ATMOSPHERIC FRICTION AS AN OBSTACLE IN LOCOMOTION.

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To plan a hull rationally, whether for air or water, one must know the pressure and friction at every point of its surface. Summing these for all parts of the body gives independently its head resistance and skin friction. In other words, the factors are to be studied separately, and then their aggregate made a minimum. In marine science this method has been used to advantage, but not so in the design of air-going hulls. Till recently it was supposed, even by eminent experimenters, that bodies of good form cleave the atmosphere without sensible friction. The writer, however, found that in air, as in water, friction is a chief element of resistance, and therefore endeavored to determine its laws accurately in his aerodynamic laboratory.

To measure the tangential force of free air flowing swiftly over even surfaces, various skin-friction planes were suspended inside a wind tunnel, by means of two fine steel wires. The tunnel itself, standing on the floor of the laboratory, measures 40 feet long by 6 feet square, and has a 5-foot suction fan at one end to generate the wind, and two cheese-cloth screens at the other end to straighten the inflowing air. The current steadily displaces the plane endwise an amount which is carefully measured, and serves to compute the wind force. As shown in one of the illustrations, the tunnel is sometimes narrowed, so as to increase the speed.

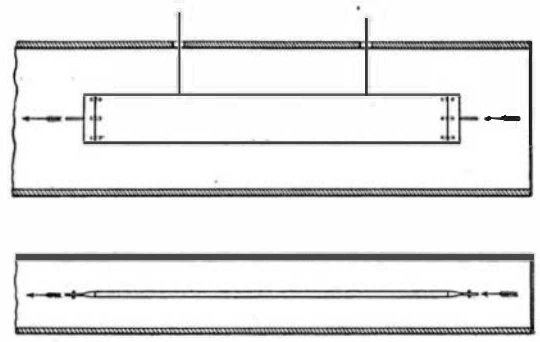
The planes employed were similar to those commonly used to determine the skin friction of water. They were smooth varnished pine boards about two feet wide, one inch thick, and having sharp ends, each end seven inches long, and they were steadied by appropriate guides. The planes varied in length from two feet to sixteen, all having identical prow and stern.

The main object was to determine the friction for various lengths of surface, at various velocities of wind, and to express the relations so found in the form of laws. To that end the total wind force on each plane was observed in a current at ten different speeds, from 5 to 40 feet a second. Subtracting the latter from the former, gave the friction on the straight sides of each board. These data revealed the laws sought for. Plotting the results, it was found that the friction varies with the length of surface as the power 0.93, and the velocity of wind as the power 1.85. The entire friction, F pounds, on a surface one foot wide and l feet long, is given by the numerical equation:

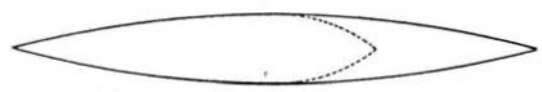
$$F = 0.00000778\, l^{0.93}\, v^{1.85}$$

in which v is the wind speed in feet per second. Of course, this value of F must be doubled for a material plane, since it has two sides. From the equation a table for engineers' use was computed, giving, at a glance, the skin friction for surfaces of various length, moving at all ordinary velocities of locomotion.

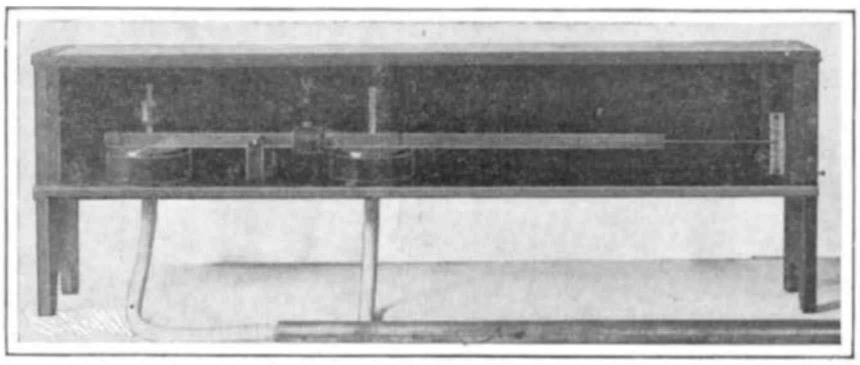
This much accomplished, some further experiments were made, to observe the effect of quality of surface on the tangential resistance. Practically the same friction was observed, whether the board was coated with dry varnish or wet, sticky varnish, or sprinkled with water, or covered with calendered or uncalendered paper, or glazed cambric, sheet zinc, or old English drafting paper, which feels rough to the touch. But when the plane was covered with coarse buckram, having sixteen meshes to the inch, the friction, at ten feet a second, was ten to fifteen per cent greater than for the smooth surface, and the friction increased approximately as the square of the speed.



