大正五年九月刊行

造船協會會報

第拾九號

（非賣品）

造船協會役員

會長	男爵 赤松則良
理事（主事）	寺野精一
理事（編輯主任）	近藤基樹
理事（主計）	福田馬之助
監事	若宮貞夫
監事	井口在屋
評議員	進經太
評議員	今岡純一郎
評議員	堤正義
評議員	末廣恭二
評議員	男爵 斯波忠三郎
評議員	藤島範平
評議員	横田成年
評議員	須田利信
評議員	山本開藏
編輯委員	島谷敏郎
	八代準
	生島莊三

地方委員

	田代訂
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	曾我清雄
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神戶	田中泰董
吳	新庄季九郎
佐世保	岩佐尙一
長崎	江崎一郎
舞鶴	缺
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浦賀	柴岡喜一郎

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神戶	鶴田傳次郎
大阪	熊倉達
大阪	松田清一
長崎	男爵 徳大寺則麿
長崎	山口泉吉

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本會記事

○臨時講演會及博覽會參觀

大正五年四月九日及十日兩日ニ於テ海事水産博覽會參觀幷ニ本會春期講演會ヲ開催ス、其概況左ノ如シ。

四月九日上野不忍池畔海事水産博覽會々場ニ參集セル本會々員約百名ニシテ、午前十時ヨリ會場各部ヲ參觀シ、正午同會場內ニ於テ水産料理試食會ヲ開キ、午後三時餘興館ヲ觀覽シ終テ隨時退散ス。

當日同博覽會ニ於テハ本會々員ノ爲メニ入場券ヲ寄贈シ特別ノ便宜ヲ與ヘラレタリ。

同日午後六時ヨリ築地精養軒ニ於テ晩餐會ヲ開ク、出席者左ノ如シ

石黒五十二君	今岡純一郎君	飯田熊吉君	伊藤由一君	磯田傳七君
腹巻五郎君	東海勇藏君	渡邊行太郎君	加茂正雄君	加藤良君
河上邦彦君	高橋新八君	武村耕太郎君	田中楳吉君	武田甲子太郎君
堤正義君	藤島範平君	小長井潔君	近藤滋彌君	寺野精一君
寺井忍君	三好光三郎君	斯波忠三郎君		

來賓

岩野直英君	藁谷年實君	浦田周六君	藤田經孝君	三輪修三君
末廣恭二君	萬朝報社	日日新聞社	國民新聞社	

四月十日午後五時ヨリ築地府立工藝學校講堂ニ於テ講演會ヲ開催シ左ノ講演アリ。

一、軍艦淺間ノ離礁並ニ應急修理工事ニ就テ

正員　工學士　岩野直英君

正員　海軍機關中佐　浦田周六君

正員　工學士　橋口保孝君

二、舶用汽罐ニ於ケル石炭重油ノ混燒法ニ就テ

正員　工學士　三橋篤敬君

三、Some hints regarding deflection of ships due to temperature difference

正員　工學博士　末廣恭二君

准員　工學士　井口常雄君

四、On Dr. Yokota's "General expression for stress components in two-dimensional problems of elasticity."

正員　工學博士　末廣恭二君

右ノ内、三橋氏ハ支障アリ當日缺席ニ付同氏ノ論文ハ更ニ十分討論ノ上掲載スルコトトセリ。

講演

軍艦淺間ノ離礁並應急修理工事ニ就テ

正員　工學士　海軍造船大監　岩野直英
正員　海軍機關中佐　浦田周六
正員　工學士　海軍造船大技士　橋口保孝

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第一編　前編

軍艦淺間の坐礁

大正四年一月三十一日午後二時三分軍艦淺間メキシコ國南カリフオルニヤ半島サンバルトロメ灣エントランスロツクノ南八十六度西四「ケーブル」ノ所ニ於テ坐礁ス艦體ハ北四十一度東ヲ向ツテ擱坐ス

坐礁後浸水ノ狀況

防禦甲板以下ニテ漏水ヲ見ザル處前部ニテハ清水庫ヨリ前方ノ水雷火藥庫黑色火藥庫及其ノ附近糧食庫ニシテ後部ニハ舵柄室アルノミ故ニ直接損所ト通ズルモノハ勿論其他ト雖モ移動喞筒僅カニ二臺ノ外人力ニテ之ヲ排水シ適當ノ防水作業ヲナスコト不可能ナレバ防禦甲板以下ハ現狀ヲ維持シ又防禦甲板以上ハ既ニ浸水シタル所ハ之ヲ排水シテ漏水防止ノ作業ヲ施シ少クトモ浸水ヲ防禦甲板以下ニ喰止ムル目的ヲ以テ日夜努力シ其結果ハ左表ニ示ス如キ成績トナレリ

自一月三十一日至二月八日　浸水狀況（順序ハ浸水ノ時刻ニ依ル）

場所（若クハ區劃）	浸水ヲ始メタル時刻	坐礁時ヨリノ時間	滿水セシ時刻	坐礁時ヨリノ時間	記事
第二罐室	一月三十一日午後二時一七分	三分	午後五時三〇分	三時二七分	內底ノ一部隆起破口ノ部ヨリ盛ニ浸水ス支柱毛布等ニテ極力防止セントセシモ水勢激烈ニシテ効果ナク遂ニ退去スルノ止ヲ得サルニ至ル
第四罐室	二—一七	一四	五—三〇	三—二七	右同
第三罐室	二—一八	一五	五—三〇	三—二七	右同
第一罐室	二—一八	一五	五—三〇	三—二七	他ニ比シ浸水增加ノ度緩ニシテ午後三時三十四分火床ヲ浸シ自然消火スルニ至レリ
前部發射管室	二—二〇	一七	防水蓋閉鎖セシタメ不明ナレトモ二月一日中ニハ滿水セシモノト認ム	二四—〇以上	艦底破損ノ爲メ汚水測深管噴水次テ水壓力ノタメニ甲板ニ小龜裂ヲ生ズ依テ支柱ヲ立テ防水ニ努メシモ前罐室增水ト共ニ同隔壁ニ於ケル螺鋲ノ間隙等ヨリ浸水木栓ニテ防ギシモ充分ナラズ浸水大ナルヲ以テ防水蓋ヲ閉鎖ス
前部水雷火藥庫	三—〇	五七	同右	同右	下方艦底破損並ニ前罐室滿水ノ結果下方並ニ後部隔壁ヨリ浸水
後部水雷火藥庫	三—〇	五七	防水扉閉鎖ノタメ不明ナレトモ一日午後滿水ト認ム	二四—〇	艦底ノ一部破損並ニ機械室浸水ノ爲メニ此部ニモ遂ニ浸水
後部發射管室	三—〇	五七	同右	同右	艦底一部破損浸水ノ爲メ汚水測深管ヨリ浸水ス圓材其ノ他ノ材料ヲ以テ防水シ二月一日午前ニハ浸水一呎內外ニ過ギザリシモ午後一時ニハ既ニ六呎ニ至リ水勢急ナルヲ以テ遂ニ防水蓋ヲ密閉シテ止ム
小砲彈藥庫及信管庫	三—三〇	一—二七	二月二日中ニ滿水ト認ム	四八—〇	下部艦底破損浸水ノ爲メ下方ヨリ此部ニモ浸水セシモノト認ム
機械室	三—三五	一—三二	二月一日午前二時	一一—五七	艦底破損其浸水壓力及後罐室ニ浸入セシ水壓力ノ爲メニ側壁床板ノ螺鋲鋼鈑ノ重ネ目等ニ弛ミヲ生ジ其間隙並ニ諸鋲等ノ貫通部罐室トノ間ノ堰戸弁等ヨリ噴水シ支柱木栓填隙等百方手段ヲ盡セドモ遂ニ滿水スルノ止ヲ得サルニ至ル
下甲板第七區（三罐「ケーシング」右舷）	四—二〇	二—二七	同右	一一—五七	罐室並ニ炭庫ニ浸水ノ結果此ノ區劃ニモ影響ヲ及ボシ主トシテ罐室ニ接スル側壁ノ鋼鈑ノ接目ヨリ浸水下甲板中最モ早ク浸水チ始メ且ツ滿水ノ狀態トナレリ

下甲板第八區（四罐「ケーシング」左舷）	四―三〇	二―二七	同	右	一一―五七	罐室並ニ炭庫ニ浸水ノ結果此區劃ニモ影響ヲ及ボシ主トシテ罐室ニ接スル側壁ノ鋼鈑ノ接目ヨリ浸水下甲板中最モ早ク浸水ヲ始メ且ツ滿水ノ狀態トナレリ
下甲板第六區（前部「ハンドルーム」）	六―〇	三―五七	午後ト認ム		四八―〇	炭庫罐室ニ滿水セシタメ此等ノ區劃ニ接スル隔壁並ニ床上ノ鈑ノ重ネ目電線諸鋲貫通部ナドヨリ浸水木栓塡隙等ニテ防ギシモ全然防ギ得ズ防水扉ヲ閉鎖ス
彈藥通路第六區	六―〇	三―五七	二月一日午前九時頃		一九―〇	炭庫ニ接スル壁ノ螺釘孔、鐵鈑ノ合セ目等ヨリ浸水横梁支柱ヲ立テツツアル中ニ甲板ノ一部ヨリノ水壓並ニウネリ毎ニ艦體ニ及ボス衝擊ノ爲メニ隆起ス
彈藥通路第四區	六―三〇	四―二七	二月二日午前八時頃		四二―〇	炭庫ニ接スル壁ノ螺釘孔、鐵鈑ノ合セ目等ヨリ浸水、横梁支柱ヲ立テ螺孔ハ木栓ニテ防ギシモ鋼鈑ノ合セ目ヨリ落下スル水ハ防止困難ニテ漏水益々增加スル中ニ遂ニ防水扉ヲ閉ズ
同第五區	六―三〇	四―二七	同	右	四二―〇	第六區ノモノニ同ジ
同第七區	六―三〇	四―二七	同	右	四二―〇	炭庫ニ接スル螺釘孔、鐵鈑ノ合セ目等ヨリ浸水横梁、支柱ヲ架シ木栓「コーキング」等ニテ防ギシモ充分ナル能ハズ防水扉ヲ閉鎖ス
同第二區	七―〇	四―五七	二月四日午後八時頃		七八―〇	炭庫戰時無線電信室等ニ浸入セシタメ側壁ノ重ネ目等ヨリ浸水ス
同第三區	七―〇	四―五七	二月三日午後八時頃		七八―〇	炭庫第五區等ノ浸水セシタメ其部ヲモ浸水スルニ至ル
同第一區	七―三〇	五―二七	二月四日午前八時		九四―〇	此區劃ニアル掌水雷科倉庫、戰時無線電信室、下部發令所ニ浸入ヲ始メシ爲メ遂ニ横通路ニモ溢レ出デ尚ホ隣區及前部彈藥庫等ノ浸水增加スルニ從ヒ四壁電纜諸桿ノ貫通部鋼鈑ノ重ネ目等ヨリ浸水ス木栓塡隙等ニテ極力防止セシモ全然止メ得ズ彈丸取リ出シノタメ二月一日午後ヨリ二日ニ亘リ徹夜排水ノ結果殆ンド全部排除シ得タルモ防水蓋閉鎖ノ後四日午前八時頃ニハ滿水ノ狀態ニアリシモノト認ム尚ホ七日午前九時ヨリ再排水午後七時三十分防水扉閉鎖十二時ニハ既ニ滿水ノ狀態ニアリ
掌砲科要具庫	七―三〇	五―二七	不明ナレドモ三日午後		七二―〇	三十一日午後八時頃ニ彈庫防水扉閉鎖後通路ヨリノ浸水ハ溢レ居リシモ庫內ニハ異狀ナカリシガ彈藥庫ニ浸水ノ結果此區劃ニモ弇桿螺釘ノ弛ミ隔鈑ノ重ネ目等ヨリ浸水セシモノナラン
掌水雷科要具庫	七―三〇	五―二七	同	右	七二―〇	同右

下部發令所	七—三〇	五—二七	同右	七二—〇	同右
戰時無線電信室	七—三〇	五—二七	同右	七二—〇	罐室トノ隔壁ニアル弁桿ノ通路部ヨリ浸水最モ大ナリ
船匠科要具庫	八—〇	五—五七	同右	七二—〇	掌砲科要具庫ニ同ジ
掌帆科要具庫	八—〇	五—五七	同右	七二—〇	同右
彈藥横通路第八區	一〇—〇	七—五七	二月一日午前八時頃	一八—〇	機械室浸水ノ爲メ此部ニ及ブ
同第九區	一〇—〇	七—五七	二月二日午前八時頃	四二—〇	同右
小銃彈藥庫	不明ナレ共三十一日午後十時頃ナラン	七—五七	二月一日午前七時頃	一七—〇	彈藥通路ニ滿水セシヲ以テ其桿管ノ通過部等ヨリ此ノ部ニモ浸水セシモノト認ム
後部副砲彈庫	二月一日早朝ナラン	一五—三	三日午前中	七二—〇	艦底ノ一部破損ト認ム尚ホ後部横通路ニ滿水セシタメ此部ニモ浸水ス
後部副砲火藥庫	二月一日早朝ナラン	一五—三	下層ハ二日午前中 上層ハ三日午前中	四八—〇 七二—〇	○
後部主砲彈火藥庫	彈藥一日午前少量浸水アリシモ彈丸ヲ浸スニ至ラズ凡テ搬出ス	一五—三	同右	同右	○
下甲板第九區（後部「ハンドルーム」）	午前四—〇	一三—五七	未タ滿水セス		機械室兩舷炭庫ニ接スル部ノ壁鈑ノ合セ目電纜通過部等ヨリ漏水其ノ大部ハ木栓「コーキング」等ニテ防ギ少量ノ浸水ハ毎日喞筒ニ依リ排水ニ努メテ平均一呎內外ノ深度ヲ保チツツアリ
彈藥通路第十區	六—〇	一五—五五	二月二日午後六時	五二—〇	彈藥第八區第十二區等ニ浸水ノ結果電纜桿ノ通過部等ヨリ此ノ區劃ニ及ボセルモノト思考ス
同第十一區	六—〇	一五—五七	二月二日午後八時	五四—〇	同右
同第十二區	六—〇	一五—五七	二月三日午前八時	七八—〇	機械室、三吋彈庫、壁及後部水中發射管室ヨリ電纜諸桿等ノ通過部ノ間隙並ニ防水管蓋ノ「ゴム」ノ破損部等ヨリ浸水セシモノト認ム三日午前防禦甲板ノ防水蓋ヲ開キ徹夜排水ニ從事シ木栓ニテ諸孔ヲ塞ギ防水蓋ニハ支柱ヲ置キ壁鈑ノ合セ目ハ「コーキング」

					ヲ爲ス等ノ手段ヲ盡セシモ尚ホ水勢止マズ彈丸搬出ノ上防水蓋ヲ閉鎖ス
火酒庫入口 同　奥 後部掌砲科要具庫 後部掌水雷科電氣要具庫	二月一日午前 六—〇	一五—五七	二月三日午前 八—〇	七八—〇	別ニ作業ヲ爲サズ
後部掌水雷科倉庫	後部水中發射管室ニ同シ				別ニ作業ヲ爲サズ
前部主砲彈藥庫	不明ナレドモ午前五時ナラン彈庫ハ同日午後ナラン彈丸ハ凡テ浸水ヲ見サル中ニ搬出セリ	一四—五七	下層ハ二月二日早朝上層ハ三日午前中	四八—〇	此部ノ艦底ハ破損セサレトモ後方破損セシ艦底ヨリノ浸水ノ横壓ノタメ隔鈑ノ釘鐵ノ弛ミテ浸水セシモノナルベク其上壓力並ニ前部發射管、前部水雷火藥庫等ヨリノ横壓ノ爲メ遂ニ此ノ彈藥庫ニモ浸水セシモノト認ム
前部副砲火藥庫		一四—五七	同右	同右	同右
前部副砲彈庫	二月一日午前ニ少量ノ浸水アリシモ彈丸ノ半數イ海水ニ浸潤スルコトナク搬出セリ	一四—五七	同右	同右	同右
艦底					六番底ヨリ二十八番底迄ハ擱坐ト同時ニ浸水ヲ始ム次デ他ノ區劃ヨリモ隣區ヨリノ水壓ノ爲メ隔鈑螺釘等ヨリ潮ノ浸水セシモノラシク三番底ハ二月一日午前八時ニハ浸水約一呎ナリ三日午後八時ニハ滿水尚ホ水壓ハ一番底ニモ及ボシ三日午後七時頃ニハ浸水約三呎ナルヲ發見二月八日頃ニハ略ボ海水面ト同高トナル二十九番底モ二月三日ニハ汚水約五呎八时ニハ潮ノ増加遂ニ滿水狀態トナル
炭庫					浸水ノ時日不明ナルモ二月一日中ニ七番炭庫ノ外全部滿水ト認ム

現狀調査

關東横須賀出發ニ先チ工作部ハ技手工手各一並ニ職工若干ヲ先發ノ軍艦ニ便乘セシメ先着ノ上關東到着前ニ出來ル限リ現狀調査ヲナサシメシガ尚ホ關東到着後モ調査ヲ行ヒタル結果左ノ如シ。

(一)淺間擱坐ノ狀態ヲ附近ノ岩ノ形狀ヨリ推察スルニ艦底ノ岩ハ最大干汐面下約二十一呎ノ岩ナルベシ岩質ハ子持石ニシテ餘リ堅カラズ艦底ノ岩ニ當リ居ル處ハ艦ノ中央部及ビ後方ニ於テハ六個ノ大ナル岩ニ乘リ其ノ觸接面約二千八百四十一平方呎ナリ其ノ他ハ懸垂シ「ウネリ」ノ爲メ前後左右ニ動搖サレツヽアリ一旦荒天ニ遭遇セバ船體ハ中央ヨリ開ヒテ二ツニ切斷サレンヲ恐ルルモ其豫防トシテハ如何トモシ難シ岩ニ當リ居ラザル所ヲ檢スルニ艦底殆ンド全面ニ亘リ凹ヲ生ズ岩ヲ掘リ開キテ觸着部ニ於ケル破損ノ狀況ヲ檢セント欲スルモ岩質弱キト「ウネリ」ニテ船體動搖スル爲メ岩ヲ掘レバ穴ハ自然ニ崩壞シテ塞ガリ作業不可能ナリ「ウネリ」ハ後方右ヨリ寄セ來ルヲ常トス。

(二)附近ノ水深ヲ精測スルニ前後ハ充分ノ深サアリ右方ニハ大ナル岩礁アリ左方ハ稍々深キモ諸所ニ突岩アリテ船ノ吃水ニハ足ラス坐礁吃水ハ三月十日調ベノ干汐ニテ前部三十二呎一吋後部二十二呎九吋滿汐ニテ前部三十七呎九吋後部二十九呎八吋ナリ左右ノ傾斜ハ右舷ニ一度半ナリ是ヨリ見レバ前部ハ汐ノ干滿ニ從ヒ一呎三吋浮キ沈ミヲナスモノナリ二月七日調ベハ干汐ニテ前部三十三呎五吋後部二十四呎三吋滿汐ニテ前部三十六呎後部二十七呎ナリ四月中或日前部三十五呎後部二十八呎ノ事モアリ但シ浪ノ爲メ精測ハ不可能ナリ。

(三)氣候溫和ニシテ常ニ晴天ナレドモ「ウネリ」アリ淺間ノ位置ハ磯ノ上ナルヲ以テ特ニ然リ平穩ノ時ニモ「ウネリ」高サ四、五呎位アリ。

(四)海水ハ清淨ナリ艦底ニ於テハ岩粉碎シテ土砂トナリ「ウネリ」ニ動亂セラレテ多少ノ濁リヲ免カレザレドモ泥土ノ濁リノ如ク甚ダシカラズ潜水工ヲ困ラスモノハ寧ロ「ウネリ」ニシテ體ヲ攫ハレ折々作業ノ危險アリ。

(五)現狀ニテハ船體屈曲變形ノ程度ハ測リ難キモ其徵候トシテ見ルベキモノヽ中甲板ニ於テハ士官室、士官食器室、士官厠、士官次室、食器室、機關長室、主計長室、第四分隊長室、第三分隊長室、第二分隊長室、第一分隊長室等ノ入口上部ノ隅ガ引キ裂カルヽ傾向ノ爲メ塗具龜裂セルヨリ肋百二十一番ニ當ル通路隔壁(兩舷共)上部ガ曲リヲ生ゼルアリ肋九十六番ニ當ル機關倉庫入口ノ上部ノ隅ニテ鋼鈑ガ鋲ニ浴フテ裂ケタルアリ同所ニ當ル掌

砲科要具庫入口ノ左下部ノ隅ニ於テモ同樣ノ裂目アリ肋九十五番ニ當ル左舷ノ通路隔壁ノ上部ガ曲リテ生ゼルアリ防禦甲板ニ於テハ肋百三十九番ニ當ル左舷通路隔壁ガ艦首ヲ向ツテ上部左ノ隅並ニ下部右ノ隅ニ於テ鋼鈑裂ケタルアリ百二十一番ニ當ル横隔壁(兩舷共)ガ甚ダシク屈曲セルアリ肋百〇三番ニ當ル機關科倉庫入口上部ノ隅ガ裂ケタルアリ肋九十五番ニ當ル横隔壁(兩舷共)甚シク屈曲セルアリ七十九番ニ當ル機關科倉庫ノ左舷入口上部ノ隅ガ裂ケタルアリ最上甲板ニ至レバ前罐煙突ノ外筒ノ下部ガ屈曲セルアリ此等ハ皆船ノ中央ヨリ押シ上ゲラレ兩側並前後ヨリ引キ下ゲラレ居ル結果ナリトス而テ諸所ニ常ナラザル軋ル音アリ又機關室ノ縱隔壁ハ「ウネリ」ニ連レテ左右ニ六吋位呼吸スル如ク動搖シツヽアリ。

(六)外底ヨリ潜水工ノ調査シ得タル破損ハ前罐室左舷ノ罐下ニ當ツテ外板「ラツプ」切レ長サ二十五呎六吋巾三吋ノ破孔アリ後部火藥庫下肋百四十九番ヨリ肋百六十九番ニ亘リ龍骨變形シ「ラツプ」離レ居ルモノアリ廣大ナル觸岩部面ニハ如何ナル破孔アルヤ知ルベカラズ凹ノ部一體ニ漏水多キハ想像ニ難カラズ次ニ内底ノ損所ハ各罐室ノ罐前ニテ一體ニ隆起アリ後罐室ニ最モ大ニシテ隆起二呎ト稱ス後罐左舷罐前ニ破孔アリ長サ十七呎四吋巾八吋ト云フ隔壁ハ肋百二十五番著シク突キ上ゲラレ足ヲ入ルヽニ足ル程ノ破孔ヲモ發見セリ又防水扉損ジ其ノ用ヲナサズ後罐室入口ヨリ肋百二十五番ニ降下スルニ罐室通路扉曲リ固着シ居リテ通行不可能ナリ而カノミナラズ罐體ガ「ウネリ」毎ニ天井ニ近ヅキ又ハ遠ザカリツヽアルハ氣味惡ルシ九十九番ノ破損之ニ次グ推進器ノ翼及舵ノ下端ニ損所アリ現在三十七番ヨリ肋百七十九番迄ハ防禦甲板以下全部浸水ス肋二十三番ヨリ三十七番迄ハ二重底ニノミ浸水ス都合浸水ノ全容量ハ八、五四三、六噸ナリ。

(七)坐礁ニ際シテハ先ヅ肋二十三番附近ノ龍骨ガ岩ニ當リ船體進ンデ大ナル岩ヲ擦リ其ノ尖頭ヲ削リ落シテ艦ハ現位置ニ止マリ種々ニ動搖シツヽ遂ニ擱坐セルモノト認ム艦底一面ノ凹ミ及前部懸垂部ノ破孔ハ正ニ此ノ作用ノ結果ナリ。

(八)罐前ニ於ケル隆起區域ノ廣キコト並ニ罐室内底ノ割目長キコトハ頂キノ廣キ岩ニ押シ上ゲラレ居ル徵候ナ

リ。

（九）艦底凹ミノ顯ハレ居ル所ヲ總テ調査スルニ鋲切レテ外板ノ繼目離レ又ハ綏ミヲ生ジタルモノハ之アリ然レドモ鋼鈑破レタル所ヲ多ク見ザルハ鋼ノ性質佳良ナルヲ證ス。

（十）按ズルニ外底破レタル處必ズシモ其内底迄破レ居ラズ又内底破レ居リテ其ノ外底ハ只凹ミノミニテ破レ居ラザルコトモアリ然レドモ淺間ハ二ケ月餘ニ亘リ波ニ搖ラレテ礁上ニ坐セルモノナレバ觸岩部面ニハ幾多ノ大破孔アリト見ザルヲ得ズ。

（十一）坐礁前ノ排水量一萬二百三十噸ニシテ約二十五呎三吋ノ水平吃水ナリシト云フ坐礁後關東到着迄ニ艦ノ手ヲ以テ重量物約九百二十三噸ヲ輕減シタルヲ以テ目下艦ノ重量ハ九千三百七噸ナルベシ重量物ヲ取リ除キタル位置及重サヨリ計算スルニ今ハ浸水ヲ全部排除スルトセバ艦ノ重量ハ前部二十一呎八吋八分ノ七後部二十五呎三吋二分ノ一ノ吃水ニテ浮揚スベキモノニ相當ス。

（十二）淺間ハ如何ナル重サヲ岩礁ニ載セ居ルカヲ概算スルニ船ノ重量九、三〇七噸浸水ノ量八、五四三噸六計一七、八五〇噸六ナリ之ニ對シ「デスプレースメント」ハ滿潮ノ時一四、四五七噸干潮ノ時一一、〇八八噸ナリ故ニ坐礁重量ハ滿潮ノ時約三、三九三噸六干潮ノ時約六、七六二噸六ナリ「ウネリ」高サ六、七呎ノ時坐礁壓力ヲ變動スルコト約一、五〇〇噸乃至二、〇〇〇噸ナリ相當ノ繫維方法ニ依リ危險ハ防ギ得ルモ船底ノ損傷ハ頗ル大ナリト知ルベシ而テ潮ノ干滿ニ依リ艦首一呎三吋位浮沈スルヲ以テ滿潮ノ時後部ノ岩ニ最モ大ナル壓力ヲ受ケテ干潮ノ時前部ノ岩ニ最モ多ク壓力ヲ受ケ居ルモノナリ。

離礁計畫の準備

至急喞筒据付ヲナシ排水試驗ニ依リ漏水ヲ觀察シ以テ破孔ノ有無所在並ニ大小ヲ推測シ且ツ如何ナル程度マデ排水シ得ベキヤヲ調査セントス而シテ幸ニ破孔小ニシテ此ノ喞筒力ヲ以テ漏水ニ打勝ツ如ンバ其儘ニテモ浮揚ヲ斷行シテ可ナリ故ニ先ヅ千噸「セントル」二臺七百五十噸「セントル」四臺及四百噸「ワージントン」一臺ヲ罐

室機械室ノ排水用トシ百噸「セントル」一臺ヲ前部浸水區ノ排水用トシ二十五噸油機唧筒二臺ヲ後部浸水區ノ排水用トシテ何レモ防禦甲板ニ据付ケ尙ホ八十噸「パルソ」一臺ヲ前部浸水區ニ、八十噸「パルソ」二臺ヲ後部浸水區ニ備ヘ而テ罐六個推定力量合計五百六十二馬力ノモノヲ上甲板ニ据付ケ出來得ル限リ艦底防水ヲ爲シタル上ニテ各區排水試驗ヲ行ヒ其結果ヲ見タル上ニテ浮揚方案ヲ定メントス。

稀有の長濤

四月二日夕刻ヨリ波高シ長濤高サ十三四呎翌朝迄ニ坐礁位置並ニ觸岩ノ模樣變更シ機械室後部ヲ中心トシ船首左舷ニ約五度廻リタリ艦ノ損害增加セル事想像ニ難カラズ此ノ時最前方ノ觸岩ガ艦底ヲ離レタルハ艦ノ懸垂狀態ヲ益々不良ナラシメタルモノナリ然レドモ此災害ハ寧ロ我意ヲ得タルモノアリトス何トナレバ此岩ガナクナリタルニヨリ船ヲ前方ニ傾斜セシメ離礁シ得ルナラント思フコトヲ得タレバナリ。

排水裝置工事

四月一日ヨリ唧筒並ニ唧筒運轉用罐据付工事其他必要ナル事業ニ着手ス後部浸水區ニ對シテハ最初八十噸「パルソ」二臺及二十五噸油機二臺ヲ備ヘタルモ唧筒試運轉ノ際力量不足ナルヲ發見シタルヲ以テ二十五噸油機一臺ヲ撤シテ雜用ニ當テ其ノ代リトシテ千噸電働「セントル」一ヲ据付ケタリ又防禦甲板上ノ五、六、七、八番ノ四個ノ炭庫並ニ上甲板左舷側ノ「ネッチング」ヲ假給水「タンク」トシ水容量約三百十五噸ヲ以テ唧筒運轉用罐六個ニ給水セントス排水裝置工事四月十九日竣工ス罐ハ工場ヨリ取リ集メモノニシテ蒸氣壓力不同ナルニ拘ハラズ各罐ヨリ多數ノ唧筒ニ給汽スル爲メ管裝置ニハ最モ意ヲ用ヒタリ。

防水工事

(一)前罐室左舷下ノ長キ外板破孔ハ鋼鈑ヲ以テ完全防水工事ヲ行フ又其ノ他ノ既知ノ外板ノ破孔ハ應急防水ヲ行フ。

(二)外板ノ緩ミハ出來得ル限リ獸脂目塗又ハ絲屑塡隙ヲ行フ。

(三)中甲板ニ在ル砲門其他舷側防水ヲ行フ。
(四)浸水區ニ開口スル中甲板「ハッチ」ハ「コーミング」ヲ三呎高クス但シ蓋ヲ用意ス。
(五)浮揚リ後觸岩部ヨリ表ハルル破孔ヲ咄嗟ノ間ニ防水スル目的ヲ以テ大形ノ帆布製防水蓆ヲ準備ス。

後部重量物卸し方

艦ヲ浮揚ゲタルトキハ之ヲ前方ニ引出スノ計畫ナルヲ以テ後部ノ重量ヲ輕減スルタメ五番乃至十四番ノ副砲(楯及砲案砲架共)後部主砲二門(天蓋砲案共)後部ノ砲彈彈丸ヲ卸ス

排水試驗

「ポンプ」ノ效力「ポンプ」配置ノ適否並ニ漏水筒所及破孔ノ大小ヲ檢シ如何ナル程度迄排水シ得ルヤヲ試ムル目的ヲ以テ四月二十二日排水試驗ヲ行フ其ノ成績左ノ如シ。

(一)前部浸水區ハ確實ニ排水スルコトヲ得。
(二)後部浸水區ハ漏水ヲ防止シ得ザルモ充分排水ノ目的ヲ達スルコトヲ得。
但シ千噸電働喞筒ハ吸入管二本アリテ各吸入先ノ高サヲ異ニス一方ガ水ヲ出デタルトキハ其ノ口ヲ閉弃スレバ可ナリト思ヒシガ實際ハ不便ナリ且ツ長ク導ク護謨蛇管ハ屈曲ニ無理ヲ生ジ不工合多シ直立ノモノ一本ニ改ムルヲ要ス
(三)後罐室ハ最モ多量ノ漏水アリテ減水思ハシカラザリシモ二時半ノ間ニ約七呎ノ減水ヲナセリ。
(四)前罐室モ右同斷
(五)機械室ハ右ニ比シ幾分多ク減水シタリ。
(六)總區排水ヲ行ヒ潜水工ヲ外底並ニ各浸水區ノ底ニ潜メテ漏水搜索ヲナサシメタルニ左舷前罐室内ニ於テ内底ニ二箇所ノ小漏水ヲ感ジ外底ニ於テ一ケ所ノ小吸込ヲ發見シタルノミ。
但シ大體ノ水流ハ後罐室ヨリ始マリ前後ニ流ルル傾向アリ而テ肋百二十五番隔壁ヨリ機械室ニ向テ流レ出ルモ

ノハ稍ヤ著シ。

（七）總區排水試驗ノ運轉時間二時四十五分ニシテ區内減水量七百五十九噸ナリ喞筒ガ一時間五千四百噸ノ推定力量ヲ働キタリトスレバ漏水量ハ一時間約五千八十七噸トナル此大量ノ漏水アルニ拘ハラズ著シキ呼キ出シ又ハ吸込ヲ感ゼザルハ全ク漏水箇所ノ廣大ニシテ且ツ諸所ニ多ク存在スルモノナルヲ證ス水頭増加スルニ從ヒ漏水量ハ更ニ増加スベキモノナリ然レ共尙ホ進ンデ幾分ニテモ防水ヲ行ハヾ所有ノ排水力ハ漏水ニ打勝チ得ルノ見込ナシトセズ。

（八）初メテ爲セル排水作業ナルヲ以テ喞筒運轉信號ノ誤錯計測ノ不熟練等試驗上精密ヲ缺ギタル所ナキヲ保セズ。

離礁方案

排水試驗ノ成績ニ鑑ミ左ノ如ク離礁方案ヲ定ム（四月二十四日）

海上平穩ニシテ艦ノ動搖少キ日ニ於テ總區排水ヲ行ヒ潛水工ヲシテ外底ヨリ至細ニ水ノ吸込ヲ調査セシメ吸込ヲ傳ツテ次第ニ觸着岩ニ迫リ破孔位置ヲ發見シテ之ヲ閉塞スルマデ毛布、布帆布等ノ防水材料ヲ破孔ニ挿シ當テ又ハ流レ込マシメントス之ヲ防水運轉ト名クベシ斯ノ如ク魂氣強ク度々防水運轉ヲ行ヒ遂ニ漏水減少シテ既設ノ喞筒力ニテ離礁ノ程度ニ排水シ得ルニ至ルヲ待チ艦ノ前部ニ水ヲ注ギテ大ナル「トリム」ヲ與ヘ後部ノ吃水ニ十八呎以内ニテ浮揚ラシメ以テ前方ニ引キ出スモノトス。

浮揚吃水の研究

小潮ノ場合ニ潮高五呎ナリ潮高五呎ノトキハ坐礁吃水ハ後部二十八呎中央三十三呎ナリ艦ハ前部懸垂狀態ニアルヲ以テ浮揚吃水ハ前部ハ四十呎ニテモ差支ヘナキモ後部ハ是非共二十八呎以内中央ハ是非共三十三呎以内タルヲ要ス故ニ小潮ノ滿潮ニ當リ後部吃水二十八呎トシ中央吃水三十三呎以内ニテ離礁セシメントスレバ前部ハ三十五呎ヨリ多ク沈マシムルヲ許サザルモノナリ但シ船ガ幾分前進シタル後ニハ前部吃水ヲ増加シ得ルモノトス。

艦自身及附屬物並ニ搭載物ノ重量ハ九、五六二噸ナリ外ニ艦ノ浮揚重量ニ加フベキモノハ水ナリ此水ヲ二別シテ浸水重量及注水重量トナス浸水重量トハ排水喞筒ノ能力上自然艦内ニ殘留スル浸水ノ重量ヲ云ヒ注水重量トハ所要ノ浮揚吃水ヲ得シムル爲メ艦ノ前方區劃ニ故サラニ注水スル水ノ重量ヲ云フ。

水ノ量ハ大排水決行ノ際ニ於ケル排水力ノ如何ニ依リテ種々ノ場合ヲ考ヘザルベカラズ故ニ茲ニ四ツノ場合ヲ想像シテ浮揚吃水ヲ豫測スルモノナリ。

第一ノ場合

前後部浸水區ハ内底上平均二呎ノ高サ迄第一乃至第六浸水區ハ内底上平均十一呎ノ高サマデ浸水殘留スルモノトシ而テ艏ヨリ肋三十七番マデノ區劃ニ注水シテ中甲板下面ヨリ下二呎三吋迄達セシムルモノトス。

然ルトキハ計算上左ノ狀態ニテ浮揚ルモノトス。

浮揚排水量		一三、一一一噸
吃水	前部	三十三呎八吋八分ノ三
	後部	二十七呎八吋八分ノ七
	平均	三十呎八吋八分ノ五
「トリム」		五呎十一吋二分ノ一

第二ノ場合

第一ノ場合ト異ナル所ハ内底上十一呎トアルヲ八呎ト假定ス。

然ルトキハ計算上左ノ狀態ニテ浮揚ルモノトス。

浮揚排水量		一二、四二九噸
吃水	前部	三十二呎十吋
	後部	二十六呎三吋四分ノ一

平　均　　二十九呎六吋八分ノ五

「トリム」　六呎六吋四分ノ三

第三ノ場合

第一ノ場合ト異ナル所ハ内底上十一呎トアルヲ七呎ト假定ス

然ルトキハ計算上左ノ狀態ニ浮揚ルモノトス

浮揚排水量　一一、二二二噸

吃水
前　部　三十二呎四吋十六分ノ一
後　部　二十五呎十一吋十六分ノ三
平　均　二十九呎一吋八分ノ五

「トリム」　六呎四吋八分ノ七

第四ノ場合

第一ノ場合ト異ナル所ハ内底上十一呎トアルヲ五呎ト假定ス。

然ルトキハ計算上左ノ狀態ニテ浮揚ルモノトス。

浮揚排水量　一一、八二八噸

吃水
前　部　三十一呎八吋四分ノ三
後　部　二十五呎一吋十六ノ九
平　均　二十八呎五吋三十二分ノ五

「トリム」　六呎七吋十六分ノ三

右ノ如ク計算ノ結果ヲ得タルヲ以テ今後排水ノ成績次第ニテハ浮揚見込立ツモノトス扨テ浮揚ケ離礁後罐ノ破烈若クハ、破孔增大其ノ他不慮ノ出來事ニ由リ排水力ニ大影響ヲ生シ罐室機械室ハ防禦甲板マデ滿水ストセバ排

水量一萬五千百五十四噸六トナル此ノ吃水平均三十四呎五吋四分ノ一ナリ此ヲ最悪ノ場合ト見做シ砲門並ニ甲板ノ要部ノ「ハッチ」ヲ閉スノ法ヲ講ジ外底防水蓆當テ方又ハ排水力回復マデ一時ヲ凌グ事ヲ得シメントス斯ノ如クセバ一旦離礁シタルモノガ再ビ沈没スル如キ憂ハナキモノトス。

第一回防水運轉

四月二十七日第一回防水運轉ヲ施行ス其ノ成績左ノ如シ。

四時間運轉ノ後機械室ハ二重底上平均深サ十呎七吋罐室ハ二重底上平均深サ十一呎九吋トナレリ。

其減水量二千九百十二噸ナリ推定喞筒力ハ五千四百噸トシ四時間ノ排水量二萬一千六百噸ニ對シ減水二千九百十二噸ナルヲ以テ漏水ハ一時間四千六百七十二噸ナリト見做スベシ前回ノ排水試驗ノ場合ニ比シ稍々可ナリト認ム。

第二回防水運轉準備工事

第二回防水運轉前ニ左ノ通リノ工事ヲ行フ。

(一)縱通彈藥道路三區四區五區壁ニ各一個ノ穴ヲ明ケ通路ノ水ガ罐室機械室ニ自然放水スル樣ニスルコト（潜水工事）。

(二)前部及後部浸水區ノ各室ハ悉皆利通シ水ヲ一箇所ニ呼ビ寄セ得ル樣隔壁下部ニ穴切リ方追加ノコト（潜水工事）。

(三)後部浸水區ヲ排水シテ其中ニアル彈藥等ノ重量物ヲ卸スコト此ノ期ニ於テ機械室等ヨリ漏水スル諸孔ヲ出來得ル限リ栓止スルコト。

(四)曩ニ定メタル砲卸シ方ニシテ未濟ノモノハ至急卸スコト。

(五)救難罐強壓通風裝置工事ヲ行フコト。

(六)左舷前罐用七百五十噸喞筒ノ排出木箱ヨリ枝管ヲ設ケ第二罐室ヨリ吸ヒ上ゲタル水ヲ前部糧食庫ニ移シ得ル

裝置トナスコト。

(七)各喞筒吸入管ノ「ローズヘッド」ヲ調ベ塵埃付キ居レバ清掃スルコト(潜水工事)。

(八)後部浸水區ノ千噸電働喞筒吸入管ヲ改造シテ一本トナシ水雷頭部庫床マデ達セシムルコト。

(九)艦前部懸部ニ六呎角ノ鋼ノ箱ニ木材ヲ塡充シタル「フエンダー」抱カセ方(近來長濤頻リニ大ナルニ依リ用心ノ爲メ)(潜水工事)。

(十)「パルソメーター」ハ容易ニ下降セシメ得ル樣ニ釣リ方ヲ改メ置クコト。

(十一)喞筒ノ防塵器ガ尙ホ充分床ニ屆ク樣ニスルコト(潜水工事)。

(十二)五月三日後部浸水區排水スルヲ以テ其ノ時通水孔(隔壁下部ニ開キタル穴ナリ)ニ物ガ塞ガリ居ラザルヤヲ改ムルコト(潜水工事)。

(十三)五月二日主砲卸シ方竣工スルヲ以テ其ノ「デリック」裝置ヲ撤去スルコト。

(十四)左側弩ニ高キ岩カ五個所アリ之ヲ五吋程切リ落スコト但シ「ダイナマイト」ヲ使用シ差支ナシ。

第二回防水運轉

五月五日第二回防水運轉ヲ施行ス其ノ成績左ノ如シ。

(一)通水孔ハ利通良好ナリ。

(二)前後部浸水區排水ハ六時間ニテ充分ナリ。

(三)千噸電働喞筒ハ罐ノ力量不足ナルヲ以テ罐室機械室ノ大排水ト同時ニ運轉スル能ハズ。

(四)「パルソメーター」ハ實際一個ダケハ順ニ下降セシメ得ルモ艙口ノ都合上他ハ固定シ置カザルベカラズ後部浸水區ノ增水ヲ防止スルニハ差支ナシ。

(五)前部糧食庫ニ水ヲ注ガントスル裝置ノ支管ノ栓扉ハ「レバー」ニテ開ク簡略裝置ナルモ開閉加減不都合ナリ。本式ノ金物ヲ以テ「スクルー」裝置ニ改ムルヲ要ス。

(六)外底防水ノ效力ハ幾分進歩シタルガ如シ罐給水機ニ故障ヲ生ジ防水運轉時間ハ僅々一時四十分ニシテ中止シタルヲ以テ舷側ト艦内トノ水準ノ差八呎十一吋ニ達シタルノミ而シテ減水増水ノ測定モ不完全ノ點アリタル如キモ第一回防水運轉ニハ十分間ニ八吋ノ割ニテ減水セシニ今回ハ十分間ニ十一吋ノ割合ナルニ徵シ今回ノ漏水約三千四百噸位ナリト鑑定ス。

有望

第一回第二回防水運轉ノ成績ニ鑑ミルニ今ヤ望ヲ屬スルニ足ルモノアリ今若シ罐室機械室ノ浸水ガ内底上十一呎マデヨリ下ル能ハズトスルモ肋三十七番ヨリ前部ニ滿水スレバ前部三十五呎二吋後部二十六呎ニテ浮カシ得ベシ此ノ減水ハ一度見ルヲ得タルモノナルヲ以テ近日中ニ浮揚ゲヲ決行セントス。

防水運轉心得書(所在艦船總員ニ示ス)

(一)防水運轉ハ潜水工ガ外底ヨリ假防水ヲ爲スニ當リ其ノ作業ヲ助クルガ爲メ浸水區ヲ排水シテ漏水箇所ニ水ノ吸込ミヲ起サシムルヲ以テ主ナル目的トシ其他此機會ニ於テ成シ得ル必要ナル作業ヲナスモノトス。

(二)曩ニ排水試驗ニ於テ一時間五千噸ノ漏水ヲ見タルニ第一回防水運轉ニ於テハ一時間四千噸ノ漏水トナレリ第二回防水運轉ニ於テハ更ニ漏水減水シテ一時間三千噸トナレリ第三回以後一層ノ好成績ヲ擧ゲンコトヲ期ス。

(三)防水運轉ハ何回行ヘバ善キヤハ豫知シ難キモ度數ヲ重ヌル程善クナルノ道理ナリ若シ防水運轉中俄ニ防水ノ效顯著トナリ浮揚ゲ有望ナルニ至ルトキハ機ヲ逸セズ大排水ト號令シテ其運轉ヲ繼續シ離礁ヲ決行スルコトアルベキニ付キ防水運轉ヲ行フニ當テハ常ニ大排水部署並ニ離礁後曳航轉錨投錨方按ヲ定メ人員ヲ配置スルヲ要ス。

(四)防水運轉ノ施行ノ日ハ海面平穩ナルヲ要ス。

(五)防水運轉ハ午前九時以後日沒以前ニ滿潮アル日ニ行フヲ要ス。

(六)防水運轉ハ滿潮時ヨリ十二時間前ニ開始スルヲ要ス。

(七)防水運轉開始後初メノ六時間ハ專ラ前部及後部浸水區ヲ排水(殘水排除トモ)スルモノトス。

(八)防水運轉開始後六時間ヲ經テ罐室及機械室ノ排水ヲ行フ。

(九)前部及後部浸水區ハ其ノ排水ヲ終リタル後ト雖モ增水ヲ防止スル爲メ適宜喞筒ノ運轉ヲ行フモノトス。

(十)大排水發令後ハ適宜ノ時機ニ於テ前部注水ヲ行フ。

第三回防水運轉

五月八日防水運轉心得書ニ基キ第三回防水運轉ヲ施行ス午前四時運轉ヲ開始シ午後三時三十分離礁有望トナリタルヲ以テ大排水ヲ令シ引出シ方配置ニ就キ午後四時四十五分離礁シタリ。

軍艦淺間ノ離礁順序

(一)當日滿潮ハ午後五時ナリ午前ハ海上極メテ平穩ナリシモ午後ニ至ッテ風力增加シ海面稍ヤ浪立チ始メタリ前部浸水區及後部浸水區ハ午前九時豫定ノ如ク排水シ終リ罐室機械室ハ午前九時三十分排水ヲ開始シ午後三時同區ノ水準內底上十呎ニ近クナレリ二號岩ハ前罐室後部ハ艦底ト岩ト離レ一呎ノ隙ヲ生ジ後部ノ艦底ノミ岩ニ重キヲ加フ此ノ時動搖次第ニ增加セリ。

(二)午後三時三十分大排水ヲ令シ直チニ前部注水ヲ開始セリ。

(三)罐室下艦底ガ再ビ岩ニ當ラザル限度マデ前ヲ沈メ後ヲ浮カセタル後チ一旦前部注水ヲ中止セリ。

(四)艦腹(重心點)ヲシテ岩ヲ離レテ充分前方ニ進マシメンガ爲メ午後四時十五分引キ出シ方ヲ始ム前進容易ナラザリシガ揚錨機ヲ以テ前方繫維索ヲ卷キ約三十米突前進セシメタリ。

(五)今ヤ舵及推進器翼ハ岩上ニ臨メリ後部ノ浮キ方不充分ノ儘ニテ餘リ引キ出シ過グレバ岩ニ觸レテ舵又ハ推進器翼ヲ破損スル危險アリ又重心點ハ今ヤ充分ニ前進シタルヲ以テ此ノ上引摺リテ艦底ヲ傷ムルヲ要セズ故ニ引出シ方ヲ中止シ且ツ後部ヲ浮カサンガ爲メ前部注水ヲ再開スル時機ヲ待ツ。

(六)此時罐室機械室ノ浸水增加シ內底上十五呎トナリ且ツ後部浸水區モ增水シツヽアリ其ノ原因ハ揚錨機ヲ一時

使用シタルガ爲メ蒸汽壓力ヲ減ジ喞筒力ニ影響シタルモノナリ。

(七)暫時狀況ヲ考ヘ排水力ノ回復ト滿潮トヲ待チタルニ排水ノ模樣良好トナリタリ此ニ於テ前部注水追加ヲ斷行ス。

(八)午後四時四十五分(豫定滿潮時十五分前)艦ハ宛モ浮キ足トナリ數行ノ長濤ニ押サレ引キ方ヲ待タズ艦ハ前方ノ深ミニ流レ出デタリ艏ヲ右ニ艉ヲ左ニ偏シテ浮ミタリ。

(九)此ノ時後部右方ノ繋維索ハ二本共ニ「ブイロープ」ノ元ヨリ切斷サレ而シテ後部左方ノ繋維索(此ハ一本ナリ)ノミ甚シク緊張シテ殘レリ依テ直ニ緊張ヲ放チタリ。

(十)艦ハ離礁後吃水前部三十五呎三吋後部二十七呎二吋ニテ傾斜ナク關東ニ曳カレテ新錨地ニ移ル。

浮揚計算ト實際作業

(一)浮揚計算ハ誤リ少ナカリシヲ認ム五月八日浮揚離礁後實側シタル吃水ハ前部三十五呎三吋後部二十七呎二吋中央三十一呎二吋二分ノ一ニシテ排水量一萬三千四百三十噸ニ相當ス此ノ排水量即チ總重量ヨリ船自身ノ重量九千五百六十二噸ヲ減ジタルモノ三千八百四十八噸ハ艦內ノ水重量ナリ艦內ノ水重量中注水重量四百五十四噸ヲ差引ク時ハ浸水重量三千三百九十四噸トナル然ルニ此ト同時刻ニ實側シタル各浸水區ノ水準ハ二重底上前部浸水區八呎前罐室十五呎四吋後罐室十三呎七吋四分ノ一機械室十二呎九吋二分ノ一後部浸水區八呎二吋ナリシヲ以テ此ニ依リ浸水重量ヲ計算シタル結果モ約三千三百九十四噸ナリ。

(二)實際作業ハ少シ手違アリシヲ告白ス午後五時ニハ後部ノ岩上ノ吃水二十八呎以上ニ達スベカリシナリ然ルニ午後三時三十分未ダ滿潮トナラザルニ己ニ艦內減水ノ極度ニ達セリ滿潮未ダシキヲ以テ艦ハ浮カズ兵員總立ニナリテ引ケドモ前進容易ナラズ遂ニ揚錨機ニテ引キ張リタルタメ前進ハナシタルモ之レガ爲メ忽チ蒸汽壓力ノ減退ヲ來シ喞筒ノ働作衰ヘ艦內再ビ增水ヲ始メタリ暫時ノ後排水力回復シ幸ニ離礁スルヲ得タリト雖モ抑モ此ノ困難ニ逢遇シタル事實ニ就キ三ツノ失アリ記シテ以テ戒メトナス(一)十日ニナレバ一層高キ滿潮アルヲ以テ

滿潮時一時間前位ニテモ所要ノ水深ヲ得ベカリシニ之レヲ待タズ八日ニ決行シタルコト(二)午前九時三十分總區排水ニ着手セバ午後三時三十分マデニハ減水極度ニ達スベキコトハ前回試驗ノ成績ニテ知リ得タル事ナリ然ルニ斯ノ如ク總區排水着手ガ一時間モ早過ギタルコト(三)船腹前進ヲ行フニ當リ蒸汽ノ力量餘裕ナキコトニ氣付カズシテ揚錨機ニテ强引ヲ爲シタルタメ排水力ニ影響ヲ生シタルコト。

假防水

五月八日淺間離礁セシヨリ同十日マデ引續キ喞筒全力ヲ以テ排水シツヽ外底ノ破孔ニ防水蓆ヲ當テ又ハ帆布ヲ丸メテ押込ム等大活動ノ末漸ク漏水減少シ喞筒三臺ヲ以テ内底上二呎ノ深サ迄ニ浸水ヲ維持シ得ルニ至レリ。

固有喞筒の使用

外底假防水次第ニ効果ヲ現シ艦ヲ傾斜スレバ内底ヲ露出セシメ得ルヲ以テ本艦固有ノ主送水機喞筒及「ビルヂ」喞筒ヲ使用シ始ム。

船體損所概略

(一)艦首摩擦損傷部ニ於テ内底ハ竪龍骨屈曲シ微少ノ漏水アルモ前部浸水區内底上ニ浸水スルモノハ主トシテ罐室ヨリ隔壁ヲ透ジテ來ルモノナリ。

(二)前罐室ハ内底隆起シ同室ノ後部ニ至レバ第二「ロンヂ」ニ沿フテ隆起シ高サ概ネ一呎ナリ而シテ構造上内底ニ抵抗アル部分(罐臺ノ下又ハ石炭庫壁ノ下等)ノ内底隆起比較的小ナルモ其ノ代リニ肋骨ノ屈曲甚シ二重底内ニ人ノ入リ得ル所ハ前方三分ノ一ノ區域ノミ其ノ他ハ「マンホール」ヨリ見ルニ高サ二呎九吋アルベキ肋骨ガ屈曲シテ高サ一呎以内トナリ居ルモノ多シ堅牢ナル「ロンヂ」ト雖モ高サ二呎以上ニテ存スルモノ稀レナリ罐前内底隆起ノ部ハ兩舷共ニ數多ノ鋲切斷シ「ラップ」開口ス其著シキ所ハ長サ十呎幅二吋ニ達セリ肋九十九番ノ隔壁ノ前方ニ於テ罐下ニ三ケ所重大ナル内底ノ横切レアリ罐下ハ堅牢ナルニ拘ハラズ斯ル横切アルハ善ク善ク强キ壓力ヲ受ケテ緊張サレタルモノナラン又九十九番隔壁ノ下部ト内底ト嚙ミ合ヒテ内底剪斷サレ又ハ隔壁曲レル所

