.

The difficulty about all these cases that had occurred was to get at the actual facts, the conditions that applied; it was difficult to repeat the conditions applying at the time of seizure in subsequent research work.

These troubles had occurred on internal combustion engines of the crosshead type, and had been due to the crosshead and not to the piston, there being expansion in the guide and consequent seizure. Then somebody opened the door and there one had the conditions which produced combustion; there was a rise of pressure, and it did not need a great rise of pressure to blow off the door of a crankcase. There was the danger that the volatile and burning material from the crankcase might be blown around the engine room.

Having experienced this trouble of crankcase explosion, he could say with confidence that it did happen.

It might be asked how explosions occurred, and whether they occurred in the water-cooled or oil-cooled types of engine. Oil could not be splashed on to the piston, for it did not become just nominally warm, but it got very hot. There was no question that there were certain vulnerables inside the engine. But when they thought of the millions of horse-power installed in the form of Diesel engines, even on the high seas only, and related it to the number of accidents that had occurred at sea, he did not think they needed to worry themselves a lot about it. However, like all good engineers, they wanted to find out what was likely to cause trouble, so that they could eliminate it.

MR. A. K. BRUCE (Past President, Diesel Engine Users' Association) said that this matter of explosions was no new thing and went back to the very early days of the petroleum engine. Sixty-four years ago, Akroyd Stuart, experimenting with a tinning pot, was disturbed by an explosion due to the inflammation of a mixture of petroleum vapour and air. He received a mental as well as a bodily shock, since he at once recognized the energy latent in the oil-air mixture. This led him to those experiments with engines burning heavy-oil which were to result, during 1890, in the evolution of the compression ignition engine. The description "crank chamber explosions" was, it seemed to him (Mr. Bruce), too loosely applied, since oil engine explosions were not confined to the crank chamber. Those whose memories went back to the early days of the Diesel engine would recall that explosions took place in the bottles containing the injection air and starting air. Such explosions could only take place, under certain circumstances in the exhaust manifold and elsewhere. The word "explosion" appeared to be used, moreover, to cover oil fires as well as explosions properly so-called, and he thought they should bear in mind that each occurrence needed to be considered in its proper category. An explosion could range from a mild "puff" to a violent detonation causing great damage.

In an experience of many years, the only case of a crank chamber explosion which had come before him was in connexion with an enclosed forced-lubrication high-speed steam engine, where a fitter, after removing a casing door on conclusion of full load test run, introduced a naked light. This caused a severe flash and the man was seriously burned. No damage was sustained by the engine. Such things would always happen unless the elementary precaution was taken of refraining from bringing naked lights into the neighbourhood of air saturated with oil mist.

It astonished him very much, when visiting the recent Engineering and Marine Exhibition at Olympia, to find that there was—so far as he could see—only one oil engine which carried an inscription calling attention to the danger of introducing naked lights into crank chambers. This inscription also drew attention to the need to shut down the engine should any accessible part appear to be overheated and to see that it had become cool before any casing door was opened. There should certainly be agreement, among oil engine manufacturers and engine users, as to the manifest importance of seeing that such an inscription was put in a prominent position on any such engine. The need for it had, indeed, been stressed in memoranda issued some time ago by the British Ministry of Transport and the United States Bureau of Shipping. He was sure that the presence of such a warning could have prevented many of the accidents of which particulars were known.

It would not be doubted that there must always be a cause —sometimes a plurality of causes—for any explosion on an oil engine. A major cause, as he did not doubt, had been an unsatisfactory condition of the engine and it could not be too strongly urged that oil engines required a particularly high degree of maintenance attention if they were to be kept in a condition affording security. Most of the troubles with oil engines were due to overloading and it could be deemed axiomatic that if an engine which, operating in a definitely unsatisfactory condition, was overloaded, then trouble was certain.

He remembered hearing Sir Charles Parsons remark that the most important thing about a steam turbine was its lubrication. This applied with equal emphasis to an oil engine and particular care should be taken by all oil engine users with a view to ensuring that there was no possibility of fuel oil mixing with lubricating oil. They should also make sure that the oil coolers were sufficiently large at the outset and that they be kept clean. Personally, he had never known a case where the oil cooler was too large but he had repeatedly found the oil cooler to be too small.

While his own experience had been mainly with engines of crosshead types where the combustion chamber was effectively isolated from the crank chamber, the vast majority of internal combustion engines were built with trunk pistons. There could be no doubt, however, that the larger the cylinder the more vital it became to make sure that the clearance was correct and that the alignment was accurate. Any discrepancies in these respects were apt to be dangerous and particularly so where the engine was heavily loaded. Should the combustion forces be taken on tie rods, distortion due to excessive or unequal tightening could make things worse.

He further believed that every effort should be made to ensure the minimum bombardment of the crankcase oil by the rotating parts, in which connexion the effective use of splash plates was much to be recommended.

He would also like to emphasize the importance of avoiding oil pools and even oil droplets on all external parts of the engine. A few weeks ago he was in one of the largest hydroelectric power stations in Canada and among other things, he examined the instructions issued to the personnel in respect of fire risks. There were upwards of thirty instructions, one of which was that no drop of oil should be allowed to exist on any surface including the floors. This was a rule which ought to be insisted upon in all engine rooms.

He had referred to trunk piston engines as requiring particular attention in respect of the clearance—with the engine in hot condition—between piston body and liner. The adequate sealing of the combustion chamber was also most important and special attention should be given to the maintenance of the oil scraper rings. With a heavily loaded engine any tendency to seize would cause immediate overheating, and this might not be discerned until the conditions had become really dangerous. It was certainly desirable that all practical provision be made in the way of instrumentation so that the condition of inaccessible parts be as far as possible under observation.

There seemed to be considerable differences of opinion as to whether or not the crankcases of large oil engines should be artificially ventilated. On this his experience with stationary engines had been that ordinary breathing vents were adequate, these breathing vents being open to the atmosphere of the engine room. Whether marine conditions were such as to require artificial venting he did not know, but it would be interesting to hear the views of marine engineers on this point.

He did not propose to refer to those aspects which were in the field of the lubricating oil and fuel oil specialists. Such considerations related, among other things, to crankcase oil viscosity and flash-point, which were affected by contamination by fuel oil. Mechanical engineers had quite enough on their hands in maintaining the engines at the required high operational level, but they could always make a periodic check on the viscosity and flash-point. It was assumed that the men in charge of running would be reminded, by a prominently positioned notice, as to certain precautions which must be taken should anything be seen to be overheated. Some of these precautions had already been referred to. Another of them was that to turn starting air into an engine in an overheated condition was a dangerous procedure.

