actions obtainable by stimulation of the abdominal sympathetic are not associated with sensation. The distinct reflex contraction of the abdominal muscles resulting from stimulation of the abdominal sympathetic is another reaction which it is difficult to believe is not associated with sensation. The latter phenomenon has a two-fold interest. In the first place, it is the basis of a well-known clinical symptom, the rigid belly wall, and, secondly, it represents a form of tonic contraction not directly inducible by artificial stimuli.

On examining critically Haller's, and to a less extent Lennander's paper, we are struck by the fact that the stimuli used are unnatural in character. It is not likely that the viscera are equally responsive to all forms of mechanical stimuli. Twisting, stretching, or squeezing the wall of the intestine from the outside may be ineffective, because the nerve endings in these organs are adjusted for stimuli of another kind. In the case of the bile duct and of the ureters a twist produces no vaso-motor effect, but distension by injection produces a well-marked rise of blood pressure.

The "referred visceral pain" was discussed next. Dr. J. Mackenzie denies that a viscus is ever directly painful, the pain felt being essentially a "referred one." For example, in pleurisy the lungs and parietal pleura are insensitive. While agreeing with Lennander in the view that the subserous layer of the pleura is sensitive, Mackenzie holds that the pain of pleurisy is mainly a referred pain due to cramp of the muscles of the thoracic wall. Mackenzie gives the following theory as to the mechanism of the different forms of "referred pain." He holds that stimulation of afferent visceral nerves by some influence increases the excitability of afferent centres in the cord connected with corresponding areas of skin. The pain is consequently referred to these cutaneous areas, and is only indirectly the result of stimulation of deep visceral afferents.

Head gives a somewhat different explanation. Impressed by the fact that inflammation of spinal ganglia produces herpes zoster, he was led to believe that afferent visceral fibres in their passage through the same ganglia as certain afferent cutaneous nerves can affect the adjoining cells connected with the latter and thus produce "referred cutaneous pain." This view is opposed to Müller's law, and was finally given up by Head. He ultimately transferred the seat of the nervous mechanism from the ganglia to deeper centres in the cord. The segments of the cord connected with "referred pain" do not correspond with the segments of the spinal axis as indicated by the ganglia. Head suggests that the "referred pain" areas correspond with the primitive phylogenetic segments of the cord. He leaves the mechanism of overflow unexplained. A remarkable fact is that the area of skin affected by referred pain is a mere patch or couple of patches, not a segment, but nevertheless more or less segmentally arranged.

The deep visceral afferents from the heart are not only those which have been most fully investigated experimentally, but also form an intermediate group between the pure visceral deep afferents and those of somatic or muscular origin. The chief afferent nerve of the heart is the depressor, and the receptive field for its stimulation is its nerve terminations in the wall of the aorta. The most adequate stimulus is distension of the walls of that vessel. The result of stimulation is a lowering of blood pressure due to a diminution of vascular tone. The nature of this tone, like that of voluntary muscles, is still obscure. It is doubtful whether stimulation of the depressor gives rise to pain directly. The areas of "referred pain" given by Mackenzie are not cranial, as we should expect, since the vagus is a cranial nerve, but mainly lie in the chest wall. Tender spots, however, are also found on the head.

Prof. Sherrington then gave a brief survey of deep non-visceral or muscular afferents. Since the work on this subject is largely due to himself, and since he has elsewhere stated his views more fully, it would not serve any good purpose to try to epitomise this part of his paper.

The paper was followed by an interesting discussion, in which Prof. J. S. Macdonald, Dr. Graham Brown, and others took part. The discussion chiefly referred to the nature and functions of the terminations of the deep

afferent muscular nerves. A number of other papers of anatomical and physiological interest were also read by the following:—Prof. Dixon (Dublin), the development of the achondroplastic skeleton; Prof. Anderson (Galway); Dr. Dickey (Belfast), the cervical pleura; Dr. Johnston (Dublin), the intercostal nerves; Drs. Goodall and Earle (London), the structure of the pancreas in relation to its functions; Dr. Maclean (Liverpool), phosphatides in the light of modern research; Prof. B. Moore (Liverpool), the chemistry of hæmolysis; Dr. S. Spicer, some points in the mechanics of respiration; Prof. Thompson, the development of the foetal heart; Dr. Leonard Hill, F.R.S., the influence of inhalations of oxygen on the onset of muscular exhaustion; Dr. Rutherford, some points in connection with the anatomy of the cranium of the fish; Dr. Waterston, some instruments used in anthropometry.

