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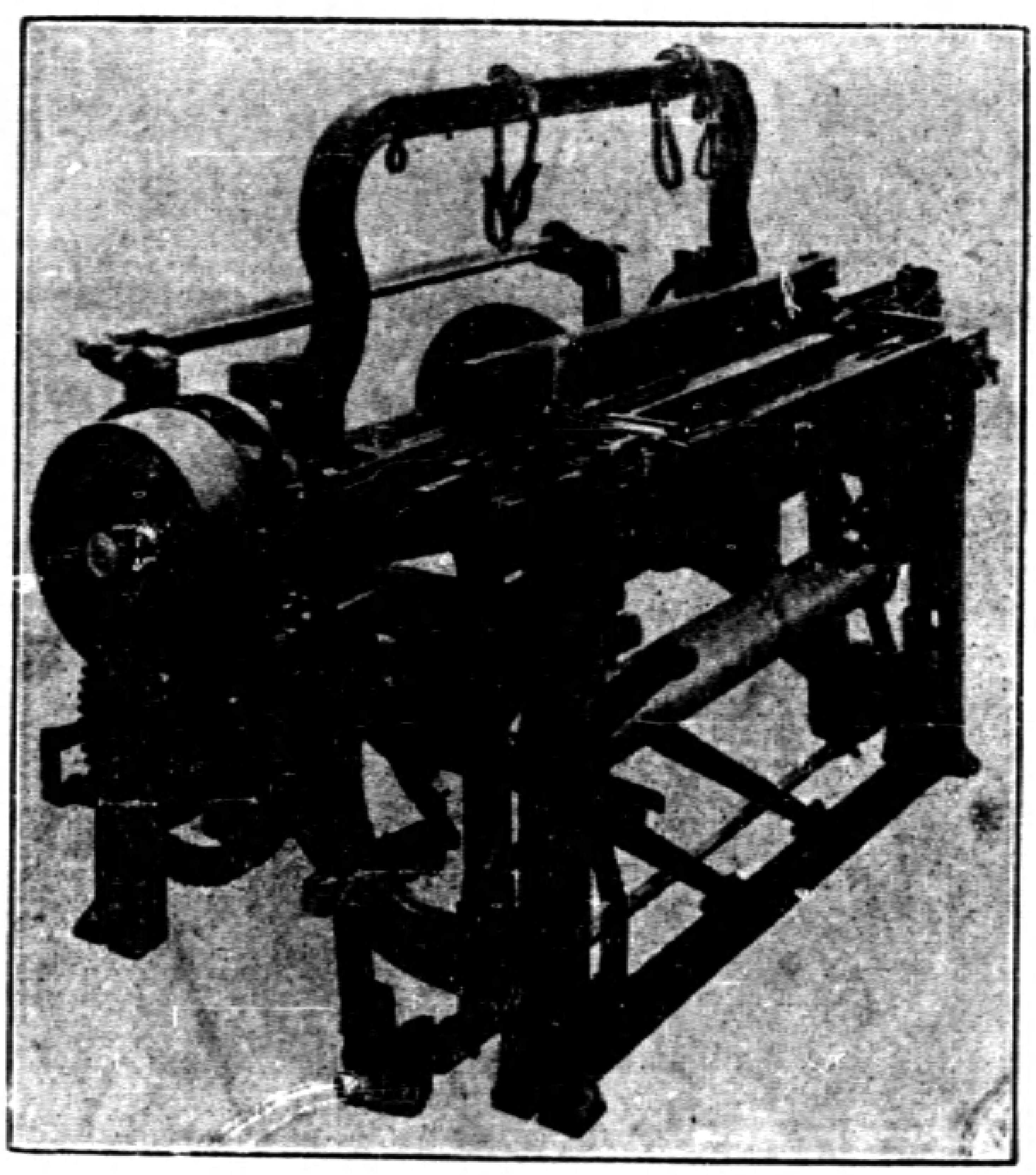

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工程

中國工程學會會刊

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附 刊:

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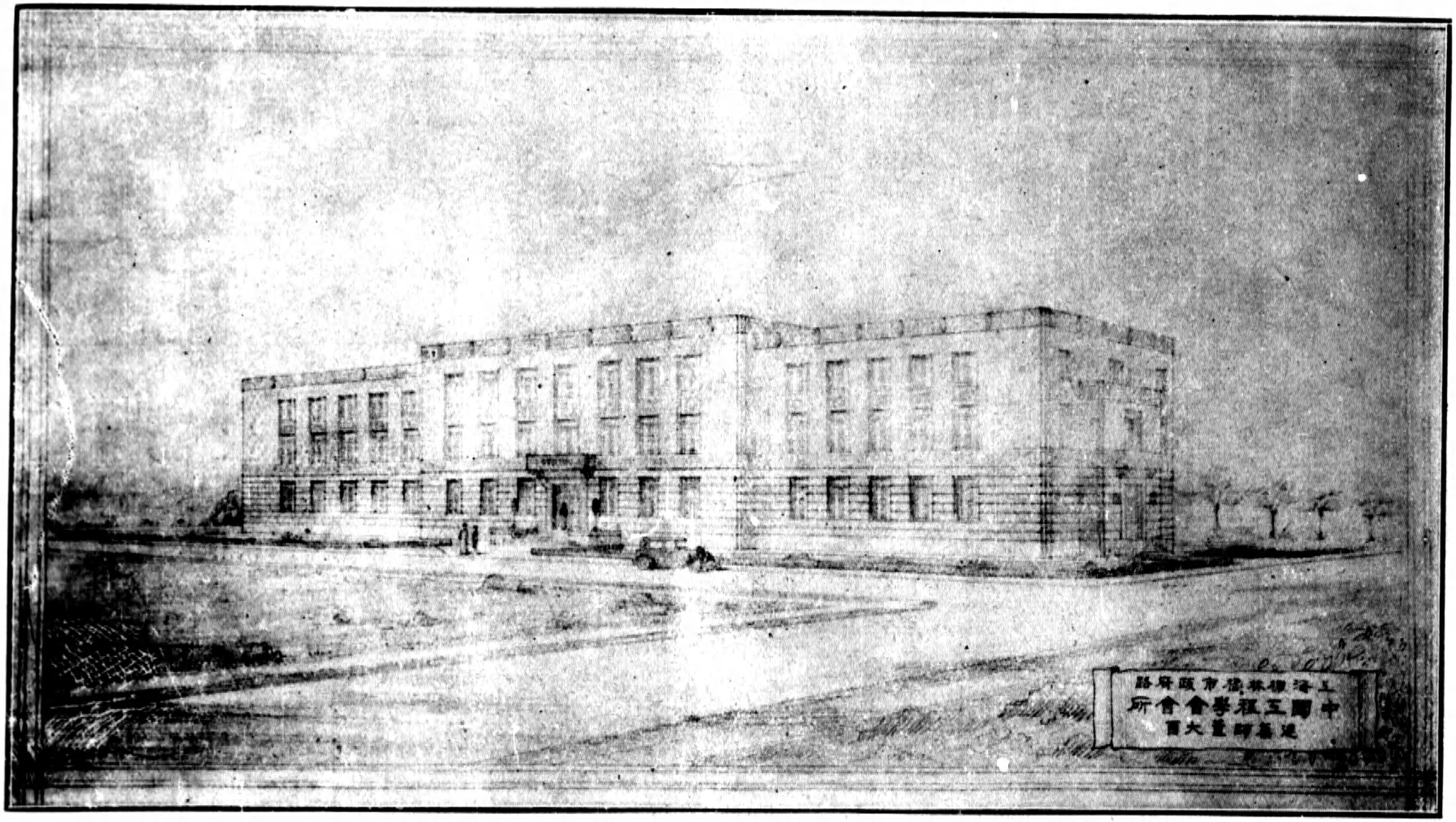

中國工程學會會所圖案

第六屆萬國道路會議中國代表團攝影

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日本鋼鐵業概觀

著者：胡博淵

(一) 緒言

日本新式製鐵事業之肇端,遠在明治七年(同治十三年).時日本政府,思開發岩手縣釜石鐵鑛,曾購置種種新式製鐵設備,不幸此項企圖,其後竟歸失敗.嗣於明治三十年(光緒二十三年),日本政府復於九州創設八幡製鐵所,中經十餘載之奮鬥,然其成績,猶未大著.及至歐洲大戰,鐵價暴騰,該所營業,始克轉入順境,同時民營諸鋼鐵廠,亦如春筍勃發,盛極一時.迨歐戰告終,鐵價復原,民營各廠,除基礎穩固者外,其他雖多告失敗,然日本　鐵事業,已立有穩固之基礎矣.

(二) 國立八幡製鐵所

沿革及產量　八幡製鐵所,在九州福岡縣遠賀郡八幡市.其創立之始,遠在明治三十年.時日本政府,痛感鋼鐵事業,有國營之必要,爰以年產鋼材九萬噸爲標準,創立該所.前後籌備四年,耗金一千五百八十四萬元.迨三十四年(光緒二十七年)二月,始克舉行第一熔鑛爐點火式,同年五月,開始鍊鋼.在最初數年,以事屬創舉,經濟技術,兩感困難.嗣經日俄歐戰兩役,日本之鋼鐵需要頓增,該所事業,日有起色,生產設備,疊經擴充,現在該所,每年所產之鋼材,已達一百萬噸,前後投下之資本,亦逾一億三千萬圓,實爲日本最大之鋼鐵廠.茲將該所最近產額增加狀況列表如下:

第一表

	大正九年(民國九年)	大正十三年	大正十四年	昭和元年(民國十五年)	昭和二年	昭和三年
生鉄	244,000噸	489,000噸	586,000噸	654,000噸	735,000噸	832,000噸
鋼塊	449,000	685,000	863,000	980,000	1,054,000	1,160,000
鋼材	297,000	493,000	653,000	739,000	830,000	937,000

主要生產設備　八幡製鉄所,分八幡本工場,戸畑作業場,及西八幡工場三處.其化鉄設備:在八幡本工場,計有熔鑛爐六座;在戸畑作業場,則有熔鑛爐二座;此外在本工場,尙有新熔鑛爐二座,目下正在建設之中.至其煉鋼設備:在本工場計有平爐工場三所,轉爐工場,坩堝鋼工場,電氣爐工場各一所;在西八幡工場有平爐工場一所.茲將其主要之生產設備,列表於後:

第 二 表

熔鑛爐	八幡本工場	熔鐵爐號數	第一號 第二號	第三號 第四號	第五號 第六號	新一號 新二號
		化鐵能力	250 噸	300 噸	350 噸	500 噸
	戸畑作業場	有一百五十噸及三百噸熔鑛爐各一座				
煉鋼爐	八幡本工場	第一平爐工場	二十五噸鹽基性平爐			十二座
		第二平爐工場	五十噸鹽基性平爐			六 座
			六十噸鹽基性平爐			四 座
		第三平爐工場	六十噸鹽基性平爐			七 座
			二百噸 Jalbot 式平爐			一 座
		轉爐工場	十噸酸性轉爐			二 座
		坩堝鋼工場	坩堝煉鋼爐			七 座
		電氣爐工場	弧光式二噸半電氣爐	各		一 座
			誘導式三噸電氣爐	各		一 座
			傾注式六噸平爐	各		一 座
	西八幡工場	平爐工場	五十噸平爐			二 座

關於煉焦設備:在八幡本工場有煉焦工場五所,洗炭工場三所,計有煉焦爐四百七十座;在戸畑作業場,計有煉焦爐一百七十五座.茲將八幡本工場煉焦爐之詳細狀況列下:

第 三 表

名稱	列表	爐數	每爐裝入量	燒成時間	副產物收集設備	蓄熱室
Koppers 式	1	120	4.6 噸	48 小時	無	無
Solby 式	2	150	5.7	30	有	無
第一黑田式	1	50 50	10.5 10.5	24	有	有
第二黑田式	1	100	11.0	24	有	有

此外八幡本工場,尚有鋼材製造場.石炭副產製造場,窰業工場及研究所等,茲不備述.

鋼鐵原料　原料鑛石,分鐵鑛,錳鑛兩種,鐵鑛之半數,係由我國大冶,象鼻山,桃冲等鑛購入.餘由馬來半島之柔佛及朝鮮之安岳,利原,殷栗載甯等鑛供給.其需要量去年爲一百七十萬噸,本年預計將增至二百萬噸.錳鑛由我國湖南之湘潭,湖北之陽新,江西之樂平,江蘇之海州及廣西之欽武等處錳鑛,供給其十分之四,餘由馬來半島及日本四國各鑛供給.所用之焦炭,均由該所自製,其原料以該所經營之二瀨炭鑛所產者爲主.惟二瀨炭粘結力稍差,須配合粘結力較強之炭,助其粘結,藉獲良質之焦炭.現在所用之配合炭,爲日本之松浦炭,高島炭,及我國之本溪湖炭,開平炭,淄川炭等,其配合率爲二瀨炭七成與配合炭三成之比例.石灰石每年約須三十五萬噸均由門司附近各採石場購入.此外所用各種雜料,則利用本工場所產之鑛滓,輥鋼皮,生鉄屑及熔爐烟塵等.茲將熔爐之原料裝入量,(平均)列表如下:

第　四　表

原　料	大正十二年(民國十二年)度 裝入量(噸)	大正十二年(民國十二年)度 對於生鉄之比率	大正十三年度 裝入量(噸)	大正十三年度 對於生鉄之比率	大正十四年度 裝入量(噸)	大正十四年度 對於生鉄之比率
鉄　鑛	720,602	1.65	633,371	1.610	784,660	1.625
錳　鑛	23,736	0.054	15,390	0.036	16,822	0.035
焦　炭	455,505	1.05	431,447	1.015	490,411	1.016
石灰石	211,364	0.485	183,860	0.432	199,741	0.414
雜　料	20,493	0.047	41,158	0.097	35,001	0.072

作業順序　八幡製鉄所之作業,向係採用銑(生鉄)鋼一貫主義.原料鐵,錳,鑛石,與焦炭及石灰石等共同裝入熔鑛爐,依熱風之作用,使鑛石之鐵分還元,成爲熔銑,其夾雜物則成鑛滓,而於爐內互相分離,每隔一定時間,即被注出,此種作業,不分晝夜行之.

由各爐注出之熔銑,立卽移入混銑爐,使其品質均一,隨時注入平爐之內.平爐多屬鹽基性者,以上述之熔銑及廢鉄爲主原料.如遇熔銑不足時,特裝入冷銑,並加鐵鑛及石灰石等,而依發生爐瓦斯,以熔解精煉之,然後注入鑄型中,作製各種鋼材用之鋼塊.

鋼塊依其在赤熱之狀態,更裝入灼熱爐內.俟經相當時間後取出,更用輾壓機壓之,截成鋼片,亦乘其在赤熱狀態,移入製品工場,製造各種鋼貨.鋼貨種類大小雖極雜多,但其作業之順序,則均相同.鋼貨之主要者,爲重鋼軌,輕鋼軌,工字鋼,溝形鋼,丁字鋼,山形鋼,球山形鋼,圓鋼,角鋼,扁鋼,線鋼,鈸力板,矽素鋼板,其他各種鋼板,車軸及外輪,工具鋼,其他特種鋼等.

製鐵所於製鋼材之外,尙行與鋼有連帶關係之副產,加工作業.如對於鑛滓,則注以水,使成水滓後,以鑛滓甎及高爐水泥,或用蒸汽吹之,使成綿狀,以製防熱,或防音之鑛滓棉.又對於熔爐排出之瓦斯,則加以洗滌,以供瓦斯機關之使用.又對於煉焦爐發生之焦炭瓦斯,則製硫酸錏 Tar, Benzol 等化學工業藥品.