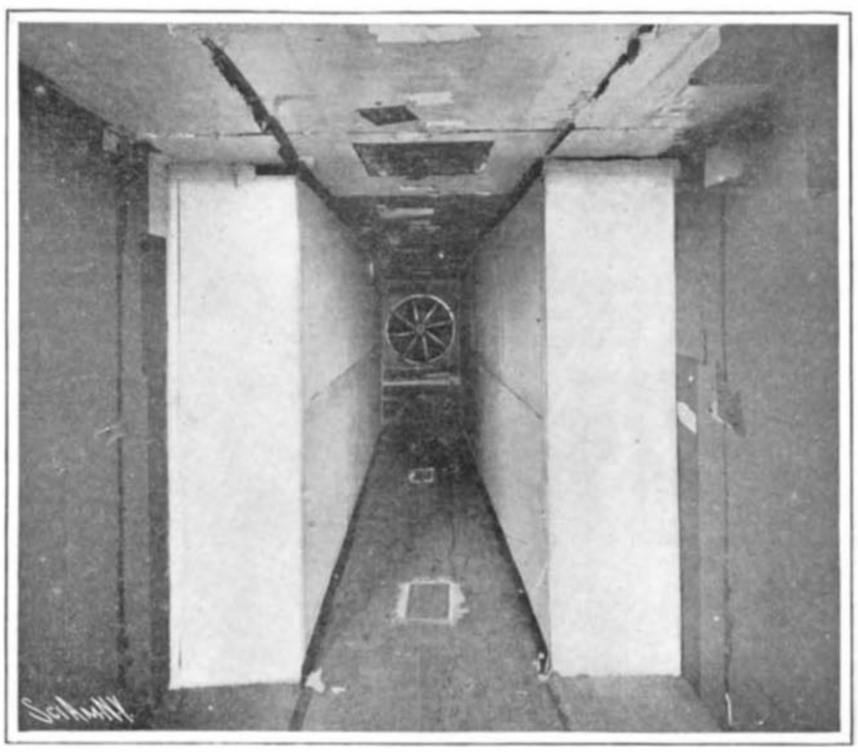
Section Through Tunnel, Showing Form and Method of Suspension of Skin-Friction Planes.



