will then differ from air-borne bodies only in the comparative slowness imposed by the resistance of the water. Ships having the same length as breadth, or rather opposing the same form and area to side progress as to forward progress could never do other than sail before the wind. No disposition of canvas could make them deviate to the right or left of their course to leeward. But by an alteration of form giving them greater length than breadth, and greater resistance to motion sideways than to motion endwise, they came to possess the power of being able not only to sail to the right or left of the course of the wind, before the wind, but also to sail towards the wind. The wind can be made to impel them towards the point from which it is blowing by means of the lengthened form acted on by the resistance of the water.

Motion directly towards the wind cannot be maintained, but by sailing obliquely towards it first to one side and then to the other progress is made in advance, and the vessel “beats to windward.” The action is like that which would be required to blow a railway car to the eastward by the action of an easterly wind. If the line of rails were due east and west, and the wind were always direct from the east, the thing could not be done. But with a wind to the south or north of east, by setting a sail in the car so that its surface lies between the course of the wind and the direction of the rails, it would then receive the impulse of the wind on its back and would drive the car forwards. There would be a large part of the force of the wind ineffective because of the obliquity of the sail ; and of the part which is effective a large portion would be tending to force the car against the rails sideways, but there would be progression to windward. In the case of the ship the resistance to side motion is due to the unsuitability of the proportions and form for progress in that direction as compared with progress ahead, but still there is motion transversely to the line of keel. This motion is called leeway. As the ship moves to leeward and ahead simultaneously there is a point of balance of the forces of the fluid against the immersed body—a centre of fluid pressure. The object of the constructor is to place the masts in the ship in such positions that the centre of pressure of wind upon the sails shall fall a little behind or astern of this centre of resistance of the fluid. In that case there is a tendency in the ship to turn round under the action of these two forces, and to turn with her head towards the wind. This tendency is corrected by the action of the rudder. If the tendency to turn were the other way, although that could also be corrected by the rudder, yet there would be danger of the wind overcoming the rudder action in squalls, and the ship would then come broadside to the wind. In that case, while she might have been quite capable of bearing the pressure of the wind blowing obliquely upon her sails, she might have her sails blown away, or her masts broken, or be her­self capsized by the direct impulsion of the wind upon the sail and upon the hull of the ship.

Many examples of disposition of sails might be given. Their dis­position is always made to satisfy the conditions that as much sail as possible is required, but if the vessel is small it must be capable of being instantly let go in a squall, or when the wind is gusty. Otherwise, where it cannot be readily let go, its area should be capable of reduction in squally weather, still retaining its efficiency, so that no pressure of the wind should be capable of upsetting the ship. If a sudden violent squall should strike the ship she should find relief, not by a large inclination, but by the blowing away of the sails out of the bolt-ropes, or the carrying away of the masts. One or other of these must of course happen if the area of canvas and the strength of the sails and of the spars are so proportioned at the moment the squall strikes the ship as to be less than the resistance offered by the stability of the ship to a large inclination. Ships are sometimes, when struck by a squall, blown over on to their sides, the sails being in the water. If the sails or spars are then cut away or otherwise got rid of the ship may right herself.

In the *Transactions* of the Institution of Naval Architects for 1881, Mr W. H. White says :—

“Any investigation of the behaviour of sailing ships at sea must take account of the conditions belonging to the discussion of their rolling when no sail is set, and must superpose upon those conditions the other and no less difficult conditions relating to the action of the wind upon the sails, the influence of heaving motions upon the stability, and the steadying effect of sail-spread.

“It may fairly be assumed that the labours of the late Mr W. Froude have made it possible to predict, with close approximation to truth, the behaviour of a ship whose qualities are known and which has no sails set, when rolling among waves of any assumed dimensions. By a happy com­bination of experimental investigation and mathematical procedure, Mr Fronde succeeded in tracing the motion from instant to instant, and checked the results thus obtained by comparison with the actual observations made in a sea-way on the behaviour of the ' Devastation.’ The details of his method, and examples of its application, will be found in the *Transactions* for 1875, and in the appendix to the report of the ‘Inflexible’ committee.

“ The conclusion I have reached, after a careful study of the subject, is that we need very considerable extensions of our knowledge of the laws of wind-pressure before more exact investigations will be possible so as to enable us to pronounce upon the safety or danger of a sailing ship. Nor must it be overlooked that sailing ships are not to be treated as machines worked under certain fixed conditions. Their safety depends at least as much upon seamanship and skilful management as upon the qualities with which they are endowed by their designers. Moreover, it is idle to pretend

that, in determining what sail-spread can be safely given to a ship, the naval architect proceeds in accordance with exact or purely scientific methods. He is largely influenced by the results of experience with other ships, and thus proceeds by comparison rather than by direct investigation from first principles. Certain scientific methods are employed, of course, in making these comparisons. For example, the righting moment at different angles of inclination is usually compared with the corresponding ‘sail-moment’; but even here certain assumptions have to be made as to the amount of sail to be reckoned in the calculation, and as to the effective wind-pressure per unit of sail-area. Between ship and ship these assumptions are unobjection­able, but they are not therefore to be regarded as strictly true.