生產能力　茲將八幡製鐵所每年之生產能力,及昭和二年(民國十六年)度之實產額,列表比較於下:

第五表

(1)——生鐵	鎔鑛爐	8座
	生產能力	830,000噸
	昭和二年產額	734,839噸
(2)——鐵合金	電力熔爐	2座
(3)——鋼塊	平爐	36座
	坩堝鍊鋼爐	7座
	電氣爐	2座
	生產能力	970,000噸
	昭和二年產額	1,054,064噸

(4)——鋼　材

品目		昭和二年產額
鋼板	線鋼及製釘材	830,030 噸
棒鋼	鋼片	
角鋼	鍛成品	
鋼軌	電氣爐鋼及坩堝鋼	
鋼軌附件	零件及其他	

(5)——焦　炭

鍊焦爐	645 座
生產能力	1,015,000 噸
昭和二年產額	859,817 噸

(6)——副產品

鑛滓磚	生產能力	26,100 噸
	昭和二年產額	7,419 噸
高爐水泥	生產能力	60,000 噸
	昭和二年產額	25,520 噸
Pitch	生產能力	31,500 噸
	昭和二年產額	32,601 噸
Creosote Oil	生產能力	14,000 噸
	昭和二年產額	15,057 噸
硫酸錏	生產能力	13,000 噸
	昭和二年產額	13,169 噸
Benzol	生產能力	9,000 噸
	昭和二年產額	8,219 噸

(三) 民營鋼鐵廠

如前所述,日本政府曾於明治七年,經營釜石鐵鑛,然歷時未久,即遭失敗.嗣於明治十七年(光緒十年),有田中長兵衛者,獨力接辦此鑛,是爲民營鐵廠之始.迨中日戰役時代,該鑛年產生鐵,已達二萬噸.在八幡製鐵所未成立以前,該鑛實爲日本唯一之製鐵所.嗣後民營鋼鐵廠逐漸發達,及至今日,除國營八幡製鐵所,及專造高級鋼材之吳海軍廠外,其餘民營諸廠,亦有足資記述者.其中尤以北海道之日本製鋼所,川崎之日本鋼管會社,鶴見之淺野製鐵所,神戶市之神戶製鋼所,大坂市之住友製鐵所及大坂製鐵會社,小倉市之淺野製鋼所及朝鮮之兼二浦製鐵所爲最重要.在上述各廠中,其備有

銑鋼一貫作業之設備者,僅爲釜石,鶴見及兼二浦三廠.茲將主要民營鐵廠之產額,列表於下:

第 六 表

廠 名	位 置	種類	昭和二年產額(民國十六年)(噸)	昭和三年產額(噸)
釜石鑛山會社	岩手縣釜石	生鐵	63,000	76,000
		鋼塊	57,000	66,000
		鋼材	50,000	61,000
日本製鋼所	北海道室蘭	生鐵	92,000	109,000
		鋼塊	27,000	32,000
		鋼材	16,000	——
東京鋼材會社	東京府大島	生鐵	——	——
		鋼塊	12,000	13,000
		鋼材	15,000	16,000
日本鋼管會社	東京市外川崎	生鐵	——	——
		鋼塊	161,000	204,000
		鋼材	156,000	205,000
富士製鋼會社	東京市外川崎	生鐵	——	——
		鋼塊	28,000	33,000
		鋼材	25,000	24,000
淺野造船所	橫濱市外鶴見	生鐵	22,000	55,000
		鋼塊	——	54,000
		鋼材	43,000	53,000
大坂製鐵會社	大坂市	生鐵	——	——
		鋼塊	39,000	52,000
		鋼材	39,000	48,000
住友諸工廠	大坂市及尼崎	生鐵	——	——
		鋼塊	51,000	51,000
		鋼材	58,000	43000
神戶製鋼所	神戶市	生鐵	——	——
		鋼塊	61,000	73,000
		鋼材	65,000	65,000

川崎造船所	神戶市	生鐵	——	——
		鋼塊	104,000	134,000
		鋼材	77,000	126,000
川崎車輛會社	神戶市	生鐵	——	——
		鋼塊	12,000	8,000
		鋼材	10,000	——
德山製板會社	山口縣德山	生鐵	——	——
		鋼塊	——	——
		鋼材	21,000	27,000
淺野製鋼所	福岡縣小倉市	生鐵	——	——
		鋼塊	44,000	47,000
		鋼材	39,000	51,000
東海鋼業會社	福岡縣若松市	生鐵	——	——
		鋼塊	——	——
		鋼材	3[illegible],000	49,000
兼二浦製鐵所	朝鮮黃海道	生鐵	129,000	146,000
		鋼塊	——	——
		鋼材	——	——
其　　他		生鐵	11,000	不詳
		鋼塊	37,000	仝上
		鋼材	31,000	仝上
合　　計		生鐵	322,000	387,000
		鋼塊	633,000	767,000
		鋼材	687,000	778,000

次將主要民營各廠之生產設備,列爲第七表如下;

第　七　表

名　稱	熔鑛爐座數	煉鋼平爐座數
釜石鑛山會社	200 噸　2 座　60 噸　1 座 25 噸　1 座	25 噸　3 座

日本製鋼所	120噸 3座	100噸 1座	50噸 1座
			60噸, 10噸, 5噸 各2座
東京鋼材會社	——		8噸 1座 10噸 1座
日本鋼管會社	25噸 2座	20噸 1座	30噸 2座
富士製鋼會社	——		25噸 1座 15噸 3座
淺野造船所	150噸 1座		——
大坂製鐵會社	——		25噸 2座
住友諸工廠	——		40噸, 80噸 各1座
			25噸 3座 15噸 2座
神戶製鋼所	20噸 1座		12噸, 16噸, 30噸 各1座
			25噸 2座
川崎造船所	——		25噸 10座 20噸 3座
淺野製鋼所	20噸 1座		25噸 3座
兼二浦製鐵所	150噸 2座		50噸 3座
後志製鐵所	20噸 1座		——
大島製鋼所	——		25噸 1座 15噸 2座
三菱造船所	——		25噸 1座
茂里製鋼工場	——		15噸 1座
羽室鑄鋼所	——		8噸 2座

又日人在我國遼寗省,尚有與我國合辦之鞍山本溪湖兩鐵廠,茲將其產額及設備列表於下:

第八表

名稱	民國十六年生鐵產額(噸)	民國十七年生鐵產額(噸)	熔鑛爐座數	
鞍山製鐵所	203,000	221,000	250噸 2座	
本溪湖製鐵所	51,000	64,000	130噸 2座	20噸 1座
合計	254,000	285,000	每年產鐵能力	272,000噸

此外別種工廠之兼產鋼材者每年所產亦達三四萬噸.故日本民營各鐵廠每年出產生鐵總量約達六十八萬噸,鋼材約達八十萬噸.

(四) 鋼鐵之供求量

明治五年(同治十一年),日本敷設京濱鐵道,始用洋式鋼鐵,迨中日戰役,其國內所產鋼材,年僅一千噸,同時外鋼之輸入,則年達二十二萬噸,故當時日本所需之鋼材,可謂全數仰給於舶來品.迨日俄戰後之明治四十年(光緒三十三年),需要量已增至五十萬噸.其內八成仰給外鋼,餘爲本國所產.但至昭和三年(民國十七年),則國內需鋼量更增爲二百三十萬噸.外加運至台灣,朝鮮等處者,約十八萬噸,合計鋼材需要總額,爲二百四十八萬噸.其內由外國輸入者,僅佔三分之一,卽年約八十二萬噸,餘均由八幡及民營各鋼鐵廠供給.茲將最近三年日本鋼材之供求狀況,列表於下:

第八表

	昭和元年(民國十五年)		昭和二年		昭和三年	
	數量(噸)	百分率	數量(噸)	百分率	數量(噸)	百分率
八幡製鐵所產量	658,000	30	713,000	32	841,000	34
民營各廠產量	587,000	27	687,000	31	820,000	33
外國鋼材輸入量	925,000	43	814,000	37	821,000	33
合　　計	2,170,000	100	2,214,000	100	2,482,000	100
日本鋼材輸出量	120,000	—	157,000	—	180,000	—
日本鋼材淨需要量	2,050,000	—	2,057,000	—	2,302,000	—

(註) 表內八幡產量,與第一表所揭者,微有不同,蓋因該所之會計年度,與曆年不同而然.

次就輾鋼,鍛鋼,鑄鋼等之普通鋼材,及包括本鋼之高級鋼材,一較其需要量時,則普通鋼材,約佔總需要量百分之九十四,高級鋼材約佔百分之六.

生鐵可依用途而分爲製鋼用及翻砂用之兩種.如聯想鋼鐵兩項之總需要量時,則有區別生鐵用途之必要.茲將日本最近生鐵之需要量,列表如下:

第九表

	昭和二年（民國十六年）		昭和三年	
	數量(噸)	百分率	數量(噸)	百分率
國內產量	911,000	61	1,093,000	61
自朝鮮輸入量	103,000	7	140,000	8
自我國東三省輸入量	190,000	13	182,000	10
自印度輸入量	261,000	18	311,000	17
自英美瑞典輸入量	22,000	1	76,000	4
合　計	1,487,000	100	1,802,000	100
自日本輸出量	4,000	—	5,000	—
日本生鐵淨需要量	1,483,000	100	1,797,000	100

(註) 上表生鐵需要量之內,其供翻砂用者,年約四十萬噸,餘可視其係供煉鋼之用.

如前所述,日本現在之鋼鐵總需要量,計在國內年需鋼材二百三十萬噸,翻砂生鐵四十萬噸,合計共達二百七十萬噸之鉅.次就日本鐵業過去之實績,並參酌其他各種要素,而一測其將來需要之增加狀況,則在昭和七年（民國二十一年）,預計國內所需鋼鐵,將增至二,七五〇,〇〇〇噸,在昭和十年,更將增至三,三〇〇,〇〇〇噸云.

(五) 製鐵原料之供求量

製鐵之根本原料,自屬鐵鑛,石炭等類.然就最後目的之鋼材生產而言,則生鐵,廢鋼等物,亦可視作製鐵之準原料.茲就日本現有之製鋼設備,一考其所需之生鐵及廢鋼之數量時,則其生產能力,每年至多能製鋼材二百萬噸,外加製鋼消耗約百分之十一(根據昭和元二年度八幡轉爐之成績).故日本每年約需製鋼原料二百二十二萬噸,除每年使用合金鐵二萬五千噸,及儘量收買廢鋼,計在國內年能購用廢鋼二十七萬噸,由海外年可輸入二十二萬五千噸（昭和三年曾輸入三十七萬噸當屬例外）外,每年實需生鐵一百七十萬噸.現在日本百噸以上熔爐之化鐵能力(連鞍山,本溪湖兩廠),

每年約達百五十萬噸.今假定其以全能力化鐵,則日本每年尚差生鐵二十萬噸.此外翻砂生鐵,每年約需四十萬噸.故日本所差生鐵之數量如次:

第十表

日本年製鋼材二百萬噸,如能儘量收買廢鋼,則其所需之	
生鐵數量	1,700,000 噸
翻砂用生鐵	400,000 噸
合計	2,100,000 噸
日本現有百噸以上熔爐之製鐵能力	1,500,000 噸
每年生鐵不敷	600,000 噸

上項之不足量,約與三座五百噸熔鑛爐之製鐵能力相當.現八幡製鐵所已在建設五百噸熔鑛爐二座,以應此項需要矣.次就日本年產鋼材二百萬噸,一檢其所需之鐵鑛總量.其關係如下表:

第十一表

日本現有設備之製鐵能力	1,500,000 噸
現在建設中之製鐵能力	550,000 噸
合計	2,050,000 噸
鞍山,本溪湖兩廠可用當地之鐵鑛	500,000 噸
其必需供給鐵鑛之製鐵量	1,550,000 噸
製造上項生鐵所要之鐵鑛(每噸生鐵需鐵鑛一·六噸)	2,500,000 噸
製鋼用鐵鑛之使用量	180,000 噸
故日本國內所要之鐵鑛總量	2,680,000 噸

對於上項需要量,每年由其本國,朝鮮,及我國長江沿岸,以及南洋羣島各鑛所能供給之數量如下:

第十二表

日本釜石及俱知安鐵山	500,000 噸
朝鮮各鐵山	500,000 噸
我國大冶桃冲各鐵鑛	1,000,000 噸
南洋羣島各鐵山	1,000,000 噸
合計	3,000,000 噸

石炭亦爲製鐵重要原料之一.日本石炭,資源雖尙豐富,然以一般石炭,大多缺乏粘結性,故於製造鎔爐所用之硬焦炭時,須配合粘力較强之炭,如我國開平炭等約三成,藉獲良質之煉鐵焦炭.現在日本每年製鐵所需之石炭,約達五百萬噸,其每年所產石炭總額則爲三千五百萬噸,故製鐵所需之石炭,約佔總數百分之十五.錳鑛爲改善鋼鐵品質所不可缺少之物,現在世界年產錳鑛共約二百餘萬噸,其中九成用於鋼鐵事業.惟日本產錳不多,故製鐵所需,殆均仰給於我國湘,甘,贛,粵,及南洋,印度各鑛,其額年達十萬噸.

(六) 日本鋼鐵事業之地位

據昭和三年(民國十七年),之統計,日本鋼材需要量,每年約達二百四十八萬噸,其中本國所產者,佔六成七分,爲百六十六萬噸,其餘三成三分之八十二萬噸則由外國輸入.此外尙有製造鋼材用及翻砂用之生鐵,約三十八萬噸,廢鋼約三十七萬噸,鋼塊及鋼片約十萬噸,共計該年所用之外國鋼鐵,尙達一百六十七萬噸.次就舶來鋼鐵類之價格與普通貿易額一加比較,則自大正九年(民國九年),至昭和二年(民國十六年)之八年間,鋼鐵類之輸入價格,達十四億九百萬元.在此期間之入超額,則達二十九億一千七百萬元,故鋼鐵之輸入價格,約佔入超額之四成七分.又昭和三年入超額爲二億二千四百萬元.同年鋼鐵之輸入價格,達一億四千九百萬元,約佔入超額之六成七分.此外以鐵爲主要材料之機械類,及鐵製品之輸入,每年約達一億圓,合計兩項約達二億五千萬元.故今後日本,如能確舉鋼鐵自給之實,則其國家經濟,及對外貿易狀況,當更行改善矣.

次就世界總產鋼量而言,最近世界之鋼材產量,每年計達八千萬噸,其內美產三千萬噸,德產一千一百萬噸,英,法各產七百萬噸,餘爲其他各國之總產量.故日本所產之一百七十萬噸,較諸列强尙屬渺無足道.今試一按日本鐵業不能十分發達之緣由,殆因一般企業家,鑑於釜石官廠之首遭失敗,及

八幡之連年虧損,毫無底止,以及歐戰時代,投機家臨時濫設,各廠之旋歸幻滅,疊次失敗的事實,故多視鐵業投資爲畏途,此實斯業不能充分發展之最大原因也.況製鐵事業,非有極大之規模,不能合於經濟的採算.今如假定設一年產鋼材三十萬噸,有銑鋼一貫設備之最小限度之鋼鐵廠,則其設備費至少須有四千五百萬元,方合經濟原則,較諸別種企業,投資鉅而獲利不易,此亦斯業不易發達之又原因也.惟近年八幡之製鐵技術,進步極速,其營業成績,亦極順利.如大正六七兩年,該所贏餘,曾各達四五千萬元.即於昭和三年,其贏餘亦達一千五百萬元.其餘民營各廠,亦咸有相當之成績,不但所產鋼鐵之品質,較諸歐,美製品,毫無遜色,即其售價,亦屬不相上下.茲將八幡鋼材,與歐美製品之價,列表比較於下:

第十三表

		八幡圓	英圓	法圓	德圓	美圓
棒鋼	國內	89.00	79.14	59.25	67.21	90.62
	輸出		79.14	55.27	55.72	至 95.07
工字鋼	國內	87.00	77.82	55.72	65.88	90.62
	輸出		70.74	50.84	50.40	至 95.07
厚鋼板	國內	97.00	85.34	65.88	75.61	90.63
	輸出		77.82	61.45	61.89	至 95.07

(註一) 八幡製品售價,係依去年八月該所發表市場交貨之期貨價格,其自工場運至市場所要之費用.每噸約需四圓餘.

(註二) 歐.美製品,係依去年八月二十二日發行 Iron Trade Review 所載市價之換算爲日金者,表中國內欄,示工場交貨之每噸定價,輸出欄示最近港口交貨之每噸定價.

(七) 結論

查日本製鐵業歷來最感困難之問題:(一)爲國內缺乏鐵鑛,此實日本製鐵事業最大之缺憾.惟近年因斯業當局不斷之努力,已能以極廉之代價,輸入鉅量之鐵鑛;(二)爲製鐵技術上之困難,在八幡創業時代,頗受此項問題

之影響,但近年日本製鐵技術極爲發達,所製鋼材之品質,較諸歐,美製品,毫無遜色,故能漸次將外國鑛鐵,自市場驅逐過半;(三)爲生產成本過高,去歲日本之鋼鐵市價,雖與英美市價,大致相仿,惟側聞各鐵廠,均以維持此項市價爲苦,且自本年新正以來,日本實行金解禁,外鐵尤將乘勢湧入,此實日下日本製鐵業者所最感脅威之點也.惟日本一般鑛鐵廠之生產設備,較諸歐,美各廠規模,尚覺過小,似應儘量擴充,以期增加生產能率.此外如促進銑鋼一貫作業之實現,及各廠協力避免重複作業,實行單種多產制度等項,均屬減輕成本之要圖.倘能於最短期間,逐漸實現,則日本今後,不惟易於抵制外鐵,而於鋼鐵業前途,不難更有長足之進步也.

國外工程新聞二則

(一) 世界最大鐵橋　英國著名鋼廠道曼朗公司承造鐵橋一座,其南北兩部,已於本年八月二十日在中央啣接.該橋橫跨澳洲 Sydney 海港,自南至北,共長 3,370 呎,最大跨度 1675 呎,重 5 萬噸,高出海面 440 呎,故雖在潮水極高之時,船舶亦可自橋下通過.橋面寬 160 呎有闊 57 呎之大路一條,鐵路四條,10 呎寬人行道二條.預計全部工程,明年可以完竣,重車卽可通行.其建築費聞爲英金六百萬磅,可算世界最大鐵橋云.