MR. G. B. FOX said that the problem of prevention of explosions in crankcases could be divided into two parts, i.e.,

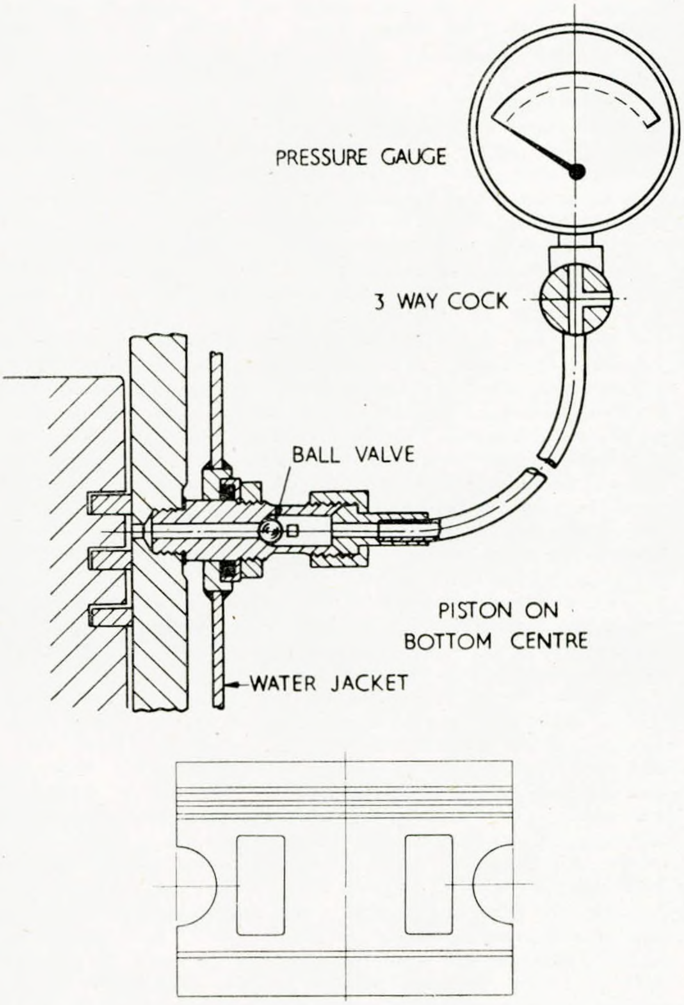


FIG. 1—*Blow-by indicator and expanded view of half a piston showing a local milled relief* $\frac{1}{32}$ *inch deep in lieu of oval turning. The other side is identical*

the formation of an explosive mixture and the means of igniting it.

It was difficult to ensure that the presence of one of these two conditions could never under any circumstances occur. A guarantee against the existence of one of them was all that was required in theory. Although possible, such a guarantee was scarcely practicable.

Considering these two factors separately, and taking the gases in the crankcase in the first place, there had been suggestions put forward that if the crankcase be kept charged with an inert gas, no explosion could occur. It had been further suggested that exhaust gas could be used economically for this purpose; it had been demonstrated that provided there was at least 7 per cent of CO_2 in the gas no explosion could take place.

Whilst this might be possible in theory, it was felt that in practice the problem of scrubbing the gas from carbon particles and removing the obnoxious acid forming constituents would be impracticable. Furthermore when blow-by existed, as it usually did more or less, a large percentage of the gas was air that had passed the rings during the compression stroke, so that unless the engine were run with a load producing well above 7 per cent CO_2 in the exhaust there would still be a risk of being within explosive mixture range. From evidence obtained in several instances, it appeared that conditions in the crank chamber had been over rich, because not until a crankcase door had been removed admitting air, had a violent explosion occurred. This condition might arise from overheated parts in the crankcase producing vapour from lubricating oil or from abnormal blow-by past the pistons.

On the contrary in normal running engines in the laboratory, samples of gas from the crankcase showed invariably that it was about 90 per cent air, thus it was felt that the factor mainly responsible was the overheating of some internal part by which both the vapour and the ignition might be produced.

It seemed then, that in order to minimize the chance of explosive conditions arising, the maximum use of temperature indicators and blow-by gauges should be made. Distant reading thermometers from main bearings; thermometers in oil pockets in crankcase doors; and a simple blow-by indicator on each cylinder together would go far to warn the engineer of abnormal conditions. A simple blow-by indicator (Fig. 1) that had proved to be invaluable for 4-stroke cycle engines in the laboratory consisted of a small hole drilled through the liner in a position between the top and second piston rings when on bottom centre; the small hole was connected by a quill through the water jacket to a non-return valve thence to a pressure gauge. The proper functioning of the top ring could be told from the pressure gauge reading and the degree of blow-by could be assessed with remarkable certainty. This indicator was used day in and day out in the laboratory; it was simple and robust and certain in action. When an engine was functioning normally, the pressure on the gauge read 50-60lb. per sq. in., and as soon as the top ring began to stick in any way, the pressure fluctuated up to (say) 100lb. per sq. in.; the pressure might ultimately go up to 200 or 250lb. per sq. in.; that indicated that early attention was required.

If remedial action could not be taken immediately after warning by the indicators, that would be the moment to apply CO_2 gas to the crankcase until such time as the trouble could be remedied.

With regard to explosion disks, etc., designed to minimize the effect of an explosion should one occur, a colleague of his told him of an interesting case in which a multi-cylinder engine was fitted on the one side of the crankcase with hand hold doors and on the other side explosion disks of a certain design. The hand hold doors were about 6 inch in diameter; they were secured in their housings by means of a simple device that squeezed out a rubber ring on the periphery. The bursting disks on the opposite side consisted of thin sheet lead supported by a plate having perforations of about one inch diameter.

A crankcase explosion did occur, when two of the hand hold doors were blown violently across the test shop, but none of the explosion disks was pierced. It suggested that one must pay careful attention to the areas involved and not place too much reliance on explosion disks. Furthermore, explosion disks should be designed for one way operation, i.e., not to let air in.

Finally he would suggest that ignition due to piston seizure was less likely to take place with aluminium alloy pistons than with cast iron pistons, partly on account of the high heat conductivity of the former. It would be interesting to know what percentage of pistons was aluminium alloy of all those involved in crankcase explosions.

MR. R. K. CRAIG (Member of Council, I.Mar.E.) said that in his opinion there was only one means of avoiding crankcase explosions, that was to ventilate the crankcase to a maximum degree, which meant using bigger fans, and passing the discharge from these through coolers to obtain recovery of oil.

He was concerned recently with a ship which was being refitted where the builders decided to vent the engine crankcases by pipes to the top deck. He told them not to do anything until proper equipment was available. Crankcases were better sealed and should never be opened until the engines had cooled down.

Reference had been made by Mr. Bruce to the posting of warning notices to engine operators in the United States. There was a Ministry of Transport requirement or recommendation in this country today that, where Diesel engines were used, such a notice must be placed in a prominent position in the engine room.

MR. BRUCE replied that he could only say that he saw a notice on only one engine at Olympia.

MR. CRAIG said that he thought if Mr. Bruce went on board any Diesel engined vessel today he would see it displayed. They had two notices—in some cases.

THE CHAIRMAN asked whether that applied only to marine engines or whether it covered land engines as well.

MR. CRAIG replied that he did not know how far the Ministry of Transport was interested in land engines, but he was speaking now of engines on board ship.

MR. F. BLACKITH said that Mr. Fox had mentioned the recording of blow-by, or checking whether or not it was likely to occur unduly at any stage of the operation of an engine. There was no doubt that the blow-by meter had given good results in their own research work.

Reference had also been made to ring gaps causing explosions, due to the high temperature caused by butting rings. It seemed to him that one of the things which it was most difficult to get engineers to do was to fit rings having sufficient gap; for some reason they seemed to think that, the closer the gap, the less would be the blow-by and the lower would be the oil consumption. A gap of 0·003 inch per inch diameter was the absolute minimum to which a ring should be fitted; a gap of 0·004 inch per inch diameter was on the safe side. It had never been proved by meters even with a gap of 1/50th of the diameter that there had been an explosion in a hot crankcase from that cause, or that the pressure did not rise until the ring gap exceeded 1/50th.