RECENT IMPROVEMENTS IN THE INTERNAL-COMBUSTION ENGINE.¹

II.

WE have already explained how important in the economical development of the internal-combustion engine is an accurate and precise knowledge of the physical properties of the working medium. The two chief features of which a knowledge is required are the calorific value of the explosive mixture and the relation between the specific heat and temperature of the ignited gases. The calorific value has been carefully ascertained for most of the gases commonly used, but the specific-heat relation is still a matter of unfortunate uncertainty. At the Leicester meeting of the British Association in 1907, under the sectional presidency of Prof. Silvanus P. Thompson, the desirability of clearing up the doubts that surrounded this subject was so keenly felt that an important committee was appointed for "the investigation of gaseous explosions, with special reference to temperature." An account of the findings of this committee was published in NATURE of June 24 last. From our present point of view the important result of the committee's work is expressed in the following extract from its report:—"Recent researches on the properties of the gases at high temperatures have definitely shown that the assumption of constant specific heat is erroneous, and have given sufficient information about the magnitude of the error to show that it is of material importance. . . . The closer approximation to the real cycle which is made by taking account of the actual properties of the working fluid, though it leads to some complication of formulæ, gives compensating advantages of real practical value." This bears out, also, a remark made by the late Prof. Zeuner² to the effect that "at any rate there must be dropped from the theory of the internal-combustion motors the former assumption of the constancy of the specific heats of the products of combustion." A curve connecting the specific heat at constant volume (C_v) of the mixture of gases, formed by the explosion of one part of coal gas in nine parts of air, with temperature centigrade (θ), which was considered to be accurate within 5 per cent., was included in the committee's report. A formula which fits this curve closely is

$$C_v = 0.172 + 0.075 \frac{\theta}{1000},$$

and although the constant in the second term on the right-hand side of this equation can only be looked upon as a first estimate, however carefully chosen, the equation does, probably, represent the high-water mark in our present-day knowledge, and from it can be deduced the limiting theoretical efficiency of engine cycles in which such a working medium is employed.

It is well known that on the basis of a constant specific heat the ideal efficiency (η) can be found from the following equation,

$$\eta = 1 - \left(\frac{1}{r} \right)^{\gamma-1},$$

where r is the ratio of compression and γ is the ratio of the specific heats. This relation applies with equal truth

¹ Continued from p. 172.

² "Technical Thermodynamics," by Prof. Zeuner.

whether the cycle followed is (1) the constant-volume cycle, (2) the constant-pressure cycle, or (3) the constant-temperature cycle, an important discovery attributed to Profs. Unwin and Callendar. The problem now arises to re-calculate the thermal efficiency (η) for a working medium of which the specific heat is *not* constant. Most of the important internal-combustion engines operate on the constant-volume cycle, and if we re-calculate the equation to suit this case, making the necessary approximations to secure a workable result of sufficient accuracy, and using the above linear law based on the British Association Committee's figures for specific heats, we find that the new efficiency equals

$$\eta \left\{ 1 - \frac{1}{4000} \left(1 - \eta \cdot T_2 + T_0 \right) \right\},$$

where T_2 is the maximum absolute temperature (centigrade) in the cycle, T_0 the suction temperature, whilst η is the value obtained from the equation

$$\eta = 1 - \left(\frac{1}{r} \right)^{\gamma-1},$$

using here the value of γ corresponding to the *absolute zero of temperature*. The value of T_0 is practically independent of the compression, and in round figures suitable to this calculation may be written down as 400. The value of T_2 for a given richness of mixture will depend upon the degree of compression before ignition, and can be calculated therefrom. In this way a new expression for the real thermal efficiency can be obtained in terms, not of T_2 , but of r , and the following table shows a few comparative figures worked out in this way. The figures for the "air-standard" efficiency are also given by way of comparison.

