in a heat-engine working with maximum efficiency. There must also be one and only one stage in which abrupt change of temperature occurs without change of volume. In the steam-engine with maximum expansion of the steam, there is abrupt rise of temperature at the beginning of the cycle. If, as in the Watt-Newcomen engine, there is also abrupt fall of temperature before expansion is complete, loss of efficiency is a necessary result.

At the present time steam-engines and oil-engines are running a neck-to-neck race as regards many employments, while elsewhere the oil-engine is everywhere being applied for quite new purposes, where no heat-engine had previously been applied. In the opinion of many persons the steam-engine is bound to be displaced more and more by the internal-combustion engine. This opinion is largely based on the current academic doctrine that the efficiency of a heat-engine depends on the absolute temperature reached in the engine. In the present paper the academic teaching has been thrown to the winds, backed though it be by the names of men to whom the whole world has good reason to be grateful. A step further may also now be taken. We suggest that the development of the steam-engine has been very greatly hindered by the fallacious teaching associated with Carnot's cycle. Engineers have been prevented from seeing clearly what the maximum efficiency of a heat-engine is, where that efficiency is being needlessly lost, and how the steam-engine can be modified to suit varying circumstances without loss, or with minimum loss, in efficiency.

We still use furnaces and boilers which waste much heat whenever an engine is temporarily out of action or doing only light duty, even though they may be so designed as to cause very little waste, during continuous full duty of the engine. It seems probable that the furnaces and boilers of the future will be gas fed, the gas being formed in a heat-insulated producer or carburettor, and only made and burnt as the steam

is required, the whole regulation being mechanical and the heat of the waste gases being nearly all returned to the furnace and boiler. Another alternative presenting similar advantages is the use of pulverised fuel. The boiler and furnace can then be made much smaller than is now usually the case.

As regards modifications of the steam-engine to suit varying circumstances, it seems that small engines, working at very high pressures, and with correspondingly small tubular boilers, will come more and more into use. A steam pressure of 100 atmospheres, with a corresponding temperature of 600° F., seems well within reach. At such a pressure the percentage loss of efficiency, owing to either the discarding of a condenser or condensation at or even somewhat above boiling-point, would not be too large. The bulky apparatus required for complete expansion can thus be dispensed with, reducing the engine to extremely compact proportions and very small weight. By these means the steam-engine can be rendered far more compact and adaptable to varying conditions under which only internal-combustion engines, or steam-engines without a condenser, are now used.

Perhaps too sanguine a view is taken of the future of the steam-engine; but it seems that in every case where either fuel economy or size of engine is of predominating importance, the steam-engine and coal will in the future displace the internal-combustion engine and oil. Even where oil or gas is alone desirable or available as fuel, it will probably turn out to be cheaper, where fuel economy and weight of engine are important, to use them as fuels for steam-engines. The latter will probably take the place of internal-combustion engines in even motor vehicles and aeroplanes. With the further development of electrical transmission of power obtained from coal and steam, the steam-engine and coal will also come more and more to the fore.

The Motion of Whales during Swimming.

By Dr. C. G. JOH. PETERSEN, Director of the Danish Biological Station, Copenhagen.

IN our two well-known Danish zoological handbooks it is stated regarding the swimming of whales, in one that "It is the screwing actions of the hind part of the body (the tail) which force the whale through the water, the tail fin acting only to balance up and down," in the other that "The whales move in the manner of fish by flapping the tail from side to side"; according to a verbal statement, this was observed by the author himself on porpoises in a tank in the Zoological Garden. In the foreign literature I have found information¹ that whales, when swimming rapidly, move the tail fin up and down; when they swim slowly, on the other hand, they perform screw-like motions. Porpoises have been observed in tanks in England to swim by moving the tail fin up and down with slight undulations to each side.

Thus there seem to be greatly divergent opinions as to the manner in which whales effect their swimming movements. I have myself seen dolphins following, e.g., the steamship of the Biological Station, and I have spoken with many others who have seen the same; we are agreed that it is impossible to see how they swim; they only tremble, but follow, apparently with ease, the largest steamship going at full speed.