Therefore, there were two points which he saw as being most important from the point of view of preventing explosions. The first was to make sure the rings had a sufficient fitted gap to prevent butting as he mentioned before. Secondly at the first sign of blow-by, prompt action should be taken to stop the engine to investigate the cause. If the rings were found to be stuck in their grooves, find out why they were stuck, whether the trouble was due to lubricating oil, and so on, and take measures to prevent the trouble recurring. If there was evidence that detergent oil should be used, then use it. Another thing was the wedge-sectioned type of ring, where the included angle was, say, 10 deg.; such rings could not stick.

He thought it might be said that the majority of ring sticking did not occur while the engine was running; ring sticking was all, he thought, what might be termed "cold sticking". A certain amount of sludge formed on the upper face of the groove; when the engine cooled down, the ring was pushed sideways by that sludge, and until the piston attained sufficient temperature again to release the ring there would be blow-by, from the starting up, leading to crankcase explosions if the requisite conditions arose in the crankcase.

Another problem was whether to use wide or narrow rings. Obviously the narrower the ring, within reason, the better the sealing. Unfortunately all pistons, no matter how well designed, suffered distortion to a certain extent; a rigid or stiff ring could not follow those distortions, and an earlier speaker was right to advocate the use of narrow rings.

The second important point was that of boss distortion and its effect on skirt seizures. It was a question as to how large a boss should be on a piston in order to carry out its duties of supporting the pin and transmitting the load; it was important to ensure that it was not too large, for too large a mass might lead to seizure. He had relieved pistons at the point where the boss joined the body with the skirt, and that did eliminate quite a lot of the risk of seizure.

Then there was the question of piston design. Often the designer or manufacturer of a piston tried to do something at a price, and that was a mistake.

Fig. 2 was a diagram of a piston, indicating the temperatures attained in the various parts, which were far too high in the centre, and also shown was a suggested design which would result in a far cooler under side of the crown.

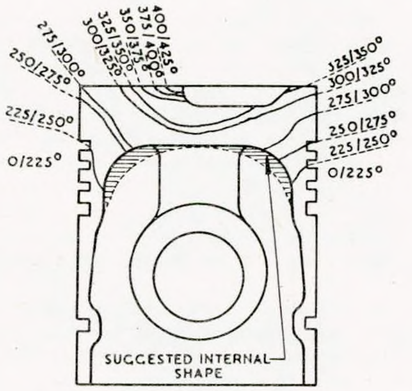


FIG. 2

THE CHAIRMAN asked whether it was an aluminium piston

MR. BLACKITH replied that it was.

Again on the question of boss distortion, in one case they came to a point where they registered some change in the structure of the material, the crystal boundaries showing signs of separating, due to flexure of the piston, and not to temperature. The piston had to be strengthened very considerably at the point in question to prevent flexure, so that they had to leave far more material there than would otherwise be necessary as shown in Fig. 3.

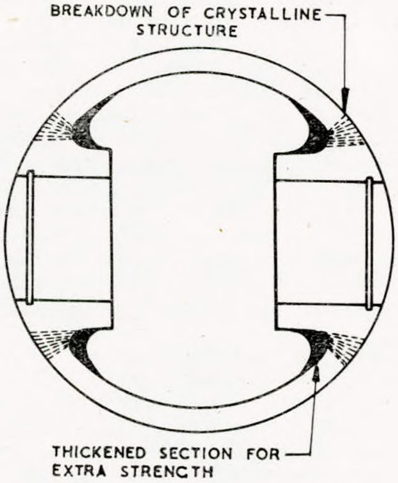


FIG. 3

MR. W. E. B. DAINTON said that he could not agree more with what Mr. Bruce had said concerning the importance of employing the right personnel, and he ventured to suggest that most of the explosions that had been experienced would not have occurred if the personnel who were on watch had really understood what they were watching and had taken sufficient interest from the point of view of preventing the conditions which had caused the explosion. It was a practical impossibility to prevent the gas in a crankcase getting into such a condition that, if anything inside was burning, or if there was a hot spot, there was a serious risk of explosion.

Some years ago he had to enquire into the causes of a small explosion that had occurred in a crankcase of a Diesel engine, and he found, as he had often found in engineering matters generally, that the best information came from something not directly associated with the subject in hand. In this case, he obtained it from reading some reports on explosions in coal mines. One of the points emerging from these reports was that the dangerous condition was not due to rich mixture, so long as that condition was maintained. With various substances there were various critical points in the mixture proportions at which explosion might occur. In the case of coal dust suspended in air there was the complication created by the gas that was given off by the dust particles. Similarly in the case of particles of oil suspended in air there was the complication of the vapour from the oil particles. When there was a thin mixture, burning within the confined space produced relatively inert gases, which had a damping effect on an explosion, but as the oxygen was used up a critical point in the mixture might be reached at which explosion or progressive combustion might occur.

Most of the so-called "explosions" in Diesel engine crankcases were really caused by burning rather than detonation, and the burning was progressive. If one ensured that the mixture in the crankcase was very thin, that was not a total answer to their problem, because in bad conditions, particularly where there was overheating, there would be a certain amount of oil vapour which no crankcase ventilation could prevent or clear adequately. Secondly, if the temperature became high enough to ignite the oil, and if there was very good ventilation the crankcase fire that would result would be very serious. So that, even if there was excessive ventilation, unless one had good maintenance and a high standard of watch-keeping, one would not provide the cure.

A suggestion made by Mr. Fox referred to prevention by added instruments. In running machinery one might make it completely fool proof. But he was afraid the British way was to build their marine engines to be run by engineers, and he would say advisedly that unless they encouraged successfully their junior men to be efficient and to take a keen interest in their engines, they would continue to have trouble.

On matters of design, recently he saw a marine Diesel engine in the works of a leading maker, so designed that the spill from the fuel pumps, which were inside the structure, drained to the outside and ran along an open gutter at the bottom of the engine into a tank. That was bad. Also the design was such that contamination of the crankcase oil with fuel oil was inevitable. He emphasized that this was a modern engine.

Crankcase explosions were the exception rather than the rule and they must not make too much of them without considering that, generally speaking, they occurred in cases where there had been a certain amount of neglect, either in watch-keeping or maintenance, and possibly a little defect in design.

Mr. J. R. P. Smith said that they might be interested in a brief description of a crankcase explosion which occurred a year or so ago in an engine which was under his charge.

This engine was of the trunk piston type, fitted with oil cooled aluminium pistons, 21·5 inch diameter. The first sign of trouble was the appearance of a small quantity of aluminium flakes on the oil strainers, but as the engine had recently been fitted with new piston heads it was thought that some aluminium shavings, which had been trapped somewhere in the system, had become dislodged. This theory was supported by the fact that the quantity found on the strainers became progressively less after each running period, until at the end of the third day practically no aluminium appeared.

The next evening, at about 5.15 p.m., two explosions occurred; the first, which was a minor one, blew off one or two of the light pressed steel inspection lids which were fitted to the crankcase doors, and the second, which occurred whilst the engine was running down after the fuel was cut off, removed the remainder of the pressed steel lids, together with some 140 sheets of glass from the engine room roof and walls.

On examining the engine it was found that the head had broken off one of the bolts used for bolting the piston head on to the body and had been bouncing up and down in the oil chamber of the piston. Aluminium had been shaved off for a while until all sharp corners had worn off the bolt head, and it had then proceeded to hammer its way through the piston crown.