アリ諸管裝置概ネ破損ス。

(三)後罐室ニ至レバ損害ハ一層大ナリ罐室ノ隆起ハ二呎ヲ超ヘ內底「ラップ」開口モ右舷長十呎幅四吋左舷長三十呎幅八吋ナルモノアリ鋲切斷ノ數モ亦多シ其他內底ハ諸所ニ於テ二重底內ノ强キ構成材料ノ爲メ突キ破ラレタル所多シ灰放射器用海水管艦底「ヂスタンスピース」ハ左舷ニテハ二呎程內底ニ突出シ右舷ニテハ四吋程內底ニ突出ス外底ガ如何ニ內底ニ接近シ居ルカヲ想像スルニ餘リアリ而シテ罐下ハ內底ニ諸種ノ破損凸凹アリ一見多ク突上リ居ラザル如キモ之ヲ防禦甲板下面ヨリ計ルトキハ罐ト諸共ニ二呎位上リ居ルコトヲ知ルナリ十一號罐ノ「スチームドラム」ハ隔壁ニ押サレテ「クラック」ヲ生ズ內底外底ハ接近シテ殆ンド二枚ガ一枚トナリ居ルガ如シ水防肋骨モ水防「ロンヂ」モ最早ヤ水防ノ用ヲ爲サズ。

(四)罐室ノ中央縱通隔壁下部大破シ腰ヲ折リテ二三呎高サヲ減ズ此附近ニテ外底ノ凹ミハ五呎ヲ超ユルナラン。

(五)罐室機械室間隔壁ノ破損ニ至リテハ更ニ甚シク船體强度上最モ憂フベキモノアリ隔壁屈曲シテ支持力ヲ減シ其下部破滅シテ內底トノ連絡切斷シ船ノ强力ハ單ニ外底ノミニ殘ルコトトナレリ然ルニ外底甚シク屈曲シ居ルヲ以テ此モ賴ミ少ナキモノナリ淺間ハ此ノ隔壁ニ於テ內底モ「ロンヂ」モ縱通セズ鋲ニテ行キ止マル樣構造シアルハ此際遺憾トスル所ナリ。

(六)機械室ニ於テハ中央縱通隔壁ガ下部ニ於テ屈曲シ居ルモ其他ハ內底ニテハ一見著シキ變形ヲ呈セズ左レド機械ノ曲肱軸等ニ可ナリ大ナル中心移變ヲ生ジ居ルニ徴スレバ內底モ少ナカラザル變形アルコトヲ知ル二重底內ヲ檢スルニ肋材縱通材曲リテ高サヲ減ズルコト約一呎半乃至三呎ナリ主疏水管扁平トナリ或ハ切レ或ハ破レ全ク位置ヲ變ズ內底「ビーム」ノ多數ハ第三「ロンヂ」ノ內側ニ於テ切斷セリ此レ中央ハ「エンジン」ノ重キニ壓セラレテ多ク突キ上ラズ第二「ロンヂ」ヨリ第三「ロンヂ」マデ小區域ニ於テ無理ニ內底突キ上ゲラレタル爲メ「シーア」サレタルモノト認ム「エンジン」モ三吋位ハ突キ上リ居ルナラン。

(七)機械室縱通隔壁並ニ後方ノ橫隔壁モ屈曲アリテ水防不良ナリ罐室機械室附近ノ大破損ニハ比スベクモナケレ

ドモ此モ可ナリ大ナル破損ナリトス。

(八)外底破孔ハ肋百二十五番附近及肋百四十七番附近ニ於テ最モ多ク且ツ其ノ區域廣シ。

(九)其ノ他損害雜多ナルモ略ス防禦甲板以上ニ於テ坐礁中船首懸垂並ニ兩側垂下ノ影響ヲ受ケ屈曲又ハ龜裂セル所アリ「ウネリ」ニ動搖スルトキ船體變形スル響キヲ聞ク所ハ肋百二十五番隔壁並ニ九十九番附近最モ著シ「ビルヂキール」舵及推進器翼モ毀損アリ。

機關損害

機關部損害モ亦大ナリ内底突上リノ結果罐据付ケ歪ミ或ハ水「ドラム」押シ潰シ就中後罐甚シ主機械ハ氣筩自身ハ破損ナキモ附屬管弇控條等殆ンド完全ナルモノナク「クランク」ハ中心ノ歪ミ四分ノ三吋アリ補機ニモ損害アリ。

修理方針

修理ニ關シ五月十六日左ノ如ク方針ヲ定ム。

船體ノ部

(一)外底破孔ヲ應急ニ塞グコト。

(二)内底ハ堅牢ナル水密及補強工事ヲ行ヒ艦ノ安全ハ主トシテ内底ニ信頼スル樣ニスルコト。

(三)隔壁其ノ他ノ損所ハ出來得ル限リ補強スルコト。

(四)隔壁下部其ノ他ノ損所ニシテ鐵工事ヲ施シ難キ所ハ「セメント」ヲ以テ充分ニ積ミ硬ムルコト。

但シ強ミノ爲メ要スル所ハ鐵條又ハ山形等ヲ以テ鐵筋「セメント」工事トスルコト。

(五)二項ノ内底工事竣工ノ後チ外底破孔當金工事ヲ行フコト。

(六)直接本邦ニ回航シ得ル程ニ強度ヲ與フルヲ以テ工事ノ主眼トス竣工ノ後チ已ムヲ得ザルトキニ限リ入渠スベキモ最近船渠所在地ガ七百海里ヲ隔ツルニ鑑ミ最モ遠航性ノ補強ニ注意スルモノトス。

機關ノ部

(一)前罐七罐(七號罐缺)ヲ最大使用壓力百二十听ニテ使用シ得ル樣ニスルコト。

(二)後罐ハ艦ノ動搖ニ對シ顚覆セザル樣ニスルコト。

(三)兩舷主機械ハ各筩及滑弁內部其他各滑動部開放檢査ノ上手入及修理ヲ行フコト。

(四)右舷主機械ハ特ニ曲肱軸承ノ偏心大ナルニヨリ同時ニ各接合棒及偏心器帶輪ヲ取外シ曲肱軸承ノ偏心ヲ成ルベク減ズルコト。

(五)蒸汽管排氣管疏水管給水管及罐氣吹用壓搾空氣管ハ豫定ノ航海ニ必要ナル應急工事ヲ施スコト。

(六)豫備給水「タンク」ハ五、六、七及八番上部庫ヲ使用スルコトトシ相當ノ設備ヲ新設スルコト。

(七)推進器翼端ノ屈曲部ヲ切リ除クコト。

排水裝置ノ部

(一)主汚水吸入管及六吋汚水吸入管共ニ甚シク破損シ應急修理ノ見込ミナキヲ以テ本諸管ニ依ラズ各區劃獨立排水法ヲ行フ樣ニスルコト。

(二)救難喞筒ハ「ペルソメーター」三臺ヲ撤去シ其他ノ救難喞筒ヲ据置キ本艦固有ノ罐ニテ使用シ得ル樣蒸氣及排氣管ヲ導キ以テ夫々ノ區劃ノ大排水ニ適セシムルコト。

(三)內底上汚水ノ排除ニハ車軸通路及曲肱坑內ハ機械室汚水喞筒ヲ以テシ後罐室ハ同室裝置ノ補助給水喞筒及灰放射機ヲ以テ、前罐室ハ後罐室裝備ノ灰放射機ヲ以テスルコト。

船體修理實施方法

事業方針ハ入渠セズシテ出來ル限リ充分ナル工事ヲ行フニアリ航海目的地ノ何レナルヲ問フコトナシ唯最善ヲ盡サンノミ而シテ先ツ左ノ如ク修理計畫ヲ定メ之ヲ實施ス。

(一)先ヅ內底工事ヲ行フニ差支ヘザル程度ニ外底假防水ヲ爲スモノトス機械室下ノ大破孔ハ此ノ目的ヲ以テ古帆

布古毛布古麻袋古疊等ヲ新帆布ニテ包ミ厚サ一呎五吋位ノ防水用「マット」ヲ作リ之ヲ大破孔ニ當テ六吋角ノ木材ヲ「ワイヤロープ」ニテ密列ニ簾ノ子ニ連ネタルモノヲ以テ被ヒ船體大廻シニ引キ締ムルモノトス。

(二)内底ハ破孔ニ當金ヲナシ鋲不良ノモノハ「タツプ」ニ取換ヘ修理シタル上ニハ「セメント」ヲ置クコト。

(三)肋百二十五番隔壁附近ハ船體强度ヲ失フコト最モ大ナル所ナルヲ以テ是非共之ヲ補强スルヲ要ス然ルニ外底屈曲甚シキヲ以テ外底ヨリ補强材ヲ有效ニ取付クルコトハ不可能ナルヲ以テ先ヅ主トシテ左ノ如ク艦内ヨリ工事ヲ施スモノナリ。

(イ)横隔壁ト外底トノ連絡破滅セル所ハ「セメント」ヲ塡充スルコト。

(ロ)罐室内底ト横隔壁ト連絡切レ居ル所ハ變形又ハ割レノ爲メ再ビ山形材ヲ以テ繋グコト能ハズ故ニ鋼板ヲ矩形ニ曲ゲタルモノニテ繋グコト。

(ハ)罐臺頂ヨリ出ヅル鋼板ト横隔壁トノ連絡ハ悉ク切レ居リテ再ビ山形材ヲ以テ繋グコト能ハズ故ニ鋼板ヲ矩形ニ曲ゲタルモノニテ繋グコト。

(ニ)機械室二重底ノ縦通材アル所ニ對シテ罐室内底上ヨリ鋼板ヲ立テ横隔壁ヲ透過シテ之ヲ縦通材ニ取付クルコト但シ「センターライン」ノモノハ假令曲リ居ルトモ之ヲ切リ外スコトナク當金又ハ鋲直シニスルコト。

(ホ)横隔壁ノ「スチフナー」ノ罐室側ノモノハ出來得ル限リ罐室内底上ヨリ「ブラツケツト」ヲ立テ「スチフナー」ニ取付クルコト。

(ヘ)(ニ)ト(ホ)トノ間ガ二呎以上距ツルトキハ別ニ罐室内底上及機械室内底下ヨリ鋼内板ヲ立テ横隔壁ヲ狹ンデ「ブラツケツト」ヲ設クルコト。

(ト)前記各「ブラツケツト」並ニ竪鋼板ハ其ノ上端前端又ハ後端ニ於テ堅牢ナル構造アルトキハ之ニモ取付クルコト。

(チ)前記各「ブラツケツト」ニハ諸所ニ山形ノ「ラグピース」ヲ附シ「セメント」ノ抵抗物トスルコト。

（リ）兩端ヲ曲ゲタル多數ノ山形材ヲ罐室内底上ヨリ機械室二重底内ニ差シ渡シ之ヲ「セメント」ノ鐵筋トスルコト。

（ヌ）罐前ニハ横隔壁ヨリ約四呎ヲ隔テヽ横隔壁ニ平行シテ鋼板ヲ以テ高サ一呎半位ニ堅牢ナル「セメント」圍ヲ立ツルコト。

（ル）以上ノ工事ヲ充分ニナシタル上ハ横隔壁ノ兩面ヨリ固ク「セメント」ヲ積ミ之ヲ包ミ込ムモノトス但シ「セメント」ニ「エキスパテンドメタル」ヲ混ジ鐵筋ニスルコト。

（ヲ）機械室内底以上ニテ横隔壁屈曲シ居ル所ハ數多ノ「スチフナー」ヲ斜メ又ハ竪ニ附スルコト。

（四）九十九番ハ艦ノ中央部ニシテ强度上大切ナル所ナリ隔壁ハ大曲リニ曲レリ内底ハ横割多ク平當金ヲ破損ノ形狀ニ合ハセテ曲ゲ作ルコト難ク之ヲ作ルトテモ强ミニ於テ滿足シ難シ山形鋼ヲ曲グルコトハ工作船ノ手ヲ以テ自在ニナシ得ルヲ以テ之ヲ應用シテ補强スルモノトス。

（イ）横割レヲ悉ク渡シテ破損ノ形狀ニ山形鋼ヲ曲ゲテ一呎毎ニ縱通ニ取付ケ之ニ高サ一呎以上ノ長キ鋼板ヲ立テ（鋼板厚サ四分ノ一吋）其ノ上緣ニモ山形鋼ヲ取付ケ「ガーダー」トナシ九十九番隔壁ト内底トニ緊着スルモノトス隔壁ノ下部ニ於テ内底ノ切レタル部分ハ隔壁ヲ切リ拔キテ「ガーダー」ヲ通リ拔キトシ隔壁ヲ「ガーダー」ノ上ニ据エルガ如ク取付クベシ。

（ロ）隔壁下部ニ前記「ガーダー」ノ取付カザル所ハ隔壁一呎毎ニ「ブラツケツト」ヲ設クベシ。

（ハ）前記（イ）（ロ）ノ工事ヲ「セメント」ヲ以テ積ミ堅ムルモノトス。

（ニ）隔壁裂目ハ當金ヲ施シ通路ノ扉ヲ新規ニ造ルコト。

（ホ）隔壁大曲リノ部ニハ深サ一呎ノ「スチフナー」ヲ縱横ニ取付クベシ。

（五）中央縱通隔壁ノ修理方法ハ左ノ如シ。

（イ）罐室縱隔壁ハ腰折レ居ル所ニ全然「セメント」ヲ詰メ込ミテ堅メ而シテ約三呎毎ニ隔壁ノ兩側ヨリ木材支

柱ヲ以テ隔壁ノ支持力ヲ維持スルコト。

(ロ)機械室縱隔壁ハ下端ノ「バウンダリーアングル」ヲ取換ヘ右舷側ヨリ「ブラッケット」ヲ取付ケ左舷側ヨリ「スチフナー」ヲ取付ケ隔壁下部ニ「セメント」ヲ積ムコト。

(ハ)隔壁ノ大曲リノ所ニハ斜メニ「スチフナー」ヲ附スルコト。

(六)罐臺ノ破損ハ當金ニテ補强スベシ。

(七)外底ハ理想トシテハ凹ミタル艦底ニ肋骨ヲ並列シテ其ノ上ヲ鋼板ニテ被ヒ恰モ外底ノ下ニ更ニ二重底ヲ附スル如クセントス然レドモ海上「ウネリ」多キ爲メ到底斯ク丁寧ナル工事ヲ遂行シ難シ但シ一部分ニテモ實行スルトシ左ノ如ク施行ス。

(イ)百二十五番下ニ二個九十九番下ニ二個ノ箱形補强材ヲ取付クルコト補强材ハ底板ハ厚サ二分ノ一吋ノ鋼板トシ側板ハ四分ノ一吋ノ鋼鈑トシ巾三呎深サ三呎(凹ミノ形狀ニ依リ增減)長サ二十呎トシ水切リノ爲メ前後端ニ丸ミヲ付ケタル長キ箱ニシテ艦底トノ取付ケハ三吋三吋ノ山形ヲ以テス取付用「タップ」ハ心巨約四吋トス。

(ロ)機械室下並ニ水雷室下ノ大破孔ニ對シテ特ニ二重底式理想ヲ以テ施行スベキモ事情許サヾルヲ以テ現在ノ假防水材ヲ其儘トシ上ヨリ大當金ヲ以テ被フベシ機械室下ノ當金ハ約二十三呎半角ナリ此當金ハ六枚ヨリ成リ各々山形鋼ノ「フランヂ」ニテ「ボルト」連結トナルモノニシテ一枚ヅヽ艦底ニ運ビ並ベテ取付クルモノトス。

(八)舵ノ下端破損部ハ「ボルト」締メトナシ開口ヲ增サヾル樣ニスルコト。

救難罐撤去ニ至ルマデノ排水狀況

五月八日離礁後最初ノ兩三日間ハ多大ノ漏水アリテ吸込ミ甚ダ强ク潛水工モ迂濶ニハ破損ニ近ツク能ハズ然ノミナラズ罐用トシテ一時間十噸ノ淸水ヲ要スル有樣ナリシガ前キニ述ベタル如キ方法ニテ急速ノ假防水ヲナシテ

大漏水ノミヲ防止シ置キテ内底ノ修理ヲ行ヒ内底工事竣工シテ艦内ニ漏水セザルニ至ラバ外底破孔ノ假防水ヲ放ツモ危險ナル吸込ミナクナルヲ以テ然ル後チ外底大破孔ノ修理工事ヲ行フ順序トセリ假防水ハ實ニ應急處置トハ雖モ最モ意ヲ用ヒテ施行シタリ然レドモ倘何所ヨリトモ知レズ尠ナカラズ漏水アリ爾來主送水機一臺（力量千六百噸）補助給水機一臺（力量四十五噸）及灰放射機喞筒一臺（力量約五十噸）合計千六百九十五噸ノ力量ヲ以テ間斷ナク排水シ今日ニ至レリ六月十日事故ナキトキハ艦ヲ傾斜スレバ内底ノ片舷ヲ乾スコトヲ得テ先ヅ好都合ナレドモ時トシテハ假防水材ノ一部自然毀損シテ不意ニ漏水ヲ增シ或ハ喞筒吸入管ニ妨害物吸付ク等突然排水力ニ異狀ヲ呈シ艦内增水シテ内底ノ工事ヲ中止スルコトアリ事業ノ進捗ニ少ナカラザル阻害トナレリ然レドモ今ノ場合已ムヲ得ザルコトナリ相當ノ手當ヲ行ヘバ平常ニ復スルコトヲ得ベク左シテ憂フルニ足ラザルコトヲ確カメタルヲ以テ浮揚用トシテ上甲板ニ据付ケタル罐ハ六月十日ニ之ヲ撤去シ畢レリ。

救難喞筒据換

前部浸水區ハ二重底内七十三番隔壁ニ接シテ「セメント」塡充ノ結果全然漏水ナクナリタルヲ以テ同區ニ備ヘタル百噸喞筒ヲ取外シ之ヲ後部浸水區ニ備フル爲メ後部彈藥通路ニ据付ヲ行フ而シテ後部浸水區ノ千噸電働喞筒ハ不要トナルヲ以テ之ヲ撤去セリ又罐室ニ備ヘタル四個ノ七百五十噸喞筒モ彈藥通路ニ据換ヘ罐室ノ排水ニ備フ七月五日之ガ試運轉ヲ行ヒタルニ成績良好ニシテ容易ニ二重底内ノ水ヲ吸ヒ上ゲ罐室内底ヲ乾スコトヲ得タリ工事進捗上ニ至大ノ便宜トナリタリ。

百二十五番ノ修理竣工

百二十五番ニ於ケル工事ハ修理工事中ノ最モ重要ナルモノトス本工事七月十七日竣工シタルヲ以テ機械室二重底水壓試驗ヲ行フ其ノ方法及成績左ノ如シ。

（一）機械室内底諸孔ヲ閉鎖ス。

（二）罐室救難喞筒ノ運轉ハ平常ノ通リ一臺ニシテ「ホース」一本トス。

(三)主送水機喞筒運轉ヲ停止ス。

(四)機械室二重底内ニ滿水シ外壓ヲ受ケシムルコト二時間ヲ過ギテ罐室二重底ニ少シク增水ノ傾向アリ但シ罐室ノ救難喞筒平常ノ通ニテ制御スルコトヲ得此ノ增水ハ「クランクピット」下ニ於テ「セメント」塡充堰止メ方ガ工事困難ナルタメドウシテモ充分ニ行カザリシニ由ルモノト認ム。

(五)中央隔壁ニ接スル部分ニ於テ罐室内底下ニ透過スル水アリ但シ少量ニシテ之ヲ適宜ノ所ニ溜リヲ作リ吸取ル樣ニスレバ可ナリ此ノ漏水ハ中央隔壁ト百二十五番ト十文字ニ交叉スル部分屈曲複雜ニシテ二重底内ヨリ「セメント」ヲ施スニ當リ其天井則チ内底下面ニ於テ充分ニ行カザリシモノト認ム。

(七)試驗時間五時間ノ後主送水機ノ運轉ヲ開始シ試驗ヲ終ル。

九十九番ノ竣工

百二十五番ニ次ギ重要ナル艦内工事ハ九十九番トス本工事七月二十六日竣工ス。

罐室ノ修理竣工

隔壁及罐臺ノ修理竣工シ前後罐室ハ豫定ノ應急修理終リヲ告ゲタルヲ以テ水壓試驗ノタメ八月三日罐室排水ヲ停止シ罐室ノ二重底ニ滿水シ内底ニ海面水壓ヲ受ケシメ維持スルコト三時間ナリ其成績左ノ如シ。

(一)九十九番隔壁ニ附シタル「ブラッケット」取付山形ノ隙ヨリ筆ノ軸程ノ緩漫ナル漏水數個所アリ。

(二)罐臺ノ根ヨリ指ノ尖程ノ噴水三個所アリ。

(三)内底「セメント」ノ肌ヨリ濕ミ出ヅル所一個所アリ。

其他異狀ナシ水壓ヲ撤去シ乾燥シタル後チ「セメント」ヲ以テ漏水個所ヲ丁寧ニ繕ヒタリ。

機關修理竣工

離礁後機關部修理着々進捗シツツアリシガ六月二十一日摺合運轉ヲ行ヒタル結果機械ハ長途ノ航海ニモ差支ナキ見込立テリ更ニ八月十日繫留運轉ヲ行ヒ一層其ノ所信ヲ强フシ茲ニ機關部竣工ヲ告ゲ船體工事竣工ヲ待チ港外

試運轉ヲ行フコトトス。

內外工事竣工

八月十五日艦內諸部工事竣工ス八月十八日外底工事竣工ス機械室下ノ大當金ハ吸ヒ付キノタメ弓形ニ曲リ中央約六吋反リ上リテ內部ノ假防水木材ニ押シ當リタリ元來構造弱ケレバ是非ナキコトナリ。

罐室排水裝置

內底ノ「マンホール」ヲ閉シ二重底ニ滿水セシムルコトハ內底ノ爲メ望マシカラズ故ニ罐室二重底ノ漏水ヲ排出スル爲メ少ナクトモ喞筒ノ「ホース」二本ハ「マンホール」ニ差入レ置クヲ要ス但シ若シ漏水「マンホール」ヲ溢レ出テタル場合ニ堰止メトナルモノナキトキハ漏水直ニ內底上ニ汎濫スルヲ以テ之ニ備フル爲メ「マンホール」四個ニ圍ヒヲ附ス此ノ圍ヒハ萬一ノ必要ナル場合其ノ「マンホール」ヲ閉スニハ支障ナキモノトス其ノ他罐室ニ備ヘアル救難「ホース」ト合計二十本皆內底上ニ止メ置キ要スル時直ニ使用シ得ベカラシム。

港外試運轉

八月二十一日港外試運轉ヲ施行ス其ノ成績左ノ如シ。

(一)午前六時二十分出港午後零時五分歸港投錨ス。

(二)早朝驟雨アリ忽チ晴快シ虹鮮カナリ(サ港百五十日雨ナク曇ダモナカリキ我等未ダ曾テ此ノ如キノ瑞相ヲ見ズ)風力二乃至三海面靜穩ナレドモ長濤アリ高カラザルモ幅ハ約船長ノ三分ノ一ナリ。

(三)機械最高回轉數五十六一時間繼續シ此ノ間速力六乃至六、四節ヲ示セリ。

(四)應急修理觀測。

(イ)船體應急修理ノ部異常ナシ。

(ロ)機關應急修理ノ部異常ナシ。

(ハ)船體構造上憂フベキ震動ナシ。

(ニ)操舵裝置故障ナシ。

(ホ)漏水ノ狀況ハ碇泊中ト大差ナク罐室ニ於テハ時々五號若クハ八號救難喞筒一臺ヲ運轉シ「ホース」二本ヲ以テ容易ニ二重底內ノ浸水ヲシテ內底以下ニ制御スルコトヲ得タリ機械臺ニ於テハ主送水機一臺百八十回轉ニテ浸水ヲ內底下約三呎ニ制止スルコトヲ得タリ罐室機械室共ニ是レ以上漏水增加ノ模樣ナシ。

(ヘ)航走速力ハ五、五節(五十二回轉)ト定ムルヲ現狀ニ適スルモノト認ム炭費一日五十五噸ノ割。

試運轉ノ成績ニ就キ所見

(一)機械ハ試運轉ノ成績ニ徵スルトキハ頗ル良好ニシテ此ノ上特ニ修理ヲ行ハズシテ本邦回航ニ堪ヘ得ルモノナリ。

(二)船體強度ハ肋百二十五番及九十九番ノ連結工事ニ最モ意ヲ用ヒタルモノナルガ試運轉ノ結果ニ見ルトキハ本工事ハ仕直シヲナサズシテ本邦回航ニ堪フルモノト判斷ス其ノ他艦內ノ工事ハ仕直シヲ要セズ。

(三)外底ハ思ヒシ程弱カラズ漏水ハ充分ニ止メ得ザルモ喞筒ノ備ヘ充分ナルヲ以テ懸念ナキモノト判斷ス然ノミナラズ萬一ノ場合ハ內底「マンホール」ヲ閉鎖シ內底ニ信賴スルノ計畫ナルヲ以テ近海航行ニハ差支ナシ故ニ試航海ヲ兼ネ海岸ヲ航海シテ海面靜カナル港ニ至リ潛水工ノ手ヲ增シ外底ノ追補改良工事ヲナサバ外底モ入渠修理ヲ要セズシテ本邦回航ニ堪ヘ得ル程度ニ爲シ得ル見込アリ。

(四)外底ノ追補改良工事トハ一層嚴密ニ外底不良箇所ヲ調査シ之ニ當金ヲナスコト機械室下ノ大當金ヲ取外シ肋骨ヲ有スル堅牢ナル當金ニ改ムルコト四個ノ箱形補強材ヲ延長スルコト其ノ他總テ箱形ノ當金ニ水切ヲ附シ出來得ル限リ航海抵抗ヲ減少セシムルコト等ナリ。

今後ノ方針

假修理ノ成績豫期以上ノ好果ヲ收メタリ今後修理ヲ要スル所ハ外底ノミナリ前記ノ所見ニ依リ今後ノ方針ヲ左ノ通リ定ム。

（一）試航海ヲ兼ネ約千五百海浬沿岸航海北上スルコト。
（二）潜水工增派ヲ東京ニ請求スルコト。
（三）目的港ニ到着セバ外底ノ追補改良工事ヲ行フコト。

サンバルトロメノ名殘

サンバルトロメハ俗ニタートルベイト稱シ灣內蠣鍋多ク集ル山ニ樹ナク野ニ水ナシ殺風景ニシテ人生慰安ノ用トナルモノナシト雖モ氣候温和ニシテ四季春ノ如ク年中降雨稀レニシテ風土概ネ健康ニ適ス故ヲ以テ滯在百五十日工作部一同ノモノ幸ヒニ苦患ナキヲ得タリ我等今日此ノ地ニ名殘ヲ惜ム。

大試運轉

八月二十三日午前五時出發八月二十六日午後豫定ノ所ニ假泊シ淺間艦底檢査ヲ行フ不良「ボルト」三本發見シ取換ヲ爲ス最初ヨリ不完全ナリシ「ボルト」ト認メタリ其ノ他異狀ナシ。

八月二十九日同三十日波荒シ異常ナシ。

九月一日長濤甚ダ大ナリ長サ船ノ長サノ約二分ノ一左舷前方ヨリ來ル淺間ガ之ニ比スベキ長濤ニ會シハ出征以來唯一度ナリト云フ船體ノ激動强キモ更ニ異常ナシ。

九月三日長濤大ニシテ九月一日以上ナリ艦ノ「ローリング」傾斜最大十七度船體機關異常ナシ九月四日無事目的港ニ着ス航程千五百浬茲ニ豫定ノ大試運轉ヲ終レリ回航中機械回轉數五十二速力六海里弱約一千馬力炭費英炭一日五十五噸ナリ。

機械室下當金取外

サンバルトロメニ於テ行ヒタル機械室下ノ舊大當金ヲ取外シ檢スルニ周圍ノ竪板ノ高キ所ニ於テ挫ケ居ルハ面白カラザル結果ナリ其ノ他ハ憂フベキ變形ナク且ツ取付「ボルト」ノ螺旋部モ異狀ナシ。

機械室下破孔眞相

機械室下ノ破孔ハ爾來眞相不明ナリシモ玆ニ始メテ眞實ヲ見取ルコトヲ得タリ其ノ他外底一般ニ新發見ノ損所モアリ外底破孔ノ眞相ハ實ハ此ノ時ニ至ツテ漸ク明カニナリタルモノナリ。

「ニユーマチツクドリル」ノ使用

潛水工ヲシテ「ニユーマチツクドリル」ヲ使用セシムルコトトシ之ニ要スル氣蓄器空氣壓搾機及發電機九月二十六日据付ケ終ル。（サンバルトロメニ於テハ艦內工事用トシテ「ニユーマチツクドリル」ヲ使用スルニ付キ淺間ノ罐ヲ氣蓄器トシテ利用シタリシモ潛水工ニ使用セシムルニハ充分ノ設備ナカリシナリ）。

艦底修理追補改良方案

軍艦淺間北上後艦底修理方案ヲ左ノ如クス。

（一）離礁前ニ行ヒタル前罐室下左舷ニ於ケル當金ハ其儘トス。

（二）九十九番下ニ於ケル二個ノ箱形補强材ハ之ヲ前後ニ各八呎延長シ補强ヲ兼ネ水切ヲ善良ナラシム。

（三）百二十五番下ニ於ケル二個ノ箱形補强材ハ之ヲ前後ニ各八呎延長シ補强ヲ兼ネ水切ヲ善良ナラシム。

（四）百二十五番附近兩側ニ於ケル梯形當金ハ其儘トス。

（五）機械室下ノ舊大當金ハ之ヲ取外シ「取付ケ穴」ノ跡ハ今マデ取付ケアリシ山形鋼ノ下緣ノ「フランジ」ヲ切リ去リテ之ヲ元ノ通リニ締付ケ穴塡メトナスコト。

大當金ヲ取外シタル跡ノ大破孔ハ出來得ル限リ周圍ノ小穴ヲ平當金ニテ塞ギ平當金不可能ノ大破孔ヲ修理スル方法ハ外板ニ相當ノ間隔ニ肋材ヲ設ケ之ヲ當金ニテ被ヒ宛モ船ガ三重底ニナレルガ如ク構造ス而シテ艦底ノ凹ミヲ均塡スル如キ高サトシ其ノ前後端ハ板ヲ曲グルノ困難ヲ厭ヒテ箱形トナスコトナカルベシ是非共傾斜水切リノ構造トナス當金ノ兩側モ出來得ル限リ傾斜シ竪板ノ高クナラザル樣ニス而シテ當金ノ中ニハ木材ヲ充實ス。

六、後部水雷室下ノ大當金ハ機械室下ノ夫ノ如ク面積大ナラズ高サモ高カラズ內部ハ假防水物モ軟カキモノ多カ

ラズ一體ニ少シハ弓形ニ押上リ居レドモ何レノ部分モ傷メラレ居ラズ且ツ此ノ所ハ艦底ノ凹ミモ甚ダ大ナラズ若シ機械室ノ當金改造方法ニ習ッテ本當金ヲ改造セバ寧ロ現在ノ當金ヨリモ高キモノトナリ水ノ抵抗增加セン現在ノモノニテ異狀ヲ呈セズトスレバ當金改造ノ必要ナシ故ニ本當金ハ取換ヲ行ハズ。

但シ取付ケヲ一層確實ニスルタメ增「タップ」ヲ行ヒ且ツ前後ニ木材ヲ以テ水切リヲ作ル。

(七)後部龍骨ノ破損ハ現在ノ塡木ノ上ヨリ箱當金ヲ行フ其ノ前端ハ水雷室下ノ當金ニ衝接シ後端ハ板金ヲ傾斜シテ水切形トス。

(八)外底ノ割目、裂目又ハ鋲不良ノ繼目、等各々肌ヲ合セタル平當金ヲ行フ。

(九)九十九番並ニ百二十五番附近ノ外底ハ以上行ヒタル當金ヲ以テ要部ヲ充滿スルヲ以テ此レ以外ニ補强材ヲ取付クル必要ナシ。

(一〇)其他艦底凹ミ多キモ破孔ハナシ强度上懸念ノ部諸所ニ木型ヲ取リテ檢スルニ補强材ノ特ニ必要ナリト認ムベキ箇所ナシ。

(一一)舵ノ破損部ハ增シ「ボルト」ヲ行フ。

(一二)艦內艦底ヲ論ゼズ「ボルト」又ハ「タップ」締メノ所及支柱ハ至細ニ檢査シ苟モ弛ミアラバ之ヲ締メ直ス又艦內「セメント」不良ノ箇所アラバ之ヲ繕フ。

工事竣工

淺間艦底工事方案ノ通リ十月二十日竣工ス。

外底破孔數六十餘ニ對シ當金ノ數五十四其ノ總面積一千〇四十四平方呎ニ達ス。

工事成績

之ヲサンバルトロメ出港ノ際ニ於ケル狀況ニ比スルニ吃水增加シ居ルニ拘ハラズ浸水制禦ノタメ常時運轉スル喞筒ハ先キニ一時間約千噸宛ノ排水ヲ要セシモノガ今ハ約六七百噸宛ノ排水ヲ續行スレバ足ルコトトナレリ潛水

難工事ノ事トテ期待ニ達セザリシハ遺憾ナリ唯以前ヨリハ善良ナルコトヲ以テ滿足セントス補強ハ淺間工事ノ主眼ナレバ勿論豫期ニ達ハザルモノナリ「ボルト」一本ト雖モ余等ガ思ハク通リナラザルモノナシ。

軍艦淺間横須賀回航

淺間、關東ハ十月二十三日午前十一時出港横須賀回航ノ途ニ就ク淺間ヲ先頭ニ單縱陣ニテ航行シ其速力及距離左ノ如シ。

原速	淺間ノ回轉	六十	(約七節)
徵速	同	三十	(約三節)
距離	六百乃至千米突		

某島マデ

十月二十四日、二十五日、二十六日引續キ荒天風力八乃至九波浪高シ淺間ノ「ローリング」傾斜二十七八度ニ達ス三十一日マデ長濤彌々大ナリ其後靜穩トナル。

某島着淺間檢査(右舷主機「クランクピン」切斷)

十一月七日午後二時其附近ニ着投錨ス。

船體ハ艦內外底共ニ異狀ナシ。

機關ハ右舷機第二低壓「クランクピン」ガ「クランクアーム」ノ根元ヨリ切斷シ居タリ此處ハ外底破損多カリシ所ニシテ中川潛水工組長ノ吸付ケラレタルモ此ノ附近ナリ本機ハ離礁後修理ニ際シ嚴密ニ檢査ヲ遂ゲタルモノニシテ當時「クランク」ニ疵ヲ認メズ其後良好ノ狀態ヲ持續シタリ然ルニ布哇着ノ二日前ヨリ第八「メインベヤリング」ノ溫度高マリタルヲ以テ投錨後「メインベヤリング」檢査ヲ目的トシテ「ターニングエンジン」ヲ動カシ居ルトキ圖ラザル所ニ斯カル破損ヲ發見セリ此ハ曩ニ已ニ內含的龜裂アリシモノカ或ハ前ニハ缺點ナカリシモノガ此度ノ航海中ニ毀損シタルモノカ詮議ハ暫ク措キ修理工事ニ着手ス。

防水作業

漏水ヲ一層減少セシムル目的ヲ以テ此際木楔鋸屑、獸脂等ヲ用ヒ外底ノ細目防水法ヲ行ヒシニ其結果機械室ノ浸水程度ハ以前ノ約半分トナリ又罐室ノ浸水程度ハ以前ヨリ約四割減ジタリ。

「クランク」應急修理竣工

「クランク」應急修理十八日竣工ス近隣ノ島マデ試運轉ヲナシ而シテ後修理部ノ檢査ヲ行ヒタルニ異狀ナシ發生馬力五百五十回轉五十五以内ニテ運轉セバ今後差支ナキ見込。

出發

出發。淺間、關東愈々横須賀ニ向フ。

横須賀歸着

十二月十八日午前九時三十分淺間、關東横須賀ニ歸着ス航海中機關檢査二回異狀ナシ。

工作部ノ勤務狀況

工作部ハ淺間救難作業ノ大部タル工作ニ關スル事ヲ掌リ其所作大要以上記述セルガ如シ碇泊作業ノ日數二百十五日航海日數八十二日其里程一萬三千四百六十六浬ナリ我等ガ卒ユル所ノ技手中島三郎、板倉庄太郎、絹川政一、福島健次郎、城谷治雄、工手川名常藏、石丸作五郎、内田清次郎、蛭田鐵五郎、藤倉鐵五郎、山田藤藏及ビ職工二百六十四名一日ノ就業時間ハ十四時乃至十六時間ニシテ苦勞尠ナカラザリシカドモ聊カモ緩ム心ナカリシカバ身心共ニ壯健ニ善ク忍ビ善ク耐ヘタリ自讃ニ似タレドモ美事ト云フヲ憚カラズ。

但シ職工中公務死亡ノモノ二名公務負傷本邦ニ歸還ノモノ四名公務負傷一時的休養ノモノ三名懲戒處分ヲ受ケタルモノ三名アリ之ヲ幸者中ノ不幸者トス。

第二編　後編

本編ニハ主トシテ離礁後機關部修理並ニ救難喞筒及罐ニ關シ前編ニ記載セザリシ詳細ノ事ヲ記スモノトス。

第一章　機關修理

機關ノ損害概略

内底突上リノ爲メ機關部ノ損害モ亦タ多大ニシテ罐ノ据付歪ミ「ドラム」押シ潰シ龜裂ヲ生ジタルモノアリ殊ニ後罐室ノ損害大ナリ主機械ハ機械臺ト共ニ突キ上ゲラレ四周ノ隔壁モ亦タ突キ上リ變形シタル所アリ而シテ隔壁ト機械トヲ連絡セル管、弁、控條ハ全部破損シ且ツ機械臺自身モ歪メル爲メ筩ト筩トノ間ノ控條承モ全部破損シ曲肱軸中心線ニ歪ミヲ生ゼリ補助機械モ傾斜破損セルモノアリ艦底内外ニ導ケル諸管ハ全部破損ス今ヨリ少シク機關局部ノ損害ノ主ナルモノヲ記サン。

罐部ノ損害

歪ミノ最モ甚シキハ十五十六號罐ニシテ突キ上リ約一呎六吋ニ達ス。

十一、十三號罐ノ「ドラム」ハ中央縱通隔壁ノH形「スチフナー」ニ押サレテ損害ヲ被ムリ十一號罐ノ如キハ約八吋半ノ裂罅ヲ生ゼリ。

前罐室罐ハ後罐室罐ニ比スレバ損害少ナシ其内七、八號罐ノ損害ハ可ナリ大ナルモ應急修理ノ見込ナシトセズ後罐室ニ至ツテハ罐ハ勿論修理ノ見込ナク蒸汽主管使用不可能又ハ大々的修理ヲ要スルモノ七本アリ補助蒸汽管ニ約一呎突キ上リ切斷又ハ變曲ス。

安全弁蒸汽捨管切斷墜落シ上部ノ通風路ハ六吋位ノ凹ミヲ生ズル所多シ。

機械部ノ損害

四月二十七日坐礁中排水試驗ノ際筩ノ上部露出セルトキ防禦甲板又ハ隔壁ヨリ計測シテ筩ノ狂ヒ位置ヲ計リ更ニ離礁後五月十四日及六月十日ノ兩回計測シ三度ノ計測寸法ヲ比較セルニ艦ノ曲リガ坐礁中ト離礁當時ト離礁後

數日ヲ經過シタルトキト漸々ニ相違セシガ狂ヒノ最モ甚シカリシハ筩ガ六吋四分ノ一突キ上リシト中央隔壁間ノ距離四吋四分ノ一擴大セルトナリ。

主蒸汽管膨脹接手ハ中心線ノ狂ヒ右舷ノモノハ側面ニテ二吋八分ノ七平面ニテ一吋十六分ノ十一左舷ノモノハ側面ニテ三吋八分ノ一平面ニテ一吋十六分ノ十三ナリ。

其他主機械筩控條及同承、右舷機械室ノ中間弇取付部、主加減弇、第二低壓筩排出管伸縮接手、復水器吐捨管、左舷主送水機械筩控條取付部等破損頻々トシテ發見サレタリ。

機械室消防喞筒ハ右舷ノモノハ甚シク傾斜シ其ノ支柱ハ三本根元ニ於テ切斷サレ吸鍔二本共彎曲シ役ニ立タズ左舷ノモノハ傾斜セルモ應急修理ノ見込アリ。

右舷推進器ハ翼端六吋乃至十四吋折レ曲リ左舷ノモノハ翼端八吋屈曲セリ。

機關ノ運轉能否決定

(一)機械ハ五月八日離礁後晝夜防水排水ニ努メ五月十六日ニ到リ漸ク浸水減ジ曲肱軸水上ニ露出セリ依テ直ニ發停輪ヲ以テ「リンク」ヲ前後進ニ動セルニ何レモ重カラズ又回轉機械ニテ數回回轉セルニ兩舷機共回轉スルヲ得タリ尙ホ接合棒ノ上下兩端ヲ艏艉ノ方向ニ同所間隙ノ許ス限リ遊動セシニ此レモ又案外重カラズ其他外見上ニハ已ニ述ベタル如ク多クノ損所アレドモ何レモ運轉ノ不可能ヲ決定スル程ノ致命傷ニアラズト認メ直ニ各接合棒偏心器帶輪及主軸承上部裏金ヲ取外シ曲肱軸ノ歪ヲ檢査スルコト丶セリ。

(二)翌日(五月十七日)各開放終リ檢査ノ結果左ノ如シ。

(A)左舷機械各軸ノ接合部ニ於ケル鍔ト鍔トノ間隙差ハ前後曲肱軸ノ鍔間ニテ下部ニ千分ノ二十五吋推力軸ト中間軸ノ鍔間ニテ千分ノ三十三吋ノ隙ヲ下方ニ有シ又中間軸ト推進軸ノ鍔間ニテハ間隙等一ニシテ差ヲ認メズ。

(B)右舷機械ノ各軸ノ接合部ニ於ケル鍔ト鍔トノ間隙差ハ前後曲肱軸ノ鍔間ニテ下部ニ千分ノ五十六吋推力軸

ト中間軸ノ鍔間ニテ千分ノ二十五吋ノ隙ヲ下方ニ有シ又中間軸ト推進軸ノ鍔間ニテ下部ニ千分ノ十吋ノ間隙ヲ有セリ。

(三)罐モ前罐七欠(七號罐)ハ割合ニ損害少ナク使用狀態ニ修理シ得ベシ。

以上機械及罐ノ狀況ニ鑑ミ低速力ニテ運轉スルニ差支ナキマデハ修理シ得ルト斷定ス。

機關部修理方針

(一)前罐七罐(七號罐缺)ヲ最大使用壓力百二十听ニテ使用シ得ル樣ニスルコト。

(二)後罐ハ艦ノ動搖ニ對シ轉覆セザル樣ニスルコト。

(三)兩舷主機械ハ各筩及滑瓣內部其ノ他各滑動部開放檢査ノ上手入及修理ヲ行フコト

(四)右舷主機械ハ特ニ曲肱軸承ノ偏心大ナルニヨリ同時ニ各接合棒及偏心器帶輪ヲ取外シ曲肱軸承ノ偏心ヲ成ルベク減スルコト。

(五)蒸汽管排氣管疏水管給水管及罐氣吹用壓搾空氣管ハ豫定ノ航海ニ必要ナル應急工事ヲ施スコト。

(六)豫備給水「タンク」五、六、七、及八番上部炭庫ヲ使用スルコトヽシ相當ノ設備ヲ新設スルコト。

(七)推進器翼端ノ屈曲セルモノハ出來得ル限リ其ノ屈曲部ヲ切斷スルコト。

排水及汚水排除裝置工事

(一)主汚水吸入管及六吋汚水吸入管共ニ甚シク破損シ應急修理ノ見込ナキヲ以テ本諸管ニ依ラズ各區劃獨立排水法ヲ行フ樣ニスルコト。

(二)二重底內ハ排水法ヲ設ケザルコト。

(三)救難用喞筒ハ二號、十一號及十二號ヲ撤去シ其ノ他ノ救難用喞筒ヲ据置キ本艦固有ノ罐ニテ使用シ得ル樣蒸汽及排氣管ヲ導キ以テ夫々ノ區劃ノ大排水ニ適セシムルコト。

(四)內底上汚水ノ排除ニハ車軸通路及曲肱坑內ハ機械室汚水喞筒ヨリノ直接吸入管ヲ以テシ後罐室ハ同室裝置ノ

(補助給水喞筒及灰放射機ヲ以テシ前罐室ハ後罐室裝備ノ灰放射機ヲ以テスルコト。

(五)救難用罐ハ本艦固有ノ罐復舊セバ全部撤去スルコト。

竣工豫定期日

回航ノ爲メ絕對ニ必要ナル工事ノ外ハ嚴ニ施行セザルコトヽシ竣工期ヲ六月二十五日ト豫定ス。

修理工事ノ概要(六月二十一日第一回試運轉施行迄ノ工事)

機關部修理方針ニ基キ六月二十一日第一回試運轉施行迄ニ實施セル工事ノ主ナルモノヲ列擧スレバ左ノ如シ。

(一)前罐七罐(七號罐缺)ハ何レモ良好ノ成績ヲ以テ使用壓力百二十听ニ對スル水壓試驗ヲ終レリ。

(二)各罐共罐臺位置ニ歪ヲ生ジタル爲メ火床ノ棧受臺ハ一吋乃至三吋四分ノ三切リ取リ大床面ヲ平ニシタル後五月二十四日ヨリ六月七日ニ亘リ焚試及安全弇調整ヲ行ヘルニ滿足ナル結果ヲ得タリ。

註、罐ノ成績右ノ如ク良好ナリシニヨリ前編ニ已ニ記セル如ク救難罐ハ六月十日迄ニ全部撤去セリ。

(三)前記七罐中八號罐ハ罐臺ノ狂ヒ最モ甚タシク從テ火床ノ棧受臺ノ切斷モ最モ甚シカリシカ使用上何等差支ナキモノト認メタリ。

火床ノ棧受臺頂部切斷一覽表

切斷寸法	第一號罐	第二號罐	第三號罐	第四號罐	第五號罐	第六號罐	第八號罐
向テ右前	1 1/8″	1 1/4″	1 3/8″	2 1/4″	2″	1 3/4″	1 3/4″
向テ右後	1″	1 1/4″	5/8″	1 5/8″	1″	1 1/4″	3 1/4″
向テ左前	1 1/8″	1 1/4″	1 1/4″	2″	2 1/4″	2″	2 3/4″
向テ左後	1 1/2″	1 1/8″	3/4″	1 1/4″	1 1/4″	1″	2 1/2″

(四)假設豫備給水裝置。

在來ノ豫備給水「タンク」ハ何レモ外底破損シ且ツ內外底板ハ殆ンド相接觸セン計リニ屆曲シ常ニ潮水ノ世界ナルヲ以テ全然使用スルコト能ハズ因テ上部炭庫五、六、七、八番ヲ豫備給水「タンク」トシテ使用スルコトトシ左記要領ニヨリ諸管裝置ヲ改造急設セリ。

(A)各舷側假設豫備給水「タンク」間ニ各連絡管ヲ設ケタリ。

(B)假設豫備給水「タンク」ト主給水「タンク」間ニ連絡管ヲ設ケ且ツ補助抽氣喞筒トモ連絡セシメ以テ給水ノ昇降ニ充ツ。

(C)主復水器疏水ハ補助復水器ノミニ排出スル事トセリ。(從來ハ二重底內豫備給水「タンク」ニモ導キアリタリ)。

(D)給水吸入管ハ主給水「タンク」ノミト接續シ豫備給水「タンク」トハ接續セシメズ而シテ吐出管ハ在來ノモノヲ前後罐室間ニテ遮斷シ使用スルコトヽシ以テ前罐ノ各罐ニ何レノ給水喞筒ニテモ給水シ得ルコトヽセリ。

(E)蒸汽管疏水ハ急設管ニヨリ補助復水器ニ導ケリ。

註、排氣管疏水ハ在來ノ管裝置ヲ修理ノ上使用セリ。

(F)罐水戾管ハ蛇管接合ニヨリ前罐室給水喞筒吸入笄筺ニ接續シ同喞筒ニヨリ上甲板ニ排出シタル後更ニ蛇管ヲ以テ假設豫備給水「タンク」ニ導クコトヽセリ。

(五)後罐ヲ使用セザル結果同室內給水喞筒及灰放射器用喞筒ヲ左ノ如ク「ビルヂ」喞筒ニ利用セリ。

(A)主給水喞筒ハ船體損害最モ大ナル百二十五番隔壁ニ沿フテ据付ケアリシニヨリ同隔壁補强材特設ノ爲メ取外シ使用セザルコトトセリ。

(B)補助給水喞筒ハ何レモ後罐室前部「ビルヂ」排出用トシテ改造管裝置ヲ設ケタリ而シテ右舷補助給水喞筒ハ此ノ外ニ前罐前部所在「ビルヂ」笄筺ト接續シ以テ七十三番隔壁ヨリ前方諸區劃ノ排水ニ使用スルコトトセリ。

（Ｃ）灰放射器用喞筒ハ何レモ前罐室及後罐室ノ「ビルヂ」排除用ニ供スルコトトシ前罐室「ビルヂ」ニ限リ片舷ノ喞筒ニテモ兩舷ノ「ビルヂ」ヲ排除シ得ルコトトセリ。

（六）後罐室内ニ於ケル蒸汽主管ハ十五、十六號罐平均管ニテ押上グラレ損害多大ニシテ使用不可能トナレリ因テ前罐室ヨリノ蒸汽主管二本丈ケハ特製管ヲ以テ取換タリ。

註、後罐ハ使用セザルニ依リ後罐室蒸汽主管二本ハ其儘トシ工事ヲ施サズ。

同樣ニ他ノ蒸汽主管三本破損セルニヨリ其ノ内前罐室ヨリノ蒸汽主管二本ハ左ノ如ク工事ヲ施セリ。

（甲）管ハ水壓力二百四十听ヲ五分間以上持續スルトキハ變形部ノ一點ヨリ僅カニ水滴カ現ハルル位些少ノ漏水アリ因テ同管壓潰部ヲ全部アセチリン瓦斯鍛接法ニヨリ塡充シタル後更ニ水壓試驗ヲ施行シ良好ノ成績ヲ得タルモ尙ホ安全ノタメ其ノ部ニ帶鐵ヲ施セリ。

（乙）管ハ二百四十听ニテ水壓試驗施行セル結果良好ナリシニヨリ更ニ三百六十听迄水壓力ヲ上昇セシカ各部異狀ナカリシニヨリ別ニ應急修理ヲ施サズ其儘使用スルコトトセリ。

五號七號罐安全弁蒸汽捨管ノ凹メル所ハ全部打出シノ上蠟付ヲ行ヘリ。

（七）兩舷共主加減弁側蒸氣主管膨脹接手ハ百二十五番隔壁（後罐室機械室間ノ隔壁）取付中間弁ト主加減弁ノ轉位同樣ナラサリシタメ此ノ二弁ヲ連絡スル膨脹接手破損シ又主加減弁ニモ裂罅ヲ生ゼルニヨリ主加減弁ニハ鑄製當金ヲ施シ膨脹接手ニハ鑄製ノ歪メル管切レヲ挿入シ應急修理ヲ施行セリ。

（八）主機械筩接續控條承ハ左舷第一底壓筩内側ノモノハ當金ヲ施シ其ノ他破損セル左舷中壓筩内側左舷第一底壓外側右舷中壓外側右舷第一底壓中側ノモノハ總テ鑄ヲ以テ新規製造換裝セリ。

（九）主機械ト中央隔壁間ノ控條ハ全部破損ニ付キ夫々應急修理ヲ施セリ而シテ中央隔壁ノ强度安全ナラズ且ツ外底破損ノ狀態ヨリ考フルニ更ニ主機械ノ舷外側ニモ控條ヲ設ケ以テ船體完全修理施行ニ至ル迄ノ間臨設控條トシテ使用スルヲ得策ナリト考ヘ工事ヲ施セリ。

（一〇）主機械開放檢査概要

(A)右舷曲肱軸中心線ハ主軸承中心線ト合セズ即チ第一主軸承ニ於テ軸面ハ裏金ノ右舷側ニ接シ第八主軸承ニ於テ左舷側ニ接觸シ其ノ反對側ニテ第一主軸承ニハ千分ノ八吋、第八主軸承ニハ千分ノ十吋ノ間隙ヲ有シ同時ニ第八主軸承ニ於テノミ下方ニ千分ノ四十吋ノ間隙ヲ有ス。

(B)兩舷機共滑動部腐蝕ノ程度ハ曲肱軸推力軸中間軸及滑頭栓ノ何レモ浸水中裏金ニ接觸セサリシ部分即チ插金或ハ中間軸承ノ冠ニ對セル部分等ハ一面ニ腐蝕シ其深度千分ノ六吋ヨリ千分ノ十吋ニ及ベルモノアリ。