(二) 蘇俄政府計劃塡塞間宮海峽　蘇俄政府因欲銜接北樺太與西伯利亞大陸陸路,擬將間宮海峽塡塞.經愼密調查,確悉如能將該海峽最狹處拉查列賓附近之海面 2 哩餘塡塞,卽可達到計劃之目的.因之北方之寒流,不致通過該處,海參威卽可成爲不凍港云.

化　學　工　程

著者：顧毓珍

緒　言

化學工程之名,始聞于一八八八年,(1)而其能在工程界獨樹一幟者,不過近二十年事耳.蓋化學工業之猛進,始自歐戰.(2)歐戰前之化學工業,乃在技藝時代,無化學工程之可言;歐戰後之化學工業,已入科學時代,實賴於化學工程.故化學工程,實爲科學時代之化學工業之產生品也.

返觀技藝時代之化學工業,多操於化學家或機械工程師之手.化學家缺乏工程智識,機械工程師缺乏化學智識;然以其堅強毅力,不折不回,經若干之演試修改,(3)而得良好結果.至其所得結果,往往守爲秘密,不輕告人;是以染色業守其染色之祕密技藝,製革業守其製革之祕密技藝.習其業者,由學徒而至技師,由技師而至廠長,均知其然而不知其所以然;所可恃者,其熟能生巧之經驗耳.如是而望化學工業進步之速,亦難矣哉.迨歐戰發生,因原料之恐慌,戰器之製造,而化學工業驟然猛進.(2)感糧食之缺乏,德國有食料代替品之製造,以染色之缺乏,美國有顏料製造業之勃興,餘若橡皮,製紙,酸鹼等業,無不因時代之需要而發達.當需要孔急之時,世人方明技藝時代之化學工業之不可恃,不經濟,不能供其所求;必欲用科學方法研究化學工業,於是化學工程尙焉.蓋昔日所謂之祕密技藝,用化學工程可以解釋其原理;昔日所謂染色之祕密技藝與夫製革之祕密技藝,用化學工程可以歸納其方法而溝通之.去昔日固有之秘密技藝,易以合於科學方法之化學工程,

(1) E. F. Hodgins: Methods of Chemical Engineering Education M.I.T. Tesis

(2) 趙承嘏　歐戰時代之化學工業　科學　八卷七期

(3) Try out Method:　對於質量無從預定,須視試驗如何而定.

宜其能節省消耗,效率增加,而有價廉物美之出品,宜其能將無數實驗室方法(Laboratory Methods),變爲工廠製造法[4] (Commercial Processes).故化學工程學術之倡明,實使化學工業由技藝時代而趨於科學時代.

方今化學工程於歐美工業界中,所占地位,不在任何工程之下,其應用之廣,且在其他工程之上.[5] 諺云:『開門七件事,柴,米,油,鹽,醬,醋,糖』是皆重要之化學工業,何一不需化學工程.再觀一國之基本工業,[6] 如鋼鐵,[7] 精鹽,酸鹹,紙漿,酒精等業,何一不需化學工程.中國欲振工業,不能無化學工程,至少化學工程之於中國,與土木,電機,機械等工程有同等之需要.然而國人習化學工程者有幾?明化學工程果爲何物而知其內容者有幾?國內大學中有化學工程科者又有幾?爲發展實業計,爲富庶民生計,爲建設新中國計,化學工程之在中國,應急待注意而提倡者也.此即作者介紹化學工程之本意,望國人三注意焉.茲分爲(一)化學工程之意義,(二)化學工程之內容,(三)化學工程與工業,(四)化學工程教育四項,申述之.

(一) 化學工程之意義

世之誤解化學工程者曰:『化學工程乃半爲純粹化學,半爲機械工程』;或曰:『化學工程卽化學』.[8] 此類解釋,非特失化學工程之眞相,抑且給聽者

(4) 如 Haber Process, Hydrogenation of Coal 等,均由實驗室方法變成大規模之工廠製造法.

(5) Chemical Engineering Achievements Reported in May Fields—Editorial Chem. & Met. Vol. 36 No. 7

(6) 孔祥熙著『基本工業計劃書』工程四卷四期

(7) 徐式莊著『鋼鐵與化學工程之關係』. 科學 七卷八號論鋼鐵業中冶礦與化學工程有同等重要,蓋焦煤與煤氣製造,均爲化學工程也.

(8) 作者恆見人指習化學工程者曰『彼習化學』,是無異指習土木或電機工程者曰:『彼習物理』.於此可見國人常以化學與化學工程混作一起而不能分別.

以謬誤之映象.美國之有化學工程,不過三十餘年;卽數年前對於化學工程根本觀念,亦頗有誤解與批評.(9) 評者謂『化學工程師係不澈底之化學家與工程師』,並謂『既有純粹化學 (Chemical Science) 及機械工程兩科,學者應任擇一科習之,不應再有化學工程科之設立』.

物質文明愈進步.專門職業愈多,而其分類愈細;專則精,精則效率增加.考工程業之演進,最初當僅有土木工程,由土木而分機械與電機工程,由機械而分紡織,汽車,航空等工程,由電機而分電力,電報,電話等工程.工程之基礎,莫不曰數學,物理,與化學;(10) 最能以物理致用者,當爲土木,電機,機械諸工程.而最能以化學致用者,惟獨化學工程.工業中應用化學之處日多,故歐,美於四十年前,(1) 有化學工程之添設,美國於三十餘年前,(9) 亦有化學工程之添設,此乃社會之需要使然.至今化學工程能在工程界中獨樹一幟,大放光明,蓋亦專而精之結果;是以化學工程之應否添設,無庸置辯矣.

工程乃科學與社會之橋樑(Engineering is the bridge between society and science.) 造橋樑者,工程師也.於物理與社會間,有土木,電機,機械諸工程作橋樑;推而至於化學與社會,其爲橋樑者,非化學工程乎?於此可見化學工程應用之多,範圍之廣,而欲與以一的確之定義頗難.略言之,其定義可謂化學工程乃一種工程,在設計,構造,及管理,工廠與設備,俾化學方法得致用於實業(Chemical Engineering is one which deals with the design, construction, and maintenance of plants and equipment set up for the commercial utilization of chemical processes.) 英國威廉博士(11) (Dr. E. C. Williams) 關於化學工程師之定義曰:(12) 化學工

(9) J. H. James Chemical Engineering Education Journal of Chemical Education Vol. I. No. 7

(10) 欲明工程與數學,物理,化學間之關係,可參閱陳廣沅著工程師一篇,載科學　十卷五期及十一期

(11) 前英國倫敦大學化學工程教授 Former Ramsay Professor of Chemical Engineering University of London, England.

(12) W. E. Gibbs: Chemical Engineering Education and Research in Great Britain. (Journal Soc. Chem. Ind. 1928)

程師之責任在能規劃大規模之化學製造方法,並能設計與處理該項工廠,使所有之化學反應與物理變化見於實用(A chemical engineer is a scientific man whose duty is to plan the large-scale commercial operation of chemical processes and to design and operate the plant required for the carrying out of the chemical reactions and physical changes involved.)

從上列化學工程與化學工程師之定義,可知化學工程與化學及機械工程確有密切關係,而決不能以化學或機械工程替代之.故化工事業,決不可以化學家或機械工程師任其勞.凡化學工程師,必須有鞏固之化學基礎——尤其在物理化學方面——,工程訓練及經濟常識.謂化學工程乃化學與機械工程之結晶品或可,若謂乃化學與機械工程之合併物卽非.(A chemical engineer is more than a combination of chemist with mechanical engineer.)

在試驗室中研究一問題,化學家與化學工程師之觀點不同.化學家研究物性物量,分析之,綜合之,其步驟之簡繁不論,其所用物品之價格更勿論.化學工程師則求最簡易之化學方法,然後研究如何從玻璃管煤氣燈變爲大鍋與煉爐,[13] 旣欲顧原料之價格,又欲知出品之銷路,再欲解決如何運送,如何裝置.所理之質量驟增,處理困難亦驟增.[14] 科學家求眞,工程師求致用;如何致用,經濟,工人,地點等,均成爲重要問題矣.至若身臨化學工廠,機械工程師與化學工程師之觀點又不同.各項化學工業中,物質不同,物性亦異,故於設備機具,非深有化學工程智識者,難於勝任.此種學識,遠在機械工程範圍以外,故若以機械工程師充之,其設備往往非不合用,卽不經用,常爲笑柄.如『腐蝕』(Corrosion)爲化工機械中之大問題,化學工程師研究各物之腐蝕情形,故於設計工廠機具,亦無不顧及.善哉!英國 Hugh Griffiths 之言曰:[15]

(13) 玻璃管等在工廠中之相當物,下書論列甚詳. J. Grossmann: The Elements of Chemical Engineering

(14) 趙承嘏著『化學工程之意義』 科學 八卷四號

(15) Hugh Griffiths: The Elements of Chemical Engineering Design. London: Benn Brothers, Ltd. 1922

『化學工程師在化學家中爲工程師,而在工程師中則爲化學家』『旣非尋常工程師又非純粹化學家可以瞭解化學工程,若謂化學家與工程師各有其言論觀點,則化學工程師又另有其態度風采.』(" ——that the Chemical engineer when in the company of chemists is an engineer, and when in the company of engineers is a chemist. ——it simply serves to show that neither of engineers on the one hand nor the chemist on the other understand the scope of chemical engineering, and whilst it is often said that the chemist and the engineer speak in different languages, it might also be stated that the chemical engineer has still another mode of expression.")

化學工程之範圍極廣,吾人平日所見其應用,僅在化學工業方面,孰知化學工程,實較廣於工業化學(Industrial Cemistry)之範圍.(16) 羅斯福總統曾對美國富源保管委員會言:(17) "Our object is to conserve the foundations of our prosperity; to use our resources, but to use them as to conserve them; not to limit the wise and proper development and application of these resources, but to prevent destruction and reduce waste." C. F. McKenna (18) 聞之則曰:『是乃化學工程師之工作也.(17) 蓋化學工程對於天然原料之處理,如何得最經濟之應用.如何利用其副產物,以及如何減少耗費,最爲注意.例如以燒柴之法燒煤爲不經濟,則用崩解蒸溜法(Distructive Distillation)取其煤氣,利用煤中之揮發液體,並利用蒸溜後所餘之焦煤;如是同爲一噸煤,用化學工程方法處理(19)後,其代價驟增.

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(16) Electrochemical and Met. Industry Vol. 6—Editorial
"The chemical engineer should not be confounded with the industrial chemist. The latter's work is restricted to the chemical industry, and the former's field of activity is wider."

(17) American Institute of Chemical Engineers Transactions Vol. 1 (1908)

(18) C. F. McKenna 爲美國化學工程學會第一任會長

(19) 欲更明燃料之處理法者,可參閱:丁嗣賢著『近年歐美各國對於燃料之研究』科學　十卷十一期

化學工程.且爲他項工業製造原料.例如汽車工業之於常人,似爲純係機械工程之範圍,孰知橡皮業與石油業,實供給汽車工業以最重要之原料.若無化學工程師之努力,設法製造價廉質堅之橡皮輪,一加侖行六十里之汽油,汽車業之不振可必也.

(二) 化學工程之內容

化學工程學說之應用於工業,遠在化學工業產生之前,蓋知其然而不知其所以然也.例如染色與製革,其技藝之倡明,遠在其理論之發現之前.其機械設備多恃不折不撓之試驗精神所得,而所得方法,多視爲秘密.故欲致力於化學工業者,必須專習一業,得其秘訣,或製紙或精鹽或炸藥;蓋一業有一業之專枝,無普通理論以領導數業也.

以科學方法治化學工業,則知其方法之應用於造紙者,可應用於造精鹽,亦可應用於造炸藥.故雖以化學工業之不勝枚舉,與其製造法之繁多,而可歸納成少數簡單方法,名曰『單箇處理法』[20](Unit Operation).在每項『單箇處理法』中,自有原理可尋,而適用於各項化學工業.例如石油業中所用之蒸溜法與煤氣業中所用之蒸溜法,其原理一也;製紙業中所用之蒸發法,與製糖業中所用之蒸發法,其原理亦一也.於是在數百化學工業中,[21]可用數十『單箇處理法』管理之,是乃由至繁而臻至簡之境,此化學工程之功也,此化學工程之所以能使工業進步神速也.觀下列兩表,可明『化學工程之內容,乃爲數十『單箇處理法』之工程,而其尤要者不過十一法耳.

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(20) 美國 A. D. Little, W. H. Walker, W. K. Lewis, R. T. Hastam 均倡用『單箇處理法』研究化學工程

(21) 一項化學工業中,有用六七『單箇處理法』者,有用八九『單箇處理法』者,詳本篇第二圖.

第　一　表 (22)

化學工程中之單箇處理法
(Unit Operations in Chemical Engineering)

(一) 能力之輸送

1. 熱之輸送—— 應用機具 (23) 如蓄熱器,換熱器,預熱器,加冷器等.

(二) 物料之輸送

1. 氣體之輸送—— 應用機具如管,唧筩,運風機等.
2. 液體之輸送—— 應用機具如管,唧筩,射揚器等.
3. 固體之輸送—— 應用機具如搬運器,升降機等.

(三) 物料之初步處理

1. 壓碎 (Crushing)
2. 研磨 (Grinding)
3. 混和 (Mixing)
4. 溶解 (Dissolving)
5. 沉澱 (Precipitating)

(四) 物料之離分

1. 固體與固體
   (1) 檢分 (Mechanical Separation)
   (2) 水分 (Hydraulic Separation)
   (3) 風分 (Air Separation)
   (4) 浮分 (Flotation)
   (5) 浸分 (Leaching)
2. 固體與液體
   (1) 積澱與傾注 (Sedimentation and Decantation)
   (2) 清濾 (Filtration)
   (3) 結晶 (Crystallization)
   (4) 風乾 (Air Drying)
   (5) 液取 (Extraction)
   (6) 凝收 (Adsorption)
3. 液體與液體
   (1) 蒸溜 (Distillation)
   (2) 蒸發 (Evaporation)
   (3) 轉分 (Centrifugal Separation)

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(22) 原表見 Report of Committee on Chemical Engineering Education of American Institute of Chemical Engineers. 1922 本表由作者略加增減,表中所舉之專門名詞,係採用中國工程學會新印之工程名詞,不詳者則由作者自譯

(23) 應用機具,可參閱　哈忒著　韓組康譯『工業化學機械』

4. 氣體與氣體

(1) 吸收 (Absorption) (2) 凝收 (Adsorption)

(3) 液化後之分解蒸溜 (Fractional Distillation after liquefaction)

5. 固體與氣體

(1) 洗滌 (Washing) (2) 靜積 (Settling)

(3) 清濾 (Filtration)

6. 氣體與液體

(1) 吸收 (Absorption) (2) 液取 (Extraction)

(3) 減濕 (Dehumidification)

(五) 反應作用與反應方法 (物料之化學處理)

1. 燃燒 (Combustion) 2. 烤燒 (Roasting)

3. 崩解蒸溜 (Destructive Distillation) 4. 電解 (Electrolysis)

5. 接觸作用 (Catalysis) 6. 其他如醱酵,鹹化,硝化等.

(六) 化學工廠之設計及建造

1. 物料分配 (Materials) 2. 機具佈置 (Layout)

3. 經濟較量 (Economic Balance)

上表所列化學工程之範圍,不免仍感繁多,今再擇其尤爲重要之『單簡處理法』列如第二表.

第 二 表 (23)

化學工程中之重要『單簡處理法』

(1) 流體之流動 (2) 熱之流動

(3) 清濾 (4) 蒸發

(5) 加濕與減濕 (6) 乾燥

(7) 蒸溜 (8) 吸收

(9) 液取 (10) 壓碎與研磨

(11) 檢分

第二表中十一項之『單簡處理法』,當以『流體之流動』及『熱之流動』兩

(24) 每項『單簡處理法』之定義及範圍詳於 Walker, Lewis, MaAdams: Principles of Chemical Engineering McGraw-Hill Book Co., 1927

項最爲重要,其餘九項爲次要.蓋無論何項化學工業,其反應率,其出產之數額,其製法之效率,均繫於原料之分配移送與能力之消減;前者恒爲流體之流動,後者恒爲熱之流動.是以其餘九項之『單簡處理法』亦無不根據於此,試舉『風乾法』(Air Drying)以明之.

風乾法(空氣乾燥法):——冷空氣必先用預熱氣燒熱,將已熱之空氣吹入乾燥機(Drier),而同時必將欲乾之物料送入該機.物料(如濕紙或潮磚)中之水分遇熱空氣而蒸發,而由離乾燥機之空氣帶出.如何運送物料,如何運送空氣,則需應用流體之流動之原理;如何預熱空氣,如何保持乾燥機中之溫度,則需應用熱之流動之原理.此外應用之法當爲加濕法與乾燥法;惟於此可見無論何項製造法,不能脫離『流體之流動』與『熱之流動』兩項『單簡處理法』矣.