There was no other damage to the engine, and he thought it was fairly safe to say that the light inspection doors saved any major damage; on the other hand, if there had not been any light doors the first explosion might not have opened up the crankcase to atmosphere, and the second explosion might not have occurred. It seemed reasonable to assume that had self-closing explosion doors been fitted to the engine, the second explosion would not have occurred, and the resultant damage to the building would have been nil.

With regard to the bolts breaking, he had not been in charge of the plant for many months when the incident occurred, but he learnt later that piston head bolts had frequently broken in the past, and that in all previous cases the break had taken place at the threaded end. The design of the piston prevented a broken bolt entering the oil chamber provided it did not break close under the head.

The bolts were $\frac{7}{8}$ inch diameter high tensile steel, and the calculated inertia stresses were very much lower than the safe working load of the bolts. The failures were therefore put down to the bolts being stressed by the unequal expansion between the aluminium of the piston and the steel.

Experiments were carried out on the piston to see what effect this difference in co-efficient of expansion of the metals had in practice and to demonstrate the importance of not over-tightening the bolts. The piston was heated up to 160 deg. F. and the nuts on the piston head bolts were pulled down as tight as possible with a given spanner. The same spanner was applied again by the same man when the piston was cold, and it was possible to tighten the nuts a further $\frac{1}{16}$th of a turn, which worked out to about 0·14 per cent of the bolt length.

Precautions which had been taken to prevent a recurrence of the breakdown were as follows:—

1. (1) New piston head bolts had been fitted throughout the engine.
2. (2) Stop pins had been fitted to prevent a broken bolt head entering the oil chamber.
3. (3) Care had been taken in erection not to pull the nuts up too tight.
4. (4) Bolt lengths would be gauged in future so that stretch could be observed.

Mr. A. F. Evans (Member, I.Mar.E.) said that perhaps he might ask Mr. Fox if it was really true that the exhaust gases could be dealt with in a scrubber and then carried into the crank chamber, so that the atmosphere in the crank chamber was inert and the risk of explosion was ruled out? Perhaps he might mention that in the conventional automobile engine where, they might take it, the atmosphere in the crankcase consisted entirely of exhaust products which had leaked past the pistons, he did not think there had been any indication that those exhaust products, which were not scrubbed and cleaned, had a bad effect on the contents of the crankcase. If it should be possible to apply the principle to the Diesel engine, it did seem to him to be a very reasonable method of eliminating this dreadful danger of explosion. In a small engine perhaps it did not matter.

Some speakers had stated that they had seen only one crankcase explosion in their lives, or perhaps they had not seen even one. He could only say that he had experienced hundreds; in the old two-cycle engines of fifty years ago there was a crankcase explosion nearly every time they were started.

The Chairman asked whether he suggested the discharge of the exhaust gases through a scrubber and back into the crankcase.

Mr. Evans replied that he did.

Mr. Fox remarked that he thought he had put his views very clearly on that point; and in future they might have more sulphur in the fuel, so that he thought the conditions would be even worse.

Mr. G. H. Thornley said that as an oil man he spoke with some trepidation before so many experienced engineers. Reference had been made to fuel dilution and low flash-point oils. Transport engines using petrol or gas oil sometimes suffered from dilution to some extent. Samples of crankcase oil from petrol engines had contained as much as 90 per cent of petrol so that the flash-point would be very low indeed. He had heard from London Transport that the very rare fires in London buses had always started in the transmission and not in the crankcase. It was generally true that the lower the flash-point the higher the spontaneous ignition temperature. Petrol falling on a hot exhaust pipe was less liable to ignite than was lubricating oil.

He thought that in enclosed crank chambers where the bearings were pressure fed, they must quite often have had explosive mixtures. This need not be due to oil vapour but to finely divided droplets of oil disseminated in the crankcase atmosphere.

Two explosions had come directly under his notice. One was in the crankcase of an enclosed steam engine which had been overhauled; after about twenty minutes running after overhaul, there was an explosion in the crankcase and a door was blown out. It was found that the crosshead guide had been over-tightened, so that the crosshead seized. Two long scratches with burnt edges were found on the bearing surface of the guide from which apparently sparks had been emitted. An exactly similar case was described in Thomsen's book "Practice of Lubrication".

In the other instance a steam turbine had been overhauled and after a short period of running there was an explosion in the main oil tank. It was found that in charging the tank with oil, allowance had not been made for the amount of oil to fill the turbine lubricating system, so that on starting the oil level dropped, allowing the auxiliary oil pump to run dry. The clearances in the geared pump being small, sparks were struck after a short period of dry running and the oil mist in the tank atmosphere was fired.

He agreed with Mr. Fox in deprecating the passage of scrubbed exhaust gas into the crankcase to provide an inert atmosphere; this would certainly lead to undue deterioration of the lubricating oil.

Mr. N. P. Blackburn (Member, I.Mar.E.) said that it seemed to him that there had been a tendency to consider just one cure for these crankcase explosions. He suggested the possibility that there was more than one cure, for the reason that there was more than one problem due to the range of engines available.

The suggestion had been made that really full-scale ventilation would provide one solution. Not so long ago they had crankcase scavenging engines; he personally did not know of explosions occurring in such engines, but it would be interesting to know if one had occurred. The answer to that question would indicate definitely whether or not full ventilation solved the problem.

They had now medium speed engines running at, say, 750 r.p.m., and they were of quite high power, those engines presented an entirely different problem to that of the slow speed engine. In the case of the slow speed engine one had a crankcase in which oil vapour existed, but where there was scarcely any oil mist. In the medium speed and high speed engines they had today lubricating oil pressures of about 60lb. per sq. in.; the oil came through the main bearing, through the crankshaft into the crank end bearing, and up the centre of the connecting rod. With bearing clearances of round about 0·008 inch, the effect was to create a very dense mist, and the droplets, when mixed with air, might form an explosive mixture. The general opinion in respect of engines of that type, both in Britain and America was that the density of the mixture of oil droplets and vapour was such that it was too rich to be explosive. He thought there must be quite a lot in that, for the simple reason that they did not hear much about crankcase explosions in engines of that type. A similar situation existed in regard to automobile engines, which had a similar form of lubrication.

On the other hand, in bigger engines they had had explosions. He suggested that the classification societies, which were now taking an interest in the danger of explosions, should be led away from the laying-down of a hard and fast rule. One rule which had been suggested was that, above a certain h.p., crankcases should be protected by explosion doors. He suggested that for an engine of 500 h.p., running at 100 r.p.m., there might be good reason for that; if it was of 2,000 h.p., running at 1,000 r.p.m., there would be a very great difference in crankcase volume and the quantity of vapour present. Whether or not they could persuade the Ministry of Transport and other authorities to consider that aspect was difficult to say; but he felt that two bodies such as theirs should at least be able to put forward an opinion worthy of some consideration.

Reference had been made to the use of instruments as a guide to the conditions existing in a crankcase. At various times he had had diffierent types of operators looking after engines, and he found that unless a man was wholeheartedly an internal combustion engineer he was prone to allow his instruments to do his watch for him. Unfortunately, instruments were not infallible, and he suggested that as they became defective they would not necessarily be replaced; this was dangerous. Certainly they would never replace the attention of a fully trained engineer. The essence of this was to have trained engineers in charge of the equipment. Maintenance and attendance should be of the necessary standard to prevent explosions arising from carelessness.

