models where the linear ratio is considerable, the residuary resistance alone should be compared by that means, the frictional resistance being independently calculated for ship and model from the results of Froude’s experiments. The law may, however, be extended with- out appreciable error to total resistance when the corresponding linear dimensions of the ships compared are not greatly different.

If it be assumed that the residuary resistance of a ship is capable of being expressed as the sum of a number of terms of the form WmVn, where W is the displacement, it appears from the law of comparison that 6*m*+*n*=6 for each term of the expression; and in the con- struction of approximate formulae of this type for residuary resist­ance, the indices *m* and *n* must satisfy this equation. The values of the indices are found to vary irregularly with the speed and type of ship; at uneconomical speeds *n* may be equal to or greater than 5, and at “ favourable ” speeds its value may be as low as 1∙5, 4 being an approximate mean value for *n* at moderate speeds. A fact pointed out by Professor Biles in a paper read before the Institution of Naval Architects in 1881 is interesting in this connexion. When the resistance of a ship varies as the 6th power of the speed, an increase in the displacement by a proportionate enlargement of dimension will not cause an increase in the resistance for the same speed ; and if the resistance varied as a higher power of the speed than the 6th, the resistance would actually be reduced by increasing the displacement.

The accuracy of the law of comparison was verified by the “ Grey- hound ” resistance experiments carried out by Froude on behalf of the Admiralty *(Trans. I.N.A.,* 1874).

The “ Greyhound ” was a twin-screw sloop 170 ft. long and of about 1160 tons displacement; the trials were made over a range of speeds extending from 3 to 12½ knots, and with varying draught and trim. She was towed from the end of a spar 48 ft. in length projecting over the side of the towing vessel, H.M.S. “ Active ” ; this ensured that the wave system and wake of the “ Active ” were prevented from reach­ing the “ Greyhound ” and influencing her resistance. A dynamo- metric apparatus was placed in the bow of the “ Greyhound, ’’ and arranged so as to record the horizontal component of the tension in the tow rope; by this means the ship’s resistance was measured under various conditions and her effective horse-power obtained. A “ log ship” or small board, ballasted to sink a few feet and remain normal to the direction of the pull, was attached to the end of a log fine which was allowed to run freely out over the end of a spar during the trials. The slip of the “ log ship ” having been obtained during inde­pendent trials, the speed of the “ Greyhound ” was estimated from the log-line readings with fair accuracy. From these results curves of resistance on a base of speed were constructed for various conditions of draught and trim; the frictional resistance was estimated from the experiments on planks, and curves of residuary resistance were obtained. A model of the “ Greyhound,” on a scale of 1/16 full size, was also towed in the experimental tank under conditions corresponding to those of the ship; as with the ship, the total resistance was measured, that due to friction was calculated, and the residuary resistance of the model was obtained. It was found, by assuming a particular value for the unknown frictional coefficient of the “ Greyhound,” that a dose agreement occurred between the residuary resistances of ship and model. This coefficient corresponded to that for a mixture of ⅓ calico and ⅔ varnish, which was probably equivalent to the condition of the ship’s bottom during the trials.

Similar experiments were carried out by Mr Yarrow *(Trans. I.N.A.,* 1883) on a torpedo boat 100 ft. long; it was found that the residuary resistance of the boat was then about 3 % in excess of that deduced by the law of comparison from experiments on a model.

As a result of the “ Greyhound ” trials, the accepted method of estimating the horse-power required for a new ship is by running a scale mode! under corresponding conditions in an ex­perimental tank fitted and equipped for the purpose. The law of comparison is applied to the residuary resistance, or, if used for the total resistance, a “ frictional correction ” is made (see below). In 1871 Froude constructed a tank and suitable apparatus at Torquay on behalf of the British Admiralty. In 1885, six years after his death, the ground occupied by the Torquay tank was required for building purposes, and a new tank was constructed at Hasíar, near Portsmouth, from the designs and under the super­vision of Mr R. E. Froude, such improvements being added as experience at Torquay had shown to be desirable. At both these tanks models of propellers as well as of ships were experimented upon, besides a variety of matters connected with the general subject.

Similar establishments have now been instituted by several foreign governments and by two private firms in Great Britain, Messrs Denny at Dumbarton and Messrs John Brown at Clydebank. The experimental tank now under construction at Teddington should prove an important and useful addition to the number of such installations in this country. It is intended to be used for general research and to be available also for undertaking such private work as may be re­quired by shipbuilding firms. Its inception is due to a committee composed largely of members of the Institution of Naval Architects, and the cost of installation is being defrayed by Mr A. F. Yarrow. The tank will form a part of the National Physical Laboratory, and its general control will be in the hands of officers of the laboratory.