“The calculations of curves of stability and the determination of the ranges of stability for ships form important extensions of earlier practice. But, even when possessed of this additional information, the naval architect must resort to experience in order to appreciate fairly the influence of sea­manship and the relative manageability of ships and sails of different sizes. There can be no question but that a good range and large area of a curve of stability denote conditions very favourable to the safety of a ship against capsizing. But, in practice, it frequently happens that such favourable conditions can scarcely be secured in association with other important qualities, and a comparatively moderate range and area of the curve of stability have to be considered when the designer attempts to decide whether sufficient stability has been provided. Under these circumstances experience is of the greatest value ; *a priori* reasoning cannot take the place of experi­ence, because (as remarked above) the worst combination of circumstances cannot be fixed, and because some important conditions in the problem are yet unsettled. Certain arbitrary standards may be set up, and ships may be pronounced safe or unsafe; but this is no solution of the problem. There are classes of ships in existence which have been navigated in all weathers, under sail, and in all parts of the world, which might be pronounced unsafe if tested by some of the standards that have been proposed ; but the fact that not a single vessel of that class has been capsized or lost at sea during many years will probably be accepted, in most quarters, as sufficient evidence of the seaworthiness of these classes, and as an indication of the doubtful authority of the proposed standards.”

For the different kinds of sails, and for sailmaking, see Sail.

The “Comet” was the first steam-vessel built in Europe that plied with success in any river or open sea. She was built in Scotland in 1811-12 for Mr Henry Bell, of Helensburgh, having been designed as well as built by Mr John Wood, at Port- Glasgow. The little vessel was 42 feet long and 11 feet wide. Her engine was of about four horse-power, with a single vertical cylinder. She made her first voyage in January 1812, and plied regularly between Glasgow and Greenock at about 5 miles an hour. There had been an earlier commercial success than this with a steam vessel in the United States, for a steamer called the “Clermont” was built in 1807, and plied successfully on the Hud­son River. This boat, built for Fulton, was engined by the English firm of Boulton & Watt. The reason for this choice of engineers by Fulton appears to have been that Fulton had seen a still earlier steamboat for towing in canals, also built in Scotland, in 1801, for Lord Dundas, and having an engine on Watt’s double­acting principle, working by means of a connecting rod and crank and single stern wheel. This vessel, the “Charlotte Dundas,” was successful so far as propulsion was concerned, but was not regularly employed because of the destructive effects of the propeller upon the banks of the canals. The engine of the canal boat was made by Mr William Symington, and he had previously made a marine engine for Mr Patrick Miller, of Dalswinton, Dumfriesshire. This last-named engine, made in Edinburgh in 1788, marks, it is said, the first really satisfactory attempt at steam navigation in the world. It was employed to drive two central paddle-wheels in a twin pleasure-boat (a sort of “ Castalia”) on Dalswinton Loch. The cylinders were only 4 inches in diameter, but a speed of

5 miles an hour was attained in a boat 25 feet long and 7 feet broad. The first steam vessel built in a royal dockyard was also called the “Comet.” She appears to have been built about the year 1822, and was engined by Boulton & Watt. This ship had two engines of forty horse-power each, to be worked in pairs on the plan understood to have been introduced by the same firm in 1814. In 1838 the “Sirius” and “Great Western” commenced the regular Atlantic passage under steam. The latter vessel, proposed by I. K. Brunel, and engined by Maudslay Sons

& Field, made the passage at about 8 or 9 knots per hour. One year earlier (1837) Captain Ericsson, a scientific veteran who is still among us (1886), towed the Admiralty barge with their lordships on board from Somerset House to Blackwall and back at the rate of 10 miles an hour in a small steam vessel driven by a screw.

The screw did not come rapidly into favour with the Admiralty, and it was not until 1842 that they first became possessed of a screw vessel. This vessel, first called the “Mermaid” and afterwards the “Dwarf,” was designed and built by the late Mr Ditchbum, and engined by Messrs Rennie. In 1841—3 the “Rattler,” the first ship-of-war propelled by a screw, was built for and by the Admiralty under the general superintendence of Brunel, who was also superintending at the same time the construction of the “ Great Britain,” built of iron. The engines of the “Rattler,” of 200 nominal horse-power, were made by Messrs Maudslay. They were constructed, like the paddle-wheel engines of that day, with vertical cylinders and overhead crank­shaft, with wheel gearing to give the required speed to the screw. The next screw engines made for the Royal Navy were those of the “Amphion,” 300 nominal horse-power, made in 1844 by Miller and Ravenhill. In these the cylinders took the horizontal