Thermal Efficiency.

Ratio of compression	"Air standard"	Real thermal efficiency (approximate figures)
4	0.43	0.30
10	0.60	0.45

Ratio, air/gas = 9/1.

It will be seen that in each case the real efficiency is about a quarter less than the "air-standard" efficiency.

This discrepancy sufficiently explains why those associated with the design and building of gas engines have expressed their dissatisfaction with the "air standard" of efficiency. The adoption of the "air standard" has led to the setting up as an ideal, to be aimed at and striven after, of a series of figures which it now appears are about one-third above the thermal efficiencies theoretically possible, and it is not surprising that engine builders, who from their practical work realised that there must be something wrong with the theory as then put forward, should have objected. It is not too much to say that had the engine builders to depend in the past solely on scientific guidance as the mainspring of their investigations, there would have been far less progress made than has been effected by the system of trial and error. Even now the state of knowledge as to gaseous specific heats is so uncertain that no accurate quantitative theory of the thermodynamics of the internal-combustion engine can be laid down. The writer has, however, endeavoured to show here and elsewhere how the problem may be investigated symbolically, and so prepared for expression in numerical form as soon as the thermal properties of the gases are actually known.

Mr. Dugald Clerk, in his 1907 paper¹ before the Institution of Civil Engineers, made some estimates of real efficiencies based on theoretical maximum temperatures of 1600° C. and 1000° C., and his results are given below.

r	Ideal efficiencies		
	If maximum temperature of cycle 1600° C.	If maximum temperature of cycle 1000° C.	On air standard
2	0.195	0.200	0.242
3	0.286	0.293	0.356
4	0.354	0.356	0.426
5	0.384	0.394	0.475
7	0.439	0.443	0.541

It was apparently contemplated that these figures might be used in comparison with engine performances in which

¹ Proc. I.C.E., vol. clxix., p. 145.

the *real* maximum temperatures were also 1600° C. and 1000° C. This, however, would be open to several objections. As an instance, take the case of an engine which by improved design was made capable of giving for the same mixture and the same compression ratio a higher maximum temperature and pressure. Such an effect might be produced, let us say, by decreasing the ratio of cooling surface to volume through an alteration in the amount of pocketing. This new engine, on the basis of comparison with an ideal cycle having an identical maximum temperature, would probably show little, if any, improvement in relative efficiency over the old engine. Such a result would tend to defeat the purpose for which comparisons with ideal cycles are made. It would seem to the author that the better way would be to compare both old and new engines with an ideal cycle having a maximum temperature corresponding to the known richness of the mixture, its calorific value, and the ratio of compression.

A factor that has affected most advantageously the recent progress of the internal-combustion engine is the great improvement that has taken place in engine indicators. The old moving lever design, although thoroughly serviceable for most steam engines and for many slow-moving internal-combustion engines, has been found entirely untrustworthy with modern high-speed internal-combustion engines. A new form of instrument has been devised in which the recording lever is a beam of light, which, having no inertia, has no time-lag. This vitally important improvement in the indicators was due, in the first instance, to the prescience of Prof. Perry,¹ and in its later stages to the experimental skill of Profs. Callendar and Hopkinson. The writer has recently calculated out the case of an indicator of which the free periodic time of oscillation was 1/300 sec., and has shown that explosions occurring even in so short a time as 1/200 sec. could be adequately followed and recorded. We believe that this oscillation period represents about the sensitiveness of one of the reflecting indicators used by Prof. Hopkinson at Cambridge, and the calculation serves to show how accurately the new instruments can be made to follow extremely rapid explosions.