(C)兩舷機共筩內部ハ槪シテ良好ノ狀態ニアリシモ高壓滑弇ハ發銹甚シク又中壓低壓滑弇ハ割合ニ良態ニアルモノト認メラルルモ未ダ完全ナル檢査ヲ行フニ至ラズ。

(D)兩舷機共吸鍔棒滑弇棒「リンク」裝置偏心器發停軸ハ槪シテ良好ナリ。

(E)兩舷機共滑坐ハ何レモ滑動面ノ約五割ハ腐蝕シ深度最モ甚シキ部ニアリテハ千分ノ十吋位ニ及ベル所アリ而シテ滑金ハ前後進面共良態ニアリ。

（一一）主機械運動部修理調整

(A)右舷第八主軸承下部裏金ノ背部ニ厚サ千分ノ四十吋ノ當金ヲ施シ其他ノ主軸承裏金ハ何レモ當リノ程度ニ應ジ摺合セ調整ヲ行ヘリ。

(B)兩舷機共各筩滑頭栓ハ腐蝕部ヲ擦リ落セリ。

(C)曲肱栓腐蝕部ハ目下鑢仕上ゲ中ナルモ割合ニ日數ヲ要シ全部完全ナル仕上ヲ終ルニハ倘ホ二三週間ヲ要スルナラン。

(D)推力軸及中間軸ノ腐蝕部ハ擦リ落セリ。

(E)滑坐腐蝕面ハ到底完全ナル滑動面ヲ得難キモ單ニ輕石磨キヲ行ヘリ。

(F)其外中低壓滑弇ヲ除ケル總テノ滑動部ハ相當ニ調整手入ヲ行ヘリ。

大要ハ右ノ如ク工事進捗セルニ付兎モ角モ來ル六月二十一日ニハ主蒸氣管其他關聯裝置ノ汽密檢査、主機械運動部ノ狀況吟味及滑動部ノ摺合セヲ行ハンガ爲メ一先ヅ各部復舊ノ上左記次第書ニ依リ繫留運轉ヲ施行シ終テ推力軸ト中間軸ヲ絕緣シ約七十回轉以內ノ速度ニテ二時間摺合セ運轉ヲ行ヒ以テ今後ニ施行スベキ工事ニ對シ最モ適切ナル判斷ヲ下スノ一助タラシメントス而シテ船體部工事竣工セバ嚴密ナル港外試運轉ヲ行ヒ船底屈折多樣ニシテ然カモ翼端切斷或ハ屈曲セル推進器ヲ以テ安全ニ繼續運轉シ得ル速力ヲ確實ニ判斷セントス。

第一回主機械試運轉次第書（大正四年六月二十一日施行豫定）

(一)試運轉ニヨリ主蒸汽管其他關聯裝置ノ氣密檢査及主機械ノ發停並ニ運動部ノ狀態ヲ仔細ニ吟味シ併テ滑動部ノ摺合セヲ行ヒ以テ本運轉結了後ノ短時日間ニ施工スベキ工事ニ對シ最モ適切ナル判斷ヲ下スノ一助タラシムルヲ目的トシ左ノ方法ニ因リ之ヲ行フ。

(二)試運轉ヲ別チテ次ノ二種トス。

(イ)繫留運轉

(ロ)摺合運轉

(三)繫留運轉ハ現羈泊ノ儘錨索等ニ不當ノ緊强ヲ加ヘザル範圍內ニテ徐々ニ前後進ニ運轉スルモノトス。

(四)繫留運轉結了後推力軸ト中間軸トノ鍔ノ接手ヲ絕緣シ前進ニテ最小回轉數ヲ五分間繼續運轉シ爾後七回轉宛遞加シ各遞加回轉數ヲ各五分間宛持續シ約七十回轉ニ達セバ一時間半連續運轉シ以テ各回轉數ニ對スル振動ノ大小ヲ認定シ以テ回航ノ際ニ於ケル參考ニ供スルモノトス。

後進運轉ノ際ハ單ニ徐々ニ回轉ヲ增加シ七十回轉ニ達シタル後約十分間運轉スルモノトス。

(五)使用罐數四罐(各舷二罐宛)トス。

摺合セ運轉中必要ニ應ジ指壓圖ヲ撮取スルモノトス。

(六)當日點火ノ二罐ハ點火時ヨリ主塞止弇ヲ微開シ置キ以テ主蒸氣管系及主機械ヲ可成徐々ニ煖機使用壓力百二

十听ニ達セバ補助罐ト併用スルモノトス。

(七)試運轉ニ關スル豫定時刻左ノ如シ。

二罐點火	午前九時
同右併用	同十一時
繫留運轉始メ	午後〇時半
同右終	同一時
摺合運轉始メ	同二時
同右終	同四時半

備考、繫留運轉開始時刻ノ比較的遲キハ單ニ高潮時ヲ選ビ以テ推進器ニ依リ攪亂セル濁水ガ主復水器內ニ入ルコトヲ可成避ケント企テシノミニシテ他ニ深キ理由アリシニアラズ。

第一回試運轉中の狀況

(A)繫留運轉ハ約三十回轉ニテ前後進ニ數回發停シ左舷機ヨリ始メ各十五分間宛運轉ス起動操縱自在ニ振動モ亦皆無ニシテ各舷高壓吸鍔棒塡坐ヨリ僅カノ漏汽アリシト後罐室ニ於ケル主蒸汽管接手ヨリ右舷ニ一ケ所左舷ニ二ケ所僅少ノ漏汽アリタルモ何レモ其程度輕微ナリシニヨリ其儘運轉ヲ繼續セリ。

(B)繫留運轉終了後直チニ兩舷推力軸ト中間軸トノ接手ヲ絕緣シ午後二時ヨリ兩舷機共同時ニ摺合運轉開始ス。午後二時二十分回轉數ヲ四十九ニ整定シ爾後次第ニ回轉數ヲ增加シ七十乃至七十四回轉ニテ運轉シ同四時二十分終了引續キ後進ニテ十分間七十回轉ニテ運轉シ同四時三十五分無事終了ス。

運轉ノ狀況概シテ良好ニシテ前後進共振動極メテ少ナク左ニ列記スル外異狀ヲ認メズ。

(一)兩舷共推力軸後部軸承ハ運轉ノ初期ニ擦熱ヲ生ゼルニヨリ灌水ヲ施シ約三十分間ニシテ擦熱漸次減ゼルモ運轉ヲ終ルマデ灌水ヲ止ムル程度ニ至ラズ而シテ兩軸承ノ中左舷ハ右舷ニ比シ稍ヤ擦熱烈シカリシモノト認

ム。

(二)兩舷共第八主軸承ハ運轉始メヨリ三十分乃至四十分ニシテ擦熱ヲ生ゼルニヨリ灌水ヲ施シ約一時間ニテ兩者共擦熱減ゼルモ運轉ヲ終ル迄灌水ヲ止ムル程度ニ至ラズ。

(三)右舷第六主軸受ハ運轉開始後一時間四十分ニテ擦熱ヲ生ゼルニヨリ灌水ヲ施シ約二十分間ニテ擦熱大ニ減ゼルモ運轉ヲ終ル迄灌水ヲ繼續セリ。

(四)右舷後部低壓「リンク」引手ト「リンク」トノ接合栓一ヶ所及同「リンク」引手ト發停軸トノ接合栓二ヶ所ハ運轉開始後二十分間ニテ擦熱ヲ生ジタルモ其程度些少ニシテ即チ浸水セル布片ヲ以テ冷却法ヲ行ヒ運轉終了迄增熱スルコトナク無事結了セリ。

(C)要之ニ推力軸後部軸承ノ擦熱ハ摺合運轉ニ有リ勝ノコトニシテ深ク憂フルニ足ラザルモ主軸承ノ擦熱セルモノハ曲肱軸中心線ノ偏心ニ起因スルモノト認ムルヲ至當ナリトス、筩、吸鍔、滑鼻、滑鼻筐、偏心器及「リンク」裝置ハ良好ノ狀態ニアリト認メラレ此ノ儘ニテモ大ナル發生馬力ニ堪ユルナラン。

滑頭、滑坐、曲肱栓推力軸承ハ航海ノ際ト摺合運轉ノ兩場合ヲ考フルトキハ其ノ滑動面ニ於ケル受壓力ニ甚ダシキ懸隔アルベキニヨリ今回ノ摺合運轉ニ異狀ナカリシトノ故ヲ以テ未ダ完全ニ調整サレタリト信ズルヲ得ザルハ勿論曲肱點蝕部ニハ大ニ工事上ノ注意ヲ要シ又滑坐面ノ腐蝕部ハ比較的良滑面トナレルモ航海ニ際シテハ船體抵抗增大セル爲メ受壓力大ニ增加スベキ推力軸承ト共ニ運轉上至大ノ注意ヲ要スベク而シテ滑頭ハ割合ニ良好ノ狀態ニアルモノト認メラル。

摺合運轉中主機械ノ摩擦抵抗ヲ知ランガ爲指壓圖ヲ撮取セルガ適當ノ指壓器發條ヲ有セザル爲正確ヲ期シ難キハ勿論ナレドモ參考ノタメ馬力ヲ算出セルニ右舷ハ從來トテモ左舷ニ比シ同一回轉數ニ對スル發生馬力大ナリシガ今回ノ成績ハ一層其ノ差大ナリ之レ右舷曲肱軸中心線ノ偏心大ナルガ爲ニ起因スル所最モ多キモノト認ム

第一回試運轉ノ成績

六月二十一日施行繫留及摺合運轉ノ成績概シテ良好ナリ即チ機關ハ直接本邦ニ經濟速力附近ノ低速力ヲ以テ航海スルガ如キ長途ノ運轉ニモ堪ヘ得ベシトノ見込ヲ有スルニ至レリ而シテ更ニ今後船體部工事竣工ニ至ルマデ約一ケ月間ニ左記二項ノ目的ヲ達センガ爲メ主機械滑動部ノ摺合調整及第七號罐復舊工事其ノ他重要ナル補助機械ニ必要ナル工事ヲ行ハントス。

此ノ目的ヲ達センガ爲メ今後ノ事業方針ヲ左ノ如ク定ム。

第一回試運轉後ノ機關部修理方針

(一)推力軸々承ハ前後部共調整スルコト。
(二)主軸承ハ擦熱セルモノヲ調査シ要スレバ他ノ擦熱セザリシモノヲモ充分ニ調整スルコト。
(三)曲肱栓ノ鑢仕上ゲ未濟ノモノハ(右舷高壓丈ケ仕上ゲ濟)仕上ゲヲ行フコト。
(四)「リンク」裝置一部ヲ調整スルコト。
(五)右舷高壓吸鍔棒衞帶調整
(六)主送水機械ハ充分ナル修理調整ヲ行フコト。
(七)蒸汽管接手漏汽部衞帶換裝
(八)第七號罐復舊工事

第一回試運轉後ノ修理工事概要

(六月二十二日ヨリ七月二十五日マデノ工事)

右記修理方針ニ基キ七月二十五日迄ニ(第二回ニ豫定セル竣工期日)實施セル工事ノ主ナルモノヲ列擧スレバ左ノ如シ。

(一)兩舷推力軸々承前後部共分解調整。
(二)右舷第八主軸承分解下部裏金ノ背部ニ厚サ千分ノ十二吋ノ當金ヲ施セリ乃チ第一回試運轉前ニ施セル當金千

分ノ四十吋ヲ千分ノ五十二吋ニ増セリ。

(三)左舷第八主軸承分解下部裏金ノ背ニ厚サ千分ノ四十吋ノ當金ヲ施セリ。

(四)右舷第六主軸承分解調整。

(五)左舷第一低壓「リンク」調整。

(六)兩舷機曲肱栓ノ腐融部擦リ落シ仕上ニハ鑛金ニテ裏金型ヲ特製シ充分ナル仕上ゲヲ行フ。

(七)右舷主送水機械ハ扇車ト扇車室間ノ遊隙過大ナリシニヨリ扇車ニ厚サ八分ノ三吋ノ當金ヲ施シ同時ニ曲肱軸ガ運轉中自然扇車側ニ片寄ラントスルノ傾向ヲ防止センガタメ扇車軸ノ軸端ニ「リグナムバイテー」ヲ裝備セル軸承ヲ新設シ以テ車軸ノ軸線ニ沿ヘル推力ヲ受ケシムルコト、セリ其ノ他勢車ノ取附及軸系等ニモ適當ノ修理調整ヲ行ヘリ。

(八)救難喞筒第三、四、五、八號ヲ夫々第一、二、三、四、罐室上方ノ彈藥通路ニ又一號喞筒ハ後部浸水區ニ備フルタメ後部彈藥通路ニ移轉セリ。

右ノ外蒸汽管接手衞帶換裝給水吐出管漏水部ヲ鑛鑄物管ニテ換裝スル等諸種ノ小工事ヲ行ヘリ。

七月二十五日後ノ機關部修理方針

竣工期限更ニ八月中旬ニ延期トナルニ付今後ノ事業方針左ノ通リ定ム。

(一)第七號罐復舊工事。

註、一旦工事ニ著手セルモ同罐下內底工事ノ爲メ中止シ製罐工ハ主トシテ船體部工事ノ助力ニ從事シタリシガ一兩日後ヨリ更ニ此ノ復舊工事ニ著手シ一週間以內ニ竣工セシムルコト。

(二)主軸承等主機械滑動部ノ主要部ニシテ然カモ機械室內「セメント」工事ニヨリ汚損セラレタル部分ハ解放手入ヲ行ヒ同時ニ要スレバ調整ヲ行フコト。

(三)右舷高壓吸鍔棒衞帶調整。

(四)右舷第一、二低壓「リンク」裝置一部調整。
(五)左舷主送水機械ハ吸鍔新製ノ上右舷ノモノト同樣完全ナル修理ヲ施スコト。
(六)後罐室兩舷灰放射器喞筒(目下「ピルヂ」喞筒トシテ使用ノモノ)及機械室兩舷「ピルヂ」喞筒ニ小修理ヲ施スコト。

右ノ外百二十五番隔壁補強ノ爲メ機械室兩舷消防機械移轉及之ニ伴フ管工事等ニシテ何レモ八月十日迄ニ竣工セシムルコト。

修理工事ノ概要(七月二十六日ヨリ八月十日第二回試運轉施行マデノ工事)

右記修理方針ニ基キ八月十日施行第二回試運轉前ニ施行セル主ナル工事ヲ列擧スレバ左ノ如シ。

(一)第七號罐修理。
七月三十一日應急修理竣工ニ付假水壓試驗施行終テ焚試及安全弁調整ヲ行ヒシニ何レモ結果良好。

(二)機械室内「セメント」工事ノタメ汚損セルニヨリ各主軸承及曲肱栓裏金分解手入ヲ行フ第一主軸承ノ如キ殊ニ「セメント」ノ浸入甚シカリシニヨリ充分ニ手入ヲ行ヘリ。

(三)右舷高壓吸鍔棒衛帶解放摺合ヲ行フ。

(四)兩舷第一、第二、低壓「リンク」ハ船底突キ上リノ影響ヲ受ケ多少ノ狂ヒヲ生ジ居レルニヨリ何レモ「リンク」引手ト發停軸接合部ニ四分ノ一吋宛前方或ハ後方ニ挿片ヲ加ヘ調整セリ。

(五)左舷主送水機械ハ扇車ト扇車室間ノ遊隙過大ナリシニヨリ扇車ノ兩側ニ厚サ合計約三分ノ一吋ノ當金ヲ施シ同時ニ曲肱軸ガ運轉中自然扇車側ニ片寄ラントスルノ傾向ヲ防止センガタメ扇車軸々端ニ「リグナムバイテー」ヲ裝備セル軸承ヲ新設シ以テ車軸ノ軸線ニ沿ヘル推力ヲ受クルコトヽセリ。
吸鍔ハ鑄鐵製ニシテ解放檢査ノ際衛帶環溝下縁ノ一部缺損セルニヨリ豫備品ト換裝セルニ是又眼付螺釘用孔附近ヨリ破損セリ因テ多少重量增加スルモ止ムヲ得ズ鏞製鑄物ニテ新製シ要部ニハ鍛鋼製嵌輪等ヲ挿入セルモノ

ヲ用ヒタリ。

其他曲肱栓裏金新製滑頭栓ハ新製ノモノヲ燒嵌シ尙ホ車軸中心線ノ調製等必要ノ工事ヲ行ヘリ。

(六)後罐室兩舷灰放射器喞筒(目下「ビルヂ」喞筒トシテ使用ノモノ)及機械室兩舷「ビルヂ」喞筒ハ總テ喞筒弇及弇坐摺合ヲ行ヒ尙ホ喞子ノ如キ摩耗甚シキモノハ白色合金ヲ鑄込メリ是レ完全ナル修理ニアラザルモ迅速ニシテ然カモ所要ノ目的ヲ充分達スルモノト認メタルニ因ル從テ本邦ニ於テ完全修理ノ際ハ換裝スベキモノナリトス。

(七)「テルテール」使用不可能トナリシニヨリ軸室內中間軸接手ニ仕懸ケヲ施シ回轉方向指示電燈ヲ機械室及艦橋ニ設ケタリ。

工事右ノ如ク進捗セリ依テ八月十日左記次第書ニヨリ第二回試運轉ヲ行フコトヽセリ。

第二回主機械運轉次第書(八月十日施行)

(一)本運轉ハ主機械各運動部調整後ハ狀態良否ヲ確メ併テ滑動部ノ摺合セヲ行ヒ以テ八月十七日頃施行豫定ノ港外試運轉ニ對スル準備タラシムルヲ目的トシ左ノ方法ニヨリ之ヲ行フ。

(二)試運轉ヲ別チテ次ノ二種トス。

(イ)摺合運轉

(ロ)繫留運轉

(三)摺合運轉ハ推力軸ト中間軸トノ鍔ノ接手ヲ絕緣シ前進ニ次第ニ回轉數ヲ增加シ約七十回轉ニ達セバ一時間半連續運轉スルモノトス。

前項ノ運轉終ラバ徐ニ後進ニ回轉ヲ增加シ七十回轉ニ達シタル後數分間運轉スルモノトス。

摺合運轉中第一回試運轉ノ際指壓圖ヲ撮取セシ時ト同回轉數ノ時指壓圖ヲ撮取スルモノトス。

(四)摺合運轉終ラバ推力軸ト中間軸トヲ接續シ繫泊ノ儘錨索等ニ不當ノ緊張ヲ與ヘザル範圍ニテ徐々ニ前後進ニ

運轉スルモノトス。

(五)試運轉ニ關スル豫定時刻左ノ如シ。

摺合運轉始　午前八時
同右終　午前十時
繫留運轉始　午前十一時四十分
同右終　正午

第二回試運轉中ノ狀況

(一)右舷第四、五、六、主軸承ハ少シク擦熱ノ傾向アリ同第八主軸承ハ擦熱セザルモ働作稍面白カラズ爲メニ推力軸ヲ上下ニ極メテ少シク遊動セシムルモノト認メタリ。

(二)前記ノ外何等故障ナク總テ次第書通リ施行セリ而テ第一回試運轉ニ比較スルトキハ働作頗ル圓滑トナリ指壓器ヨリ算出セル馬力ヲ比較セルニ摩擦抵抗モ亦減ゼリ。

第二回試運轉後開放檢査狀況

(一)右舷第四、五、六主軸承分解檢査ス裏金ノ當リハ少シク油道ノ埋マレル所アリシモ甚シカラズ摺合復舊ス。

(二)右舷第八主軸承ハ特製計器ニ依リ詳細ニ調査シ下部裏金ノ背部ニ厚サ千分ノ六吋ノ當金ヲ増セリ即チ已ニ施セル當金千分ノ五十二吋ヲ五十八吋ニ増加セリ。

附記、前二項ノ外ハ更ニ異狀ナカリシニヨリ解放セズ。

解放檢査部調整復舊終リ八月十九日船體部工事モ全部竣工シ同二十一日港外試運轉ヲ行フコトヽナレリ。

港外試運轉成績(八月二十一日「ザンバル」「トロメ」沖ニ於テ施行)

試運轉方案觀測檢視部署其他當日ノ狀況ハ前編ニ審カナルニヨリ略シ此處ニハ專ラ機關ニ關スル成績ヲ記スルモノトス。

(一)試運轉中ノ機關ノ狀態ハ頗ル良好ニシテ此ノ後何等工事ヲ施スコトナク直接本邦ニ回航シ得ルコト確實ナリト認ム

(二)當日最大回轉數五十六回轉ナリシモ機關ハ尙ホ多數ノ回轉數ニテ運轉シ得ルコト確カナリト認ム。

應急修理トシテ艦外底ニ施セル箱形當金ノ橫斷面ニ受クル直衝抵抗ヲ算出シ坐礁前ノ實馬力ニ加算セル實馬力ガ試運轉ノ結果ニヨリ實際發生馬力ト大差ナキヨリ考フルトキハ差支ナキ限リ箱形當金ノ橫斷面積ヲ減ズルト同時ニ充分ナリ水切リヲ當金ノ前後部ニ施スコトヲ得ルトセバ抵抗減ジ從テ炭費ヲ減少スルト共ニ經濟速力モ幾分高ムルコトヲ得ベク爲メニ長途ノ航海ニ對シ益スル所大ナルベシト信ズ。

豫定港ニ於テ本邦回航前ニ行フベキ機關部工事

(一)離礁後ヨリノ沿革

機關ハ五月八日離礁後晝夜防水排水ニ努メ五月十六日ニ至リ漸ク浸水減ジ曲肱軸水上ニ露出セリ因テ機關ニハ直チニ應急修理ヲ施シ運轉ニ適スルヤ如何ヲ調査セシニ當時短距離ノ某港マデ運轉シ得ルコトハ翌日直ニ決定セルモ其後引續キ精査ノ結果主機械ハ特定修理後ノ年月長カラズ且ツ昨春以來練習航海ニ引續キ今回ノ戰役行動ニ從事シ頗ル多數ノ時日ニ亘リ運轉セルニモ係ハラズ滑動部ノ狀態良好ニシテ主軸承裏金白色合金ノ如キモ充分ナル厚味ヲ殘存セシニヨリ比較的短時日ノ間ニ應急修理ヲ終ルコトヲ得即チ六月二十一日第一回繫留運轉ヲ施行シ其成績良好ニシテ直接本邦ニ經濟速力附近ノ低速力ヲ以テ航海スルガ如キ長途ノ運轉ニモ堪ヘ得ベシト認ムルニ至レリ而シテ其後船體工事竣工期限延期ニ伴ヒ完全修理ノ場合ヲ考慮シツツ出來得ル丈ノ修理調整ヲ行ヒ八月十日更ニ第二回繫留運轉ヲ行ヒ益々良好ノ成績ヲ得次デ八月二十一日船體工事竣工後ノ港外試運轉ニハ一層ノ良成績ヲ擧グルコトヲ得更ニ八月二十三日ヨリ九月四日ニ至ル北上回航中何等故障ナク頗ル良態ナリ。

(二)大要右ノ如キ狀態ニアリ且ツ豫テ懸念ヲ有セシ主機械中心線ニ惡影響ヲ來タスナラント想像セラレシ入渠モ

取止メトナレルニ付本邦ニ向ケ出發前ニ施行スベキ機關工事ハ皆無ナリ因テ造機部殘留職工ハ主トシテ造船工事ニ從事セシムルモノトス。

本邦ニ向ケ出發後某洋中島迄

(右舷第二低壓曲肱栓切斷)

大正四年十月二十三日愈々本邦ニ向ケ出港原速回轉六十、六十三ニテ某洋中島ニ直航ス十一月五日該洋中島到着ノ二日前迄運轉狀態概シテ良好ナリシガ五日午前五時右舷機械第八主軸承帶熱ノ傾向ヲ生ジ少シク灌水ヲ始メタルヲ故障ノ初マリトシ爾後次第ニ右舷機械ノ動作諸所不良トナリシガ兎モ角モ運轉ヲ繼續シツヽ十一月七日午前豫定地點ニ投錨直ニ推力鍔ノ調整ニ着手セルニ第二低壓曲肱栓ト艉方腕トノ間ハ切斷セルヲ發見セリト云フ。

右舷第二低壓曲肱栓切斷前ノ來歷概要

(一)此ノ曲肱栓ハ坐礁中上部思案點ヨリ約九十度右舷側ニ倒レタル位置ニアリシモノナリ。

(二)離礁後曲肱栓ハ何レモ腐蝕セルニヨリ充分腐蝕面ヲ摺リ落シ倘ホ特殊ノ型ヲ作リ優秀ナル職工四名ヲシテ十日間ニ亘リ眞圓ニ仕上セシメタルモノニシテ即チ斯ル長時日ノ間精細ナル仕事中ニモ何等損所ヲ發見シ得ザリシモノナルニヨリ内含的裂疵ガ其當時已ニ存在セシヤ否ヤハ知レザルモ何等表面ニ肉眼ヲ以テ識別シ得ル裂疵ナカリシモノナリ。

(三)「サンバルトロメ」ニ於ケル應急修理終リ八月二十三日同港發回轉五十二速力六海里弱約千馬力(兩舷合計)ニテ九月四日豫定港ニ入港迄航程千五百浬何等異狀ナク運轉繼續セリ。

(四)豫定港淀泊中ハ同港ヘ回港中ノ狀態良好ナリシニヨリ特記スベキ機關部工事ヲ施行セズ。

(五)今回ハ二千五百浬續航シ投錨後曲肱栓切斷ヲ發見セルモノニシテ而モ投錨二日前迄ハ運轉狀態良好ナリシト云フ今此航海中ノ運轉狀況ヲ日記的ニ記スレバ左ノ如シ。

年月日	時刻	記事
大正四年十月二十三日		發回轉六〇、
同　十月二十七日		回轉六三、ニ增加ス
同　十一月五日		十一月五日迄運轉狀態概シテ良好
同	午前五―〇	右舷機械第八主軸承帶熱ノ傾向アリ少量ノ灌水ヲ行フ
同	同　六―〇	帶熱增進ニ付灌水ヲ增加ス
同	同　六―三〇	第七主軸承帶熱ノ傾向アリ爲念灌水ヲ行フ
同	同　九―〇	高、中第一低壓滑座帶熱ノ傾向アリ
同	同　一〇―〇〇	高、中第一低壓曲肱帶熱ノ傾向アリ
同	同　一〇―〇〇	滑動部ニ於ケル觸接ノ狀況ヨリ判斷スルニ曲肱少シク前方ニ推移セルモノト認ム
同	午後三―五〇	中壓偏心器漸次帶熱ノ傾向アリ
同	同　四―二〇	中壓偏心器ニ灌水ヲ行フ
同	同	推力軸第一、二、三、馬蹄少シク浮キ上リタルガ如ク認メラル
同	同　五―〇	第七、八主軸承中壓偏心器帶熱ノ傾向減却セズ試ニ灌水ヲ中止セバ直ニ增溫ノ傾向ヲ生ズルヲ以テ灌水部ハ總テ其儘繼續スルコト、セリ
同　十一月六日	午前八―〇	高壓第一低壓滑座下部前方及上部後方漸次帶熱增進ノ傾向アリ又高壓、中壓曲肱、中「リンク」滑金增熱ノ傾キアルヲ認ム而シテ增溫ノ傾向最モ多キ高壓滑座高壓、中壓曲肱壓ニ少シク灌水ヲ行ヒ中壓「リンク」滑金ニ對シテハ通風冷却法ヲ實施ス
同	同	右舷機械運轉狀態ニ鑑ミ現回轉繼續ハ不安ヲ感ズルニ至レリ依テ豫テ回轉回轉五十四ニ對スル炭費試驗ヲ行フ豫定ナリシヲ以テ之ヲ實施シ此ノ回轉減少ニ依リテ前日來ノ帶熱ヲ幾分緩和セントス
同	午前九―〇	回轉五四ニ對スル炭費試驗開始
同	同　一〇―〇〇	回轉減少ニ伴ヒ各滑動部一般ニ冷却セルヲ認ム
同	同　一〇―三〇	中壓偏心器灌水ヲ中止ス
同	午後一―〇	炭費試驗結了、回轉增加ニ付中壓偏心器灌水ヲ再始ス
同	同　一―三〇	回轉增加ハ右舷機械各滑動部ニ帶熱セザル範圍トシ回轉六〇、ニ整定ス 左舷機械ハ右舷機械回轉減少ヲ補フタメ回轉六五ニ增加ス
同　十一月七日		右舷機械第七、八主軸承中壓偏心器、高、中、壓曲肱、高壓滑座前日ニ引續キ灌水冷却又中壓「リンク」滑金モ通風冷却
同	午前一〇―三〇	高壓曲肱擦熱ノ現象ヲ呈ス全力灌水ヲ行フト同時ニ右舷機械回轉ヲ五〇ニ減少ス

同　十一月七日	午前一〇―五〇	高壓曲肱擦熱減少ニ就キ灌水ヲ減ズ回轉五五、迄復舊整定ス而テ左舷機械回轉六五、ニ整定續行ス
同	同一一―五三	投錨
同	午後二―三〇	轉運中右舷主機械軸前方ニ約二分ノ一吋偏移シ滑座「リンク」裝置曲肱等何レモ帶熱ノ傾向ヲ生ジタルニ付推力鍔ノ調整ニヨリテ軸ヲ後方ニ移動セントスルニ際シ第二低壓曲肱栓ト後方腕トノ間ニ於テ切斷セラレアルヲ發見ス更ニ精査スルニ同栓ノ前方ニ於テモ周圍ノ約四分ノ一ニ渉リアルヲ認ム

曲肱栓切斷面ノ狀態

(一)切斷ノ位置ハ第一圖ニ示ス如シ栓ノ全周ノ約二分ノ一ニ對スル切斷面ハ疵面幾分摩耗シ稍滑カナル面トナリ其ノ他ノ切斷面ハ生疵ニシテ曲肱カ上部思案點ニアルトキ栓ノ頂部ヨリ右舷側ニ寄レル生疵ノ部ハ疵面粗慥ニシテ結晶性組織ヲ顯出セル所アリ。

(二)前方腕ト栓トノ接續部ニ生ジ居レル裂疵ハ栓ノ全周ノ三分ノ一ニ亘リ其ノ深サ栓ノ中空部ニ達セザルモ應急修理ノタメ同所穿孔ニ際シ檢査セル結果ニヨレバ栓ノ外周ト中空部トノ中途迄ハ裂ケ居ルモノト認ム。

曲肱栓切斷ノ原因

切斷ノ原因ヲ推究スルニ曲肱軸中心線ノ狂ヒ及積荷ノ關係上石炭滿載ノ當初ハ機械室後部隔壁ヨリ後方ニ於テ浮力約七百二十噸超過セルニヨリ此ノ隔壁附近ニ於テ船體ガ少ナカラザル無理ヲ受ケ居ルコト並ニ栓切斷面ノ材質モ亦餘リ良好ナラザルコトヲ認メ得ルモ此等ハ何レモ曲肱軸切斷ノ原因ト信ズル能ハズ只ダ幾分切斷ヲ速カナラシムルノ一助タリシモノト認ムルヲ至當トス。

因テ切斷ノ原因ハ坐礁當時ヨリ離礁迄ノ期間ニ於テ已ニ内含的或ハ肉眼ヲ以テ識別シ得ザル裂疵ヲ生ジ居リシモ「サンバルトロメ」ヨリ北上航海中ノ發生馬力ニテハ此ノ裂疵ヲ速カニ擴大セシムルニ足ル丈ケノ負荷ヲ此部ニ加フル能ハズ爲メニ千五百浬ノ長航程モ何等異狀ナク運轉シ來レルモ更ニ出發シ其列島ニ至ル航海中前編ニ記セルガ如ク出發後直ニ數日間ノ荒天ニ遭遇シ且ツ發生馬力ハ前航海ニ比シ大ナリシヲ以テ爰ニ初メテ裂疵ヲ速カニ擴大スルニ足ル負荷ヲ加フルニ至リ日ヲ追フテ益々裂疵擴大シ遂ニ切斷セルモノト判斷スルヲ最モ至當ナリト認

ム。

曲肱栓應急修理

切斷曲肱栓應急修理ハ淺間救難着手以來最重要ナル工事ノ一ニシテ是ヲ機關部最後ノ努力ト思ヒ定メテ十一月八日細心ノ注意ヲ以テ着手シ同十八日良好ナル出來上リヲ以テ竣工セリ切斷曲肱栓ノ心棒トシテ淺間汽艇「ダビツト」徑九寸半ノ鋼材ニ加工中所々ニ疵ヲ發見シ他ニ代用スベキ鋼材見當ラザリシヲ以テ一時ハ困却ノ思ヒヲナセシカドモ此ニテ所要ノ目的ヲ達スルニハ敢テ差支ナシト認メ大部分ハ其ノ儘使用セリ。

右舷主機械第二低壓曲肱栓應急修理圖（第一圖參照）

切斷曲肱栓應急修理法ハ第一圖ニ明ラカナレドモ今少シク解説セバ左ノ如シ。

（一）參個ノ皷形楔ハ主トシテ「トーション」ニ堪ヘシムルコトトシ同時ニ「ベンデング」ニモ堪ヘシメ切斷部ノ結合ヲモナサシムルコト。

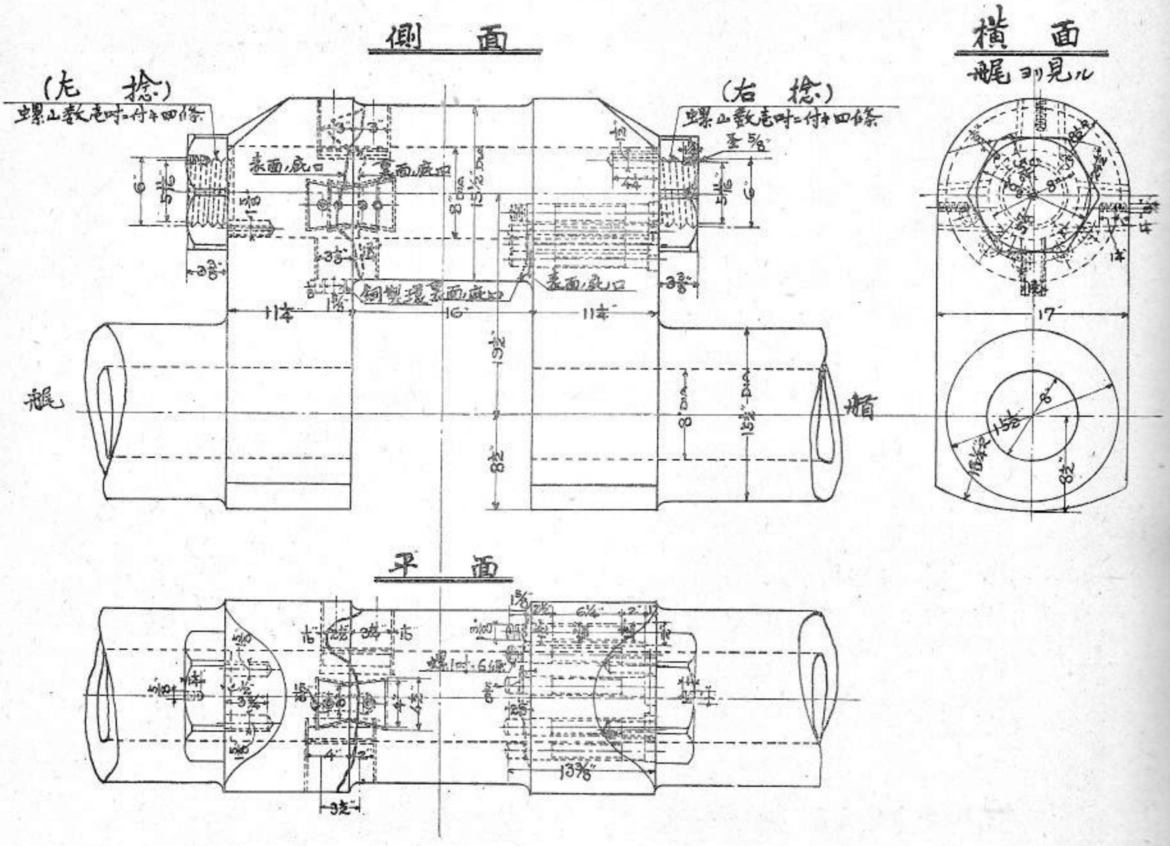
此ノ楔ハ栓ノ滑動面ヨリ中空部ニ至ルニ從ヒ次第ニ大キク造レリ單ニ「トーション」ニ堪ヘシムル目的ニ對シテハ寧ロ反對ニ栓滑動面ノ方ヲ大キク造ラバ可ナレドモ運轉ニ際シ遠心力ニテ次第ニ楔ハ拔キ出スコトトナルベシ因テ本圖ノ如ク造リ運轉ニ伴ヒ楔ハ次第ニ締ルトモ弛マザル様ニ計劃セリ。

此ノ楔ノ底面ハ圖ニ示ス如ク何レモ栓ノ中空部ヲ貫通セル八吋ノ鋼丸棒ト密接セシムル様工事ヲ施シ以テ楔ヲ確實ニ正當ノ位置ニ居ラシムルト同時ニ「ベンデング」ニ堪ユル力モ幾分増加セシムル様企テタリ。

（二）亞鈴形楔ハ工事上皷形楔ヲ施シ得ザルニヨリ單ニ形狀ヲ換エタルノミニシテ目的皷形楔ト全然同一ナリ。

（三）栓ノ中空部ニ挿入セル徑八吋ノ鋼丸棒ハ主トシテ切斷部ヲ丈夫ニ結合シ「ベンデング」ニ堪ヘシムルヲ主トシ同時ニ此ノ八吋丸棒ト曲肱腕トノ間ニ前後端各二本宛ノ丸鋼楔ヲ挿入シ以テ「トーション」ニモ堪ヘシムルコトセリ此目的ヲ達スルニハ栓ノ中空部ニ挿入スベキ八吋鋼丸棒ハ中空部一杯ノモノタラザルベカラズ殊ニ運轉スレバ温度高マリ弛ム傾モアリ是非共固キモノヲ打込マザルベカラズ。

第壹圖

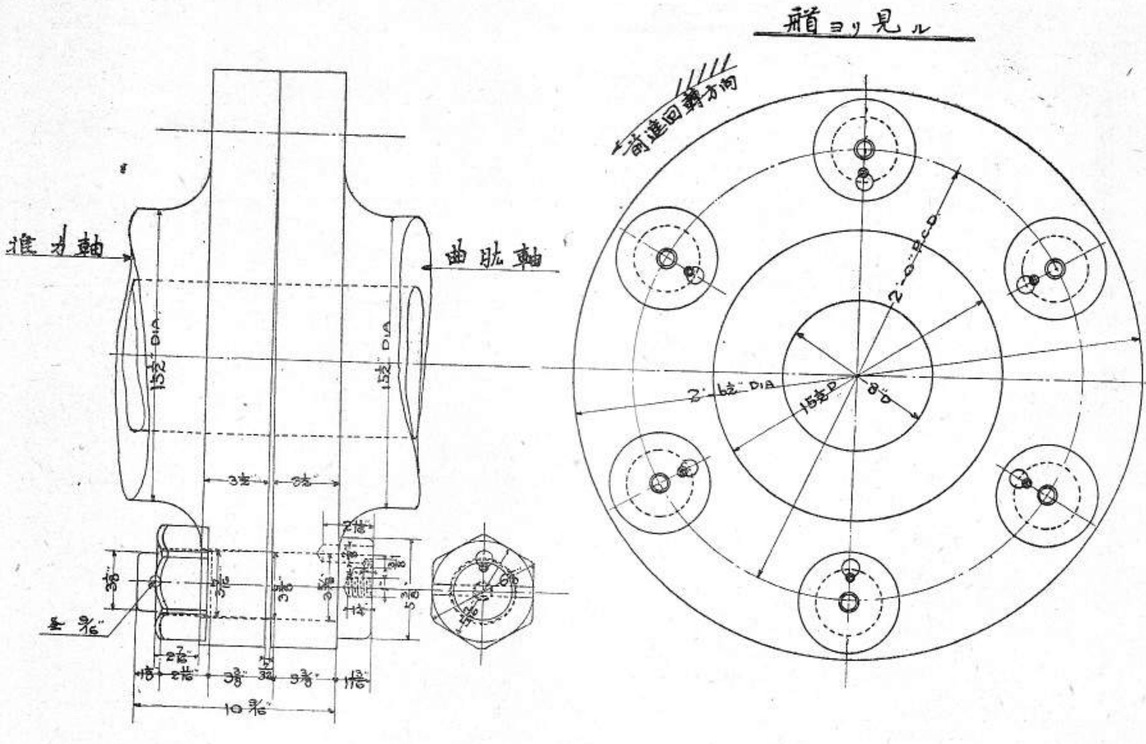


右舷主機械第二低壓曲肱栓應急修理圖

尺度 四分三吋ヲ壱呎トス

備考 太キ線ハ損所ヲ示ス

第貳圖



右舷主機械曲肱軸ト推力軸ノ聯接手應急所置圖

尺度 壹吋二分ノ一ヲ壹呎トス

「淺間」附圖

此ノ八吋丸棒打込ミニハ「バラスト」ヲ使用シ約七時間ヲ要セリ即チ割合ニ時間ヲ要シ工事ハ少シク困難ナリシモ出來上リハ大ニ滿足スベキモノトナレリ八吋鋼丸棒ヲ打込ミタル後丸鋼楔ヲ前後端ニ二本宛挿入シ次ニ丸棒ノ兩端ニ母螺ヲ緊締セリ。

(四)栓ノ前端裂疵ハ五本ノ長キ螺釘ヲ以テ緊締セリ。

工事概要右ノ如シ因テ三個ノ鼓形楔及亞鈴形楔一箇ガ主トシテ剪斷應力ニ堪ユルモノトシテ今後安全ニ發生シ得ル馬力ヲ算定シタルニ回轉五十五發生實馬力五百五十ヲ最大限トシテ運轉スルヲ至當ナリト認ム。

註、萬一ノ必要ニ迫ラバ回轉六十三發生實馬力七百五十迄ハ短時間運轉スルモ可ナリト思考スルモ已ニ此ノ發生實馬力ニ對シテ應急修理部ノ受クル負荷ハ曲肱軸新造當時ノ認可應力ノ約九割ニ達シ且ツ前記ノ如ク使用鋼材ニ思ハシカラザル所アレバ安全ナリト斷定スル能ハズ。

右應急修理施行ノ際右舷曲肱軸ト推力軸トノ接手鍔ノ下端ニ於テ千分ノ二百廿吋間隙ヲ有セルヲ發見セルニヨリ第二圖ニ示ス如ク同鍔接手用螺釘全長ノ約半バヨリ次第ニ細ク削リ即チ螺糸部ニ至リ直徑十六分ノ一吋ヲ減ジ且ツ螺釘頭ト母螺底部トノ間隔ヲ三十二分ノ七吋增加シ以テ同鍔接手ハ運轉中常ニ上部ニ於テハ兩鍔相接觸シ下部ニ於テハ三十二分ノ七吋ノ間隙ヲ自由ニ有シ得ル樣接續シ以テ曲肱栓應急修理部ニ此ノ接手ノ歪ヒヨリ來ルベキ緊張ヲ除去スルコト、セリ此ノ處置ニ關聯シ第八主軸承下部裏金ノ底部ニ施シアリシ厚サ千分ノ五十六吋ノ當金ヲ除キ適當ノ調整ヲ行ヘリ而シテ近隣ノ島マデ試運轉ヲ行ヒ原速五海里乃至六海里ニテ約八十哩航海ノ後直チニ應急修理部ヲ檢査セルニ曲肱栓修理部ハ何等異常ナク良好ノ狀態ニアリ又應急處置ヲ施セル軸鍔接手螺釘全部拔キ取リ檢査セルニ螺釘孔ト摺レ合ヒ多少擦傷ヲ生ゼシモノアリシモ甚ダシカラズ數日航海ノ後ニハ自然ニ擦リ減リ摩擦面增加シ又螺釘ノ受クル力モ平均スベク從テ同部ヨリ發スル音響モ次第ニ滅ズベシト認メタルニヨリ其儘復舊ス。

出發横須賀回航中

(一)十一月二十一日出港後回轉五十三ニテ繼續運轉應急修理部音響モ止ミ益々良好ノ狀態ニアリシモ爲念十一月二十七日右舷機停止ノ上接手鍔螺釘四本拔取リ檢査セルニ各擦面約一平方吋增加シ滑ラカナル面トナレリ右ノ如キ良好ノ狀態ニアレバ最早本邦到着迄ハ開放檢査ヲ強ヒテ行フ必要ナキモノト認ム。

(二)應急修理部何等異常ヲ認メザルモ十二月六日爲念再ビ開放檢査ス曲肱栓修理部ハ異常ナク良態ニアリ同時ニ應急處置ヲ施セル主軸接手螺釘全部(六本)取外シ檢査セルニ螺釘ノ殆ンド半周ニ當リヲ生ジ其ノ部千分ノ十三吋摩耗シ面ハ頗ル滑ラカナリ。

航海十六日間ノ摩耗如斯少ナク殘リ十日間ノ航海ニハ(橫須賀着迄)摩擦面モ增加セル事故一層摩耗ノ割合減ズベク益々良態ニテ運轉ヲ繼續シ得ベシト信ゼリ。

橫須賀到着前日(十二月十七日)房州湊村沖假泊ノ好時機ヲ利用シ曲肱栓修理部檢査ヲ行ヘルニ異狀ナク良態ニ了リ同時ニ應急處置ヲ施セル主軸接手螺釘全部(六本)取外シ檢査セルニ摩擦面ハ前回檢査ノ時ヨリモ一層滑ラカトナリ想像以上ノ良態ニアルモノト認メラル從テ吳回航前橫須賀ニ於テ修理ノ必要ナク益々良態ニテ運轉ヲ繼續シ吳ニ到着シ得ルモノト信セリ。

橫須賀發吳着

十二月二十三日午前十時吳ニ向ケ橫須賀出發海上頗ル平穩ニシテ恰モ鏡ノ面ヲ滑走スルガ如シ二十七日午後五時三十分早瀨水道西入口ニ假泊翌二十八日午前九時拔錨同日午後一時半吳ニ入港ス船體機關異狀ナシ。

十二月二十九日(吳入港ノ翌日)應急修理部精細ニ檢査ヲ行フ其ノ狀況左ノ如シ。

第二低壓曲肱栓修理部ト皷形楔二個ノ內曲肱ガ上部思案點ニアルトキ內側ノモノガ曲肱腕ト嵌合セル部ニ於テ曲肱ガ前進方向ニ回轉スルトキ壓力ヲ受ケベキ一邊ニ千分ノ二十五吋ノ遊隙ヲ生ジ上部ノ鼓形楔ニハ同樣ノ一邊ニ千分ノ十五吋ノ遊隙ヲ生ゼル外何等異狀ナク頗ル良態ニアリ。

前方腕ト栓トノ間ニ發見セシ裂傷ハ應急修理常時ノ儘ニシテ少シモ擴大セリト認メズ應急處置ヲ施セシ曲肱軸

ト推力軸トノ接手螺釘ハ摺レ合ヒノ面積各約十六平方吋ニ達シ概シテ良好ノ滑動面ヲ有シ摩耗寸度千分ノ二十一吋ナリ。

以上ハ十月十九日某島出發以來昨日投錨迄ノ航程四千二百四十二浬（航海日數三十日十四時間機械總回轉數二百七十六萬四千五百）ヲ運轉セシ後ノ狀況ヲ示セルモノニシテ檢査ノ結果ヨリ判斷スルトキハ應急修理部ハ今後更ニ長距離ヲ航海スルモ安全ナリト斷言スルニ足ルモノト認ム

註此ノ航海中ノ回轉數ハ主トシテ毎分四十九回轉ナリシガ時トシテハ五十一回轉ニテ運轉セシコトモアリ參考ノ爲メ附記ス。

第二章　雜件

救難喞筒準備

救難用トシテ約一萬噸ノ排水力量ヲ得ンガ爲メ準備シタル喞筒大體要目次ノ如シ。

救難喞筒大體要目

形式	毎時力量　噸	臺數	總水頭三十呎ニ對スル算定馬力　I、H、P	排水管徑　吋	蒸氣管徑　吋	機械ノ幅　呎—吋	機械ノ長　呎—吋	機械ノ高　呎—吋	備考
遠心喞筒	四、〇〇〇	四	二四〇	二七	五	六—八	七—六	一〇—六	
同	一〇〇	一	一五	八	二	三—六	六—六	四—六	
同	七五〇	四	七五	一三	二吋二分ノ一	四—八	六—八	六—八	
同	一、〇〇〇	二	一〇〇	一二	二吋四分ノ一	五—六	八—八	六—〇	
ウオーシングトン	四〇〇	一	三五	一三	二吋八分ノ三	三—一〇	一四—〇	五—八	
パルソメーター	八〇	一	正味馬力四	五	一	三—四	二—一〇	四—六	
同	八〇	一	四	五	一	三—四	二—一〇	四—六	
同	八〇	一	四	五	一	三—二	二—三	四—六	

同	四〇〇	一	二〇	八	一吋八分ノ七	四—四	四—四	八—五
電働遠心喞筒	一、〇〇〇	一	一〇〇	一四	一	三—四	五—八	三—六

右ノ内四千噸喞筒ハ船渠排水用ノモノナリシガ其ノ後同船渠ニハ電働喞筒ヲ備ヘタル爲メ不用トナリタルモノニシテ其ノ後數年間使用セザリシモノナレバ働作如何ヲ考慮シ四臺ノ中二臺ハ蒸氣力及電力ノ都合上全然使用シ得ル見込ナカリシモ單ニ豫備トシテ搭載セルモノナリ。

喞筒ノ要目概シテ確ナラズ或ハ要目表及試運轉成績表ヲ有スルモ多クハ排水ノ水頭ノミ二十五呎以上ハ試驗ヲナシアリテ吸水ノ水頭ハ僅カニ四呎乃至八呎半迄試驗セルモノノミナリ救難喞筒ノ成績表トシテハ物足ラザルノ思ヒナキヲ得ズ今後此種喞筒ノ試驗ニハ吸水ノ最大水頭ヲ決定スルニ足ル試驗ヲ施行シ置ク必要アルヲ感ズ。

救難喞筒用罐準備

罐大體要目

形式	數	使用壓力（听）	火床面積（平方呎）	塞止弇（口徑）	罐本體ノ寸法 徑（呎吋）	罐本體ノ寸法 長	推定馬力	普通燃燒度（听）	最高燃燒度（听）	備考
汽車罐	一	五〇	九、四四二	二吋二分ノ一	三—六	一二—四	一二	二〇	三〇	
直立罐	二	一〇〇	一八、五	三吋四分ノ三	五—一一	一〇—六	八〇	二五	四〇	
汽車罐	一	九〇	八、六	二吋八分ノ三ノモノ二個	四—〇	一〇—六	八〇	三〇	四〇	
單面圓罐	一	六〇	三二、三	四吋四分ノ一	七—〇	二一—六	一五〇	一五	二五	
單面戻火圓罐	一	九〇	三九、三五	五吋八分ノ三	一〇—〇	一三—一	二四〇	二〇	三〇	

罐ノ蒐集ニハ大ヒニ困却シタリ已ムヲ得ズ前表ノ如ク過大ナル罐マデ搭載セザルベカラザルニ至レリ而シテ使用壓力ニ高低ノ差アリ不便ナレドモ勿論無キニ勝ルベク例令低壓力ニテモ「パルソメーター」用又ハ蒸氣送風用トシテ案外有效ニ働カシメ得ルコトモアルベケレバ蒸氣管及給水管裝置複雜トナルハ忍バザルベカラズ。

罐ノ蒸發力ト喞筒ノ蒸氣消費額

(一)汽車罐ハ一ハ百噸喞筒一臺ヲ辛フジテ運轉シ得ベシ他ハ千噸喞筒一臺ヲ運轉スルニ適ス。

(二)直立罐一臺ハ七百五十噸遠心喞筒一臺ヲ運轉スルニ適ス。

(三)單面圓罐ハ八十噸「パルソメーター」三臺及同四百噸一臺合計四臺ヲ受持タシムルハ少シク無理ナルベシ(「パルソメーター」ハ蒸汽消費量非常ニ多ク時ニハ一馬力ニ千五百斤モ要スルモノアレバナリ)。

(四)單面戻火罐ハ四千噸喞筒一臺又ハ此ノ力量ニ相當スル喞筒ヲ運轉スルニ適ス。

以上ノ如ク割當テ前表ノ罐全部ヲ使用スルトキハ合計七千二百四十噸ノ喞筒力量ヲ發揮セシメ得ル次第ナレドモ種々ノ點ヨリ餘裕モ存セザルベカラズ又時トシテハ煙突低部ニ蒸汽送風モ行フ必要アルベシ因ッテ先ヅ六千噸ノ力量ヲ發揮シ得ルモノト見積ルヲ至當トス。