化學工程無時不需機具設計與經濟較量(25)(Apparatus Design & Economic Balance).卽由上舉之例而言,預熱器之大小,乾燥機之構造,均須視空氣之濕度(Humidity)與溫度,物料之質地多寡而定.運送空氣之速率愈大,所需之煽風機亦愈大,則所需之動力(Power)亦多;多用動力,用較大之煽風機則多費金錢.而同時空氣之速率增加,預熱器傳熱愈快,物料中水分之蒸發亦愈快.是以欲設計而施用經濟之空氣乾燥機具,則至少須顧及上列諸點,是則非諳習化學工程不能爲也.

(三) 化學工程與工業

現代工業發達,化學工程之功爲大.本篇緒言中已詳述化學工程,實爲科學時代之化學工程之產生品,而使化學工業由技藝時代趨於科學時代.H. C. Parmelee(26)稱化學工程關工程界之新紀元而爲工業發達之產物.工業

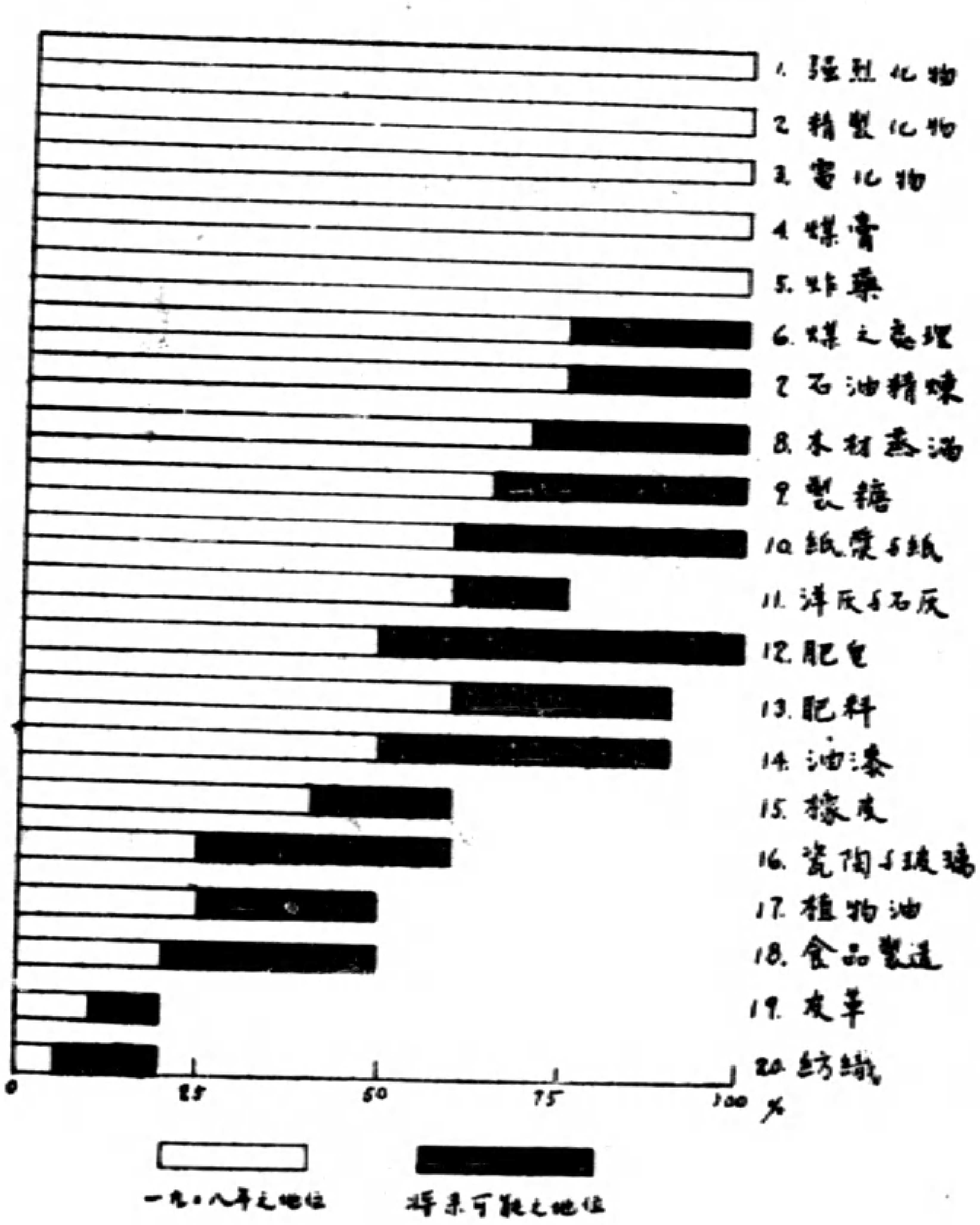
(25) 欲詳知箇中情形,可參閱 C. Tyler: Chemical Engineering Economics. McGraw-Hill Book Co. 1926

(26) H. C. Parmelee: Chemical Engineers for Industry Chem. and Met. Vol. 35 No. 1

界之需用化學工程,美國在二十年前[26]已如此,至近年尤甚.[5] 英國Sir Alfred Mond[27]曾對化學工業社演說謂『以前之化學家,過受工業界之誇獎.蓋化學家在實驗室中,似覺極容易極簡單之方法;孰意施置工廠,化學工程師不知須耗費多少心力,戰勝多少艱難.眞眞大工程師能使不能生利之化學方法變爲生利』.於此可見化學工程在工業界之地位,日加重要.下列第一圖,[28]即表明化學工程於美國二十項工業中之地位(此表係美國一九二八年之調查最近調查,尚付闕如).

第一圖

化學工程於美國工業中之地位



第一圖中之最上五項工業,即强烈化物,精製化物,電化物,煤膏,炸藥,已完全爲化學工程之範圍.其餘十五項中,將來可完全爲化學工程之範圍者,爲煤之處理,石油精煉,木材蒸溜,製糖,製紙,肥皂六種;將來可大有發展者,爲肥料,油漆,洋灰與石灰.將來紡織業中(29) —— 尤其是人造絲 ——,應用化學工程之處必多,可以預卜.

本篇前已述及化學工業中之製造方法,可歸納成較爲簡單之

(27) Sir Alfred Mond: Chairman of Imperial Chemical Industries, Ltd.

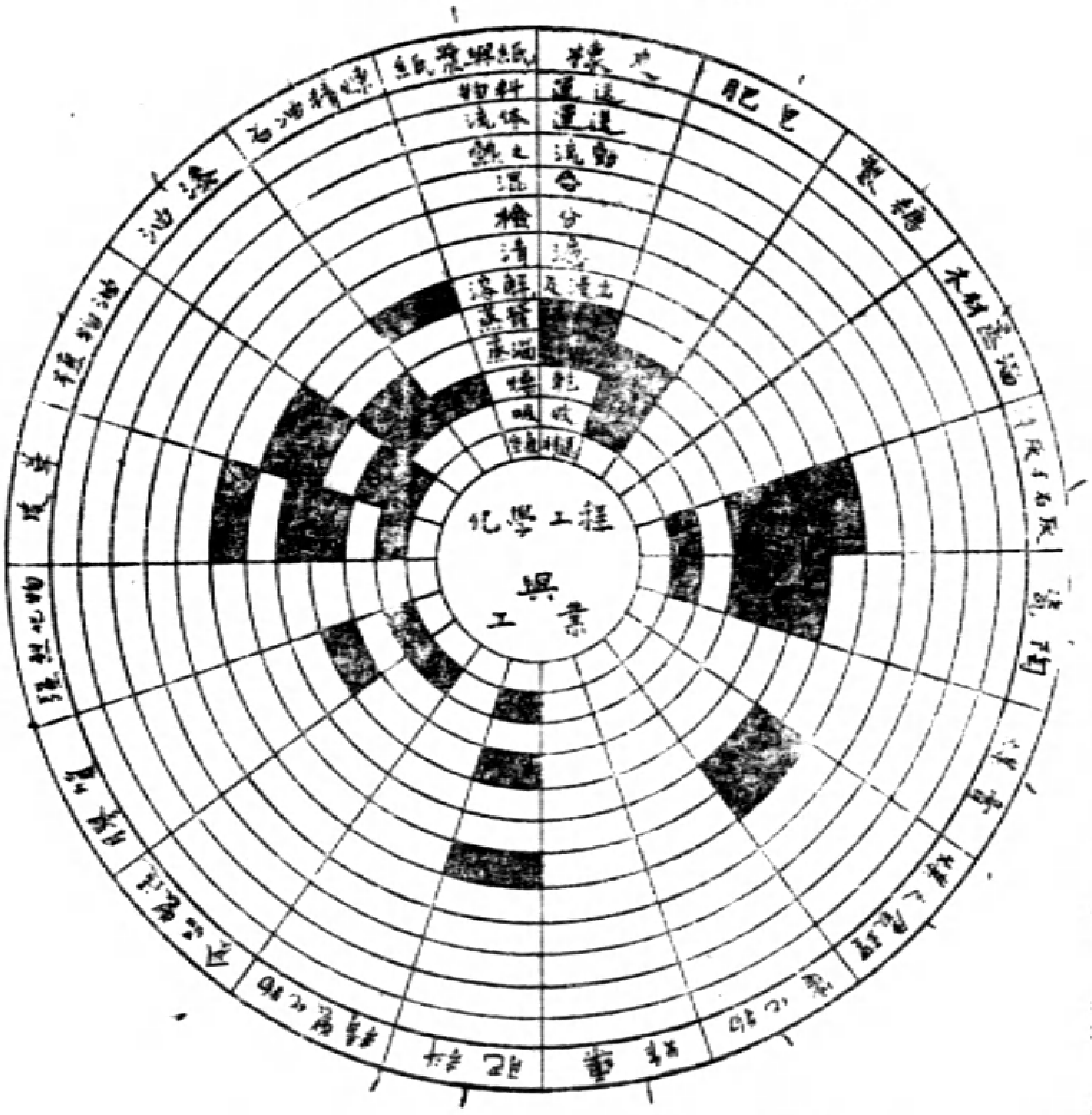
(28) Industry's Common Bond in Chemical Engineering Chem. and Met. Vol. 35 No. 1

(29) E. C. Bertolet: The Textile Industries need influence of Chemical Engineering. Chem. and Met. Vol. 35, 1

『單箇處理法』(Unit Operation). 每項『單箇處理法』之如何應用,雖因各箇工業而異,然其應用之原則,與及處理之方法則一.所以欲明化學工程與工業之關係,又可觀其『單箇處理法』與各項工業之應用如何而定,列如第二圖[30](圖中空出者,爲應用該項『單箇處理法』).

第二圖

單箇處理法與化學工業



(圖中塗黑者指尚未應用該項"單箇處理法")

工業愈發達,分工愈精密,於化學工業尤甚,廠有專製原料者,有處理原料者,有專製商品者;往往一專製商品之廠仰求原料於五六廠者.譬如造紙廠,須向酸鹼廠中購買鹹灰,明礬,硫磺,再須向電化廠中購買氯氣及苛性鈉.各項化學工業之脣齒相依,當無疑義.且化學品實爲原料之原料,各項工業無不需用,至其最後出品,吾人覺難辨其固有之化學物料矣.據一九二八年美國工業之調查,[31] 凡三十工業,必須用化學工業出品,價額合美金八萬萬元之多,而三十工業中所用之天然原料不過五倍此數耳.

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(30) 摘錄 Industry's Common Bond in Chemical Engineering Chem. and Met. Vol. 35 No. 1 擇原圖中較爲不重要之『單箇處理法』刪去.

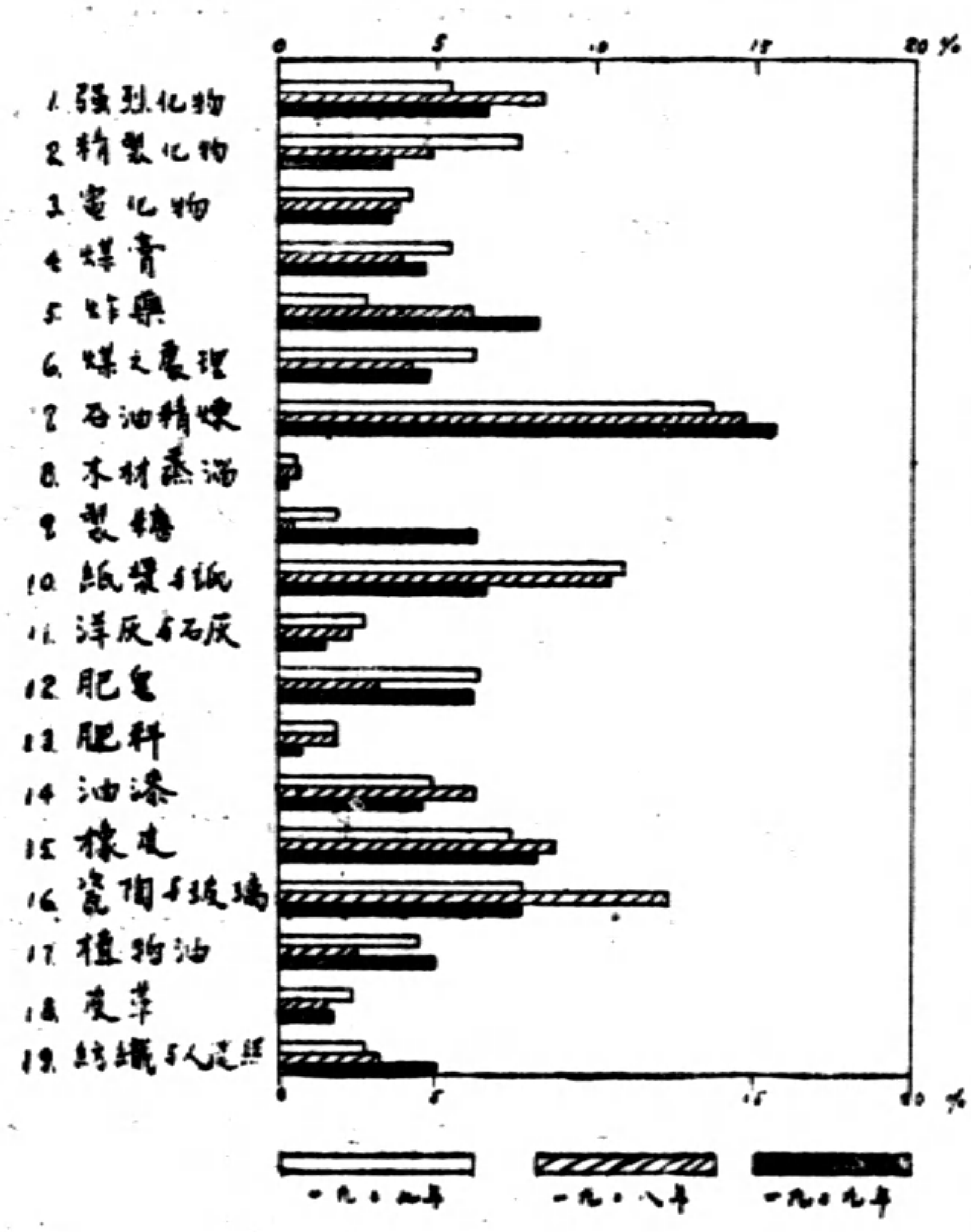
(31) Estimated Consumption of Chemicals by Consuming Industries Chem. and Met. Vol. 35 No. 1

(四) 化學工程教育(32)

今日歐,美化學工程之如是發達,皆由於工業與教育之共同合作;(33) 故言化學工程不能不及化學工業,而更不能不及化學工程教育.美國大學之初設化學工程科,設備既不同,課程亦各殊.蓋當時辦理化學工程科者,有純粹化學家,有機械工程師;以化學家辦之,其弊在偏於理論,不合實用;以機械工程師辦之,其弊在偏重機械課程,缺少化學課程.兩者通病,在不合化學工程之本意,成爲一不化學不機械之一科.(9) 其後於一九〇八年,有美國化學工程學會之組織,會中附設化學工程教育專門委員會,每年調查研究,以求化學工程科之進步,而使各大學均有相類而適當之課程.加以諸實業家,化學工程師,化學家之提倡,始克臻現在完美之境.現今有化學工程科中凡

第三圖

美國化工畢業生之百分分配表



(32) 本節所述,多限於美國之化學工程教育.關於英國者,可參閱 W. E. Gibbs: Chemical Engineering Education and Research in Great Britain. Jour. Soc. Chem. Ind. 1928

(33) H. C. Parmelee: "The Development of Chemical Engineering in this country has been fortunate in many respects, not the least of which has been the close co-operation for 20 years between industry and education in expressing and meeting, respectively, the need for the chemical engineer." Chem and Met. Vol. 35 No, 1

八十校,[34] 每年化學工程科畢業生有八百人.一九二八年之化學工程科學生較前一年增百分之二十.每年畢業生之入工業界者之分配,列爲第三圖.[34]

觀第三圖,可知近三年來,美國化學工程科畢業生於工業界之分配.讀者須知美國化工科畢業生,年多一年,原圖既系根據百分計算,故於許多工業中,一九二九年之百分計算,或較弱於一九二八或一九二七年,惟其人數則未必較少,或竟過之.然分配之大致趨向,可以立見;以入石油煉業者爲最多占六分之一),其次爲橡皮業與炸藥業.十九項工業中之需要化學工程師如此;然無完善之化學工程科,良好之化學工程教育,以培植人才,使致用於工業,則工業決不能繼續發達,此化學工程教育之所以爲重要,而工業界之必須與合作也.最重要者爲「化學工程實習學校」之設立;使習化工者自臨化學工程,實地試驗研究製造方法,考察化工原理,以及機具之構造,工廠之佈置.是乃以現代之化學工廠,供作化學工程科之試驗室,紙上談兵等弊盡行去矣.美國麻省理工大學 (M. I. T.) 河海河省立大學 (Ohio State University) 均有此類設立,前者之化工實習學校,作者曾身歷其間,殊覺實地經驗之可貴,遠非書本之所能盡述,更非於實驗室中所能得也.

