importance that she should be capable of great velocity when acted upon by a force in a direction oblique to that of her length, and at the same time that the deviation of her course from this line should be the least possible.

The principles on which this deviation of the course of a ship from the line of her keel, or the angle of lee-way, de­pends, will now be explained ; and the causes will be shown which occasion the actual results of observations on ships to differ from the theoretic principles which have been ad­vanced by writers on this subject ; and such methods will be suggested for making further observations in reference to these qualities as may be desirable, with a view to col­lect data to supply the deficiencies resulting to the theory from the imperfect state of our knowledge respecting the resistances of fluids, particularly as they affect the oblique passage of a ship through the water.

Whatever may be the angle which the direction of the wind makes with the plane of the sails, the only effective force of the wind on the sail is that part of the whole force which can be resolved into a direction perpendicular to the surface of the sails ; therefore, whatever may be the whole force of the wind, its effective force will vary as the sine of the angle which the direction of the wind makes with the sail ; and as the velocity of the ship is in proportion to the effective force of the wind, it will also, all things else re­maining the same, vary as the sine of this angle. Now, as, when the ship is under sail, the direction of its motion should coincide with the middle line, that is, with the di­rection of the keel, since the plane of resistance is less when the ship moves in that direction than it is when the line of motion cuts the ship obliquely, all that part of the force of the wind which acts in any other direction than that of the keel must be disadvantageous to her progress, as tending to force her in a direction in which she will meet with an increased resistance from the water. From what has been said above, this injurious tendency must necessarily occur in every circumstance of the action of the wind on die sails of a ship, excepting in that under which the trim of the sails is at right angles to the middle line of the ship, as, un­der all circumstances, the force of the wind on the sail may be resolved into two, both of which will have effect on the ship, the one acting perpendicular and the other parallel to the middle line: or, if we suppose AB (fig. 9) to be the middle line of a ship, and CD the direction of the yard, making with AB the angle DEB less than a right angle ; and suppose FE to represent the quantity and direc­tion of the force of the wind; from E and F draw EG perpen­dicular and FG pa­rallel to DC, and from G draw GH perpendicular to AB ; then GE will re­present the effective force of the wind on the sail, and GH and HE will be respectively equal to the parts of that force employed in propelling the vessel in a lateral and in a di­rect course. If CD, the direction of the yard, were per­pendicular to AB the line of the keel, the lateral effort of the wind, or the force GH, would be lost, and have no ef­fect on the ship ; but when CD is oblique to AB, what­ever may be the quantity or direction of the force FE of the wind with respect to AB, it may be resolved into two forces, both of which will be effective on the ship. As long as DEB, the angle formed by the direction of the yard with the line of the keel, remains the same, its complement, the angle GEH, will remain the same; and as GHE is a right angle, the triangle GEH will remain similar to itself, and the proportion between GH and HE will be invariable, and therefore the effort to cause the deviation of the course from the line of the keel, or the action of the force GH, will be in an invariable proportion to the force acting to propel the vessel along that line, or the force HE ; and, as we know from what has been before said, that the forces GH and HE must be respectively equal to, and opposed by, the lateral and direct resistances of the water acting in the directions HG and EH, the motion of the ship must be along some line *ah,* such that the equilibrium between these forces may be maintained. This is the principle on which the deviation of the course of the ship from the line of the direction of the keel depends.

The angle of lee-way is determined as follows: Suppose the direct and lateral resistances of the water to the pas­sage of the vessel to be respectively R and r, and the sur­faces respectively opposed to these resistances to be *d* and *e,* and the angle DEB which the sail makes with the line of the keel to be *c ;* then, if the angle of lee-way be sup­posed to be *x,* we have

R : *r : : d ∙* cos.2 *x* : *e* ∙ sin.2 *x*

R\_d’cos.2z\_ *d*

*' r e∙* sin? *x e* ∙ tan.\* *x,* R EH sin. *c*

and — = 777⅛ = = tan. c

*r* HG cos. *c*

*d*

.∙. — s- = tan. *c:*

*e∙* tan. *X*

*. d*

or, tan.\* x — e cotan. c

*!d*

tan. *x — λJ* - cot. c.

*e*

From this equation, also, it appears that the angle of lee­way depends wholly on the angle of inclination of the sail to the line of the keel, without in any way involving the velocity of the ship ; and most writers on naval architecture have in this manner considered the question of the equili­brium which exists between the force of the wind and of the resistance of the water in producing this angle. Bou­guer has calculated an elaborate table of the angles of lee­way for various classes of ships for the several degrees of in­clination of the sail to the keel, from 30° to 90° ; but the re­sults which he has obtained differ essentially from those de­rived from observation on the actual performances of vessels.

According to the theory which has been explained, and on which Bouguer founded his calculations, the lee-way depends solely on the angle formed by the yard and the keel, and is uninfluenced by any other cause, and therefore is neither affected by the angle which the direction of the wind makes with the sail, nor by the velocity of the vessel ; but this is contrary to the facts elicited by the experience of the actual motion of a ship under sail. From the geo­metrical construction which has been given, it is evident, that whatever may be the force or the direction of the wind, the proportion which GH bears to HE will increase as the angle DEB diminishes, and so far the theory agrees with experiment ; but it is well known to all who have ob­served the motion of a vessel through the water, that with­out any alteration in the direction of the wind with the keel, the lee-way varies with every variation in the velocity of the vessel ; and also, from this same cause, the alteration in the velocity, all things else remaining the same, if the angle formed by the direction of the wind with the keel be altered, the angle of the lee-way will also experience an alteration ; in fact, so greatly does the angle of lee-way de­pend on the velocity of the ship, that in the same vessel, under similar circumstances of bracing of yards and direc­tion of wind with the keel, the only varying circumstance being a difference in the force of the wind, the quantity