In the spring of 1924 I was by chance present at a catch of porpoises in the Bramsnæs Vig (by Holbæk),

and there I bought the tail of a porpoise just caught. Dr. Blegvad, the assistant of the station, and I dissected it; Fig. 1 is a sketch of the result. At the base the tail fin is very flexible, so long as it is in a fresh condition, similar to the carpus of the hand of man. The vertebræ here are very flexible in relation to each other, and the vertebral column extends right out to the posterior edge of the fin. No muscles are found in the tail fin itself, only four strong tendons extending right out to the extreme vertebræ; these tendons may move the horizontal fin up and down, but scarcely with any force, and doubtfully sideways. The flukes of the tail fin consist only of epidermis and fibrous tissue; they are somewhat elastic for movements up and down. Of other muscles in the tail (hind part of the body), there are two for lateral motions and two for vertical motions; they terminate with strong tendons some distance from the root of the tail fin.

The tail fin with its vertebræ may thus be moved up and down by bending at the root; but these movements do not seem to produce force enough for powerful swimming, because, amongst other reasons, the flukes will impede the speed considerably when in their extreme positions. One can well imagine that quick movements of the flukes towards the horizontal position may give a small speed, as when a rudder is moved in a little boat; this produces a slight speed, if the motions towards the central

¹ Beddard, "A Book of Whales," London, 1900; Murie, "On the Anatomy of a Fin-Whale," Proc. Zool. Soc., 1865; T. Bell Pettigrew, "Animal Locomotion," London, third edition, 1883.

position are the strongest. But if we imagine that the extreme part of the tail (the hind part of the body) itself is moved up and down, even if these movements are only slight, the elastic fin would be enabled to take up suitable inclined positions for up-and-down movements and thus give effective power during the full extent of the motion (Fig. 2).

FIG. 1.—Combination of a vertical, transverse section and a vertical, longitudinal section through the tail of the porpoise. 1, Dorsal muscle; 2, the two upper tail fin muscles; 3, the two lateral muscles; 4, the two lower tail fin muscles; 5, ventral muscle; 6, layer of blubber; 7, left upper and lower tail fin tendon. II, The tail fin seen from above, with its two upper tendons and the vertebrae denuded. III, Transverse section through the tail.

In order to try this, I had a thin steel plate made, shaped like the tail fin of a porpoise, and attached it to a vertical stick; when this stick was moved up and down in the water at a suitable speed (rhythm) the plate produced a powerful current rearward, simultaneously forcing the stick forward, against the edge by which I supported it. The steel plate I employed was too thin and flexible for a continuation of these experiments; for I could only "swim slowly" with it, and to procure a stronger one took so long, that I was not able to proceed further; but the experiment had proved, without doubt, that by means of small movements up and down of the terminal part of the tail, the tail fin of the dolphin may be employed as an excellent means of propulsion, inasmuch as its muscles (tendons) may give it the correct rigidity, corresponding with the varying speed through the water; in this the operations of the four named muscles and tendons surely may be sought. When the dolphin starts swimming, large movements are required to move a sufficiently large quantity of water, but, when speed is once gained, the water will be felt hard, and then only small but quick motions up and down, with more force and more rigidity in the tail for each stroke, are required. Dolphins are said to be able to follow destroyers up to a rate of about 30 knots, *i.e.* at the same speed as fast trains go between Copenhagen and Korsør.

It is the great drawback in all steamship propellers that their mould cannot conform with the variation in speed, and that they are quite without elasticity; they yield, therefore, only a comparatively small effective power. Mr. Vogt, an engineer, has endeavoured with the pendulum propeller to produce a variable pitch by means of a complicated system of springs (metal springs), and he really succeeded in this; but the construction seems to have been too expensive to make use of practically.