結　論

由上而觀,可見所爲化學工程者,並非一種工業之技藝,又非半爲化學半爲機械工程之學科,而爲設計,構造,及管理工廠與設備,俾化學方法得致用於實業之一班獨立工程也.於近代工業中,應用之廣,範圍之大,遠勝任何工程;而於國家之富源,更負重大使命,中國果欲振興工業也,則化學工程不能後於任何工程,國人而不欲注意於化學工程,則中國雖有其他諸工程之發展,吾可斷中國之工業,依舊不振,而其他工程之發展亦必有限量也.故中國欲振工業,必須以化學工程與任何工程並重.方今國內洋貨充斥,利權外溢,愛國者痛心疾首,高呼『抵制』『抵制』;然徒呼『抵制』,不自製造,是束手待斃之策.應用化學品之仰仗於外國者,觸目皆是;望國人急起直追,從事化學工程以圖化學工業之發達也可.

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(34) How Industry Absorbs College Graduates in Chemical Engineering Chem. and Met. 36 No. 7 1929

INTER-COMMUNICATION BETWEEN AUTOMATIC AND MANUAL TELEPHONES

自動電話與非自動式通話之研究

By B. J. Yoh (郁秉堅)

General.— In order to carry the traffic from both manual to automatic and automatic to manual in a telephone network or interconnected offices, when one of the exchanges has been changed into automatic working, several systems have been developed in each case. Of course, they will not be in existance as soon as all exchanges in the network have been changed into automatic.

From Manual to Automatic Systems. When the automatic exchange is introduced into existing manual networks, one of the problems is naturally to have a scheme for handling traffic from manual subscribers. The methods used can be generally segregated into two classes.

Class 1. Methods where the manual "A" operator completes connection without the aid of a "B" operator. The "A" operator, as shown in Fig. 1, goes on in an order wire to the desired automatic exchange and then controles the establishment of the connection in the automatic exchange by means of either a dial or key-sending equipment located on the "A" position of the manual exchange.

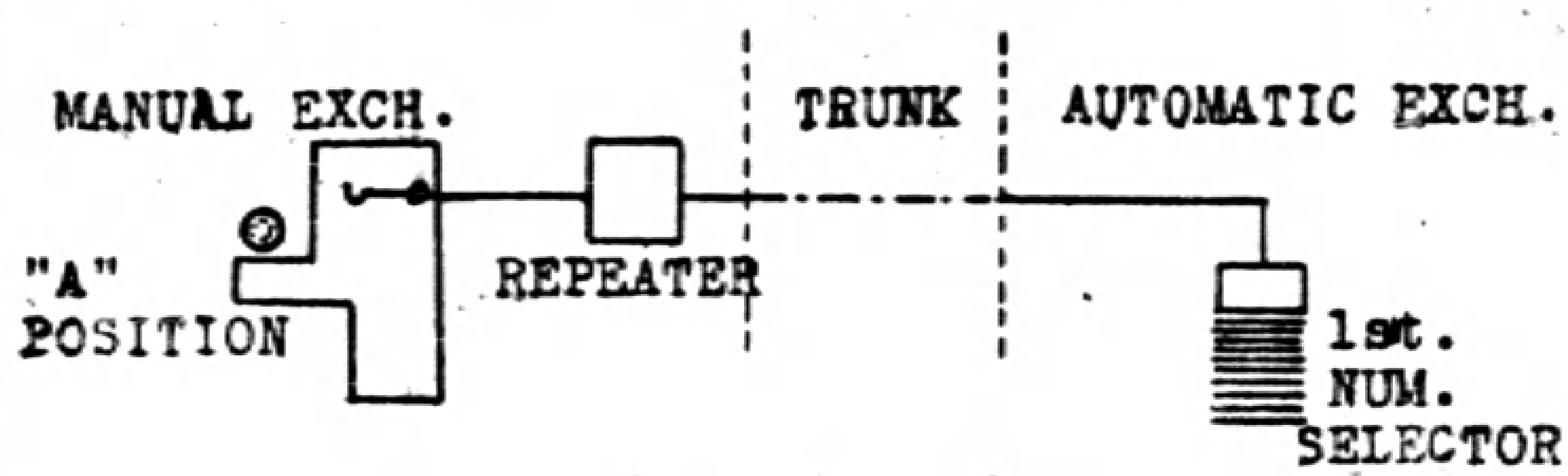


Fig. 1. *Manual Operator "A" Completes Connection Without The Aid Of "B" Operator.*

Class 2. Methods where the manual operator "A" completes connection with the aid of a "B" operator via an order wire. As shown in Fig. 2, the "A" operator goes in on an order wire to the desired automatic exchange and gives the order to a "B" operator, as usually referred to as a "Semi B" or "Cordless B" operator. This operator assigns a trunk and completes the call in the automatic exchange either by means of a dial or a keyboard. It may

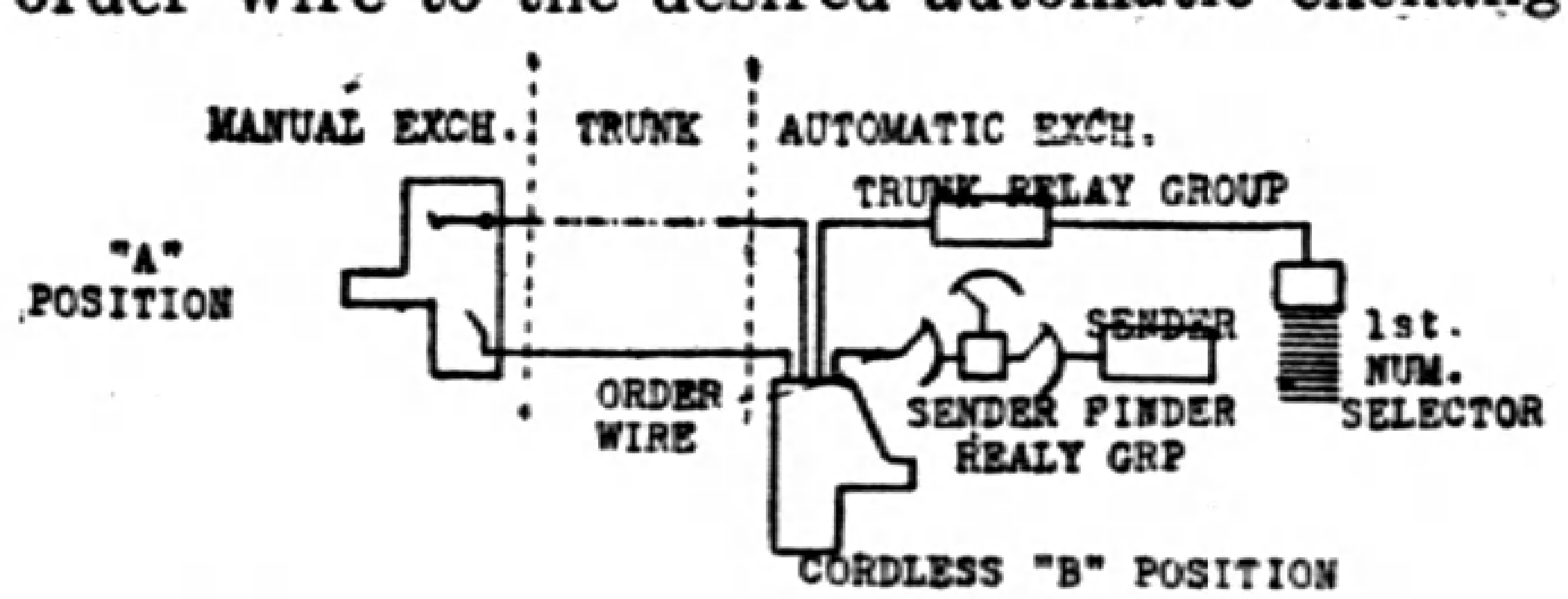


Fig. 2. *Ordinary Order Wire Scheme From "A" Operator To Cordless "B" Operator.*

be noted that in so far as the "A" operator is concerned, this method of completing a call from a manual to an automatic subscriber is identical with that used for the completion of a call from a manual to a manual subscriber.

The order wire method of trunking contains several inconveniences, principally during heavy loads in confusion on the order wire. The tendency is, therefore, to-wards the application of methods in Class 1. They have the feature of "direct" or "straight-forward" trunking and no "cordless B" equipment or operators in the automatic exchange. There are, however, cases where a "cordless B" operator is preferred, so, the methods in Class 2 have still been used.

In order to get the merits of "direct" trunking and to do away with the order wire but retaining the "cordless "B" position, Mr. Ostline of Automatic Telephone Manufacturing Company has suggested a method, which is represented by Fig. 3.

The volume of manual to automatic traffic at any one exchange is at a maximum when the exchange is just under conversion and will gradually decline until the time when all offices in the network become automatic, then, it will be a minimum. The traffic remaining at that time may be that incoming from the trunk and toll exchanges, and a small amount from exchanges outside the area.

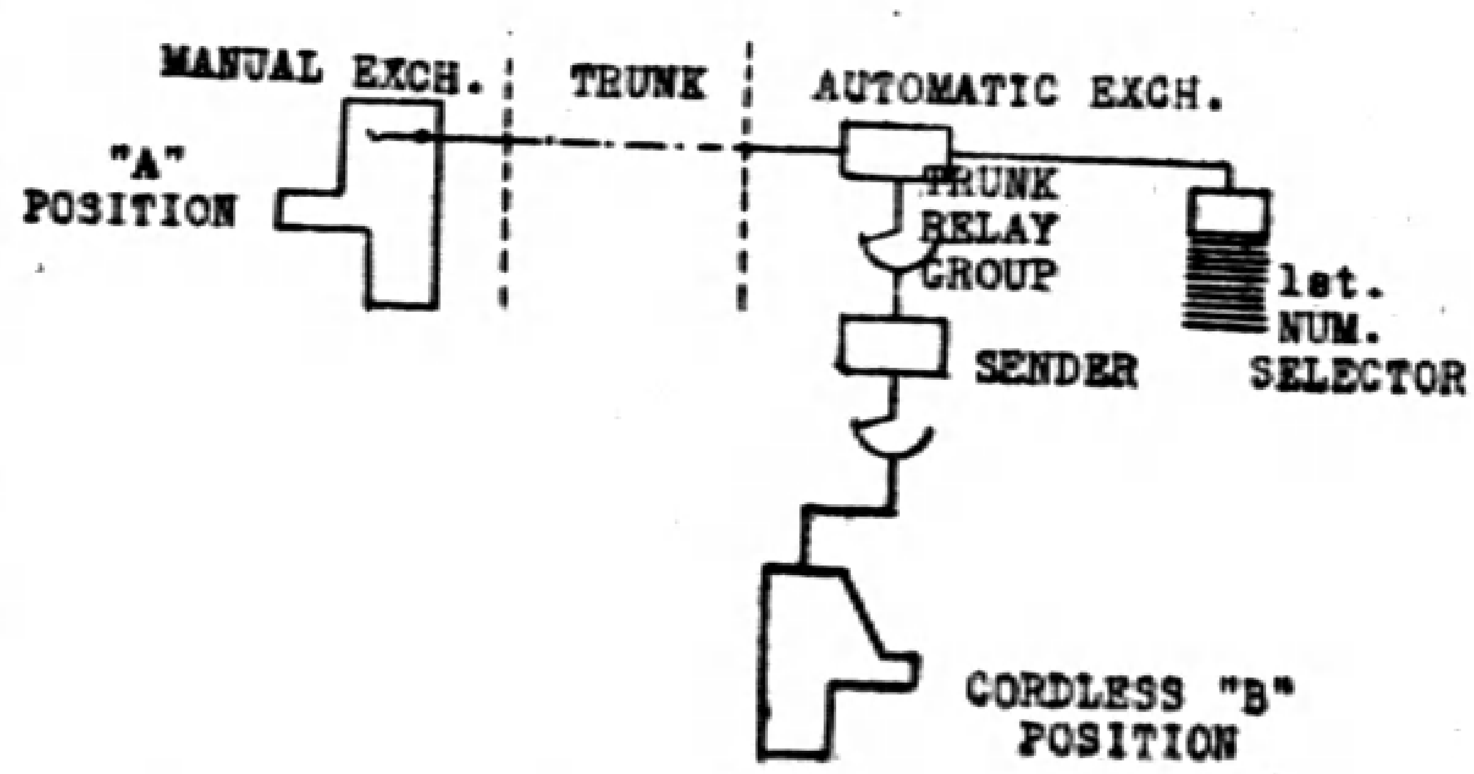


FIG. 3. *Ostline's suggested Scheme.*

From Automatic to Manual Systems.— The traffic outgoing from automatic exchanges to manual exchanges may be divided into going from automatic exchanges to manual exchanges may be divided into four types, namely: Junction, Trunk, Toll and Special. The junction traffic which is the inter-area traffic, and by far the largest proportion, forms one of the most difficult problems when converting a large area to automatic working. There are three possible methods of working automatic to manual calls:—

Method. 1. Automatic subscribers dial exchange code only and inform "B" operator verbally, as shown in Fig. 4. The objection of this method of working would be the bad effect on service due to the automatic subscribers sometimes having to dial the code and also numerical digits and at others dialling the code only.

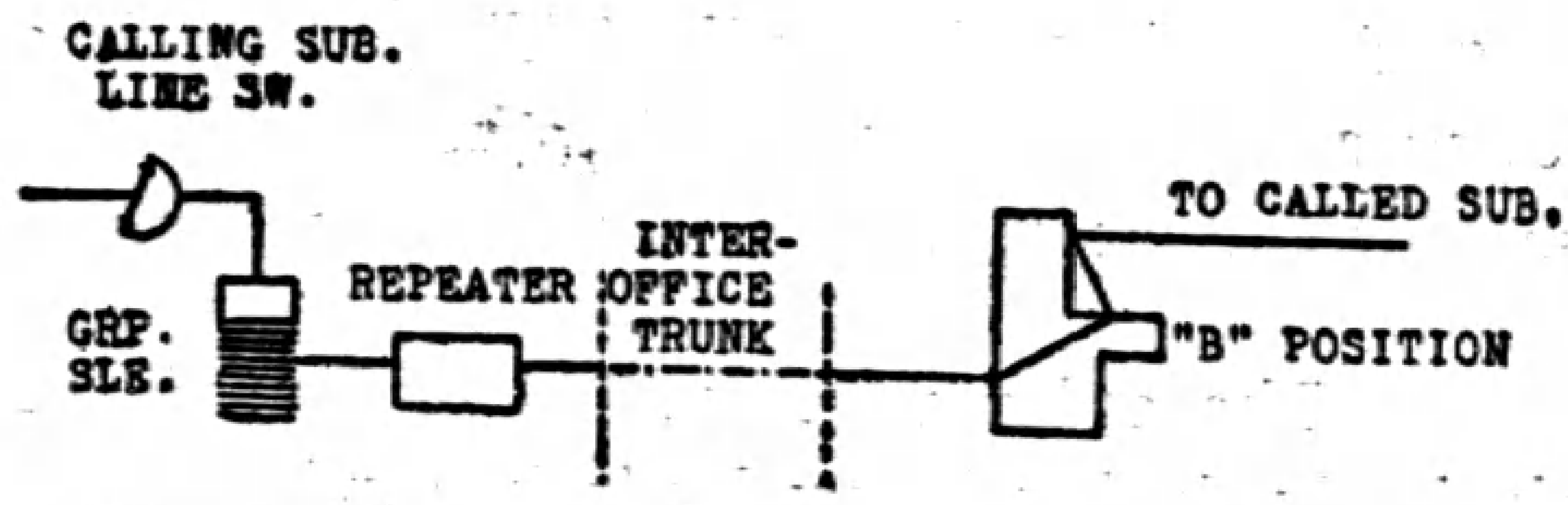


FIG. 4. *Automatic To Manual Call, Method 1.*

Method 2. This method fits automatic switches at the manual exchanges. It seems very attractive, as if each manual exchange were equipped with first numerical, second numerical and final selectors, incoming calls from automatic exchanges could be directed to these switches as thus proceed as for an ordinary straight automatic call. There are, however, several drawbacks, chiefly due to the limitted space and the different operating voltage in manual exchanges.

