明治三十七年四月刊行

（非賣品）

造船協會會報

第貳號

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造船協會役員

會長　男爵　赤松則良君
理事　三好晋六郎君
理事　佐雙左仲君
理事　宮原二郎君
理事　進經太君
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評議員　寺野精一君
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評議員　小島門彌君
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造船協會會報第貳號

本會記事

○總會速記錄

明治三十六年十一月七日東京帝國大學工科大學造船學教室ニ於テ午後一時開會

會務報告、豫算決算

○理事佐雙左仲君　諸君、是ヨリ開會致シマス、會長赤松男爵ハ、三重、和歌山兩縣下ヲ歷訪スルノ約束ガアツテ旅行セラレマシテ、今日ハ遺憾ナガラ出席スルコトガ出來ヌト云フコトデゴザイマスカラ、私ガ此ノ席ニ著キマス

例ニ依リマシテ昨年ノ總會以後今日マデノ會務ヲ報告致シマス

浦賀地方委員石川綾治君ハ洋行サレマシテ委員ヲ辭サレマシタノト、佐世保ノ地方委員原田貫平君ガ橫須賀ヘ轉任ニナリマシタカラ、其ノ代リトシテ役員會ノ決議ヲ以テ

浦賀地方委員ヲ　太田喜代二郎君ニ
佐世保地方委員ヲ　柴岡喜一郎君ニ

囑託致シマシタ、夫レカラ昨年ノ總會以後今日マデ會員ノ異動ヲ報告致シマス、入會者ハ

贊成員　永田三十郎君　小野清吉君
正員　笹瀬成一君　江村義三郎君
吉田仙之助君　坂湛君
篠田恒太郎君　小長井潔君
協同員　松波仁一郎君　伊藤莊次郎君
茂木鋼之君　上田琢磨君
國富吉信君　中林長國君
橫山愛吉君　賀屋洋介君
楡井次郎君　石原市松君
渡邊四郎君　香月錠之助君
日高林三郎君　藤井治三郎君
多羅尾源三郎君　山崎鉉次郎君
准員　大洞直次君　金子直人君
池田三代吉君　川島庄太郎君
淺川彰三君　吉川襄坪君
井上高次郎君　高部乾吉君
八谷孝敏君　伊東秀夫君
桑田豐吉君　堀江正三郎君
中根經三君　後藤源作君

柴田秀生君　竹内正三君
若松卯之助君　今村奈良吉君
增田勘次郎君　鷲山兵太郎君
石井勇次郎君　山崎常次郎君
長島条藏君　石部太郎君
味岡新太郎君　鈴木丹藏君
岩井重太郎君　村上其次郎君
野村廣太郎君　白髮長三郎君
大津新太郎君　永村清君
笠次雄君　山本榮吉君
武田圖南三郎君　芝野政一君
山縣淺吉君　八木彬男君
高原常一君　白石保太郎君
藁科祐雄君　井上要君
阿部梧一君　佐藤龍四郎君
荒木美作次君　田中岩吉君
小野虎助君　平野龍亮君
横溝則和君　隈部謙君
江中六助君　丸山庸二君
石渡松吉君　本原耿介君

古田敬德君　布施正彥君
西田保三郎君　大島義胤君
稻葉秋藏君　高岸音次郎君
鳥山壽三郎君　永松文一君
德大寺則麿君　佐枝新平君

准員ヨリ正員ニ轉セラレマシタノガ

野尻狂介君　鈴木圭二君

退會者ハ

准員　細馬彌太郎君

又死亡セラレマシタノハ

正員　子爵內藤政共君　准員　田中廣次君
准員　松田鎮次郎君　准員　岩澤留吉君

ノ四君デアリマス、誠ニ哀悼ノ至リデゴザイマス

此ノ異動ヲ計算致シマスルト、今日ノ現在會員ノ數ハ

名譽員　二十四名　贊成員　十七名
正員　百二十四名　協同員　六十九名
准員　百八十七名

合計四百二十一名デゴザイマス、昨年ノ總會ノトキヨリ八十三名ノ增加ニナリマス

偖茲ニ一ツ報告シテ置キマスノハ、本年七月大阪ニ於テ臨時講演會ヲ

開キマシテ大阪神戸ニ於ケル工場ヲ巡覽致シマシタ件デゴザイマス、是ハ御承知ノ通リ一昨年ノ總會ニ於テモ一寸報告致シテ置キマシタガ、大阪神戸地方ノ會員ノ希望デゴザイマシテ、本會ニ於テモ大ニ望ム所デアリマシタカラ、幸ヒ今度大阪ニ於テ第五回内國勸業博覽會ガ開カレマシタニ付テ、此機ヲ以テ臨時講演會ヲ開イタラ宜カラウト云フノデ、役員會デ決議ニナリマシテ實行致シマシタ、其次第ハ近日發行致シマスル會報ニテ御承知ヲ願ヒマス、實ニ其會タル盛會デゴザイマシテ、此會ニ利益アルコトガ多カッタノデアリマス、是ハ本會ノ爲メ賀スベキ次第デゴザイマス

夫レカラ昨年總會以後寄附金ヲ受ケマシタコトヲ報告致シマス

名譽員	古市公威君ヨリ	金五十圓
名譽員	男爵赤松則良君ヨリ	金五十圓
贊成員	永田三十郎君ヨリ	金六十圓
贊成員	小野清吉君ヨリ	金六十圓

又臨時講演會ニ付テ寄附金ヲ受ケマシタノハ

高田商會大阪支店ヨリ	金二十圓
大阪阿部製品所ヨリ	金五十圓
藤永田造船所ヨリ	金五十圓
小野鐵工造船所ヨリ	金五十圓

デゴザイマス、夫レカラ會計ノコトニ移リマシテ報告致シマス

明治三十五年十月一日ヨリ明治三十六年九月三十日ニ至ル一ケ年間ノ收支決算デゴザリマス

一金千四百五十九圓十七錢	收入高
内	
金三百九十圓	寄附金
金百五十五圓	入會金
金七百七十七圓五十錢	會費
金百三十一圓十七錢	預ケ金利子
金五圓五十錢	雜收入
一金千二百六十五圓一錢六厘	支出高
内	
金五圓五十六錢	消耗品費
金二百五十九圓十九錢一厘	印刷費
金三十六圓六十錢	郵便費
金五十八圓五十錢	總會費
金百八十九圓	報酬及手當
金五圓	事務所借料
金五十七圓四十一錢五厘	雜費
金六百五十三圓七十五錢	臨時講演會諸費

差引

金百九十四圓十五錢四厘	殘高
一金二千七百七十五圓二錢三厘	繰越高
合計金二千九百六十九圓十七錢七厘	現在金

斯樣デゴザイマス、此ノ支出高ノ内ニ臨時講演會諸費六百五十三圓七十五錢ト云フノガゴザイマス、是ハ前刻申上ケマシタ大阪ニ於テ開キタル臨時講演會及工場巡覽ニ關スル費用デアリマシテ、全ク臨時ノコトデ前以テ諸君ノ協賛ヲ經テ置クコトガ出來マセンダカラ、役員會ノ決議ヲ以テ實行シタ譯デゴザイマスカラ、是ハ事後承諾ヲ願ヒマス、即チ總決算ニ合シマシテ定款第二十三條ニ依リ御承諾ヲ請ヒマス、御質問ガゴザイマスレバ御尋ネ下サレタウゴザイマス、御異議ハゴザイマセヌカ、御異議ガ無クバ御承認ニナッタモノト決シマス

次ニ定款第二十三條ニ依リ、本年十月一日ヨリ來年九月三十日マデノ一ヶ年間ノ出納豫算ヲ提出シテ諸君ノ協賛ヲ經ベキ筈デゴザイマスガ之レハ先例モアルコトデゴザイマスカラ、通常ノ費用ノ豫算ハ役員會ニ御一任ニナルコトヲ御承認ヲ得タイノデゴザイマス、御異存ガゴザイマセヌケレバ、豫算ハ役員會ニ御任セニナッタモノト決シマス

之レデ會務報告、決算、豫算ハ議了致シマシタ、是ヨリ評議員ノ改選ヲ行ヒマス

評議員改選

○理事佐雙左仲君　豫テ御通知致シテ置キマシタ通リ寺野精一君、近藤基樹君、和田垣保造君、此ノ三君ハ三十三年十月ニ選擧セラレマシテ、三年經チマシタカラ、本會細則第六條ニ依リ改選致シマス、御手許ヘ廻シテ置キマシタ投票ヲ御差出ヲ願ヒマス

（投票計算）

開票ノ結果ヲ報告致シマス、投票數三十枚

二十一票	寺野精一君
十九票	近藤基樹君
十三票	和田垣保造君

此ノ三君ガ多數デ當選ニナリマシタ、御承知ヲ願ヒマス

之レデ總會ヲ終リマシタ、是ヨリ講演會ニ移リマス

* * *

○講演會　講演會ニ於テ左ノ講演アリタリ

A plea for a floating dry dock.	エフ、ピー、パービス君
我大學ニ於ケル造船學	三好晋六郎君
佛國ニ於ケル造船業保護制度ノ沿革	湯河元臣君

○晩餐會　十一月七日講演會解散ノ後東京帝國大學構内集會所ニ於テ晩餐會ヲ開ク出席者左ノ如シ

伊藤定弘君　今岡純一郎君

越智誠二君　和田垣保造君

甲斐鐵三郎君　加茂正雄君

高山保綱君　鶴田傳次郎君
內田嘉吉君　國富吉信君
山崎甲子次郎君　松長規一郎君
眞野文二君　藤島範平君
小島門彌君　近藤基樹君
近藤仙太郎君　寺野精一君
淺岡滿俊君　佐波一郎君
佐雙左仲君　木村齋雄君
三好晋六郎君　進經太君
須田利信君

來賓

丸山熊男君　古市公威君
男爵菊池大麓君　男爵鈴木大亮君

○會員異動　總會後ノ入退會者左ノ如シ

入會　准員　宮崎勉一君
退會　正員　古川庄八君

講演

A PLEA FOR A FLOATING DRY DOCK.

By Professor F. P. Purvis.

〔Read at the general meeting of the Association
of Naval Architects, November 7, 1903〕.

My object in this short paper is to lay stress on some of the reasons why I think a little more attention should be paid to the relative advantage of a floating dry dock as compared with a graving dock. I am quite alive to the fact that the best test of the advantage to be obtained is a practical one, and that within a comparatively short period from now that test will be applicable on a pretty large scale in this country; but having myself some practical knowledge of the construction of a fairly large floating dry dock, and of the design construction and working of a slipway, I may suggest some matters about the general requirements, and the best way of providing for them.

The use of steel material for floating structures seems to be remarkably on the increase. During the present year we have heard of a floating workshop as a companion to the new dry dock built for Durban; this structure is not only portable but self-propelling, and can move from place to place at a speed of some 7 knots. We have heard too of a coal haul-about at Portsmouth for the purpose of carrying coal to the ships and of bunkering them by the help of appliances of the most approved type; the haul-about at present finished carrying a comparatively small quantity, but to be followed by a larger carrying some 13,000 tons.

In connection with the new Hunan (Konan) service we hear of floating barges intended to be used in the triple service of pier, warehouse and waiting rooms. Shortly before coming out to Japan I had the designing for the Mersey Dock Board, Liverpool, of the crane-barge *Hercules* to carry a floating crane; the vessel is self-propelling at the speed of 8 knots, and can handle a boiler or other weight of 50 tons at a distance of 38 feet clear of the belting on the vessel's side.

I propose at present to deal with the following matters: —

1st. The general effect of modern improvements in reducing the relation of weight of dock to lifting power, and–as a consequence–reducing the relation of cost to lifting power.

2nd. The question of preservation; and examination of objections to the use of a steel structure.

3rd. Some points in the design of the new dock for the Cavite Naval Station, Philippine Islands.

4th. Some advantages of the L dock as against the ⊔ dock, with suggestions as to its practicability.

Under the first of the foregoing heads I may cite the case of the dock I myself had to do with (the Koninginne Drydock of Amsterdam), a dock of the Rennie type, see Fig. 1, 400 feet long, having 8 pontoons with a space of 10 inches between; the side girders bound them all together and kept them at the distance mentioned. The weight of material employed was 3,160 tons, the lifting power with 6 inches freeboard was 4,000 tons, or with pontoon deck awash 4,500 tons; the weight of material per 100 tons of lifting capacity, taking the extreme of 4,500, was thus 70 tons. In the Cavite dock, now under construction at the Maryland Steel Co., U. S. A., the similar figure is $\frac{7200 \times 100}{20,000} = 36$

tons per 100 of lifting capacity. Several modern docks have approximately the same ratio, some quoted by Mr. Clark giving a somewhat less ratio. In the matter of cost the figures I shall give require some explanation before they confirm the reduction I have mentioned. The Amsterdam Dock cost £52,000=£11.55 per ton of lifting power; the Cavite Dock Contract price is £231,000 (delivered in America) = £11.55 per ton of lifting power. It has to be explained that the accepted tender of the Amsterdam Dock was the lowest (but one) of 18, ranging from a little below £52,000 to £95,000; how much the contractors lost over the building I never heard, but it must have been a pretty considerable sum. The Cavite Dock, on the other hand, being built in America, is necessarily dearer than if built in Europe. So that the apparent identity of cost, £11.55, of the two docks, per ton of lifting power, would in a fair comparison be destroyed, partly by adding to the cost of the earlier, partly by taking from the cost of the later structure. Instead of the Cavite Dock it might have seemed better to take the new Bermuda Dock, with lifting power 15,500 tons and contract cost £195,000 = £12.6 per ton; but I have not been able to get sufficient particulars of this dock to explain this high figure.

What is the length of life of a floating dock? This can be answered exactly in the case of the old Bermuda Dock which was sent out to her destination in 1868 and replaced by the new dock in 1902. The exact nature of her decrepitude I have not seen stated; there is some suggestion of want of care in upkeep during her earlier years; also of difficulty of access to some essential parts.

The Koninginne Dock was finished in 1878, and has therefore enjoyed (in fresh water) the long life of 24 years. The Company which owns her, has recently (in 1899) added a larger dock, the Wilhelmina, to its plant, capable of lifting 7,500 tons; but this I take it is to accommodate the newer steamers of the Nederland Stoomvaart Maatschapij, now so much larger than they were 24 years ago; the reason for the new dock is not that the old one is past service.

The remark just made points to probably the chief reason for substituting new docks for old, whether the docks are of the dug out type or the floating type. Growth of size of ship or change of shape, puts the existing dock out of date and makes the new dock a necessity; it is certain however that this cause (for reasons frequently pointed out) must be much less effective in the case of a floating dock than the other; increase of length for instance absolutely disqualifies the one dock, but not its rival. It is true that the dry docks of to-day–whether stone structures (such as the large new Liverpool graving docks) or steel such as the Cavite design, seem to anticipate all possibilities of future growth, so as to make it difficult to conceive of a date–however remote–when their dimensions will be antiquated; possibly however some change in the method of working docks, or in the locality most suited for strenuous activity, will detract from the utility of some of them and render them old long before their time.

One objection to the floating dock that I have heard somewhat frequently raised in Japan is the prevalence of bad weather, especially during typhoon periods. I may meet this objection in some measure by stating the effect of a storm, in which the wind pressure is assumed at 54 lbs. per square foot on the Cavite design; such a storm if blowing on the broadside of the dock fully exposed, would give a moment of 12,200 foot tons; this would be sufficient to heel the dock only about $\frac{1}{2}$ a degree; in this calculation I take the dock alone in her worst position as regards stability and allow for effect of loose water in every compartment.

In this connection it seems almost too trivial to point out that in boisterous weather, or even in weather threatening to be dangerously boisterous, no one who was responsible would attempt to dock a ship either in Europe or Japan. Whether the number of days lost on this account would be more in the east than in the west I leave to your judgement, or to a critical examination and comparison of meteorological returns.

Another objection sometimes raised to the floating dock is the possible damage to the ships taken on it through longitudinal bending. The necessity for caution is so serious in this respect that one would not wish to say a word involving a doubt of it. In all modern designs the permissible stress on structure both of dock and ship is carefully attended to. One practical matter, tending to show that the approach of danger is more readily seen than might be expected, I may quote from the Koninginne Dock. During her construction I made a large number of calculations to ascertain how much water should be allowed to remain in the end pontoons, when the ship was short and heavy; the object of the water was to place weight in the ends and so distribute the load and avoid undue stress on dock or ship (as I have mentioned the side girders bound the pontoons together, and gave whatever longitudinal strength the dock possessed.) When the dock came to be used, the dockmaster found he had a better guide than the results of my calculations, in the tendency to buckle shown by the top plating of the side girders; by judiciously observing the behaviour of that plating, he was able to get good guidance as to the safety or otherwise of reducing the water in the dock's end compartments.

In the design for the Cavite Dock, see Fig. 2, the advantages appear to be derived chiefly from the following: —

(1) The absence of any bolted joint over the main portion of the dock, 320 feet in length; within the range of the principal weights of a ship lifted-at least of a warship-there is thus no weakening of the dock structure caused by a joint.

(2) The extension of the side girders, unweakened by any bolted joint, over practically the whole length of dock.

(3) The design and method of attachment of the two end pontoons; these pontoons, while taking their full shore in the lifting power of the dock, are easily detached; they can then be docked themselves, or used for docking the main portion. The maximum height to which every portion can be lifted clear of water, is 5 feet; this seems quite an important feature-although not a new one in self docking.

I thing there can be no doubt as to the advantages to be obtained from these modifications introduced into a dock design; they seem admirably adapted to add strength to the structure in ordinary working and facility in the matter of self docking.

In view of these merits it seems almost captious to ask for further improvements. Nevertheless I think one very simple improvement might be made. This would be in avoiding reducing the depth of side wall, as is done in the Cavite design outside the main portion, by the depth of the pontoon; some reduction or practical reduction, is doubtless necessary, to get proper bearing for the end pontoon, but this may be limited to 6 feet or even less, in place of the 18 feet 6 inches–which is the pontoon depth. The sketch (Fig. 3) shows in general form what my proposal amounts to. For connection of end pontoon to side wall the only security needed in addition to the forked guides of the sketch, would be a few short heavy bolts; these would take any unbalanced weight of the pontoon and contained water; in practice the buoyancy of the pontoon should always be adjusted to exceed the weight; no bolts would then be necessary; should the weight of pontoon and contained water, by inadvertence, exceed the weight, some other attachment becomes necessary and hence the bolts.

In the event of the determination to construct some sort of floating dock, the question would still be an open one as to whether the double wall form should be adopted, or the L dock preferred. My own preference would certainly be the latter. From the point of view of possible emergencies, the one sided dock has so much to commend it; emergencies I mean both such as might arise from some peculiarity in the trim of the ship due to damage, and such as might be due to abnormal form of ship-departing largely from present adopted types. But the advantage I have more particularly before my mind in advocating the L form is the extra facility in working a dock when it becomes immaterial whether a ship is drawn on or off along the dock axis or at right angles thereto; it might easily make all the difference of gaining or losing a tide, and in any case it simplifies the arrangements of those in charge and in proportion reduces the number of hands to be employed. No doubt the L dock standing alone is wanting in stability; but in his off shore arrangement Mr. Clark has shown very fully how to compensate for this, and in practice has done so in several instances; I see nothing to prevent the off shore arrangement being adopted in most cases; should it not be available there is still the arrangement of a float described by the present Mr. Clark's father to the I. N. A. in 1876; if this float were used it would no doubt be modified to meet some modern growth of ideas; possibly it would be made to carry a workshop or a store of material of such nature as the close proximity to the dock seemed to indicate as of paramount importance.