罐ノ保溫トシテ石綿製布團(厚サ約一吋半)ヲ用意搭載セリ。

發電機及電働機準備

罐ノ力量充分ナラズ更ニ少シク增加シ廣キモ搭載シ得ルモノナケレバ工作船ニ於テ發電シ水上電送ニヨリ電働機ニテ喞筒ヲ運轉セン考ニテ次表ノ如ク發電機及電働機ヲ搭載セリ。

發電機及電働機大體要目

形式	電力又ハ馬力	數	電壓	回轉數	幅	長サ	高サ	備考
シーメンス 直流發電機	五〇 KW	一	八〇 V	五〇〇	三—一〇 呎吋	八—六 呎吋	六—〇 呎吋	
同	八八	二	一一〇	五五〇	四—六	一〇—六	七—〇	
直流電働機	六〇 HP	一	二二〇	八五〇	三—一〇	五—八	三—一〇	
同	六〇	一	二二〇	八五〇	四—〇	五—六	三—六	
同	五〇	一	二二〇	九〇〇	三—八	五—六	三—六	
同	六五	一	一〇〇	三五〇	五—六	九—二	三—六	

右ノ發電機三臺ヲ工作船ニテ運轉シ水上ヲ送電シ淺間ノ喞筒据付位置マデノ距離五百米突ト見積リ之レニ必要ナル電纜及約二百呎ノ調革（喞筒四臺用）ヲ用意セリ。

汽働喞筒ヲ電働喞筒ニ改造

横須賀ヨリ「サンバルトロメ」ニ至ル航海中七百五十噸遠心喞筒二臺千噸遠心喞筒一臺ニ豫テ準備セル滑車ヲ裝置シ此等汽働喞筒ヲ電働機ヨリ調革仕掛ケニテ作動セシメ得ル改造準備ヲ行ヘリ。

以上ニヨリ（工作船ガ淺間ノ近傍二百米突以内ノ處ニ羈泊シ得ルコト、ナラバ）電力ニテ三千五百噸（前記改造ノモノニテ二千五百噸外ニ千噸電働喞筒一臺合計三千五百噸トナル）ノ排水力量ヲ得ベシ即チ蒸氣喞筒ト合計力量九千五百噸ヲ排水シ得ルベキコトトナル。

主ナル管類準備

（一）蒸汽用屈曲自在銅管ハ出來得ル丈ケ多數ヲ搭載スルコトトシ搭載前ニ一應水壓試驗ヲ行ヒ搭載セリ。

蒸氣用屈曲自在銅管搭載表

内經	數量	一本ノ長サ	總長サ	備考
二吋二分ノ一	二〇本	一五、〇呎	三〇〇呎	
一吋	四本	五、〇米	二四、五米	一、管ハ全部二百听水壓施行良好ノモノ 一、管水壓後接合金具ハ全部ノ手入ヲ行ヘリ
一吋	一本	四、五		
一吋八分ノ三	一本	四、五	一七、五	一、徑別及長サハ接合鍔部ニ刻印シ置ケリ
同	一本	五、〇		
一吋八分ノ三	二本	四、〇		
一吋二分ノ一	一本	四、五	九、五	
同	一本	五、〇		
二吋	一本	五、〇	九、	
同	一本	四、〇		

二吋四分ノ三	三本	五、〇	一九、五
二吋四分ノ三	一本	四、五	

(二)吸入用護謨蛇管ハ千噸唧筒二臺七百五十噸唧筒四臺並ニ四百噸唧筒一臺ニ對シ各々吸水弁函ヨリ吸水口ニ至ル距離六十呎ト見積リ五吋護謨蛇管ヲ準備セリ。

(三)百噸遠心唧筒及四百噸「パルソメーター」用トシテ八吋及十吋護謨蛇管ヲ用意セリ。

護謨蛇管搭載表

內徑	長	數	備考
五吋	一五呎	一四〇本	二千百呎 全長
五	一六	六同	九十六呎
五	三二	四四同	千四百八呎
一〇	一六	三同	四十八呎
八	一六	二〇同	三百二十呎
			總長三千九百七十二呎

(四)四千噸唧筒吸入管其他ノ唧筒ノ排水管用トシテ八分ノ一吋鐵板ニテ製造セル徑十五吋ノモノ二百八十呎、八吋乃至十二吋ノモノ二百呎準備セリ。

以上ノ外蒸汽排氣給水管用トシテ多數ノ銅管ヲ用意セルコト左表ノ如シ。

銅管受拂明細表

品名	寸度 內徑	寸度 厚(ゲージ番號)外徑	寸度 長	搭載數	拂	殘
銅製目無管	五吋	一二	一〇呎	八	八	〇

同	四吋四分ノ一	一二	一三	六	二	四
同	四吋二分ノ一	一三	一七	二	一	一
同	四吋	一一	一五	一五	一三	二
同	四吋	一二	一三	八	八	〇
同	三吋二分ノ一	七	一六	九	九	〇
同	三吋二分ノ一	一〇	一五	二	二	〇
同	三吋二分ノ一	一一	一五	一	一	〇
同	三吋	一〇	一五	五	五	〇
同	三吋	一一	一六	二五	一四	一一
同	二吋二分ノ一	八	一五	九	九	〇
同	二吋二分ノ一	一三	一五	一九	一九	〇
同	二吋二分ノ一	一三	一〇	一一	一一	〇
同	二吋	一〇	一五	二二	二二	〇
同	一吋八分ノ五	一〇	一六	三〇	三〇	〇
同	一吋四分ノ一	一四	一五	一〇	一〇	〇
同	一吋	一〇	一五	一九	一九	〇
同	四分ノ三	一二	一五	六	六	〇
同	八分ノ五	一三	一五	一五	九	六
同	二吋ノ一	一四	一六	一六	一六	〇
同	八分ノ三	一四	一六	三〇	一八	一二
同	五吋四分ノ三	一一	一〇	六	四	二
鑄付銅管	六吋二十二本ノ全長(百九十八呎)			二二	二二	〇
同	五吋(四本ノ全長三十二呎)			四	四	〇
銅管	十一吋八分ノ七	十二吋四分ノ一	一一	一	一	〇
同	八吋二分ノ一	八吋八分ノ七	一三	一	〇	一

同	八時二分ノ一	八時四分ノ三	一七	一	〇	一
同	八時二分ノ一	八時十六分ノ三	一七	二	一	一
同	八時	八時四分ノ一	一七	三	一	二
同	七時十六分ノ九	七時四分ノ三	一七	四	〇	四
同	七時	七時八分ノ三	一七	一	〇	一
同	七時二分ノ一	七時四分ノ三	一七	一	一	〇
同	一時	一時十六分ノ三	一五	一〇	一〇	〇
同	四分ノ三	一二	一五	一〇	〇	一〇

備考、拂ハ離礁前排水裝置ニ使用セルモノ及離礁後諸管裝置ノ一部復舊ニ使用セルモノヽ合計ヲ示セルモノニシテ離礁前ニ使用セルモノハ全部ノ約六割トス。

淺間ニ据付ケノ事ニ決定セル罐及喞筒

罐ハ全部上甲板ニ据付ケ喞筒ハ蒸汽力ニテ運轉シ得ル範圍内ニテ可成具合宜キ多數ノモノヲ防禦甲板非浸水部ニ据付クルコトヽセリ。

救離罐番號表（作業ノ便利ノ爲メ番號ヲ附ス）

番號	名稱	使用壓力	備考
一號	汽車罐	五〇听	
二號	直立罐	一〇〇	
三號	汽車罐	九〇	
四號	直立罐	一〇〇	
五號	單面圓罐	六〇	
六號	單面戻火罐	九〇	

備考、火床面等ノ詳細ハ救難喞筒用罐準備ノ項ヲ參照スベシ。

救難喞筒番號表(作業ノ便利ノ爲メ番號ヲ附ス)

番號	名稱	排水口ノ徑	備考
一號	百噸遠心喞筒	八吋	
二號	八十噸「バルソメーター」	五	
三號	七百五十噸遠心喞筒	一三	
四號	七百五十噸遠心喞筒	一三	
五號	同右	一三	
六號	記憶ニ便ナラシムル爲メ奇數番號ヲ右舷偶數番號ヲ左舷ニ据付タルモノトセルタメ配置上六號ヲ缺クコトヽナレリ		
七號	千噸遠心喞筒	一二	
八號	七百五十噸遠心喞筒	一三	
九號	千噸遠心喞筒	一二	
十號	四百噸「ウオジングトン」喞筒	一三	
十一號	八十噸「バルソメーター」	五	
十二號	同右	五	
十三號	千噸電働遠心喞筒	一四	
十四號	二十五噸石油發動機喞筒	二、五	

備考、要目詳細ハ救難喞筒準備ノ項ヲ參照スベシ。

罐運搬据附

五號罐ハ二十噸六號罐ハ十八噸ノ重サアレバ人力ニテハ淺間上甲板ニ取入ルヽ能ハズ因テ重量輕キ一號ヨリ四號迄ノ罐(何レモ五噸以内)ヲ先ヅ据付ケ「メーンデリック」ヲ使用スルコトヽシ三月二十九日着手四月三日竣工引續キ五號、六號ノ大罐ハ爐筒及罐管等ハ全部盲板及木栓ヲ施シテ水防シ木材及ビ浮箱ヨリ成ル筏ノ浮力ニ依ッテ

海上ニ浮ベテ運搬シ四月五日搭載終ル斯クシテ罐ハ上甲板ニ充分ニ固定シ豫テ準備セル石綿製布團(厚一吋半)ニテ保温セリ通風ノタメ排氣送風及蒸汽送風管ヲ各罐ノ煙筒底部ニ夫々設ケタリ。

給水喞筒及給水「タンク」

給水喞筒ハ一號ヨリ五號ニ至ル五罐ハ夫々固有ノ附屬給水喞筒ヲ搭載セシガ六號罐ニ對シテハ「ウエーヤ」式ノ給水喞筒ノ働作確實ニシテ六號罐ニ要スル力量ノ三倍ヲ給水シ得ルモノヲ準備シ此ノ餘力ヲ以テ他ノ給水喞筒ノ不時ノ故障ニ對スル補助装置ヲ兼シムルコトヽセリ。

豫備給水「タンク」トシテ上部石炭庫四、六、七、八番ヲ使用セリ給水重量ガ浮揚作業ニ差支ヘナキトキハ五百噸ノ水ハ貯ヘ得ベシ又給水「タンク」トシテハ給水喞筒ノ働作ヲ考慮セル結果上甲板左舷釣床格納所ヲ水防シテ使用セリ約三十噸ノ罐水ヲ貯フルコトヲ得タリ。

給水「タンク」ニ水量缺乏セバ優力ナル給水喞筒又ハ消防喞筒ニ依リ補充スルモノトス排氣蒸氣管ノ疏水ハ可成給水「タンク」ニ導ケリ。

罐ノ力量ハ餘裕ナキヲ以テ大排水中罐水濃分高マラバ申譯ナシ故ニ萬難ヲ忍ビ絶對的最後ノ必要ニ迫ルニ非ラザレバ海水ヲ使用セザル方針トシ豫備給水「タンク」モ大容積ノモノヲ準備シタリ罐水ノ供給ニハ淺間ノ苦心一通ナラズ千五百浬ヲ隔ツル地ニ運送船ヲ派シテ運搬スルコトモアレバ僚艦ノ助力ヲ仰グコトモアリ工作船ハ他艦ヘノ供給ハ勿論自己ノ消費量ヲ補フニモ不足ニシテ是亦他ヨリ供給ヲ仰ガザルベカラズ其後時々遭難船淺間ヨリ救難スベキ船ガ眞水ノ供給ヲ受ケタルコトモアリ珍ラシキコトナラズヤ。

註、大排水總喞筒運轉ヲ十二時間繼續スルトセバ正味百五十噸ノ罐水ヲ要スベシ從テ少クトモ二百噸ノ罐水ハ用意セザルベカラズ。

喞筒据附

一號ヨリ十二號ニ至ル排水喞筒ハ四月一日据付ニ着手シ同十一日マデニハ全部据付終リ必要ナル蒸汽管等ノ關

聯諸装置モ亦竣工シ排水運轉準備整ヘルモ最モ困難ヲ感ゼシ吸入蛇管取付非常ニ困難ニシテ未ダ五分通リモ終ラズ漸ク四月十六日ニ至リ第一回排水試驗ヲ施行シタリ排水試驗結果後部浸水區ニ對シテ更ニ第十三號電働遠心喞筒ノ据付ヲ要スルコトヲ發見シ四月十八日着手同二十日据付竣工ス。

註、此電働機ハ一〇〇「ボールト」ノモノヲ用ヒ淺間八十「ボールト」發電機ヨリ送電セリ吸入蛇管取付工事モ大努力ノ結果四月二十日全部竣工ス排水装置工事茲ニ初メテ完備セリ。

防禦甲板ハ極メテ少量ノ漏水アリシモ喞筒据付ニハ最良ノ位置ナリ依テ總テノ喞筒ハ此甲板ニ据付クルコトシ吸入弇函ハ干潮時ヲ選ビ機械室「ハッチ」圍板ニ又罐室通風路ノ圍板ニ穴ヲ穿チ弇函ヲ夫々内側ニ突出セシメタリ。喞筒排水管ハ夫々相當ノ鐵板製管ヲ用ヒ何レモ喞筒排水口ノ直上ニテ中甲板ヲ貫キ中甲板ニ特設セル木製「タンク」(高サ三呎六吋、幅二呎三吋、長六呎七吋)ニ排水セシメ(但シ「ウオシングトン」喞筒排水管ニハ木製「タンク」ヲ用ヒズ)更ニ此ノ「タンク」ヨリ鐵板管ニテ中甲板舷側ニ排水セシムルコトトセリ。

註、(一)此ノ排水管ハ病室、次室、分隊長室等所々通過セシメタルニヨリ居住者ノ不便大ナリシコトト察セラルルモ排水上ノ利益ハ多大ナリシモノト認ム。

(二)木製「タンク」ノ利トスル所ハ排水管ノ曲屈ヲ減ジ以テ工事ヲ容易ナラシムルト同時ニ喞筒ノ揚水水頭ヲ減ズルコトヲ得ベク又喞筒起動ノ際「向ヒ水」ヲ送ルニ甚ダ便利ナリ。

(三)向ヒ水ハ小形消防喞筒及二十五噸石油發動機喞筒ヲ以テ送レリ。

吸入護謨蛇管導キ方

千噸喞筒ニハ一臺ニ付五吋蛇管八本、七百五十噸及四百噸喞筒ニハ一臺ニ付七本、宛導カザルベカラズ七本、八本、ノ五吋蛇管ヲ通風路等ノ狹隘屈曲セル鋼壁ヲ所々ニ切リ破リ導クハ中々困難ニシテ潜水工ノ苦心察スルニ餘リアリ如何ニ苦心スルモ所ニヨリテハ蛇管ノ屈曲意ノ如クナラズ到底直接吸入弇筺ニ接續シ能ハザル所アリ因テ屈曲セル特製鋼管ヲ吸入弇筺ニ装置シ以テ接續ヲ容易ナラシメタリ。

特製鋼管ト蛇管ヲ接合スルニハ銅管ノ鍔ヲ固定ニ造リ蛇管ノ鍔ヲ自由ニ廻ル樣装置シ柔軟鋼線鋼ヲ兩鍔締付螺釘孔ニ通シ滑車ヲ以テ索引シ締付螺釘孔ヲ出合ハシメ以テ接續ヲ容易ナラシムルノ方法ヲ採リタルガ非常ナル好成績ヲ收メタリ特ニ百噸喞筒及電働千噸喞筒用八吋護謨蛇管ハ蛇管ノ通路ニ少シニテモ曲リアルトキハ取付困難ナルモノニシテ若シ此ノ方法ニヨラザリセバ或ハ到底取付ケ得ザリシナラン。

蛇管ハ所々隔壁ヲ切リ破リ罐室內底機械室曲肱抗等ニ導ケルモノナレバ要所ニハ木材等ヲ置キ蛇管ノ損傷ヲ避クルコトトセリ。

諸管装置

蒸汽排氣給水等諸管装置ニ付キ少シク解説スレバ左ノ如シ。

蒸汽管ニハ石綿板ヲ卷キタル上ニ荒毛氈ヲ卷キ其上ヲ藁繩ニテ卷キタル所モアリ帆布ニテ卷キタル所モアリ。

管ト鍔トハ殆ンド全部鑞付ヲ行ハズ折リ返シ法ヲ以テ迅速ニ工事ヲ施セルガ結果良好ナリキ（排氣管給水管モ同樣ナリ）。

救難喞筒以外ニ蒸汽管ヲ導ケルハ揚艇機揚錨機發電機ナリ。

排氣管ハ數ケ所ノモノヲ合同シタルノ後前後部煙突ノ內、外筒間ニ放氣セシメタリ。

給水管ハ罐ニ夫々附屬セル給水喞筒ニテ給水シ得ルト同時ニ他給水喞筒ニテモ給水シ得ル樣導ケリ其ノ外必要ニ應ジ豫備給水「タンク」ノ水ヲ給水「タンク」ニ送リ或ハ舷外ヨリ清水海水ヲ取入レ得ル樣装置セリ諸管ヲ導クニ當リ艦內固有装置管ヲ可成利用セントセルモ全長ノ百分ノ五モ利用スル能ハザリキ。

註、（一）喞筒ノタメ特設セル蒸汽管ノ全長千四呎排氣管六百九十四呎給水管四百八十一呎ナリ。

（二）弇、嘴モ意外ニ多數ヲ要セリ即チ弇二十四個、嘴十三個、丁「ピース」二十二個ヲ使用セリ而シテ此ノ使用數ノ約四割ハ淺間艦內諸所ヨリ取外シ使用セリ。

罐ノ力量

初計畫通リ千噸喞筒二臺、七百五十噸喞筒四臺、四百噸及百噸喞筒各一臺、八十噸「パルソメーター」三臺ハ裝備セル罐六個ヲ以テ汽醸セバ先ヅ辛フジテ運轉繼續シ得タリ。

註、罐ノ力量充分ナラザルヲ以テ喞筒運轉前或ハ中途一部分喞筒止動ノタメ餘力ヲ生ゼシトキハ給水ヲ成ルベク高溫度ニ加熱シ置クコトトセリ。

排水防水運轉中ニ時々蒸汽壓力著シク下降セルコトアリシハ前記計畫以外ニ千噸電働喞筒用ノ發電機又ハ揚錨機ヲ運轉シタル場合若シクバ給水管ガ灰爐ニヨリ過度ニ熱セラレタル結果給水意ノ如クナラザルタメ一時混雜ヲ來タサン場合ニ多カリシモノト認ムルモ又一方ヨリ考フレバ罐ノ力量ニ些少ノ餘裕モナカリシモノト云フベシ。

罐氣醸中ノ最大燃燒度ヲ記錄ヨリ拔萃セバ左ノ如シ。

二號、四號罐	（直立罐）	三十二听
三號罐	（粟橋汽車罐）	二十七听
五號罐	（單面圓罐）	二十七听
六號罐	（單面戾火罐）	二十八听

但シ離礁當日ハ記錄ヲ取ルノ暇ナカリシニヨリ當日ノ最大燃燒度不明。

石炭ハ第二種和炭ヲ使用シ給水溫度七十八度ニシテ平均蒸發水量石炭一噸ニ對シ七、三二噸ヲ得タリ。

喞筒ノ能力

喞筒吸水頭ハ左記ノ高サマデ少シモ差支ナク排水シ得タリ而シテ百噸喞筒ノ如キハ尙ホ餘力アリト認メタリ。

百噸喞筒	二十二呎
七百五十噸喞筒	二十五呎
千噸喞筒	二十五呎
八十噸「パルソメーター」	二十呎

百噸喞筒ハ動作頗ル良好ニシテ回轉數六百迄ハ何等異狀ナク運轉シ得タリ又排水量モ優ニ百噸以上ヲ排水シ得ルモノト認メタリ。

七百五十噸、千噸喞筒何レモ良好ニ働作セリ。

四百噸「ウオシングトン」喞筒ハ働作先ヅ良好ナリシモ機體稍大ニ過ギ運搬ノタメ通路ヲ切リ開ク等不便尠ナカラズ喞子喞筒ハ艦底ノ溜水ヲ引クニ適スルヲ以テ遠心喞筒ノミニテモ不便ナルベケレド機體ノ過大ナル喞子喞筒ハ隨分不便ナリ。

「パルソメーター」ハ低壓力蒸氣ニテモ能ク動作シ便利ナレドモ蒸汽消費量多大ナルハ缺點ナリ殊ニ今回ノ如キ罐ニ餘力ナキ場合ニ於テ然リトス。

空氣壓搾喞筒使用（「ニューマチツクドリル」用トシテ）

離礁後「サンバルトロメ」ニ於テ罐室內底修理等ニ際シ鋲若シクバ螺釘用孔ノ鑽揉ヲ要スル所多シ依テ罐管氣吹掃除用空氣壓搾喞筒ヲ使用シ十號罐ヲ氣蓄機用トシ同罐水面計臺管ヲ氣吹掃除用空氣主管ニ連絡シ「ニューマチツクドリル」ニ送風セシガ大ニ便利ナリキ殊ニ「ドリル」ノ空氣管接續金具ト氣吹掃除空氣管ノ接續金具ト同一ナリシハ甚ダ好都合ナリ「ドリル」ハ十五听ニテモ頗ル良ク回轉スルモ此裝置ニテハ使用壓力三十听ト定メ喞筒回轉數百以內（最大回轉數二百）ニテ二臺ノ「ドリル」ヲ完全ニ働作セシムルコトヲ得タリ而シテ別ニ試驗セル所ニヨレバ喞筒回轉數ヲ二百ニ保ツトキハ三十听使用壓力ニテ四臺乃至五臺ノ「ドリル」ヲ使用シ得ベシ。

次ニ淺間北上シテ後チノ工事ニ潛水工用「ニューマチツクドリル」ニ送氣センガタメ「ドリル」用空氣壓搾機ヲ淺間上甲板ニ据付ケタリ其ノ要目左ノ如シ。

電働機附空氣壓搾喞筒

電働機二百二十「ボルト」五十五馬力

喞筒ハ一分間「フリーエヤ」五百立方呎ヲ發生ス

喞筒壓力八十听

此電働機ニ送電スル爲メ百十「ボルト」八十八「キロ」發電機二臺上甲板ニ据付ケ良好ノ結果ヲ得タリ。

鋲打ノ速ナリシ事

特ニ造船工ト競爭セシムル爲メ艦外底補强用「ガーダー」(九十九番肋材ノ左舷ノモノ)組立鋲打ヲ製罐工ニ命ジタルニ鋲鑪二臺製罐職工十四名ニテ午前五時半ヨリ午後七時十分マデ即チ十三時間四十分ニテ(晝食夕食時間ヲ含ム)徑四分ノ三吋鋲千二百本左シタル不良ノ成績ナク打チ終レリ必死トナリテ働ケバ隨分早キモノナリ鋲打チノ速ナリシ新記錄ト見做スベキモノナラン參考ノ爲メ附記ス。

救難工事ニ用ヒタル主ナル材料

左表參照「アセチリン」及酸素瓦斯ノ使用ハ頗ル多額ニ昇リタリ主トシテ切斷ニ使用シタルガ溶接ニモ亦使用シ實ニ必要缺クベカラザル工業材料ナリ又離礁前ヨリ「セメント」七千袋ヲ準備シタルガ應急修理ノ爲メ遂ニ六千二百五十一袋二百五十一噸ヲ使用シタルコトモ異數ト謂フベシ次ニ船體修理用鋼材ハ特別ノ箇所ノ外ハ必ズ十封ノ鋼板三吋ノ山形四分ノ三吋ノ鋲又ハ「ボルトナット」ヲ用ユルコトニ一定シ思ヒノ儘ニ使用セシメタリ厚キ鋼板ハ手重クシテ急ギノ工事ニハ適セズ。

救難工事船體機關ニ使用シタル主ナル材料表

品目	數量	備考
鋼板	四八屯、九三〇	三百二枚主トシテ厚サ四分ノ一吋四呎八吋ノモノナリ
山形鋼	二六、〇二九	延長八千五百五十呎主トシテ三吋三吋七封半ノモノナリ
鋲	六、六〇〇	二萬六千五百本主トシテ徑四分ノ三吋ノモノナリ
「ボルトナット」及「タップ」	一〇、五六四	二萬九千九百七十本主トシテ徑四分ノ三吋ノモノナリ
木材	一三三、四〇〇	角材挽材丸太各種尺メ八百九十本ナリ

「セメント」	二五一、〇〇〇	四十五瓩入六千二百五十一袋
帆布	二、五〇〇	一、二、三號各種百二十五反
「ワイヤロープ」	一、〇〇〇	周一吋乃至三吋半ノモノ七十三房半
綱類	六、七〇〇	周一吋乃至四吋ノモノ九十八房
古毛布	一、〇〇〇枚	
銅製目無管	五、八一七	徑八分ノ五吋乃至十一吋八分ノ七ノモノ總長三千七百一呎
銲付銅管	二、〇三五	徑五吋六吋二吋半ノ三種總長四百七十呎
丸鋼	三、六六二	八分ノ三吋ヨリ四吋マデ二三七本
鍍地金	四、〇〇〇	
銅	七三六	
錫	一五〇	
亞鉛	七〇	
「ホワイトメタル」	五〇〇	
鑄鐵地金	二四五	
酸素	一、三三六、〇〇〇律	
「アセチリン」瓦斯	二九二、〇〇〇	
「カーバイト」	七二罐	
白絞油	三、五六四律	
內部礦油	四五〇	
「ダイナモ」油	一、三一四	
石油	一八〇	
煉瓦	一、五〇〇ケ	
煉瓦粉	六〇〇瓩	
石綿漆喰	一、五〇〇	
石綿織物	三二〇	四卷
石綿製紙	八七〇	一四二枚

眞鍮線入石綿製織物	二〇三
絲屑	一、二一〇
蠟燭	二〇、一〇〇本

（後編終り）

○會長（寺野精一君）　唯今岩野、浦田、橋口ノ三君カラ種々有益ナル御話ガゴザイマシタガ此救助工事ニ付テ何カ御尋ニナリタイコトガゴザイマスレバ極箇單ニ願ヒタイト思ヒマス……別段御質問モナケレバ皆サンニ代ッテ御兩君ニ御禮ヲ申上ゲマス、淺間遭難ノコトハ國家ニ取ッテ非常ニ大ナル出來事デアリマシタガ、御兩君初メ當事者各位ノ御盡力ニ依ッテ無事ニ離礁ガ出來テ內地ヘ歸航シタト云フコトハ國民ノ大ニ感謝スル所デゴザイマス、殊ニ遠隔ノ地ニ於テ非常ニ御苦心ニナッタ御話ヲ詳細ニ承ハリマシテ、會員一同大ニ利益ヲ感ジマシタ、一同拍手シテ御禮ヲ申シタイト思ヒマス。（一同拍手）

寄稿

會報第拾八號を手にして

協同員　柴田齡二

近來會報の内容が大に充實せられて、生等後進を稗益する事は少くありませんので、非常に感謝して居る所であります、所で今回會報第拾八號の送達を受けまして、相變らず興味を以て讀みましたが、中に幾分不肖の感じた點がありますから、之を書いて御送りして、それによりて先輩諸氏の高敎を受ける事が出來れば非常に仕合せだと存じます。

第一は螺旋軸折損の原因でありますが、先輩柴田敏千代氏の講演がありまして、それに付て郵船會社側及び遞信省側の御意見も出て居ります、所が小生が見ました所では、柴田氏の御説は折損の直接原因を論じて居らるゝ様でありますし、而して郵船會社側及び遞信省側は「ザーヴエーイング」と云ふ方からの御意見が主として出て居る様であります、それで郵船會社側は六年遞信省側は八年を一般に軸の衰弱、從て危險程度に達するものと大略見られて居る様であります、多數の軸を御取扱になつて、如斯有益な數字を御示し下さいました事は、吾人後輩の誠に感謝する所でありますが、茲に小生は使用者側から、直覺的に感じた所を申上げて見度いと思ふのであります。

それで螺旋軸は全體に於て海水に接觸する所が悪くなる、從て或る程度に衰弱したるものは、「サーヴエーイイング」側からして不合格とせらるゝに至ると云ふ事は、「サーヴエーイング」の眞意味からして尤な次第ではありますが、併し衰弱して居るから直にそれが危險であるであらうかと云ふ事は、私は少し疑があると思ひます、即危險とは其直接の原因それ自身が分らねば、其程度は明でないことになります、即ち丸で新しい疵のないものでも、折れる事もあり、所謂社外船杯では隨分古いものを使つて居つても、折れずに濟んで居るものも少くない、從て必

至の原因は必ずしも所謂衰弱即海水作用のものと、直接の關係はない樣で、唯衰弱したものは强力上折れ易いと云ふ副原因に過ぎないと思ひます、而して折れた軸が又大抵は普通の計算にて、所要强力の數倍の力を有つて居るのが普通で、又驚く程早く悪るくなるのもあれば、又同じ狀態でも左程に悪くはならぬのもあります。

以上を考へ合せて見れば、材料それ自身が非常な關係を持つて居ることは明でありますが、小生には材料とか、海水作用の副原因とか云ふことは分りませぬから、先づ一般に强力として差支ないものとは見做せると云ふ點から出發して、そして自身操縱して見て、又船の上で感じた所の直接原因らしいと思ふ所を述べて見度いと思ひます。

元來私はあまり螺旋軸の折損に付て研究しては居りません、であるから、ほんの直覺的な感じそれ以外の事は述べることは出來ませんが、唯方面が違つて居るから玆に駄足を添えて見るのであります。

それで螺旋軸で折れるのは如何う云ふ種類が一番多いかと云へば、黃銅卷が二ケ所にあるもので、そして何處から折れるかと云へば中央部の黃銅卷の兩端である、又如何なる場合かと云へば、荒天航海中又は其後に折れるのが殆んど皆の場合の樣であります、それで之以外のものは不聞にして餘り多く耳にしませんから、重に此三點から見て直覺的感じと照合して見ることゝ致します。

荒天航海中には螺旋軸は果して如何なる有樣になるかと云へば、船體が非常に屈曲する從て軸が彎曲作用を受けると云ふことゝ、又螺旋が波濤の衝擊を受けると云ふことがあります、そして其程度は如何程であるかと云へば、小生の推想では三百呎の長の中古船で「シャット」全體の長さが受ける彎曲が、最大振幅二吋以上でなかろうかと思ひます、それは何で左樣に思ふかと云へば、船が入渠した時と出て貨物を入れた時と、「シャフトライン」の相違が一吋以上に及ぶことは往々にして珍しくない事でありますが、波濤の中では船體の前部と後部とが、高さ拾數呎の二つ波の上に乘ることは少くない、隨て斯る場合や波の模樣によりては、隨分二吋位は曲るであらうと思ふのであります、數字の處は慥かではありませんが、併し彎曲することは慥かな事實で彎曲の狀態は舳艫部

が揚げられて中央部が下げられる時が一番多い樣に思はれます、そして恐らく此數字は過大ではありますまいと思ひます。

次に「プロペラー」を波が衝擊する力、之は極めて不判然でありますが兎に角存外偉大な力に相違ない、と云ふのは「プロペラー」は其全面に對して、平均三四磅の壓力を加へらるれば、普通の機關では回轉中のものを停止せしめらるゝことになります。所で波の力は彼の防波堤等の勘定から見れば、慥かにそれ以上或は遙かにそれ以上であると思はるゝ、即「プロペラー」は機關の馬力或はそれ以上の力を以て衝擊せらるゝのであります、尤も螺旋全面を波が衝擊する場合は追波の時しかない、追波の時には船の速力が之を緩和するし、其外の場合には全面に及ぶこともなく又「ブレード」が曲つた角度を持つて居る、從て機關は容易に波の爲に停止せらるゝことはないが併し一時的には隨分停止せらるゝことは稀しからぬことであります。

それで以上の二つの力が「シャフト」に及ぶ時には、其二者の結合又は衝突によりて、軸の彎曲即一側は壓縮せられ他側は延長さるゝと云ふ作用を起すことゝなります、所で此彎曲に抵抗するものは船尾管兩端及び黃銅卷で、殊に黃銅卷の兩端は激しく之に抵抗することゝなります、荒天航海中に軸に及ぼす變化は之が重もなるものであります。

それなれば二個の黃銅卷の內、あるものが何故弱いかと云へば、其內一ケの黃銅卷は軸の中央部にある、其處では彎曲作用の爲めに鐵又は鋼質が伸縮して、其反覆作用によりては外面は元より內組織も脆弱になり易い點であります。其處に黃銅卷兩端の抵抗が「ストレッス」を起こして之を助長することになるのであります、さうして强力の弱い方の端又は力の中心に近い方の端に働くと思ひます。

斯く申せば黃銅卷の强力が、軸材より强い樣に聽こゆるのでありますが、黃銅卷の强力が必ずしも軸より强くなければ軸に影響を與へないとは云はれない、而して黃銅卷は軸の外周の外部に於て厚さを以て居るからして、厚さ次第では隨分質量として大きいものとなり、其影響の及ぼす所が少ないとは云はれないと思ひます、そして

黄銅卷の方が延びて軸に密着して居らないとか、割れて來るとか云ふこともありますから、慥に其抵抗の非常であつたことを知ることが出來ると思ひます、自然衰弱に反比例する彎曲の増加が自乘的計算となり、外力と機關の力と二種の力が加算せられたものが、所謂所要强力の數倍となりて軸の力を超過し、茲に於て折れるのではなかろうかと思ふのであります。

それで小生の所感を押し擴げて此以外にも及ぼして申上げれば、近來汽船は漸次長いものが多くなつて居る、けれども其大さが太くなつて居る爲めに、所謂耐海性が多いのと、航海時間切り詰めの爲めに無理な航海をすることが多い、即怒濤を乘り切ることが多くなつて居ります、それから一方吃水が深いのに双螺旋になると云ふ風で「レーシング」が少い、從て「ガバーナー」は廢せられ「スロットリング」をすることが少くなつて居ります、從て「シャフト」の「ケース」が比較的多くなつたのではなかろうかと思ふて居るのであります、そして所謂社外船は船の古いのが多いし、從て航海も無理が少ないと云ふ點もあり、速力を餘り出さぬから扭力が少い、從て軸は古くとも「ケース」が少いのではなかろうかと思ふのであります。

それで小生の意見は唯所感に過ぎませんが、此所感上から見ての防禦法を云ふて見れば、間接的には無論船體及び機關の操縱に注意することでありますが、此方に充分には行き兼ねるとして、直接的には黄銅卷を通しにして、軸の中央部即强力上の弱點に「ストレッス」を集中せしめない樣にすること、又防腐蝕法を充分に施し、或れば折損部分の鐵又は鋼の「グレイン」の狀態を研究して見ては如何かと思ふのであります。又出來螺旋軸の樣に長くしないで、新造船の時に可成太さを太くしては如何がであらうかと思ふのであります序に申上げ度いことは新造後七八年で軸が悪くなると云ふ事柄に就て、軸それ自身も悪くなるに相違ありませんが、船體と云ふものが漸次に强力が弱くなるのと、波に揉まれて彎曲する程度が漸次に大きくなると云ふことも考へなければならぬ事ではなからうかと思ひます、それなれば古い船は軸が直ぐ痛まなければならない筈ですが、それには「ゆとり」が充分に出來て居りもしませうし、又中間軸自身も彎曲し易くなる爲めに、螺旋軸の方に

力を及ぼすことが少くなるのでなかろうかと思ふのであります、現に古い船では最後の「メインベアリング」即中間軸へ最も近い「ベアリング」の上の「ブラス」は、充分に締付ると燒けて來るので、締められないと云ふ樣な事がありますし、何れにしても彎曲と云ふ事は重大な問題だと思ふて居るのであります、從て柴田敏千代氏所說の樣な船尾管の兩端の抵抗を受くる場合も、往々にしてあり得可き事と思ふのであります。

以上はホンの所感に過ぎません。

第二伊東博士の船舶操縱裝置に就ては、私も亦之に就て工夫を凝らした事がありまして、慥か明治三十四五年頃と記憶して居りますが、私が苦心中に米國だかで其發明があつて、發表せられたのを聞いて中止したことがあります、當時の私の工夫は頗る簡單なるものでありまして、伊東博士の案出せられたものの樣に用意周到ではありませんでしたので、之を附ける爲に受くる利益が附けない爲めに受ける不利より大きいとは思いませんでした。

伊東博士の計畫及び希望は可能不可能の域は既に之を超越して居ります、故に殘る處は其便不便利益不利益の點丈けでありまして、其價値の判斷は百の理論よりも之を實驗するのに若くはないのでありますが、茲に私の氣付いた一二の不利の點のみを擧げて見ることと致ます、(私は伊東博士の成功を希望するものでありますが併し「プレコーション」としては不利の點を考察する方が順序でありまして、又不完全ではありますが自分で工夫した關係から思つた儘を申上ぐるのであることを諒として頂き度いのであります)。

船長と云ふものは衝突とか坐礁とか云ふ樣な危難が迫つて來た際には、其判斷力の餘裕が少し許りあるとないとによつて、大事件を惹起すに至つたり又はせずして終るものでありますから、之に機關操縱をも兼ねて思慮せしめることは餘程深慮を要することであらうと思ひます、元より船長は斯る際に船橋に居つて、機關室の操縱が自分の思ふ樣にならぬので、焦慮する場合も少くありませんから一概には云はれないけれども、船橋操縱にすれば船長に監視的に腦力を費さしめると云ふことは云ひ得らるゝことと思ひます、此點は大に考へて置かなければならない點だと信じます。

同時に斯う云ふ場合になつて船橋に居る人々が、眼前に危險の迫るのを目擊しながら、冷靜に機關を操縱することが出來るかどうかと云ふことも考えて置かねばならぬ所でありまして、それは一つは人格及び心理の問題となることであります。

斯う云ふ風になつた時に船橋に居るものと、間接に此危難を悟る所の機關室の機關士との間に、機關操縱の上で冷靜の程度に相違のあるのは明白でありますが、それにも係らず機關室でさへ吾人の實驗によりますに、倘ほ狼狽が之に伴ふことが少くありませんので、現に沈沒の危險があると云ふ樣な報が來ると前進と後進とを間違へた場合は往々ありまして、幸に監視者が多い爲めに一二回轉で直つたとか、塞汽弇の開閉を間違へたとか云ふ樣な外部に知れないで濟んだ錯誤は慣れて居つても決して少くはないのであります。

それでありますから機關室では操縱は一等機關士が之に當つて、機關長は監督的陪審的地位に居ることになつて居ります、そして油差や他の機關士やも皆陪審的な地位に居るのと同樣になつて居ります。

危險が迫つた際には船橋上では人手の不足を感じますのが常であります、又船長は自然船首とか船尾とか舷側とかの注目に熱中しまして、船橋の末端が最上船橋に立つのを常とします、從て斯る際に特に必要な冷靜な監督的陪審的地位を守ることは出來ません、自然操縱者は一人になつて間違があつても容易には分らないではないかと思はれます、つまり機關室と船橋と何れが冷靜が保てるか、何れが監視的注意が充分に行き届くかと云ふことは、又大に考えなければならぬことであらうと思ひます。

又機關室では船橋から機關を操縱せらるゝことになると、各自が極めて鋭敏に動作をせなければなりません、何故かと云へば機關室では操縱には中心と配置がありまして、操縱中は相呼應して働作する樣に訓練されて居ります、從て此期間には一等機關士が無言で頤を以て差圖をしても、順序上習慣上直ぐに他の人が之を了解することが出來る樣になつて居りますが、突然不用意に操縱せらるゝ樣になれば、中心と配置とは之を定めることが出來ないことはありませんが、腦の中に準備がないから咄嗟に判斷する必要が出來て來て、各自獨立せる判斷力が

入用になつて來る、從て從來の樣な下級機關士又は油差では間に合はない樣になりはせんかと思ふのであります、つまり機關室では「テレグラフ」が鳴つて皆が之を見る、そして順序を踏まれるのを見乍ら秩序的に習慣的に各自の判斷力が出て來るので、機關室操縱が遲いと云ふことはそれ自身弊害であつても、機關室では大事な判斷力の準備が此裡に生ずるものであると云ふことをも考えねばならぬ事と思はれます。

又推進器が何かに當たとか「プライミング」や「ドレーン」で危險だとか、機關の一部に異狀が出來たとか云ふ樣な場合など、即突然停止を要する場合には、機關室では瞬間にして停止して其害を免かるゝことが出來るけれども船橋では自然停止の時機を失つて、災害を過大にならしむる場合も少くないことと思はれます、尤も之に反して機關室よりは船橋の方で早く危險を感じて、之を停止し得ると云ふ樣な場合もないではありますまいけれども、概して損傷を大ならしむる場合は船橋操縱の方に多いと見なければなるまいと思ひます。

又通常三千噸乃至五千噸の汽船では出入港其他の際には船橋には、船長と三等運轉士と丈けしか配置することが出來ません、さうして三等運轉士は船長の使命を帶びて奔走する場合が澤山あります、斯う云ふ風で船橋操縱を行うとすれば、責任上熟練した運轉士と生徒の樣なものとを增員して、機關の操縱と日誌の記錄をさせなければなりませぬ。

それなれば機關室の方では操縱や記錄の用事がなくなるから、人員を減らしてもよいかと云ふと決して左樣には參りません、機關室の人員は當直に割り當てゝ必要な人間丈けしか居らない、それであるから當直以外の用事の操縱や日誌の勞を省かれたからとて、其爲めに人間を減らすと云ふことは出來ないのであります。

以上は氣の付いた點の一二でありまして、最も不便な場合と不利な點許りを撰み出して見たのでありますから、以上の樣であるから此裝置は使はれないと云ふのではありませぬ、前にも申す如く實際の判斷は實驗の上で定めそれで使用區域も決定するのでありませうが、兎に角以上を記して博士及び先輩の一顧に供へることゝするのであります。

Some Hints Regarding Deflection of Ships due to Temperature Difference.

By

Dr. K. Suyehiro, *Member.*
T. Inokuty, *Junior Member.*

(Read before the Spring Meetings of the Society of Naval Architects, Japan. April 10th, 1916.)

(The importance of investigating the present subject was first noticed by Prof. Purvis who suggested to one of our students to study this as a topic for his graduation essay. However, most likely due to lack of time, the student was unable to solve the problem set to him. So we have endeavoured to investigate the subject sufficiently to get some hints in this direction. Under such circumstances, several points involved in the present paper—for instance the relation of stresses in heated and unheated portions and the assumption (2) as to temperature distribution—are due to the suggestion by Prof. Purvis.)

Deflection of ships is undoubtedly one of the important problems connected with the structural strength of ships and its actual measurement as well as theoretical investigations thereon are reported to kindred Societies from time to time.[1] As far as our knowledge goes, except one paper only,[2] written by F. S. Smith of U. S. Navy, the papers deal with the deflection caused by loading. In the paper just mentioned, it was reported that in the Neptune, an American Collier ($L\,520' \times B\,65' \times$ Drft. $27'-7\frac{5}{8}''$) maximum increase of hog of 1 inch was observed on a rise of temperature of 7 degrees F (temperature of air ?). If such an enormous amount of deflection caused by temperature difference is really possible, all the information with regard to deflection of ships so far obtained—especially the deflection after launching, an operation in which temperature distribution

1). Read and Stanbury, "On the relation between stress and strain in the structure of vessels" I.N.A. 1894.
Siemann, "Elastische Formänderung des Schiffskörper," Schiffbau, 1910.
Cornbrooks, "Data on hog and sag of merchant vessels." Am. S.N.A.M.E., 1915.

2). Smith, "Change of shape of recent colliers," Am. S.N.A.M.E., 1913.

is likely to be totally upset—will perhaps be of no value.

The object of the present paper is to see mathematically to what extent a ship may experience deflection under an assumed mode of temperature distribution. Evidently the temperature of a ship will generally be distributed in a very complicated manner (see the end of this paper), and consequently the resulting deflection will not permit of being attacked mathematically. As a preliminary investigation, we attempt here to find only the qualitative value of the deflection, with which actual observation should be compared.

Throughout this paper the following nomenclature is used (refer to Fig. 1—3.) :—

$L =$ length of ship.

$\Delta x =$ small portion of the length.

$\delta x =$ uniform elongation of Δx.

$\delta\xi =$ elongation of the top of the structure due to pure bending of Δx.

$Y =$ distance of the top of a section from its neutral axis.

$Y' =$ „ „ „ bottom of a section from its neutral axis.

$y =$ distance of a point in a section from its neutral axis.

$z =$ amount of hog (or sag).

$a =$ sectional area of a section.

$da =$ infinitesimal sectional area.

$\delta\theta =$ angle through which one end section of Δx is turned relative to the other.

$I =$ moment of inertia of a section about its neutral axis.

$h =$ distance between water line and neutral axis.

$E =$ stretch modulus of steel.

$k =$ coefficient of thermal expansion of steel.

$t =$ temperature.

Now if a ship is heated by the sunshine or other agent, the heat will be conducted through the hull to the sea water and surroundings. When the flow of heat becomes steady, a definite distribution of temperature will be attained in the ship.

Let us suppose, for the sake of simplicity, the distribution in a section is the same at both sides of the ship and put

$$t = f(y).$$

In consequence of such a non-uniform distribution of temperature the ship will be subjected to change of its shape, which may most likely be analysed into a pure elonga-

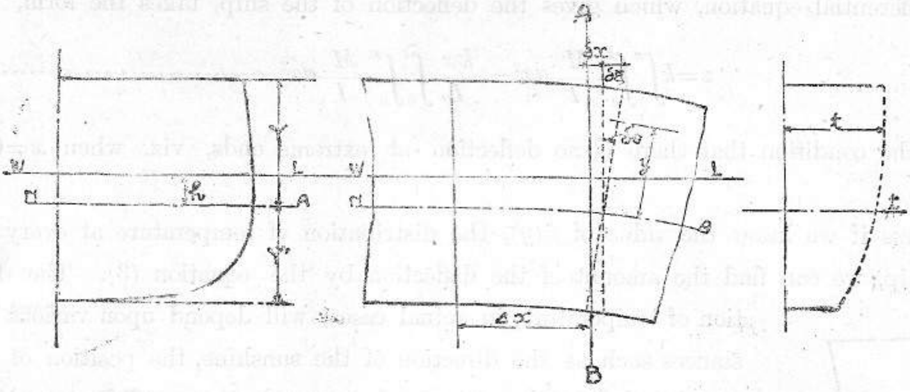


Fig. 1.

tion and a pure bending. As these deformations are caused by internal strain, not by an external force, stresses in the ship will be so distributed that the resultant force of the stresses in every section of the ship is in equilibrium in itself.

From the condition that the resultant force of the stresses in the section AB (see Fig. 1) vanishes, we have

$$\int \frac{E}{\Delta x}(\delta x - kf(y)\Delta x)\,da = 0 \quad \text{.........................(1)}$$

Similarly, as the resultant couple of the stresses must also become zero, we have

$$\int \frac{E}{\Delta x}\left(\frac{\delta \xi}{Y}y - kf(y)\Delta x\right)y\,da = 0 \quad \text{.........................(2)}$$

Of these two equations, the former has no importance in the present problem. From the latter, we obtain

$$\frac{\delta \xi}{Y \Delta x} I = k\int f(y)\,y\,da$$

Now if we put $\int f(y)y\,da = M$ and make Δx indefinitely small, this equation is transformed into

$$\frac{d\xi}{Y dx} = \frac{d\theta}{dx} = \frac{d^2 z}{dx^2} = k\frac{M}{I}$$

where z is the amount of hog as already described. As is well known, the integral of this differential equation, which gives the deflection of the ship, takes the form,

$$z=k\int_0^x\int_0^x \frac{M}{I}dx^2-\frac{kx}{L}\int_0^L\int_0^x \frac{M}{I}dx^2 \quad\cdots\cdots(3)$$

under the condition that there is no deflection at extreme ends, viz. when $x=0$ or L, $z=0$.

Thus if we know the value of $f(y)$, the distribution of temperature at every section of a ship, we can find the amount of the deflection by the equation (3). The distribution of temperature, in actual cases, will depend upon various circumstances such as the direction of the sunshine, the position of shadow cast by shelter, the extent of nonconductive covering, and heat of engine and boiler space. Consequently it is not only very complex in its nature but never attains a constant state. However it will suffice our present purpose, if we assume a simple mode of distribution of temperature, which may not be far from actual occurrence.

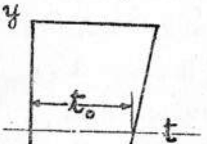


Fig. 2.

(1) If temperature is so distributed throughout a ship that it changes linearly with height and attains extreme value at the top and bottom.

Distribution of such a nature may occur in a shallow draught boat when she is heated by the sunshine from right above. In this case we may assume

$$t=f(y)=\tau y+t_0$$

in which τ is temperature gradient per *unit* height and t_0 temperature at neutral axis. Then

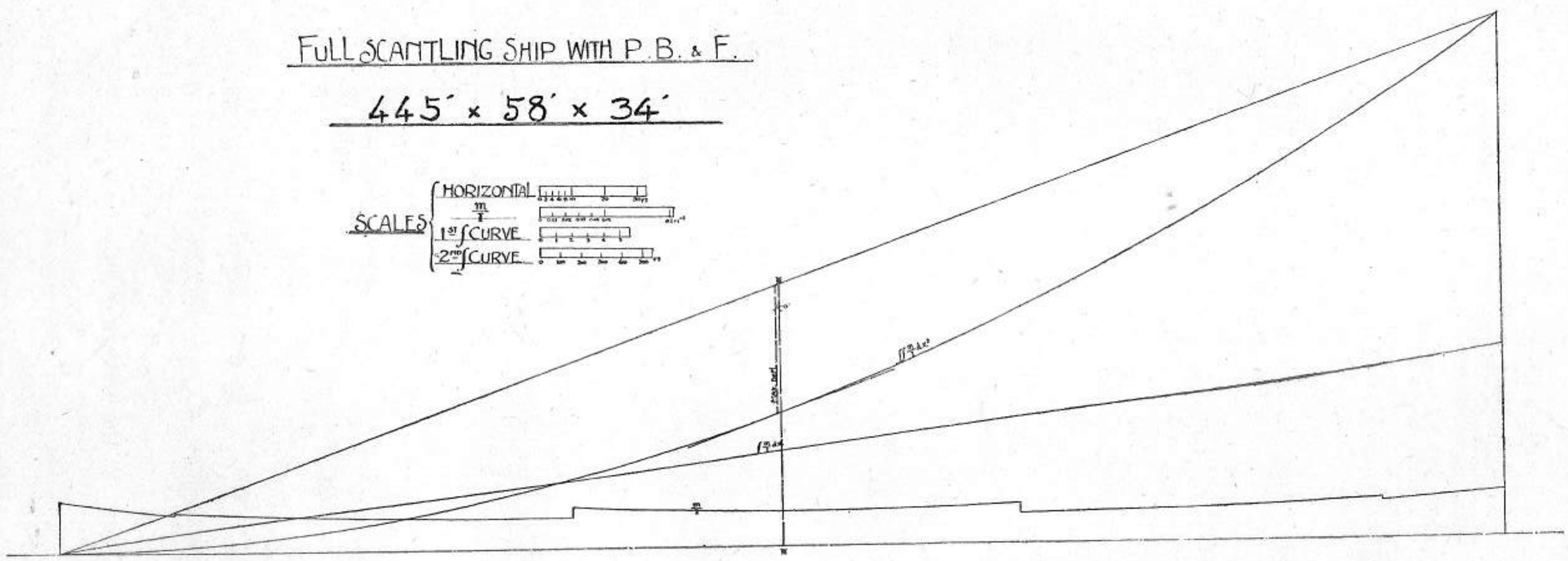
$$M=\int_{-Y'}^{Y} f(y)\,y da=\int_{-Y'}^{Y}(\tau y+t_0)\,y da=\tau\int_{-Y'}^{Y} y^2 da=\tau I$$

As it is assumed that the distribution of temperature is the same throughout the ship, we have from (3),

$$z=k\int_0^x\int_0^x \tau dx^2-\frac{kx}{L}\int_0^L\int_0^x \tau dx^2=\frac{k\tau}{2}\,x(x-L)$$

The amount of hog is evidently a maximum at $x=\frac{L}{2}$ *i.e.* at midship, and it is

$$z=\frac{L^2}{8}\,k\tau\,,$$



FULL SCANTLING SHIP WITH P. B. & F.
445' × 58' × 34'
SCALES
HORIZONTAL
1ST ∫ CURVE
2ND ∫ CURVE

Fig. 4.

in which $k=0.000012\,(C^{\circ})$.

Therefore, when the temperature gradient is $1^{\circ}\,C$ per foot

$$z \text{ in inches} = 1.25 \times 10^{-7} \times L^2$$

A few examples are here shown :—

Length of ship	Maximum deflection for a temperature gradient of $1^{\circ}\,C$ per $1'$
580′	4.20″
445′	2.48″
370′	1.71″

(2) The parts above and below the water line are at different, but uniform temperatures.

Temperature distribution of such a nature may occur in a ship at night or on a cloudy day when the upper part assumes the temperature of the air and the lower part that of the sea water; in certain other cases it is also conceivable.

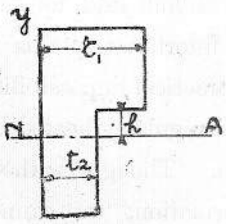


Fig. 3.