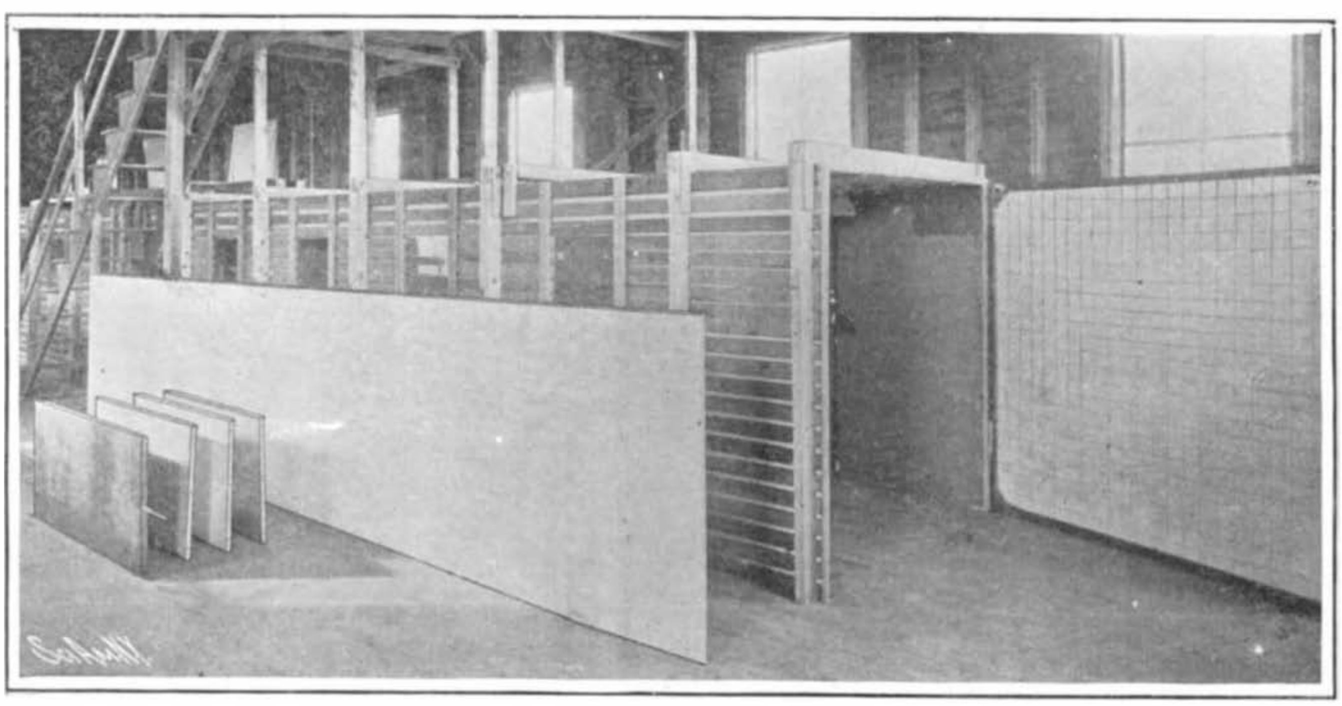
Symmetrical Spindle Showing Length for Minimum Skin Friction.



The Pressure-Tube Anemometer



Interior of Tunnel Constructed so as to Increase the Resistance.



Exterior of Wind Tunnel, Showing the Screen Removed and the Skin Friction Planes in the Foreground.

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The fact that such a variety of materials exhibit practically the same friction seems to indicate that this is a shearing force between the swiftly-gliding air and the comparatively stationary film adhering to the surface, or embedded in its pores. If, as seems to be true, there is much slipping, this means that the internal resistance of the air is less at the surface than at a sensible distance away. As the shearing strength of a gas is due to the interlacing of its molecules, owing to their rapid motion normal to the shearing plane, it may be that the diminution of shearing resistance near a boundary surface is due to the dampening, within the film, of the component of molecular translation normal to the surface.

To summarize the results attained thus far, it may be said that within the ascribed limits of size and wind speed:

(1.) The total resistance of all bodies of fixed shape and aspect is expressed by an equation of the form

$$R = a\, v^n$$

R being the resistance, v the wind speed, a, n, numerical constants.

(2.) For smooth planes of constant length and variable speed, the tangential resistance may be written:

$$R = a\, v^{1.85}.$$

(3.) For smooth planes of variable length l, and constant width and speed, the friction is

$$R = l^{0.93}$$

(4.) All even surfaces have approximately the same coefficient of skin friction.

(5.) Uneven surfaces have a greater coefficient of skin friction, and the resistance increases approximately as the square of the velocity.

On comparing the above results with those obtained by Froude for water, it is found that the equations are very similar. The exponents are nearly the same for a variety of materials, and the coefficients are to each other roughly as the densities of air and water. This fact is of considerable practical interest. For it is well known that the head resistances of any two fluids are directly as their densities; and hence, if their friction coefficients also bear nearly that ratio, the total resistances must be approximately as their densities. Thus the data obtained from water-resistance measurements may be used with fair accuracy to estimate the air resistance on various-shaped models. However, this must be said with reserve, as it is but roughly true, and not for all material surfaces.

The laws of skin friction may be applied with advantage to many practical questions in transportation. They show, for example, that every surface of constant major section has some length for which the resistance is a minimum, and beyond which it increases with the length. The symmetrical spindle outlined in one of the views illustrates this. Its resistance is a minimum when the length is about twelve calibers, or nearly seven times the major diameter. Beyond this length the friction exceeds the true head resistance. A still better form consists of a two-caliber bow, shown dotted in the figure, combined with a twelve-caliber stern, making the length about five times the major diameter. Similar results are found for posts having the form of a two-edged sword.