For the docking of warships it may well be said that the one sided dock does not offer so good facilities for shoring as the two sided; this I must readily admit but I would ask "are side shores so necessary, even in a warship?;" in this matter I have looked carefully through Captain Asaoka's paper of two years ago; the stresses he mentions therein are only those in the vertical direction, and for these provision can be made in a one sided just as well as in a two sided dock. For other stresses, in a horizontal direction, may not the ship's beams be considered to amply provide for what is necessary; certainly just before a launch the beams alone resist any sideways stress, with the weights then on board; and surely when the ship comes to be dry docked the beams again may be considered sufficient.

Fixing then on an L dock, I should take advantage of the Cavite design to divide the dock into three portions Fig. 4; the centre portion would have the side girder projecting at each end to the extent of the full length of the dock; the box at the other side would also project to the full length of the dock; the two end portions would have each one side wall, and the arrangements for attaching these ends to the projecting side wall and projecting box of the centre portion would be as already indicated. There being but one side wall the necessity for breadth between the walls, or breadth over all becomes considerably modified. Suppose the problem before a designer to be such a modification of the Cavite design as should obtain the same lifting effects with an L form. In the Cavite design much consideration seems to have been given towards determining the most suitable length; it may be well to take this, viz. 500 feet, as a fixed quantity; the two possible variables are then breadth and depth; the Cavite dock has 134 feet total breadth and 18 feet 5 inches depth of pontoon; instead of these a total breadth of 94 feet and depth of 26 feet 4 inches will be found to give the same lifting power with the pontoon deck awash and assuming the same weight of dock; but weight of dock might be reduced; this is on account of the increased depth and the smaller scantlings hence required for obtaining the same strength. The less weight would imply less cost; and the exact limit to which the reduction might be carried would depend on two considerations; lst, on the allowable depth of pontoon in view of local conditions of the site of the dock; 2nd, on the minimum breadth that might be considered desirable for working purposes.

For self-docking, when taking the main portion of the L dock on the two end portions, it would be necessary to make two sets of disconnections; the end portions would have to be removed clear of the main portion; and the outer ends of the parallel booms of the off shore arrangement would have to be detached from their usual attachment to the side wall of the main portion; the end portions would then be brought into position opposite the parallel booms; and the outer ends of the latter would be temporarily secured to attachments on the side walls of the end portions of the dock; the stability obtained by means of these parallel booms would thus be available as at other times, the only difference being that the stability is brought to bear on the end portions of the dock in place of the main portion.

Such a dock as I have indicated would appear to be capable of dealing with ships of which the possible limits are somewhat difficult to define; the limit in length direction is that of the unsupported ends that may be allowed; the limit in breadth direction is considerably more than the breadth of dock less side wall (viz. 80 feet); the limit of draught is as in the Cavite design, amounting as an extreme to some 40 feet. The limit of lifting power is, as in the Cavite design, 20,000 tons; bnt even this can scarcely be said to be the extreme; should it be necessary after many years, to exceed it, some addition to the length or breadth or draught of the end pontoons might be made that would do what was needed; the cost of such addition per ton of extra lifting power being probably not much more than the initial cost per ton.

In the foregoing I have started with the Cavite dimensions as a good instance of extreme requirements; a floating dock designed for this country would probably have in view the requirements of merchant ships rather than of warships; warships docked thereon would be the exception rather than the rule; much smaller dimensions than the above would therefore suffice; but my remarks as to the absolute limits of such smaller dock would still apply. Should the extreme lifting power, for instance, be fixed at 6,000 or 10,000 tons, the length, breadth and draught of the ship that might be lifted would be practically unlimited (unlimited that is, within the range of the lifting power); the 6,000 or 10,000 tons would indeed limit the weight, but this also might at any future time be considerably increased by some alterations to the end pontoons.

POSTSCRIPT. A letter from the Engineer to the Amsterdam Drydock Co., received since the above paper was read, gives some interesting particulars connected with the *Koninginne* Dock (aged 24 years) and the *Wilhelmina* Dock (aged 4 years)

"I have much pleasure in informing you that our old dock
"is still doing remarkably well. We never had any
"pontoon out of the water; we only canted the dock now
"and again to paint the water-edge; but farther, the
"dock in the water is almost new yet. The inside, of
"course, is not so good. This we have cleaned and
"cement washed say every 3 years, and although there is
"a reduction of thickness, it is still quite strong
"enough to carry the 4000 ton load, which we have often
"had on her. As you know this is an iron dock.
"Our new dock, of 7500 ton lifting power, is of steel,
"and I am sorry to say, requires more care and looking
"after against rusting than our iron dock does.
"Still I believe 40 years for the life of a floating
"dock is quite safe, even if of steel."

"W. Fenenge."

The following publications are those which I have chiefly consulted for the purpose of my paper:—

"On the Nicolaieff floating and depositing dock," by Latimer Clark. Trans. I. N. A. 1876.

"On the double power floating dock and the hydraulic "grid" by Latimer Clark. Trans. I. N. A. 1879.

"Recent improvements in docks and docking appliances," by Lyonel Clark. Trans. I. N. A. 1897. (Vol XXXVIII)

"The floating dock as an adjunct to a War Navy," by Lyonel Clark. International Congress of N. A., Paris Exposition, Paris. 1900.

"Floating drydocks-their military possibilities and value" by Rear-Admiral John D. Ford, U. S. Navy (Journal of the Am: Soc: of Naval Engineers, February 1903).

"The Cavite steel floating drydock. Its strategic "value in defending the Philippines" by Civil Engineer A. C. Cunningham, U. S. Navy (Journal of the Am: Soc: of Naval Engineers, May 1903).

FIG. 1.

KONINGINNE DRYDOCK

AMSTERDAM.

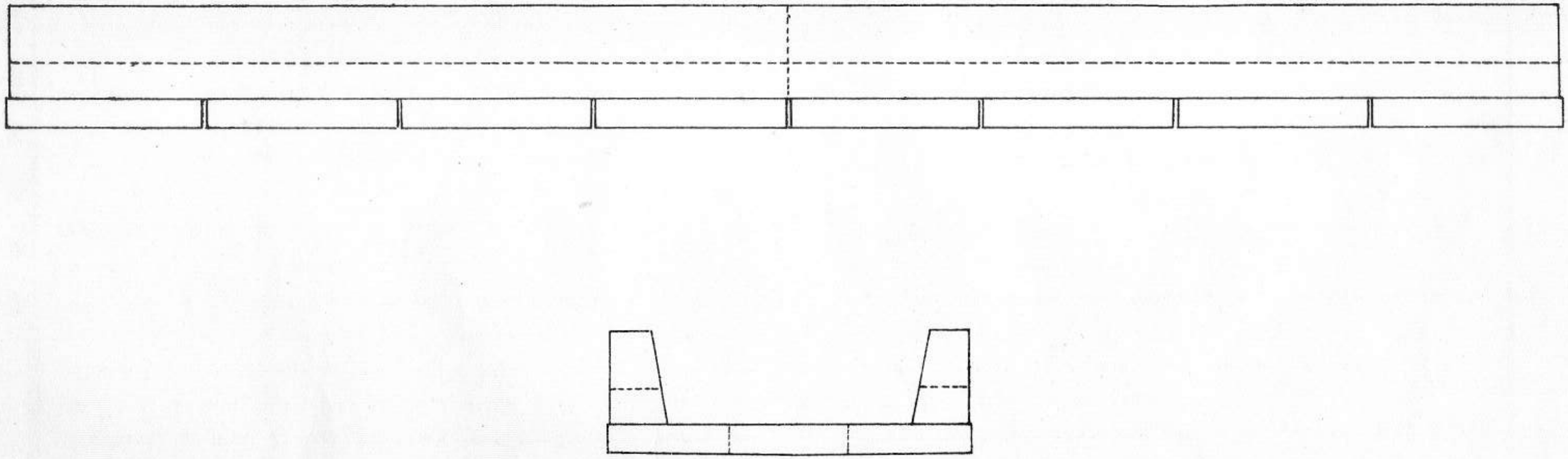


FIG. 2.

CAVITE DESIGN.

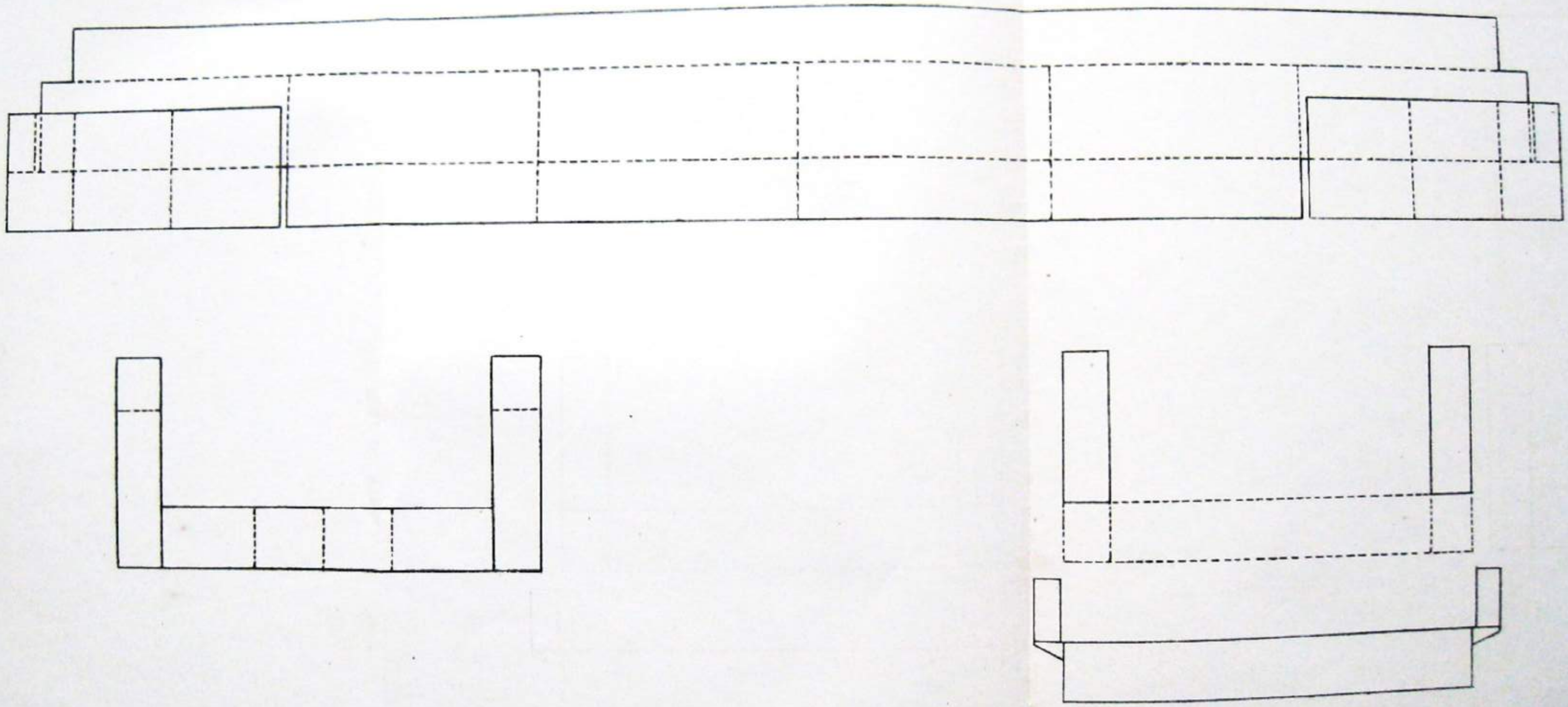


FIG. 3.
CAVITE DESIGN.
ENDS ALTERED

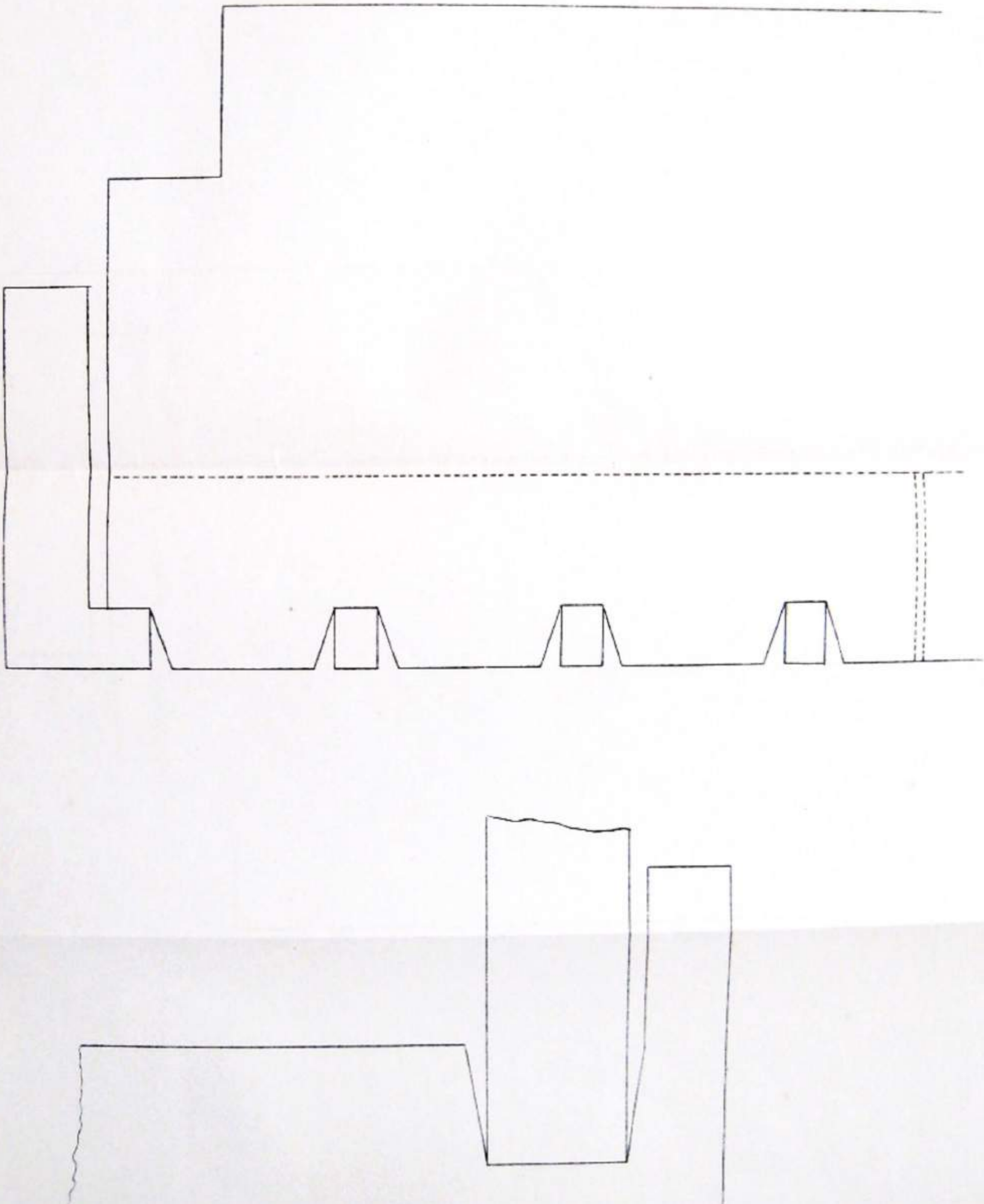
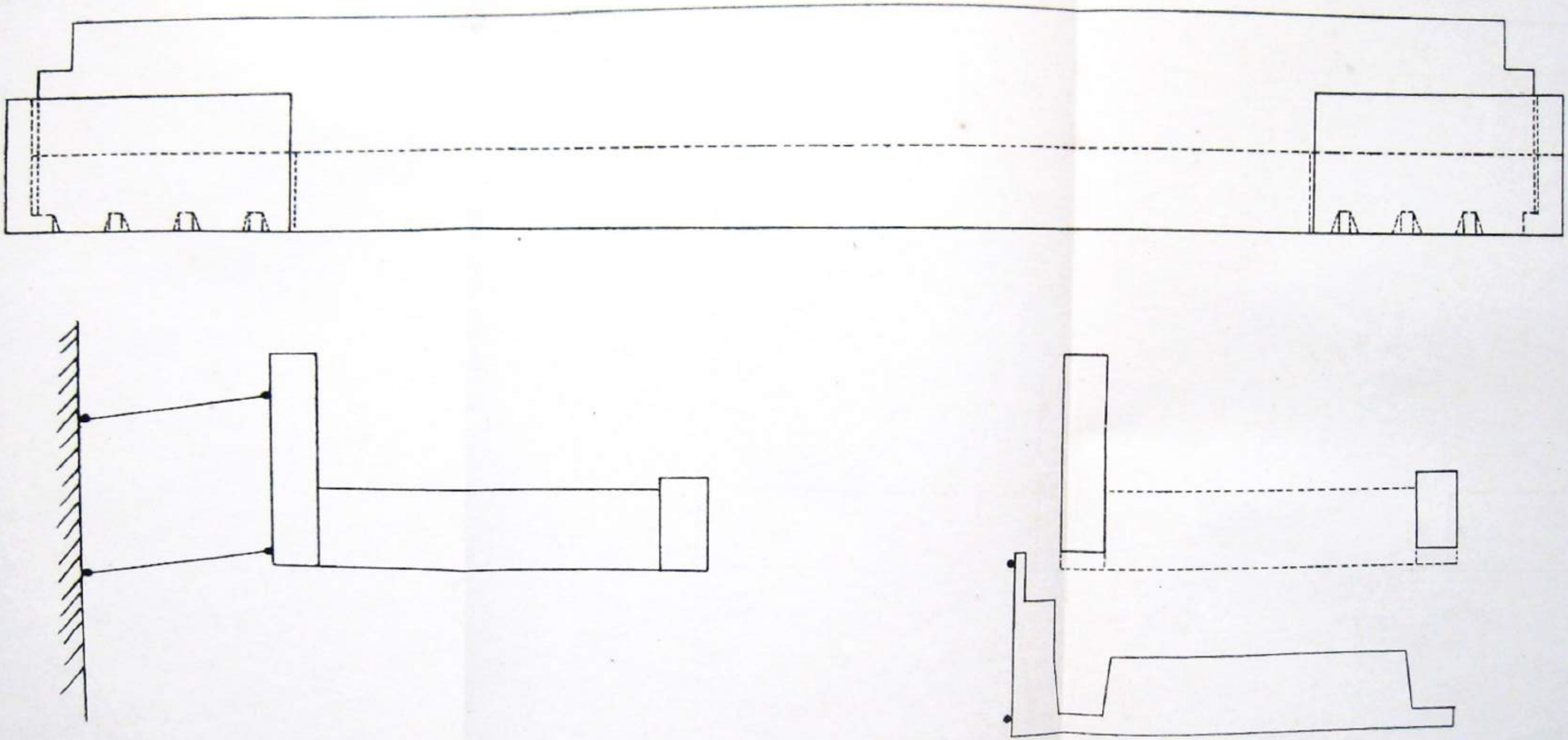


FIG. 4.

L DOCK.