He had not seen crankcase explosions of any real magnitude, but on several occasions he had seen what was referred to as a "blob". He had seen it from a turbine gearcase, but it was not followed by any serious explosion. It would seem that one general protection would be, not an explosion door, but just a flap valve which would let off that first puff which, as had been previously mentioned, created a condition in the crankcase which guarded against combustion, since the crankcase atmosphere became inert. If fresh air could not get in, there was great probability that heavy detonation would not occur.

Mr. G. Soutar (Member, I.Mar.E.) said that he would align himself with Mr. Craig in expressing the opinion that there should be excess of air in the crankcase. There were three essentials for combustion; there must be a combustible vapour, sufficient air to support combustion and sufficient heat to fire the charge. If there was too much air, he did not see how there could be an explosion.

During the war he had experience of General Motors' Diesels. In these engines there was probably a considerable oil mist underneath the piston since piston-cooling was carried out by a squirt of oil projected on to the under side of the crown. However, provision was made for positive air venting. There was a fairly large breather at the front end of the engine, and the blower suction was connected to the crankcase; air was drawn right through the engine from the front end, and presumably cleaned out the vapour which otherwise might remain there to cause an explosion. So far as he knew—and he was open to correction—there never had been an explosion in a General Motors engine, and he thought that excess of air provided a better solution to the problem of crankcase explosions than would the use of inert gas or reliance on the products of combustion. Incidentally, one of the best ways of deteriorating a lubricating oil was to allow it to be contaminated with the products of combustion which were blown past the rings.

Mr. H. D. Adam (Member, I.Mar.E.) said that he agreed with Mr. Bruce when he talked about keeping the oil cool. There had been quite a number of crankcase explosions and what they called "puffs", but in all cases the engines had been very hot. If they kept the oil cool, prevented carbon formation and had better bearings, they would prevent hot spots, which were, of course, due to high temperatures.

The Chairman (Mr. W. Howes) said that from a discussion such as they had had this evening, he doubted if they could expect to arrive at any definite conclusions; several speakers had referred to the complexity of the problem; but he thought that such a discussion was extremely valuable, because it brought out what he likened to trigger ideas—the sort of ideas that set one thinking on lines that might have very beneficial results.

It was obviously quite right to emphasize Mr. Windeler's point that, considering the very large number of internal combustion engines in use, serious crank chamber explosions were very rare. Unfortunately when such explosions occurred with serious results they made prominent headlines, and they gave rise to disturbing doubts in the minds of their fellow engineers, who were closely associated with the operation of such engines. So that whilst it was wrong to exaggerate the danger, it was very desirable to discover the cause and eliminate the risk.

He thought they would agree that today they were exposed to many hazards which were more pronounced than the hazard of serious crankcase explosion.

Like many of them he had experienced many crankcase "puffs", but never a real explosion. He had, however, experienced a number of nasty backfires from boiler flues, and some mishaps with air compressors, all of which had been due to carelessness.

Several speakers had commented about venting crankcases by flap valves, but he thought there was a feeling that if venting was done to relieve an explosion, it constituted danger by flaming oil; whereas they were concerned with prevention more than with relief.

Mr. Craig had expressed a decided preference for ample ventilation of a sealed crankcase, which he assumed involved a blower and large cooler. This might be a promising suggestion, providing the cooler could master the heat generated by abnormal hot spots.

He thought that notice should be taken of the references to adequate oil cooling; and it might be as well if engine designers and oil people got together on this subject. He rather thought that the oil people assumed that the crankcase oil must be very hot and provide oil accordingly; whereas the cooler the oil the less the risk of inflammation. Some small increase in bearing clearances and a lower oil temperature might be an advantage.

Not only were coolers often on the small side, but they were prone to fouling and to air locking. There was a type of horizontal cooler having many baffles, and if the baffles were a close fit in the shell, choking could occur and air could be trapped, resulting in a considerable reduction in cooling effect; such coolers should have channels through all baffles for passing air to the end vents.

Violent turbulence in crankcases had been referred to, and he wondered what was the effect of sharp edges on oil misting. Oil that was blown off a sharp edge was atomized; that was the principle of some atomizers.

The sharp edges of crank webs moving at high speed and oil coming off sharp edges anywhere in turbulent air, he thought created mist and it might be that if all edges were well rounded the oil would be blown off in larger drops. There was no doubt that the larger the drops the less chance of ignition, because a large drop would quench a small spark, whereas the same spark might ignite a very small particle of oil and start an inflammation.

Reference had been made to piston temperatures. He ventured to remind them that Mr. Fox had, on another occasion, explained that the working temperature of aluminium pistons was much lower than was the working temperature of cast iron pistons, and that crankcase temperatures and oil temperatures would consequently be lower. Further, the melting point of aluminium was much lower than was the case with cast iron, so that in the event of seizure the temperature of aluminium would not exceed its melting point—that was some 1,220 deg. F., whereas cast iron would go up to some 2,250 deg. F., resulting in a much more rapid rise in crankcase temperature.

Coming to the warning of unduly hot pistons or bearings, thermometers fitted to crankcase doors as suggested by Mr. Fox was very good advice; because, if they were in line with the oil flung off the cranks, they would immediately indicate a rise of temperature, and early precautions could be taken.

With regard to the difficulty of nicely fitting bevelled end rings, so as to avoid blow-by or seizure, it might be better to use stepped end rings; but such rings should not have sharp corners where the steps emerged.

Mr. Bruce had, very rightly, emphasized the desirability of warning notices about the removal of the doors of a very hot engine and against naked lights. The fixing of appropriate notices on all engine doors was very desirable.

Mention had been made of bus engines; but he doubted if small engines constituted much danger, because the quantity of atmosphere in such crankcases was relatively small; it might be that such an atmosphere could explode without doing any damage at all, unless, of course, a naked light was inserted.

A very important reference had been made to personnel. He was sure that they all agreed on that point. They all knew how a questionable engine could be made to work well if given good maintenance, whereas a perfectly good engine could give a great deal of trouble if badly maintained or carelessly operated. Satisfactory maintenance could not be too strongly emphasized.

INSTITUTE ACTIVITIES

Minutes of Proceedings of the Ordinary Meeting held at the Institute on Tuesday, 11th April, 1950

An ordinary meeting was held at the Institute on Tuesday, 11th April 1950 at 5.30 p.m. Mr. G. Ormiston (Chairman of Council) was in the Chair. A paper entitled "Further Developments in the Burning of Boiler Fuels in Marine Diesel Engines" by John Lamb, O.B.E. (Member) was read and discussed. 202 members and visitors were present and eleven speakers took part in the discussion.

Mr. A. F. C. Timpson (Member of Council) proposed a vote of thanks to the author which was carried by acclamation.

The meeting terminated at 8.40 p.m.

Minutes of Proceedings of the Ordinary Meeting held at the Institute on Tuesday, 9th May, 1950

An ordinary meeting was held at the Institute on Tuesday, 9th May 1950 at 5.30 p.m. Mr. G. Ormiston (Chairman of Council) was in the Chair. A paper entitled "Noise in Passenger Accommodation of Ships" by A. J. King, D.Sc., was read and discussed. Twenty-eight members and visitors were present and seven speakers took part in the discussion.

Mr. J. Turnbull (Vice-Chairman of Council) proposed a vote of thanks to the author which was carried by acclamation.

The meeting terminated at 7.15 p.m.