Take another illustration. It has been taught that the power needed to just support a thin plane gliding through air diminishes with the velocity, because the angle of flight decreases indefinitely with the speed, and the resistance was supposed to do the same. The fact is that after a certain moderate velocity the resistance of a gliding plane, and still more so the propelling power, increase with the velocity. For instance, a thin foot-square gliding plane weighing one pound soars with the least expenditure of power at a speed of about 40 miles an hour, and at 80 miles an hour the power required is more than twice as much.

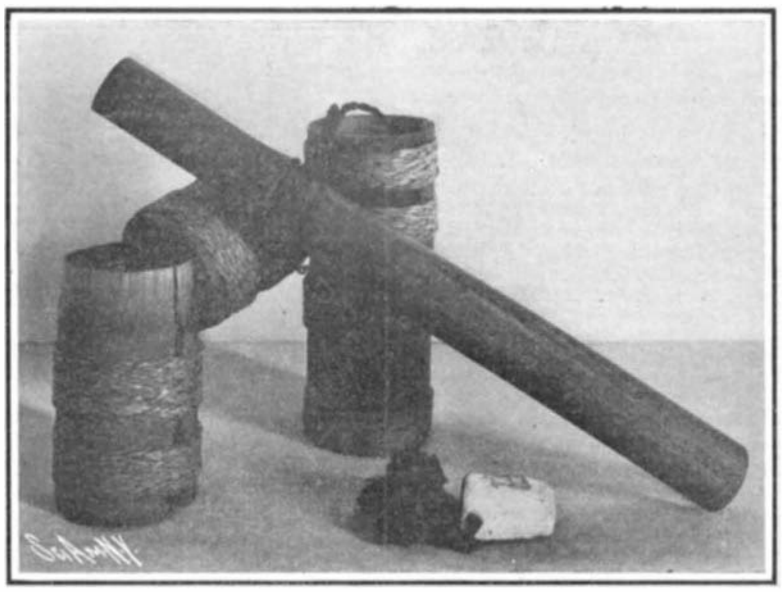
Again, the friction on a long railway train may equal or exceed the true head resistance, while on a short train or single car, the friction is comparatively inconsiderable. Now, though the head resistance may be very greatly reduced by sharpening the front and rear, the skin friction cannot be reduced appreciably by any treatment. Hence, it is apparent that the total air resistance of a long train or hull cannot be reduced very largely by any treatment, whereas the resistance of a single coach, like a street car or automobile, may be reduced several per cent by use of suitable prow and stern.

In conclusion, it may be said that both theory and experiment show that the atmospheric friction about equals the head resistance on symmetrical hulls of easiest shape, on double-edge sword shapes of least resistance, and on soaring planes gliding at the most economical angle of flight.

THE MORO FIRE MAKER.

BY C. H. CLAUDY.

The match has been said to be the greatest civilizer of the world, but it has not yet completed its work. There are still tribes of barbarous and semi-barbarous people who use nature's means for producing fire, either by friction with or without apparatus, or the contact of two substances which produce a spark, as flint and steel.



MORO FIRE MAKER. BAMBOO TO BE STRUCK WITH CHINA AND TINDER.

The Moros, of great interest to us on account of our experience with them in the East, use a method distinctive from other savage races, and of interest not only for its uniqueness, but as showing the effect of environment on invention.

This apparatus consists, as shown in the accompanying photograph, of a bamboo stick, a bit of china, and tinder. The cylindrical cases, which are also shown, are part of the device as it is used, one being a case for tobacco, and the other a case for the china and tinder. The whole, connected with cords, is worn at the belt. To use the apparatus, the native takes the bamboo firmly in his left hand, and in his right holds the bit of china by the finger and thumb, and on the thumb side pinches a bit of tinder. The edge of the china is then struck sharply down and along the bamboo, producing a bright and long spark, which catches in the tinder and ignites it. Very little practice is required to enable even a novice to light a fire by this means. Obviously, when the apparatus was first devised, no china was available, and doubtless some sharp stone took its place. Now, however, bits of broken china, such as are found in cheap eating houses, are regarded as best for the purpose, and universally used.

The thoughtful reader will at once draw an analogy between this means of fire making and the flint and steel of our own ancestors. In the eastern tropics, however, bamboo is the commonest of woods, and so was doubtless observed many times to make a bright spark when struck where flint, in contact with metal, was seen once. In consequence, after the first bright thinker had devised this way of using the spark, the method held its popularity and obtains to this day, although the flint and steel is so much simpler, easier, and more portable.