It would be useless to base any deductions on the records given by one of the old type of instruments in such a sharp explosion as this. Errors of as much as 5 per cent. are now known to have occurred in the measurements of horse-power made by the old instruments. On the other hand, it cannot be denied that the older type was a great deal easier to handle, and that it could be used by comparatively untrained persons. The new reflecting kind, despite its accuracy of measurement to within 1 per cent. of the power, is rarely seen in workshops, and the measure of "indicated horse-power" has been very commonly abandoned in favour of the measurement of "brake horse-power" both in the case of large and small engines. In the case of the numerous small high-speed petrol engines, the practice of actually measuring brake horse-power is often replaced by the use of a rating formula giving a "nominal" horse-power. It seems at first sight extraordinary that there should be a reversion to the old unscientific "N.H.P.," but, despite their apparent similarity, the "N.H.P." of the old days of the steam engine and boiler, and the "rating H.P." of the modern petrol engine, are really based on very different considerations, and, as there appears to be every likelihood that the latter will be constantly revised with the aid of the best scientific advice possible, there is little real foundation for any scientific objection to it. The pioneer work done by Prof. Callendar in promoting this advance cannot be too gratefully acknowledged. Others have also worked at the problem since, and a considerable "output" of rating formulæ has resulted.

That in most common use is $H.P. = \frac{D^2 N}{2.5}$, where D is cylinder diameter in inches and N is the number of cylinders. This formula was put forward with the authority of the Royal Automobile Club, and experience has shown that in the great majority of cases it gives wonderfully good results. It may even be doubted whether any of the far more complicated

¹ "The Steam Engine," by Prof. Perry, p. 117.

formulae since brought forward give a more accurate measurement. It is, of course, not fitted for use with racing motors, in which everything in design is sacrificed to piston speed, high mean pressure, and a sufficient endurance to last through a few races. For an engine having 4-inch cylinders the Royal Automobile Club formula gives a rating of 25.6 horse-power, which is about the brake horse-power that a normal engine of this size would yield when driven at a normal speed. Racing motors of this size have, however, given almost, if not quite, 100 horse-power, and even if it were possible to do so it is a question whether it is worth while to search out a formula which would embrace such divergent practice and conditions of operation. The Royal Automobile Club formula corresponds to combining a piston speed of 1000 feet per sec. with a mean pressure of 67.2 lb. per square inch. Before it can be revised a complete series of careful experiments on engines of sizes ranging from 2 inches to 10 inches should be carried out.

In the succeeding article the writer proposes to discuss details of the recent mechanical improvement of the internal-combustion engine in relation to the theoretical investigations already discussed.

H. E. WIMPERIS.

CONFERENCE OF ENGINEERS AND SHIP-BUILDERS AT GLASGOW.

A JOINT summer meeting of the members of the Institution of Engineers and Shipbuilders in Scotland and of the North-east Coast Institution of Engineers and Shipbuilders was held in Glasgow on August 4, 5, and 6. It is of interest to note that, although a large number of works and shipbuilding yards was thrown open to visitors, no works in which Admiralty work is under construction were included. This arises from the firms concerned paying respect to the wishes of the Admiralty that as much secrecy as possible should be observed regarding the details and progress of Government work. Wednesday and Thursday mornings were reserved for the reading and discussion of papers, of which we give brief extracts.

Sir Andrew Noble contributed some notes on the history of propellants. Perhaps the easiest way of showing the striking difference between the old gunpowders and some of the modern propellants is to quote two tables given by the author. As both the units of heat and the quantity of gas vary considerably, depending on the pressure under which the propellant is exploded, the author has taken the transformation approximately at the pressures at which the propellants are generally used in guns.

Older Propellants.

	Pebble	R.L.G.	F.G.	Mining powder	Spanish powder
Volumes of gas ...	278	274	263	360	234
Units of heat ...	721	726	738	517	767
Comparative energy ...	200.438	198.924	194.094	186.120	179.478

Modern Propellants.

	Cordite, Mark I.	Italian ballistite	M.D. cordite	Norwegian 167	Nitro-cellulose	Norwegian 165
Volumes of gas ...	875.5	810.5	913.5	899.9	934.0	909.9
Units of heat ...	1246.0	1305.0	1030.0	1005.5	924.0	935.5
Comparative energy	1,090,873	1,057,703	940,905	904,850	863,016	851,212

It will be seen from the tables that the comparative energies of the modern explosives are more than four times as great as those of the older propellants.