Now let t_1 be the temperature of the part above the water line and t_2 that of the part below the same. Then,

$$y = \text{from } h \text{ to } Y \qquad f(y)=t_1$$
$$y = \text{,, } -Y' \text{ ,, } h \qquad f(y)=t_2$$

in which h is the distance between the neutral axis and the water line. In this case,

$$\int f(y)\,yda = \int_{-Y'}^{h} t_2 yda + \int_{h}^{Y} t_1 yda = t_2\int_{-Y'}^{h} yda + (t_1-t_2)\int_{h}^{Y} yda + t_2\int_{h}^{Y} yda = t_2\int_{-Y'}^{Y} yda + (t_1-t_2)\int_{h}^{Y} yda = t.\text{m}$$

where $t=t_1-t_2$, the temperature difference and $m=\int_{h}^{Y} yda$, the moment of the sectional area above the water line with respect to the neutral axis.

Therefore, under the assumption that one and the same temperature distribution exists throughout the ship, we have from (3),

$$z = kt\left[\int_0^x\int_0^x \frac{m}{I}\,dx^2 - \frac{x}{L}\int_0^L\int_0^x \frac{m}{I}\,dx^2\right]$$

This integration has been performed graphically in a well known manner for three different ships (one of the graphical integrations is shown in Fig. 4 as a sample) and the results obtained are shown in the following table :—

講演 温度の差異に基づく船體の變形に關する研究

Type of ship	Dimensions	Draught	Max. deflection due to a temperature difference of 1° C	Position where max. deflection occurs.
Shelter dk. with f'cle ..	580′ × 68′ × 46′ (to S.D.)	31′ − 10″	0.153″	13′ − 0″ abaft
Full scantling with p. b. and f............	445′ × 58′ × 34′	26′ − 3″	0.092″	1′ − 0″ ,,
Spar dk. with p. and partial shelter deck.	370′ × 47′ × 30′ (to S.D.)	21′ − 6′	0.087″	3′ − 9″ ,,

Putting aside the enormous values derived from the assumption (1), we can see from this table that if a temperature difference of say 10° *C.*, which is not improbable, exists between the parts above and below the water line, we might expect the occurrence of a ma ximumdeflection of somewhere about one inch in a medium sized boat. This amount is evidently comparable with the extent of deflection which is generally observed due to loading or after launching. Therefore, it seems that in measuring deflection of a ships—especially in the case of launching—it would be well, if possible, to measure the temperature of hull and its surroundings; unfortunately this is a matter of practical impossibility when she is irregularly heated by the sunshine. Though, without further information, we cannot assert it, yet the discrepancy of the permanent stresses in the two sister boats Yasaka Maru and Suwa Maru recorded by the Terano-Yamamoto strain-meter,[3] may perhaps be traced back to a temperature deformation.

Actual observation of temperature distribution.

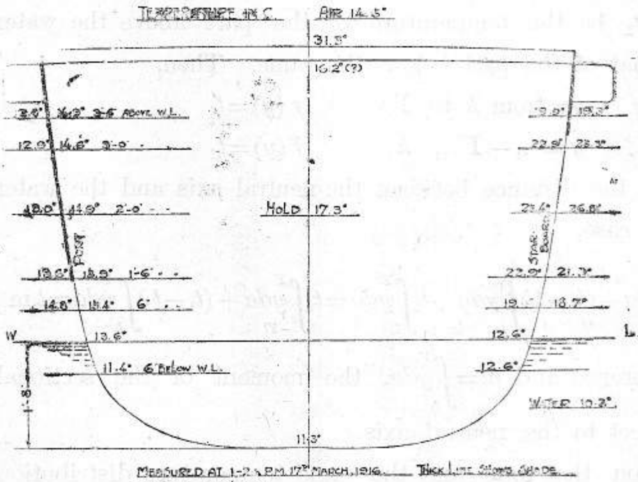


Fig 5.

In order to see how temperature is distributed in an actual ship, we measured temperature of a barge at various spots along the line of a frame by means of a thermo-

(3) 寺野山本兩氏著(新案「ストレインレコーダー」ト其應用)及今岡氏質疑 造船協會々報 第十四號

electric junction. The observed distribution is shown in Fig 3. As the diagram shows, temperature of this ship had a mode of distribution intermediate between the assumptions (1) and (2). However, we could neither measure the distribution of temperature throughout the ship nor the actual deflection that occurred. Therefore, we must hesitate to draw conclusions from such an incomplete observation.

Throughout this paper, we are only theorizing. Unfortunately we have not often the chance of making actual measurement in a ship and cannot say to what extent our investigation holds good in actual case. We should be much gratified if somebody who is interested in this problem and is daily occupied with ships would test the validity of our results by making further experiments along this line.

講演

前號掲載横田博士の彈性に關する論文の討議

On Dr. Yokota's "General Expression for Stress Components in Two-Dimensional Problems of Elasticity."

BY

DR. K. SUYEHIRO, *Member*.

(Read before the Spring Meetings of the Society of Naval Architects, Japan. April 10th, 1916.)

I am not qualified to discuss a paper written by such an able mathematician as Dr. Yokota; the paper is far beyond my mathematical knowledge. But, by nomination of our Chairman, I was designated to write the present short note.

Dr. Yokota's paper is the most severest mathematical paper ever put before the Society, and ought perhaps rather to be put before a mathematical society. His method of solving elastic problems is altogether original, and he is to be congratulated on his success in introducing a new method to the mathematical theory of elasticity.

However, so far as its practical applicability is concerned, it seems that the method is not without inconvenience. The expression found by him has too much of a fundamental form to be applied to solving elastic problems. As is described below, the nature of the expression is just as if a potential function, or the like, satisfying the equation $\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}=0$ were said to be expressed by $V=f(x+iy)$ in general. No doubt such an expression of the potential function would be the most general in a purely mathematical sense. But in practice the expression is, with a few exceptional cases, generally much developed for solving potential problems. In a similar manner his general expression has room for much interpretation before it may become surmountable by us who are not generally trained to manage such higher mathematics as the theory of functions. If the expression be discriminated according to various systems of co-ordinates and put into a more feasible form freed from complex quantities, we should obtain those expressions given by Love ("Treatise on the theory of elasticity," Vol. I, Page 334.) As Dr. Yokota starts the solving of each problem from its very source, the operation, in some cases, may become unduly complex, for instance, while his first example can be solved after Love's method in a few lines, it takes a comparatively prolonged and rather difficult process in Dr. Yokota's hands. This I say from an engineer's stand point. Apart from its practical applicability, his method has many strong points—in that the expression is practically independent of the sort of orthogonal co-ordinates; besides it has a novel nature. It may be added that a solution of mathematical or physical interest is not necessarily to be expected to have also an engineering interest. With regard to the bearing of the paper on practical questions, I can say nothing, because, so far as I can guess, he lays no stress on practical questions; although he shows several examples he does not tell us how they are to be applied to the practical questions of naval architecture.

It may not without interest to a few among the members, who do not absolutely refrain from mathematical formulæ, to show how his expression and Airy's equation are connected each other.

As is well known among mathematicians

$$\frac{\partial^4 F}{\partial x^4}+2\frac{\partial^4 F}{\partial x^2 \partial y^2}+\frac{\partial^4 F}{\partial y^4}=0 .$$

in which F is Airy's "stress function" having the nature:—

$$X_x=\frac{\partial^2 F}{\partial x^2},\ Y_y=\frac{\partial^2 F}{\partial y^2} \text{ and } X_y=-\frac{\partial^2 F}{\partial x \partial y} .$$

Expressing symbolically $D=\frac{\partial}{\partial x}$ and $D'=\frac{\partial}{\partial y}$, we have

$$(D^4+2D^2D'^2+D'^4)F\equiv(D^2+D'^2)^2F=(D-iD')^2(D^2-D'^2+2iDD')F=0 .$$

Now put $\quad (D^2-D'^2+2iDD')F=X_x-Y_y-2iX_y=V.$

Then, as $\quad (D-iD')^2V=0,$

$$V=yf_3(x+iy)+f_2(x+iy) \quad \cdots\cdots\cdots\cdots (1)$$

Again put $\quad (D^2+D'^2)F=X_x+Y_y=V'.$

Then, as $\quad (D^2+D'^2)V'=0,$

$$V'=Rf_1(x+iy) \quad \text{or} \quad If_1(x+iy) \quad \cdots\cdots\cdots\cdots (2)$$

in which R and I are written after Yokota's notation.

講演 前號掲載横田博士の彈性に關する論文の討議

In these equations (1) and (2), f_1, f_2 and f_3 arearbitrary functions connected each other by the following equation:—

$$(D^2+D'^2)V=(D+iD')^2V'$$

As $(D^2+D'^2)f_2$ is evidently zero,

$$(D^2+D'^2)yf_3(x+iy)=(D+iD')^2\{Rf_1(x+iy)\quad\text{or}\quad If_1(x+iy)\}$$

Therefore, by the elementary principle of a function of a complex variable, namely

$$(D+iD')^2Rf_1=\frac{1}{2}(D+iD')^2f_1 \text{ and } (D+iD')^2If_1=-\frac{1}{2}i(D+iD')^2f_1,$$

we have, when R is taken, $\qquad f_3(x+iy)=if_1'(x+y)$

and when I is taken, $\qquad f_3(x+iy)=f_1'(x+iy)$

Thus, we have

$$\begin{cases} X_x-Y_y-2iX_y=iyf_1'(x+iy)+f_2(x+iy) \\ X_x+Y_y=Rf_1(x+iy) \end{cases}$$

or

$$\begin{cases} X_x-Y_y-2iX_y=yf_1'(x+iy)+f_2(x+iy) \\ X_x+Y_y=If_1(x+iy) \end{cases}$$

The former pair of equations are the expression obtained by Dr. Yokota. Thus it seems that his expression corresponds to intermediary integrals of Airy's equation. Lastly, it is to be added that the fact that Dr. Yokota's expression is derivable from another, does in no way lower its merit; in mathematical science every specialized equation can be derived from its fundamental one.

Some Hints Regarding Deflection of Ships due to Temperature Difference.

正員 工學博士 末廣恭二

最初ノ溫度ノ差ニ基ク船ノ「デフレクション」ト云フコトハ斯ウ云フコトヲヤツタラ宜カラウト云フパービス先生ノ御創意ニ基キテ,昨年ノ工科大學三年生ノ卒業論文トシテ學生ニ課セラレタノデアリマスガ,時間ガ無カツタ爲メ完全ニ行カナカツタ,ソレヲ敷衍シテ見樣ト思フテ私共兩名デヤツテ見マシタガ,大體ノヤリ方ハコヽニ書イテゴザイマス,「アツサンプシヨン」モ書イテゴザイマス,ソレカラ出マシタ數字モコヽニ書イテゴザイマス,併シ最後ニ書イテゴザイマス通リ,之レハ唯ホンノ理窟ヲ述ベタノミデ,實際斯ウ云フ事ハドウナルモノデアルカト云フコトハ精細ニ實測ヲシテ見ナケレバ分ルモノデゴザイマセヌ. 併シ我々ハ不幸ニシテ實測ヲ爲ス機會ニ乏シキモノデアリマスカラ,コヽデハ唯,若シ斯ウ云フ風ナ溫度ノ分布ガ成立ツナラバ,コノ位ニナリハシナイカト云フコトヲ申上ゲルニ過ギマセヌ. ソレカラモウ一ツノ

On Dr. Yokota's "General Expression for Stress Components in Two-dimensional Problems of Elasticity."

ト云フノハ,是ハ最初ニ書イテゴザイマス通リ,實ハ私ノ力ノ及ブ所デハゴザイマセヌカラ,何モ申スベキ筈ノモノデモナシ,申シタクモナイノデゴザイマスガ,横田君ガ之ニ關スル論文ヲ二回迄モ造船協會デ御讀ミニナツタニ拘ラズ,一モ「デスカッション」ガ無イノハ甚ダ不都合デアルト云フコトデ,理事アタリデ,若シモ何カ話スコトガ出來ルナラバヤツテ見ナ

イカト云フ御勸デゴザイマシタカラ,大變時機ガ後レテ居リマスガ,雜誌ノ方ニ寄稿シマス積リデ書キマシテゴザイマス. ソレデ其體裁デ書イタノデゴザイマスガ,併シヤハリ雜誌ニ寄稿ト云フコトヨリ「ペーパー」ニシテ讀ンダラ宜カラウ. 横田君ガソレニ付テ御答下サルニモ工合ガ宜カラウト云フ事デ,「デスカッション」トナルベキモノヲ一ノ「ペーパー」トシテ讀ミマスニ過ギマセヌ. 尙ホ附加ヘテ御斷リヲ致シテ置キマスガ,サウ云フ風ナ理事アタリカラ御話ガアッタ爲メ已ムナク書イタ次第デアリマシテ,元來私ノ力ノ及バヌ所デゴザイマスカラ,或ハ盲者ガ象ヲ捜ッテ,耳ノ部分ダケ捜ッテ見テ,象ハ平ベッタイモノデアルト言フタト云フヤウナ,トンチンカンノ「コンクリユージョン」ヲ致シテ居ルカモ知レマセヌ.ドウカ宜シク横田君ノ敎ヲ受ケタイト思ヒマス.

Discussion.

○ **Dr. F. P. Purvis.**

Note on Prof. Suyehiro's and Mr. T. Inokuty's Paper.

The paper is one which is naturally very interesting to myself; whether the problems involved are of practcal importance, or only of academic interest, I am not quite able at present to decide. I have pointed out to the authors that the method used is capable of further application than they give it; and it is this further application that I pressed upon the student last year in the case alluded to at the beginning of the paper. This further application is the induced stress brought about by the non-uniform heating of the structure; each part, from its position, is free to take up part only of the expansion or contraction due to temperature; in so far as it cannot respond to the temperature a stress remains, compressive for increase, tensile for decrease of temperature. The value of this stress is easily derived from the expressions in the paper. Taking compression positive, tension negative,

$$\text{Internal stress} = E\left\{ kf(y) - \frac{\delta x}{\Delta x} - \frac{d\xi}{\Delta x} \right\}$$

If we apply this expression to case (2) on page (5). & take

$B=$ area above water, temperature t_1

$A=$ total area, so that $A-B=$ area below water, " t_2

$m=$ moment of B about $N.A.$

$-m=$ " $A-B$ " ".

then from equation (1) on page 3,

$$\frac{\delta x}{\Delta x} = k\,\frac{Bt_1+(A+B)t_2}{A};$$

and from equation (2) on page 3,

$$\frac{\delta\xi}{\Delta x} = k.\,Y\,\frac{\int f(y)y\,da}{\int y^2\,da} = k\,\frac{Y}{I}(mt_1-mt_2)$$

$$= k\,\frac{Y}{I}\,m\,(t_1-t_2);$$

also $kf(y)=kt_1$ for the portion above water,

$k+t_2$ " " below ".

Hence above water,

$$\text{Internal stress} = K.E.(t_1 - t_2)\left\{\frac{A-B}{A} - \frac{Y.m}{I}\right\};$$

and below water,

$$\text{Internal stress} = K.E.(t_1 - t_2)\left(-\frac{B}{A} - \frac{Y.m}{I}\right).$$

With any of the three ships given on page 6, for $t_1 - t_2 = 10°\ C$.

Maximum stress works out about 1. ton per sq. inch. It is at least worthy of further consideration whether stresses of this nature (when added to other stresses) could ever become of serious importance.

○橫田正年君

私ガ一昨年ノ暮ト昨年ノ春デシタカ,讀ンダ「ペーパー」ニ對シテ末廣君ガ許ヲシテ下サレタコトニ付テハ大變有難イコトト思ヒマス,自分ハ是マデ二三度,斯ウ云フ風ナ「ペーパー」ヲ書イタコトガアリマシタガ,ナカナカソレヲ讀ンデ下サル方ガアリマセヌ,從テ批評モ無シ,其儘ニナル場合ガ多カツタノデアリマス. 是ハ唯我々造船協會バカリサウ云フ次第デハナイノデ,現ニ理科ノ方ノ方々ノヤツテ居ラルル所ノ數學物理學會ニ於テハ是ハ一例デアリマスガ,イツカ田丸卓郎君ガ或論文ヲ讀ンデ,アトカラソレヲ其會ノ雜誌ニ出シタ所ガ,誰モソレヲ讀ンデ呉レタ人ガ無イ,唯一人,長岡半太郎君ガソレヲ讀ンデ,其次ノ會ノ時ニ,何カ終ノ方ノ批評ヲチヨツトヤツタ. 其時ニ田丸君ガ大變ニ喜ンデ,少クモ長岡君ハ自分ノ「ペーパー」ヲ終マデ讀ンデ下サレタ,實ニ有難イト御禮ヲ言ツタコトヲ覺エテ居リマスガ,ソレト同ジヤウナ譯デ,私ノ先般ヤツタツマラヌ「ペーパー」ニ付テ末廣君ガ讀ンデ批評シテ下サレタコトハ誠ニ嬉シク感ズル次第デゴザイマス,デ之ニ付テハ折角讀ンデ下サレタノデアリマスカラ,私ノ意見モ申述べ,又同君カラ之ニ對スル御意見モ伺ヒ,種々ヤリタイト考ヘテ居ツタノデアリマスガ,併シ最早時間モ追々迫ツテ參リマシタノ

デ,サウ云フ譯ニ參リマスマイカラシテ. 唯簡單ニ私ノ考ダケヲチョット心付イタ所ダケ御話シテ,ソレデ終リタイト思ヒマス.

私ノ今ノ論文ハ斯ウ云フモノヲ一ツヤッテ見ヤウト云フ考ヲ起シタノハ抑々末廣君ガ種々「ストレッス」ノ問題ヲ解カレタ「ペーパー」ヲ讀ンデソレカラ又イングリスノ「ペーパー」ナドヲ讀ンデ,其手數ガ如何ニモ面倒デアル,種々ノ手續ヲ經テ問題ガ解ケルト云フ風デアルカラ,是ハ我々「エンジニア」ガ使フニハ甚ダ面倒デアル. 何カ茲ニ「バウンダリー.コンヂション」ヲ與ヘテ,普通「バウンダリー.コンヂション」ニ於ケル「デスプレスメント」或ハ「ストレッスコンポーネント」ノドチラカ,或ハ兩方合セタモノガ何カ條件ヲ與ヘルカラ其與ヘタモノデ答ノ出ルモノヲ造リタイ,途中ノ「プロセス」ヲ省イテ何カ一遍デ答ノ出ルモノヲ造リタイト云フコトガ,元此論文ヲ作ッタ趣意デアッテ,從テ我々「エンジニア」ガ使フニ最モ都合ノ好イ形ヲ自分ハ出シタ積リデアリマス,不幸ニシテ末廣君ノ書カレタモノヲ見ルト「エンジニア」ニハ少シ面倒過ギルト云フ御意見デアリマスガ,私ノ考ハサウデナイ,元々「プラクチカル」ニ一遍ニ答ノ出ル,途中ノ面倒ノナイモノヲ造リタイト云フ趣意デアリマス,ソレカラ問題ニ依ッテハ却テ面倒ニナルト云フコトモ,ココニ末廣君ガ御書キニナイテ居ル,コノ「エキザンプルワン」ノ如キ,私ノ考デハラブガ解イタモノヨリ横田ノ解イタ方ガ簡單デアルト思ヒマス. 併シソレハ又人ニ依ッテ種々言フ所ガアリマセウカラ,必シモ私ハソレヲ主張スルノデアリマセヌ.又中ニハ末廣君ガヤラレタヨリモズット簡單ニ解ケテ居ル問題モアリ,又却テ面倒ニナッテ居ルノモアリマス.種々ノ問題ヲ「エキザンプル」トシテ解イタノデアリマス.ソレカラ「プラクチカル.アップリケーション」ニ對スル說明ガ無イト云フコトデアリマスガ,是ハ私ノ解イタ問題ハ既ニモウ末廣君ナリイングリスナリ,或ハ其他ノ種々ノ人ガ解イテ居ルモノデ,ソシテ「プラクチ

カル」ニドウ云フ風ニ應用スルカト云フコトハ末廣君,イングリス等ガ精シク説明サレテ居ルノデアルカラ,殊更ニ私ガ茲ニ此論文ノ「エキザンプル」トシテ説明ヲシナカツタノデアリマス.何カ新シイ問題ガ解カルレバ其ニ付テ十分「プラクチカル」ノ「サイド」ニ入ツテヤリタイト思ヒマスガ.併ナガラ斯ウ云フ風ナモノデ解ケル問題ハ大抵定マツテ居ルノデ,略ミ今迄ノ例デ盡キテ居ルモノト考ヘマス,是ヨリ新シイモノハ餘リ出來ナイヤウニ考ヘマス.ソレカラ末廣君ハ「エーアリー」ノ「ストレッス.ファンクション」カラ「ゼネラル.ストレッス」ヲ出サレタノデアリマスガ,此「ストレッス.ファンクション」ヲ出スニ付テ種々ノ「コンヂション」ガアル.「エーアリーノ「ストレッス.ファンクション」カラ「ストレッス」ヲ出シ「ストレッス」ヲ「ゼネラル」ニシタト云フノデ,詰リ或幾ラカノ假定ガアツテ,ソレヲ本トシテ,左ノ方ニ行ケバ「ストレッス.ファンクション」ガ出,右ノ方ニ行ケバ横田ノ「ゼネラル.エキスプレッション」ガ出ルノデ,片方ノモノヲ持ツテ來テコツチノ方ヲ證明シタト云フコトニ當ルト私ハ考ヘマス.ソレカラ私ノ最モ苦心シタノハ「ヂスプレスメント」ノ「バウンダリー.コンヂション」ヲ與ヘタトキニ「ゼネラル.ストレョス」ヲ出シタ,「ストレッス」バカリデ「バウンダリーコンヂション」ヲ與ヘタニ限ラズ「ヂスプレスメント」デ與ヘタトキモ兩方出シタコトデアリマス,其「パーテキュラル.ストレッス」バカリ.デ「バウンダリー.コンヂション」ヲ與ヘテ居ルトキハコヽニ末廣君ガ出サレタ此式ヲ使ヘバ宜シ,「ヂスプレスメント」或ハ「ヂスプレスメント」「ストレス」ト兩方ヲ以テ「バウンダリー.コンヂション」ヲ與ヘタトキハ矢張リ横田ノ初ノ方ニ出シテアルモノヲ使フト都合ガ宜イト考ヘマス,ソレハ其「エーアリー」ノ「ストレッス.ファンクション」カラ出スコトガ出來ナイモノデ,初メノ假定カラ段々ト順序ニ行カナイト出ナイモノト考ヘマス.

マダ種々ポツポツ考ヘテ居ツタノデゴザイマスガ,今思出シタ所ハ其

クラヰノモノデアツテ,玆ニ種々末廣君ガ私ノ「ペーパー」ニ對シテ讃辭ヲ列ベラレテ居ルノハ甚ダ恐縮スル次第デ,是ハ決シテ當ラヌコトト考ヘマス,ドウカ末廣君ニ於テモ御遠慮ナシニ横田ノ缺點ヲ尙ホ此上ニモ御話下サレバ幸デアルト考ヘマス.

○末廣恭二君

最初ニバービス博士ノ「デスカッション」ニ御答イタシマスガ,元々此問題ハバービス博士ノ御創意ニ基キテ居ルモノデ唯學生ノヤリ切レナカツタコトヲ私ガヤツタ,少シ歩ヲ進メタト云フダケノコトデアリマス,此問題ハ實際家ノ始終船ニ接觸シテ居ル人ガモツト實驗ヲ積ンデ下サレナケレバ事實ドウデアルカト云フコトハ分リ兼ネル,コヽニ書イテアリマス通リ,スミスノ運炭船ニ就テ唯一回ノミノ「オブサーベーション」ガアルダケデ,其外ニハ何モ無イカラ實際觀測ガ甚ダ不充分デアル.ドウカ實地ニ關係ノアル方ガ御暇ガアツテ且ツ多少ノ興味ヲ持タレルナラバ實測ヲサレムコトヲ私ハ希望シテ居ルノデアリマス,バービス博士ハ本問題ニ聯關シテ「ストレッス」ノコトヲ論ズ可キダガ之レガ論ジテナイト云フコトヲ云ハレマシタガ,此論文ヲ前以テ御目ニ掛ケタトキ既ニ同様ノ御注意ヲ受ケタノデアリマシテ,博士ノ云ハレル通リ此問題ノ「オンリーハーフ」ヲヤツタノミデアリマス,「オリジネーター」タルバービス博士ガアトデ何カ「ノート」ヲ書イテヤルト云ハレマシタガ是ハ深ク感謝スル次第デゴザイマス.

ソレカラ今横田君カラ私ノ同君ノ論文ニ對スル批評ニ對シテ更ニ御批評ヲ受ケマシタ本文ニ御斷リ申シテアル通リ,無我夢中デ書イタノデアリマシテ,先刻モ申シタ通リ,象ノ耳ダケ捜ツテ象全體ト思ツタト云フノト同ジデアリマス.「ストレーン」デ現ハサレテ居ル式ヲ使ツテ「エキザン

プル」二及三ヲ解カレテ居ラルヽヿハ知ツテ居リマスガ,「ストレーン」ノ式ノ方ハ私ハ氣ヲ付ケテ居ラナカツタノデ,耳ヲ捜ツテ足ノ方ヲ捜ツテ居ラナカツタノデアリマス. 一般ニ「エーアリー」ノ式ハヨク使ハレテ居ルモノデアリマスカラ,私ハソレヲ使ツテ出シタラドンナモノカト云フコトヲ考ヘテ試ミタノデアリマス,ソレカラ「アップリケーション」ノコトヲ御書キニナラナカツタ趣意ハ今ノ御話デ十分了解スルコトガ出來マシタ,ソレカラ問題ガムヅカシクナル,ヤサシクナルト云フヿトハ,是ハ無論,人々ノ考ニヨルコトデ,變ナ數學ガカツタコトヲ申シテ如何デゴザイマスカ知リマセンガ,人ニ依ルト何デモ物體ノ「モーション」ヲ解クニ「ラグランヂユ」ノ式デ解ク人ガアリ,或ハ普通ノ「アクセレレーション」ノ式デ解ク人ガアリマスガ,之レハ人々ノ習慣ヤ好ミニ因ルコトデアリマス,私ガコヽニ申シタ趣意ハ,外ノ方法ハ何レモ「エラスチシチー」ノ理論ノ土臺カラ出發シテ居ルガ色々途中ノ運算ヲシテ各種ノ「コールヂネート」ニ對シテ解式ヲ與ヘルマデニ持テ來テアル故ニ誰デモソレニ實際ノ條件ヲ當嵌メサヘスレバ良イノデアルカラ簡單デアルト云フ意味デアツテ,即普通ノ方法ハ近クナツテ居ル各々離レタ途ヲ通ジテヲルガ其目的ニ達スル結局問題ヲ當嵌メルヤウニ迄ヤツテ居ルカラヤサシイト云フノデ其途中ガヤサシイトカヤサシクナイト云フノデハナイ,横田君ノ方法ハ出發點カラ目的地迄ノ距離ハ無論近クナツテ居ルト私ハ考ヘテ居リマスガ何レノ場合デモ唯初メカラ出發セネバナラヌト考ヘマス.

○會長 (寺野精一君) マダ此問題ニ付テハ種々御議論ガアラウト信ジマスガ,丁度十時ニナリマシタカラ閉會イタサウト思ヒマス,就テハ會ヲ閉ヂマス前ニ私個人トシテ一言末廣君ニ向ツテ御禮ヲ申上ゲタイコト

ガアリマス,タシカ一昨年デゴザイマシタカ本會ニ於テ私ト山本武藏君ノ考案ニ係ル「ストレーン,レコーダー」ノ「アップリケーション」ヲ御披露シタ際ニ,其成績ニ就テ疑ヲ存シテ居リマシタ點ニ付テ解釋ヲ與ヘテ下サレテ,暗夜ニ一道ノ光明ヲ認メタ感ガアリマス,爾來其點ニ就テ餘リ深ク研究セズニ居リマシタガ其見當ヲ與ヘテ下サレタニ付テハ將來我々ハサウ云フ意味ヲ以テ更ニ研究シタイト思ヒマス,此點ハ末廣君ニ深ク感謝ノ意ヲ表シマス.

サテ末廣君ノ兩方ノ「ペーパー」トモ非常ニ有益ナル,且ツ御骨ノ折レタ「ペーパー」ト考ヘマスガ,斯ノ如キ有益ナル「ペーパー」ヲ本會ニ提出シテ下サレタコトハ本會ノ深ク感謝スル所デゴザイマス,會員一同ニ代リマシテ末廣君ニ御禮ヲ申上ゲマス.

ON THE STAL TURBINE.*

By

Mr. Helmer Hedberg.

(Read before the Societies of Naval Architects, and Mechanical Engineers on the 4th February, 1916.)

The Stal turbine is the name of the Ljungström Steam Turbine, as manufactured in Sweden and has its name from the initial letters in the manufacturing concern, Svenska Turbinfabriks Aktiebolaget Ljungström, i.e. Stal. The inventors are two Swedish engineers, Birger and Fredrik Ljungström, who after thoroughly developing the invention started the manufacturing company, *Stal*, at Finspong, Sweden.

Before starting a more detailed description of the Stal turbine we will make a brief comparison between a Ljungström-turbine and an ordinary turbine of the Parsons type, both shown in the Figure 2 diagrammatically and in vertical section, the latter above, the former below in the Figure. The comparison with the Parsons turbine is made, because that type as well as the Ljungström-turbine, is a pure reaction turbine, so that the latter is a further development of the former. As can be seen from the sections, the size of the whole Ljungström-turbine is about the size of the exhaust of Parsons. In both cases the exhaust is practically of the same size, as about the same amount of steam passes through the two turbines. While the exhaust of the Ljungström-turbine holds the whole turbine blading, the Parsons turbine apart from the exhaust consists of a stator arranged in steps and of considerable size, inside of which a rotor also arranged in steps is moving supported by bearings on both sides. Between those revolving and stationary parts are situated, the blade rings through which the steam passes in axial direction from one end of the turbine to the exhaust at the other end. The corresponding parts of the Ljungström-turbine consist, as shown by Figure 2, of only two discs, running in opposite direction, between them the necessary blade system is placed, so that the steam instead of working in an axial direction as in the Parsons turbine, works in radial direction from the centre out to the periphery, in both cases going downwards through the exhaust. Instead of the special bearings used by the Parsons turbine, the

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revolving parts of the Ljungström-turbine are connected to the shaft ends of each generator and special bearings for the turbine thus made unnecessary. The axial balancing of the Parsons turbine, necessary on account of the step-formed revolving drum, is accomplished through special steam pistons, which revolve with the drum, and the diameters of which are chosen so as to enable the axial balancing to be maintained through a special thrust bearing outside one of the main bearings. In the Ljungstrüm-turbine the corresponding axial balancing is performed simply through surfaces under pressure on the rear side of the rotating discs and by means of special automatic tightening arrangements, which will be described later on, and which make the thrust bearings used in other turbines superfluous; at the same time they make the equalizing of the pressure on both sides of the revolving discs possible, simply through drilled holes (shown in Figure 2) instead of special pipe connections, as used in the Parsons turbine.

From Figure 2 it can also be seen, that the floor space occupied by the Ljungström-turbine is only a fractional part of the space required for other turbines, a reduction, which for turbines of larger power reaches so far as to be only 1/8th of the floor space needed by others.

This is best understood by a few examples. The turbine alone for a 1000 K.W. steam turbine arrangement is only 20 inches and for a 7000 K.W. arrangement only 30 inches in length.

Figure 3 shows the whole system, the steam turbine situated in its own exhaust and the two electric generators placed one on each side of the turbine in axial direction and built with the exhaust as one single cylinder body of extra strong and absolutely symmetrical dimensions. As mentioned before, the revolving fields of the electric generators with their bearings are utilized for supporting the two turbine discs, which are connected to the shaft ends of the two rotors, revolving in opposite directions. Electrically these two systems work as one because the stators of the generators are coupled in parallel to the line and the two rotors are connected in series, receiving their magnetizing current from the common exciter, which can be seen on the right hand side of Figure 3. The electric generators being thus connected in parallel, their speed and load will be the same, and the rotors being connected in series a simultaneous disloading will be effected, should the exciting current by accident be cut off. It has therefore been proved unnecessary to apply a speed-regulator to more than one of the shafts, while special so-called safety regulators are applied to each shaft, working independently, so that either one can bring the unit to rest in case the speed limit on its side is exceeded.

Fig. 1.

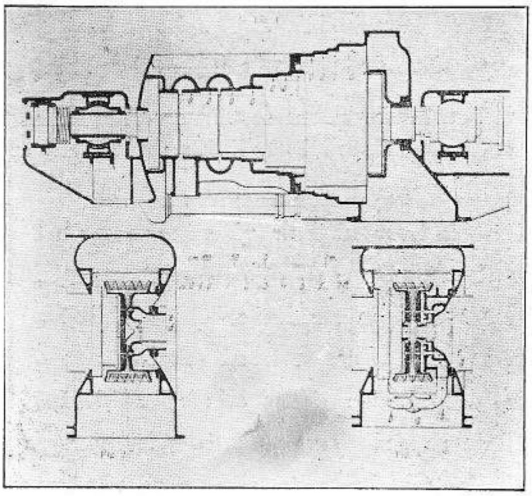


Fig. 2.

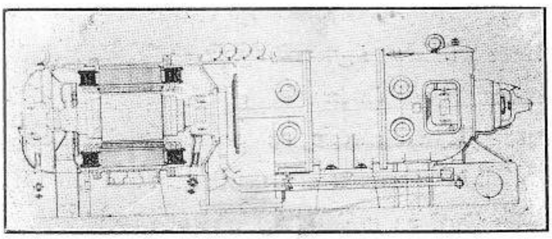


Fig. 3.

The influence on the turbine of this arrangement is naturally that the relative speed of the two discs and also the relative speed of the blade rings carried by these discs is doubled, i.e. if for an A.C. generator of 50 cycles each, one of the rotors makes 3000 revolutions per minute, then the relative speed between the turbine discs, i.e. the blade rings, is 6000 turns. The result of this arrangement is, that each blade ring in such a double rotating turbine performs work equal to the square of the relative speed inside the turbine, which means four times as much work per blade ring as in a single rotation turbine. As a consequence the amount of blade rings of a double rotation turbine will be reduced to 1/4th and these can be easily accommodated between two discs with a relatively small radius small enough to avoid dangerous stresses in the material, even at high speed. The extremely compact dimensions of the Ljungström-turbines is thus explained and it must be remembered, that restriction of size is not obtained at the expense of economy of steam; this on the contrary is higher in this turbine than in others, a fact which is proved by the superior steam figures obtained.

The construction of the complete system, steam turbine as well as generators, in one single cylinder, is an extraordinarily important factor towards attaining these results. In building the whole unit together in one piece one gets the best possible rigidness in connection with the most complete symmetry; this makes a special base-plate unnecessary, at the same time that all stresses in the system (heat stresses etc.) are directed towards the centre and the very particular centering of the revolving and the stationary parts, which is effected at the time of erection, pertains under all different temperatures and load conditions, independent of any sinking of the building or of a more or less firm foundation, as can be seen from Figure 4.

On account of its rigidity and symmetrical form the Ljungström-turbine can be placed directly on the condenser, the foundation of which is thus the only one required for the whole plant, an arrangement by which a special mean floor can be avoided. The condenser foundation can be made considerably cheaper and less solid than is otherwise possible, because a sinking of the foundation will in no way change the relative positions of the different parts in the unit and therefore be permitted within reasonable limits. On the other hand the foundation for other turbines is considerably more expensive and requires large space, thus increasing the space needed for the plant as a whole.

It is quite plain that the building necessary in adopting the Ljungström-turbine is much reduced in height as well as in floor space, so that a considerable saving of space is made; this must be put to the credit of the system. It may be of interest to know that for the first 1400 K.W. plant, the cost of the foundation was only equivalent to ¥190:—The floor space needed as compared with other turbines ought not to exceed one half as a rule, besides the reduction in height.

The central part of the turbine system, i.e. the blade rings, has naturally been used as the starting-point for the system as a whole, so that around the same all the other parts have been grouped in such a way as has been deemed necessary to obtain the highest efficiency in the blade system. It is therefore in the first place the blade system itself that has been taken into consideration, and this will be explained with the help of Figure 5.

As mentioned before the main qualification for getting the necessary number of blade rings within the radius, limited in size on account of the revolving speed and stress of the material, is the adoption of the double rotation system, whereby the number of blade rings is reduced to 1/4th. The second essential, viz. that the radial dimension of the blades be made small enough, consistent with strength and safety in running, required the design of details and methods of manufacture, without which a complete construction of the turbine could not be carried out. The solution of the purely practical manufacturing problem was therefore the first goal to reach and it was not before this was effected that the complete construction was worked out.

The welding process has now come to a point of perfection, opening new possibilities for the turbine technique, practical as well as constructive, which are in a striking way demonstrated by the Ljungström-turbine, this being the first to fully utilize those possibilities. The different operations necessary for making the blade rings of the Stal turbine will now be described with help of the Figure 5. The blades are cut to suitable lengths from ready made bars, in the manner usual in other turbines. Then the ends of the blades are faced off in order to enable them to fit in holes, which are punched in channels turned out in a lathe near the edge of two circular iron plates. The blades numbered in Fig. 5, upper middle sketch, are placed between those plates 2, 2, ready for welding. The plates are mounted each on its nave placed on one common shaft, which keeps the whole together while the welding process is going on. As shown by Figure 5, in the middle lower sketch the channel formed profiles at the edge of the two iron plates are filled by means of the welding, so that the ends of the blades, thrust through the holes into the channels, are welded with the plates to one single piece. When this operation is completed, the iron plates are put in the lathe and

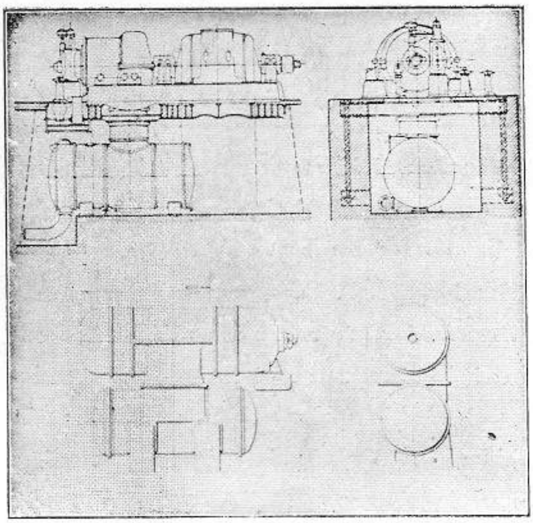


Fig. 4.

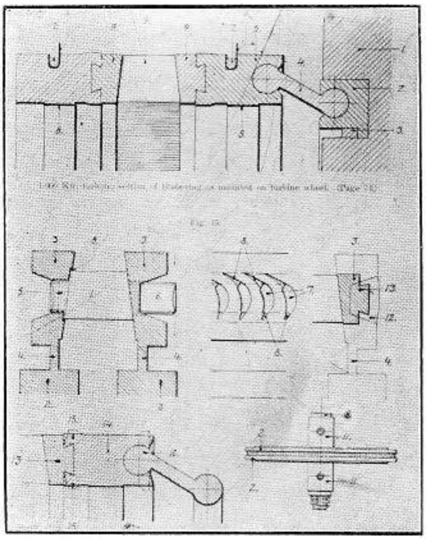


Fig. 5.

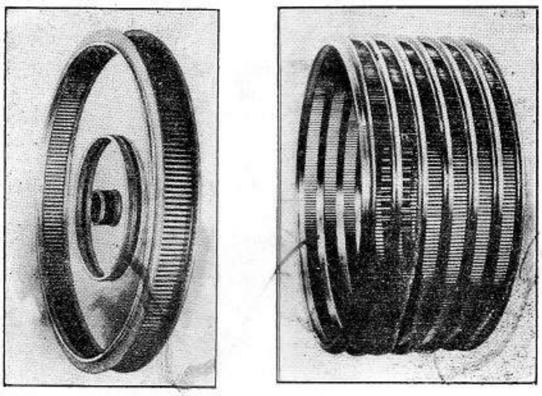


Fig. 6.

dovetails cut, shown by the shaded section in Figure 5 everything below the shaded portion and right and left of it being removed. The bladings are thus at the same time cut off from the plates, the diameter of which is correspondingly decreased; this is the case each time the plates are used; they are thus employed for rings of successively smaller diameter. The blade ring is now, thanks to the welding, on single piece, although it was originally composed of the outer strip of the two plates and of blades up to 800. The blades have, however, despite their small dimensions, received from the welding a more trustworthy fastening than any other blade design strengthened as it is by an arrangement shown in the section in the upper left and lower right sketches of Figure 5. The dove-tail profile, not being strong enough in itself to stand the centrifugal stresses, is strengthened by special reinforcing ring (14), which are supplied with a groove between the numbers 15, 15 of the upper left hand sketch, in which the dove-tail form is inserted axially and fixed in this position by means of a rolling operation which closes the edges of the reinforcement ring around the dove-tail thus making the two pieces practically one; thus the strength of the reinforcing ring gives the supporting capacity, with which one has to count when considering the centrifugal and other stresses arising when the turbine is running. Furthermore Figure 5 shows how in the same way reinforcing ring is by rolling, made to enclose the circular edge of a conical ring numbered to in left and sketch, 4 in right, the other edge of which is also circular and fastened into a third ring. This third ring is placed in its groove in the common turbine disc, to which half the number of rings belonging to one turbine is fastened. The right hand sketch shows accordingly a section of a completed blade ring as well as its fastening to the turbine disc through the medium of the conical ring mentioned; this ring is the so called expansion joint.

The object of the expansion joint is to permit the comparatively thin blade ring to expand and contract independently of the thick turbine disc, to which it is fastened, and the heating up and cooling off of which at different loads must necessarily require much longer time. The difference in temperature between the blade ring and the turbine disc will naturally correspond to a drop in temperature in the conical ring from one of its edges to the other, so that the two edges will get a correspondingly changed relative diameter causing a change in the conicity of the expansion ring. The result is therefore a movement in the angle of the conical ring, which movement can easily be carried out on account of the circular shape of the two edges, which adjust themselves without temperature stresses and independently one to the diameter of the blade ring and other to the diameter of the turbine disc.

The scope of expansion of the blade rings in closely adapting themselves to the existing temperatures is of great importance not only as regards the strength but for. the radial clearance, which can be kept constant under different and quickly changing load conditions.

As seen from Figure 5 the complete blade section shows very thin U-shaped so called tightening strips, numbered 7, 7, fastened to the reinforcement rings and reaching as far outside of the same as is required by the distance to the next larger blade ring. This distance is made such that a direct contact between the reinforcement rings of the different blade rings is out of question. These tightening strips are made of pure nickel and therefore can not be eaten away by rust. At the same time they are made so thin, that if contact should occur during the run of the turbine they would be worn off, and not produce any injurious heat. Because of this and on account of the expansion joint previously mentioned, all the clearance spaces between these tightening strips and the next blade ring can be made as small as possible without any risk to safety in working, so that the steam leakage past the blade rings is reduced to a minimum, and the steam economy of the turbine is most favourably influenced.

Figure 6 shows a few complete blade-rings as they appear before fastening to the turbine disc. The rings shown on the left hand side are the largest, the smallest, and one intermediate ring of a 1000 K.W. turbine. The largest diameter is about 2 feet 10 inches. On the right of the same figure is shown the largest ring of a 5000 K.W. turbine, the diameter of which is a little more than 3 feet, not much larger than a blade ring for 1/5th of that power. In both cases the rings are assumed to rotate with a speed of 3000 turns per minute, and in order to reach that much larger output with correspondingly larger exhaust surface, the blade ring has the shape of a drum, the blades being divided into several shorter pieces with their intermediate reinforcement rings, fastened at the two edges in the same fashion as has been previously described for the single blade rings. By this means an extremely rigid design is obtained, the critical speed of which is as high as 6000 revolutions for turbines which in practice run only at 3000 revolutions. Radial deflections on account of faults in the balancing, arising from inaccuracy of manufacture, are indefinitely small, so that comparatively small clearance may be maintained even when using blade drums; this ensures specially low percentage leakage for turbines of larger power.

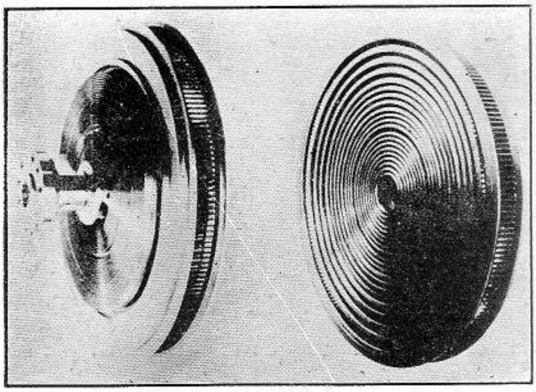


Fig. 7.

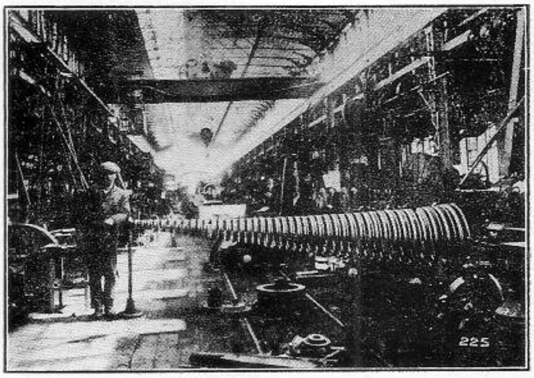


Fig. 7.-A.

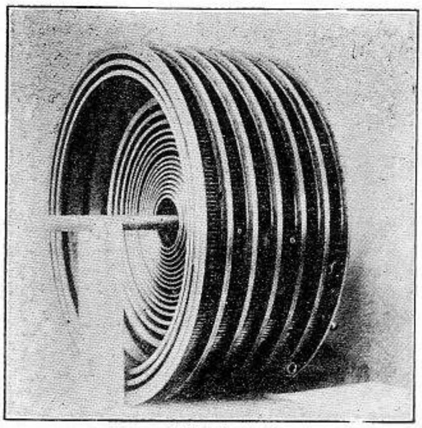


Fig. 8.

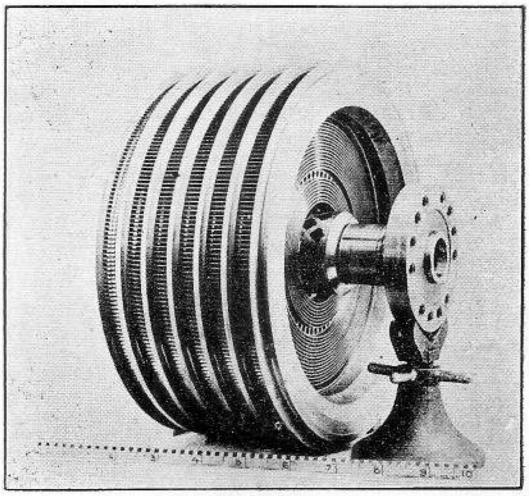


Fig. 9.

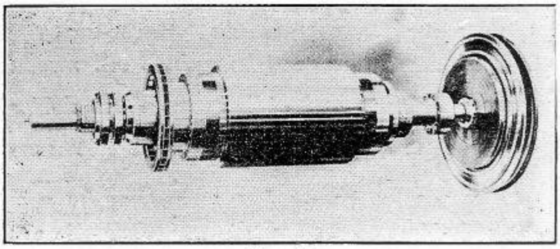


Fig. 10.

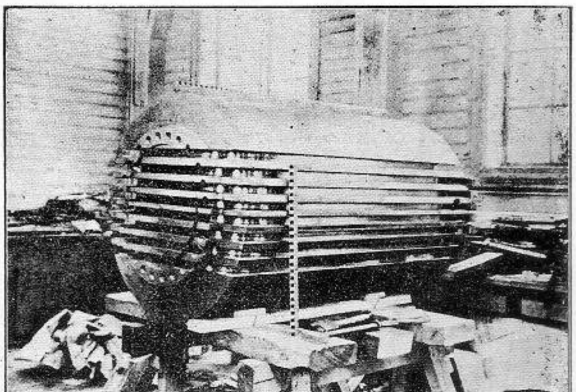


Fig. 12.

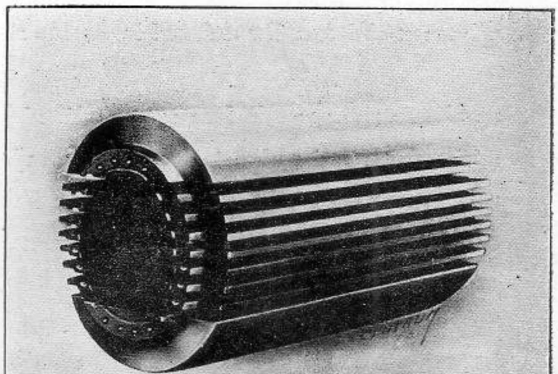


Fig. 11.

It is worth mentioning, that all the different parts are subjected to very severe tests according to a special schedule, where the stresses are divided into factors, each one of which is analyzed separately; the tests include strength and elasticity as well as the determination of the so called curve of exhaustion of the material. Such tests have also been made at different temperatures up to 500°C. with the help of apparatus specially designed for the purpose. The testing of the material has also been extended to include the other parts of the turbine and is regularly used as one of the operations in the manufacture. The Brinell's ball impression test has in this connection received a very extensive use, and it may be of interest to know for instance that material out of which reinforcing rings are made, is tested not only at one spot but at several different points all around the periphery in order to ensure a thoroughly good material.

Figure 7 shows the disc of a 1000 K.W. turbine; on the right seen from the side on which the blade rings are fastened one outside of the other, and on the left seen from the opposite side mounted on the shaft journal, the flange of which is bolted to the rotor of the respective electric generator; the disc is furnished with the so called dummy discs, corresponding to the balancing pistons in the Persons turbine, the task of which is to counteract the axial steam pressure in that turbine. These dummy discs will later on be shown in detail in a section of the turbine (see Figs. 26 and 30.)

Figures 8 and 9 show views of a made up turbine disc for a 5000 K.W. turbine generator (see also Fig. 30.)

Figure 10 shows a complete turbine disc mounted on its rotor for a 1000 K.W. steam turbine.

Figure 11 shows the two pole magnet core of a rotor as it is constructed in the works at Finspong. This rotor is based on the well known design first introduced by the Westinghouse Manufacturing Co., but has been improved in essential points in the make as used by Stal.

Figure 12 shows the same rotor, provided with windings consisting of thin ribbons of copper placed in the slots between layers of pure mica. On account of the simple form of the windings the mica insulation can be arranged in a very effective and strong way, and a reliable rotor procured even for the highest temperatures. This fact supplies the reason why no cooling channels in the rotor are required, sufficient cooling being effected by a stronge current of air under high pressure passing through the air gap between the stator and the rotor. Any gradual plugging up of the cooling channels in the rotor, thereby causing over-heating of the same and risk of disturbance, is therefore excluded. The centimeter scales show the size of the rotor; under normal conditions two rotors are big enough for a 3000 K.W. steam turbine plant of the Ljungström type.

Figure 13 shows how the same rotor is provided with mental wedges driven into the slots outside the copper windings, which are thus furnished with an excellent support against centrifugal forces as well as temperature stresses; dislocation of the mica insulation as well as a displacement of the balance when running being thus avoided. These metal wedges placed as they are all around the rotor, compose to a great extent a short circuiting coil, which in the event of short circuit in the stator, will greatly counteract the starting up of dangerous stress between the coils of the rotor, a condition that still more increases the safety of the rotor design.

Figure 14 shows a complete rotor as manufactured by Stal in Finspong for a 2800 K.W. steam turbine plant. Both the bearings as well as the fan for the ventilation, situated at one end, and the two slip rings for bringing the exiting current in and out are plainly seen.

Figure 15 shows a stator for a 7000 K.W. turbine with a number of coils inserted in their respective slots. This stator belongs to the Willesden Power Station in London, gives a normal tension of 11000 volts, and has been tested up to 25000 volts.

Figure 16 shows a stator of a 2800 K.W. aggregate. The photograph plainly shows the design of the end connections, including a great number of strong clamps which are connected to two concentric rings, whereby an extra rigid design with triangle connections is gained to resist eventual stresses caused by short circuits. Furthermore it will be seen from the figure that the leads are extended a certain distance in radial direction, before they are connected peripherically. It is possible on account of this design to place the axial cooling channels of the stator between the radially extended leads inside of the innermost of the concentric rings of the end supports, an arrangement which permits cleaning of the channels by means of special brushes without the necessity of dismounting the machine in any way.

Consequently, as no channels are necessary in the rotor and the cooling canals as well as the end connections of the stator are easily accessible for cleaning the temperature of the machine may always be kept moderate, and safety against disturbances caused by overheating avoided in the best way possible; extra filters for cleaning the air are in most cases unnecessary.