By means of the elastic and flexible structures of which the tail fin and the tail of the porpoise are made it is, on the other hand, possible to obtain an enormous effective power by comparatively few and

small movements; thus there is no need for astonishment that this little fin is really able to give such a high speed to the big animal. Mr. Vogt, with whom I have debated this matter, agreed fully with me on this point, as well as, on the whole, with my views upon this matter.

The objection may be raised to this illustration of the swimming movements of the whale, that the movements up and down of the tail itself must evidently impede the speed through the water; but the tail of the whale is, as a rule, so compressed in the terminal part that the resistance offered is considerably diminished, and, furthermore, it refers only to small, vertical movements.

As is well known, many fishes swim by performing lateral movements with the tail, because the fin is set vertically, *i.e.* on the same principle as the motions of whales, which only move the fin up and down, because this is situated horizontally; that fish in addition to these movements may also perform screw-like motions, is also well known from seeing goldfishes in aquaria. But they do this only when swimming slowly; if speed is desired, it is gained by means of strokes from side to side, analogous to the up-and-down strokes of the whales.

It is now easily understood why many people, including myself, who have observed dolphins following steamships during speed, have seen nothing but a trembling of their bodies, because the movements of the tail and the fin are up and down and comparatively slight, and vertical movements are not easily observed from above. Had there been sideways or screw-like motions, they could not have escaped the observer; that such movements also may be performed by whales, I do not doubt, but they occur only during quite slow movement, when the whale feeds, or when for some other reason it is in no hurry.

When, especially from observations of porpoises in tanks, lateral motions of the tail are mentioned, or

FIG. 2.—The positions of the tail fin (IV.) during downward movement of the tail, (V.) during upward movement of the tail.

that the tail is used in a fish-like manner by strokes from side to side, this evidently arises from the fact that here the animal the whole time had to steer in order to avoid running against the sides of the tank. The observations themselves undoubtedly are correct. But statements to the effect that the tail fin is exclusively used for steering up or down are false; it may be used for this, and certainly also for steering sideways, but the flukes of the tail fin are the proper

organs for propulsion of the whale, as the propellers are in a ship, and the importance of the tail (hind part of the body) corresponds to that of the ship's engine which moves the propeller.

If we compare the size of the propeller of a steamship with the size of the ship, the propeller seems small, and still it may, in spite of its slight effective power, propel the ship; the tail fin of a dolphin or a whale is not smaller in comparison with the size of these animals than the propeller of the steamship, but larger, if anything. Thus, bearing in mind the obviously far greater effective power of the fins of

the whales, it is not to be wondered at that these animals may follow the biggest steamships with ease, and even follow our quick destroyers; in fact, a harpooned whale may carry away a steamship with great velocity through the water, in spite of the steamer backing full speed with its propeller.

I have presumed that the anatomy of the tail and the tail fin is mainly the same in the porpoise as in the other whales; this, however, as well as so many other things concerning this matter, I must leave to others, who may get an opportunity to examine it more closely.

Physics in Radiology.

SEVERAL notable papers were read before the Physics Section of the International Congress of Radiology, which was held at the Central Hall, Westminster, on June 30-July 4. The work of the Congress began with a joint discussion, in which the Physics and Radiology Sections met for a full day's consideration of the difficult problem of X-ray measurement. This discussion was opened at 10 A.M. on July 1 before a large attendance, by Sir William Bragg and Dr. Becquerel, the president (Dr. T. Holland) occupying the chair. The importance of such a discussion, in which representative men from practically all over the world took part, is obvious, and it is satisfactory to be able to report that the practical outcome has been a definite proposal as to the mode of initiating the formation of an International Committee to deal with the matter.

Sir William Bragg dealt generally with the importance of physical measurements and referred to the difficulties already met with in determining the brightness of light. He pointed out that the X-ray problem has special added difficulties of its own. First comes the question of a unit, and then the production of standards to be expressed in terms of the agreed unit, and finally it remains to ascertain what biological effects are associated with certain rays, or groups of rays, so measured. He was hopeful that a successful issue will ultimately result from the efforts now being made throughout the world towards setting up a suitable system of X-ray measurement, but he warned his hearers that the question of an X-ray unit is beset with more difficulties than have ever been met with in the case of any other unit which science has been called upon to devise. Finally, he directed attention to the principles which must underlie such a system, and set the problem clearly before the meeting.