The Admiralty experimental tank at Haslar is nearly 400 ft. long, 20 ft. wide and 9 ft. deep. The main experimental carriage spans the whole width of the tank, and carries a secondary railway on which the subsidiary carriages, which carry the experimental apparatus of different kinds, are adjusted in position. The main carriage runs on rails on the side walls, and can travel the whole length of the tank; it is driven at various speeds by a wire rope from a stationary engine of ample power. Ordinary speeds range from 100 to 800 ft. per minute, while an extreme speed of 1200 ft. per minute can be obtained; the speeds are regulated by a highly sensitive governor. The models, generally from 10 to 14 ft. long, are made of hard paraffin wax, somewhat over 1 in. in thickness; they are cast in a mould, with an allowance of about ¼ in. for finishing. The model is shaped accurately by being placed bottom up on the bed of a machine in which a pair of revolving cutters, one on each side of the model, cuts out on its surface a series of level lines, whose contours are precisely similar to those on the drawing of the ship whose model is under treatment. When all the level lines have been cut in, the model presents the appearance of a series of steps, the bottom angles of which correctly represent the true form the model should possess. The paraffin ridges between these level lines are trimmed off by the use of suitable tools and the outside surface made quite smooth with flexible steel scrapers. The model is ballasted to its required displacement and saddled with a frame, which carries the guiding attachment and also the towing-rod, and is then placed below the dynamometer. The towing-rod at its for- ward end is then in a position to impart horizontal forces by a hard steel surface to a knife-edge on the dynamometer lever within the model at about the level of the water surface. There are various delicate arrangements with knife-edge adjustments, which result in the horizontal forces being transmitted through a spiral spring, the extensions of which are multiplied by a lever and recorded by a pen on a paper-covered cylinder, distance and time being simul- taneously recorded. The speed and resistance corresponding to each experiment are deduced from these elements, a most necessary condition being that the speed shall be uniform throughout each experiment. By somewhat similar arrangements on a subsidiary carriage, the action of model screw propellers is tested either in undisturbed water or behind a model, the speed, rate of rotation, rotary resistance and thrust being measured.

An interesting account by Dr Glazebrook of some experimental tanks in various countries, together with particulars of some improvements in their equipment, appears in *Trans. I.Ν.A.,* 1909.

Of the very large number of experimental results that have now been obtained from the trials of ships’ models in the tanks referred to above, comparatively few have been made public. In connexion with the Torquay and Haslar tanks some few of the reports by the elder Froude and Mr R. E. Froude have been published by order or permission of the Board of Admiralty, chiefly through the Institution of Naval Architects. Amongst these may be mentioned the “ Greyhound ” experiments recorded in 1874; the “ Merkara ” results in 1876; experiments on the effect produced on the wave-making resistance of ships by varying the length of parallel middle body, in 1877; results obtained from models of three merchant liners in 1881; papers in 1888 and 1892 on the “ constant ” system of notation of results of model experiments, used at the Admiralty Experimental Works; and some results of a systematic series of model experiments by Mr R. E. Froude appeared in 1904. Some records of the experiments made at private and foreign experiment establishments have also appeared.

Some of the most important of these experiments are described in these notes; it remains to show how they are applied in practice to obtain an estimate of the indicated horse-power required to drive a ship at any speed. If the resistance has been obtained from a model experiment, or inferred by the law of comparison from data obtained with a vessel of similar type, the effective horse-power is known; and by assuming a suitable value for the propulsive coefficient (vide *Propulsion)* the indicated horse-power is determined.

If model experiments or data for exactly similar ships arc un­available, the method of estimating the power which is probably most commonly used is one involving a relation between I.H.P., displacement, and speed, which is expressed by the formula—

(Speed),× (Displacement)\* \_

rτl.ρ.

C being called the Admiralty coefficient. The value of C varies considerably at different speeds even for the same ship. For it to be constant, the I.H.P. must vary as the cube of the speed; if resistance varied as the square of the speed and I.H.P. as resistance and speed, the condition of constancy would be fulfilled. Actually, owing to variations in the index of the speed to which the resistance is proportional, in the length and form of the ship and in the machinery and propellers, this method of estimating I.H.P can only be used with great caution, care being taken that the values of C selected for comparison are taken from ships of fairly similar type, and of corresponding lengths and speeds.

Another means of obtaining approximate estimates of the power