Method 3. Automatic subscribers dial full number as the ordinary practice, and numerical portion displayed on lamps in the front of "B" operator. It renders calls from subscribers in an automatic exchange to those in a manual exchange completely automatic so far as the calling subscriber is concerned. It also furnishes means for greatly facilitating certain classes of traffic in a manual exchange by superseding the usual order wire method which may be liable to misinterpretation during busy hours of traffic. Two schemes have been devised in this case:

1. The Call Indicator (C. I.) System.
2. The Coder Call Indicator (C. C. I.) System.

The general method of operation of the call indicator may be seen in Fig. 5. At the originating automatic office the dialing by the subscriber of the first or first and second digits of the number determines the routing of the call to the required manual office through a repeater. The first disengaged trunk is seized, immediately engaging a trunk relay group and associated cord circuit at the manual position. Each incoming trunk on the position is directly associated with a trunk relay groups which is

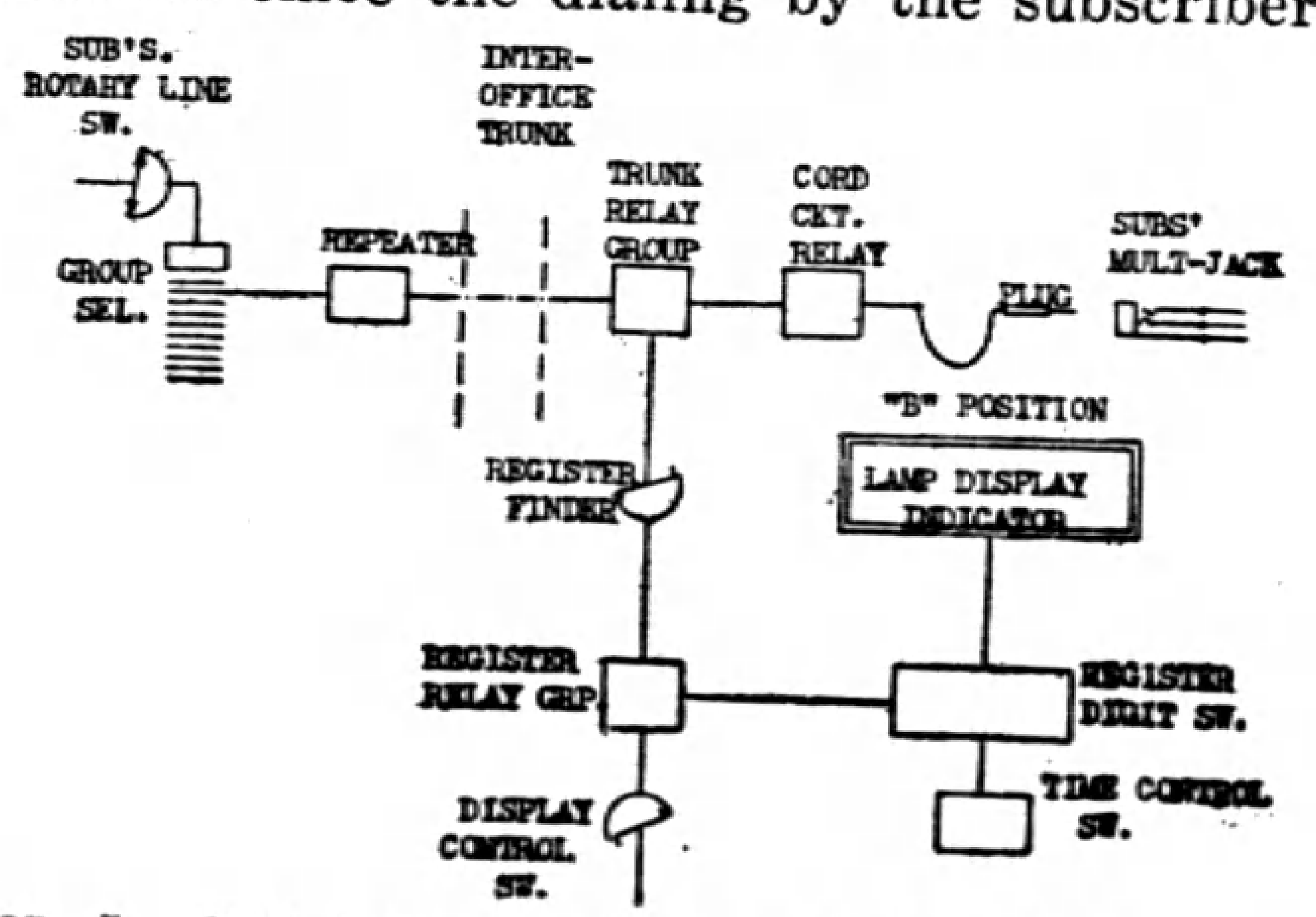


FIG. 5. *Call Indicator System, Schematic Showing Method of Operation.*

particular to that circuit. A rotary line switch, individual to the trunk, is now engaged and functions as a finder to select the first idle register relay group and register digit selector.

The register relay group is now ready for received the impulses representing the number and are received and stored via the register relay group on the register digit switch, which consists of controlling relays associated with single action step-by-step Strowger minor switches responding to the regular impulses from the dial. Having received all the impulses, the wipers of the minor switches are in the position determined by the numerals dialled, and on the completion of the unit digit, if the display board is not already showing a number, the call will be displayed. At the same time, an assignment lamp in front of the associated cord and plug will be lighted, informing the operator which plug to use.

If the subscriber's line is disengaged, the plug is inserted in the multiple and the number shown on the display-board disappears and the next number stored appears in its proper sequence. The assignment lamp associated with the trunk is also extinguished and the supervision of the call is taken care of by the supervisory lamp. Should the called number be already engaged, the operator plugs into a busy jack, putting the usual busy tone on the calling subscriber's line.

In the Coder Call Indicator System, the calling subscriber at the originating automatic office, as shown in the Fig. 6, dials in the usual manner, the first digit or first two digits seizing an outgoing C. C. I. repeater to the manual office. A rotary line switch associated with the repeater finds and connects the repeater to a disengaged coder. The numerical digits in the shape of regular Strowger impulses are now dialled into the coder, and there translated into code impulses, and stored ready for transmission along the junction until the last numerical digit has been received.

Upon the seizure of the trunk, the relays in the incoming trunk relay set operate and a marker controlled from a marker distributor, immediately starts rotating and connects itself to the trunk through the repeater. Depending on the sequence of the calls, the display controller will next connect the trunk through the marker to the decoding and storing relays. As soon as the decorder is connected to the trunk, the number stored in the coder at the originating office will be transmitted in code along the junction. The code impulses are then transferred to the storing relay group and the coder and decoding relays are immediately released for other calls.

As soon as the number is stored, it is also shown on the position display board. The operator now takes up any plug on the position and tests the multiple jack of the number required and if disengeged, inserts the plug. This causes the rotary switch associated with the cord to act as a finder, proceeding to connect itself with the trunk displaying the number. If the called line is engaged, the operator depresses a key common to the position, which causes a busy tone to be put on to the calling subscriber in the usual manner. The number shown on the display-board is also automatically wiped out and the next number displayed if stored ready.

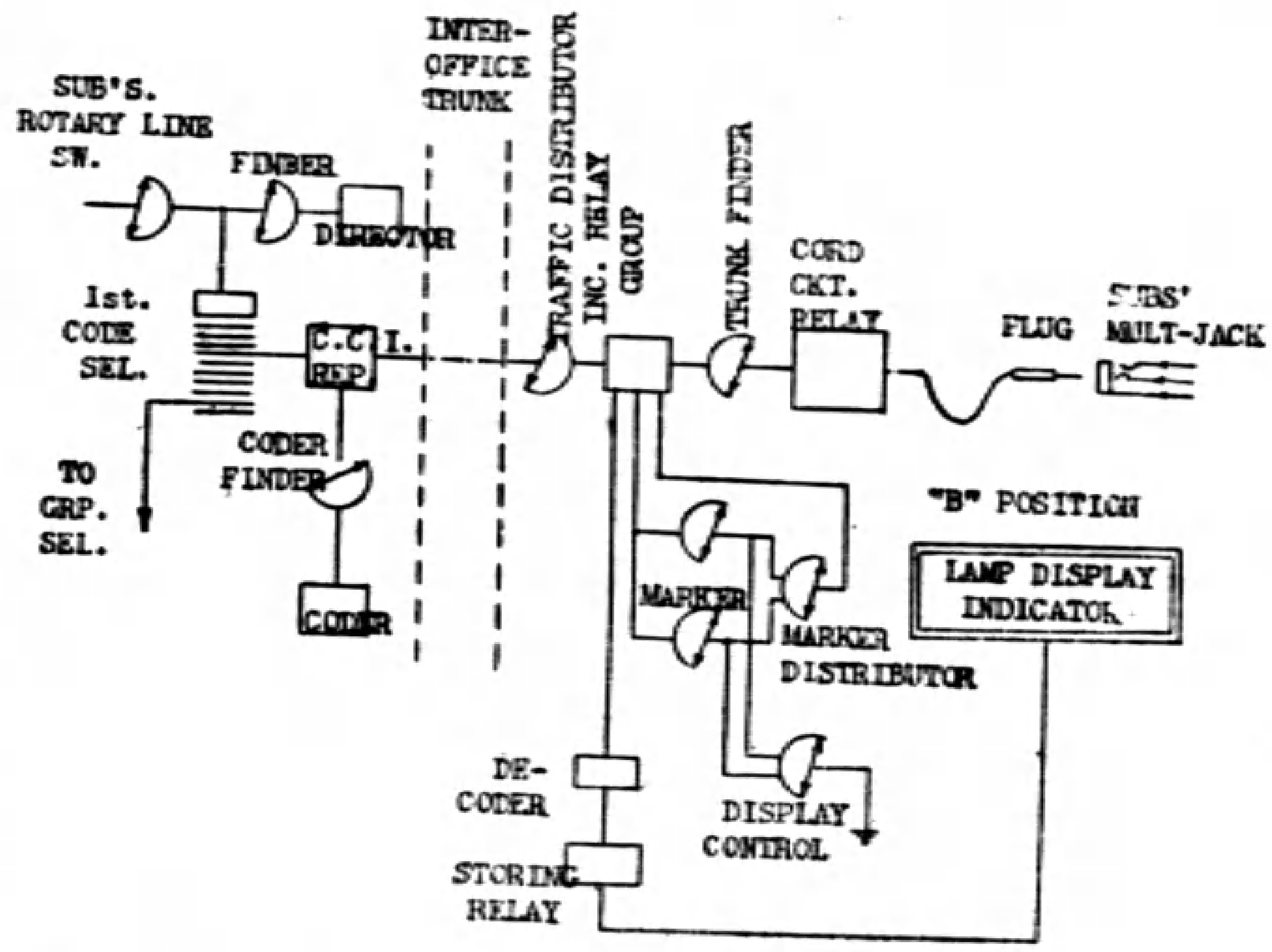


FIG. 6. *Coder Call Indicator, Method Of Operation.*

Immediately on the storing and displaying of a number, and before the connection is complete, the decording relay group is connected to the next trunk on which a call may be waiting, and is available for immediately receiving another in code form.

The chief differences between Call Indicator and Coder Call Indicator may therefore be briefly summarized. In the Coder Call Indiacator System, regular Strowger impulses are converted into coder impulses by means of positive, light negative and heavy negative working for transmission along the inter-office trunk and are translated back into numerals for display at the manual end. The code impulses are transmitted along the junction in a minimum of time. In the Call Indicator System, all the equipments are rigidly located in the manual office, while in the Coder Call Indicator, the Coder is located in the automatic office and the decording equipments are located in the manual office. Thus, the methods of trunking and grading in both cases are different.

The economical and operating advantages which attend the use of the coder call indicator are considerable. The method of call distribution embodied in this system enables economics in the apparatus to be made compared with ordinary call indicator system as the amount of equipment can be apportioned on a traffic basis. The flexibility of coder call indicator for handling the traffic is ideal and far superior to the usual call indicator, a uniform load being distributed to all manual operators.

The total amount of automatic to manual traffic in the area will steadily increase from the time when the first automatic exchange is installed until a maximum is reached about the middle of the transition period, and then it will steadily decrease as more and more exchanges become automatic.

Mechanical Tandem Exchang.— Chief reasons on the introduction of the tandem junction working in telephone networks are:

1. Saving inter-office trunks, and
2. Offering higher trunking efficiency.

Ordinary tandem working on a strictly manual basis, however, has limitations due to the increased time required to complete a connection and the liability of error caused by the introduction of the additional operator. With the introduction of Mechanical Switching in the tandem exchange and the projection of the call to a call indicator position in the terminating exchange thereby increasing the speed of completion and reducing the liability of error, the limitation of tandem working are largely removed and the full benefits realized.

In the network having both automatic and manual exchanges, the Mechanical Tandem Exchange is required to route the traffic as follows:

From manual exchange to automatic exchange.

From manual exchange to manual exchange.

From automatic exchange to manual exchange.

As soon as all the manual exchanges in the network are converted into automatic working, the tandem exchange, then, becomes a Junction Center.

The method of handling traffic in the mechanical tandem exchange is illustrated in Fig. 7. Traffic from "A" positions of a manual exchange will be dealt with in a similar manner to the traffic incoming to a cordless "B" position at an automatic exchange. The "A" operator will "order wire" the call to the cordless "B" operator at the tandem exchange, who will set up the call to the automatic switches via her key sending equipment. If the call is for a manual exchange, it will be directed to a call indicator position at that exchange, and the numerical portion of the required number with effect the required display on the lamp panel at the call indicator position. If the call is for an automatic exchange, the numerical digits will go out to the switches at the automatic exchange in the regular manner.

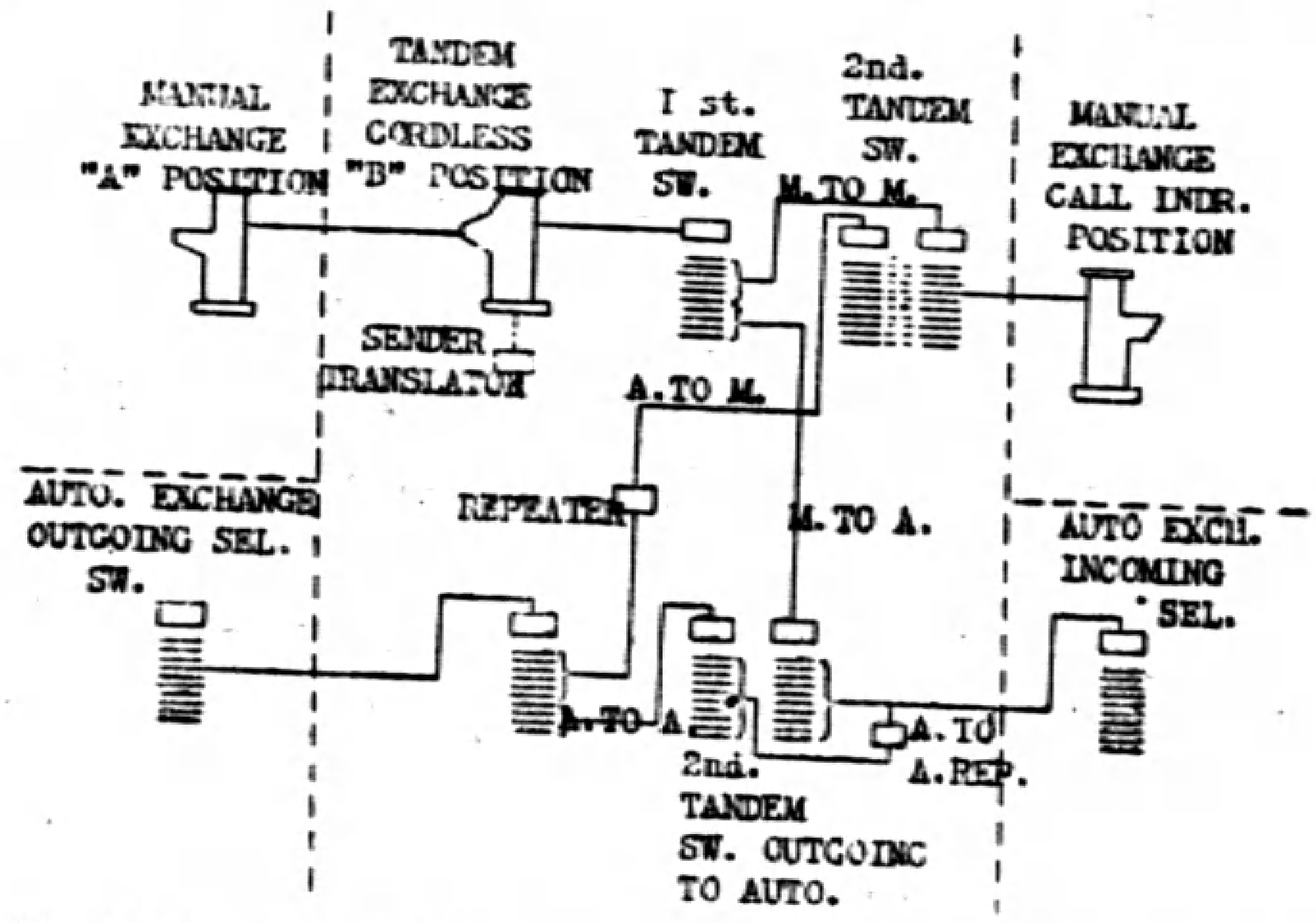


FIG. 7. *Mechanical Tandem Exchange Routing Scheme.*

Traffic originated in an automatic exchange will be carried direct from the levels of the outgoing switches to the first tandem switches at the mechanical tandem exchange. In the case of a call for a manual exchange, the first and second tandem switches will be operated and the numerical portion of the required number will be displayed at the call indicator position of the manual exchange. A call for another automatic exchange will pass out via levels on the first and second tandem switches and will be routed through repeaters to the required automatic exchange.