(PROPOSED)



我大學ニ於ケル造船學

明治三十六年十一月七日造船協會講演會ニ於テ

三好晋六郎

私ガ是ヨリ御話申上ゲヤウト存ジマスコトハ、或ハ御通知申上ゲタ演題ハ適當デナイカモ知レナイ、私ノ目的ハ大學ノ造船學ノ授業上ニ就テ、學校ニ餘リ御關係ノ御深クナイ人達ニ我大學ノ造船學科ノ歷史、並ニ現今ノ狀況ヲ御話申スノガ目的デアリマス

ソレデ大學ノ造船學科ノ起原ヲ尋ネマスト、元ハ工部大學校ノ機械學科ノ中ニ造船學ト云フ課目ガアリマシタ、併シ是ハ一科獨立シテ居リマセヌノデ、恰モ機械科中ノ一課目ノ如クニ承知シテ居リマス、且ツ造船學ハ明治十三年頃マデハ事實ニ於テ敎ヘテ居ラナカッタ、一番初メニハ土木學若クハ機械學ヲ卒業シタモノニシテ志願ノ者ニハ特別ニ造船學ヲ授業スル、斯ウ云フコトニナッテ居リマシタ、其後此ノ規則ヲ變ヘテ、土木學ノ卒業生ヲ拔イテ機械學ノ卒業生ニシテ志願者ニハ造船學ヲ授ケルト云フコトニナリマシタ、然ルニ十三年頃ニソレヲマタ變ヘマシテ、機械學科ノ中デ希望者ニハ第四年生ヨリ第六年生ニ至ル三ケ年間ニ、造船學ノ理論ヲ講授シ且ツ便宜ノ造船所ニ遣シ實地修業サセマシタ、之ガ其ノ時分ノ工部大學校ノ規定デアリマス、又同校ノ規則デハ修學年限ハ六ケ年デアリマシテ、二ケ年ノ豫科ヲ終ッテ及第シタモノハ志望ノ專門學ヘ入ル、故ニ造船學ヲ志望スルモノハ先ヅ機械學科ノ中一ケ年ヲ修業シ然ル後四年生トナッテ始メテ造船學ヲ敎ハルヤウニシタノデアリマス、是ガ造船ヲ規則正シク敎ヘル初メデアリマシタ、此ノ規定ニ依テ十四、十五、十六ト三年ノ間造船學ヲ敎授シ其ノ間ニハ長崎造船所又ハ橫須賀造船所等ヘ派遣シ實地ヲ研究サセマシタ、是ノ規則ニ依テ十六年五月初メテ三名ノ卒業生ガアリマシタ、而シテ其ノ年即チ十六年ニ至テ工部大學校デ造船學科ヲ獨立ノ一學科ニナリマシタガ主任ノ敎授ハナク敎務ハ矢張機械科ノ主任敎師ノ支配ノ下ニ置カレタノデアリマス、然ルニ十九年ニ工部大學校ト東京大學ガ合併サレマシタノデ造船學ハ純然タル一學科目トナッタノデアリマス、卒業生ノコトハ詳シクアトデ述ベマスガ大體ヲ言ヒマスト十六年ニ三名出シマシテ三十六年マデニ百十一名ノ卒業生ヲ出シマシタ

ソレデ現今ハドウ云フ敎授課程デアルカト言ヒマスト、高等學校ヲ及第シテ造船學科ニ這入ッタ第一年生ノ時分ニハ、寧ロ本科ニ必要ナル素養ノ豫科學課ヲ多ク與ヘル、數學ノ如キハ高等數學デハアリマスガ第一期及第二期間毎週三時間、力學ガ一年間毎週一時間、應用力學ガ一年間毎週平均二時間、熱機關ガ一年間毎週平均二時間、機械學ガ一年間毎週一時間、機械製造法ガ一年間毎週一時間半、製造冶金學ガ第一期及第二期間平均二時間半、水力學ガ第二期及第三期間平均一時間半、造船學ノ講義ガ一年間毎週五時間、ソレカラ應用力學ノ製圖及演

習ガ一年間毎週二時間、造船學ノ計畫及製圖ガ一年毎週平均九時間、舶用機關計畫及製圖ガ一年間毎週八時間、第二年生ニナリマスト造船學ヲ專ラトシテ一年間毎週十時間、蒸氣ガ第一期及第二期間毎週一時間、舶用汽機ガ一年間一時間半、水力機ガ第一期及第二學期間毎週一時間、電氣工學大意ガ第一期及第二學期毎週二時間、工藝經濟學ガ第二期及第三期ニ毎週一時間半、造船計畫及製圖ガ毎週平均二十時間半餘、此外實地演習ノ爲メ夏季休業中即チ七月十一日ヨリ九月十日マデハ各私立造船所若クハ海軍造船廠ヘ出張セシメテ實地研究ヲサセテ置キマス、第三年生ニナリマスト、第一學期即チ七月ヨリ十二月マデ六ケ月間ハ各造船所ニ於テ實地演習ノミヲヤラセテ居リマス、第二學期及第三學期ハ造船學ヲ毎週約四時間、又第二期ニハ計畫及製圖ヲ毎週三十時間、ソレデ第三學期中ハ卒業計畫及論文ニ從事サセテ置キマス之レニ依テ及第シタル學生ハ卒業致シマス、是ガ現今ノ學科ノ模樣デアリマス

ソレカラ造船學ノ卒業生ノコトハ前ニ一寸御話申シマシタ通リ、十六年ニ始メテ卒業生ヲ出シマシテ、其ノ以後二十一年間ニ百十一名出シタノデアリマスガ、此ノ大多數ハ極メテ近年ニ至テ增加シタノデ、三十二年以後ニハ著シク志願者ガアリマシタ從ッテ卒業生モ多數ニナリマシタ、故ニ造船學ノ敎室ガ從來ノモノデハ何分手狹デアッテドウシテモ學生ヲ收容スルコトガ出來ナカッタガ、大學デモ希望者ニハ是非志望ヲ達シサセルヤウニト云フ方針、又文部省デモ同樣デアッテ年々百方繰合セテ學生ヲ入レテ居リマシタガ、無論學生ノ殖エルコトハ希望スルノデアリマスガ、如何ニモ敎室ガ狹イ、ソレデ三十一年頃カラドウシテモ敎室ヲ殖シテ下サランケレバ殘念ナガラ學生ヲ增加スルコトガ出來ナイト云ッテ、或ハ假小屋ノ製圖室ヲ建テ一時ヲ補ヒマシタガ直ニ又不足ニナリマシテ、ソレカラ又假小屋ノ建足シヲシテ授業スルヤウナコトヲシテ居リマシタガ、ソレデモ希望生ノ全數ヲ入レラレナイト云フノデ敎室ノ新築ヲ願ッタ、ソレデ計畫ヲ立テ、出シタ所ガ、或ハ文部省デ省カレ、或ハ大藏省デ削ラレルト云フヤウナコトデ議會通過マデニイカナイノデアリマシタガ、幸ヒニモ其後文部大臣閣下ノ盡力ニ依テ、一昨年カラ著手シテ今日諸君ガ御覽ニナリマシタ所ノ此ノ敎場ガ新築ニナリマシテ、本年七月カラ此方ヘ移ッテ授業ヲ始メルコトガ出來タノデアリマス。即チ此ノ圖面ガ此ノ敎室デアリマスガ、建築方法カラ言ヒマスト木骨煉瓦二階建デアッテ、始メ希望イタシマシタノハ、モウ一ツ此方ニ袖ガ欲シイト思ッテ計畫シタノデアリマスガ、是レダケアッタラ宜カラウト云フコトデ減少サレタ結果、妙ナ形チニナリマシタガ、總坪數ハ三百六十坪アリマス、議會デ協定サレタ豫算ノ建築費ハ全部デ十萬九千三百七十六圓、其中ニ四千百二十六圓ノ設備費モ這入ッテ居リマスガ、ザット十一萬圓バカリデアリマス、故ニ一坪ガ約三百圓ニ當ッテ居リマス、二階ノ製圖室ガ一番廣イ

敎室デ百六十三坪、其次ノ敎室ガ九十二坪、又唯今居リマス講義室ガ三十坪デアリマス、其他ニ二ツ稍ヤ小ナル講義室ガアリマス、併シ二階ノ製圖室ナドハ御覽ノ通リ机ガピッチリ並ンデ通路ガ殆ンド無イヤウニナッテ居リマスガ、ドウシテモアレダケナイト現在ノ學生ヲ收容スルコトガ出來ナイ、ソレデ唯今ノ學生ハ何人アルカト申シマスト、第三年生ガ十九人、第二年生ガ二十四人、第一年生ガ二十七人合計七十人、其他ニ撰科生ガ一人アリマス、實ハ造船學ニハ撰科生ヲ入レルダケノ餘地ハアリマセヌガ、是ハ韓國人デアリマシテ、高等學校モ中々好イ成績デ仕舞ッテ來テ居ルカラ特ニ許可シタ次第デアリマス、合セテ七十一人ノ學生及生徒ガゴザイマスカラ、チヨット御覽ニナルト大變大キナモノデ、緩ヤカニ使用シテ居ルヤウナ御考ガアルカモ知レマセヌガ決シテサウデアリマセヌ、餘程儉約シテ室ヲ使ッテ居リマス、殊ニ全部ガ造船學デハゴザイマセヌ、階下ノ半分程ハ造兵學科ノ方デ使ッテ居ルノデアリマス、併シ舊造船學科敎室ニ比較イタシマスト餘程廣ク且便宜ニナリマシタカラ、授業上及研究上ニ大變便利ヲ與ヘラレマシタ

ソレカラ是レダケノ學生ヲ利用シテ參リマス職員ハドウ云フ狀況ダト云フコトヲチヨット御話シタイト思ヒマス、造船學ノ專任敎授ガ二人外國敎師ガ一人、講師ガ一人、助敎授ガ二人デ、敎員ガ總計六人デゴザイマス、ソレニ助手ガ一人、小使ガ三人、是レダケヲ此ノ建物ノ中デ使ッテ居リマス、又經費ハドノ位ニナッテ居ルカト云フト、敎授其他ノ給料ハ別デアリマスガ、敎室ノ經費ハ三十六年度ニハ四千二百七十三圓、此ノ内學生ニ貸付スル旅費ガ千十圓、又內國旅費トシテ六十圓、千七十圓ハ旅費トシテ使ッテ仕舞フノデアリマスカラ、殘リガ三千二百三圓、此ノ內ニテ圖書、雜誌、諸器械及模型等ヲ購入スル費用モ含ンデ居リマスカラ此ノ金額ハ決シテ多イ經費デハナカラウト思ヒマス、從テ隨分儉約シテ使ッテ居リマス、併シ是レモ十年バカリ前ニ比較スレバ非常ナ增加デアリマス

ソレカラ十六年以降年々卒業シテイッタ卒業生ハドンナ狀況デアルカト申シマスト、十六年ニハ三人卒業シタ、十七年ニモ三人、十八年ニハ二人、十九年ニハ一人、二十年ニハ四人、二十一年ニハ二人、二十二年ニハ一人、二十三年ニハ四人、二十四年ニハ一人、二十五年ニモ一人、二十六年ニハ三人、二十七年ニハ一人、二十八年ニハ三人、二十九年ニハ二人、三十年ニハ七人、三十一年ニハ九人、三十二年ニモ九人、三十三年ニハ十八人、三十四年ニハ十四人、三十五年ニハ十七人本年ガ十四人、是ガ卒業生ノ狀況デアリマスガ、唯大ニ幸福トシテ居ルコトハ、一年ニ一人モ卒業生ノ無イ年ハナカッタ、造船學科ヨリモ需用ノ多大ナル學科デモ前記二十一年間ニハ一人モ卒業生ノ無カッタ年モアリマシタ、然ルニ造船學科デハ、一人ト云フノハ劍呑ナ數デハアリマシタガ十六年以來二十一年間年々卒業生ガ繼續シテ居ルノハ大

ニ滿足デアリマス

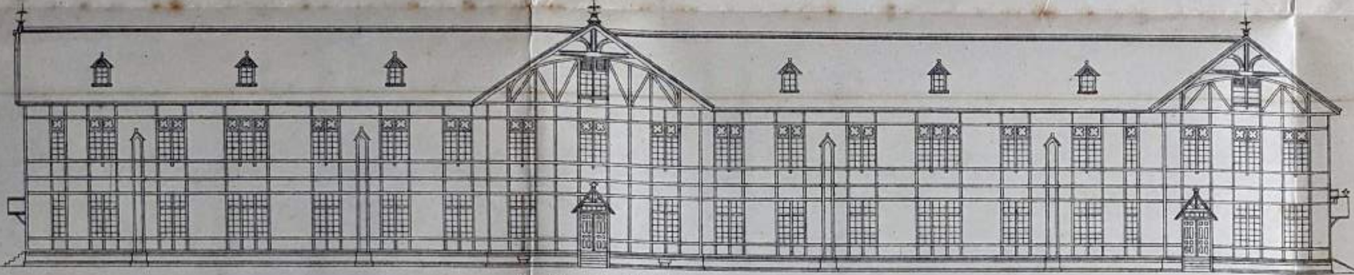
サテ此ノ卒業生ハ世ノ中ニ出テドウナッタカ、何ヲシテ居ルカト云フコトモ大ニ考ヘナクテハナラヌ、ソレヲ調ヘテ見マシタラ斯ウ云フ結果デス、即チ海軍ノ技術官トシテ現ニ奉職シテ居ル人ガ三十四人、是レガ一番多イ、ソレカラ私立造船所及船渠會社ニ從事シテ居ル人ガ二十六人、遞信省ニ海事技術官トシテ奉職シテ居ルモノガ二十八人、汽船會社ニ從事シテ居ル人ガ十八人、ソレカラ造船學ノ敎官ガ六人、設計監督等ノ業ニ自營シテ居ル人ガ五人、ソレカラ極ク不幸ナ事デアリマスガ死亡者ガ四人、是ハ甚タ哀悼ノ至リデアリマス、又大學院ニ入ッテ尙ホ研究シテ居ル學生ガ三人アル、兵役ニ從事シテ居ル人ガ二人、外國ヘ留學シテ居ル人カ一人、合計百十一人、尤モ外國ヘ留學シテ居ルノハ此外ニ二人アリマス、一人ハ造船學ノ敎官デ、一人ハ私立造船所ニ從事シテ留學シテ居ル人デスカラ其方ニ入レマシタ、ソレカラ此外ニ工部大學校デ機械學ヲ卒業シテ更ニ造船學ヲ修業サレタ人ガ一人居リマス、其人ハ海軍ノ技術官ニ奉職サレテ居リマス、ソレカテ專科生、專科生ト云ッテモ一科グラヰデナク、造船學ノ本科生ト同シヤウニ修學シテ相當ノ試驗ヲ通過シタ人ガ二人アル、此ノ二人ハ私立造船所ニ從事サレテ居リマスガ、是等ヲ卒業ノ中ニ加ヘルナラバ總計百十四人ニナリマス、是等ノ諸君ノ內四名死亡者ヲ除キテハ皆各々自分ノ學ヒ得タ所ヲ更ニ研究シテ、智識ト學術ヲ以テ日本ノ造船業若クハ造船學ニ貢獻セラレテ居ル諸君デアリマス

以上ハ今日新築ノ敎場ヲ御覽ニナッテ頂クト同時ニ、斯ウ云フヤウナ狀況デアルト云フコトヲ御話スル爲メニ述ヘタノデアリマスカラ、別ニ何モ益スルコトノアラウ筈ハゴザイマセヌ寧ロ大學ノ造船學科ノ廣告ヲシタヤウデアリマシテ、諸君ニ對シテ甚タ御氣ノ毒ニ考ヘマス、然ルニ諸君ニ於テハ御謹聽下サレマシタハ眞ニ有リ難ク感謝イタシマス

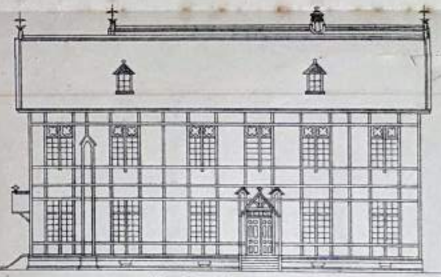
東京帝國大學工科大學造船學造兵學教室側面及平面圖

縮尺参百分之一

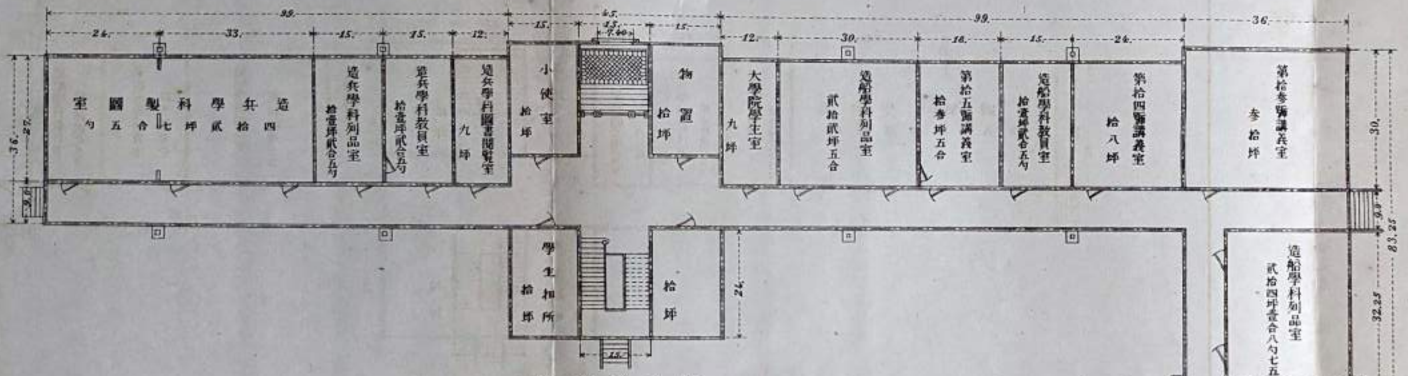
總建坪参百六拾坪



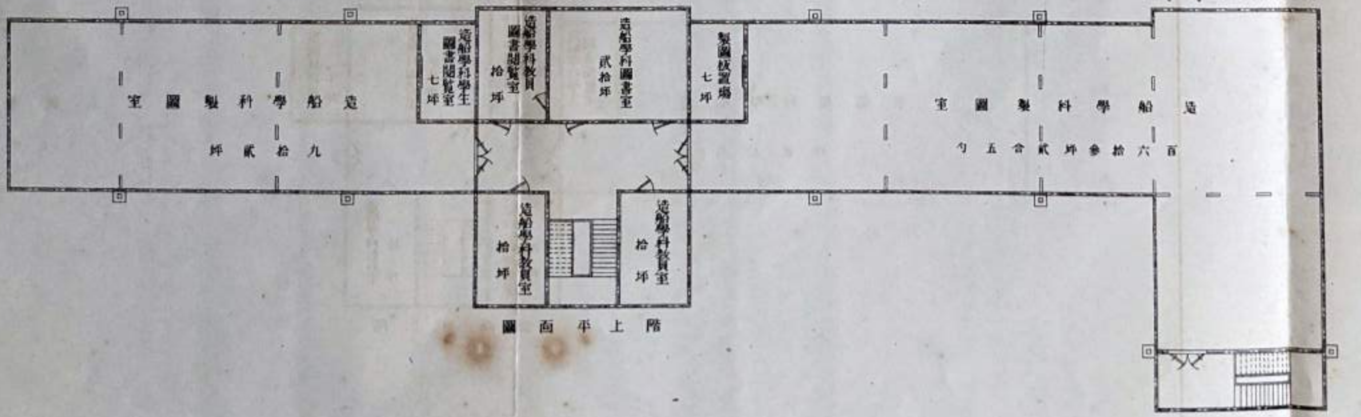
北東面建圖



西側面建圖



階下平面圖



階上平面圖

佛國ニ於ケル造船業保護制度ノ沿革

明治三十六年十一月七日造船協會講演會ニ於テ

湯河元臣

私ハ此會ノ協同員ノ末ニ列ツテ居ル湯河デゴザイマスガ、今日ハ此會デ何カ御話ヲ申上ゲルヤウニト云フ御相談ヲ受ケマシテ、非常ニ名譽ナ事ト考ヘマシタガ、御承知ノ通リ自分ノ學ビマシタ事ガ此會ノ事業ニ餘リ關係ヲ有タヌノデ是ト申ス材料モ無イノデゴザイマス、併シ折角御相談ヲ受ケマシタルコトユヘ、淡泊無味デハゴザイマスガ、佛蘭西ノ造船保護制度ノ沿革ト云フ題デ簡單ニ申上ゲヤウト思ヒマス