As regards the serious question of erosion, in the case of very large guns it is important to remember that, while the surface of the bore subject to the more violent erosion increases approximately as the calibre or a little more, the charge of the propellant required to give to similar projectiles the same maximum velocity increases as the cube of the calibre. Consequently, unless special arrangements as to the projectile are made, or other means adopted, the life of the largest guns before re-lining must be short when compared with that of smaller guns. Attention should be given to the best method of reducing erosion when very large charges are used, either by lowering the temperature of explosion or possibly by introducing some cooling agent with the charge.

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The author has tested the capacity for erosion of several explosives, and has found these to vary considerably, but all give similar results with varied charges. Thus the erosion due to one three-quarter charge was less than that of a full charge, but two three-quarter charges gave more erosion than one full charge. Two half charges gave less, but three half charges gave more, erosion than one full charge. These experiments controvert the statement which has been made frequently that the erosion due to four three-quarter charges, as also that due to sixteen half charges, are equivalent to the erosion due to one full charge.

A paper on the trials and performances of the S.S. *Otaki*, by Engineer-Commander W. McK. Wisnom, R.N., is of interest in view of this vessel being the first merchant vessel fitted with a combination of reciprocating and turbine machinery. The *Otaki* was built by Messrs. Denny, of Dumbarton, and delivered in November, 1908. She has since completed a voyage to New Zealand and back, and is virtually a sister ship to the twin-screw vessels *Orari* and *Opawa*, fitted with reciprocating engines and constructed by the same builders. All three vessels belong to the New Zealand Shipping Company.

The only important differences in the vessels consist in an increase in length of the *Otaki* of 4 feet 6 inches to make up for the loss in cargo capacity due to three shaft tunnels instead of two, and also the modified design of the stern and stern post in the same ship. The boiler installations in the three vessels are identical. The engines of the *Otaki* consist of two sets of ordinary triple-expansion reciprocating engines driving wing propellers, and a low-pressure turbine driving a central propeller. In ordinary ahead working the reciprocating engines exhaust into the turbine, and change valves are fitted so that the reciprocating engines can also exhaust direct to the condensers.

At the trials on the measured mile at Skelmorlie the *Orari* attained a mean speed of 14.6 knots; the *Otaki*, under the same conditions, attained a mean speed of more than 15 knots for a total water consumption per hour of 6 per cent. less than that of the *Orari*. The total water consumption per hour in the *Otaki* at 14.6 knots was 17 per cent. less than in the *Orari* at the same speed.

On the run from the Clyde to Liverpool, with the vessel partly loaded, on November 21 and 22, 1908, at about half power, the coal consumption was about 1.387 lb. per horse-power per hour for all purposes. Scotch coal was used, having a heating value of about 7500 centigrade units.

As regards the performance of the *Otaki* on service, the coal consumption on the voyage from Liverpool to Teneriffe was 11 per cent. less than the mean for the sister vessels *Orari* and *Opawa* under similar conditions and at practically the same speed. For the round voyage, at the same speed, the coal consumption of the *Otaki* is about 8 per cent. less than that of her sister ships. The engines of the *Otaki* made a non-stop run from Teneriffe to New Zealand, a distance of 11,669 miles as logged, which is probably the longest continuous run yet made by a marine turbine. The turbine worked perfectly satisfactorily throughout the whole round voyage.

The New Zealand Shipping Company is to be congratulated in allowing this experiment to be made, and also for its courtesy in rendering available the very full information contained in the paper regarding the performances of their vessels.

PAPERS ON REPTILES AND FISHES.

A NEW species of leathery, or leather-back, turtle from the Miocene of Maryland is described by Mr. W. Palmer in No. 1669 of the Proceedings of the U.S. National Museum under the name of *Psephophorus calvertensis*, this being the first representative of the genus, which was previously known from the Tertiaries of Europe and Egypt, hitherto recorded from American deposits. It is, however, pointed out that certain dermal armour from the Zeuglodon Limestone of North America, figured by Müller in his work on Zeuglodon, probably belongs to the same genus.

In No. 1681 of the same publication Dr. L. Stejneger gives the name *Mesopeltis longifrenis* to a snake from