Conclusion. — This paper has mainly concerned itself with the application of the different methods for the inter-communication between automatic and manual telephones. The requirements of these methods during the period of transition may be briefly summarized as follows:

1. To ensure smooth operation between the two systems.
2. To give efficient service between the two.
3. Full automatic method of calling from automatic subscribers to manual ones is preferable.
4. Both initial and operating costs should be as low as possible.

複筋混凝土梁計算捷法

著者：趙國華

(一) 緒言　(二) 複梁在計劃,複核上所起之問題.
(三) 公式之說明及列題之說明.　(四) 結論.

(一) 緒　言

鋼筋混凝土梁內之鋼筋,恒安置于斷面之下部.此係鋼筋混凝土性質上當然之事實.但在特殊情形之下,有時于上下二方各置之者,則前者稱之曰單梁(Simple R. C. beam)後者稱之曰複梁(Double R. C. beam).關于單梁之計算甚簡易,而應用範圍亦較狹,惟複梁之計算,用通常方法,甚爲繁雜但其用途甚廣.本篇卽就該項計算上加以改良,並利用最便利之方法曰 Nomograph* 製成圖表三種以資應用,使之充分簡單,並可免除大部分之計算,因而勞力與時間,亦可節省多多矣.惟事屬初創,雖經作者試驗至再,惟恐尙有差池,深幸海內同志俯而教之.

本篇之作原因向先吾國所通行關於鋼筋混凝土工學之書籍如 Holl's R. C. Construction," Tayor & Thompson's "Concrete, plain and Reinforced" 以及新近通行之 "Urguhart & O'Roucke's "Design of Concrete Structures" 等書,恆用冗長之公式及理論以充教材,缺少實用上之例題.且處處用繁雜而須經驗之假定,已使初學者茫無頭緒,更因各書所附之表格,範圍較狹,往往不能直接讀得,而須用判讀法讀出之,以致時生差誤,且所用之單位制度,俱爲英制,但本國現下情形又須積極改成公尺制,在此過渡時期,至少限度亦須英公

* nomograph 一字擬譯成『圖表學』或有用 nomogram 者原字之意義謂 "The graphical presentation of laws", 在美國所通用曰 Alinement Chart, 英國則用 Alignement Chart.

二制參用,好在中國之工程事業,尙未十分發達,能在數年之內,努力改革用英制之習慣,猶未晚也.因以上種種之原因,欲以棉力補救於萬一,故不揣簡陋,將數年來研究所得,分別錄出以供諸先進之指正.今先就關於複筋梁計算之一部,先行供獻,俟他日另有機會,再將關於T梁及彎曲與直壓應力同時作用之部材(member)之計算方法,逐一發表之.

(二) 複梁在計算,複核上所起之問題

由已知彎曲力率,及材料之應力而定梁之斷面,此項步驟是曰計劃.由已定之斷面而求其抵抗力率或材料之應力,此項步驟,是曰複核.計劃,與複核二種尙可分成若干問題討論之.今分別言之如次:—

歸於計劃上所起之問題有二:

(一) 上下鋼筋量及梁寬一定時,由彎曲力率以定其深度.

例如連梁(Continuous beam)支點處,受負彎曲力率時,有一部分鋼筋向上彎曲,而過支點,有一部分則在下部通過,此時鋼筋量與梁寬爲已知,而所須求出者僅爲其深度.

(二) 彎曲力率大於該梁所能任負,而混凝土斷面尺寸,又爲其他條件所限止者,(如建築,裝飾,採光,換氣等關係)則增加鋼筋用量以求其平.

例如懸臂梁(Cantilever beam)之弧度已定,及外彎曲力率已知,而求懸臂內所需鋼筋之量.如首都之中山橋,外觀爲一拱形,實爲二懸臂梁所兜成,該懸臂梁內鋼筋用量之決定,卽用下述之方法.

歸於檢算上所起之問題有二:

(一) 由已知之斷面而求其最小抵抗力率.

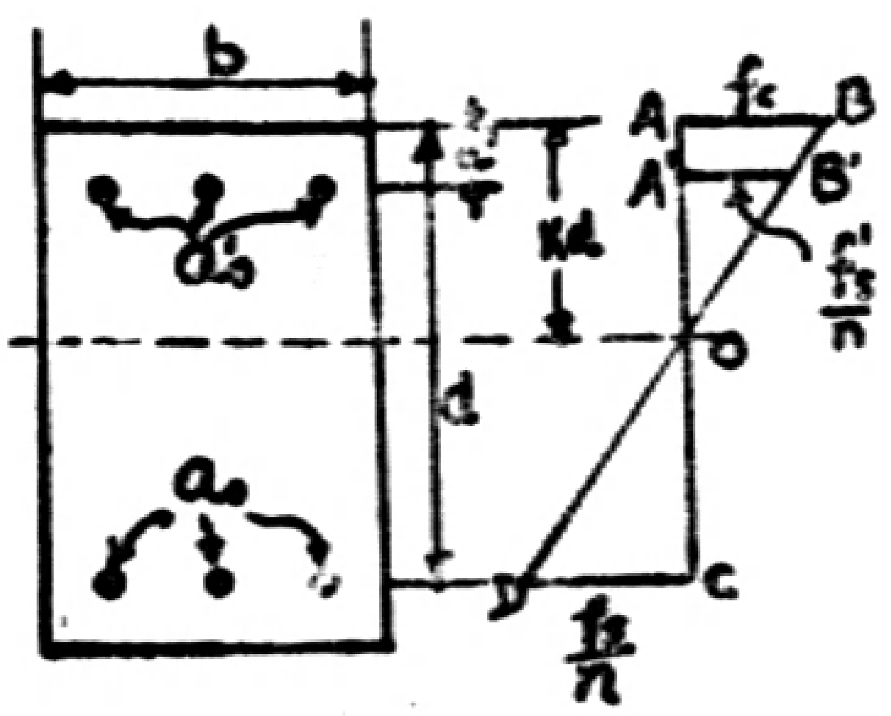
(二) 由已知之斷面而求其最大之應力.

此項檢算上所起之問題,由於混凝土斷面之尺寸,在計算時往往帶有另星小數,而在實際施工或製圖時,常作爲整數,又所用鋼筋之大小,往往與市

場上所供給者不符,致生差異,又斷面上部鋼筋之位置,往往不能與其所假定者符合,因以上之種種原因,故須有檢算之必要究屬該項最後決定之斷面,能負多大之抵抗力率及其材料所起最大之應力.

(三) 公式之誘導及例題之說明

(一) 第一問題之解法.



第一圖

依第一圖之斷面.

假定	梁之有效深度 (Effective depth)	$=d$
	梁之寬度	$=b$
	抗壓側鋼筋百分比	$=P_c$
	抗張側鋼筋百分比	$=P_t$
	抗壓側鋼筋中心至邊緣距	$=d'$
	中軸距比	$=k$
	彈率比	$=n=15$
		$d'/d=\beta$

求該斷面之混凝土及鋼筋關於中軸線所起之一次率而置之爲零卽

$$bd^2\left\{\frac{k^2}{2}-n\left[(1-k)P_t-(k-\beta)P_c\right]\right\}=0.$$

$$\frac{k^2}{2}-n\left[(1-k)P_t-(k-\beta)P_c\right]=0.$$

$$k^2+2n(P_t+P_c)k-2n(P_t+\beta P_c)=0.$$

解上列 k 之二次式則得

$$k=-n(P_t+P_c)+\sqrt{2n(P_t+\beta P_c)+n^2(P_t+P_c)^2}\quad\ldots\ldots\ldots(1)$$

上式中,如 P_t, P_c, β, n 四值爲已知,則 k 值卽可求得.

又求該斷面混凝土及鋼筋二項關於中軸線所起之二次率 (moment of Inertia) 應爲

$$I=bd^3\left\{\frac{k^3}{3}+n\left((1-k)^2P_t+(k-\beta)^2P_c\right)\right\}$$

將上式代入材料力學上之基本公式.

$$M=\frac{If}{c}=\frac{If_c}{kd}$$

$$=\frac{f_c\ bd^3\left\{\frac{k^3}{3}+n\left((1-k)^2P_t+(k-\beta)^2P_c\right)\right\}}{kd}$$

$$=f_c\ bd^2\left\{\frac{k^2}{3}(1-k/3)+\frac{nP_c}{k}(k-\beta)(1-\beta)\right\}$$

$$=R\,f_c\ bd^2 \quad\cdots\cdots\cdots(2)$$

即 $R=\frac{k^2}{2}(1-k/3)+\frac{nP_c}{k}(k-\beta)(1-\beta)=\frac{M}{f_c\ bd^2}\cdots\cdots(2)'$

又由相似三角形AOB,COD中可得

$$f_s=\frac{n(1-k)}{k}f_c=\frac{f_c}{Q}$$

即 $Q=\frac{k}{n(1-k)}=\frac{f_c}{f_s}$

$$M=R.\ Q.\ f_s\ .\ bd^2 \quad\cdots\cdots\cdots(3)$$

∴ $d=\sqrt{\frac{M}{Rf_c\ b}}\cdots\cdots\cdots(4)$

$$d=\sqrt{\frac{M}{R.\ Q.\ f_s\ b}}\cdots\cdots\cdots(5)$$

今由第一式可知,因 P_t, P_c, 值之變更,而使 K 值同時亦起變化.而所求之 d 值.亦因之發生問題,究用(4)式抑用(5)式以定之乎?此點在通常之書藉上都未論及,使初學者莫衷一是.但依研究所得,凡由(1)式求得之 K 值大於 $\frac{15}{15+\frac{fs}{fc}}$ 者,則用(4)式決定其深度,若小此數者,用(5)式以決定之.今舉一例以明之.

例一 已知之項目

$b=12''$, $P=P'$, $as=3$ sq. in.

$M=750,000$ in. lbs.

$f_c=750$ lb/sq. in. $f_s=16,000$ lb/sq. in.

求梁之有效深度.

解. 今假定 $j=7/8$*

*如用於本國現在各市所規定之容許應力範圍之內,j 值恆可假定爲 7/8 以計算之.

則　$d=\frac{M}{asf_sj}=\frac{750,000}{3\times16,000\times7/8}=17.85$ inches

而　$P_t=P_c=\frac{3}{12\times17.85}=.014.=1.4\%.$

假定　$d'/d=0.10$

今　$P_t+P_c=2.8\%.$

$P_t+\frac{d'}{d}P_c=1.54\%.$

由圖表（1）得　$k_1=0.38$

但　$k=\frac{15}{15+\frac{16,000}{750}}=.414.$

$\therefore\quad k_1<k.$

故用（5）式以求 d 今

$$Q=\frac{k_1}{n(1-k_1)}=\frac{0.38}{15(1-.38)}=0.0408.$$

由圖表（1）得

$$R=\frac{M}{f_c bd^2}=0.302.$$

$$\therefore\quad d=\sqrt{\frac{750,000}{0.302\times0.0408\times16,000\times12}}=17.75\text{ inches}$$

即爲所求梁之有效深度,苟若不察,誤用（4）式以求之,則其結果又復不同,此點不可不加以注意,今就用（4）式以求 d 値之結果

$$d=\sqrt{\frac{750,000}{0.302\times750\times12}}=16.6.\text{ inches}$$

又關於 j 値一項先由假定而算出 d 値復將此 d 値代入次式

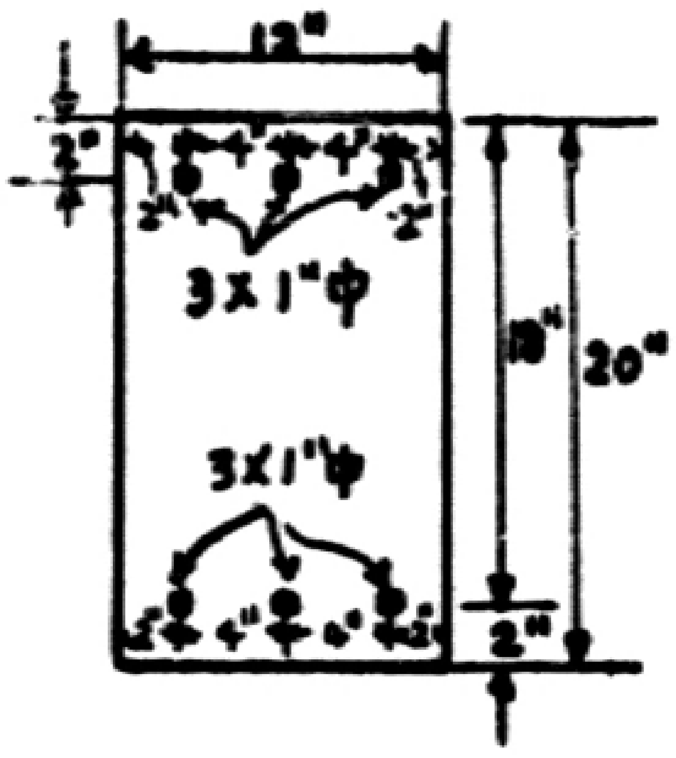
$$j=\frac{M}{f_c bd^2}\cdot\frac{Q}{P_t}$$

而得 j,此値是否與假定相同,此亦檢算之一法.惟在本例中之⅞,及依本國情形而用8/9,往往適合,故此項手續可省.惟因其他之關係,則須有檢算之必要.

如斷面已經決定,因在實施時之便利,不能吻合計算所得之尺寸,則由此

已決定之斷面以求其最大應力或最小抵抗力率.但應用何式以決定之,則在通常書籍上又復含糊莫辨,往往將二值,俱行求出而比較之,但亦可視K_1值之大小而立即判斷之,如K_1值大於$\frac{n}{n+\frac{fs}{fc}}$時,則梁之抵抗力率及材料之最大應力以抗壓側為準,即用(a)式決定之,若小於時,則以抗張側為準或即用(3)式決定之,今舉例以明之:

例二　若於例一所得之結果中為實施時之便利,其斷面應如第二圖圖內所示.



第二圖

$d=18$ in.

$as=as'=3$ sq.. in.

$b=12$ in.

$d'=2$ in

求其最小抵抗力率及材料之最大應力.

解.　今. $P_t=P_c=\frac{3}{18\times12}=1.39\%$

$\frac{d'}{d}=\frac{2}{18}=0.111.$

$P_t+P_c=2.78\%$

$P_t+\frac{d'}{d}P_c=1.55\%.$

由圖表一可得

$$k_1=0.385<\left(\frac{n}{n+\frac{fs}{fc}}\right)$$

故可逕由(3)式求之

由圖表一可得　$R=\frac{M}{f_c bd^2}=0.295.$

而　$Q=0.0417$

故　$M_s=0.295\times0.0417\times16{,}000\times12\times\overline{18}^2=766{,}000$ in. lbs.