The philosophy of the device will at once be apparent. The sharp edge of the china scrapes off a bit of bamboo—not much, because the wood is hard and the outside has quite a glaze—but enough to be made incandescent by the friction of the stroke. The tinder catches this spark, and the desired flame is the result.

The photograph was made from the object in the possession of Mr. W. W. Dinwiddie, of Washington, D. C.

A Japanese observatory has been built at Chemulpo and was opened in March, 1905.

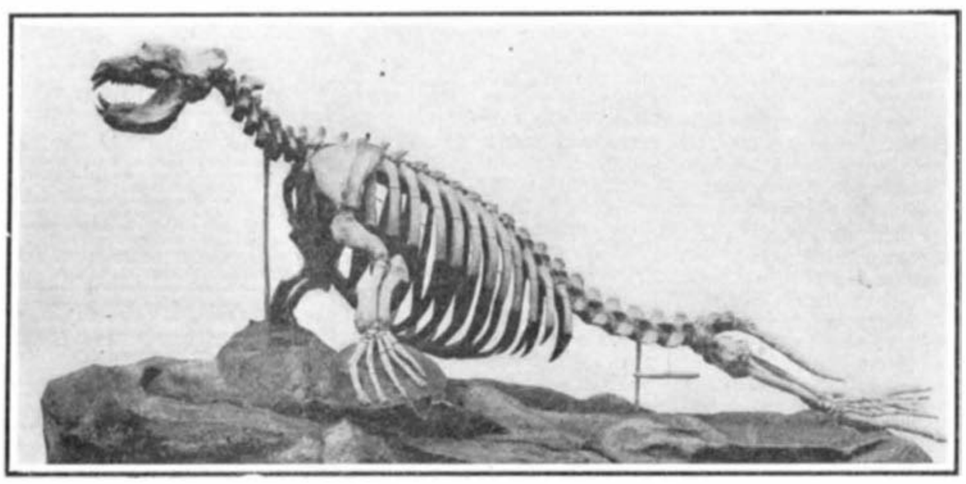
MOUNTING A MONSTER SEA ELEPHANT.

BY HAROLD J. SHEPSTONE.

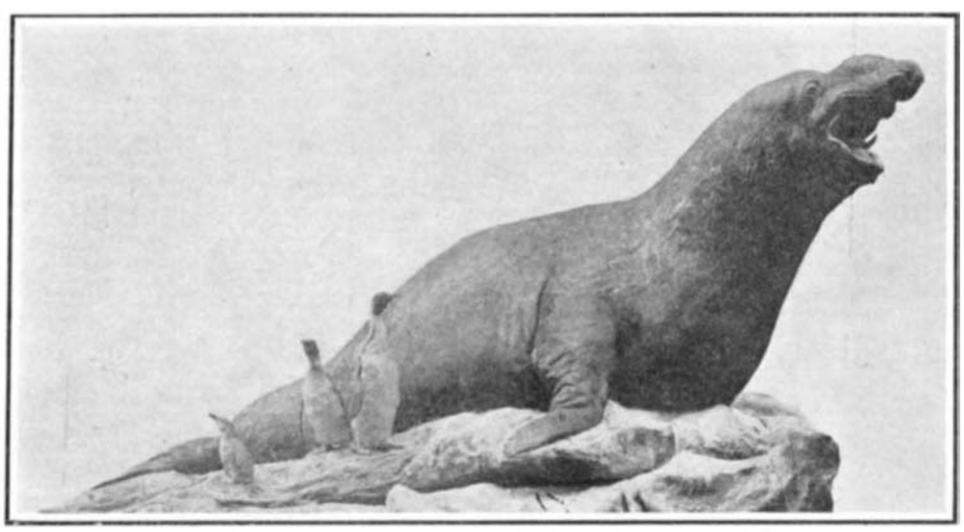
A new and interesting attraction at the Berlin Zoological Garden is a mounted specimen of a monster sea elephant. It can claim the distinction of being the largest sea elephant that has ever been killed, while the mounting of the giant animal is undoubtedly a clever piece of taxidermic work.