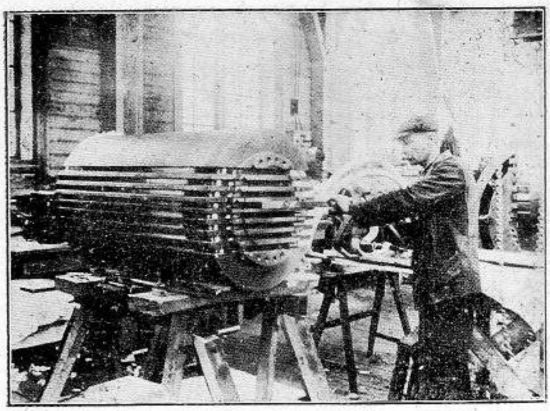


Fig. 13.

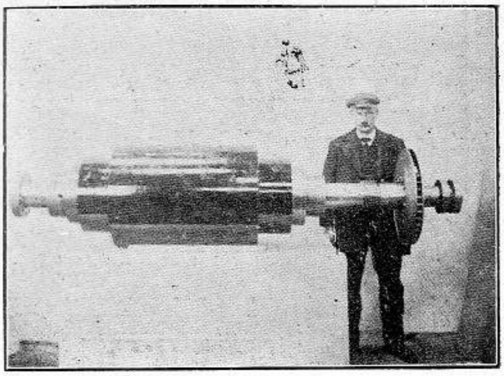


Fig. 14.

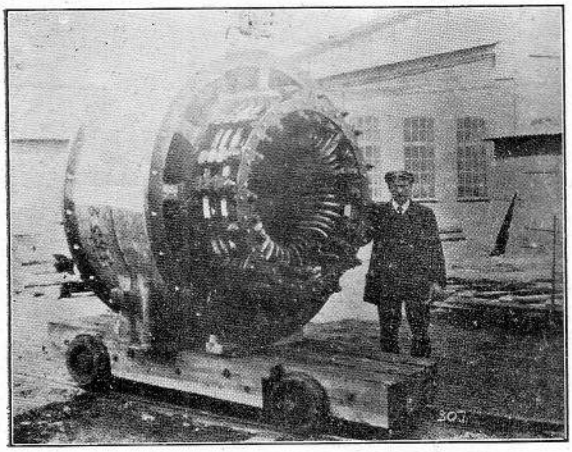
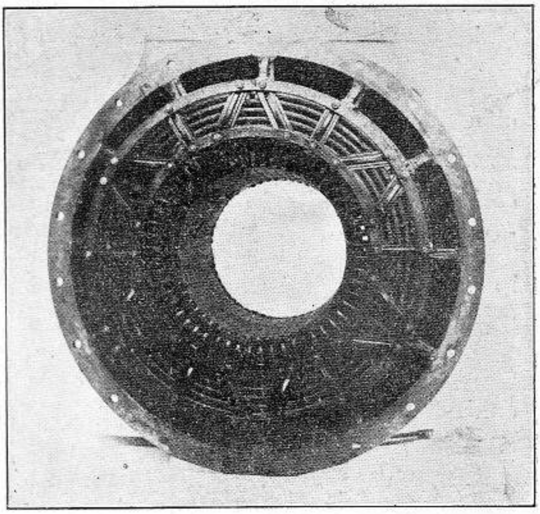


Fig. 15.



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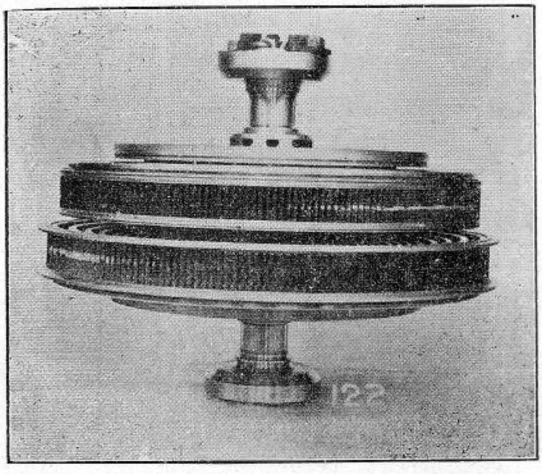

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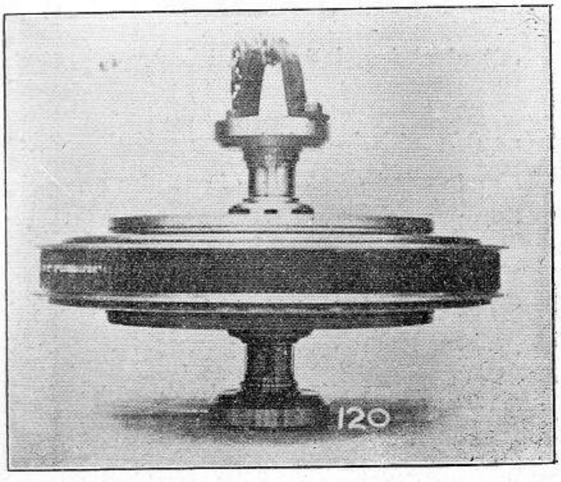

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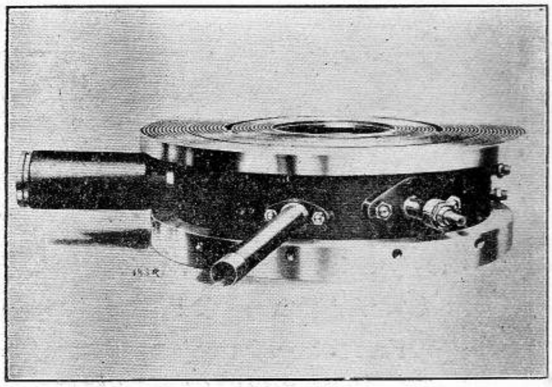


Fig. 19.

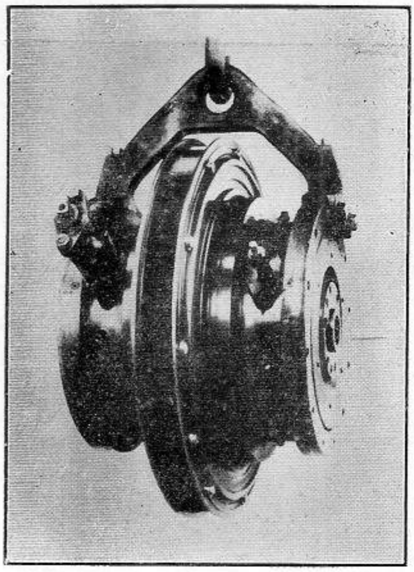


Fig. 20.

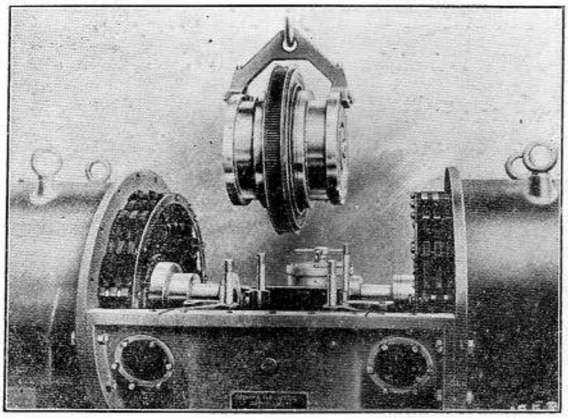


Fig. 21.

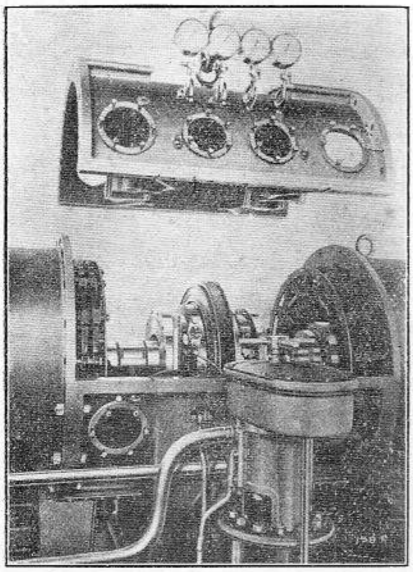


Fig. 22.

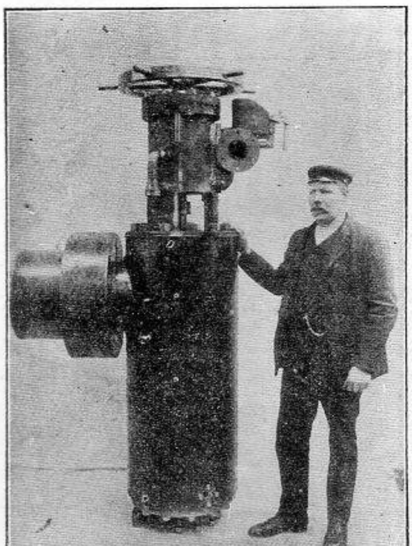


Fig. 23.

The manufacture of electric generators in conformity with design described has been taken up by Stal in Finspong with the idea of securing the same accuracy and care for this part of the plant as is used for the turbine, and also because the intimate connection between the electric generators and steam turbine, comprehended in the design, makes a simultaneous trial necessary; besides which such matters as time of delivery etc. are made independent of outside firms.

Practical results gained with these generators have fully demonstrated the advantages of the design. In taking up the manufacture of the electric generators the Stal has been guided by the experience gained by most firms in similar cases. Among these might be mentioned the A.E.G. in Berlin, where the work-shops for the electric generators have been placed close to the turbine works, although this concern already owned very extensive work-shops for electrical machinery. The reason is that high speed generators directly connected to steam turbines present mainly a mechanical problem, which is therefore most easily solved in connection with the steam turbine manufacture.

The connection of the turbine system to the electric generators and the design of the blade rings being thus described, there remains to be shown the putting together of the main parts of the turbine and the insertion, of the same in the united plant.

Figures 17 & 18 show how the two turbine wheels are put together axially, the rings of one wheel interposed between every two rings of the other wheel.

Figure 19 shows the lower of the two stationary steam inlet chambers, which are placed are on each side of the turbine wheels. To the left is the steam inlet pipe and to the right a valve, used when effecting the overloading of the turbine. Between those two arrangements is the outlet pipe for the shaft leakage, the leakage being carried from the shaft packing in the centre of the steam inlet chamber, through which the shaft end passes to a special feed water heater. This will be more clearly shown in Fig. 26 which gives a section of the turbine. At the top of the figure is shown the stationary half of a labyrinth packing for the axial balancing of the turbine, matching the moving half of the same design, which is fastened on the rear side of turbine disc. The edges and grooves of these fit inside each another when brought together, as shown Figures 20 & 21, which include the turbine with its two steam inlet chambers temporarily held together by a champing device specially made to facilitate the erection and the dismounting of the unit. The different parts are kept in their relative and correct position by small metal pieces resting on the outer flanges of the steam chests. When lowered in the right position these flanges are bolted to the turbine casing and the shaft ends to the flanges of the rotor situated just inside the bearings.

Figure 22 shows the turbine parts in working position. After this the lowering of the upper half of the casing takes place. Previous to these operations a special paste is applied to every surface to make absolutely airtight joints all round. As mentioned before the turbine is placed in its own exhaust, where vacuum prevails, on account of which the tightening can easily be made effective. The high pressure joints found in other turbines are therefore altogether avoided in the Stal for the turbine proper, while on the other hand the introduction of the steam in this as in other turbines must be accomplished by tightening joints subject to high pressure. These have in the Stal turbine received a shape, which particularly simplifies the erection and the dismounting of the turbine. As the temperature of the condenser prevails inside the turbine casing, the same does not need any sort of outer insulation and the unit as a whole when running is practically kept at ordinary room temperature, a fact which is not only an economical gain but also a material advantage at times of mounting and dismounting, when insulating plates with their many bolts etc. are altogether done away with.

The dismounting and putting together of the Ljungström-steam-turbine therefore requires only short time and few workmen on account of the small weight and the compact shape of the different parts, as well as the advantages just mentioned. With 3 or 4 trained men the dismounting of a 1400 K.W. machine can be easily finished within two hours, and the mounting of the same takes about three hours. These figures do not represent the shortest time recorded, the operations mentioned having been accomplished within one and two hours respectively or for mounting and dismounting, three hours in all. Under normal conditions it is in any case possible to inspect all the inner parts of the turbine within 6 hours if 3 or 4 trained men are at disposal. In this connection it may be worth mentioning that on one occasion, when only one man was to be had, he finished the mounting of a 1400 K.W. steam turbine within the same time necessary for several men to do the same work on other turbine types.

Figure 23 shows the inlet valve for a 7000 K.W. turbine plant. The lower part of the valve is a water cooler, big enough to hold water in a highly disseminated condition and so avoid shocks. A special water separator is therefore not normally necessary with this type of turbine, as it is always supplied with the turbine in the form of the inlet valve. The separator is also provided with a steam strainer made of nickel plates with small holes, to prevent large particles, which might damage the mechanism of the turbine from entering. In addition there are special means of safety inside the turbine, of catching all particle larger than of a certain size.

While impurities of large size are thus removed the inventors have succeeded in guarding the turbine against the action of more minute impurities such as those caused by bad boiler water. At the Willesden Power Station in London, where the condition of the feed water is especially severe, causing heavy coatings of dirt on the blade rings of ordinary Parson turbines, it was proved by dismounting the 1000 K.W. Ljungström-turbine installed that the discharge of dirt on the blading of this turbine was exceedingly small. The time wasting and frequent scraping of the blading necessary with other turbine systems is therefore avoided with the Ljungström type, which besides can easily be cleaned by means of steam jet apparatus specially designed for the purpose.

By avoiding the dirt savings are made not only in time and money, but also in steam consumption, which is increased by dirty blades.

Figure 24 shows a side view of a 1000 K.W. unit as a whole with one half in section and also an end projection of the whole plant. The side projection on the right shows the oil tank with the pipings to and from the different bearings. The circle in the tank indicates an oil reservoir with a water cooling arrangement, through which the oil passes before it leaves the tank. The pipes running alongside the turbine are connected through special pipes to the bearings of the generators; these are clearly seen in the section. The oil circulation is maintained by means of an oil pump of the Cog-wheel-type situated in the tank and driven by a vertical shaft, and worm gear from the rotor shaft of the generator situated above. The amount of oil per second is so large, that the size of all lubricating channels must be made particularly ample, and as the oil before its entrance to the pump is forced through a strainer in the tank, there is no risk of blocking the channels. In order to ensure the lubrication of the bearings, when starting the turbine, there is a hand driven oil pump mounted on the tank, by which at starting pressure is applied to the inlet valve, lifting it and at the same time pumping oil to the bearings. As the inlet valve can not be opened by the wheel but only by means of oil pressure, the starting of the turbine is only effected by the hand driven oil pump, and thus the lubrication of the bearings is automatically secured. This type of pump is replaced by a centrifugal steam driven pump in the large units. With these, on opening the steam inlet valve by means of the steam oil pump, the starting up is effected with the same result as regards the lubrication of the bearings.

The above mentioned vertical shaft for driving the oil pump is in its upper part provided with a regulator shown to the right in the upper part of the figure. The regulator controls the speed of both the generator shafts by an oil valve. This valve controls the pressure under the piston, thus lifting the inlet valve, which is closed by a strong spring placed on the other side. The inlet is shown to the left of the end protection, and it is in the upper part of the same that the oil piston is situated. Besides the regulator the turbine is provided with special safety devices, which act upon mechanism as soon as the speed of either of the generator shafts exceeds a certain limit. The oil pressure under the piston of the inlet valve is thereby released, and the valve closed by the pressure of the spring, and the machine is stopped.

The synchronous speed between the two generators constituting the unit, is automatically gained by connecting the same in parallel. The rotors are coupled in series and receive their exciting current from the common exciter, directly driven from the same generator shaft as drives the regulator. At the starting up of the aggregate, the two generators come into phase automatically as soon as the speed of about 1400 turns per minute is reached, this being the speed at which the exciter commences to deliver current to the two rotors. The two generators can therefore be considered as one machine as regards operation, instruments etc.

Figure 25 shows a vertical section of the turbine casing with interior turbine parts and inner bearings for the electric generators. From the inlet valve, situated on the rear side of the casing, there are as shown two inlet pipes connected from below to the two steam chests situated on each side of the two turbine discs, which rotate in the centre. A section of these steam chests as well as the connection of the pipes to the same will be clearly understood from the next Figure 26 showing the assembled turbine parts in section. To the left of the figure a section of the bearings is shown with the oil inlet coming from beneath, and outside of the same the return pipes for the oil. As seen from Figure 25 the bearings are connected to the turbine casing by means of bent arms, which make deflection possible, corresponding to the difference in temperature between bearing and turbine casing. The way of bolting the outer flanges of the steam chests to the casing is also shown. On the bearing to the right can be seen the adjusting screws, by means of which the bearings are put in the correct position at the erection of the plant.

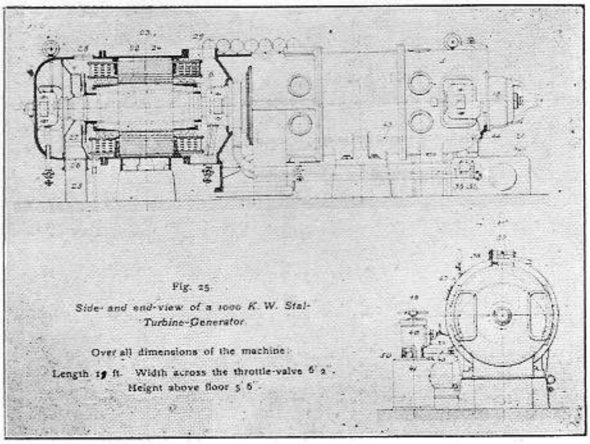


Fig. 24.

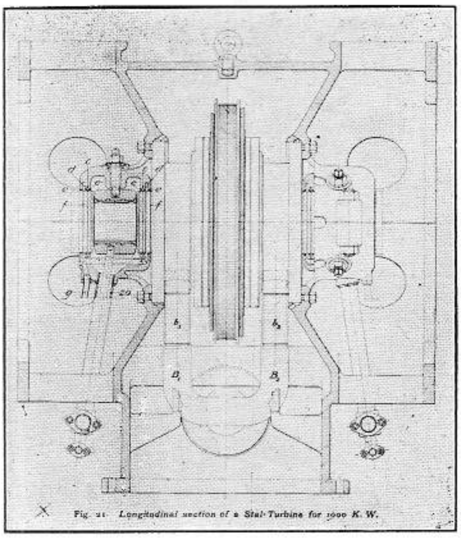


Fig. 25.

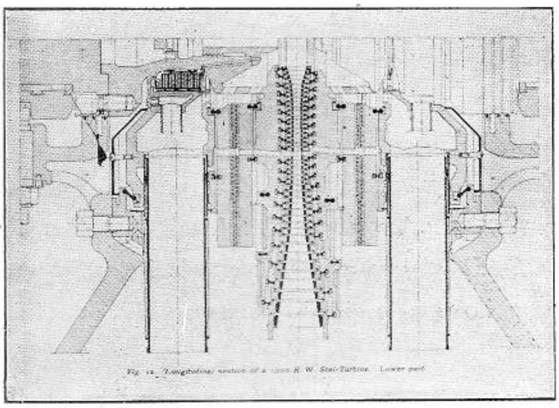


Fig. 26.

Figure 26 shows the lower half of the turbine parts as situated inside the turbine casing. As already described these consist of the blade system, the different blade rings of which are plainly shown with their expansion joints; they are connected alternately to the disc on the right and the disc on the left.

The passage from the centre outwards and comparison between the length of the blades in the rings of different diameter is also seen in the figure. On each side of the turbine wheels are situated the two steam inlet chambers the appearance of which has already been shown in Figures. One of the shaft ends is shown to the left in figure 26 and between the two shaft ends and the steam chests, are two shaft packings of the labyrinth type, with the separate outlets, mentioned on page 31 in Figure 20 they are here shown with the ends cut off. The design of the shaft packing will be explained in detail later on. (see pages 35 & 36.)

The steam enters through the Y-formed inlet pipe B_1B_2 of the Figure 25, the two outer pipes of which, one for each steam chest, are there shown in section. These pipes have collars of circular profile, which at the inlet to the steam chests fit tightly to the middle of short pipes, fastened to ends of the steam inlet chambers.

An elastic tightening arrangement is thus obtained, providing for the steam inlet pipe, on account of its thin walls, being heated up faster than the steam chest with its relatively thick dimensions. From the concentric inner part of the steam inlet chambers the steam passes through holes made in the pipe-formed nave of the turbine discs into the centre of the blade system and thence out through the same to the exhaust and the condenser.

Beside the blade system the steam passes also through two other passages from the steam chambers. One of these passages is the shift packings; the other passage is situated between the balancing edges fastened on the rear part of the turbine discs and on the steam chests. The grooves and edges, as described on page 29 fit into one another, forming the zig-zag concentric labyrinth shown in Figure 28. The pressure in axial direction caused by the steam between the turbine discs is counteracted by the pressure put up by the steam passing through the stationary and the moving parts of the labyrinth packing. How this is automatically effected will be explained along with the detailed section of the labyrinth.

A close examination of the section (Fig. 26) will show that the expansion rings, described in connection with the design of the blade rings, are used only not in connection with those rings but also in several other places. Such a ring is seen at the fastening of the steam chest, and is situated between the outer flanges and the main body of the chamber. A ring formed connection of comparatively small section is thus provided between the hot chamber and the cold flange, which quite naturally assumes the same temperature as the condenser.

The great drop in temperature, which exists at this point, is wholly taken up by the expansion ring, so that dangerous stresses in the material are avoided and at the same time the loss of heat is reduced to a minium.

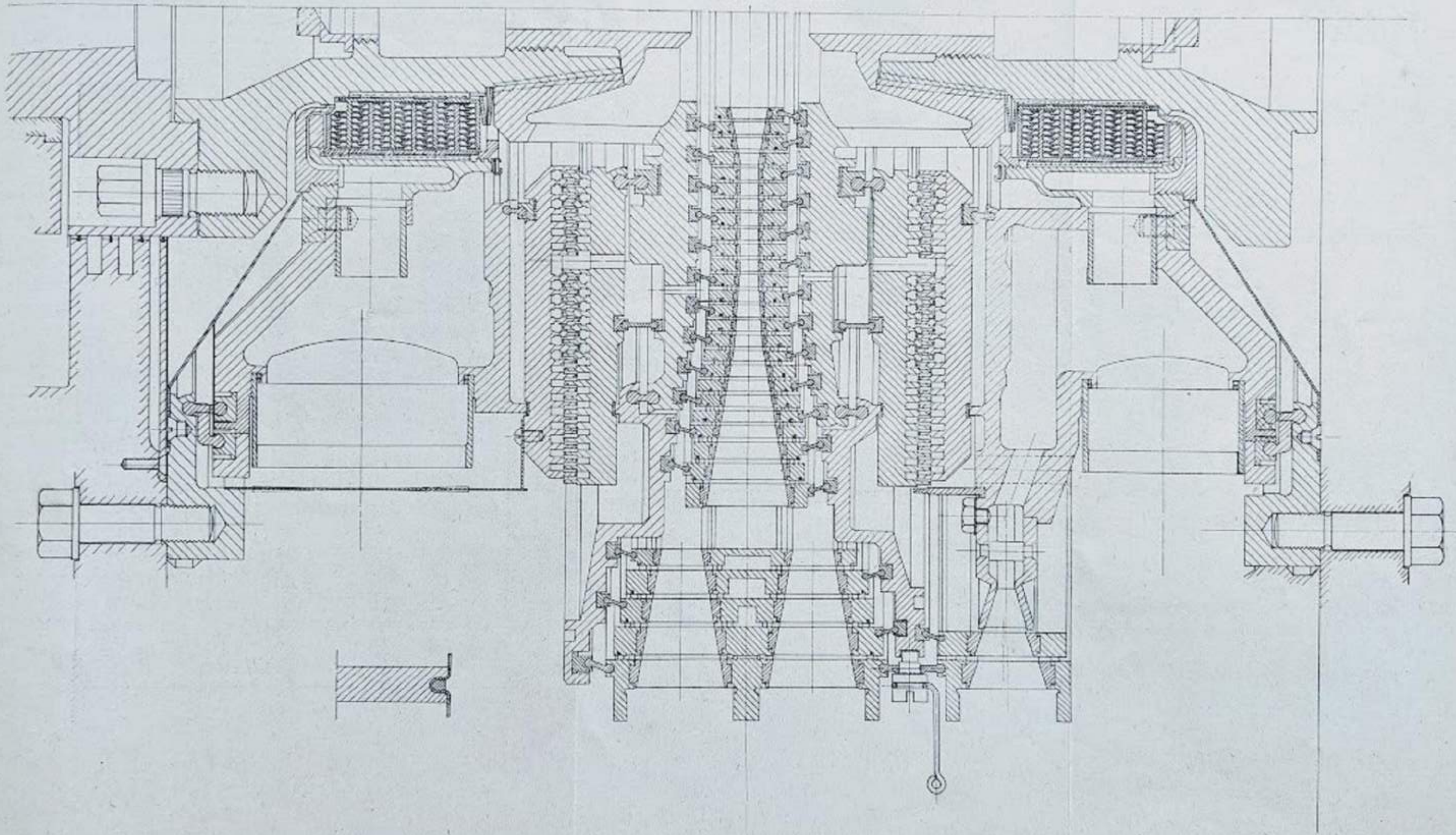
The balancing plates are also fastened by means of such expansion rings, so that they have full liberty to expand, independently of the temperature of the steam chambers or the turbine discs. This gives the advantage, that the steam passing between the plates practically alone decides the temperature of the same. The relative diameter of the plates remains unchanged on account of the equal thickness of the same, and the clearance can be kept small, in consequence of which the steam leakage between the balancing plates under all working conditions is small, with a favourable result as to the steam economy.

As seen from the figure the turbine discs are divided radially into three concentric parts, these also being united in the same fashion by means of expansion rings. Expansions caused by the high temperatures prevailing in the centre of the turbine can therefore be effected without any dangerous stresses arising, though this would happen if the central part of the turbine disc were fixed to the outer part of the same, the temperature of which is nearly that of the exhaust steam or condenser.

A common character for all the expansion rings in the turbine is that they materially prevent the transfer of heat from the warmer to the cooler parts, great thermal advantages being thus gained, the high temperature of the inlet steam really being concentrated and retained in the centre of the turbine. The fact that the shaft ends are hollow and therefore transfer the least possible quantity of heat to the bearings situated close by also contributes to a good result in this respect. Any overheating of the bearings on account of the short carrying distance and in case of highly superheated steam is therefore avoided. The cylindrical pipe shape of the naves of the turbine discs is also designed for the purpose of compensating the stresses caused by difference in temperature.

From the section as a whole one can plainly see that the whole system is very flexible to heat, a fact which will ensure safety when working, especially when highly superheated steam is used. To make the clearance between all movable parts where the

STAL TURBINE.
SECTION THROUGH BLADING.



steam can escape as small as possible, very thin strips are always used about the blade rings, the dummy discs and the shaft packing so that the least possible over-heating will occur in case the moving parts or moving and stationary parts touch. Hence without danger to the turbine the great advantage can gained of letting actual wear decide the clearance just necessary between the edges of the tightening strips, and the leakage can be reduced to a minimum even at the highest temperatures.

By the arrangements now described the Ljungström-turbine can be guaranteed to have the combined advantages put forward for both the reaction turbine and the impulse turbine, without the disadvantages of the same. To the most economical way of utilizing the steam according to the reaction principle has been added in the Ljungström-turbine the capability of the impulse turbine to stand and utilize high steam temperature. In these circumstances and the double rotation principle there lies the logical and natural explanation of the superior steam figures, which have been realized in the practice.

The assembly of parts in Figure 27 shows in the upper left hand corner a complete shaft packing for a 1000 K.W. turbine and in the lower left hand corner one of the rings for the same. A few of these rings are shown in section to the right, entering into one another, the left hand set mounted on the shaft and the right mounted on the steam inlet chamber. By means of wedges, shown in the section both the sets are prevented from slipping from the part on which each is mounted.

As can be seen from the Figure the concentric offsets between the rings consist of thin cylinders ending in a conical shape of extra thin dimension, this being the real tightening strip of the labyrinth system through which the steam has to pass is zig-zag and axial direction. Should the thin strips touch the cylinder forms close to them the heat would be so small that no deformation would be caused. The area of all the ring sections is the same. The expansion or contraction of the parts thus happens simultaneously and is equal in amount, leaving the clearances mutually unaltered. These expansions and contractions are independent of the temperature of the shaft end or the steam chest, because the guiding flanges of the shaft packing rings are not tightly fastened to the parts on which the rings are placed, but by means of deep grooves turned in axially immediately outside the guide, thus giving the system a radial elasticity leaving enough liberty for the radial extension of the parts of the rings, which enter into one another. This is of special importance for the right function of the shaft packing, because the latter is at full load subjected to steam of perhaps 350° C., while on the other hand with a sudden throwing off of the whole load it must work at a vacuum, and this causes the air to rush through the shaft packing, which is thus exposed to a sudden difference in temperature of about 300° C.

Experience has shown that *t*he clearance of the shaft packings remains unchanged and can be kept so small that the leakage in spite of the high pressure is immaterial. Beside, this leakage is by no means a loss, as the steam is carried to a feed heater situated outside the turbine so that its heat is brought back to the boiler. The Ljungström-turbine has a considerable advantage over other turbines as regards the shaft leakage, because in the latter types the steam leakage goes directly to the condenser, this condition naturally representing a direct loss of steam. However, in the steam figures given for the Ljungström-turbine, no account is taken of this difference, although it amounts to as much as 1 or 2%.

Figure 28 shows an enlarged view of part of the labyrinth packings between the balancing plates; these plates appear in Figs. 26 & 30 right and left of the blade discs, the geometrical axis of the turbine is situated below the figure. The concentric teeth nearest the centre are furnished with hollows, the purpose for which will be given later on. If we assume the right hand part of the section to be the balancing plate, which revolves with the turbine, and further that steam passes through the blade system as well as through the labyrinths shown in this figure in direction from below and upwards, then there will arise an axial steam pressure, which will cause the revolving disc to move in either one direction or the other depending upon the side on which the pressure is strongest.

Assuming that the largest pressure is on the side of the blade system, the two balancing discs shown in this section will come closer together, so that the tightening strips in the lower part come inside the widened part, thus leaving a considerably larger area for the steam to pass. Inspecting the upper part, situated farthest from the centre, we find so alteration of the areas open for the steam to pass. Consequently we get an increased inlet area without the corresponding increase of the outlet and the pressure between the plates must necessarily be raised until a complete equilibrium is attained between the pressure on each side of the moving turbine disc.

If we now assume, that the largest pressure is originally prevailing between the two balancing plates, so that these have come somewhat apart, then there will be the opposite relation as before between the labyrinth and its tightening strips. The areas of

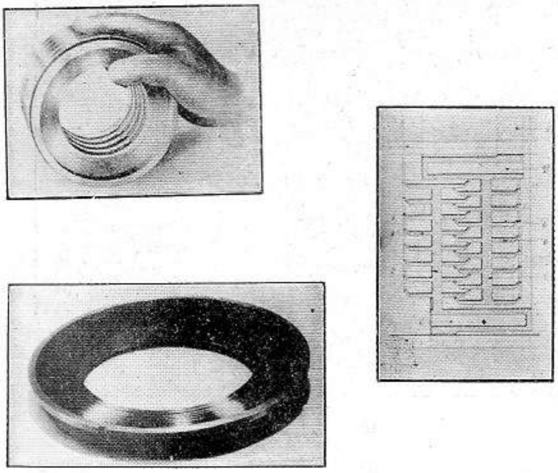


Fig. 27.

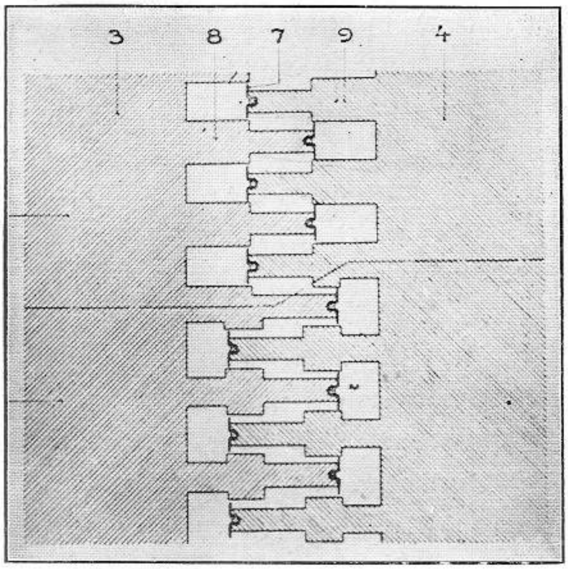


Fig. 28.

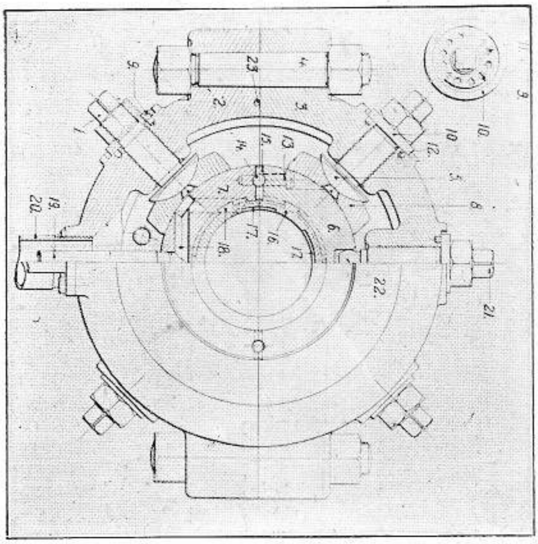


Fig. 29.

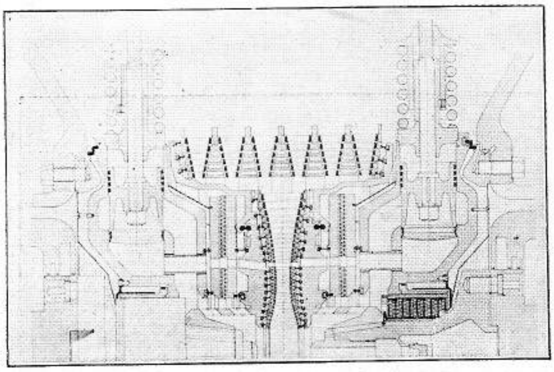


Fig. 30.

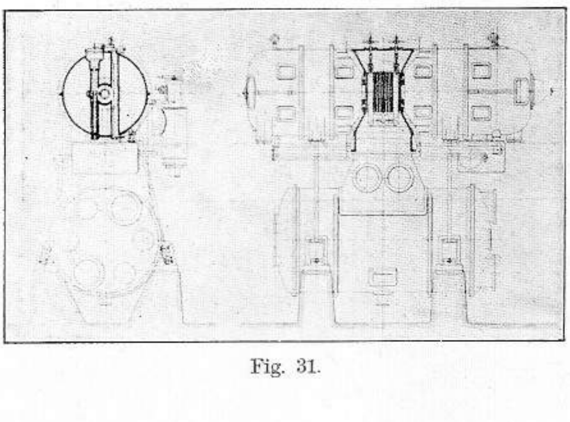


Fig. 31.

the clearance in the upper parts will be increased leaving a free outlet for the steam, while on the other hand at the inner part no difference occurs. The pressure between the places must therefore fall till the point is reached when absolute balance is gained. It is proved in practice that the balancing is completely automatic at any load, keeping the discs within the limit of a few tenths of a millimeter. Any thrust bearing for fixing the axial position of the revolving parts is therefore unnecessary, and the relative axial position of the turbine disc is automatically fixed inside the turbine itself.

The thrust bearing common in other turbines situated at a considerable axial distance from the balancing pistons necessarily causes an axial position, changing according to variation of the temperature, thus naturally increasing the steam leakage, which besides in general is dependent on the core expended by the engineer in charge when looking after the thrust bearing. It is quite obvious that under such conditions the exact adjustment with small clearances which may be obtained on trials at an invariable load and by specially trained men, can not be kept under actual working conditions by the engineer in charge, but must be considerably increased. When running normally the steam consumption will therefore be higher than the tests have indicated; this does not apply to the Ljungström-turbine, in which the clearances are not adjustable, and entirely independent of the greater or smaller accuracy displayed by the engineer as regards working safety as well as economy. A distinct advantage is also the simplification attained, making the thrust bearing superfluous.

Figure 29 shows the arrangement previously mentioned for adjustment of the bearings in order to get the rotor in exact position in the centre. As seen from the figure the lining is held up by adjustable bolts with spherical heads secured to the casing of the bearing. Under these heads there are loose pieces of steel, which fit exactly to the lining. The rotors can by this arrangement be easily centered with 0.02 parts of a millimeter and it has been proved by frequent dismountings and mountings, that this precision is maintained so well that any readjustment is superfluous at the usual inspections, after the turbine has once been put to work.

Figure 30 shows the inner parts of a 5000 K.W. turbine provided with blade drums of the previously type described on page 28 for the low pressure part, while on the other hand the inner, high pressure part only requires blade rings with a single row of blades (see also Figures 8 & 9.)

The figure, upper half of the installation, shows also the automatic overload valves, mounted on the steam inlet chambers. These are divided into two concentric chambers, of which the outer one, receiving the high pressure steam, is put in connection with the inner one by lifting the overload valves. The steam passes from this inner chamber through axial pipes and holes drilled in the turbine discs into the larger section of the turbine, so that the necessary larger areas are had for the transmission of the larger amount of steam necessary for the overload wanted. The valves open in such a way that, at a certain load, there will be a certain pressure in this part of the blade system transmitted through the holes in the turbine discs and the pipes in the steam inlet chamber to the bottom side of the pistons for the overload valves, the springs of which are so set that they yield to the pressure mentioned and thus open the valves, so that the high pressure steam can pass through.

Figure 31 shows a complete 5000 K.W. plant. The turbo-generator is mounted on the condenser, and supported at both ends by special, nearly vertical stays, in their turn resting on springs on the condenser body, indicated by dotted lines in the end view. This arrangement with elastic supports is the normal one used for equalizing the temperature extensions of the condenser and the exhaust tube. The support of the ends of the units is thus uniform and unchanged even when the turbine is dismounted.

The condenser type used by Svenska Turbinfabriks Aktiebolaget Ljungström for the turbine units manufactured by them is of English origin, known as the Contra Flow Kinetic System, considered by many leading power station experts to be the best system known so far. The manufacturing concerns in Finspong have secured the rights to manufacture this system, with which they very best result has been reached confirming the favourable opinion given about the same.

As the Contra Flow System is well known a detailed description of it is rather unnecessary, but a few points might well be remembered in this connection. The advantage of the air pump arrangement in the Contra Flow System is, that it is obtained by extremely simple and reliable means consisting of an ordinary centrifugal pump and a few mouth pieces. The pumping power is very flexible on account of the steam jet connected in series, and it can be very much increased by letting more steam through the steam ejector, thus increasing the pumping capacity in the even of leakage of air into the condenser. The amount of power needed is not larger with this system, but rather smaller, than that required for other systems, because the reserve power is here situated in the steam-ejector, the steam of which is always returned to the condenser,

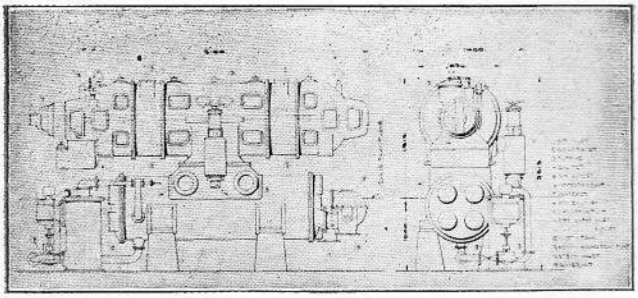


Fig. 32.

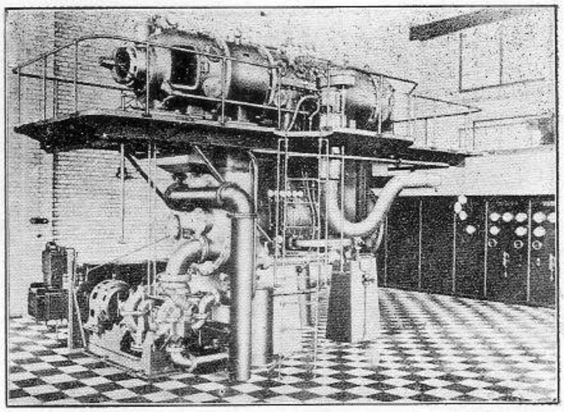


Fig. 33.

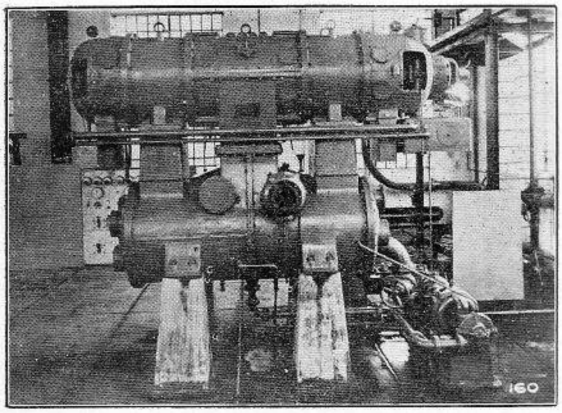


Fig. 34.

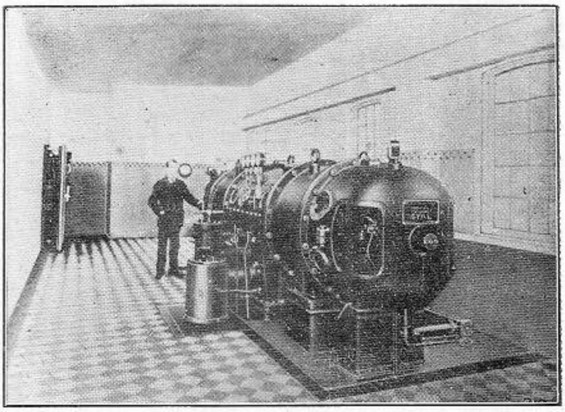


Fig. 35.

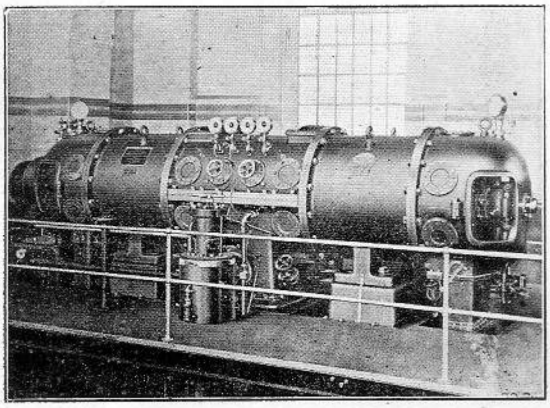


Fig. 36.

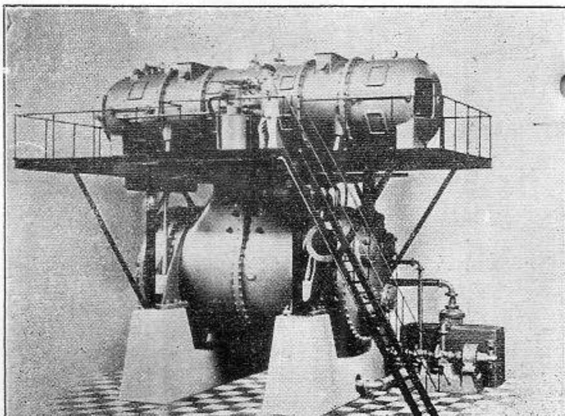


Fig 37.

and therefore does not represent a loss of heat. As seen from figure 32 the pumping arrangements have received a very compact form.

Some of the very first Ljungström steam turbine plants and their records in practical work may be of some interest.

Figure 33 shows the first turbine made of this type. It had 1000 K.W. capacity, was erected in the Willesden Station in London and afterwards taken over by the same concern. The turbine then run during a period of two years with such a result that the order for a 7000 K.W. unit was placed with the Ljungström people.

Figure 34 is the first Ljungström plant in Sweden, erected at Sandvikens Iron Works as a reserve to the hydraulic power; it is of 1400 K.W. capacity. A 2800 K.W. unit is now doing its work in the same power station.

Figure 35 is a 1400 K.W. machine at Skärblacka Paper Mill, running to the great satisfaction of the owners. It is well worth mentioning that the guaranteed steam figures for all plants delivered have been considerably surpassed at the trials, as for instance with this machine, where a result nearly 5% better than that guaranteed was actually reached.

Figure 36 shows the first plant delivered by the English manufacturers, the Brush Electric Engineering Co., Ltd., and erected at the St. Pancras Power Station in London. According to an official report from the operating superintendent at this power station the records show a saving in coal of not less than 16000 *yen* per year as compared with the Parsons turbine used at the same place, which means that the plant could be paid off in 3 years, a result which must be considered to be more than satistactory. Such figures and still better ones are easily proved by the results reached, but are naturally in the first place dependent on the length of time in a year, during which the turbine is working. If a power station gets such an economical machine in addition to several other plants previously installed, it is only natural that it will reach a load-factor, which will exceed the one normal for the power station and the value of the steam saving must therefore be increased to a considerable extent.

Figure 37 is a model of the 7000 K.W. plant delivered to the Willesden Power Station in London. The condenser is of extra large dimensions and could readily be used for a 10000 K.W. unit.

As to the steam consumption figures for the Stal turbines actually obtained, it may be mentioned that a 1400 K.W. plant at 1000 K.W. only used 11.2 lbs. of steam per

K.W. hour. The corresponding figure for a 2800 K.W. unit. is 10.7 lbs. per K.W. hour. Comparisons between the Stal turbine and others have shown a superiority of the former of usually between 10 and 15%. The value of this, from a purely economical point of view, can be readily understood from the fact that on a working time of 3000 full load hours per year, 10% improvement of the steam economy of the turbine, for the buyer, means saving the cost of the plant, including steam-turbine-generator and condenser, in one year, on account of the saving in coal. That still better results can be reached is shown by the previously mentioned report from the operating superintendent of St. Pancras Power Station in London. And it is quite obvious that such a long working period a 6000 or 7000 load hours per year can be expected in certain cases, for instance when the turbine is used in a Power Station together with several other turbines, in which case its value will be three fold told to the owner in case of 10% superiority in tho steam consumption. Naturally these figures all depend upon prices of coal and machinery at different places. The information given refers to conditions as they were in Europe last year.

The Stal turbine is superior not only when used for ordinary power station work or similar purposes, but it has also gained admirable results when used for the purpose of ship propulsion.

The first steamer fitted with the Stal turbine is a Swedish coastwise freight steamer, named Mjöhner, a sister ship of which was furnished with ordinary triple machinery. A comparison between the two showed a coal consumption of more than 42% less, to the credit of the Stal steamer, and after in every respect successful service of about one year the owners ordered Stal turbines for three more of their new boats.

The Mjölner machinery consists of two 400 K.W. Stal turbine generators of 7200 revolutions delivering alternating current of 120 cycles to two three-phase induction motors of a speed of 900 revolutions. This speed is then reduced by a helical gear to 90 revolutions per minute, being the most economical for the propeller used.

As the steamer also trades in icy waters, a safety arrangement has been introduced to prevent the breaking of the propeller shaft, or the teeth of the helical gearing. This protecting arrangement consists of slipping clutches inserted between the motor and the smaller spur wheels.

The arrangements for manœuvring are made in such a manner that there is no difficulty in handling the engines single-handed.

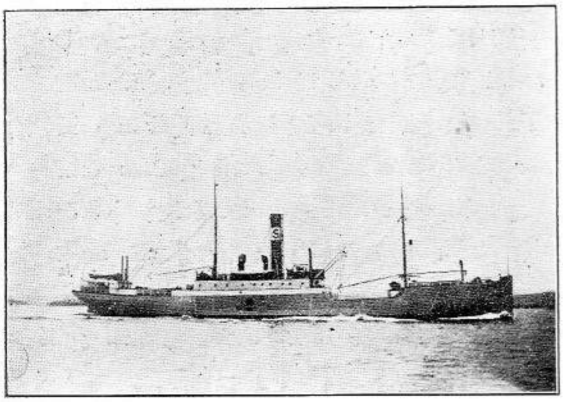


Fig. 38.

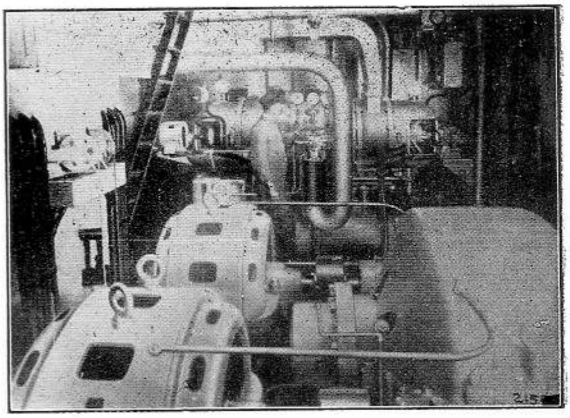


Fig. 39.

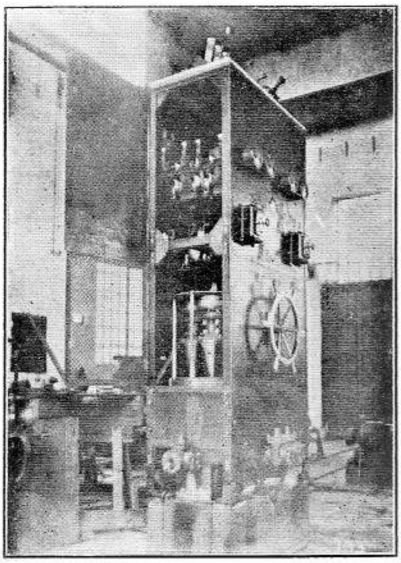


Fig 40.

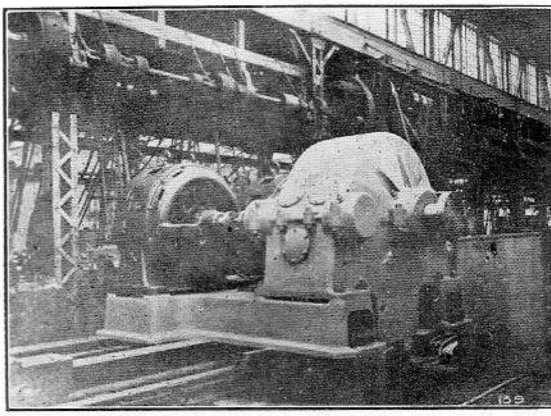


Fig. 41.

The electrical manœuvring has shown itself to be particularly satisfactory, it being possible to reverse the machinery considerably quicker, at the same time as the gradual speed regulation can be made to a considerably lower speed than in the case of piston machinery, a fact which when going in fog or manœuvring in a harbor is of great advantage.

A few figures 38 to 41 from the Mjölner are here shown.

The Ljungström people in Finspong are now busy on orders for Marine turbines from concerns in England and Russia as well as Sweden and Norway.

The matter of the Stal turbine for marine use is so extensive, that it will be impossible to make any closer study of the same here, but a combination of the different items forming the total gain that can be expected, when using a Stal turbine-electrical machinery, may be of some interest. They are:

1. Decreased fuel consumption, i.e. decreased cost for fuel per trip.
2. Increased dead weight capacity on account of the smaller weight as compared with ordinary triple-machinery.
3. Increased dead weight on account of the smaller bunkers needed for the trip.
4. Decrease of the expenses for oil, packings and other machinery parts.
5. Decrease of the repairing and up-keep costs.
6. Decrease in cost for food and wages on account of the smaller number of men needed.
7. Increased propeller effect, that means increased speed.
8. Increased economy by using electrically driven winches.

To these may be added a few, in some cases considerable, advantages from the constructive point of view:

1. The possibility of installing machinery in a limited space and of big enough power to obtain a certain high speed, which would otherwise require considerably larger dimensions of the ship, with increased cost for building the same.
2. The possibility, by placing the motors far aft, but keeping the generators and boilers amidships, to avoid tunnels for the shafts, at the same time retaining the trim of the ship unaltered and independent of the change in the banker quantity.
3. The possibility of installing the generators above the main deck, so that the space below the deck otherwise used for the machinery can be used for freight.

The Stal people have lately made up a proposal for replacing tne present quadruple machinery of 16000 S.H.P. in the Cunard line's S/S Caronia with Stal turbines.

The comparison may be thus summarised:

Coal consumption, alternative I. 0.673 lbs. per I.H.P. and hour.

Coal consumption, alternative II. 0.655 lbs. ,, ,,

Corresponding figure from the trial trip of S/S Caronia....1,292 lbs.

The saving in coal is thus C^a 50%.

The saving in weight of machinery is about 50%.

The saving in space is such that still using the present boiler plant, a 27000 S.H.P. Ljungström turbo-electric machinery can be installed.

This assumes turbo-electric propulsion, but the Ljungström people have also worked out designs for steam turbines working directly on the propeller shaft through some gearing arrangement. The turbine is in this case designed to be directly reversible and work astern with 40% of the full load power at 2/3 of the normal speed.