佛蘭西ノ國ニ於ケル海運事業ノ保護ト云フコトハ餘程長イ沿革ヲ有ツテ居ル事柄デアリマシテ、自分ノ國ノ海運事業ハ、自然ノ成行キニ放任シテ居ツテハナラヌ、國ニ於テ之ヲ保護シ、サウシテ外國ノ競爭ニ對立セシメナクテハナラヌト云フ觀念ハ餘程久シイ以前カラアツタノデ、歴史ニ基イテ見マスト、千六百年代カラ今日ニ至ルマデ一貫シテ居ル所ノ一ノ佛蘭西ノ國是ト申シテモ宜シイ位デアリマス、此間ニハ無論此ノ觀念ヲ實行スル方法手段ニハ種々變化ガゴザイマシタケレドモ其ノ精神ハ常ニ同ジ事デゴザイマシタ、併シ其ノ方法ハ十九世紀ニナツテカラ最モ頻繁ニ變遷シタノデアリマス、今日ハ其ノ方法ノ中デ特ニ造船事業ニ關係シタ事柄ヲ概略申上ゲル考ヘデゴザイマス

千六百年代ノ半バニ於ケル佛蘭西ハ、國王ト致シマシテハルイ第十四世、宰相ト致シマシテハコルベール、名君デアリ賢相デアル人ガ相竢ツテ、大ニ佛蘭西百般ノ制度文物ノ改善ヲ企テマシテ、從ツテ佛蘭西ノ商業、工業、貿易業、是等ノ仕事ニ對シテ種々ナ制度ヲ設ケテ成功ヲ企テタノデアリマス、其一トシテハ海運事業ノ擴張ト云フコトモ大ニ著目セラレタノデアリマス、千六百年代ノ佛蘭西ニ於ケル海運ノ有樣ハドンナデアツタカト申シマスト、簡單ニ右ノコルベールト云フ人ノ言葉ヲ借リテ申シマスト斯ウ云フ事ヲ申シテ居ル、千六百六十四年ニ於キマシテハ、佛蘭西ノ諸處ノ港ニ在ル「レーヅンナーブル」即チ「リーヅチーブル」ノ船ハ僅ニ二百艘シカ無カツタト云フコトデアリマス、然ルニコルベールト云フ人ハ先ヅ第一ノ仕事ト致シマシテ、非常ニ高イ賃金ヲ出シテ和蘭ノ造船ノ職工ヲ聘シマシテ、サウシテ佛蘭西人ニ造船業ノ練習ヲサセタノデゴザイマス、ソレカラ又一方ニ於キマシテハ、特ニ佛蘭西ノ造船所ニ向ツテ船ヲ注文スルモノニハ一種ノ金ヲ給シテ其事ヲ奬勵シタ、ソレカラ又山林ノ臺帳ヲ作リマシテ濫伐ヲ防ギ、一方ニ於キマシテハ勅令ヲ出シテ外國製造ノ船舶ニハ輸入税ヲ課スル、又一方ニ於キマシテハ造船用ノ材木ノ輸出ヲ禁ズル、斯ノ如クニ種々ナ方面カラ造船業ヲ保護シタ結果ト致シマシテ、佛蘭西ノ造船業ハ非常ナル速力ヲ以テ發達シテ參リマシテ、製造船舶ノ數ハ左程デモアリマセヌデシタケレドモ、製造船舶ノ品質ト言ヒマスカ、資格ト云フモノハ世界中デモ競爭者ノ無イ程ニ進ンダト佛蘭西ノ書物ニハ

書イテアリマス

ソレカラ又當時佛蘭西ニ於テ造船ニ使フ材木ハ、歐羅巴ノ北部バルチック沿岸アタリカラ出ル材木ヨリモ、價ハ幾分カ高カウゴザイマスケレドモ、其木ノ性質ノ良カッタコトハ是亦世界デ等シク認メテ居ッタ所デアリマシテ、是等ノ事情ニ依テモ佛蘭西ノ造船業ハコルベールノ施設ノ結果トシテ大ニ賞讃サレテ居ッタノデアリマス

此ノ制度ハ殆ド百年餘モ續イテ居リマシタラウガ、玆ニ一ツ恐ルベキ競爭者ガ出タノデアリマス、其爲ニ前ニ述ベマシタ制度ダケニ安ンジテ居ルコトガ出來ナクナッタノデアリマス、其ノ恐ルベキ競爭者ハ申スマデモナク英吉利デアリマス、當時英吉利ガ海上ニ追々勢力ヲ振フヤウニナリマシタ原因ハ、御承知ノ通リ主トシテ彼ノ「ナビゲーションアクト」、航海條例ノ結果デアルト云フコトハ疑ヒナイ事實デアリマシテ、此ノ航海條例ハ千六百五十一年カラ實施セラレタノデアリマスガ、其後追々保護主義ガ擴張サレマシテ、千六百六十年ノチャーレス第二世ノ條例ニ於テ殆ド英吉利ノ船舶ノ獨占權ヲ十分ニ確メタノデアリマス、彼ノ獨逸ノ皇帝ウキルヘルム第二世ガ「吾々ノ將來ハ海上ニ在ル」ト言フタノデ、世界ノ人ノ耳ヲ峙テタノハ千九百一年、一昨年ノ事デアリマスガ、サウ云フヤウナ事ハ既ニ二百五十年前ニ英吉利ノ條例發布ノ際ノチャーレス第二世ノ勅語ノ中ニ書イテアリマス、即チ英吉利ノ富ト平和ト國ノ力ト云フモノハ全ク海上ニ在ルト自分ハ考ヘルニ依テ今此ノ條例ヲ發布スル譯デアル、汝臣民等モ協力シテ其旨ヲ體シロト云フ事ガ書イテアリマス、ソレデ比較シマス爲ニ簡單ニ英吉利ノ航海條例ノ要點ヲ述ベテ見マスト、第一ノ要點ハ、英吉利ノ土地デ造ラレタル船デナケレバ英吉利ノ船舶ト云フコトハ出來ナイ、又英吉利ノ旗ヲ立テルコトハ出來ナイ、即チ外國ノ船舶デアッテ英吉利ノ法律ハ之ヲ保護シナイト云フコトデアル、第二ハ、歐羅巴以外ノ國カラシテ英吉利ニ輸入スル貿易品ハ、英吉利ノ船舶デナケレバ搭載スルコトガ出來ヌ、第三ト致シマシテハ、歐羅巴中ノ或國カラ英吉利ニ輸入スル商品ニ付テハ、第三國旗デ運送スルコトガ出來ナイ、第三國旗ト申シマスノハ法律デ言フ第三者ト同ジ事デ、當事者デナイト云フ意味デス、言ヒ換ヘマスレバ英吉利ニ輸入シマス物産ヲ製造スル國トカ若クハ荷物ガ其處カラ出テ來ル所ノ其國ノ船デ英吉利ヘ持ッテ來レバ第三者デナイ、故ニ自國ノ貨物ヲ自國ノ船デ輸出スレバ宜イガ甲ノ國ノ船ガ乙ノ國ノ物産ヲ積デ英吉利ニ輸入スルコドハ禁ズル、斯ウ云フ規定デアリマス、第四ニハ、英吉利本國ノ沿岸貿易、及ビ本國ト殖民地ノ間ノ貿易ハ英吉利ノ船デナケレバ許サヌト云フノデアリマス、第五ト致シマシテハ、第三ニ申シマシタル、他國ノ船ガ自國ノ貨物ヲ搭載シテ英吉利ニ輸入スル商品ノ輸入稅ハ、英吉利船ニ搭載シテ來タ商品ヨリモ重イ輸入稅ヲ課スル、此五點ガ航海條例ノ主ナル精神デアリマス、要スルニ英吉利ノ貿易ハ即チ英吉利デ造ッタ船デナケレバナラ

ヌト云フコトニ歸著スルノデ、ツマリ英吉利ノ貿易ハ外國デ製造シタル船ニハ指ヲモサ、セナイト云フノデ、今日ノ英吉利ノ自由主義トカ何トカ云フ眼カラ見マスト、コンナ事ヲヤツタカト思フヤウナ極端ナ事ヲヤツテ居ツタノデアリマス、是ガ原因トナリ、英吉利ハ追々ニ海上ノ覇權ヲ握ルヤウニナリマシテ、和蘭ノ跋扈ヲ防ギ、更ニ進ンデハ歐羅巴北部ノ沿岸諸國ノ貿易ハ自分ガ獨占スルヤウナ有樣ニナツテ參ツタ

夫レガ爲ニ佛蘭西ハ、到底今マデノ有樣デハ之ニ打勝ツコトガ出來ヌト考ヘマシテ、遂ニ千七百九十三年ニ至リマシテ、殆ド英吉利ト同ジヤウナル規則ヲ制定シタ、名前マデモ同ジニシ、條文ノ字句マデモ同ジニシタト云フノハ、多少英吉利ニアテツケタヤウナ觀念デアラウト思ハレル佛蘭西デハ法律ニ「アクト」ト云フ字ヲ使ツテ居リマセヌガ是ハ「アクト、ド、ナビゲーション」ト云フ名前ヲ付ケタノデアリマス、此規定ハ千七百九十四年一月一日即チ發布ノ翌年カラ實施サレタノデアリマスガ、其中ニ造船業ヲ獨占スルト云フ規定ハ斯ウ云フ風ニ書イテアリマス、佛蘭西ノ本國、殖民地又ハ佛蘭西ノ占領シテ居ル土地ニ於テ製造セラレマシタ船カ、又ハ戰時ニ當リマシテ敵國ヨリ捕獲シテ、捕獲審檢所ニ於テ正當ノ捕獲デアルト云フ判決ヲ受ケタル船デアルカ、又ハ佛蘭西ノ法律ニ違背シタニ依テ沒收シタル外國船舶デナケレバ佛蘭西ノ船トハ看做サヌト云フコトニナツテ居ル、其他航海ノ特權トカ、荷物搭載ノ規定トカハ全ク英吉利ノ規定ト同一デアリマスソレカラ千七百九十四年ニナリマシテ、前ニ申シマシタ法律ガ實施サレテ少シ經ツテ斯ウ云フ規則ヲ出シタ、外國ノ船舶ガ、佛蘭西ノ本國又ハ屬領地ニ於キマシテ海難ニ遭フテ大破損ヲ生ジマシテ、其ノ所有者又ハ保險者ガ之ヲ賣却シヤウト云フヤウナ場合ニ、其ノ所有權ノ全部ガ佛蘭西人ニ歸シテモ、其ノ修繕費ガ買ヒマシタ價ノ四倍以上掛ラナケレバ佛蘭西ノ船ニスルコトガ出來ナイト云フ規定、モウ一ツハ、佛蘭西ノ船ガ外國デ難破シタ場合ニハ一噸六「ルーブル」、其ノ當時ノ一「ルーブル」ハ幾ラデゴザイマスカ、一噸六「ルーブル」以上ノ費用ヲ出シテ外國ニ於テ修繕スルコトハ出來ナイ、若シ此制限以上ノ費用ヲ出シテ修繕スレバ、其ノ商船ハ佛蘭西ノ船デナクナツテ仕舞フ、外國ノ船ニナルゾヨト云フ規定デアリマス、是等ハ一方カラ見ルト實ニ極端ナ話デアツテ、殆ド常識ニ缺ケテ居ルガ如キ規定ト思ハレマスガ、其時ハ眞面目ニ斯ウ云フ事ヲ極メマシタ、ソレカラ前ニ申シマシタコルベールノ造船用木材ノ輸出禁止法ハ千八百三十六年マデ續イテ參リマシタガ、其年ニ此ノ禁止ヲ解キマシテ、其代リニ一「ステール」、即チ一立方「サンチメートル」ニ付テ十「サンチーム」乃至一「フラン」ノ輸出税ヲ課スルコトニナリマシテ、木材ノ貿易ニ多少自由ヲ得マシタガ此ノ規則ノ結果造船用ノ材木ノ價ガ非常ニ騰貴スルコトニナツテ色々苦情ガ起リマシタ爲ニ、千八百四十一年ニナツテ右ノ輸出税ヲ一「ステ

ドル」ニ付テ二十五「フラン」ニ上ゲマシタノデ二十五倍ホド增額シタノデアリマス、併ナガラ造船業者ノ方カラ見ルトモット輸出稅ヲ高クシテ貰ヒタイ、或ハ進ンデ前ノヤウニ絕對的ニ廢シテ貰ヒタイト云フヤウナコトヲ願ツテ居ル者モアルヤウニナツタ、是ガ千八百四五十年ノ頃ノ話デアリマス

以上申シマシタノハ主トシテ船體ノ事ニ關係イタシマスガ、機關ノ事ヲ御話申シマスト多少趣キヲ異ニシテ居リマス、當時ノ英吉利ニ於キマシテハ、鐵、石炭ナドノ採掘ガ段々盛ンニナツテ參リマシテ、製鐵ノ仕事モ非常ニ發達イタシテ參リマシタ、佛蘭西デモ製鐵業ハ隨分ヤリ、品質モ左ホド劣ツテハ居リマセヌガ、價ガ非常ニ高クナツテ居リマシテ、其ノ結果英吉利ト十分競爭スルコトガ出來マセヌガ故ニ蒸氣機關ガ追々海運事業ノ重要ナル位地ヲ占メルヤウニナリマシテ、佛蘭西ノ機關ノ製造ニ從事シテ居リマス者ハ、英吉利ノ競爭ニ對スル爲ニ、政府ガ保護ノ道ヲ執ラレムコトヲ請求シマシタ、又一方ノ航海業者ハ、之ニ反對ノ議論ヲ唱ヘマシテ、折角英吉利ニ於テ廉價ナルモノガ出來ルノニ、內地ノ物ヲ保護シテ、英國カラ買フコトガ出來ヌト云フコトニナツテハ困ルト言ヒ出シタ、是ガ佛蘭西ニ於テ造船業者ト航海業者ノ利害ノ衝突スル議論ノ起ツタ初メト申シテモ宜イノデアリマス、併ナガラ佛蘭西政府ハドウシテモ造船業ヲ發達サセナケレバナラヌト云フノデ千八百十六年ノ法律デ、蒸氣機關ノ輸入ニ對シテハ一割五分ノ從價稅ヲ課シマシタ、ソレカラ千八百十八年ノ法律デ、舶用機關ニ限ツテ其ノ割合ヲ三割ニ高メマシタ、然ルニ航海業者ハ成ルタケ輸入稅ノ減少スルコトヲ希望シ、造船業者ハ更ニ之ヲ高メタイト希望シマシテ矢張利害ガ衝突シテ居ルノデアリマシタ、政府ハ尙ホ佛蘭西ノ工業ヲ保護シナクテハナラヌト云フ方針デ、千八百三十六年ニ更ニ規則ヲ制定シテ、蒸氣機關ノ製造ニ使用スル爲ニ輸入スル原料、即チ鐵材ニ課スル輸入稅ハ、後日ニ至ツテ其原料ガ百馬力以上ヲ有シテ居ル機關トナリ、ソレヲ汽船ニ据附ケルト云フ曉ニハ返シテヤルト云フ工業保護ノ規則ヲ出シタ、一種ノ戻稅即チ「ドローバック」デス、然ルニ造船業者ト航海業者ノ軋轢ハ益々激シウゴザイマスガ故ニ、千八百四十一年ニナリマシテ兩方ノ利害ノ衝突ヲ調和シテ見タイト云フ考ヘカラ又一ツ規則ガ出タ、即チ兩方トモ利益ヲ得ル仕組ミノ規則デアリマス、其ノ要點ハ、外國ノ航路、即チ遠洋航路ニ使用スル佛蘭西ノ船ニ据附ケル外國製造ノ機關ノ輸入稅ハ全部免除シテ無稅トスル、是デ航海業者ノ目的ハ達シサセタ、其代リニ佛蘭西ノ製造者ガ之ヲ自分ノ國デ製造シタ時ニハ其ノ代償ニ對シテ三割三分ノ奬勵金ヲ與ヘル、依テ前ノ原料ノ輸入稅ハ返還スルト云フ戻稅ノ規定ハ廢スル、詰リ兩方ニ利益ヲ與ヘタノデアリマスガ、是ガ佛蘭西デ奬勵金ト云フモノヲ拵ヘタ初メデアリマス、ソレデ右ノ外國製造ノ機關ノ輸入稅ヲ免除スルト云フコトハ外國航路ニ使用スル汽船ノ機關ノミデアリマシテ、其他ノ

汽船ノ機關ニ付テハ千八百十八年ノ法律デ規定サレタ三割三分ノ從價税ヲ徴收サレル筈デアリマスケレドモ、船主等ハ實際遠洋航路ニ使用シナイ船ニ据附ケル機關マデモ遠洋航路ニ使用スル汽船ニ据附ケル豫備ノ機關デアルナドト申立テマシテ、無税輸入ヲ企テル者ガ多クナリ、其ノ結果莫大ノ脱税者ヲ生ズルヤウニナリマシタカラ、千八百四十五年ニ法律ヲ改正シテ、再ヒ舶用機關ノ輸入税ヲ課スルコト、ナリマシテ、今度ハ從前ノ從價税ヲ廢シテ重量税トシテ一百「キログラム」ニ付テ四十五「フラン」ノ輸入税ヲ課シタノデアリマス、之ヲ從價税ニ換算スルト約二割七分ニ當ルト云フコトデアリマス、此ノ新シイ規則ノ制定ノ結果トシテ千八百四十一年ノ法律ノ、機關製造業者ノ奬勵金モ同ジ割合ニ重量税ニ換算シテ與ヘルト云フコトニナリマシタ、斯ウ云フ風ニシテ機關ノ内國製造ヲ保護スルト云フコトヲ遣ツテ居リマス中ニ、蒸氣船ノ航海ガ益々盛ンニ發達シテ參リマシテ、外國製造ノ機關ニ輸入税ヲ課スルコトハ航海業者ニ於テ非常ニ不便ヲ感ジテ參リマシテ諸處デ不平ノ聲ヲ漏スト云フ有様ニナツテ參リマシタ、是ガ千八百四五十年頃ノ話デアリマス