It was found some eighteen months ago by whalers off the coast of the Falkland Islands. They promptly surrounded the monster, and subsequently slaughtered it—no easy task—and the hide with the raw skeleton was purchased at a high price by Mr. J. F. G. Umlauff, the proprietor of the famous Umlauff Museum in Hamburg.

He at once commenced the difficult task of mounting the giant sea mammal. It took him six months to complete the work, which cannot be regarded as an excessive amount of time. A laborious piece of work was the removing of the fatty matter from the skin, which was entirely permeated by blubber canals. Before the animal was finally dressed a model was made, and there being a distinct lack of pictorial representations of the sea elephant, the artist had very little material to guide him.



Skeleton of the Giant Sea Elephant.



From the tip of its tail to the tip of its tusk the specimen measures 21 feet.

THE GREAT SEA ELEPHANT. A REMARKABLE PIECE OF TAXIDERMIC WORK.

Some idea of the size of the monster may be gaged from the fact that from the tip of its tail to the tip of its tusk it has a total measurement of nearly 21 feet. Such an animal, when alive, would weigh 10,000 pounds, or nearly 4½ tons. The circumference of the body at its widest part is some 18 feet. The skull alone measures 2 feet 3 inches long and 1 foot 3 inches high. The sea elephant, or seal elephant, is in many ways an interesting creature. So far as size goes, he can give points to the walrus, but he is certainly not so ferocious looking. Except for the curious nose (whence his Greek name) he is just a big black seal fairly agile in the sea and clumsy ashore, like all his kind. He is about the bulk of a hippopotamus, although more hirsute and with a less extensive opening of the jaws. He holds among seals the unique position of being common to both hemispheres, although from the ardor with which he has been hunted, very few specimens exist now north of the equator. Just now, however, the sea elephant is enjoying a respite, and is consequently increasing in numbers rapidly, particularly in the southern seas. He forms practically the only population of many an otherwise lonely series of barren rocks in the Antarctic Ocean. His food consists chiefly, if not entirely, of cuttlefish. Formerly the animal was hunted by whalers upon all the islands of the Antarctic Ocean, notably Kerguelen's Land and the South Shetland, where they abounded in immense herds. The creatures were slaughtered for their hides and blubber.

The animal has derived the title elephant from the fact that it possesses a kind of trunk, or proboscis. This characteristic is only found, however, in the old males. It extends quite a foot beyond the angle of the mouth. In other respects, also, the males are distinguished from the females, more especially by their size. The female, on the average, attains only half of the length attained by the males, and only one-third the weight of the latter. Old males also lose the hair from the nether part of the neck, the skin thickening in this part and getting barky and cracked, deep intersected furrows dividing it into irregular patches. The tusks of the males reach a length of four to five inches, their external part being smooth and conical, while the part imbedded in the flesh is furrowed and slightly curved. The tusks of the males are solid; at the lower end only a slight cavity appears, while in the female they are shorter, and, moreover, almost hollow up to the point. Sailors and seal-hunters are fond of using these hollow teeth of the females for pipe-bowls, quills from the wings of pelicans supplying suitable stems for the pipes. The monster sea elephant seen in our picture has been mounted with penguins beside it. As already stated, it is the size of this sea mammal that has attracted attention. Even old, experienced whalers declare they have never met a larger specimen.

The first marine engineering in the modern sense was the adaptation of the steam engine as already in familiar use on shore to a modification of the centuries old method of mercantile propulsion, the oar. Some attempts were actually made to adapt the steam engine to a series of oars, which would have meant something like a mechanical trireme; but of course the trained mechanical sense soon saw that the collection of the oars in a revolving wheel was the correct solution. As oars had been used on both sides, so it was natural at first that the paddle wheels should be on both sides; a center wheel was also tried, but it is interesting to remark that practically about the same time that the sidewheels were used on the seaboard, the first marine engine was the shore engine modified to suit the circumstances, and thus on the seaboard the engine was designed and worked with what we now consider an exceedingly low pressure. On the western rivers, where the change has been made in the location of the wheel, there was also the additional change of dispensing with the condenser and using very much higher pressures. It was doubtless due to this fact—that the first non-condensing engines really carried a very high pressure—that the term "high pressure," in the early days meant non-condensing. The reason for the difference is of course very clear; the western rivers are very shallow and it was necessary to make the machinery as light as possible; on the seaboard and the rivers of that section there was deep water and the vessels could carry heavy machinery.