Such an arrangement will probably be of great use for fast going destroyers and other smaller was ships, but on the other hand the turbo-electric machinery is as a rule the superior of the two, when used for ordinary trading and passenger vessels as well as larger warships.

Tokyo, the 21st of Jan. 1916.

HELMER HEDBERG.

第四回三好奬學資金懸賞當選論文

AN ANALYSIS OF MODEL SCREW PROPELLER EXPERIMENTS.

By

S. Motora, *Member.*

There are many quantities which are introduced in investigation of the action of a screw propeller. They may be summerised as follows:—

1. speed of advance
2. number of revolutions
3. thrust
4. turning moment
5. thrust horse-power = thrust × speed of advance
6. shaft horsepower = 2π × revolutions × turning moment
7. efficiency = $\dfrac{\text{thrust horsepower}}{\text{shaft horsepower}}$

As will appear in the above table, the quantities (5), (6) and (7) are derived from (1) to (4). For a given propeller the quantities (1) to (4) are connected by some definite relation with each other. If any two of them be given, the other two are determinate, and it follows that if any two of these seven quantities be given, the remaining five are determinate.

Now a screw propeller many be characterised by following elements:—

1. diameter
2. pitch or pitch ratio
3. area or area ratio
4. number of blades
5. form of blades
6. thickness of blades
7. diameter of boss &c. &c.

All these elements have influence on the action of propellers. But for a type of propellers which does not much deviate from usual practice, (5), (6) and (7) are less important in comparison with (1), (2), (3) and (4). Hence it is not difficult to apply the results of experiments obtained from the most usual type of propellers to any other type without any serious error, provided suitable corrections are to be made.

The action of a screw propeller may be represented by the equations, taking into accounts the predominant elements i.e. diameter, pitch ratio, and area ratio only as variables:

$$T=P\,D^2\,V^2 f_1 \qquad (1)$$

$$M=P\,D^3\,V^2 f_2 \qquad (2)$$

where $T=$ thrust

$M=$ turning moment

$P=$ the density of water

$D=$ diameter of the propeller

$V=$ speed of advance

f_1 and f_2 are coefficients proper to the individual propeller. The validity of the above formulas is evident by the principle of dimensions, for the dimension of thrust is $[MLT^{-2}]$ and that of $\rho D^2 V^2$ is $[ML^{-3}.L^2.L^2.T^{-2}]=[MLT^{-2}]$ which is identical to the dimension of thrust. Similarly the dimensions of the both members of the equation (2) are $[ML^2T^{-2}]$.

Analytical expressions for f_1 and f_2 are difficult to obtain theoretically. They can be determined by experiments only. It is, however, evident that f_1 and f_2 are some functions of pitch ratio, area ratio and slip ratio. Moreover as a propeller accompanies more or less suface disturbance according to the depth of immersion, and is affected by the viscosity of water, they must also be affected by dimensionless quantities $\frac{gD}{V^2}$ and $\frac{\rho VD}{\mu}$; where g is the gravity and μ represents the viscosity of water. In some cases the atmospheric pressure seems to be an important factor, as in the case where cavitation phenomenon takes place, then f_1 and f_2 are again affected by $\frac{P_0}{\rho V^2}$ where P_0 shows the atmospheric pressure. If $\frac{\rho VD}{\mu}$ and $\frac{P_0}{\rho V^2}$ be kept unchanged, the law of comparison is strictly applicable whatever may be the form of f_1 and f_2, and the results of the experiments which have been carried out by eminent experimenters such as Mr. R. E. Froude, Mr. D. W. Taylor and others, showed that within certain range of values of V and D which are practicable in tank experiments, the operation of propellers follows approximately the law of comparison. Hence, within the range of V and D, $\frac{\rho VD}{\mu}$ and $\frac{P_0}{\rho V^2}$ can be taken as constants. But, for wider range of values of V and D than mentioned above as in the case of comparing the operation of model screws to that of full sized ones where the ratio of linear dimensions will sometimes exceed fifty, the terms due to $\frac{\rho VD}{\mu}$ and $\frac{P_0}{\rho V^2}$ seem no more to be constants. Unfortunately, it is very difficult to obtain the effect of viscosity and pressure either by experiments or by theory. The only means to be tried is to compare the results of model propeller experiments to those of speed trial of full sized ships and propellers and to find correction factors. It is, in the present condition of our knowledge about the problem of ship propulsion, the most accurate process available. Hence, a careful study of experimental results of model propellers would be of great value for designers.

Surface disturbance is a function of the immersion of propeller. But unless the propeller is so near to the water surface that it draws in air from the surface, the immersion has no appreciable effect on the action of a propeller. Since, in most of actual cases, we have sufficient immersion, we may omit the terms due to $\frac{gD}{V^2}$; and even in the case of insufficient immersion, it is possible to find some corrections to be applied.

The equations for T and M may, omitting the terms due to $\frac{\rho VD}{\mu}$, $\frac{P_0}{\rho V^2}$, and $\frac{gD}{V^2}$, now be written as follows:—

$$T=\rho D^2 V^2 f_1(p, a, s) \tag{3}$$

$$M=\rho D^3 V^2 f_2(p, a, s) \tag{4}$$

Hence

$$e=\frac{TV}{2\pi n M}=\frac{1}{2\pi}\cdot\frac{f_1}{f_2}\cdot\frac{V}{nD} \tag{5}$$

where p = pitch ratio

a = area ratio

s = slip ratio $=1-\frac{V}{npD}$

n = number of revolutions per unit time

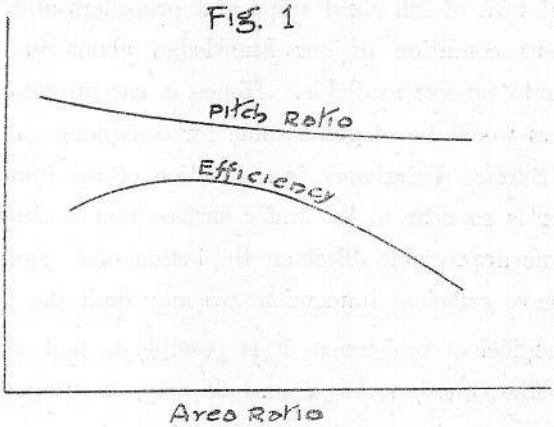
Divide the both sides of (3) by D^2V^2 and replace s by its expression, we get

$$\frac{T}{D^2V^2}=\rho f_1(p, a, 1-\frac{V}{npD}) \tag{6}$$

If $\frac{T}{D^2V^2}$ and $\frac{T}{nD}$ be known, this equation represents a relation between p and a, and for each set of values of p and a which satisfy the equation (6), corresponds a definite value of e which is also a function of $\frac{V}{nD}$. We may construct a diagram expressing the relation between p, a and e, taking any one of them as the abscissa and the remaining two as the ordinates. It is the most convenient way to take a as base. Fig. 1 shows an example of such diagrams.

As will be seen in the diagram, there is a set of values for a and p which gives maximum efficiency corresponding to given values of $\frac{T}{D^2V^2}$ and $\frac{V}{nD}$.

For every set of $\frac{T}{D^2V^2}$ and $\frac{V}{nD}$ there exists a set of values of a and p which gives maximum efficiency. If we adopt the space coordinates and take $\frac{T}{D^2V^2}$ and $\frac{V}{nD}$ parallel to x and y axis respectively, and $e, p,$ and a parallel to z axis, we will get three curved surfaces. The height of any point on the e surface represents the maximum efficiency attainable for $\frac{T}{D^2V^2}$ and $\frac{V}{nD}$ which correspond to the coordinates parallel to x and y axis of the point. The points on p and a surfaces with the same x and y values show the most favorable combination of p and a. If we cut the e surface by equidistant planes which are parallel to xy plane and project the lines of intersection on the same plane, we will get a series of contour lines. Similarly we can get contour lines for a and p on the same xy plane.



In designing a propeller T and V may be taken as known quantities. Supposing a ship is required to be driven at an assigned speed, the resistance of the ship at that speed is readily speed, the resistance of the ship at that speed is readily estimated by model experiments or by some other methods. Then T and V may be computed by the formulas.

$$T=\frac{R}{1-t}$$

$$V=(1-w)V_s$$

where V_s = speed of the ship

R = tow rope resistance of the ship at the speed V_s

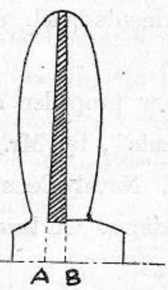
$(1-t)$ = thrust deduction factor

$(1-w)$ = wake factor

To obtain the accurate values for thrust deduction and wake factor is another difficult problem. But since it is out of the object of this paper it will not be described at length here. For the present, we may take T and V as given. Next things to be considered are the number of revolutions, the diameter, the pitch ratio and the area ratio. Of these four quantities, the first two are more or less restricted within certain limits, the number of revolutions being in close relation with propelling machinery, and the diameter being limited by the ship's draught. On the other hand pitch ratio and area ratio are not limited in any way. If we assume suitable values for number of revolutions and diameter, we should select p and a without any restriction for their magnitudes, so as to get maximum efficiency attainable. Hence the number of revolutions and the diameter may be taken as the primary independent variables, and the efficiency, the pitch ratio, and the area ratio as the dependent variables, the thrust and the speed being supposed to be given quantities. Since both of the variables $\frac{T}{D^2V^2}$ and $\frac{V}{nD}$ contain D, there is some inconvenience in using the chart. To avoid this, $\frac{V}{\sqrt{T}}D$ and $\frac{\sqrt{T}}{V^2}n$ may be taken as primary variables where the former is the square root of the reciprocal of $\frac{T}{V^2D^2}$ and the latter is the reciprocal of $\frac{V}{nD}$ multiplied by the square root of $\frac{T}{D^2V^2}$.

For shortness, denote $\frac{\sqrt{T}}{V^2}n$ by Cn and $\frac{V}{\sqrt{T}}D$ by C_D. C_n and C_D, therefor, represent n and D respectively in certain scale. Hence we can, at a glance, find efficiency corresponding to the values of n and D which are to be adopted, or determine n and D which will give the greatest efficiency, harmonising with other requirments such as the engine speed and the ship's draught.

There are two valuable informations published on the model screw propeller experiments, namely, "Results of Further Model Screw Propeller Experiments", by Mr. R. E. Froude, and "Speed and Power of Ships", by Mr. D. W. Taylor, Naval Constructor U. S. N. It will not be needed to enter in detail of their investigations. A brief description will suffice here.

	Froude	Taylor
number	36 in total comprising 12—three blade elliptical 12—three blade wide tip 12—four blade elliptical	120, all three blade elliptical
diameter	9.6 in.	16 in.
nominal pitih ratio	0.8, 1.0, 1.2, 1.4	0.6, 0.8, 1.0, 1.2, 1.5, 2.0
area ratio $\frac{\text{Expanded Area}}{\text{Disc Area}}$	0.287, 0.395, 0.503, for three blade elliptical 0.437, 0.584, 0.730, for three blade wide tip 0.383, 0.527, 0.671, for four blade elliptical	0.229, 0.306, 0.382, 0.458, 0.535
thickness ratio $=\frac{AB}{Dia}$ 	0.03	0.1033 0.0774 0.0516 0.0258 } for screws of 0.229 area ratio 0.0894 0.0672 0.0448 0.0225 } for screws of 0.306 area ratio 0.0800 0.0600 0.0400 0.0200 } for screws of 0.382 area ratio 0.0730 0.0544 0.0363 0.0181 } for screws of 0.458 area ratio 0.0676 0.0507 0.0338 0.0169 } for screws of 0.535 area ratio
diameter of boss	0.91 in.	3.125 in.
immersion	0.64 ft. or 0.8 D	16 in. or 1 D
speed of advance	300 ft. per min.	5 knots or 506.67 ft. per min.

Charts I, II, III, IV and V are calculated from the experimental results of Mr. Froude. Charts I and III are the efficiency charts for three and four bladed screws of elliptical blades respectively, corresponding slip ratios being shown in dotted lines in the same charts. Charts II and IV represent the contour lines of pitch ratio and area ratio also for the two kinds of propellers. It should be remarked that the pitch ratio used in the analysis of Mr. Froude's experiments is the analysis pitch ratio defined by him and consequently the slip ratio shown in Chart I and III is not the nominal slip ratio but is computed by using the analysis pitch ratio. Chart V is constructed by superposing the charts I and III, the explanation of this chart will be found later on. Charts VI, VII and VIII are computed from the experimental data informed by Mr. Taylor. Chart VI shows the efficiency of three bladed elliptical type with thickness ratio of .04, Charts VII and VIII being the same as chart VI except that the thickness ratio are .06 and .08 respectively.

In comparing the Charts I, VI VII, and VIII, it will be found that the contour lines obtained from these two data are quite similar in their configuration, there being only slight difference in efficiency values. If we take notice of the considerable difference of conditions of these two sets of experiments, for instance, the type of model propellers tried, the apparatus employed, and methods of experiments &c., the agreement seems quite satisfactory.

The curve *AA* in the Charts I, III, VI, VII and VIII, are the locus of points at which the straight lines Cn=constant touch the contour lines and therefore they determine the diameter and the efficiency for any assigned value for n; similarly the curves *BB* are the locus of points at which the straight lines C_D=constant touch the contour lines and they determine the revolutions and the efficiency for any given value of the diameter.

It is obvious in designing a propeller that it is desirable to determine diameter and revolutions so as to locate C_n and C_D near to the curves *AA* or *BB* as possible, if the efficiency of propeller only is to be taken into accounts. But in actual case where a propeller works in ship's wake, the problem is not so simple. A propeller which is less efficient when the propeller alone is considered, may give better performance when combined with ship, than more efficient one. It is out of the scope of the present paper to investigate the interaction of propeller and hull. It must, however, be noted that though the propeller efficiency is quite different from the propulsive efficiency, yet it is by no means a useless attempt to study the nature of the propeller action in open water. It will be of great value to calculate C_n and C_D for ships which have shown successful performances and to plot them on the charts. It will serve as competent guide for a designer. I have analysed the trial result of several ships and found that the majority of C_n and C_D thus found lie between AA and BB.

A few conclusions which are brought out from these charts may be mentioned.

1. The efficiency is high at small number of revolutions, associated with large diameter, pitch ratio, and area ratio, and falls off gradually as revolutions increases, diameter, pitch ratio, and area ratio also becoming smaller. It will be inferred from the form of the curves that we can attain greater efficiency than those shown in the charts by adopting small value for C_n and large one for C_D. It might be possible to get such a high efficiency, but it requires heavy, slow running engine and large propeller which will be prohibitive in practical case. On the contrary, as there is general tendency in recent days to adopt high revolutions for propeller in virtue of the extended use of turbine engine, it will often be found that C_n is so great that it lies outside of the field which is covered by the contour lines and in these cases the difficult problem of cavitation usually takes place. It is well known fact that model screw does not cavitate in tank experiment while full sized one does in similar condition. If we can construct an efficiency chart with respect to full sized propellers, there may exist considerable difference between this and the charts shown in the paper. Even in this extreme case it is practicable, by carefull analysis of trial results, to calculate the corrections, and by its application, we can infer the most favourable number of revolutions for turbine and propeller and determine the corresponding diameter, pitch ratio, area ratio and efficiency. These charts suggest us that a screw propeller is an exceedingly successful apparatus for driving ship of moderate speed when coupled with engine of moderate number of revolutions, but that some other means of ship propulsion should be looked for to meet the ever growing tendency of higher speed for ship and engine in these days.

2. Any particular combination of pitch ratio and area ratio occurs only once in each chart and the efficiency shown in the charts corresponding to the combination is a little lower than the maximum efficiency of the propeller characterised by the combination and the slip is greater than that of the maximum efficiency.

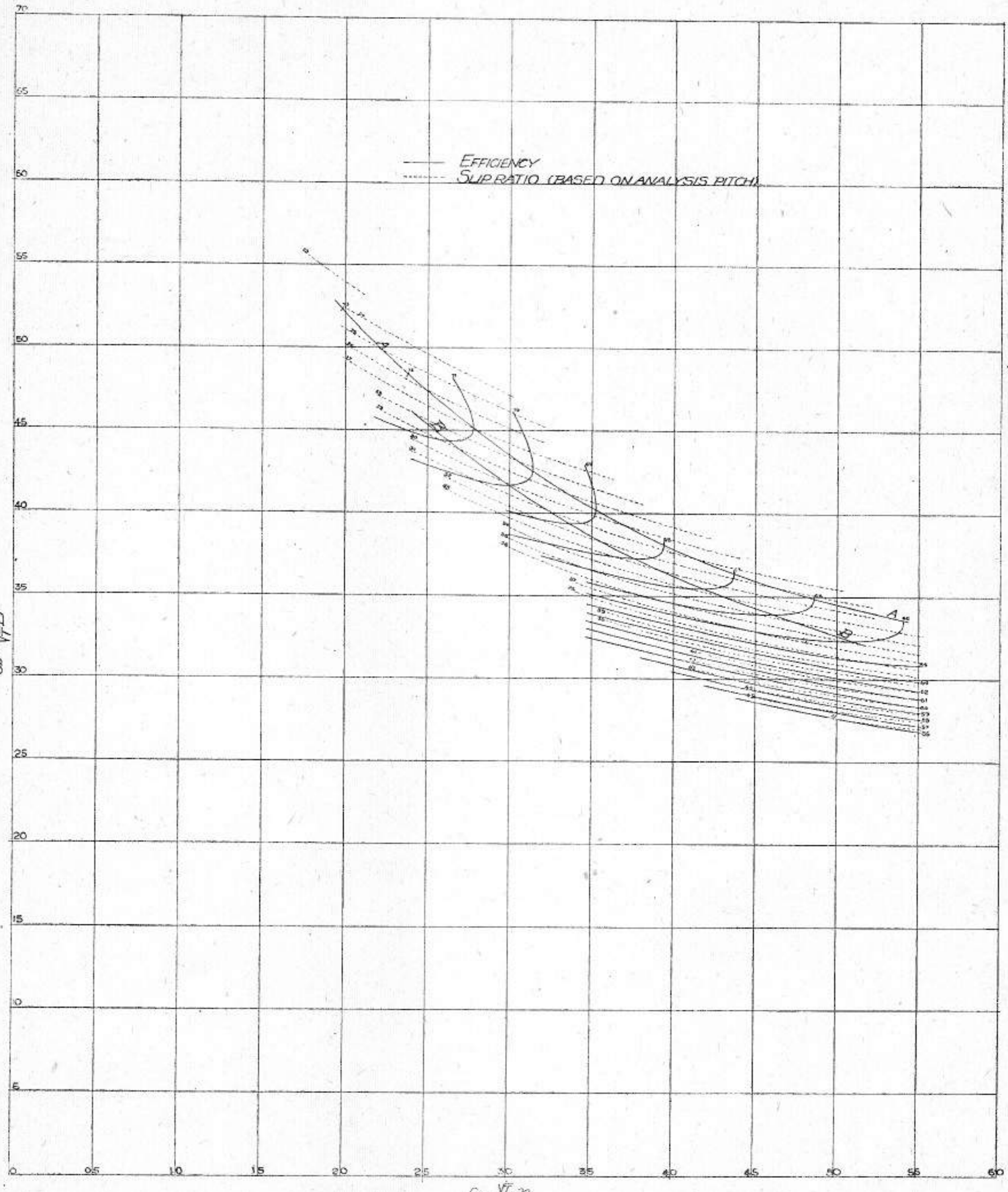
3. Chart V is constructed by superposing chart III on chart I. It will be found that the contour lines intersect at the curve DD. Above this line three bladed propeller

gives better efficiency than four bladed one, while below it four bladed one is superior. It is frequently required to keep the diameter of propeller within certain limit, especially in merchant ship where the load is variable. In this case the four bladed propeller is distinctly preferable. The reason why two bladed propeller is not adopted except in small craft is quite evident. There are many opinions about the comparative merit of the three bladed and the four bladed propellers enunciated by several authorities. Summarizing their opinions, it may be said that the three bladed propeller has not only better efficiency than the four bladed one, but it should be lighter and cheaper, that four bladed propeller is recommended only in cases where a greater portion of each blade is above the surface of the water during the upper half of its revolution as in the case of cargo steamer without sufficient load, especially in rough water, and that in these conditions four bladed screws will run more smoothly. Captain Dyson has pointed out in his "Screw Propeller" that in the case where the diameter is to be reduced below certain limit, the four bladed screw will give better propulsive efficiency than three bladed screw. That is exactly the point which the chart V brings out. At a glance, we can determine which of them, the three bladed or the four bladed, is to be preferred, while it requires somewhat lengthy calculation if one follows Captain Dyson's method.

4. Charts VI, VII and VIII give us valuable information about the effect of the blade thickness on the action of propeller. It is generally accepted that the thinner the blade the more efficient a screw will be. This statement may be accurate in similar sense as three bladed screw is more efficient than four bladed screw. It appears that there exists some limiting value of thickness corresponding to given value of C_n and C_D which give maximum efficiency. To make the blade thinner beyond this limit seems quite useless. The thickness ratio in these charts are rather too large and I have tried to get a chart for screws of thickness ratio 0.02, but failed because there is no maximum in the efficiency curve shown in Fig. 1. within the range of area ratio covered by the model screws experimented with. Even in constructing these charts, it was often necessary to make use of the method of exterpolation and moreover since there have been considerable difficulties in fairing curves passing through the points which were calculated by experimantal data, they can not, by no means, be accurate.

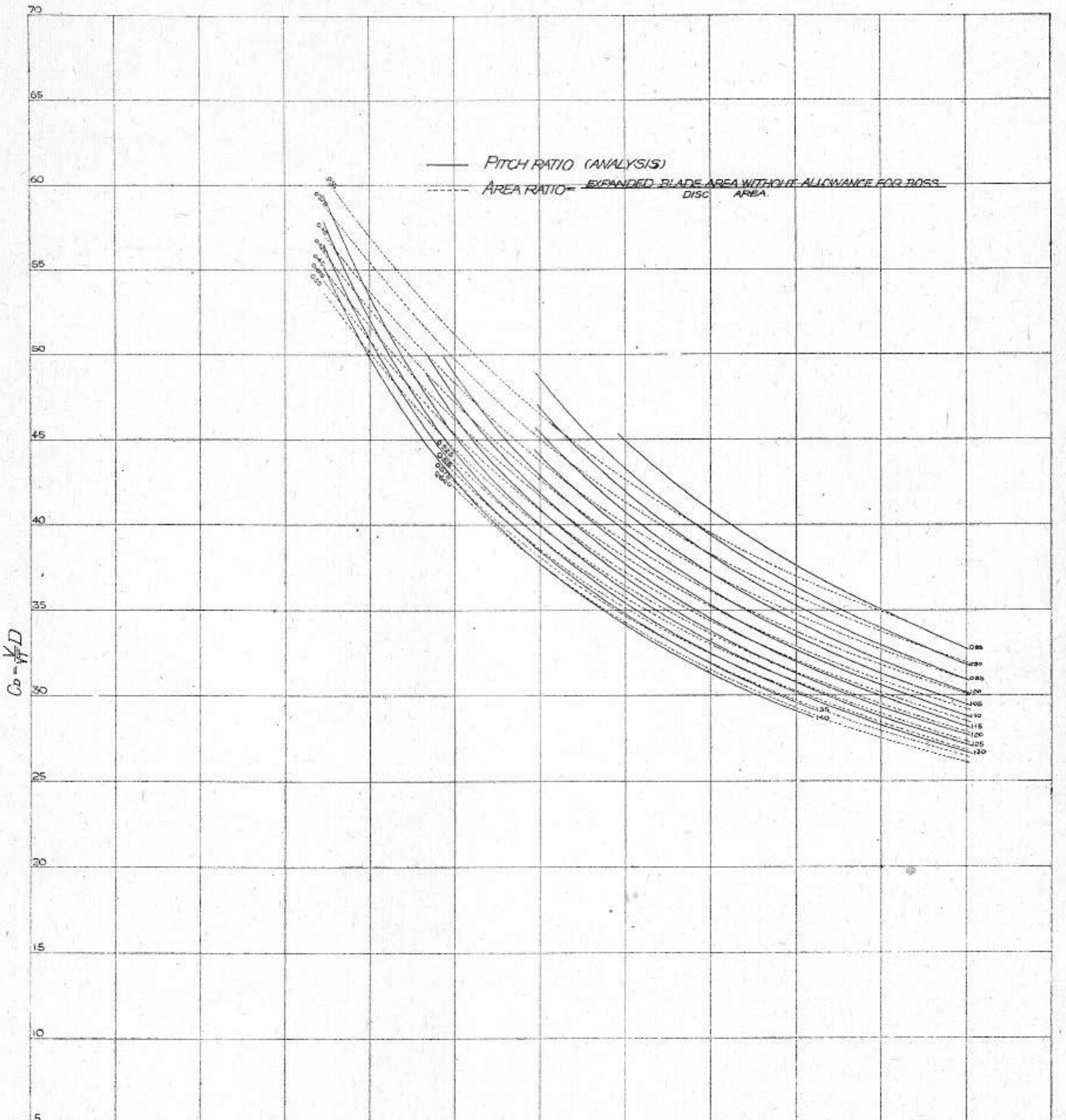
In preparing these charts it is intended to express the most complicated problem of screw propeller in the simplest form by keeping the number of variables as small as possible and assuming that our choices of the pitch ratio and the area ratio are quite free. Since all the omitted variables have little, if any, effect on the action of a screw propeller and furthermore the last assumption need not be strictly adhered to because it is apparent from Fig. 1. that any slight deviation of the pitch ratio and the area ratio from those corresponding to the maximum efficiency does not produce any material difference from the maximum efficiency, these charts can practically be applied for wider range of conditions than what is specified in the course of constructing the charts.

CHART I EFFICIENCY & SLIP RATIO THREE BLADED ELLIPTICAL SCREWS (FROUDE)



T = THRUST IN TONS
n = NUMBER OF REVS PER MIN.
V = SPEED IN KNOTS.
D = DIAMETER IN FT.

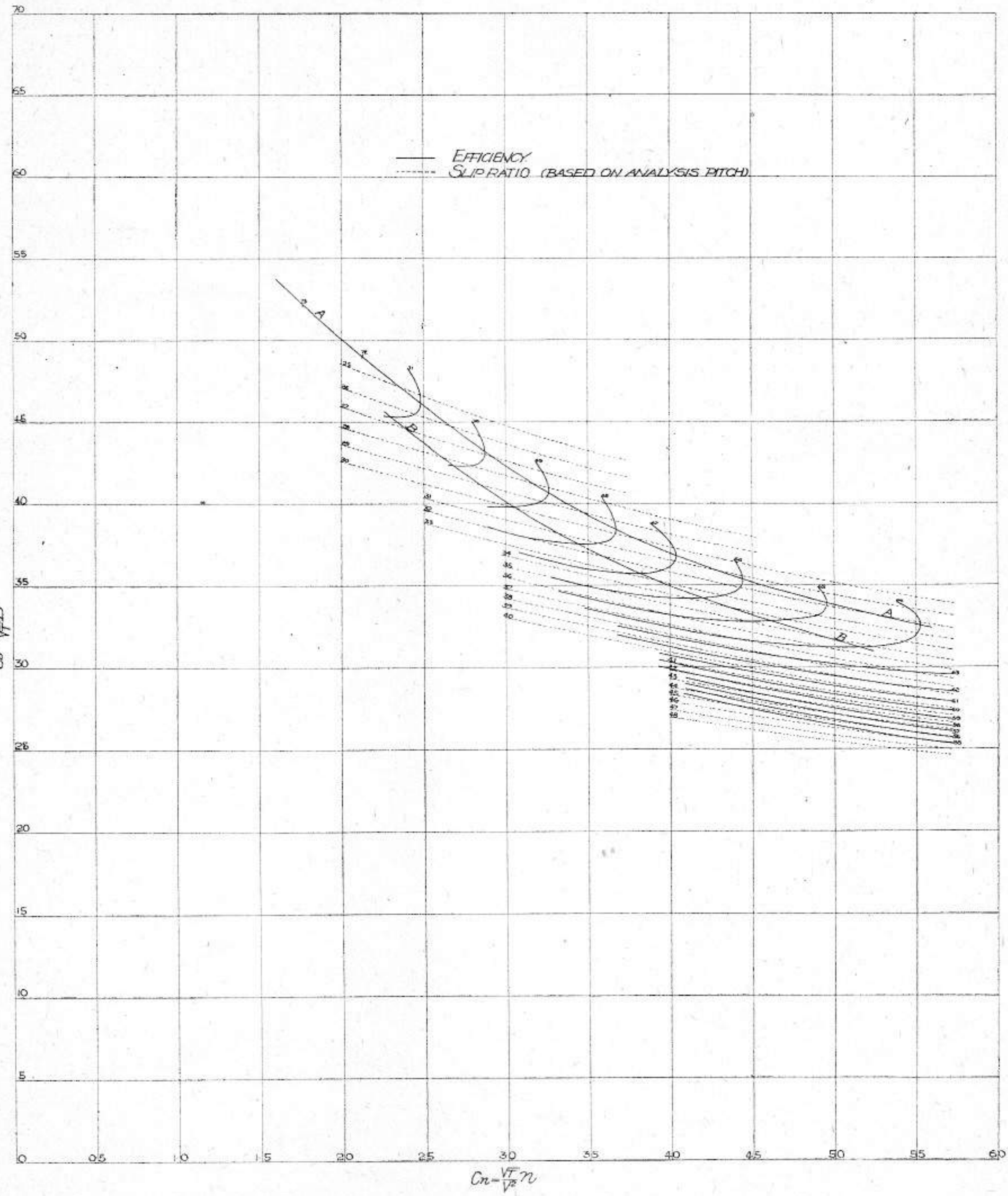
CHART II PITCH RATIO & AREA RATIO
THREE BLADED ELLIPTICAL SCREWS (FROUDE)



T = THRUST IN TONS
n = NUMBER OF REVS PER MIN

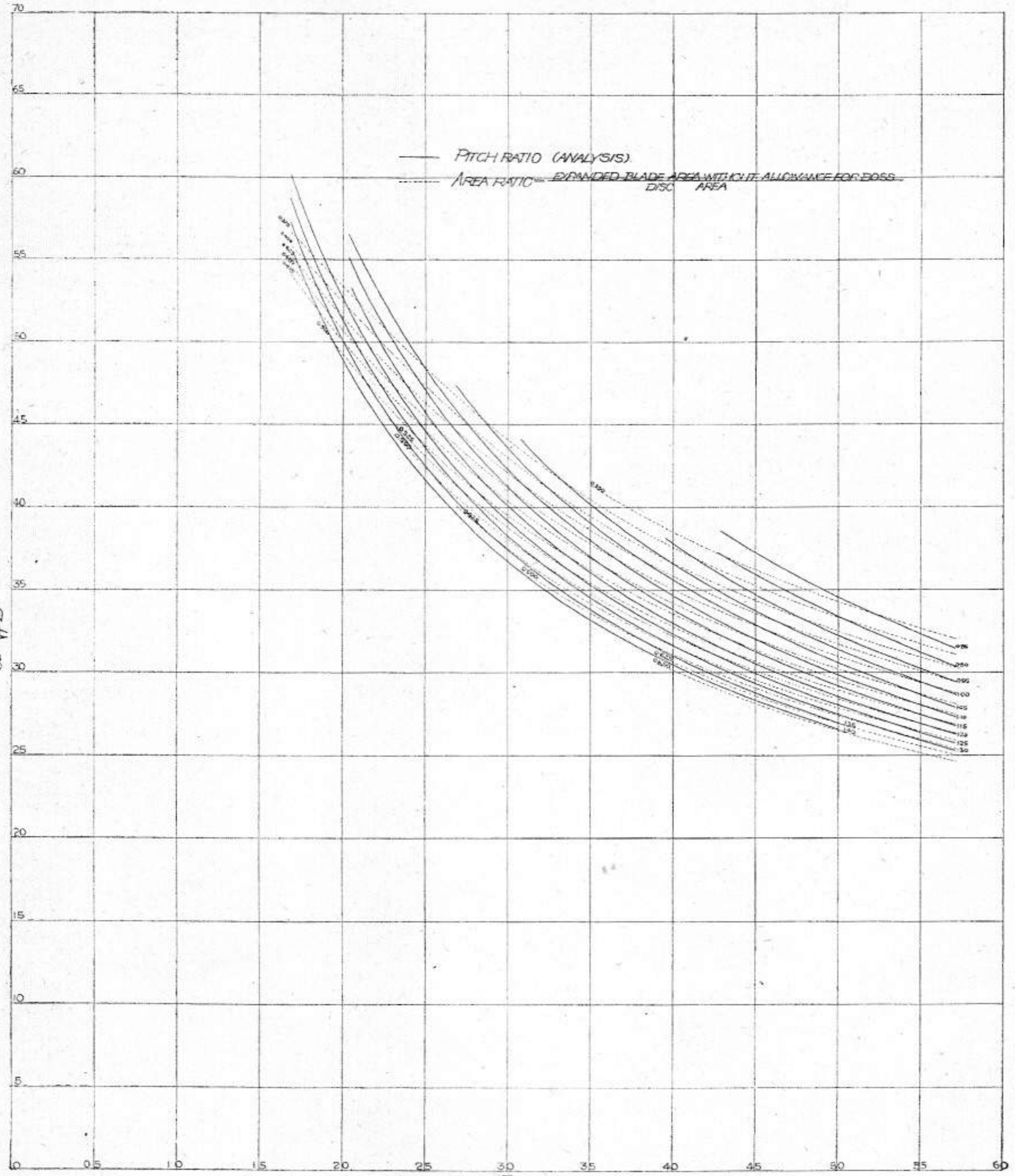
V = SPEED IN KNOTS
D = DIAMETER IN FT.

CHART III EFFICIENCY & SLIP RATIO FOUR BLADED ELLIPTICAL SCREWS (FROUDE)



T = THRUST IN TONS
n = NUMBER OF REVS. PER MIN.
V = SPEED IN KNOTS
D = DIAMETER IN FT.

CHART IV PITCH RATIO & AREA RATIO
FOUR BLADED ELLIPTICAL SCREWS (FROUDE)



T = THRUST IN TONS
n = NUMBER OF REVS PER MIN
V = SPEED IN KNOTS
D = DIAMETER IN FT

CHART V. COMPARISON OF THREE BLADED SCREW & FOUR BLADED SCREW.

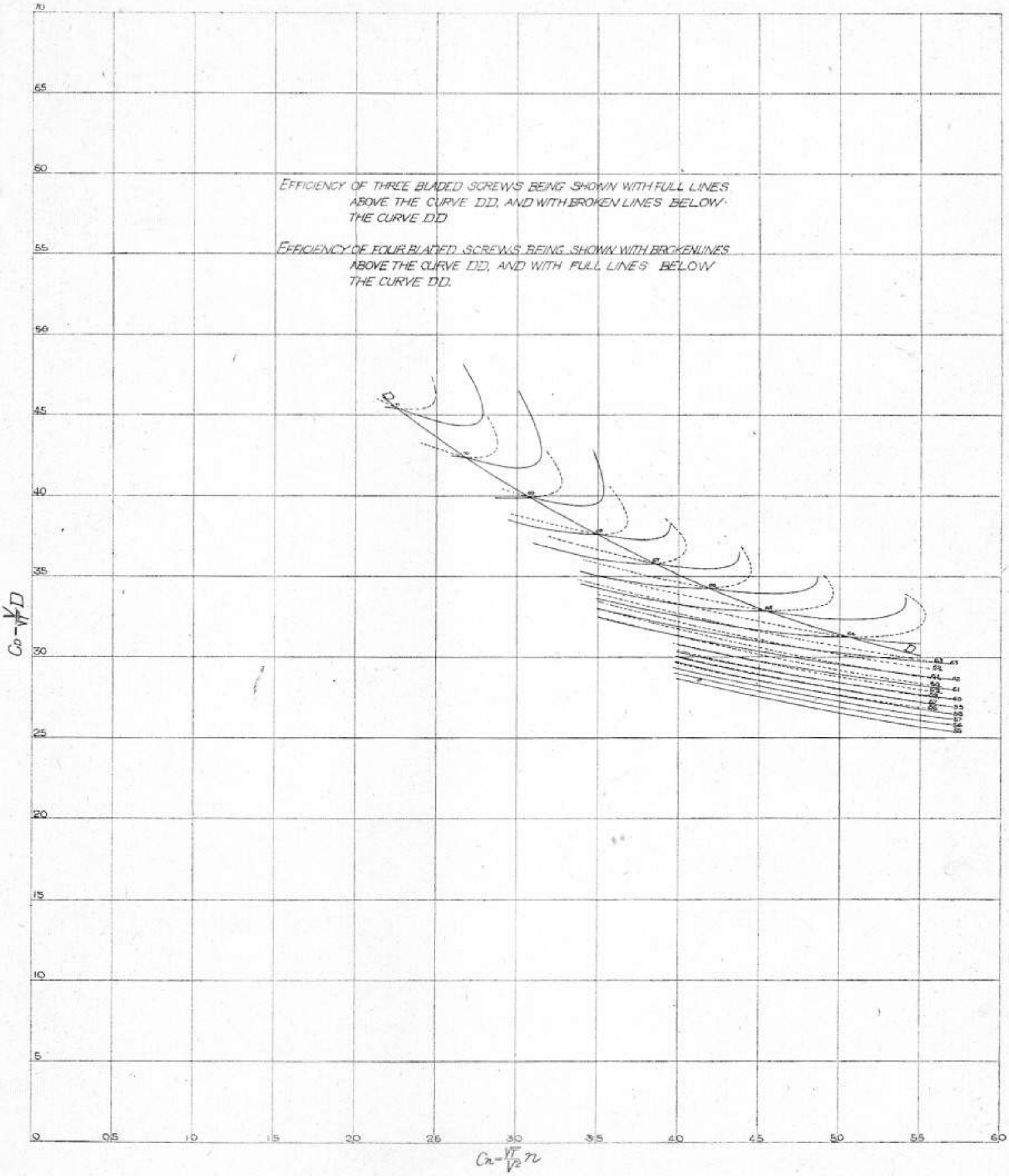
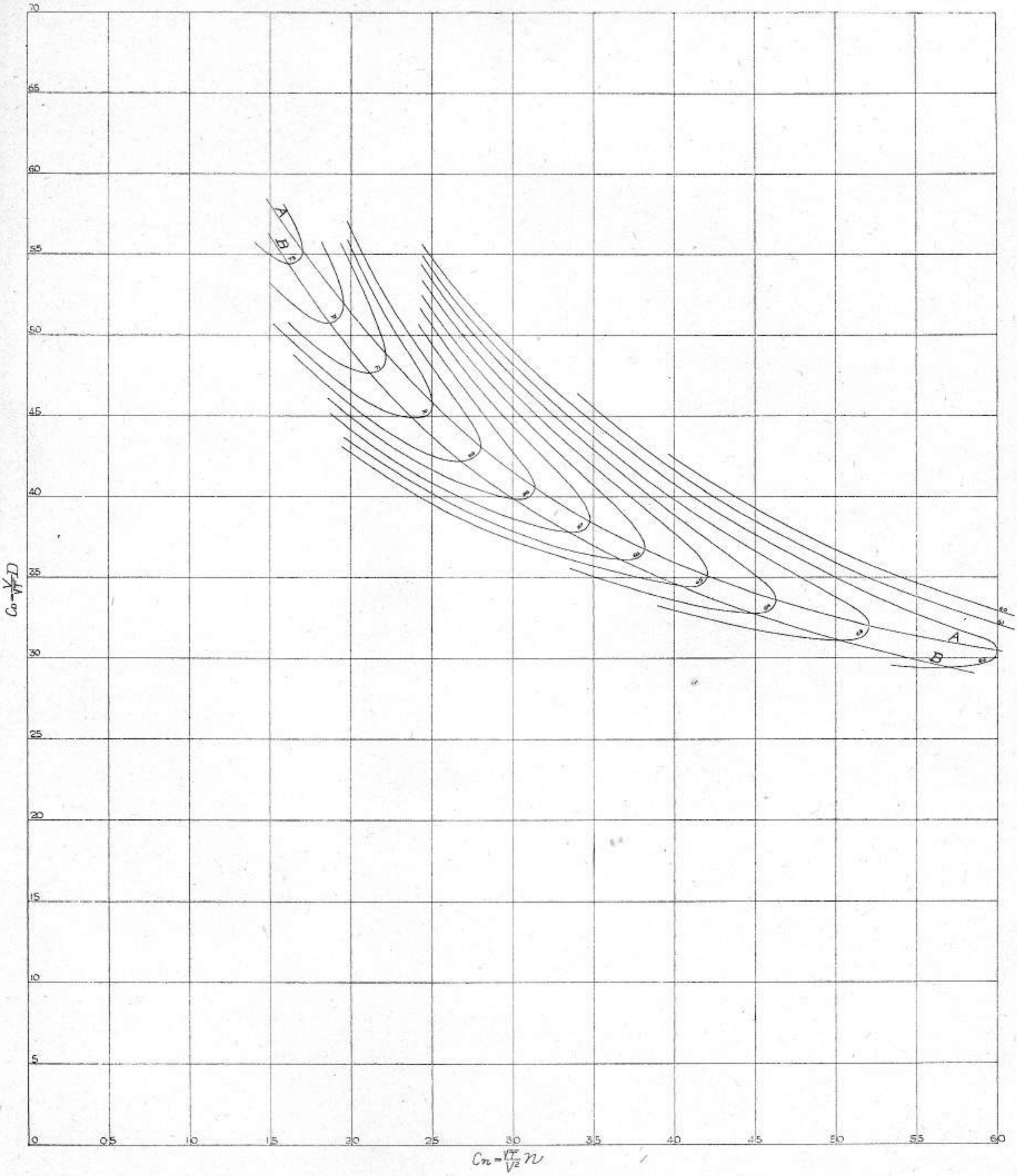


CHART VI
EFFICIENCY OF THREE BLADED SCREWS (TAYLOR).
THICKNESS RATIO = 0·04



T = THRUST IN TONS
n = NUMBER OF REVS PER MIN
V = SPEED IN KNOTS
D = DIAMETER IN FT.

CHART VII
EFFICIENCY OF THREE BLADED SCREWS (TAYLOR).
THICKNESS RATIO = 0·06

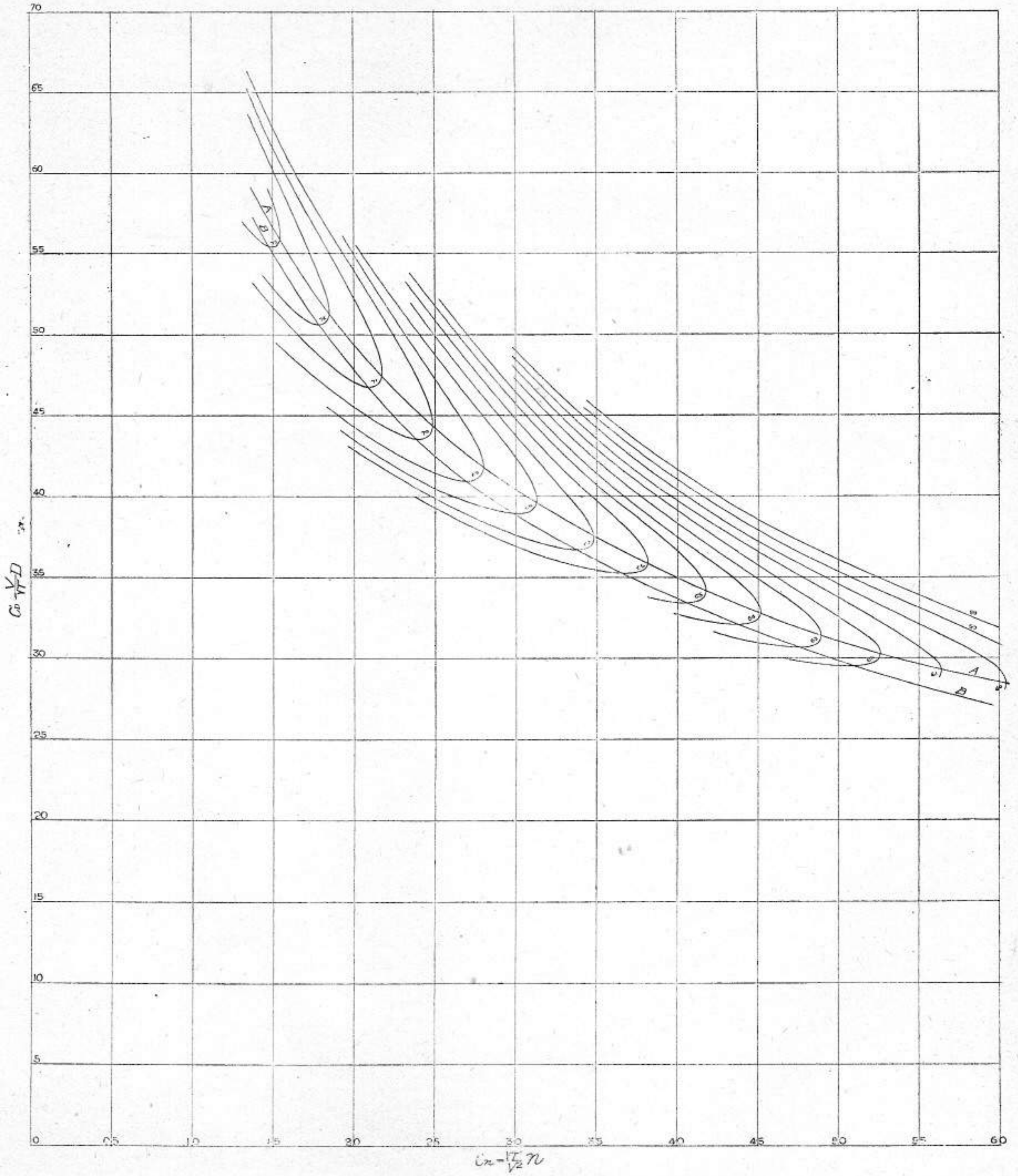
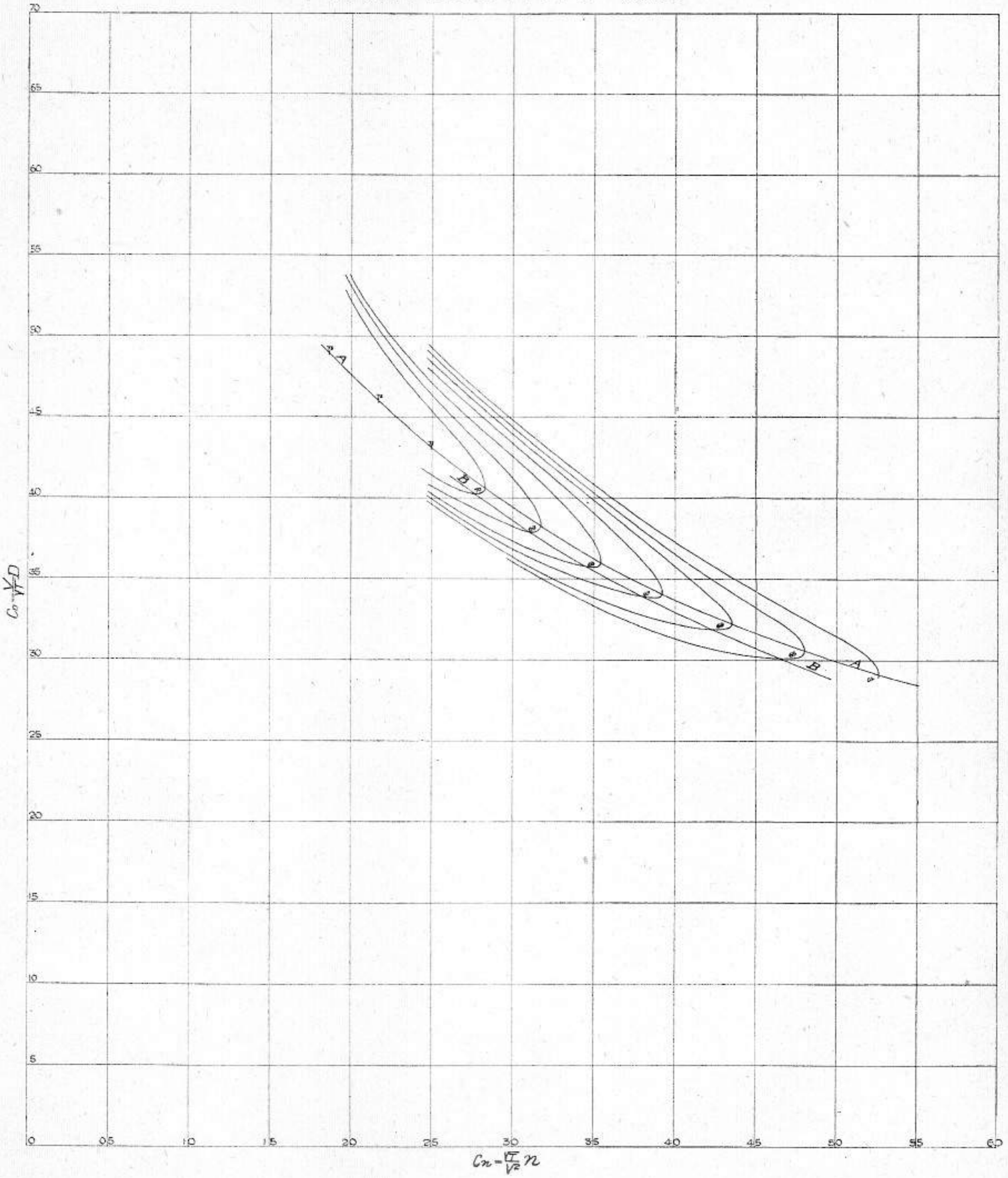


CHART VIII
EFFICIENCY OF THREE BLADED SCREWS (TAYLOR).
THICKNESS RATIO = 0·08



APPENDIX.

Fuller Explanations being demanded by one of the juries on the prize essay "*An analysis of model screw propeller experiments*":—

For chart. I.

Examples of how the resistance is obtained from Froude's figures.

It will be sufficient if this is done for

.68 efficiency,
.33 slip ratio

only;

but all the items necessary to understand the process should be stated.

For chart. II.

Similar examples, of how the results are obtained from Froude's figures.

Say for 1.33 pitch ratio;

also for .45 area ratio.

The following further communications were made by the author.

Communications.

S. Motora.

There will be several ways of obtaining the charts from the data given by Dr.

Froude in his 1908 paper. In fact, I have found that the method I have employed in preparing the charts I and II which refer to three-bladed screws was not convenient; so in the succeeding calculation for four-bladed screws some improvements have been made. By this reason, I will explain the process of obtaining the charts III and IV, though the required examples refer to the charts I and II. It will be observed that the only difference between the calculation of the three-bladed screws and the four-bladed screws exists in the values employed for the B (blade factor) and the efficiency correction which will appear in the tables I*a* and I*b* in the following explanations.

The process of obtaining the charts III and IV.

1. Draw the following two sets of curves on the base of $C_A=\frac{n'^2H}{BV^5}$ (where $n'=\frac{rev\ o}{100}$, denoted by R in Froude's paper).

   a. $x=\frac{n'pD}{V}$ for p=0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5,

   b. e=efficiency for p=0.8, 0.9, 1.0, 1.2, 1.3, 1.4, 1.5,

These curves, as indicated by Froude, are correct for the three-bladed elliptical screws of 0.45 disc area ratio (Fig. 1).

2. From these curves the following tables are computed.

   a. Seven tables of efficiency, corresponding seven area ratios 0.3, .35, .45, .55, .65, .75, .80, each table referring to the area ratio assigned in the head of the table. An example will be seen in the table I*a*.

   B is the blade factor given in the Froude's paper,

$$C_A=\frac{n'^2H}{BV^5}=\frac{TV'\times2240\times6080}{33000\times60}=\frac{6.8775}{B}\ \frac{Tn'^2}{V^4}$$

   By this relation the first, second, and third columns are written down. The efficiency values are taken from Fig. I and entered into the upper line of the space prepared for each value. Then, add the correction for e which are also obtained from Froude's paper, and the results are shown in the lower lines.

   b. Seven Tables for $\frac{n'D}{V}$; the values of x are taken from Fig. 1, divide them by p shown at the head of the respective column, the quotients $\left(=\frac{n'D}{V}\right)$ are written in the lower lines in the space corresponding to each C_A values. (Table I*b*).

3. Combining these tables, eleven diagrams are constructed; an example is shown

in Fig. 2. Each diagram refers to as pecified vslue of C_A or $\frac{\sqrt{T}}{V^2}n'$ and consists of two sets of seven curves, corresponding to seven area ratios employed and showing e and $\frac{n'D}{V}$ on the base of pitch ratio.

4. In each of the above diagrams draw straight lines parallel to the base corresponding to $\frac{n'D}{V}=0.9$, 1.0, 1.05, &c.; take the e and p corresponding to the points of the intersections of these straight lines and $\frac{n'D}{V}$ curves. These values are entered in a table, one for eacn of the diagrams. (Table II.)

5. The tables are now plotted in curves. (Fig. 3.)

6. Then find the maximum points of each of e curves and read the corresponding values of e, p and a. These values are shown in the Table III which represents the full results and not an example as in the case of preceeding tables.