此ノ時分ニ於キマシテ、對岸ノ英吉利ノ狀況ハドウカト目ヲ著ケテ見マスト、英吉利ニ於キマシテハ前ニ申シマシタ航海條例ナドノ保護政策ガ十分ニ結果ヲ現ハシマシテ、久シク海上ニ威張ツテ居ツタ所ノ和蘭ヲ斥ケ、自分ガ之ニ代ルヤウニナリマシテ、其ノ結果工業モ發達スルシ貿易モ益々進ンデ參リマシテ、終ニ保護政策ハ自分ノ國ニ却テ利益デナイト云フ有様ニマデ進歩シテ來タ、其ノ理由ハ申スマデモアリマセヌガ、自分ガ保護政策ヲ採用シテ居リマスト、他國デ同一ノ主義ヲ執ルノヲ批難スルコトモ出來ナイ、從ツテ自分ノ國デ造船業、其他ノ實業ガ何程發達シテモ、外國デ輸入税ヲ高ク課シテ他國ノ製造品ノ輸入ヲ妨害シマスト製造品ノ販路ヲ得ルコトガ出來ヌト云フコトニナツテ來ルカラデアリマス、ソレ故ニ英國ニ於キマシテハ千八百二十四五年ノ頃カラ段々自由貿易論ガ出テ參リマシタ、リチヤード、コブデンナドト云フ人ハ自由貿易ニ非常ニ熱中シタ人デアル、千八百三十八年ニマンチェスターニ於キマシテ「アンチ、コーン、ロー、リーグ」即チ穀物ノ輸入ヲ禁止スル法律ヲ廢スルト云フ同盟會ヲ組織シマシタ、コレガ自由貿易論ノ第一ノ旗揚デアリマシテ、今マデ英吉利ハ自分ノ國ノ麥ヲ作ル農民ヲ保護スル爲メニ外國ノ麥ノ輸入ヲ禁ジテ居リマシタ、併ナガラ追々人口ハ增加スルケレトモ麥ノ産出ハ之ニ伴ハス其價ガ段々高クナルト云フノデソレヲ廢止スルヲ目的トシタ會デアリマス、一方デハサウ云フ會ガ起ルシ、又一方デハ議會アタリデモ、英吉利ハ鐵ト石炭ガ盛ニ出ルノデ、其鐵ト石炭ハ實ニ工業ノ骨トモナリ肉トモナルモノデアル、此富ヲ天カラ享ケテ居ルノハ即チ英吉利ガ世界ノ工業ノ競爭ニ勝ツト云フ基礎デアルカラ保護主義ナド、云フヤウナ障壁ハ成ルベク去ツテ世界ニ横行濶歩スル方ガ宜イナド、云フ說モ出タ

ノデアリマス、ソコデコブデンノ奔走ノ結果穀物條例ヲ廢スル目的ヲ達シマシタカラ、其餘力ヲ以テ更ニ進ンデ航海條例ヲ廢スルト云フ考ヲ起シマシテ、千八百五十一年ニナリマシテ航海條例ヲ廢止スル目的ヲ達シマシタ、是ニ於テ英吉利ハ全ク自由貿易主義トナツテ今日マデニ至ツテ居ルノデアリマス

ソコデ英吉利ノ政策ニ斯ウ云フ變化ガアリマシタノガ妙ナ反響ヲ佛蘭西ニ與ヘタノデアリマス、千八百五十一年ニ唯今ノ倫敦ノクリスタル、パレースニ博覽會ガアツタ頃デアリマス、其時ニ佛蘭西ノ當時ノ宰相シュバリエート云フ人ガ博覽會見物ニ英吉利ヘ參リマシテ會場內ニ於テ料ラズモコブデンニ出會ヒマシテ、保護主義ヤ自由主義ノ話ナドヲシナガラ場內ノ陳列ノ模樣ヲ見テ步キマシタ所ガ、實ニ甲ノ國ニ非常ニ能ク出來ル物デアツテ、乙ノ國ニ於テハソレガ非常ニ必要ナ物デアルニ拘ラズ乙ノ國ガ保護主義ヲ採ツテ居ル爲メニ自由ニ買フコトモ出來ズ、其極僅カナル者ノ、其事業ニ從事シテ居ル者ノ利益ヲ保護スル爲メニ、全般ノ人民ノ利益ヲ無視スル如キ結果トナルモノデアルト云フコトガシュバリエート云フ人ノ頭ニ起ツテ參リマシテ、ドウモ佛蘭西ニ於テハ非常ナル輸入稅ヲ課シテ居ルガ甚ダ面白クナイ事デアルト云フ考デ、コレガ其當時カラ佛蘭西ニ於テモ此思想ヲ唱ヘテ行クト云フコトノ原因ニナツタノデアリマス、ソコヘ持ツテ來テ奈破烈翁三世ト云フ人ガ熱心ナル自由主義デアリマシタ、又國內各州カラモイロイロ同樣ノ考ヲ持ツ人モ出テ自由主義ノ議論ガ起ツタモノデスカラ遂ニソレ等ノ事情カラシテ、千八百六十年ニナツテ奈破烈翁三世ノ時ニ英吉利トノ間ニ一ツノ條約ガ出來マシタ、其條約ニ於キマシテ始メテ英吉利デ製造シタ船ノ輸入ヲ許スコトニナリマシタ、併シ木製ノ船ハ一噸二十五「フラン」、鐵製ノ船ハ一噸七十「フラン」ノ輸入稅ヲ拂ハナケレバナラヌト云フコトニナリマシタ、是ガ沿革上一ノ大段落デアツテ、千七百九十三年以來外國製造船舶ノ輸入ヲ禁ゼラレタ制度ガ、此時ニ始メテ無クナツテ仕舞ヒマシタ、ソレデ機關ニ對スル輸入稅ハ百「キログラム」ニ就テ前ニハ四十五「フラン」デアリマシタノガ二十「フラン」ニ減ゼラレタノデアリマス、ソレデ斯ノ如ク保護ト云フコトガ大分ニ薄ライデ參リマシタガ、尙各種ノ議論ガ出マシテ、モツト自由主義ニ近寄リタイト云フ議論ガ盛ンニ起ツテ參リマシテ、千八百六十二年ニ至ツテ高等商業會議ト云フモノガ出來マシテ、ソレニ海運事業ノ調査ヲサセルト云フコトニナリマシタ、二年間調査會ガ續キマシテ、千八百六十四年ニ決議發表トナリ政府ハソレヲ基礎トシテ千八百六十五年ニ法律ヲ出シマシタ、議會ニ於テモ非常ナ議論ガ起リマシタガ、結局大多數ヲ以テ可決セラレマシテ千八百六十六年ノ法律トナリマシタ、其法律ノ規定ハ前ヨリ亦一層自由主義ニ近クナツテ參リマシテ、其規定ノ大體ハ航洋船ノ製造、修繕等ニ必要ナル一切ノ材料ハ輸入ノ時カラ一箇年內ニ之ヲ使フト云フコトヲ條件ニシテ輸入稅ヲ免除シテ、

又外國製造ノ船舶モ一噸二「フラン」ノ税ヲ納メテ輸入スルコトヲ得ルコトニシタノデアリマス、ソレト共ニ前ノ機關製造ニ對シマスル奬勵金ハ廢スルコトニナツタノデアリマス、是等ノ事蹟ニ依ツテ見ルト英吉利ト佛蘭西トハチヨツトヤリ方ガ違フト考ヘル、英吉利ニ於テハ極端ナ保護主義ヲ千六百六十年カラ千八百十五年マデ百五十五年ノ間終始一日ノ如ク實行シテ參リマシタガ、佛蘭西ニ於テハ英吉利ヨリ百三十年後レテ千七百九十三年ニ航海條例ヲ實行シタニモ拘ラズ、千七百九十三年ヨリ未タ七十年モ經タナイデ千八百六十年ニ於テ其主義ヲ拋ツタノデアリマスカラ、是ガ歷史上ニ於テ兩國ノ海運事業ノ優劣ノ分レテ今日ノ懸隔ヲ生ジタル一ノ原因デハナイカト思ハレマス

斯ノ如ク殆ド自由主義ト云ツテモ宜シウゴザイマセウ、佛蘭西ガ激變ヲ致シマシタ結果ハ甚ダ宜シクナクナリマシタ、造船業モ一向進歩スル模樣モナク出入ノ船舶ノ數ハ却テ減少スルコトニナリマシテ、ソコデ又保護主義ノ論者ハ氣焰ヲ高メテ、議會ニ於テモ千八百六十年ノ奈破烈翁ノ條約ハ早速之ヲ廢棄スルガ宜カラウ、之ヲ廢棄スル順序手段ヲ研究シタラ宜カラウト云フ議論ヲ發スル者モアリマシテ、政府攻擊論ガ中々盛デアリマシタカラ政府ニ於テモ此制度ノ激變ニ就テハ其移リ變リヲ成ルヘク圓滿ニ經過スルヤウナ經濟上ノ處分ヲ研究スルコトヲ誓ヒ、議會ニ於テモ特別委員ヲ以テ其事業ヲ研究シテ見ヤウト云フコトニナリマシテ、千八百七十年カラ調査ニ著手シマシタ所ガ不幸ニシテ普佛戰爭トナツテ其事業ハ中止サレルコトニナツタノデアル

普佛戰爭終局ノ結果トシテ「フランクフォルト」ノ條約ガ締結サレタ後、佛蘭西ノ境遇ハ全ク一變シテ仕舞ツタ、何シロ五十億「フラン」ト云フ償金ヲヤラネバナラヌ必要ニ迫ラレマシタカラ、一切ノ税ハ是ガ犧牲ニシナケレバナラヌ事ニナツタ、ソコデ關税モ保護主義ノ爲メニ輸入税ヲ課スルト云フノデナク、唯收入ヲ增加スル大必要ノ方カラシテ、各種ノ關税ヲ增加スルコトニナツタノデアリマス、ソレカラ其後ニ引續キマシテ保護主義ノチエールト云フ人ガ內閣ヲ組織スルヤウニナリ、此制度ハ逆戾リヲシテ千八百七十二年ニナツテハ又外國製造ノ船ニ向ツテ輸入税ヲ高クスルヤウニナツタ、即チ外國製造船ノ輸入税ハ一噸ニ就テ、木製帆船ハ四十「フラン」、鐵木交造帆船ハ五十「フラン」鐵製帆船ハ六十「フラン」デアリマス、又汽船ニ付テハ右ノ外機關ノ輸入税トシテ百「キログラム」ニ付テ二十「フラン」ヲ加ヘルト云フコトデアリマシタ、ソレカラ船體ノミノ輸入税ハ一噸ニ付テ木製ガ三十「フラン」、木鐵交造四十「フラン」、鐵製五十「フラン」ト云フコトニナツタノデアリマス、所ガ是ハ其當時墺地利ノ條約ニ一噸二「フラン」デ輸入ガ出來ルト云フ規定ガアツタモノデスカラ、之ニ抵觸スルト云フコトカラシテ、外國ガ異議ヲ唱ヘテ法律ヲ發布シテモ施行スルコトガ出來ヌト云フ關係カラ、結局輸入税ハ前ノ通リ一噸二「フラン」造船材料ノ輸入ハ輸入後一箇年內デ使用スルト云フ條件ヲ以テ無税トスルト云フ規定

ハ千八百八十一年マテ繼續シテ來タノデアリマス、此千八百八十一年ト云フ年ハ佛蘭西ノ造船及航海事業ニ就テ非常ナ大段落ノ付クベキ彼ノ有名ナ航海造船ノ奬勵ニ關スル法律ガ發布サレタノデアリマス

一體私ノ考ハ是カラ奬勵法ノコトニ立入ッテ其變遷カラ現今ノ有樣ヲ述ベマシテ、之ヲ獨逸ニ比ベ日本ニ比ベテ研究シテ見タイト云フ考デアリマシタガ時間ガアリマセヌカラ詳シクハ述ベマセヌガ、詰リ八十一年ニ奬勵法ガ出テ十年バカリ行ハレテ九十三年ニ第二ノ奬勵法ガ出テ、千九百二年ニ第三ノ奬勵法ガ出タ、斯ウ云フ順序ニナッテ目下ソレガ行ハレテ居ル、其規則ノ結果トシテ航海造船ノ各當業者ノ衝突各法律ノ得失ダノ其成績ノコトニ至リマスレバ、多少面白イ話モ出來マスケレドモ、要スルニ歷史上佛蘭西ノ有樣ヲ見テチヨット目ニ立ツ事柄ハ、ドウモ定見ガ無イヤウニ思ハレル、朝令暮改ト云フヤウナ事ヲ始終繰リ返シテ居ルト云フコト、、モウ一ツ船ノ奬勵等ノコトハ是ハ畢竟法律家ガ考ヘテ自分ノ理想デ斯ウシテ見ヤウ、ア、シテ見ヤウト思ヒ過ギルノデハ無イカト感ジラレマス、デ佛蘭西ノ今ノ奬勵法ノ規定デモサウデアリマスガ、船ノ見方ガ一種妙ナ風ニ見テ居ル、船ヲ一ノ目的物ノ如クニ觀察シテ居ルノガ根本ノ誤リデハ無イカト思ハレル、船ハ商業トカ貿易トカノ道具デアッテ、船ガ獨立シテ生レ獨立シテ生長スルモノデハ無カラウト思フ、即チ船ノ必要ノ理由ハ他ニアッテ、航海トカ商工業ノ發達トカ云フコトガ無ケレバ船ハ要ラナイ譯デアリマスカラ、ドウシテモ其方ノ本ニ水ヲヤラナケレバ末ノ花ハ開カヌコトデハナイカ、佛蘭西デハ船ヲ見テ船ハ造リサヘスレバ出來ル、動カシサヘスレバ動カスコトニナルゾト云フ筆法デアルガ、船ハ夫レ自ラデ動クモノデアルト云フ考ハ經濟上カラ見テドウ云フモノデアラウカト云フ感ジヲ起シマスガ、ソレ等モ航海奬勵法ノ研究ト併セテ研究シテ見タラ面白イ事デアラウト思ヒマスガ、今日ハ追々遲クナリマシタカラ是デ御免ヲ蒙リマス、誠ニ順序モゴザイマセヌ話ニ長々御清聽ヲ煩ハシマシタノハ謹テ謝スル所デアリマス

寄稿

THE REACTION AND EFFICIENCY OF THE SCREW PROPELLER.

by

Y. Wadagaki, Esq., Member.

Fig. (1).

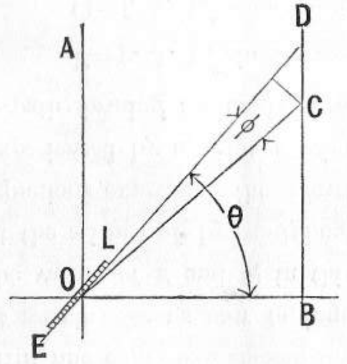


Fig. 1 is a diagram showng the geometry of an element of the screw propeller. OA represents the centre line of the shaft, EL the cross section of one of the blades, when in its vertical position.

OB is the developed circumference of the circle described by the elment EL in one revolution of the screw.

BD stands for the pitch of the screw while BC represents the actual advance made by the screw in one complete revolution through water, so that their difference corresponding to the distance CD will be the amount of slip. The angles BOD and COD are respectively called the pitch and the slip angles.

To consider the system of forces acting on an elementary area such as EL, let

R = Radial distance of the element from the shaft centre in feet.

D = Diameter of the circle described by the element in the rotation of the screw in feet, so that D = 2R.

C = Pitch of the screw in feet.

r = Pitch ratio $= \frac{C}{D}$

S = Slip ratio $= \frac{CD}{BD}$

θ = Pitch angle.

ϕ = Slip angle.

A = Area of the element in square feet.

N = Number of revolutions of screw per minute.

V = Speed of net axial advance of the element in feet per minute.

P = Normal pressure on the elementary area in lbs. per sq. ft.

Q = Tangential resistance in lbs.

T = Axial thrust in lbs.

F = Transverse component of the normal and tangential resistances in lbs.

Now without making any assumption as to the exact laws according to which the blades will be resisted in its motion through water, the fundamental principles of the science of forces lead us directly to the equations

$$T = P.\cos\theta - Q.\sin\theta$$

$$F = P.\sin\theta + Q.\cos\theta$$

$$\text{Useful work} = V.\,T = C.\,N.\,(1-S)(P.\cos\theta - Q.\sin\theta)$$

$$\text{Total work} = 2.\,\pi.\,R.\,N.\,(P.\sin\theta + Q.\cos\theta)$$

The efficiency is then

$$E = \frac{\text{Useful Work}}{\text{Total Work}} = \frac{r}{\pi}(1-S)\left(\frac{P.\cos\theta - Q.\sin\theta}{P.\sin\theta + Q.\cos\theta}\right)$$

But, since, $\tan\theta = \frac{r}{\pi}$

we get

$$E=(1-S)\left\{\frac{1-\frac{r.\,Q}{\pi.\,P}}{1+\frac{\pi.\,Q}{r.\,P}}\right\}\cdots\cdots\cdots(1)$$

From this equation it is easy to see that for a screw of given ratio of pitch to diameter, working with a given rate of slip per cent, the efficiency solely depends on the ratio existing between the normal pressure P and the tangential resistance Q. The importance of using screws of thin blades with fine edges and smooth surfaces is here apparent without any comment. It remains for us now to inquire about the laws of nature controlling the values of P and Q in this equation. With our present knowledge of the science of hydro-dynamics, we may take it for granted that the equations expressing the normal pressure and the tangential resistance experienced by a plane moving through the water with any speed V_1 on a path forming the angle ϕ with it, are of the forms

$$P=p.\,A.\,V_1^{x}\sin\phi\cdots\cdots\cdots(2)$$

$$Q=f.\,A.\,V_1^{z}\cdots\cdots\cdots(3)$$

where p and f are respectively the pressure and friction per unit of surface, and A the area of the plane.

We get then,

$$\frac{Q}{P}=\frac{f.\,A.\,V_1^{z}}{p.\,A.\,V_1^{x}.\,\sin\phi}=\frac{f}{p.\,V_1^{(x-z)}.\,\sin\phi}$$

Reverting to fig. 1, we also see that

$$OC.\ \sin\phi=CD.\ \cos\theta,$$

Therefore,

$$\sin\phi=\frac{\pi.\,r.\,S.}{\sqrt{\pi^2+r^2}.\ \sqrt{\pi^2+r^2(1-S)^2}}$$

Hence

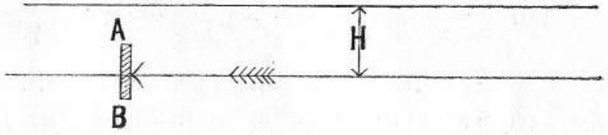
$$\frac{Q}{P}=\frac{f.\ \sqrt{\pi^2+r^2}.\ \sqrt{\pi^2+r^2(1-S)^2}}{p.\,\pi.\,r.\,S.\ V_1^{(x-z)}}\ .\cdots\cdots\cdots(4)$$

If the two exponents of the speed, x and z, were equal to each other, then, the efficiency of the screw with a given ratio of pitch to diameter and working with a given rate of slip would remain constant at all speeds. As a matter of fact, however, they are not quite equal. A generally accepted value of the exponent x is 2. On the authority of the late Dr. Froude, we may take the value of the exponent z as a quantity varying from 1. 85 to 1. 9 according to the nature of the surface. If that is the case, then, the ratio between the normal pressure P and the tangential resistance Q, as given in equation (4), can not remain constant for varying speeds, other things being equal. The efficiency of the screw must therefore be affected to some extent by the variation of the working speed, the general tendency being a slight increase in efficiency with increase in speed, always supposing the screw to be worked at the same slip ratio.