Minutes of Proceedings of the Extraordinary General Meeting held at the Institute on Monday, 12th June, 1950

An Extraordinary General Meeting was held at the Institute on Monday, 12th June 1950, at 4.30 p.m. Mr. J. Turnbull (Vice-Chairman) was in the Chair.

The Minutes of the Extraordinary General Meeting held on the 24th January 1950, were read by the Secretary, and were confirmed and signed.

The Chairman said that as members were aware from the notice which had been circulated at the proper time, the meeting had been called for the purpose of considering, and if deemed desirable passing (with or without modification), the following Special Resolution:—

That subject to the provisions of Article 20 of the Royal Charter of the Institute dated 23rd April 1933, the By-Laws of the Institute shall be amended as indicated hereunder:—

By-Law 4.—Delete the present wording and substitute new wording as follows:—

4. Members. Candidates for election or transfer into the class of Members shall be at the time of such election or transfer at least thirty years of age, shall hold a position of responsibility in the science or practice of engineering or shipbuilding, and shall be either:

(i) (*a*) engineers who hold a First Class Certificate of Competency issued by the Ministry of Transport or an equivalent qualification, and have held for three years subsequent to obtaining such qualification a position of responsibility in the science or practice of engineering or shipbuilding; or

(*b*) engineers who have held for not less than five years the rank of Lieutenant(E) Royal Navy, Royal Australian Navy, Royal Canadian Navy, Royal New Zealand Navy, Royal Pakistan Navy, or the Indian Navy; or

(ii) those who have served an engineering or shipbuilding apprenticeship of not less than four years, or have an approved University degree in the science of engineering or naval architecture and have had not less than two years' practical engineering or shipbuilding experience, and have held for five years a position of responsibility in the science or practice of marine engineering or shipbuilding.

By-Law 6.—Associate Members. In the first paragraph substitute "an approved University degree" for "a University degree".

By-Law 7.—Associates. Sub-paragraphs (i) (*b*), (*c*) and (*d*).—Delete the present wording and substitute new wording as follows:

(*b*) the rank of Sub-Lieutenant(E) Royal Navy, Royal Australian Navy, Royal Canadian Navy, Royal New Zealand Navy, Royal Pakistan Navy, or the Indian Navy; or (*c*) the rank of Lieutenant(E) South African Naval Forces (Permanent Forces); or (*d*) an approved University degree or recognised diploma in engineering or naval architecture;

By-Law 8.—Graduates. In clause (iii) substitute "Sections A and B" for "Part A".

By-Law 30.—Delete "The Graduate Examination Fee shall be £1".

Before he asked for the resolution to be put formally, members might wish to discuss it, and he would call on Mr. Longmuir to make a brief statement on the reasons for and the history leading up to the proposal.

Mr. T. W. Longmuir said he would like to support the resolution and to explain it before it was put formally. He supported it firstly because he was an old member of the Institute and also a Member of Council, and secondly because he was strongly in favour of the proposal.

At the last Extraordinary General Meeting in January very eloquent and impressive speeches were made against the resolution then proposed. It had been said that candidates were allowed to become members of the Institute at too early an age, and every one of the speakers on that occasion—Mr. Bennett, Mr. Atkinson, Mr. Christensen, General Davidson and others—emphasized the fact that there should be an age limit—a minimum age limit—of thirty. The General Purposes Committee and the Council had taken note of these views and now put the resolution forward in the same form as before but with the insertion of the words "at least thirty years of age".

The Council had devoted considerable attention to this resolution. One of the proposed alterations to By-Law 4 as it now stood was to the effect that engineers applying for membership of the Institute must have held a position of responsibility for three years. The reason for this was that the Council had taken into account the fact that the Institute desired responsibility as well as age, and in general a man did not obtain a position of responsibility until he had his First Class Certificate of Competency. At the time when he himself had joined the

Institute the period was, he thought, five years.

In putting the resolution forward the Council had no wish to make any major alteration as to the admission of members. This proposed change in the By-Law was due solely to the introduction of the new Associate Membership Examination. At the last meeting, however, the examination had not been mentioned and the only major point that had been raised was the question of a minimum age-limit of thirty; nor did he imagine the examination would be mentioned that evening.

He asked members, when the vote was taken, to support the Council, who had gone very thoroughly into the matter, and to give their assent to the Special Resolution as it now stood.

The CHAIRMAN asked whether any other member had any comments to make. There being no speakers, he called upon Mr. Longmuir to propose the adoption of the Special Resolution.

MR. T. W. LONGMUIR proposed and MR. T. A. CROMPTON seconded that the Special Resolution be adopted.

MR. T. A. BENNETT said he had proposed at the last meeting that the minimum age-limit of thirty years be retained. There was so much support for this proposal that the Council had been asked to reconsider the matter, and the result was that the question of three years' additional experience before qualifying for membership had never been brought up. In the resolution then put forward the three years was not required to be subsequent to obtaining a First Class Certificate, but Mr. Calderwood had stated that that was in fact the intention. In 1946 he (Mr. Bennett) had moved an amendment to the existing regulations which required five years' experience, and the Extraordinary General Meeting had accepted the amendment and had rejected the five-year period. From 1946 to the present time candidates applying for membership had to have a First Class Certificate, to be thirty years of age and to hold a position of responsibility. It might be as well to explain why this extra qualification was brought in.

In 1934 proposals had been made—which he thought he could claim to have led—for raising the standard of membership. Just before 1935, in fact, a candidate could gain admission as soon as he had obtained his First Class Certificate, and that had been the requirement for membership since the formation of the Institute. There was no question of five years before 1934. After twelve months of discussion—during the whole of 1934—the Council had decided that to qualify for membership a man must be thirty years of age and hold a position of responsibility and a First Class Certificate. Mr. Vose, he thought, and some others had then said, "How are you going to judge a position of responsibility in the case of a man at sea?" It was thought that if he had had his Chief's Certificate for five years he must have held a position of responsibility, and the five years was put in not to keep a man out but to help him in. It was not necessary, but the Council had made it compulsory.

While this rule was in force, there had been many objections. Engineers would say it was not their fault if they had not got their certificate by the age of twenty-five. They might have been in big ships and unable to serve the necessary time on watch; also there were slumps and consequent periods of unemployment. The result was that they were twenty-five or twenty-six before they obtained their Second Class Certificate. To get a First Class Certificate a man had to be in charge of a watch. That was not easy today. Of the last twenty Chiefs who had passed from the school in which he was engaged fourteen were over twenty-seven when they had obtained their Certificates. If one went to the North-East Coast or to Cardiff, one would probably find it was easy to get a Chief's Certificate at twenty-five, because as soon as a man got his Second Class Certificate he took charge of a watch.

He could not see how this period of three years was going to increase the status of the Institute by one iota. If the point was that some candidates on election were too young, the best plan would be to make the age thirty-three for everybody, but it was discrimination against the men in the big ships, who should be getting the best experience, to say that the First Class Certificate was not of itself sufficient qualification.

He did not want always to be against the Council, but it was they who were proposing to alter the rules. The Membership Committee had worked very well—and he thought Mr. Youldon would bear him out. When a man of thirty who had his Chief's Certificate applied for admission it was thought that he had held a position of responsibility, and as the Institute was intended primarily for sea-going engineers, that man should be allowed in.

He did not propose to put forward any amendment but would leave it to the meeting. He hoped the Council would reconsider this matter very carefully before they made this discrimination, particularly against the men in the larger ships, which the resolution would entail.