7. From this table a diagram (Fig. 4) is constructed. The e curves for each $\frac{\sqrt{T}}{V^2}n'$ value are shown on the base of $\frac{n'D}{V}$.

The curves corresponding to the intermediate values of $\frac{\sqrt{T}}{V^2}n'$ which were employed in the calculation are obtained by constructing the cross curves of this diagram.

Similar curves p and a are obtained in quite aimilar ways.

8. Now, draw a set of straight lines e=constant and take the values of e, and $\frac{n'D}{V}$ and $\frac{\sqrt{T}}{V^2}n'$ corresponding to the points of the intersections of the straight lines and the curves. The Table IV shows these values. The second lines in each space corresponding to $\frac{\sqrt{T}}{V^2}n'$ are simply the quotients of $\frac{n'D}{V}\Big/\frac{\sqrt{T}}{V^2}n'$ which are to be substuted for $\frac{n'D}{V}$ for the sake of convenience of practical application.

Similar tables for p and a are computed. (Tables V, VI.)

9. The contour curves for e, p and a sre obtained by simply plottiag the values given in these tables.

10. A table is computed by the Fig. 5, showing the values of p corresponding to $\frac{n'D}{V}$ and $\frac{\sqrt{T}}{V^2}n'$ given in the first line and in the first column. The slip ratio $(=s)$ is calculated by the formula,

$$s=1-\frac{1}{p}\,\frac{V}{n'D}\times\frac{60.80}{60}$$

The results are written below the corresponding p value. (Table VII.)

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11. Plot these s values on the base of $\frac{n'D}{V}$. (Fig. 7.)

12. Take the $\frac{\sqrt{T}}{V^2}n'$ and $\frac{n'D}{V}$ corresponding to the points of the intersections of the straight lines s=constant and the curves. (Table VIII.)

13. Contour curves will easily be obtained by this table.

TABLE I*a*. EFFICIENCY. (4 Blades.)

$a = .35$

$B = .1106$

$$C_A = \frac{6.8775}{.1106} T\frac{n'^2}{V^4} = 62.185\left(\frac{Tn'^2}{V^4}\right)$$

$\frac{\sqrt{T}}{V^2}n'$	$T\frac{n'^2}{V^4}$	C_A	Pitch Ratio. .8	.9	1.0	1.1	1.2	1.3	1.4	1.5
			Correction for e in %							
			−.45	−.70	−.95	−1.15	−1.25	−1.25	−1.25	−1.25
.016	.000256	.01592	48.00 47.55	57.15 56.45	63.70 62.75	68.35 67.20	71.42 70.17	73.10 71.85	74.00 72.75	74.00 72.75
.020	.00040	.024875	55.45 55.00	62.85 62.15	67.70 66.75	70.94 69.79	72.60 71.35	73.00 71.75	72.72 71.47	71.97 70.72
.024	.000576	.03582	60.23 59.78	66.05 65.35	69.62 68.67	71.55 70.40	72.15 70.90	71.75 70.50	70.64 69.39	69.15 67.90
.028	.000784	.048755	63.10 62.65	67.60 66.90	70.10 69.15	71.00 69.85	70.85 69.60	69.70 68.45	68.20 66.95	66.25 65.00
.032	.001024	.063675	64.77 64.32	68.08 67.38	69.86 68.91	69.80 68.65	69.15 67.90	67.50 66.25	65.58 64.33	63.40 62.15
.036	.001296	.080590	65.50 65.05	67.90 67.20	68.98 68.03	68.45 67.30	67.30 66.05	65.35 64.10	63.00 61.75	60.62 59.37
.040	.001600	.099495	65.66 65.21	67.32 66.62	67.85 66.90	67.00 65.85	65.35 64.10	63.15 61.90	60.58 59.33	57.98 56.73
.044	.001936	.12040	65.50 65.05	66.66 65.96	66.65 65.70	65.50 64.35	63.60 62.35	61.00 59.75	58.35 57.10	55.60 54.35
.068	.002304	.14328	65.10 64.65	65.98 65.28	65.46 64.51	63.98 62.83	61.76 60.51	59.10 57.85	56.35 55.10	53.70 52.45
.052	.002704	.16815	64.70 64.25	65.15 64.45	64.36 63.41	62.52 61.37	60.00 58.75	57.20 55.95	54.50 53.25	
.056	.003136	.19501	64.30 63.85	64.30 63.60	63.26 62.31	61.05 59.90	58.38 57.13	55.60 54.35	52.75 51.50	

$\frac{n'D}{V}$ (4 Blades.)

TABLE Ib.

$a=.35$

$B=.1106$

$C_A=62.185\left(\frac{Tn'^2}{V^4}\right)$

$\frac{\sqrt{T}}{V^2}n'$	$\frac{Tn'^2}{V^4}$	C_A	Pitch Ratio.							
			.8	.9	1.0	1.1	1.2	1.3	1.4	1.5
.016	.000256	.01592	1.1020 1.3775	1.1310 1.2565	1.1620	1.1945 1.0860	1.2290 1.0242	1.2640 0.9722	1.3005 0.9288	1.3365 0.8910
.020	.00040	.024875	1.1400 1.4249	1.1780 1.3087	1.2170	1.2580 1.1436	1.3000 1.0834	1.3425 1.0327	1.3875 0.9910	1.4315 0.9542
.024	.000576	.03582	1.1785 1.4730	1.2240 1.3599	1.2710	1.3200 1.2000	1.3685 1.1405	1.4170 1.0900	1.4680 1.0485	1.5185 1.0125
.028	.000784	.048755	1.2180 1.5225	1.2700 1.4110	1.3240	1.3785 1.2532	1.4340 1.1950	1.4900 1.1462	1.5455 1.1040	1.6005 1.0670
.032	.001024	.063675	1.2575 1.5718	1.3155 1.4615	1.3755	1.4360 1.3055	1.4975 1.2480	1.5580 1.1985	1.6180 1.1557	1.6790 1.1194
.036	.001296	.080590	1.2970 1.6211	1.3610 1.5121	1.4260	1.4925 1.3568	1.5580 1.2985	1.6235 1.2490	1.6890 1.2065	1.7545 1.1697
.040	.001600	.099495	1.3350 1.6687	1.4050 1.5610	1.4760	1.5465 1.4060	1.6165 1.3472	1.6870 1.2977	1.7570 1.2550	1.8270 1.2180
.044	.001936	.12040	1.3715 1.7142	1.4470 1.6076	1.5235	1.5990 1.4536	1.6735 1.3947	1.7480 1.3445	1.8220 1.3014	1.8950 1.2634
.048	.002304	.14328	1.4080 1.7600	1.4885 1.6536	1.5685	1.6485 1.4985	1.7280 1.4402	1.8070 1.3900	1.8850 1.3465	1.9605 1.3070
.052	.002704	.16815	1.4440 1.8049	1.5275 1.6970	1.6120	1.8965 1.5423	1.7800 1.4835	1.8635 1.4335	1.9440 1.3885	2,0250 1.3800
.056	.003136	.19501	1.4800 1.8500	1.5680 1.7420	1.6565	1.7445 1.5860	1.8320 1.5267	1.9190 1.4762	2.0030 1.4308	

Upper figures in every rectangular space are x.

Lower ,, ,, ,, ,, ,, ,, x/p.

TABLE II.

$\frac{\sqrt{T}}{V^2}$ $n' = .04$

$\frac{n'D}{V}$	a / p & e	.30	.35	.45	.55	.65	.75	.80
1.20	p			1.498	1.470	1.452	1.443	1.436
	e			57.75	58.95	59.25	59.15	58.95
1.25	p	1.450	1.412	1.364	1.342	1.328	1.320	1.313
	e	57.28	59.05	61.20	61.85	61.95	61.45	61.00
1.30	p	1.327	1.294	1.254	1.234	1.222	1.214	1.210
	e	60.55	61.95	63.70	64.00	63.75	62.95	62.27
1.35	p	1.222	1.194	1.160	1.144	1.134	1.126	1.122
	e	63.05	64.15	65.45	65.35	64.65	63.58	62.60
1.40	p	1.133	1.110	1.080	1.066	1.056	1.050	1.046
	e	64.92	65.70	66.55	66.00	64.92	63.40	62.20
1.45	p	1.056	1.034	1.008	.9[illegible]6	.988	.982	.978
	e	66.05	66.68	67.05	66.12	64.70	62.50	61.15
1.50	p	.9880	.970	.946	.936	.928	.923	.920
	e	66.66	66.95	66.82	65.60	63.85	61.20	59.55

TABLE III.

$\frac{\sqrt{T}}{V^2}n' = .016$	$\frac{n'D}{V}$	.9	.95					
	e	72.85	72.50					
	p	1.450	1.360					
	a	.430	.313					
$\frac{\sqrt{T}}{V^2}n' = .020$	$\frac{n'D}{V}$	1.00	1.05					
	e	71.95	71.75					
	p	1.342	1.252					
	a	.467	.390					
$\frac{\sqrt{T}}{V^2}n' = .024$	$\frac{n'D}{V}$	1.05	1.10	1.15				
	e	70.45	71.05	71.00				
	p	1.347	1.248	1.168				
	a	.5195	.440	.400				
$\frac{\sqrt{T}}{V^2}n' = .028$	$\frac{n'D}{V}$	1.10	1.15	1.20	1.25			
	e	68.45	69.60	70.05	70.00			
	p	1.351	1.250	1.164	1.092			
	a	.5680	.4935	.4465	.420			
$\frac{\sqrt{T}}{V^2}n' = .032$	$\frac{n'D}{V}$	1.15	1.20	1.25	1.30	1.35		
	e	66.12	67.80	68.68	68.98	69.05		
	p	1.350	1.246	1.165	1.090	1.026		
	a	.579	.516	.470	.436	.385		
$\frac{\sqrt{T}}{V^2}n' = .036$	$\frac{n'D}{V}$	1.20	1.25	1.30	1.35	1.40	1.45	
	e	64.00	65.90	67.15	67.95	68.20	68.00	
	p	1.345	1.246	1.158	1.086	1.020	.966	
	a	.586	.520	.484	.437	.418	.373	
$\frac{\sqrt{T}}{V^2}n' = .040$	$\frac{n'D}{V}$	1.20	1.25	1.30	1.35	1.40	1.45	1.50
	e	59.25	62.00	64.00	65.50	66.50	67.05	67.00
	p	1.451	1 334	1.236	1.154	1.080	1.014	.962
	a	7.66	.006	.550	.497	.450	.424	.390

TABLE III.—*Continued.*

$\frac{\sqrt{T}}{V^2}n' = .044$	$\frac{n'D}{V}$	1.25	1.30	1.35	1.40	1.50	1.55	1.60	
	e	57.30	60.15	62.30	64.15	65.80	66.05	66.00	
	p	1.434	1.322	1.226	1.143	1.012	·954	.906	
	a	.650	.595	.540	.488	.434	.405	·357	
$\frac{\sqrt{T}}{V^2}n' = .048$	$\frac{n'D}{V}$	1.30	1.35	1.40	1.45	1.50	1.60	1.65	1.70
	e	55.60	58.42	60.83	62.67	63.94	65.10	65.25	65.23
	p	1.413	1.310	1.214	1.132	1.062	.945	.896	.854
	a	.679	.590	.540	.500	·465	.415	.370	.333
$\frac{\sqrt{T}}{V}n' = .052$	$\frac{n'D}{V}$	1.40	1.45	1.50	1.60	1.65	1.70	1.75	
	e	57.15	59.55	61.35	63.82	64.35	64.45	64.50	
	p	1.292	1.200	1.120	·990	.934	.886	.847	
	a	.583	.549	.495	.440	.420	.390	.350	
$\frac{\sqrt{T}}{V^2}n' = .056$	$\frac{n'D}{V}$	1.40	1.45	1.50	1.55	1.60	1.70	1.75	1.80
	e	53.30	55.90	58.26	60.25	61.85	63.45	63.72	63.90
	p	1.372	1.274	1.184	1.107	1·038	.926	.881	.840
	a	.645	.586	.547	.510	.471	.423	.384	.360

EFFICIENCY.

Upper figures in every rectangular space are $\frac{vD}{V}$

Lower " " " " " " " $\frac{V}{\sqrt{T}} \cdot D \left(= \frac{\frac{vD}{V}}{\frac{\sqrt{T_{n'}}}{V^2}} \right)$

$\frac{\sqrt{T_{n'}}}{V^2}$ \ v	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
.016																			809 51.25
.020																			
.024																	1.153 48.03		
.028														1.097 38.82	1.119 39.96	1.188 44.82			
.029													1.095 37.75	1.119 38.58	1.153 39.76				
.030													1.117 37.23	1.145 38.16	1.191 39.70				
.031													1.144 36.90	1.177 7.97	1.238 39.93				
.032												1.144 35.35	1.171 36.59	1.209 37.78	1.290 40.31				
.033											1.146 34.72	1.171 35.48	1.203 36.45	1.247 37.78					
.034											1.170 34.41	1.197 35.20	1.232 36.20	1.281 37.67					
.035											1.199 34.25	1.226 35.08	1.263 36.08	1.322 37.77					
.036										1.199 33.30	1.224 34.00	1.253 34.80	1.293 35.91	1.359 37.75					
.037									1.201 32.45	1.224 33.08	1.250 33.78	1.280 34.60	1.325 35.81						
.038								1.205 31.70	1.225 32.23	1.248 32.84	1.273 33.50	1.307 34.30	1.367 35.71						
.039							1.209 31.00	1.227 31.46	1.249 32.02	1.273 32.64	1.301 33.36	1.339 34.33	1.400 35.89						
.040					1.196 29.90	1.212 30.30	1.229 30.72	1.248 31.20	1.270 31.75	1.297 32.42	1.329 33.22	1.369 34.22	1.446 36.15						
.041			1.189 24.00	1.203 29.34	1.218 29.70	1.235 30.12	1.253 30.56	1.273 31.05	1.295 31.63	1.323 32.27	1.355 33.05	1.403 34.22							
.042	1.183 28.15	1.195 28.45	1.209 28.77	1.223 29.12	1.239 29.50	1.256 29.90	1.274 30.33	1.295 30.83	1.320 31.42	1.349 32.12	1.385 32.97	1.440 34.28							
.043	1.201 27.93	1.214 28.23	1.227 28.53	1.242 28.88	1.259 29.28	1.275 29.65	1.295 30.11	1.319 30.67	1.345 31.28	1.375 31.98	1.415 32.90	1.476 34.32							
.044	1.218 37.08	1.232 28.00	1.245 28.29	1.262 8.68	1.278 29.04	1.297 29.47	1.317 29.93	1.341 30.47	1.369 31.11	1.403 31.81	1.442 32.77	1.524 34.63							
.045	1.235 27.44	1.250 37.78	1.265 28.11	1.281 28.46	1.299 28.87	1.318 29.29	1.339 29.75	1.363 30.29	1.391 30.91	1.425 31.67	1.475 32.78								
.046	1.253 27.23	1.269 37.58	1.284 27.91	1.301 28.28	1.319 28.67	1.339 29.11	1.360 29.56	1.385 30.10	1.413 30.71	1.470 31.52	1.506 23.74								
.047	1.273 27.07	1.287 27.38	1.304 27.74	1.322 28.13	1.341 28.53	1.361 28.96	1.383 29.42	1.404 29.98	1.439 30.62	1.479 31.47	1.516 23.89								
.048	1.291 26.89	1.306 37.20	1.323 27.56	1.341 27.93	1.360 28.33	1.381 28.77	1.404 29.25	1.430 29.79	1.461 30.43	1.503 31.31	1.886 33.04								
.049	1.309 26.70	1.325 27.04	1.341 27.37	1.360 27.75	1.379 28.14	1.400 28.57	1.425 29.08	1.453 29.65	1.487 30.34	1.536 31.34	1.628 33.18								
.050	1.327 26.54	1.343 26.86	1.360 27.20	1.379 27.58	1.399 27.98	1.421 28.42	1.447 28.94	1.475 29.50	1.512 30.24	1.563 31.26									
.051	1.344 26.35	1.361 26.68	1.378 27.02	1.398 27.41	1.419 27.82	1.442 28.27	1.467 28.76	1.498 29.37	1.537 30.14	1.589 31.16									
.052	1.363 26.21	1.379 26.52	1.397 26.86	1.416 27.23	1.437 27.63	1.461 28.09	1.488 28.61	1.519 29.21	1.557 29.94	1.614 31.03									
.053	1.379 26.02	1.397 26.36	1.416 26.72	1.436 27.09	1.459 27.53	1.483 27.98	1.510 28.49	1.543 29.11	1.583 29.87	1.659 31.30									
.054	1.396 25.85	1.415 26.20	1.434 26.55	1.455 26.94	1.477 27.35	1.503 27.83	1.532 28.37	1.565 28.98	1.609 29.79	1.697 31.42									
.055	1.413 25.69	1.433 26.05	1.453 26.42	1.475 26.82	1.498 27.23	1.523 27.69	1.553 28.24	1.587 28.85	1.635 29.72	1.774 32.25									
.056	1.432 25.57	1.451 25.91	1.472 26.29	1.495 26.69	1.517 27.09	1.543 27.55	1.572 28.07	1.609 28.73	1.663 29.69										

PITCH RATIO.

Upper figures in every rectangular space are $\frac{n'D}{V}$

Lower " " " " " " " $\frac{V}{\sqrt{T}}D\left(=\frac{\frac{n'D}{V}}{\frac{\sqrt{T}}{V^2}n'}\right)$

$\frac{\sqrt{T}}{V^2}n'$ \ p	.9	.95	1.0	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
.016							1.035 64.69	1.007 62.93	.981 61.30	.954 59.62	.931 58.18
.020					1.149 57.45	1.115 55.75	1.089 54.45	1.052 52.60	1.026 51.30	1.000 50.00	.977 48.85
.024					1.197 49.88	1.163 48.46	1.129 47.04	1.102 45.92	1.076 44.83	1.049 43.71	1.027 42.79
.028				1.281 45.75	1.245 44.46	1.212 43.29	1.178 42.07	1.151 41.11	1.125 40.18	1.100 39.28	1.076 38.43
.032			1.373 42.91	1.330 41.56	1.293 40.41	1.259 39.34	1.227 38.35	1.200 37.50	1.172 36.63	1.147 35.85	1.126 35.19
.036			1.418 39.38	1.377 38.25	1.340 37.22	1.306 36.27	1.275 35.42	1.246 34.61	1.219 33.86	1.195 33.19	1.174 32.61
.040		1.513 37.83	1.464 36.60	1.423 35.58	1.386 34.65	1.352 33.80	1.320 33.00	1.292 32.30	1.266 31.65	1.242 31.05	1.220 30.50
.044	1.606 36.50	1.553 35.30	1.507 34.25	1.467 33.34	1.429 32.48	1.396 31.73	1.365 31.02	1.337 30.39	1.310 29.77	1.286 29.23	1.265 28.75
.048	1.647 34.31	1.594 33.21	1.549 32.27	1.510 31.46	1.472 30.67	1.439 29.98	1.409 29.35	1.380 28.75	1.354 28.20	1.329 27.69	1.307 27.23
.052	1.687 32.44	1.634 31.42	1.590 30.58	1.550 29.80	1.514 29.11	1.481 28.48	1.450 27.88	1.422 27.34	1.396 26.84		
.056	1.728 30.86	1.675 29.91	1.630 29.11	1.591 28.41	1.554 27.75	1.521 27.16	1.491 26.62	1.463 26.13	1.437 25.66		

TABLE VI.

AREA RATIO.

Upper figures in every rectangular space are $\frac{n'D}{V}$

Lower " " " " " " $\frac{V}{\sqrt{T}}D\left(=\frac{\frac{n'D}{V}}{\frac{\sqrt{T}}{V^2}n'}\right)$

$\frac{\sqrt{T}}{V^2}n'$ \ a	.35	.375	.40	.425	.45	.475	.500	.525	.550	.575	.600	.625	.6
.061		.920 57.50	.910 56.87	.901 56.31	.893 55.81	.886 55.37							
.020		1.059 52.95	1.043 52.15	1.026 51.30	1.010 50.50	.995 49.75	4.982 9.10						
.024		1.187 49.46	1.160 48.33	1.137 47.37	1.114 46.42	1.093 45.54	1.073 44.71	1.056 44.00	1.040 43.33				
.028		1.282 45.79	1.250 44.64	1.223 4.368	1.197 42.75	1.174 41.93	1.150 41.07	1.130 40.36	1.112 39.72	1.094 39.07			
.032		1.359 42.47	1.329 41.53	1.300 40.63	1.271 39.72	1.245 38.91	1.219 38.10	1.195 37.35	1.173 36.66	1.153 36.03	1.136 35.47		
.036	1.466 40.72	1.431 39.75	1.398 38.83	1.367 37.97	1.337 37.13	1.308 36.33	1.280 35.55	1.254 34.83	1.230 34.16	1.208 33.55	1.188 33.00		
.040	1.541 38.53	1.504 37.60	1.467 36.68	1.435 35.88	1.402 35.05	1.369 34.23	1.340 33.50	1.313 32.83	1.288 32.20	1.265 31.63	1.243 31.08	1.223 30.58	1 30.1
.044	1.613 36.66	1.572 35.73	1.533 34.84	1.497 34.02	1.461 33.20	1.427 32.43	1.396 31.73	1.368 31.09	1.343 30.52	1.318 29.90	1.295 29.43	1.274 28.96	1.2 28.5
.048	1.682 35.04	1.637 34.10	1.596 33.25	1.557 32.44	1.518 31.62	1.483 30.90	1.450 30.21	1.421 29.60	1.395 29.06	1.369 28.52	1.345 28.02	1.324 27.58	1.30 27.17
.052	1.749 33.63	1.700 32.69	1.656 31.84	1.614 31.04	1.577 30.32	1.539 29.59	1.505 28.94	1.473 28.33	1.446 27.81	1.419 27.29	1.395 26.83	1.371 26.36	1.35 25.98
.056	1.815 33.41	1.765 31.52	1.717 30.66	1.673 29.87	1.631 29.13	1.594 28.46	1.559 27.84	1.527 27.27	1.496 26.71	1.469 26.23	1.443 25.77	1.418 25.32	1.39 24.91

SLIP RATIO.

Upper figures in every rectangular space are p

Lower " " " " " " $s\left(=1-\frac{1}{p}\frac{V}{n'D}\times\frac{60.80}{60}\right)$

$\frac{n'D}{V}$ \ $\frac{\sqrt{T}}{V^2}n'$	.016	.020	.024	.028	.032	.036	.040	.044	.048	.052	.056
.9	1.449										
	0.223										
1.0	1.274	1.342	1.453								
	.2046	.2449	.3026								
1.1	1.130	1,174	1.249	1.350	1.469						
	·1848	.2155	.2624	.3176	.3729						
1.2		1.050	1.098	1.165	1.249	1.345	1.452				
		.1958	.2309	.2752	.3239	.3721	.4184				
1.3				1.028	1.091	1.159	1.236	1.322	1.415		
				.2417	.2856	.3274	.3693	.4104	.4491		
1.4					.969	1.021	1.080	1.143	1.213	1.292	1.372
					.2531	.2911	.3298	.3667	.4032	.4398	.4724
1.5						.916	.962	1.010	1.062	1.120	1.184
						.2626	.2978	.3312	.3639	.3968	.4294
1.6								.906	.945	.987	1.038
								.3010	.3299	.3584	.3898
1.7								.821	.854	.887	.927
								.2740	.3021	3280	.3570
1.8											.840
											.3298

TABLE VIII.

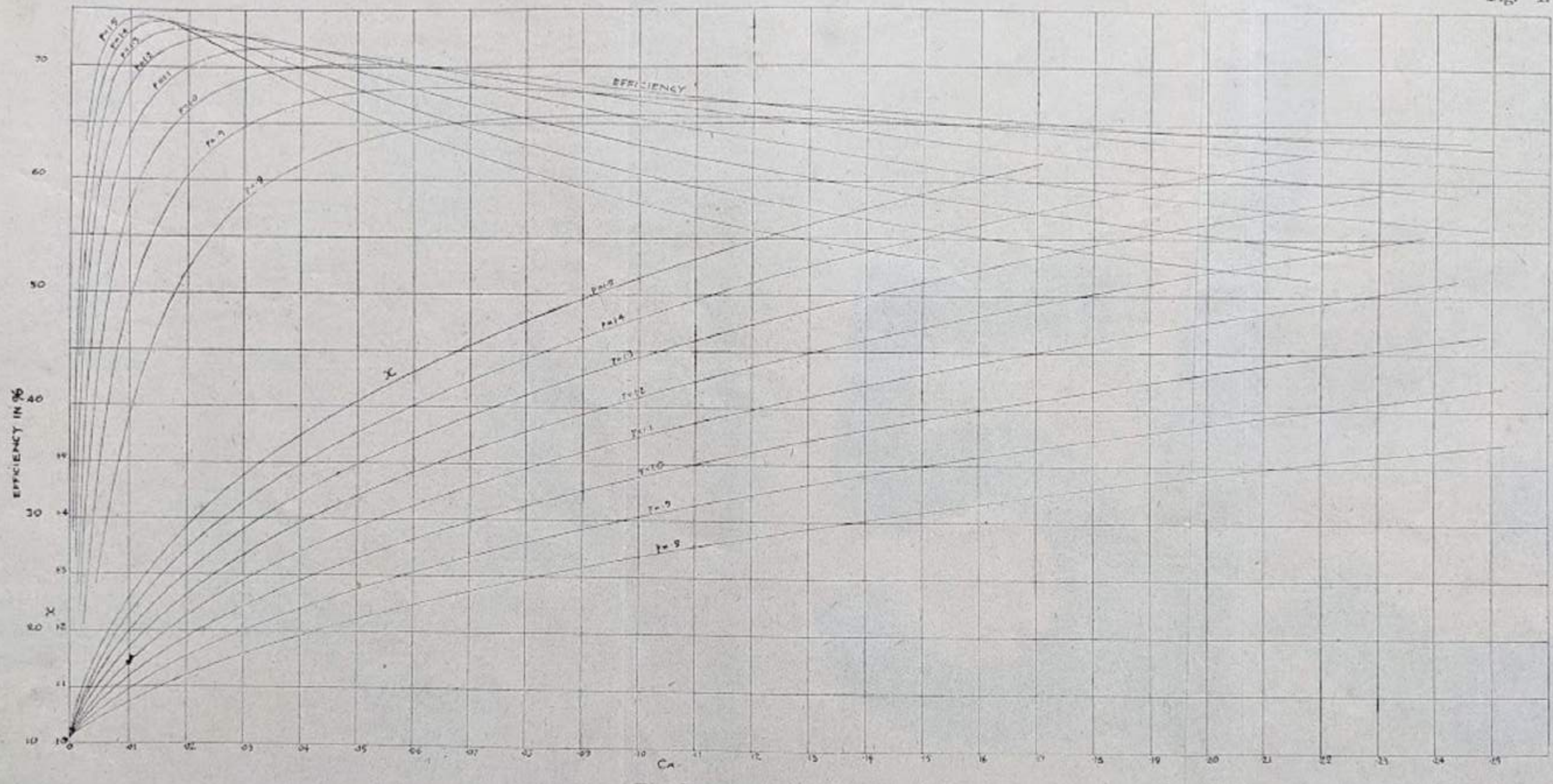
SLIP RATIO.

Upper figures in every rectangular space are $\frac{n'D}{V}$

Lower „ „ „ „ „ „ $\frac{V}{\sqrt{T}}D$

$\frac{\sqrt{T}}{V^2}n'$ / s	.016	.020	.024	.028	.032	.036	.040	.044	.048	.052	.056
.20	1.019 63.66	1.176 58.795	1.3295 55.39								
.21	.971 60.69	1.126 56.295	1.277 53.20								
.22	.926 57.875	1.081 54.045	1.233 51.37								
.23	.885 55.31	1.012 52.10	1.194 49.745	1.338 47.78							
.24		1.007 50.35	1.160 48.33	1.305 46.60	1.447 45.215						
.25		.976 48.80	1.127 46.95	1.272 45.425	1.410 44.06	1.549 43.025	1.686 42.15				
.26		.946 47.30	1.097 45.70	1.240 44.28	1.377 43.03	1.512 42.00	1.640 40.995				
.27		.918 45.90	1.069 44.54	1.210 43.21	1.345 42.03	1.475 40.97	1.598 39.95				
.28		.894 44.70	1.044 43.495	1.183 43.25	1.316 41.12	1.440 39.995	1.561 39.02	1.680 38.18			
.29		.872 43.60	1.019 42.45	1.156 41.28	1.288 40.248	1.408 39.11	1.526 38.15	1.639 37.25			
.30		.850 42.50	.996 41.50	1.133 40.46	1.262 39.435	1.379 38.3	1.492 37.3	1.602 36.41	1.708 35.58	1.808 34.77	1.911 34.13
.31			.973 40.54	1.109 39.605	1.236 38.622	1.350 37.5	1.461 36.525	1.567 35.61	1.669 34.77	1.767 33.98	1.865 33.30
.32			.952 39.665	1.087 38.816	1.213 37.905	1.325 36.30	1.432 35.8	1.535 34.885	1.633 34.02	1.729 33.25	1.824 32.57
.33			.932 38.83	1.066 38.07	1.189 37.155	1.299 36.08	1.404 35.10	1.504 34.18	1.60 33.33	1.694 32.58	1.785 31.88
.34			.912 38.00	1.055 37.32	1.167 36.372	1.275 35.415	1.377 34.42	1.475 33.52	1.569 32.69	1.658 31.89	1.748 31.21
.35			.892 37.165	1.025 36.605	1.144 35.75	1.252 34.775	1.351 33.77	1.447 32.89	1.539 32.06	1.626 31.27	1.713 30.59
.36				1.007 35.96	1.124 35.125	1.23 34.165	1.326 33.15	1.420 32.27	1.510 31.46	1.596 30.69	1.682 30.03
.37				.990 35.355	1.104 34.50	1.208 33.55	1.303 32.57	1.395 31.70	1.484 30.92	1.568 34.15	1.651 29.48
38.				.971 34.68	1.084 33.875	1.187 32.97	1.28 32.00	1.339 31.11	1.458 30.37	1.542 29.65	1.624 29.00
.39				.953 34.035	1.065 33.28	1.166 32.385	1.258 31.45	1.346 30.59	1.433 29.85	1.516 29.15	1.597 28.52
.40				.935 33.39	1.046 32.685	1.145 31.80	1.236 30.895	1.323 30.07	1.408 29.33	1.490 28.65	1.571 28.05
.41							1.216 30.40	1.301 29.57	1.385 28.85	1.466 28.19	1.546 27.61
.42							1.195 29.87	1.279 29.07	1.362 28.37	1.442 27.73	1.521 27.16
.43							1.174 29.35	1.258 28.59	1.34 27.92	1.421 27.33	1.497 26.73
.44							1.154 28.845	1.238 28.14	1.318 27.46	1.398 26.88	1.474 26.32
.45							1.134 28.345	1.217 27.66	1.297 27.02	1.376 26.46	1.451 25.91
.46							1.116 27.90	1.198 27.23	1.276 26.58	1.354 26.04	1.428 25.50
.47							1.097 27.42	1.178 26.77	1.256 26.13	1.333 25.63	1.406 25.11
.48							1.078 26.95	1.159 26.34	1.236 25.75	1.313 25.23	1.385 24.73

Fig. 1.



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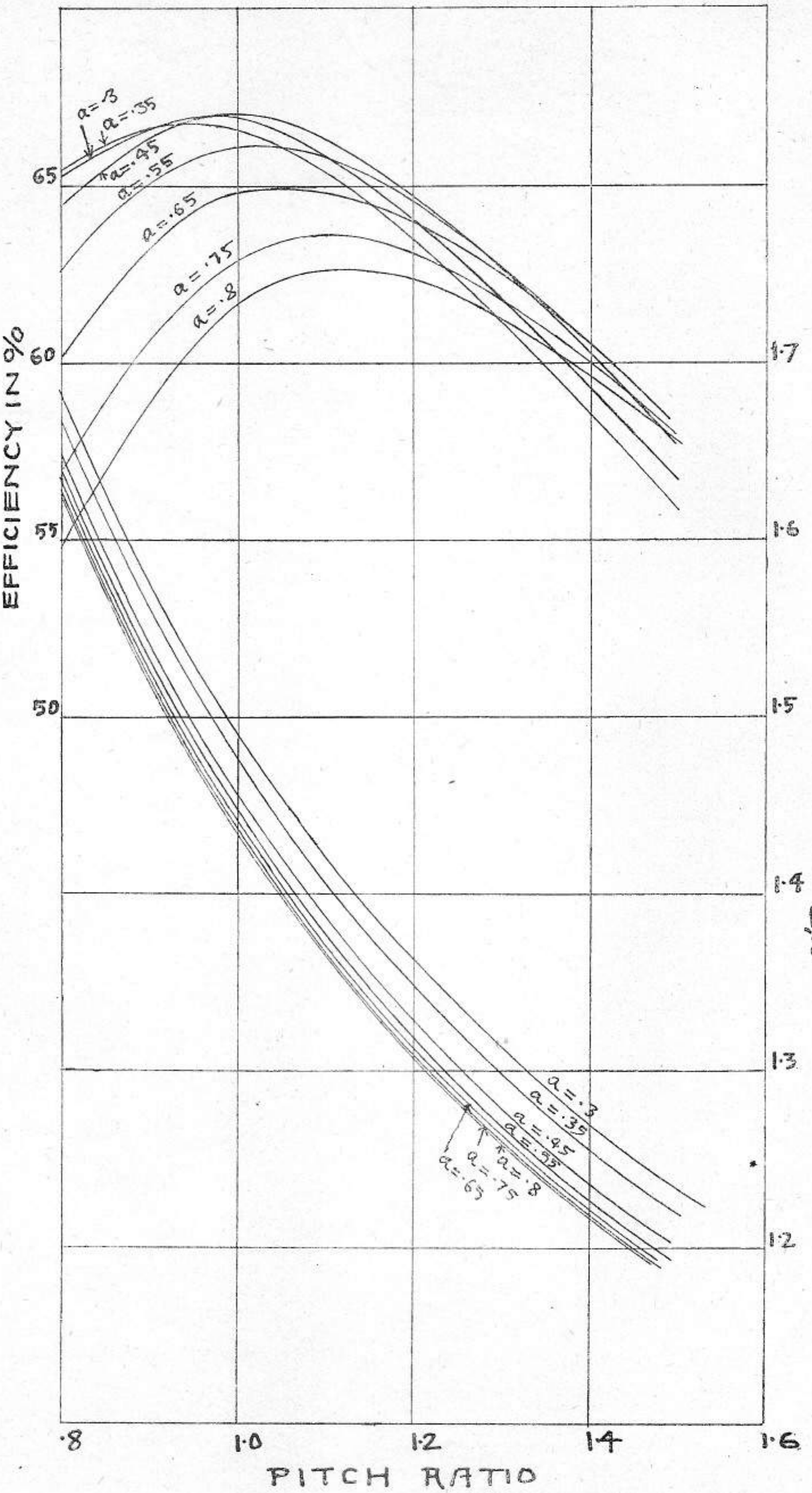
$$\frac{\sqrt{T}}{V^2}n' = .040$$

Fig. 2.



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$\frac{\sqrt{T}}{V^2}n' = .040$ Fig. 3.

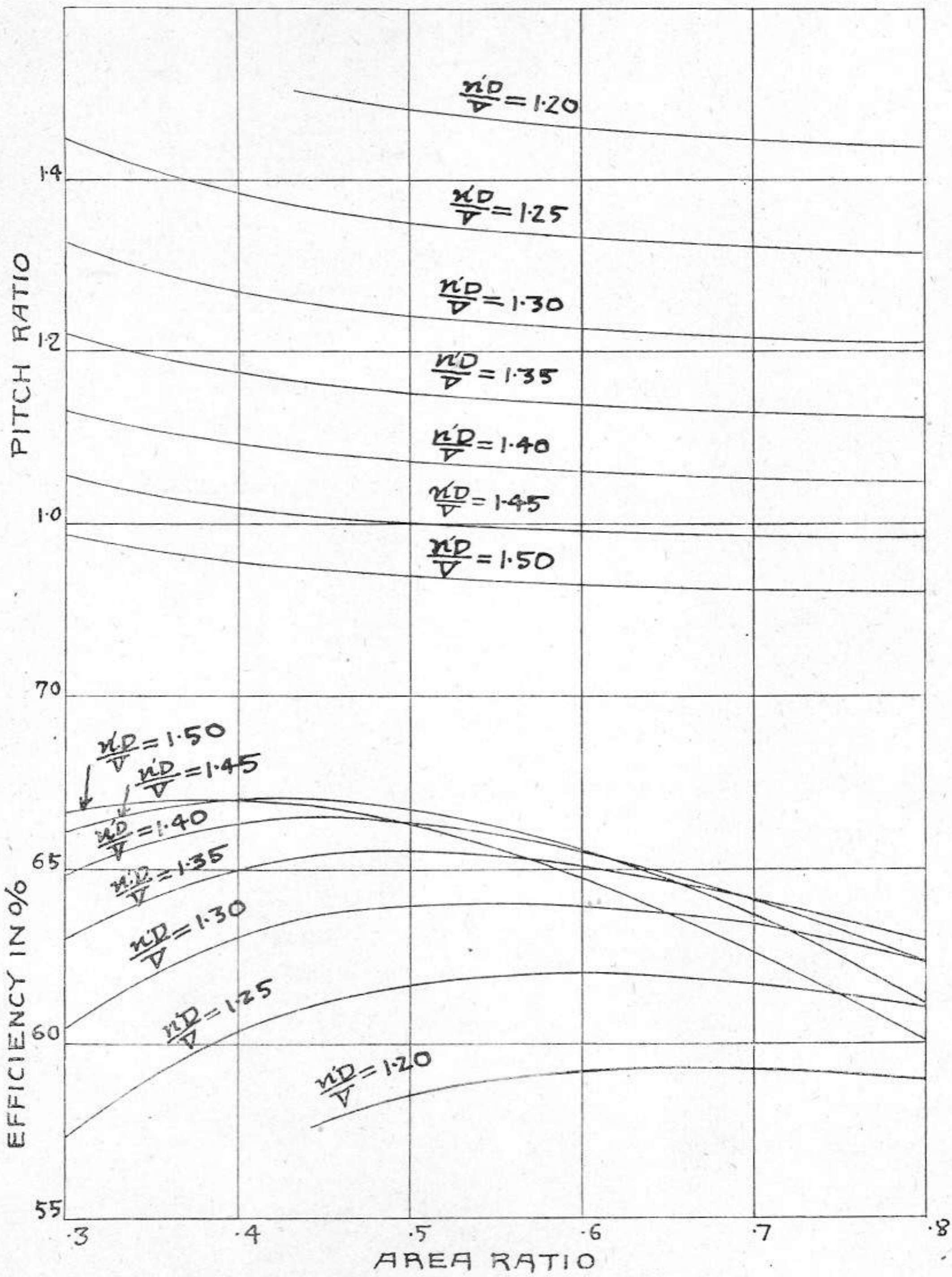

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Fig. 4.

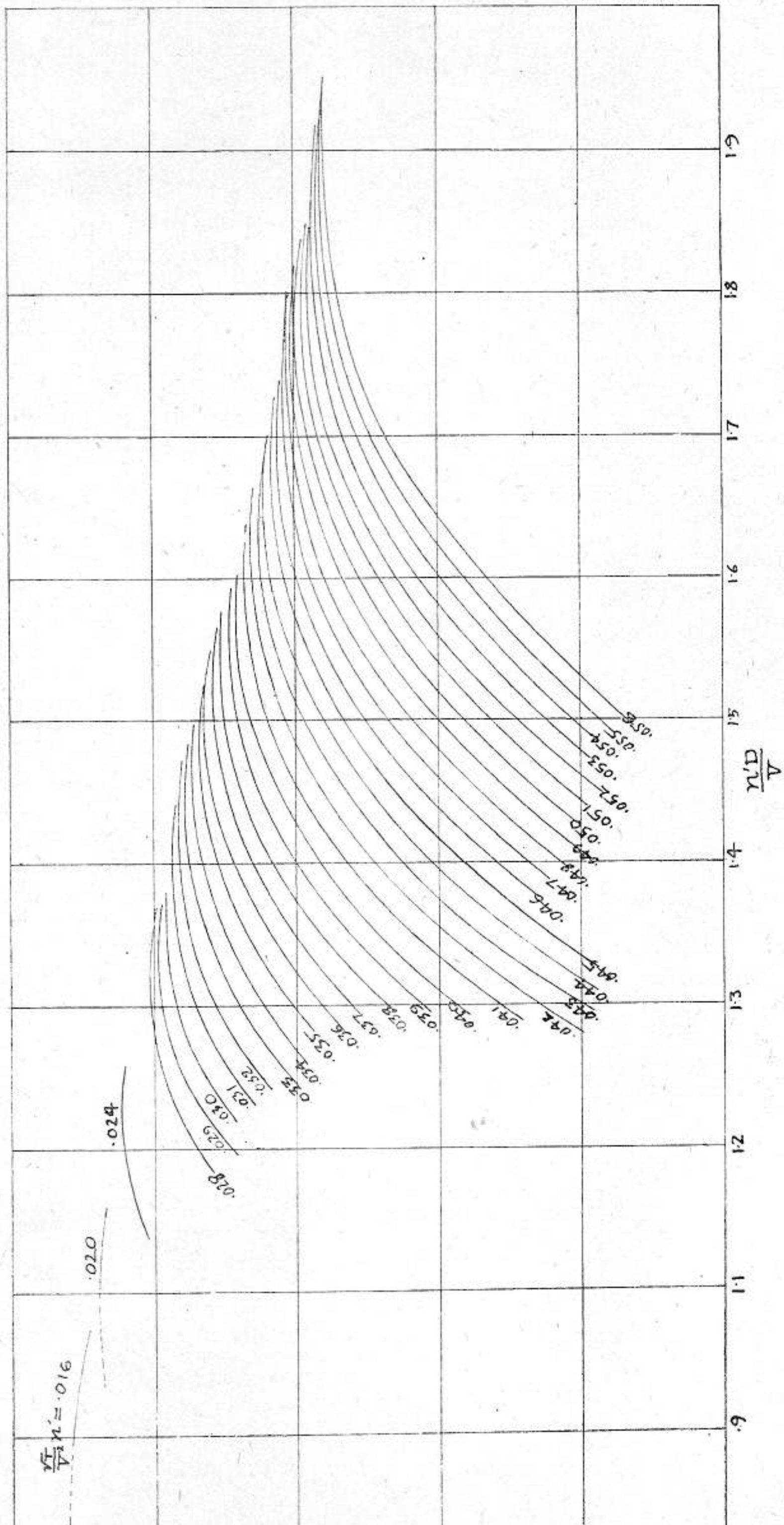

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Fig. 5.

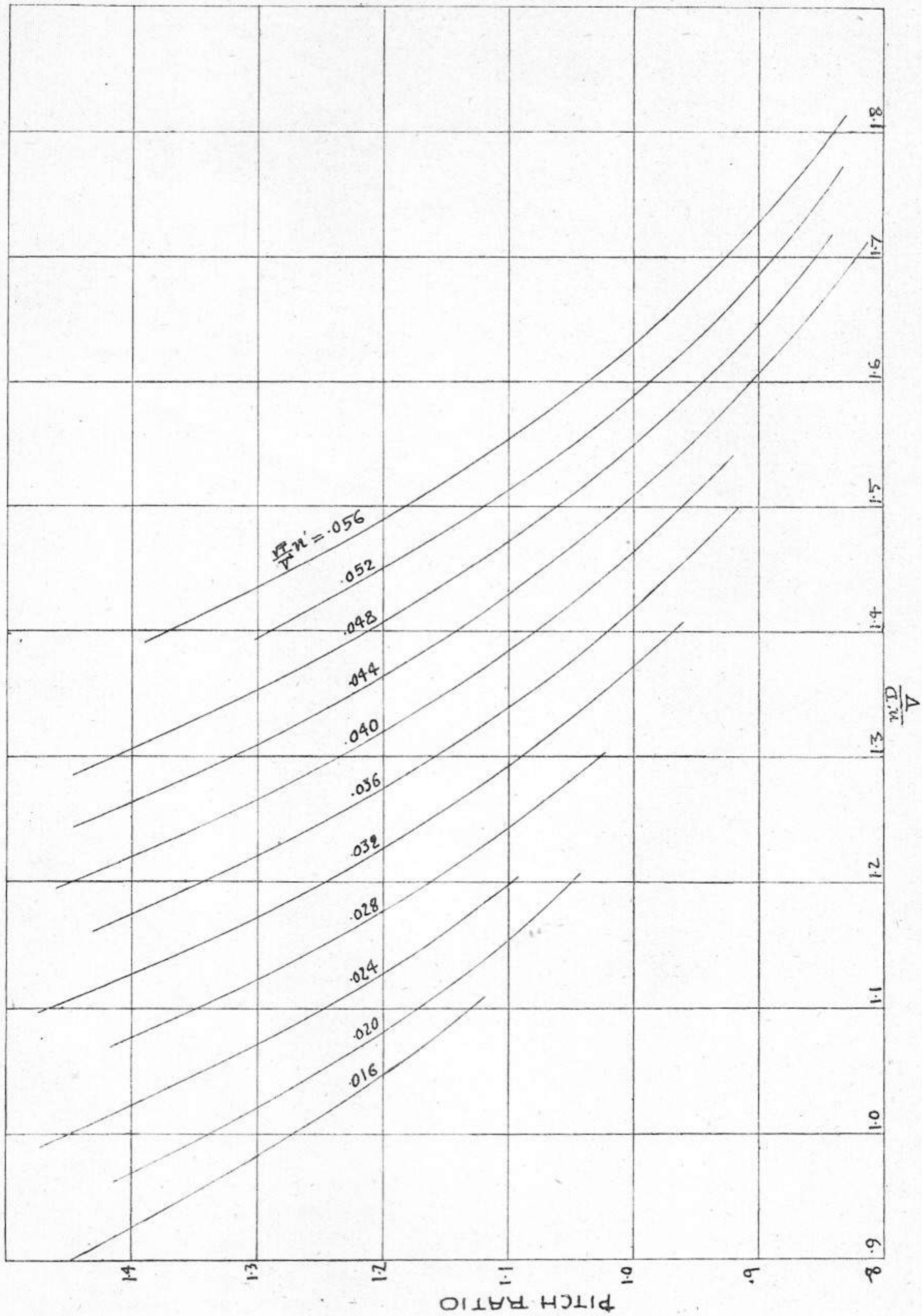

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Fig. 6.

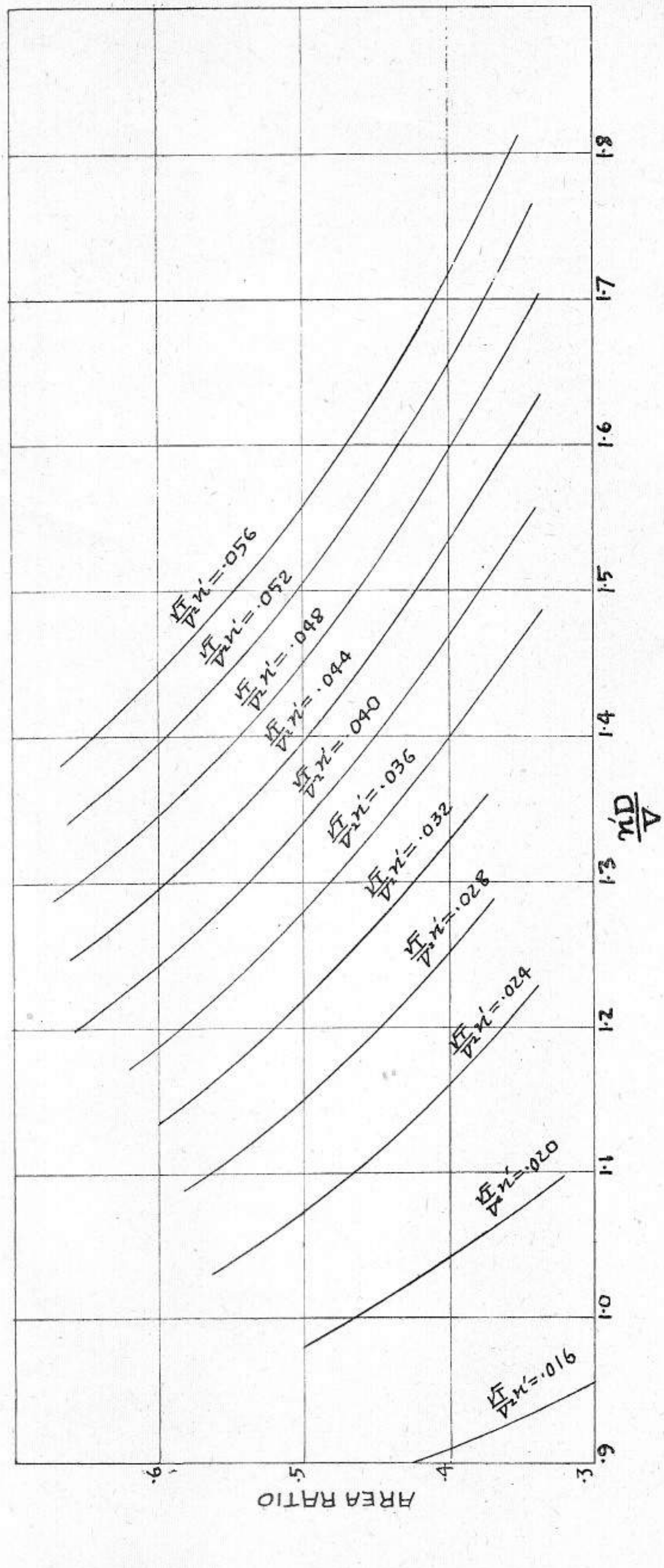

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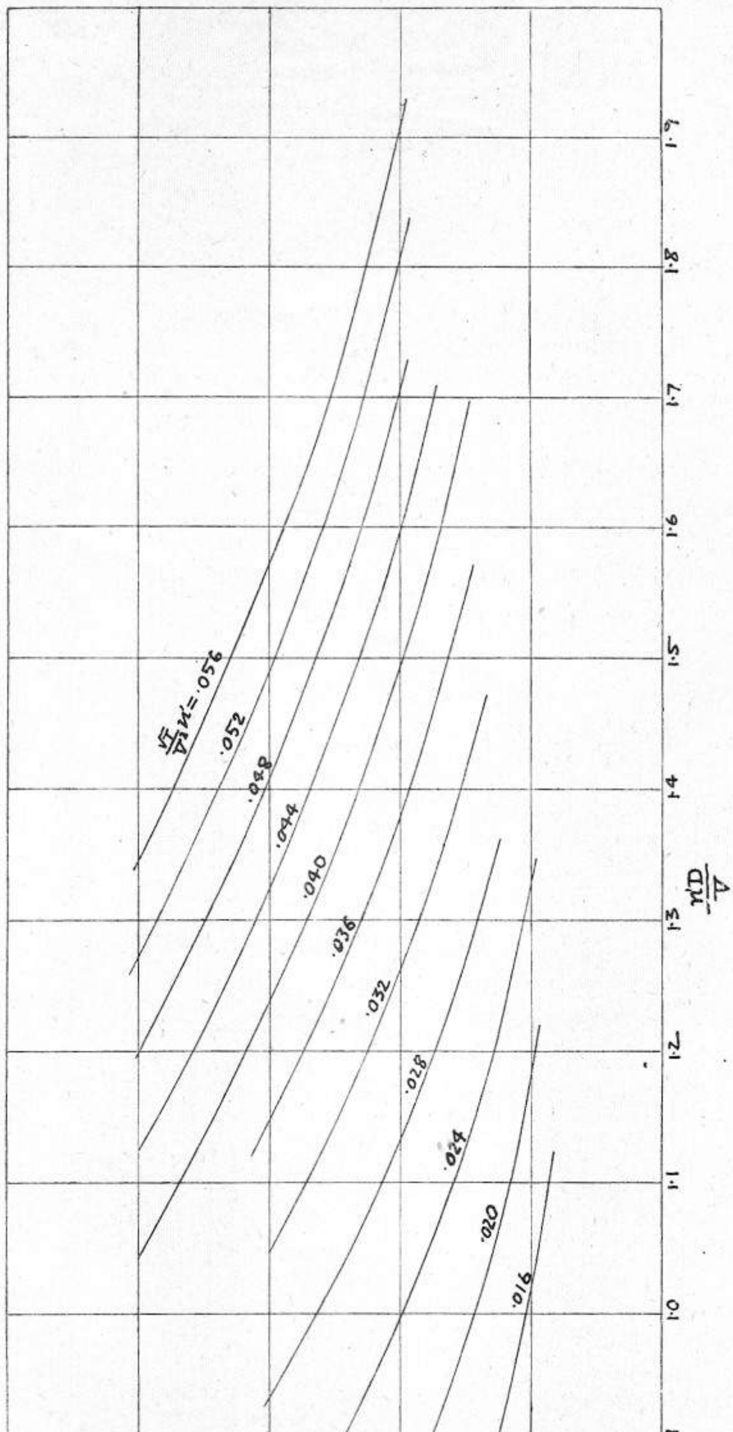
Fig. 7.



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