Thus far, we have confined our attention to the action of one small unit of the screw surface. In view of the varying radial distances and obliquities of the elementary surfaces at different points, the particles of water can not be supposed to move all in parallel directions. This peculiarity of the screw surface giving rise to mutual inter-ference of water particles acted upon at different points, coupled with the possible inter-ference of the action of one blade with another, not to mention the influence due to the complicated phenomena of wake current, leaves us almost no hope to get at the true aggregate effect of the whole screw, by means of mathematical integration.

Equation (4) has been deduced on the hyphothesis that the motion of the elementary surface of the screw through the water can take place without causing any disturbance on the surface of the latter which will necessitate the expenditure of a certain amount of energy. But this condition can hardly be fulfilled in the actual working condition of real screw propellers.

Fig. (2)



In fig. (2), let AB be an indefinitely thin plane board of unit area, completely immersed in water at a mean depth of H feet below the surface. When the board is at rest, the pressure acting on one side oj it is of course equal and opposite to that acting on the other side. Its amount my be expressed by the equation,

$$P = Po + H. W.$$

Where Po is the pressure of atmosphere in lbs. and W the weight of unit volume of water in lbs. Now suppose this board to be moved in any direction at a moderate speed of V feet per second. The pressure on the front face and the back of the board will then respectively become.

$$P_1 = P_0 + H. W + \frac{a_1 b_1 V^2}{2g}. W \cdots\cdots\cdots\cdots (5)$$

$$P_2 = P_0 + H. W - \frac{a_2 b_2 V^2}{2g}. W \cdots\cdots\cdots\cdots (6)$$

where a_1 and a_2 are certain coefficients depending on the viscosity of water in which the board is immersed, and b_1 and b_2 some functions of the angle made between the plane of the board and its line of motion. The resultant effective pressure on the board would therefore be

$$P_3 = P_1 - P_2 = \frac{(a_1 b_1 + a_2 b_2) V^2}{2g}. W \cdots\cdots\cdots\cdots (7)$$

We thus see that the head resistance to the motion of plane area, deeply immersed in water and moving in any direction, relatively to its own surface, is independent of the depth of immersion. This statement, however, must be received with a certain qualification, for it can hold good only within the limit of speed which does not produce any disturbance on the surface of water. With the increase of speed, the pressure on the back of the supposed plane is being diminished until, at last, its amount is reduced to nothing, when

$$P_0 + H. W = \frac{a_2 b_2 V^2}{2g}. W \cdots\cdots\cdots\cdots (8)$$

Beyond the limiting speed defined by this equation, the back side of the plane can make no further contribution to the increase of effective pressure on the plane. That is to say, after this limit has been reached, the demand for any increase of the effective pressure can only be responded to by a further accumulation of pressure in front of the plane. To the occurrence of this peculiar phenomenon in the operation of screw propellers, the name of the "Cavitation" has been given.

After this incidence has taken place, the equation (7) must be converted into the form

$$P_3 = P_0 + H. W + \frac{a_1 b_1 v^2}{2g}. W \cdots\cdots\cdots\cdots (9)$$

At this stage of our investigation, it becomes necessary to examine what is the precise nature of the coefficient b_1 in above equations. Reliable informations in this respect are much wanted; for, although numerous experiments had been made by Colonel Beaufoy, M. Joëssel, and others, the results obtained by them are limited to low speeds. But whatever may be the absolute values of b_1 at moderate speeds, one thing is certain that it can not remain unchanged at very high speeds. When a certain speed is reached the pressure due to the velocity of the moving board becomes so high as to exceed the sum of the pressure of atmosphere and the pressure due to the depth of immersion. At this point the upper surface of water commences to feel the influence of the accumulated pressure on the front face of the moving plane. If the speed of the moving board be increased still further, the water will have simply to be heaped up in masses above its original level and then pass away in the shape of waves, only to be succeeded by others. This means, of course, the expenditure of a certain amount of power and can only be accomplished at the expense of pressure in front of the moving board. In other words, the value of the coefficient b_1 in above equations has to be decreased beyond a critical speed defined by the equation

$$P_0 + H.\ W = \frac{a_1 b_1 V^2}{2g}.\ W \text{ ......(10)}$$

From what we have seen already, it will be evident that screw propellers with a given ratio of pitch to diameter and working with a given slip ratio, can not maintain a constant efficienny for all speeds; for, when the speed exceeds the limit indicated above, the depth of immersion becomes a factor that must not be neglected. Although, from the nature of equation (1), it has often been inferred that for every different ratio of pitch to diameter, in any type of screw, there is a particular slip ratio at which, and at which only, maximum efficiency can be obtained, this particular slip ratio, it may be asserted, is a quantity depending on the type of screw as well as the speed at which it has to be worked. An important point that must be borne in mind in this respect is the influence of surface ratio on slip ratio, which has a general tendency of modifying the effective pressure per unit area of blade surfaces. Take for example two screws of an equal diameter and pitch, designated A and B respectively, and working at the same slip ratio. Suppose A screw to have wider blades than B screw. Then the blades of A screw will be operating in contact with the same particles of water for a longer period than those of B screw. Consequently, the water on leaving the following edge of A screw will have more velocity imparted on it than the water that has been discharged from B screw, although to all appearances, these two screws are working at the same slip ratio. Conversely, if the water upon being discharged from these two screws get the same amount of acceleration, the wider blades would necessarily show a less amount of slip ratio than the narrower blades. In other words, the amount of sternward acceleration imparted to the water is proportional not merely to the simple slip ratio in the usual sense of the term employed, but, in the case of screws of widely different proportions, to a compound ratio, expressed by

$$S' = \text{Slip ratio} \times \left(\frac{\text{mean length of screw}}{\text{pitch}} \right)^x$$

where x is an exponent to be determined by experiments.

Let $S = \text{Slip ratio}$.

L = Mean axial length of screw.

c = Pitch of screw.

r = Pitch ratio.

a = Surface ratio.

θ = Pitch angle at periphery of screw.

n = Number of blades on each screw.

Neglecting the existence of the central boss, we have, for an indefinitely short length of screw,

$$\frac{\text{Expanded area of blades}}{\text{Projected area of blades}}=\frac{1+\sin\theta}{\cos\theta}$$

Therefore, for screws with blade area similarly distributed radially, we have

$$a=\frac{\text{Expanded area of blades}}{\text{Disc area}}$$

$$=\frac{n.\ L.(1+\sin\theta)}{c.\ \cos\theta},\quad \text{approximately.}$$

Hence

$$\frac{L}{c}=\frac{a.\ \cos\theta}{n\,(1+\sin\theta)}$$

$$S'=S\left\{\frac{\alpha.\ \cos\theta}{n\,(1+\sin\theta)}\right\}^{x}=S\left\{\frac{\alpha.\ \pi}{n\,(r+\sqrt{\pi^2+r^2})}\right\}^{x}\cdots\cdots\cdots(11)$$

This is then the true measure of effective slip, if all the acceleration of water were to take place, only during the period actually required by it in passing through the screw. As Mr. Barnaby says in one of his papers, however, "the water is influenced by a screw before it is actually in contact with it, and will run toward the screw in virtue of a defect of pressure, or suction produced forward of it. The action of the propeller on the water is principally to accumulate pressure, which has the effect of increasing the velocity of race after contact with the blade surfaces has ceased." Mr. Barnaby further says that "the length of the blades may be supposed to be so small that no appreciable change of velocity can take place in the stream while actually passing through them; but on leaving them the speed of the stream is further accelerated up to the final speed."

That there is a certain amount of truth in this statement is unquestioned; but, surely, it can not be pushed so far forward as to ignore the influence of the surface ratio on the final efficiency of the screw, especially for very high speeds. We have as yet no authentic information based upon experiments as to the relative amounts of acceleration imparted on the water at the different points of its passage. At all events, however, it is certain that there will be some acceleration, while the water is actually passing through the screw, and that its amount will vary with the area of the blades as well as the speed at which the screw is being worked. That being the case, equation (11) may be found useful, when judiciously employed in the study of mutual relations between the surface ratio and the efficiency of the screw. The bearing of this equation on the performance of the screw may be interpreted as follows:—

(a) For any given efficiency, an increase of pitch ratio is attended with an increase in slip ratio, the surface ratio being supposed to remain the same.

(b) To maintain a constant efficiency with different slip ratios, the surface ratio must be modified to suit the slip ratios, supposing the pitch ratio to remain unaltered.

(c) With an increase in pitch ratio, the surface ratio may be so increased as to maintain the slip ratio unchanged.

(d) For any given design of the screw, the slip ratio is proportional to the total amount of acceleration which the water has finally received on leaving the limit of action of screw blades.

(e) It is possible to change the pitch, slip, and surface ratios altogether, and yet maintain the same efficiency, when these changes are made in such a way as to keep the total amount of power expended in the acceleration and friction of water, unaltered, for any given amount of useful work performed.

(f) There is no material difference in the maximum obtainable efficiency between screws of different pitch ratios, when their surface ratios and slip ratios are such as would secure the best possible combination in each case.

We have arrived at these conclusions by the consideration of the manner in which the power is expended to overcome the head resistance and the surface friction of the screw blades.

Enough has been said as to the mode of fluctuation which takes place in the coefficient of direct pressure for varying speeds.

Now it can not be doubted that there will also be a similar fluctuation in the coefficient of friction of the screw blades for different rates of speeds. But, as to how much, experimental data have not as yet been obtained.

That the frictional resistance experienced by a plane board moving obliquely through water depends upon the angle of obliquity is well known. The flow of water is found to separate into two branches at some point on the front face of the moving blade to go round its opposite edges. The greater the angle of obliquity, the nearer the point of separation toward the centre of the blade; and the position of this point of separation is a factor which determines the net amount of friction.

In the case of the propeller blades the virtual angle of obliquity depends not only on the pitch angle of the screw, but also on the amount of slip; for they have to work in the very midst of water which they have already set in motion. It follows therefore that the coefficient of friction for propeller blades can not remain unaltered when working at different rates of slip. When the working speed of the screw becomes so high as to produce a partial "Cavitation" behind the blades the usually accepted law of frictional resistance can not be supposed to hold good any longer.

Abtruse arguments which are not supported by some undisputable evidence of facts are not acceptable to the inquisitive minds of the present day. It is therefore proposed in what follows to verify the truth of our contention by a number of actual examples ascertained on practical experiences. The simplest way to see whether the law of squares of speeds for the direct pressure and surface resistances of propeller blades can be maintained for a whole range of working speeds is to construct a diagram with the logarithms of the number of revolutions per minute and those of the mean effective pressure of steam per square inch of the piston area, as the co-ordinates of the curve for successive speeds. For this purpose, tables, (1) to (9), have been compiled from the data of progressive speed trials of the vessels, well known to the members of this Association; and fig. (3) is a diagram prepared from the informations contained in these tables. It will be observed that in no case the curve thus constructed remains perfectly straight. The main part of this irregularity is of course due to the irregular variation of the wave-making resistance on the part of the ship's hull, and the gradual change of the mechanical efficiency on the part of the engines, although there may also be more or less influence due to the fluctuation of the so called wake coefficients and thrust deduction. But whatever may be the change that takes place in the resistance of the ship with the variation in speeds, it will always cause a corresponding change in the pressure acting on the face of the propeller blades; and when the speed of the ship gets so high that its resistance for any further increase of speed increases by more than the squares of speeds, it is quite natural that the propeller blades would also feel the effect of the change of conditions and meet with the resistance more or less different from that indicated by the law of squares of revolutions per minute. The apparent disparity of results which we often meet with in practice in the performance of screw propellers is no doubt due to the adoption of usual rule based upon the law of squares of revolutions for all speeds, whereas, in truth, this law can not be extended beyond the limit which is associated with the occurrence of the phenomena of the "Cavitation" and surface disturbances. That being the case, it would appear to be well-nigh impossible to establish a general formula which can really express the true efficiency of any given screw for a very wide range of working speeds. If, however, we confine our attention within a narrow range of working speeds, the curves in fig. (3) may, without any serious error, be taken as being practically straight; and equation (1) may then be used to express the efficiency of the screw for those speeds, provided, of course, that we know the correct values of the cofficients of direct pressure and frictional resistance of the blades, appropriate to those speeds. Herein lies the great benefit that can be derived from a careful study of experimental results for screws of similar type and proportions, working under similar conditions. Thus, for screws of any given type working within a limit of speeds, sufficiently below the critical point which is associated with the occurrence of the phenomena of "Cavitation" and surface disturbances, it is not a very difficult matter to estimate a definite amount of real slip which would give the maximum efficiency for any fixed ratio of pitch to diameter, or having fixed upon a certain value of pitch ratio to correctly locate the standings of the screw with regard to its efficiency for different values of slip ratios. One of the most remarkable instances in the similarity of actions of similar screws is furnished by the comparison of the curves in fig. (3) for screws of the Japanese Cruiser "Suma" and the British Cruiser "Good Hope".

As will be seen in the diagram, these two curves are almost entirely parallel up to a certain point beyond which the "Good Hope" shows a marked tendency to deviate from its general course which it has followed up to this point. This is a striking evidence that some change has taken place in the condition in which the Good Hope's screws have been working and may naturally be attributed to the occurrence of the "Cavitation" and surface disturbances. That this is so has amply been proved by a greatly improved performance of her sister ship, the "Drake," where the blade area has been much increased to diminish the real slip ratio. This and many other examples generally point to the conclucion that the accepted theory of screw propulsion can remain true only within the limitation of speeds as has already been explained and when we confine ourselves to one particular ratio of blade surface to disc area. In other words, any formula for the efficiency of the screw propeller to be applicable generally under all circumstances, must contain some functions of surface ratio and the speed at which it has to be worked.

With these qualifications, however, the teachings of Froudes are as good to-day as when they were first taught, and it would prove both interesting and instructive to investigate what use we can make of these old-established doctrines of screw propulsion in their actual application to our present practice. According to Mr. Barnaby, the relation between the pitch ratios and corresponding slip ratios which would give the best results for a standard type of the screw is as follows:—

r	s %	r	% s	r	s %
0.8	15.55	1.4	19.5	2.0	22.9
0.9	16.22	1.5	20.1	2.1	23.5
1.0	16.88	1.6	20.7	2.2	24.0
1.1	17.55	1.7	21.3	2.3	24.5
1.2	18.2	1.8	21.8	2.4	25.0
1.3	18.8	1.9	22.4	2.5	25.4

Where r and s% respectively denote the pitch ratio and the corresponding slip, per cent, which would give the best results in combination. The above table may approximately be represented by the empirical formula

$$S = 1. - \frac{0.8312}{r^{0.1}} \quad \cdots\cdots\cdots\cdots (12)$$

which, when worked out, would give the following values:—

r	S %	r	S %
0.8	15.02	1.7	21.2
0.9	16.00	1.8	21.7
1.0	16.88	1.9	22.1
1.1	18.06	2.0	22.5
1.2	18.41	2.1	23.8
1.3	19.00	2.2	23.35
1.4	19.63	2.3	23.5
1.5	20.30	2.4	24.9
1.6	20.69	2.5	24.18
Average error			0.28

Let Ca and Cr denote the disc area constant and the revolution constant, then.

$$Ca = \frac{A.\,V^3}{IHP} \quad \cdots\cdots\cdots\cdots (13)$$

$$Cr = \frac{D.R}{V} \quad\text{..........}(14)$$

Where D = Diameter of screw in feet.

A = Disc area ef screw in square feet.

V = Speed of the ship in knots per hour.

R = Revolutions per minute.

IHP = Indicated horse power.

Mr. Barnaby has compiled a table from a complete sets of experiments made by Mr. R. E. Froude, showing the relation between the values of Ca and Cr which in various combinations would give varying efficiencies in the performance of the screw. On examination of this table, it becomes at once apparent that the disc area constant for any given efficiency varies as four-fifth power of the pitch ratio, other things being equal. In fact, this has been definitely stated in Mr. Froude' s paper of 1886. We have then

$$Ca = \text{constant} \times r^{0.8} \quad\text{..........}(15)$$

Now $Cr = \frac{D.R}{V}$

and $V = \frac{CR.(1-S)}{101.33}$

where C is the pitch of screw in feet.

Therefore

$$Cr = \frac{\text{constant}}{r(1-S)} \quad\text{..........}(16)$$

Eliminating the values of S between the equations (12) and (16), we have

$$Cr = \frac{\text{constant}}{r^{0.9}} \quad\text{..........}(17)$$

That is to say, for any given efficiency of the screw, the revolution constant is inversely prportional to nine-tenth power of the pich ratio, other things being equal.

Eliminating the values of r from equations (15) and (17), we get for any givn efficiency of the screw, the following relations :—

$$Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}} = \text{Constant} \quad\text{..........}(18)$$

Working out this formula with numerical values of Ca and Cr given in Barnaby's Table we get for any ratio of pitch to diameter the following results :—

Abscissa value.	Efficiency %	$Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$
5	63	3. 66
7	67	3. 49
9	69	3. 36
11	69	3, 24
13	68	3. 15
15	66	3. 06
17	63	2. 98

Fig. (4) is at once a simple and convenient diagram giving the efficiency of the screw for successive values of $Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$, which is applicable to any ratio of pitch to diameter. Equation (18) enables us to locate in the curve of efficiency the position occupied by any given screw when its trial results are known. The standing positions in the curve of efficiency of screw propellers of some of the vessels belonging to the Imperial Japanese Navy have thus been plotted on fig. (4). From equation (18) and the diagram fig. (4) it is easy to find the necessary working condition required in order to secure the maximum efficiency. According to the indication of the diagram, we may take the following equations as the essential conditions to be fulfilled in order to get the best result :—

$$\frac{Ca}{r^{0,}} = \text{any value between 184 and 251} \cdots\cdots (19)$$

$$Cr \times r^{.9} = \text{any value between 115 an1 109} \cdots\cdots (20)$$

$$Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}} = \text{any value between 3.24 and 3.36} \cdots\cdots (21)$$

The curve of efficiency in fig. (4) is a slightly distorted parabola within the range of efficiency there mentioned. Taking the point of maximum efficiency as the apex of a parabola, we may represent this curve by means of an equation of the form

$$(Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}} - 3.31)^2 = \frac{(69 - E)}{50}$$

where E is the efficiency of the screw per cent. We have then,

$$E = 69 - 50(Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}} - 3.31)^2 \quad \cdots\cdots (22)$$

Working out this formula with the figures given in Barnaby's Table, we get for any ratio of pitch to dameter the following result :—

Abscissa value.	Efficiency %	$Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$
5	62.88	3.66
7	67.38	3.49
9	68.88	3.36
11	68.76	3.24
13	67.72	3.15
15	65.88	3.06
17	63.60	2.98

Which gives the numerical values of the efficiencies per cent little different from those mentioned in Barnaby's Table.

The equation (18) is an equation for a curve of hyperbola, so that the relations between the disc area constant Ca and the revolution constant Cr for any given efficiency can be represented graphically on a system of co-ordinates with $Ca^{\frac{1}{8}}$ and $Cr^{\frac{1}{9}}$ as axes of X and Y, which is applicable to any ratio of the pitch to diameter of the screw.