MR. D. M. REID, supporting Mr. Bennett, said he worked with the latter and had seen the records of people going through the School. In addition, he was reminded that some fifteen years ago he was a junior in a large company. One particular ship had three Fourth Engineers, each of whom had a Chief's Certificate. They were all very good, sound men, but none of them was in charge of a watch, and they were employed in the boiler rooms. The proposed wording—"a position of responsibility"—would, he thought, automatically mean being in charge of a watch, and these men would have had their Chief's Certificate for a long time before they were in charge of a watch and they became Third Engineers. This was a definite case in point.

In addition, this was, after all, the Institute of Marine Engineers and not an institute of shipbuilders or engine builders. The normal qualification of a marine engineer was a Chief's Certificate. Some marine engineers had gone further and had obtained additional qualifications, but nevertheless that was the normal qualification. A man with a Chief's Certificate—provided he had reached the age of thirty—who had been going to sea since the age of twenty-one was a fairly responsible man, and he should be allowed to enter the Institute as a Member.

For these reasons the feeling of the meeting should perhaps be tested, and therefore he moved that the words "subsequent to obtaining such qualification" be deleted from the proposed alteration to By-Law 4 (i) (*a*).

MR. I. S. B. WILSON, seconding the amendment, said he endorsed the remarks of the last two speakers. One point should be made clear. A distinction had been drawn between the men in the smaller ships and the men in the larger cargo vessels and liners. This did not mean that the former were inferior; the main point was that the man in the smaller ship would have an advantage over the other. That was to his mind unfair, and an unfair condition in a by-law could not come to any good.

MR. W. LYNN NELSON said that as a Member of Council he had discussed this matter at length with his colleagues. He thought the meeting should try to get a clear view of what the Council had in mind. He would therefore like to explain why the Council had put the Special Resolution forward.

There was, he thought, a lack of comprehension as regards the position of the Institute of Marine Engineers at the present time. He pointed out that the First Class Certificate of Competency issued by the Board of Trade or the Ministry of Transport was not—in the true sense—a certificate of efficiency as a marine engineer but a certificate relating to safety of life at sea. Why should the Institute follow blindly behind the Board of Trade or the Ministry of Transport regulations concerning a certificate of competency that happened to be allied to the marine engineering profession because of the Merchant Shipping Act relating to Safety of Life at Sea? They were a scientific institute for the advancement of the profession of marine engineering, not for safety of life at sea alone but for efficiency as a whole and proficiency in marine engineering. If they were simply to follow safety of life at sea rules, then all he could say was "God help the Mercantile Marine of Great Britain!"

Here was a contradiction of facts. Some speakers, including his friend Mr. Bennett, had referred to the big ships and the small ships. That was not the problem of the Institute of Marine Engineers; it was a problem that had arisen owing to the fact that the Ministry of Transport had distinct regulations. Their regulations said that one must be on watch for so many hours a day to qualify for certain certificates. That the big ships had four engineers on the watch and the small ships two did not affect the Institute of Marine Engineers. Their object was to take care of all marine engineers as a scientific body for the advancement of the science of marine engineering. That was what must be borne in mind before the resolution was voted upon. It had not been agreed upon haphazardly; a lot of time had been devoted to its consideration. It was proposed in the interests of the Institute of Marine Engineers as a body for scientific advancement.

He would ask members to forget for a moment this Certificate of Competency issued by the Board of Trade or the Ministry of Transport. They wanted, as members of the Institute, engineers who had attained a certain level, a certain agreed standard, which would add repute to the Institute and raise the standard as a whole and which would make it a good institution. Personally, he abhorred the idea of the Institute of Marine Engineers following blindly behind the Ministry of Transport Certificate of Competency. Let them forget that! This was 1950—not 1912 or 1914.

MR. D. M. REID said he quite agreed that this was not 1912 but 1950. He also agreed that the main object of the Certificate of Competency in the early days was to ensure safety at sea.

MR. W. LYNN NELSON, interpolating, said it was still so.

MR. D. M. REID, continuing, said it was still said to be so, but he saw the questions set in the examinations, and those questions did not deal just with safety at sea. They required a good sound engineering knowledge in Part B. They required good theoretical knowledge in Part A. It was not fair, to his mind—not at all fair—to say that having a Chief's Certificate just meant that one knew the safety regulations. This was definitely not the case in these days in his view.

MR. W. LYNN NELSON, in reply, said that unfortunately owners and everyone else had automatically followed the Certificate of Competency because they had nothing else to put in its place, and therefore efficiency and safety of life at sea had become synonymous, as they must do.

The CHAIRMAN said the discussion had been very interesting, and he had been glad to see that the issues were very clear. He had been a little afraid the meeting might become involved in very complicated amendments to the regulations.

The amendment to omit the words "subsequent to obtaining such qualification" was put to the meeting and was lost by twelve votes to twenty.

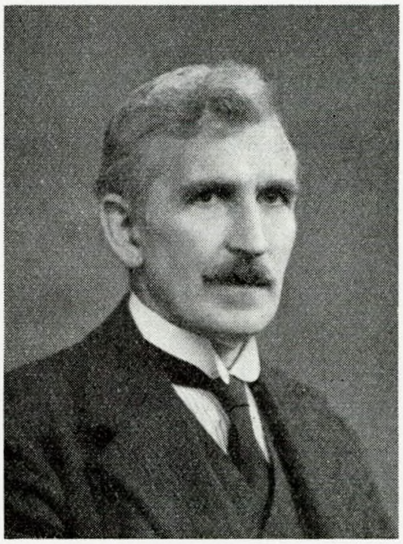
The Special Resolution was then put to the meeting and was passed by twenty votes to twelve.

The proceedings then terminated.

SUMMER GOLF MEETING 1950

The summer golf meeting was held at Hadley Wood Golf Club on 8th June 1950 on a day of perfect sunshine. This helped to make the occasion a most enjoyable one for the twenty-six players who participated.

Messrs. H. A. Dawson and W. Ridley tied for the Cup with net scores of 71, and Mr. Ridley was awarded the Cup on the best score in the last nine holes. He received an oak clock, and Mr. Dawson, who also won first prize in the afternoon with Mr. E. F. J. Baugh with a score of one down, chose to receive with his partner a Ronson table lighter. Messrs. A. Cameron and F. Sands tied with Messrs. A. E. Crighton and J. A. Goddard with 2 down. Messrs. Cameron and Sands were judged the best on the last nine holes, and they each received an oak barometer. Mr. Goddard was awarded a tankard on the toss of a coin from Mr. Crighton.



MR. RIDLEY

At the distribution of the prizes by Mr. Robertson after tea a hearty vote of thanks was passed to the Committee of Hadley Wood Golf Club, and particularly to the Steward, Mr. Baxter, for the very excellent arrangements which had been made for the occasion.

Grateful thanks and appreciation were also accorded to the following donors of the prizes:—Mr. N. M. Niven (Messrs. Drysdale and Co. Ltd.), Messrs. Foster Wheeler and Co., Messrs. J. Stone and Co. Ltd., Messrs. E. F. J. Baugh, T. A. Crompton, R. K. Craig, W. J. Ferguson, J. A. Goddard, R. B. Grey, G. Ormiston, R. B. Pinkney, J. A. Rhynas, A. Robertson, C. C. Speechly, W. Tennant, J. Turnbull.