Dr. Becquerel, of Paris, spoke more in detail with reference to the conditions which the medical radiologist has to face, referring to the pioneer work of Villard, and discussing the actual methods of measurement suggested by Solomon, Krönig and Friederich, Seit and Wintz, and others. He made an eloquent appeal for international unity in regard to the question of X-ray measurement.

On the conclusion of the formal opening of the discussion, the chairman of the Physics Section (Major C. E. S. Phillips) presided for the rest of the day. In the course of his remarks, Dr. Becquerel strongly urged the setting up of an International Committee to deal with X-ray measurements, and Dr. Finzi, who spoke later, also directed attention to the matter and seconded Dr. Becquerel's proposal, which on being put to the meeting was carried with enthusiasm.

Dr. Becquerel was followed by Dr. Solomon (France), Dr. Behnken (Germany), Prof. Grebe (Germany), Dr. Altschul (Czechoslovakia), Dr. Shaxby (Cardiff), who read a communication from Dr. A. Dauvillier

(France), Dr. Finzi (London), Dr. Moore (London), Prof. Wintz (Germany), Dr. Reyjeski (on behalf of Prof. Dessauer), Dr. Glasser (U.S.A.), Prof. Friederich (Germany), Dr. Mallet (France), Dr. Holdfelder (Germany), Prof. Holthausen, Dr. Coliez, Prof. Crowther (Reading), Prof. Russ (London), and Dr. Ernst (U.S.A.). The chairman directed attention, at the conclusion of the discussion, to the principal points raised, and emphasised the desirability of taking steps towards the establishment of an International Committee to pursue the subject.

On Wednesday evening the Silvanus Thompson Memorial Lecture (inaugurated by the Röntgen Society) was delivered (in English) by the Duc de Broglie, and attracted an enthusiastic audience. The nature of the secondary radiations set up by X- and gamma rays, and attempts to understand the process by which they are initiated, are matters of great importance and interest to radiologists generally, and especially to those searching for clues as to a biophysical explanation of the effects of radiations upon tissues. The Duc de Broglie eloquently summarised our present knowledge of this subject, and gave a valuable account of some recent researches by French physicists who have been extending the work begun by Rutherford, C. T. R. Wilson, Ellis, and others, relating to the problem. At the conclusion of the lecture the Silvanus Thompson Memorial Medal was handed to the Duc de Broglie by the president.

On Thursday morning an interesting paper on the radiography of coal was read by Mr. Norman Kemp, and Dr. Bouers then described a new metal X-ray tube (Metalix) for use in radiography and X-ray therapy. This was followed by an important paper by Prof. Friederich (Freiburg) in which some new results were described. The last paper of the morning was read by Dr. Koopman, of Amsterdam, who showed a novel type of Potter-Bucky diaphragm. The variety and originality of these papers were striking, and interesting discussions followed each one of them.

In the afternoon the Section did not meet, on account of the visit to the National Physical Laboratory, which had been arranged for that day in response to the kind invitation of the Director.

The Section again met on Friday morning at 10 A.M. for a discussion of methods of protection, opened by Dr. G. W. C. Kaye, of the National Physical Laboratory. An animated debate followed, to which M. Pilon (Paris) sent a written contribution (read by Mr. Gough), and the following took part: Dr. Ferreux (Paris), Mr. Pullin (London), Dr. Pirie (Montreal), Dr. Shaxby (Cardiff), and Dr. Moore (London). Dr. Kaye, in his reply, directed attention to the need of standardising the scheme of protection, and proposed the following resolution, which was seconded by Mr. Pullin and unanimously agreed to:

"That the Physics Section of the first International