Froud's experiments from which these important results have been deduced were made at a moderate speed of about 2 knots per hour and with small models of screws having a fixed ratio between the blade surface and disc area. Therefore in the application of these formulae to the design of high speed screws, some discretion must be exercised in order to make a sufficient provision for the prevention of the loss due to the occurrence of the "Cavitation" and surface disturbances. The values of constants $Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$ calculated from the data of progressive speed trials and mentioned in annexed tables. (10) to (19), plainly show the influence of the surface ratio on the efficiency of the screw. Picking up the values of the constants $Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$ for maximum speeds (A) and the speeds (B) corresponding to maximum efficiency, we find the following relations:—

Names of ships.	Surface ratio.	Value of $Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}}$ at	
		(A) speed	(B) speed
Drake	0. 370	3. 316	3. 416
Good Hope	0. 267	3. 294	3. 359
Shikishima	0. 396	3. 250	3. 318
Asahi	0. 340	3. 211	
Mikasa	0. 380	3. 235	
Izumo	0. 396	3. 345	
Yoshino	0. 370	3. 281	3. 491
Chitose	0. 415	3. 279	3. 335
Naniwa	0. 364	3. 345	
Akitsushima	0. 398	3. 367	
Suma	0. 345	3. 268	3. 406
Akashi	0. 370	3 303	3. 420
Yayeyama	0. 415	3. 315	
Chihaya	0. 458	3. 228	3. 326
Harusame	0. 483	3. 432	
Murasame	0. 452	3. 380	
Asagir i	0. 540	3. 451	3. 529

Now, the two British cruisers, the Drake and the Good Hope, are ships of identical lines and displacements; and they have the screws of the same diameter and of approximately equal pitches. Our own battleships the Shikishima and the Mikasa, have screws of exactly the same pitch and diameter. The principal dimensions of the screws for the third cruisers, the Suma and the Akashi, are approximately equal except in the matter of surface ratios. So are also those of the screws of T. B. destroyers, the Murasame and the Harusame. In each case, one of the pair which is working with a greater blade surface, infallibly gets, a higher value in the constant $Ca^{\frac{1}{8}}\ Ca^{\frac{1}{9}}$ for any given speed. As this constant rapidly falls with the increase of slip, it becomes a matter of paramount importance to provide an ample blade surface in the case of screws intended for high speed.

Sometimes, screw propellers which plot pretty high in the curve of efficiency do not actually give a very satisfactory result as in the cases. of T. B. destroyer Murasame and the British cruiser Good Hope. This apparent anomaly is no doubt due in some measure too the influence of the wake current, following along the ship's stern. But it is equally, probable that the speed of the screws is getting too high for the amonnt of the blade surfaces provided, to enable them to work without producing the "Cavitation". The writer would therefore propose to use the following formula in the design of screw propellers intended to run at very high speeds

$$A^{\frac{1}{16}}\ Ca^{\frac{1}{8}}\ Cr^{\frac{1}{9}} = 3.15 \quad \cdots\cdots\cdots\cdots (23)$$

where A is the ratio of the total helicoidal surface to disc area of the screw

Table (1)　(T. B. Destroyr. Asagiri)

Revolution	IHP.	$\frac{\text{IHP}}{\text{R.}}$	log. R.	log. $\frac{\text{IHP}}{\text{R.}}$
145	313	2. 16	2. 1614	0. 33445
154	375	2. 43	2. 1875	0. 38561
165	459	2. 78	2. 2175	0. 44404
175	550	3. 14	2. 2436	0. 49693
190	663	3. 49	2. 2787	0. 54283
203	820	4. 02	2. 3075	0. 60423
217	980	4. 50	2. 3365	0. 65321
236	1240	5. 25	2. 3729	0. 72016
255	1625	6. 37	2. 4065	0. 80414
272	2125	7. 80	2. 4346	0. 89209
287	2600	9. 05	2. 4579	0. 95665
301	3010	10. 00	2. 4786	1. 00000
314	3360	10. 65	2. 4970	1. 02735
326	3675	11. 25	2. 5132	1. 05065
337	3960	11. 75	2. 5276	1. 07004
348	4250	12. 2	2. 5416	1. 08636
358	4543	12. 65	2. 5539	1. 10208
367	4890	13. 3	2. 5647	1. 12385
376	5375	14. 3	2. 5752	1. 15534
385	6250	16. 25	2. 5855	1. 21086

Table (2)　(Torpedo Gun boat. Chihaya)

Revolution	IHP.	$\frac{\text{IHP}}{\text{R.}}$	log. R.	log. $\frac{\text{IHP}}{\text{R.}}$
98	480	4. 9	1. 9912	0. 6902
107	600	5. 61	2. 0294	0. 7490
117	800	6. 85	2. 0682	0. 8357
126	990	7. 85	2. 1004	0. 8949
136	1260	9. 25	2. 1335	0. 9661
145	1560	10. 7	2. 1614	1. 0294
155	1890	12. 2	2. 1903	1. 0864
165	2280	13. 8	2. 2175	1. 1399
175	2740	15. 6	2. 2430	1. 1931
186	3370	18. 1	2. 2695	1, 2577
198	4200	21. 1	2. 2967	1. 3243
213	5300	24. 8	2. 3284	1. 3945

Table (3) (Cruiser. Akashi)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
81	960	11.8	1.9085	1.07188
89	1300	14.6	1.9494	1.16435
97.5	1700	17.4	1.9890	1.24055
106	2200	20.7	2.0253	1.31597
114	2850	25.0	2.0569	1.39794
123	3700	30.0	2.0899	1.47712
131	4630	35.4	2.1173	1.54900
140	5670	40.6	2.1461	1.60853
148	6800	46.0	2.1703	1.66276
151.5	7400	49.0	2.1804	1.69020

Table (4) (Cruiser. Suma)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
45	200	4.45	1.6532	0.6484
50	230	4.6	1.6990	0.6628
55	320	5.82	1.7404	0.7649
60	395	6.6	1.7782	0.8195
65	480	7.39	1.8129	0.8686
70	604	8.65	1.8451	0.9370
75	722	9.61	1.8751	0.9827
80	870	10.86	1.9031	1.0354
85	1030	12.1	1.9294	1.0828
90	1250	13.9	1.9542	1.1430
95	1450	15.3	1.9777	1.1847
100	1700	17.0	2.0000	1.2304
105	1978	18.8	2.0212	1.2742
110	2360	21.5	2.0414	1.3324
115	2776	24.1	2.0607	1.3820
120	3200	26.7	2.0792	1.4265
125	3610	29.0	2.0969	1.4624
130	4075	31.4	2.1139	1.4969
135	4655	34.5	2.1303	1.5378
140	5160	36.8	2.1461	1.5658
142	5735	40.4	2.1523	1.6064

Table (5)　(Cruiser. Yoshino)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
82.5	1440	17.4	1.9165	1.24055
88	1750	19.8	1.9445	1.29667
93.8	2063	21.9	1.9722	1.3.044
99.3	2500	25.2	1.9969	1.40140
105	3100	29.6	2.0212	1.47129
111	3750	33.7	2.0453	1.52763
117.5	4595	39.1	2.0700	1.59218
123.8	5575	45.1	2.0927	1,65418
130.5	6780	51.9	2.1156	1.71517
138.5	8100	58.5	2.1414	1.76716
148.2	11630	78.8	2.1708	1,89653
163.2	15815	97.0	2.2127	1.98945

Table (6)　(Cruiser Chitose)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
94	3120	33.3	1.9731	1.5224
100	3500	35.0	2.0000	1.5441
106.5	4000	37.5	2.0273	1.5740
112	4550	40.6	2.0512	1.6085
118	5250	44.5	2.0719	1.6484
124.7	6150	49.2	2.0959	1.6920
132.2	7250	55.0	2.1212	1.7404
132.7	8700	62.1	2.1452	1.7931
147.7	10600	71.5	2.1605	1.8543
157.2	13000	83.0	2.1965	1.9191

Table (7) (Battle ship shikishima)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
45	875	18.4	1.6532	1.26482
51.5	1200	23.2	1.7118	1.36549
57.5	1565	27.2	1.7579	1.43457
64.4	2060	32	1.8089	1.50515
71	2680	37.8	1.8513	1.57749
79	3650	46.1	1.8976	1.6637
85	4690	55.2	1.9294	1.7419
91	6020	66.1	1.9590	1.8202
97.5	7750	79.4	1.9890	1.89982
99	8138	82.5	1.9956	1.91645
103.5	9500	92	2.0149	1.96379
109	11375	104.1	2.0374	2.017
114.4	132 0	115.3	2.0584	2.061
118	15188	129	2.0719	2.11059

Table (8) (British Cruiser Good Hope)

Revolution	IHP.	$\frac{IHP}{R}$	log. R.	log $\frac{IHP}{R.}$
51	2689	52.8	1.7076	1.7226
65.8	5096	77.4	1.8182	1.8887
77.5	7953	103	1.8893	2.0128
90.0	12108	134.2	1.9542	2.1271
99.8	16960	170	1.9991	2.2305
109.1	22478	206	2.0374	2.3139
126.2	31088	246	2.1011	2.3909

Table (9) (Brtiish Cruiser Drake)

Revolution	IHP.	$\frac{IHP}{R.}$	log. R.	log. $\frac{IHP}{R.}$
47	1685	35.9	1.67210	1.55509
64	4014	62.9	1.80618	1.79865
75.1	6520	87.0	1.87564	1.93952
87.6	9872	112.1	1.94250	2.04961
98.5	14801	146.0	1.99344	2,16435
111.5	22534	202 0	2.04728	2.30535
122.4	31409	257.0	2.08778	2.40993

Table (10) (T. B Destroyer Asagiri)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
12	145	315	424	85	3. 490
13	154	375	450	83	3. 507
14	165	459	460	82. 5	3. 514
15	175	550	471	81. 5	3. 519
16	189	663	476	82. 5	3. 529
17	203	820	462	84	3. 523
18	217	980	456	84. 5	3. 519
19	236	1240	425	86. 5	3. 498
20	255	1625	380	89	3. 460
21	272	2125	335	91	3. 414
22	287	2600	316	91	3. 390
23	301	3010	311	92	3. 387
24	314	3360	316	92	3. 394
25	326	3675	326	91	3. 403
26	337	3960	341	91	3. 422
27	348	4250	356	90. 5	3. 438
28	358	4543	371	90	3. 454
29	367	4890	383	89	3. 463
30	376	5375	385	88	3. 461
31	385	6250	366	87	3. 451

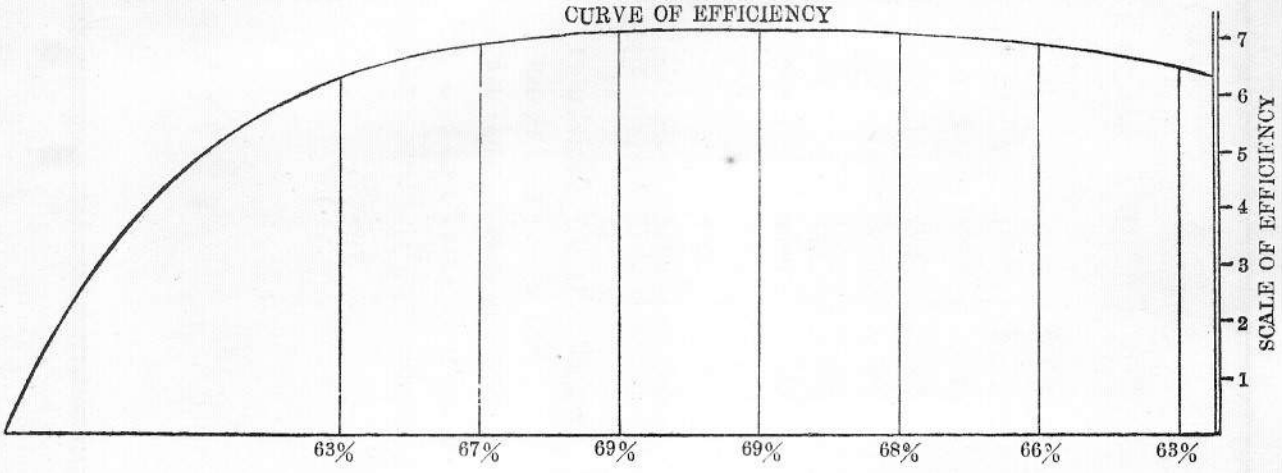
Twin screws, 7′–0″ diameter.
Pitch of screw = 9′–0″
Pitch ratio = 1. 29
Area of three blades = 20. 8 square ft.
Surface ratio = 54%

Table (11) (Torpedo Gun boat Chihaya)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
9	88	375	246	88	3. 272
10	98	480	265	88	3. 303
11	107	600	281	87. 5	3. 326
12	117	785	281	87. 5	3. 326
13	126	990	281	87. 5	3. 326
14	136	1260	276	87. 5	3. 318
15	145	1560	276	87	3. 316
16	155	1890	276	87	3. 316
17	165	2280	274	87	3. 313
18	175	2740	270	87	3. 307
19	186	3370	259	88	3. 294
20	198	4200	242	89	3. 270
21	213	5300	222	91	3. 243
21. 48	222	6016	210	93	3. 228

Twin screws, 9′–9″ diameter.
Pitch of screw = 12′–0″
Pitch ratio = 1. 33
Area of thse blades = 29 square ft.
Surface ratio = 45. 8% nearly

Mr. Barnaby's Table.



Pich-ratio	c_A	c_R	c_A	c_R	c_A	c_R	c_A	c_R	c_A	c_R	c_A	c_R	c_A	c_R
0.80	468	122	304	128	215	134	157	142	115	150	86	160	65	171
0.90	506	109	329	114	234	120	170	127	125	135	93	144	71	154
1.00	546	99	355	104	251	109	184	115	135	123	100	131	76	140
1.10	585	91	380	95	270	100	196	105	144	113	107	120	82	128
1.20	625	83	405	87	288	92	210	97	154	104	115	111	87	119
1.30	665	77	431	81	306	85	224	91	163	97	122	103	93	111
1.40	704	72	456	76	325	80	236	85	173	90	129	97	98	104
1.50	742	67	482	71	342	75	250	79	183	85	136	91	104	98
1.60	780	63	507	67	360	71	263	75	193	80	144	87	109	93
1.70	..	..	533	63	378	67	276	71	202	76	151	82	115	88
1.80	..	..	558	60	396	64	290	68	212	73	159	78	120	84
1.90	..	..	584	57	415	61	304	65	222	69	166	75	125	81
2.00	..	..	609	55	432	58	315	62	231	67	173	72	131	77
2.10	..	..	635	52	450	56	329	59	241	64	180	69	136	75
2·20	..	..	660	50	469	54	342	57	250	62	187	67	142	72
2.30	..	..	685	48	486	52	355	55	260	59	194	64	148	69
2.40	..	..	710	47	505	50	369	53	270	57	202	62	153	67
2.50	..	..	736	45	523	48	381	52	280	56	209	60	159	65
	5		7		9		11		13		15		17,	

Scale of Abscisa value.

$$\text{Disc-area} = C_A \times \frac{\text{I. H. P.}}{(\text{Speed in Knots})^3}. \qquad \text{Revolutins} = C_R \times \frac{\text{Speed in Knots}}{\text{Diameter in feet}}.$$

Table (12) (Cruiser Akashi)

Speed	Revolution	IHP.	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
11	81	960	336	92	3.420
12	89	1300	324	92.5	3.414
13	97.5	1700	314	93.5	3.397
14	106	2200	302	94.5	3.384
15	114	2850	287	94.5	3.363
16	123	3700	268	96	3.340
17	131	4630	256	96	3.321
18	140	5670	249	97	3.313
19	148	6800	245	97	3.307
19½	151.5	7400	243	97	3.303

Twin screws, 12.41 ft diameter.
Pitch of screw = 15.1 ft.
Pitch ratio = 1.21
Area of three blades = 45 square ft.
Surface ratio = 37% nearly.

Table (13) (Cruiser Suma)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
8	64	470	260	98.5	3.337
9	70	600	290	96	3.373
10	77	780	305	95	3.391
11	84	1000	316	94	3.402
12	91	1280	321	93.5	3.406
13	99	1640	320	94	3.407
14	107	2100	310	94	3.394
15	115	2770	290	94.5	3.367
16	125	3600	271	96.5	3.347
17	135	4600	254	98	3.325
17.33	142	5735	215	101	3.268

Twin screws, 12.3 ft diameter.
Pitch of screw = 15′−0″
Pitch ratio = 1.22
Area of three blades = 41 square ft.
Surface ratio = 34½%

Table (14) (Cruiser Yoshino)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
12	82. 5	1440	356	94. 5	3. 455
13	88	1750	373	93	3. 469
14	93. 8	2063	395	92	3. 489
15	99. 3	2500	400	91	3. 491
16	105	3100	393	90	3. 479
17	111	3750	389	90	3. 474
18	117. 5	4595	376	90	3. 460
19	123. 8	5575	365	89. 5	3. 445
20	130. 5	6780	350	89. 5	3. 427
21	138. 5	8100	340	90. 5	3. 427
22	148. 2	11630	271	92. 5	3. 331
23	163. 2	15815	229	97. 5	3. 281

Twin screws, 13′−9″ diameter,
Mean pitch of screw = 16′−8″
Mean pitch ratio = 1. 21
Area of three blades = 55 square ft
Surface ratio = 37%

Table (15) (Cruiser Chitose)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
14	94	3120	234	87	3. 252
15	100	3500	256	87	3. 285
16	106	4000	272	86	3. 230
17	112	4550	285	85	3. 321
18	118	5250	295	85	3. 335
19	124. 7	6150	295	85	3. 335
20	132. 2	7250	292	86	3. 335
21	139. 7	8700	282	86. 5	3. 223
22	147. 7	10600	266	87	3. 301
23	157. 2	1300	248	89	3. 281

Twin screws, 13 ft diameter.
Pitch of screw = 17′−6″ (mean)
Mean pitch ratio = 1. 35
Area of three blades = 55 square ft.
Surface ratio = $41\frac{1}{2}$% nearly.

Table (16) (Battle ship shiki shima)

Speed	Revolution	IHP	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
6	38. 75	680	145	110	3. 140
7	45	875	178	109	3. 219
8	51. 5	1200	194	109	3. 254
9	57. 5	1565	211	108	3, 284
10	64. 4	2060	221	110	3. 310
11	71	2680	225	110	3. 318
12	77. 5	3590	220	110	3. 308
13	80. 44	4690	213	105	3. 278
14	91	6020	208	110	3. 289
15	97. 5	7750	198	111	3. 268
16	103. 5	9500	196	110	3. 261
17	109	11375	196	109	3. 258
18	114. 4	13220	200	108	3. 263
19	119	15190	205	106	3. 266

Twin screws, 17′−0 diameter.
Pitch of screw = 18′−0″
Pitch ratio = 1. 06
Total blade area of one ecrew = 90 sq. ft.
Surface ratio = 39. 6% nearly

Table (17) (British Cruiser Good Hope)

Speed	Revolution	IHP	$\frac{2A.V^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
10. 6	51	2689	251	91. 5	3. 295
13. 63	65. 8	5096	282	92	3. 270
15. 91	77. 5	7953	286	93	3. 356
18. 1	90	12108	279	94. 5	3. 351
20. 58	99. 8	16960	290	92. 5	3. 359
22. 09	109. 1	22467	271	94	3. 337
23. 05	126. 2	31088	223	104. 2	3. 294

Twin screws, 19 ft diameter.
Pitch of screw = 22′−9½″
Pitch ratio = 1. 2
Total blade area of one screw = 76 square ft.
Surface ratio = 26,7% nearly

Table (18) (British Cruiser Drake)

Speed	Revolution	IHP	$\frac{2A.V^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_R^{\frac{1}{9}}$
9.52	47	1685	290	94	3.365
13.06	64	4014	314	93	3.395
15.41	75.1	6520	318	92.5	3.398
17.93	87.6	9872	330	93	3.416
20.03	98.5	14801	306	93.5	3.386
22.16	111.5	22534	270	95	3.339
24.11	122.4	31409	252	96.5	3.316

Twin screws, 19 ft diameter.