MEMBERSHIP ELECTIONS

Elected 12th June 1950

MEMBERS

Leslie George Bartlett, Lieut.(E), R.N.
John C. Bentley
Donald Lougher Brown
James Howard Chadwick
Ernesto Roberto Florit, Lt.-Com'r(E), A.N.
Alec Lee Hobden, Lt.-Com'r(E), A.N.(ret)
Kenneth Andrew Birrell Liddle
Eric Milson
John Pontikos
John Prest
Svend Huusmann Ravn
William Terence Colborne Ridley, Com'r(E), R.N.
George William Robinson
Trevor Wilson Ross, Engr. Capt., O.B.E., M.Sc., B.M.E., R.A.N.
William John Hedley Schofield
Desmond William Knuckey Vagg
Brian Ward
Frederick Charles Williams, Lieut.(E), R.N.

ASSOCIATES

Oku Ekpe Asuquo
William Ritchie Austin
Howard Arthur Brett
Joseph Callon
John Bradley Carr
James Cowley
William Daley
Gilbert Errington Easton
John William Hickling
Geoffrey Payne Hodge
David William Edgar Kyle
Garfield Trevor Miles
Alexander Marshall Miller
David Donaldson Miller
Derek Sydney Richmond
John Nankervis Rowe
Denton Willoughby Sayers, M.B.E.
Ernest Craig Sides
John Walker Smyth
Walter McBryde Swan
Frans Gerard van Asperen
Eric Whitehouse

TRANSFER FROM ASSOCIATE MEMBER TO MEMBER

Herbert Sales

TRANSFER FROM ASSOCIATE TO MEMBER

Gordon McKenzie Blair
Harry Hatfield
Maurice Stewart Hunter
Albert Geoffrey Pearson
Gordon Pybourne
Colin Reynolds, Lieut.(E), R.N.
Terence Rowan
Zozislaw Kazimierz Szwede
Gwilym Owen Thomas
Bertram Couch Tonkin

TRANSFER FROM GRADUATE TO MEMBER

Alexander Dennis Taylor

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

Gordon Dales

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Harry Newton

TRANSFER FROM STUDENT TO ASSOCIATE

James William Geoffrey Hall

Elected 10th July 1950

MEMBERS

Harold Stanford Alchin
Richard Douglas Apsimon
Stanley Beckett
Thomas Arthur Branton, Lieut.(E), R.N.
John William Robertson Brock
Emile Isidore Alexandre Buchard
Gordon Lord Tannock Dawson
Charles Henry Dodd
Robert Dryden
Percival John Emmerson
Arthur Eric Gale
William Hetherington
Thomas Forster Hilton
Frank Henry Kerr
Leonard George Linder, Lt.(E), M.B.E., R.N.(ret)
J. J. Macnamara, Lieut.(E), R.N.
James Ebenezer Turpie Mackie
James McAulay
James Olanda Noon
John Watkins Northwood, Lt.(E), M.B.E., D.S.C., R.N.
James Orange
Everard Robert Read, Lieut.(E), R.N.
John Robson
John Edward Scott
Arthur Tate

ASSOCIATES

George Allan Anderson
Albert Aru
Leslie Bristow, E.R.A., R.N.
Anthony John Calvey
Charles Benjamin Clapson, Lt.(E), D.S.M., R.N.(ret)
Andrew Thomas Crook, D.S.M., B.E.M.
Kenneth Jones Heavisides
Arakkal Thomas Joseph
Jamshed Nowroji Kanga
Frederick Donald Langley
Eric William McKay
James Hope Marshall
Walter Gameson Matthews
William Henry Preston, Sen'r Comm'd Engr., R.N.
Peter Scott Rosseter
John Xavier Shum
Anthony Claude Soward
Frank Henry Trenchard
Isaac Vella

STUDENT

Samuel Raju Hubert

TRANSFER FROM ASSOCIATE TO MEMBER

Panagiotis Bourboulis
Philip James Stewart
Ronald Pearson Dunwoodie
Alan Mitchell McPhee
Ernest Tye
Terence John Walsh

TRANSFER FROM ASSOCIATE TO ASSOCIATE MEMBER

John Spence

TRANSFER FROM GRADUATE TO ASSOCIATE MEMBER

Ahmad Sherif, Sub.-Lt.(E), R.E.N.

TRANSFER FROM STUDENT TO ASSOCIATE MEMBER

Henry Harcourt Shepherd, Lieut.(E), R.N.

OBITUARY

P. INNES ADIE (Member 2232) was born in 1869. He served his apprenticeship with Messrs. J. and G. Thomson Ltd., Clydebank. Following seven years sea-service he became a ship and engineer surveyor to Lloyd's Register of Shipping. Mr. Innes Adie was elected a Member in 1912 and was the Institute's Local Vice-President in Buenos Aires from 1924-29. He died there in November 1948 aged seventy-nine years.

JOSEPH MANLEY (Member 9530) was born in Whitehaven in 1887 and educated there. He served his apprenticeship with Messrs. Ramsey, Marine Engineers, Whitehaven. He joined the Royal Navy in 1907, rising from Engine Room Artificer to Lieut. Com'r(E), and serving for many years in H.M. submarines. During the 1939-45 war he was in charge of an establishment at Rosyth for training artificer apprentices, Royal Navy. He was elected a Member in 1943. Lt. Com'r Manley died suddenly on the 21st November 1949.

FRANK MOSS (Member 10926) was born in 1898 and educated at Woodchurch Road, Birkenhead, Council School, leaving at fourteen years of age to spend two years on the *Mauretania* as a bell boy. He served his apprenticeship with Messrs. Cammell, Laird and Co., Ltd., Birkenhead, and then commenced his sea service with the P.S.N. Co. Following this he served for a number of years in the Far East with a German firm, transferring for a short time to Messrs. Jardine Matthesion Ltd. Mr. Moss then served with two Greek companies, by one of which, Messrs. N. G. Kyriakides Shipping Co., he was employed at the time of his death at sea on the 14th January. He was elected a Member of the Institute in 1932.

PETER ALOYSIUS MCKENNA (Member 11279) was born in 1902 and educated at Bridlington Grammar School. He served his apprenticeship with Earle's Shipbuilding and Engineering Co., Ltd., Hull, and then saw sea service on cargo vessels until he obtained his Second Class Certificate. From 1926 to 1934 he served with Messrs. Shaw, Savill and Albion Co., Ltd., and the Aberdeen and Commonwealth Line, obtaining his First Class Certificate in 1931. He served in cableships with Cable and Wireless Ltd., in all parts of the world from 1934 until 1945 when he transferred to G.P.O. cableships. At the time of his death Mr. McKenna was Chief Engineer on the S.S. *Eclipse,* having joined the Vacuum Oil Co., Ltd., two years previously. He was elected a Member in 1947.

ROY THOMPSON (Member 10525) was born in 1914 and educated at The Tynemouth Municipal High School. He served his apprenticeship with Smiths Docks Co., Ltd., North Shields, and commenced his sea-going career at the age of twenty-one with the Anglo-Saxon Petroleum Co., Ltd. Except for a brief period during the 1939-45 war when he transferred to Elder Dempster and Co., Ltd. and Union Castle Line Ltd., he served continuously with the Anglo-Saxon Petroleum Co., Ltd., until the time of his death which occurred following a fire on board the tanker *Lingula* at Pulda Samboe. Mr. Thompson was Chief Engineer of this vessel. He was elected a Member of the Institute in 1945.