Pitch of screw = 23′=0″.

Pitch ratio = 1.21

Total blade area of one screw = 105 square ft.

Surface ratio = 37%

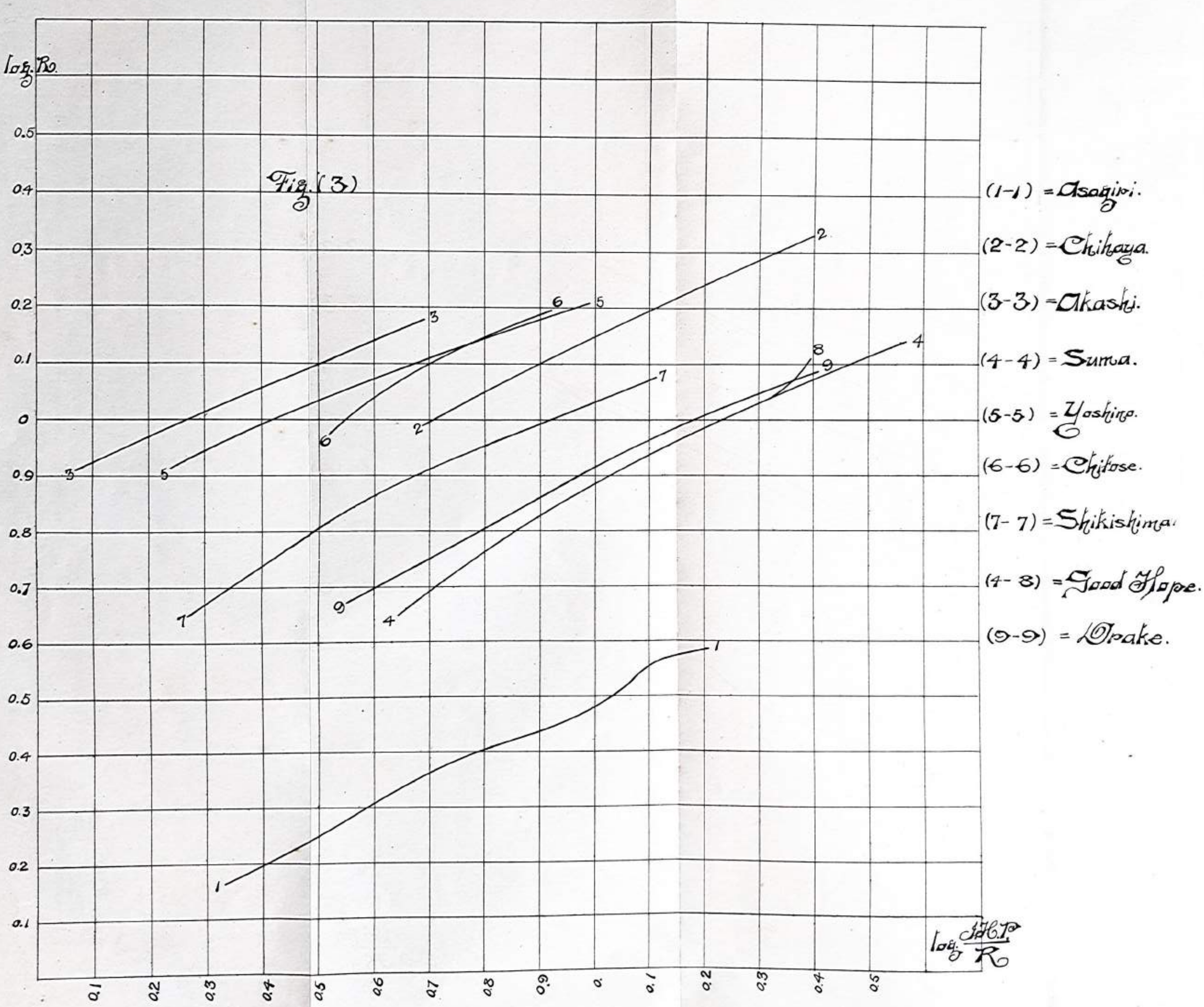
Table (19)

Performance of Screw propellers in some of the vessels of Imperial Japanese Navy at full power.

Names of Ships	Data of Propellers.									
	Diameter	Pitch	Blade area	Pitch ratio	Surface ratio	Revolution	Speed	Horse power	$\frac{2AV^3}{IHP}$	$\frac{R.D}{V}$	$C_A^{\frac{1}{8}} C_K^{\frac{1}{9}}$
Shikishima	17′−0″	18′−0″	90毋	1. 06	0. 396	118. 8	18. 59*	15145	193	108. 5	3. 250
Asahi	17′−9″	20′−0″	84	1. 13	0. 34	108 4	18. 24	16335	182	104.	3. 211
Mikasa	17′−0″	18′−0″	86	1. 06	0. 38	124. 4	18. 5	16548	174	114. 5	3. 235
Izumo	15′−0″	15′−6″	70	1. 03	0. 396	161.	22	15700	240	110.	3. 345
Yoshino	13′−9″	16′−8″	55	1. 21	0. 37	163. 2	23	15815	229	97. 5	3. 281
Chitose	13′−0″	17′−6″	55	1. 35	0. 415	154. 4	22. 7	12500	248	88. 5	3 .279
Naniwa	14′−0″	18′−0″	56	1. 28	0 364	124. 2	18. 72	7233	279	93.	3. 345
Akitsusu	13′−6″	17′−6″	57	1. 3	0. 398	103.	16. 7	4257	312	87.	3. 367
Suma	12′. 3	15′−0″	41	1. 22	0. 345	142.	17. 33	5735	215	101.	3. 268
Akashi	12′, 41	15′. 1	45	1. 21	0. 37	151. 5	19. 5	7390	243	97.	3. 303
Yayeyama	10′−6″	16′−0″	36	1. 52	0. 416	172.	20. 75	5630	275	87.	3. 315
Chihaya	9′−0″	12′−0″	29	1. 33	0. 458	222.	21. 48	6016	210	93.	3. 228
Harusame	7′−0″	9′−0″	18. 6	1. 29	0. 483	370.	28. 95	5250	356	89.	3. 432
Murasame	7′−0″	8′−6″	17. 4	1. 21	0. 452	377. 4	27. 4	5373	295	96.	3. 380

* This is the speed actually oblained by Shikishima, whereas the figures given in table (16) have been taken from the curve of progressive speeds, drawn through the average points.

Fig. (3)


log. Ro.
0.5
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0.2
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0.1
0.2
0.3
0.4
0.5
log. I.H.P./R
1
1
2
2
3
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4
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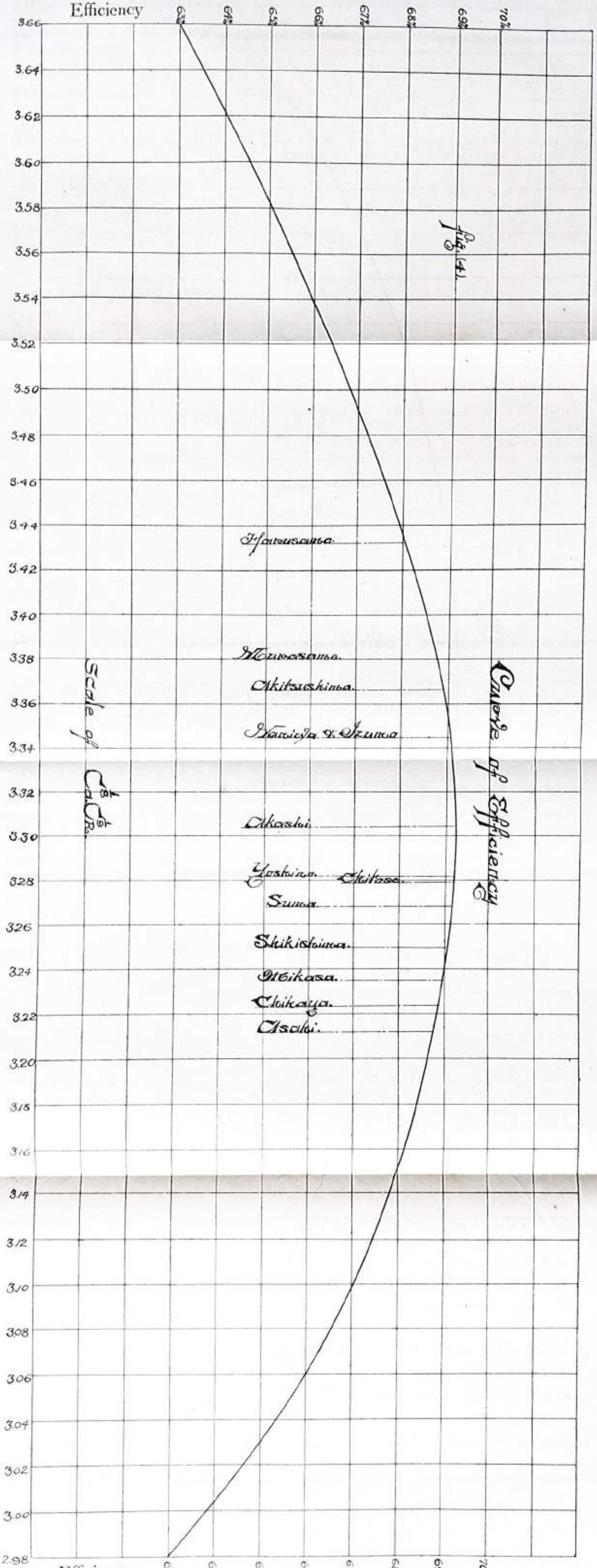
5
6
6
7
7
8
9
9
(1-1) = Asagiri.
(2-2) = Chihaya.
(3-3) = Akashi.
(4-4) = Suma.
(5-5) = Yoshino.
(6-6) = Chitose.
(7-7) = Shikishima.
(4-8) = Good Hope.
(9-9) = Drake.


Efficiency
63% 64% 65% 66% 67% 68% 69% 70%
3.66 3.64 3.62 3.60 3.58 3.56 3.54 3.52 3.50 3.48 3.46 3.44 3.42 3.40 3.38 3.36 3.34 3.32 3.30 3.28 3.26 3.24 3.22 3.20 3.18 3.16 3.14 3.12 3.10 3.08 3.06 3.04 3.02 3.00 2.98
Fig. (4).
Harusame
Murasame.
Akitsushima.
Naniwa & Izumo
Akashi
Yoshino. Chitose.
Suma
Shikishima.
Mikasa.
Chihaya.
Asahi.
Curve of Efficiency
Scale of $C_a^{\frac{1}{8}} C_{R_2}^{\frac{1}{9}}$
Efficiency
63% 64% 65% 66% 67% 68% 69% 70%]

SIGNIFICANT FIGURES IN NUMERICAL CALCULATIONS.

By S. Yokota, Esq., Member.

There is nothing more important for an engineer than to make his design successful, and this end is always attained at by the aid of accurate and reliable numerical calculations. This is why so many engineers pay special attentions to them and contrive several methods of minimizing their errors and mistakes.

But it is sometimes noticed in numerical calculations that tremendous number of figures is worked out, notwithstanding the significant figures of the same must be only the first few. Thus, for example, in the process of finding a metacentric height often ten or even more figures are calculated for the moment of inertia of a water-plane about an axis, in spite of the fact that only the first few figures are significant even if we neglect the errors due to Simpson's rules.

Now, the superfluous calculations of this kind are not only meaningless and waste of time but also increase chances of mistakes due to mental confusion. Nevertheless, on the other hand, it is absolutely not good to cut away significant figures too boldly for the simple reason of simplifying calculations. In this case it is better to start with less figures from the beginning to obtain a required degree of accuracy in the result.

The usual rule followed by physicists and engineers is to calculate up to about one-tenth of the corresponding error.

It is for this reason that somtimes even a length of several hundred miles is neglected as small while even a fraction of a microm is retained as large in another case.

The following is one article in my lecture on ship-calculation in the College, and is here reproduced in order partly to show how errors stand in numerical calculations for those who perchance neglected to pay attentions to this subject and partly to fill my part as a member of this society.

Let a and a' be two numbers, and ε and ε' the corresponding errors. For example, if we measure an ordinate from a quarter inch scale sheer draught and its length is $10{\cdot}8$ feet, there is a maximum error of somewhat $0{\cdot}05$ of a foot, so that the number is $10{\cdot}8$ and the corresponding error is $0{\cdot}05$.

We will see how error stands after each arithmetical operation.

(1) Addition.

$$(a \pm \varepsilon) + (a' \pm \varepsilon') = (a + a') \pm (\varepsilon + \varepsilon').$$

Example :

$$(10{\cdot}8 \pm 0{\cdot}05) + (11{\cdot}0 \pm 0{\cdot}05) = 21{\cdot}8 \pm 0{\cdot}1.$$

$$\therefore \quad 10{\cdot}8 + 11{\cdot}0 \doteqdot 21{\cdot}8.$$

(2) Subtraction.

$(a \pm \varepsilon) - (a' \pm \varepsilon') = (a - a') \pm (\varepsilon + \varepsilon')$, since both ε and ε' may have positive as well as negative values.

Example :

$$(18{\cdot}2 \pm 0{\cdot}05) - (10{\cdot}1 \pm 0{\cdot}05) = 8{\cdot}1 \pm 0{\cdot}1.$$

$$\therefore \quad 18{\cdot}2 - 10{\cdot}1 \doteqdot 8{\cdot}1.$$

(3) Multiplication.

$(a \pm \varepsilon) \times (a' \pm \varepsilon') = aa' \pm (\varepsilon a' + \varepsilon' a) + \varepsilon\varepsilon'$, since the probable error is larger when ε and ε' have the same sign than otherwise.

Example:

$$(10{\cdot}5 \pm 0{\cdot}05) \times (18{\cdot}2 \pm 0{\cdot}05) = 191{\cdot}10 \pm 1{\cdot}435 + 0{\cdot}0025.$$

$$\therefore \quad 10{\cdot}5 \times 18{\cdot}2 \doteqdot 191.$$

(4) Division.

$$\frac{a \pm \varepsilon}{a' \pm \varepsilon'} = \frac{a}{a'} \pm \left(\frac{\varepsilon}{a'} + \frac{\varepsilon' a}{a'^2}\right) + \cdots\cdots\cdots.$$

Example:

$$\frac{32{\cdot}4 \pm 0{\cdot}05}{26{\cdot}7 \pm 0{\cdot}05} = \frac{32{\cdot}4}{26{\cdot}7} \pm \left(\frac{0{\cdot}05}{26{\cdot}7} + \frac{0{\cdot}05 \times 32{\cdot}4}{26{\cdot}7^2}\right) + \cdots\cdots\cdots$$
$$= 1{\cdot}21348 \quad \pm (0{\cdot}00187\cdots + 0{\cdot}00227\cdots) + \cdots\cdots\cdots$$
$$= 1{\cdot}21348 \cdots \pm 0{\cdot}00414\cdots + \cdots\cdots\cdots.$$

$$\therefore \quad \frac{32{\cdot}4}{26{\cdot}7} \doteqdot 1{\cdot}213.$$

(5) Squaring.

$$(a \pm \varepsilon)^2 = a^2 \pm 2\varepsilon a + \varepsilon^2.$$

Example:

$$(45{\cdot}2 \pm 0{\cdot}05)^2 = 2043{\cdot}04 \pm 2 \times 0{\cdot}05 \times 45{\cdot}2 + 0{\cdot}0025$$
$$= 2043{\cdot}04 \pm 4{\cdot}52 + 0{\cdot}0025.$$

$$\therefore \quad \overline{45{\cdot}2}^{\,2} \doteqdot 2043.$$

(6) Cubing.

$$(a \pm \varepsilon)^3 = a^3 \pm 3\varepsilon a^2 + 3\varepsilon^2 a \pm \varepsilon^3.$$

Example:

$$(45{\cdot}2 \pm 0{\cdot}05)^3 = 92345{\cdot}408 \pm 3 \times 0{\cdot}05 \times 2043{\cdot}04$$
$$+ 3 \times 0{\cdot}0025 \times 45{\cdot}2 \pm 0{\cdot}000125$$
$$= 92345{\cdot}408 \pm 306{\cdot}4560 + \cdots\cdots\cdots.$$

$$\therefore \quad \overline{45{\cdot}2}^{\,3} \doteqdot 9235 \times 10.$$

(7) Extracting square root.

$$(a \pm \varepsilon)^{\frac{1}{2}} = a^{\frac{1}{2}} \pm \frac{1}{2} \cdot \frac{\varepsilon}{a^{\frac{1}{2}}} - \cdots\cdots\cdots\cdots.$$

Example:

$$(38{\cdot}7 \pm 0{\cdot}05)^{\frac{1}{2}} = 6{\cdot}22093\cdots\cdots \pm \frac{1}{2} \cdot \frac{0{\cdot}05}{6{\cdot}2209\cdots\cdots} - \cdots\cdots\cdots$$
$$= 6{\cdot}22093\cdots\cdots \pm 0{\cdot}0040\cdots\cdots\cdots.$$

$$\therefore \quad \sqrt{38{\cdot}7} \doteqdot 6{\cdot}221.$$

(8) Extracting cube root.

$$(a \pm \varepsilon)^{\frac{1}{3}} = a^{\frac{1}{3}} \pm \frac{1}{3} \cdot \frac{\varepsilon}{a^{\frac{2}{3}}} - \cdots\cdots\cdots\cdots.$$

Example:

$$(39{\cdot}9 \pm 0{\cdot}05)^{\frac{1}{3}} = 3{\cdot}41709\cdots\cdots \pm \frac{1}{3} \cdot \frac{0{\cdot}05}{11{\cdot}67\ \cdots} - \cdots\cdots\cdots$$
$$= 3{\cdot}41709\cdots \pm 0{\cdot}0014\cdots\cdots\cdots.$$

$$\therefore \quad \sqrt[3]{39{\cdot}9} \doteqdot 3{\cdot}417.$$

Hence, *if we start with a certain number of significant figures we obtain about the same number of significant figures after every* *arithmetical operation.*

This, of course, is a very very rough rule, but may serve as a general guide.

Another remark will suffice to conclude this article; namely :—
if we calculate the displacement of a ship whose length and mean draught are respectively 350 feet and 20 feet from a sheer draught and if we allow the error of 0·05 foot in reading the lengths of ordinates, there may be the maximum error of 20 tons, although the most probable error will be under this amount. If we use Simpson's rule in calculating the displacement, there is another source of error besides that above mentioned.

If my reader feel any interest by this very rough remark, I am very much gratified, and will recommend him to read over the very worthy and concise book : "Vorlesungen über Numerisches Rechnen," von Dr. J. Lüroth.

End.

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