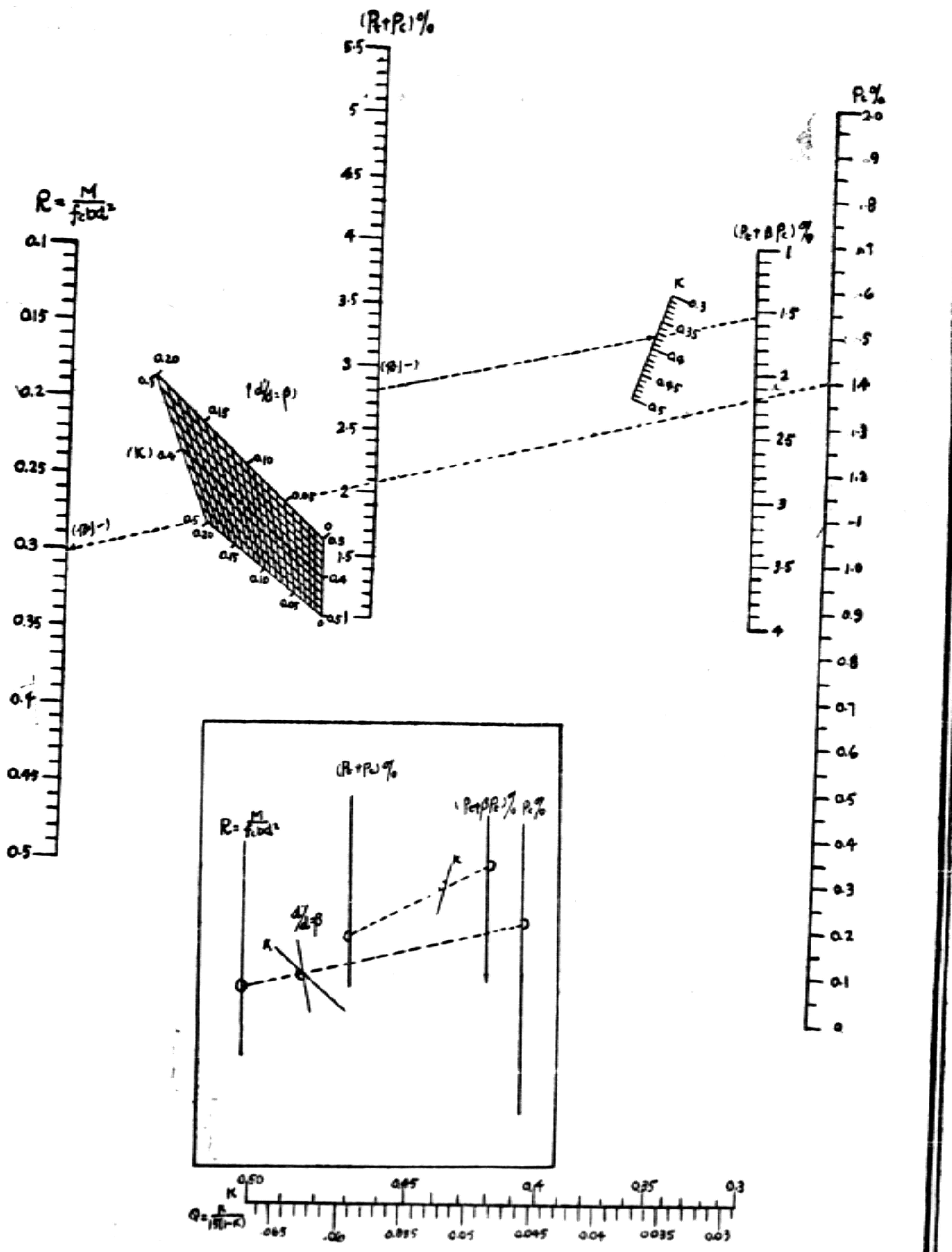
而　$f_s=\frac{750{,}000}{0.0417\times0.295\times12\times\overline{18}^2}=15.700$ lbs./sq.in.

如用(2)式求之則其結果如下

$M_c=0.295\times750\times12\times\overline{18}^2=861{,}000$ in. lbs

$f_c=\frac{750{,}000}{0.295\times12\times\overline{18}^2}=654$ lbs./sq. in.

計劃及核祘複筋梁用之圖表(其一)



今 $M_s > M_c$ 故以 M_s 之值作準,而其應力之比較,則可用下法求之.

梁內材料所起之應力,與可許應力之差,與可許應力之比,作者命之曰保險率,相差如爲負則險,所差爲正則安,故以名之,而保險率大者較小者爲安,值愈大則愈安,然又不能不顧及材料之經濟問題,故須有一定之限度.

今依保險率之定義而比較其安全之度.

鋼筋之保險率　$\dfrac{16,000-15,700}{16,000}=1.87\%$

混凝土之保險率　$\dfrac{750-654}{750}=12.80\%$

故該梁抗壓側所起之安全度大於抗張側,故材料內所起之應力應以抗張側之鋼筋爲準.

由是可知此項第二步手續可斷然的廢除,此點乃爲本篇特點之一.

(二) 第二問題之解法 (其一).

假定已知彎曲力率,梁之寬度及容許應力,以求上下鋼筋之量.

解. 今由 (1) 式置

$$\sqrt{2n(P_t+\beta^1 P_c)+n^2(P_t+P_c)^2}=\gamma$$

$$n(P_t+P_c)=S.$$

則　$K=\gamma-S.$

代入 (2)' 式則得

$$\frac{M}{f_c bd^2}=\left\{\frac{1}{2}(\gamma-S)^2\left(1-\frac{\gamma-S}{3}\right)+\frac{nP_c}{\gamma-S}(\gamma-S-\beta)(1-\beta)\right\}$$

$$=\frac{1}{6}(\gamma-S)(3-\gamma+S)+nP_c\left(1-\frac{\beta}{\gamma-S}\right)(1-\beta).$$

$$=\left\{\frac{1}{2}+\frac{n}{3}(P_t+P_c)\right\}\left\{2n(P_t+\beta P_c)+n^2(P_t+P_c)^2\right\}^{\frac{1}{2}}$$

$$-\frac{1}{3}\left\{n^2(P_t+P_c)^2+n(P_t+\beta P_c)+\frac{3n}{2}(P_t+\beta P_c)\right\}$$

$$-(1-\beta)nP_c\left\{1-\frac{\beta}{\left(2n(P_t+\beta P_c)+(P_t+P_c)\right)^{\frac{1}{2}}-n(P_t+P_c)}\right\}\cdots\cdots(6)$$

於(6)式之中若P_c,P_t,β三值爲已知,即可直接求得$\frac{M}{f_c bd^2}$之值而不必再由(1)式求k,代入(2)式求R.如若R,β二值已知則由該式可定P_t,P_c.之值.但P_t,P_c二值可得任定,而成種種之配合,故如先知斷面內一例之鋼筋量,即可求得他方應需之量,又於若干種配合之中比較鋼筋用量之多寡,而取其最經濟之結果,故(6)式之用處甚大.但在事實上該式之繁,一望而知之.因此法之長處不可放棄,故由作者費數星期之久,不避繁雜,利用圖表學,將該式製成圖表一紙.惟β值一項,則因計算過繁,不能詳備,深引爲憾.如將來有暇,定當繼續進行.此項圖表甚爲簡單,而所求之結果,亦可於極短時間找出之.而關於β值在計劃時,本屬假定,故實用上在計劃較薄之梁或坂(Slab)時用0.15,梁深較厚則用0.10,故本圖表用以計劃,已足敷應用矣.茲舉二例以明其用法如次:

例三.　已知　$M=320,000$Kgcm.

$b=100$ cm,　$d=20$ cm

$f_s=1,260$ Kg/cm²　$f_c=42$ Kg/cm.²

$d'/d=\beta=0.10$.

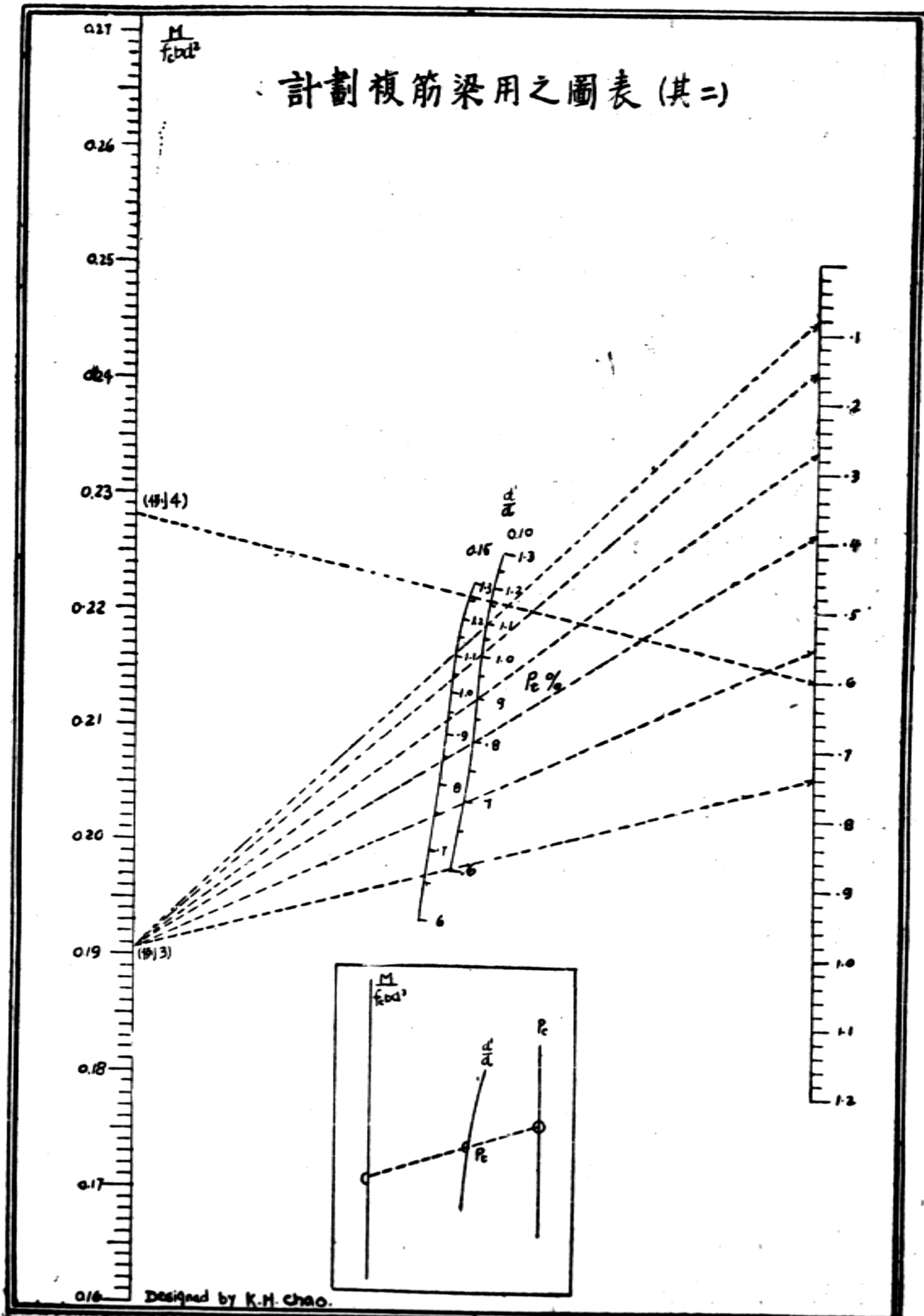
求上下鐵筋之百分比.

解.　今　$$R=\frac{M}{f_c bd^2}=\frac{320,000}{42\times100\times\overline{20}^2}=.1905.$$

由圖表二可得

$P_t=0.6\%$	$P_c=0.74\%$	$P_t+P_c=1.34\%$
$P_t=0.7\%$	$P_c=0.55\%$	$=1.25\%$
$P_t=0.8\%$	$P_c=0.39\%$	$=1.19\%$
$P=0.9\%$	$P_c=0.27\%$	$=1.17\%$
$P_t=1.0\%$	$P_c=0.15\%$	$=1.15\%$
$P_t=1.1\%$	$P_c=0.075\%$	$=1.175\%$

由以上之結果,可見抗張側之鋼筋用量大時較爲經濟.本項中以1.15%爲最經濟之鋼筋百分比.


計劃複筋梁用之圖表 (其二)
M / f_c bd²
(例4)
(例3)
d'/d
0.10
0.16
P_c %
Designed by K. H. Chao.

例四. 已知　$M=860,000$ in. lbs.

$b=12$ in. $d=22$ in.

$f_s=16,000$ lbs./sq. in.　　$f_c=650$ lbs./sq. in.

$d'/d=\beta=0.10$,

as$=4\sim\frac{7}{8}$''中$=3.06$ sq. in.

求抗壓側應須鋼筋之量

解. 今　$P_t=\frac{3.06}{12\times 22}=1.16\%$

而　$R=\frac{860,000}{650\times 12\times 22^2}=0.228.$

由圖表二可得

$P_c=0.6\%$.

故　as'$=0.6\%\times 12\times 22=1.584$ sq. in.

用　$2\sim\frac{7}{8}$''中　稍不足其所需,

(三) 第二問題之解法 (其二)

今假定鋼筋梁斷面bd及經濟鋼筋比 P,則此斷面所起之抵抗力率爲

$$M_1'=f_s P\left(1-\frac{k}{3}\right)bd^2$$

如此項斷面不足勝任外來之彎曲力率,其所不足之彎曲力率,應由上下二方各增鋼筋用量,使上下鋼筋所起之隅力,適足以抵抗其不足.苟鋼筋加於該斷面之內而不變其二側之最大應力時(卽使 k 値不變),此項增加鋼筋之量所起之偶力,應依原斷面所起之應力計算之.故在抗張側所增之鋼筋百分比,應由下式求得之:

$$M_2=M-M_1=f_s(d-d')as,=f_s\left(1-\frac{d'}{d}\right)P_1bd^2.$$

或　$$P_1=\frac{M-M_1'}{f_s(1-\beta)bd^2}\cdots\cdots\cdots\cdots(7).$$

故抗張側鋼筋百分比之總和應爲

$$P_t=P+P_1\cdots\cdots\cdots\cdots(8)$$

又由第一圖中之相似三角形A'OB',COD,而得

$$f'_s = f_s \frac{1-k}{k-d'/d} \cdots\cdots\cdots\cdots\cdots\cdots(9)$$

故抗壓側所用之鋼筋百分比P_c可由下式求得之

$$M_2 = M - M_1 = f'_s\ (d-d')as_2 = f'_s\ (1-d'/d)P_c\,bd^2.$$

或 $$P_c = \frac{M-M_1}{f'_s(1-\beta)\,bd^2} \cdots\cdots\cdots\cdots\cdots\cdots(10)$$

將(7),(10)二式中消去 $M-M_1$,而以 $f'_s = f'_s \frac{1-k}{k-d'/d}$ 代入而化簡之則得

$$P_c = \frac{1-k}{k-\beta}P_1 \cdots\cdots\cdots\cdots\cdots\cdots(11)$$

今因 $$M = M_1 + M_2 = f_s\ [P(1-k/3) + (1-\beta)P_1]bd^2.$$

∴ $$M' = \frac{M}{f_s\,bd^2} = P(1-k/3) + (1-\beta)P_1.$$

或 $$P_1(1-\beta) = M' - P(1-k/3).$$

∴ $$P_1 = \frac{M'-P(1-k/3).}{(1-\beta)}$$

而 $$P_t = P_1 + P = \frac{M'-P(1-k/3)}{(1-\beta)} + P \cdots\cdots\cdots\cdots(12)$$

$$P_c = \frac{M'-P(1-k/3)}{(1-\beta)} \cdot \frac{1-k}{k-\beta} \cdots\cdots\cdots\cdots(13)$$

故若已知 M, P, β, b, d, f_s 等值卽可由(12),(13)式直接求得其上下所需之鋼筋百分比.

茲將以上各式,求得一適合本國現在各市所規定之建築條例,假定 $f_s/f_c = 30$ (因 $f_s = 18,000$ lbs/sq.in $f_c = 600$ lbs./sq.in $f_s = 1,260$ Kg./cm², $f_c = 42$ Kg/cm²)

依以上之假定,則斷面內之經濟鋼筋百分比

$$P = 0.565\%$$

而中軸距比 $$k = 1/3$$

故 $$P_t = \frac{M'-0.565\% \times (1-1/9)}{1-\beta} + 0.565 \cdots\cdots\cdots\cdots(14)$$

$$= \frac{M'-.00503}{1-\beta} + 0.565\%$$

$$P_c = \frac{M'-0.00503}{1-\beta} \cdot \frac{2/3}{1/3-\beta} = \frac{2M'-0.01006}{(1-\beta)(1-3\beta)} \cdots\cdots\cdots(15)$$

今將(14)(15)二式,利用圖表學製成圖表一種,以資實施應用.今舉一例,以明其用:

例五. 已知 $M=320,000$ Kg cm. $\beta=0.10$

$b=100$ cm, $d=20$ cm,

$f_s=1,260 Kg/cm^2$, $f_c=42 Kg/cm^2$.

求 P_t, P_c 之值

解. 用(12)(13)二式之解法.

(1) $$k=\frac{n}{1+nf_s/f_c}=1/3$$

(2) $$P=\frac{f_c k}{2f_s}=0.565\%$$

(3) $$M_1=f_s\,p(1-k/3)bd^2=253,300 \text{ Kg cm.}$$

(4) $$M_2=M-M_1=320,000-253,300=66,700\text{Kg/cm.}$$

(5) $$P_1'=\frac{66.700}{1,260(1-0.1)\times 100\times \overline{20}^2}=0.00147,$$

(6) $$P_t=0.00565+0.00147=0.00712.=0.712\%$$

(7) $$P_c=P_1\frac{1-k}{k-\beta}=0.00147\frac{1-1/3}{1/3-0.1}=0.00421.=0.421\%$$

用圖表之解法.

先算出 $$M'=\frac{M}{f_s bd^2}=\frac{320.000}{1,260\times 100\times \overline{20}^2}=0.00635$$

由圖表三即讀得 $P_t=0.71\%$

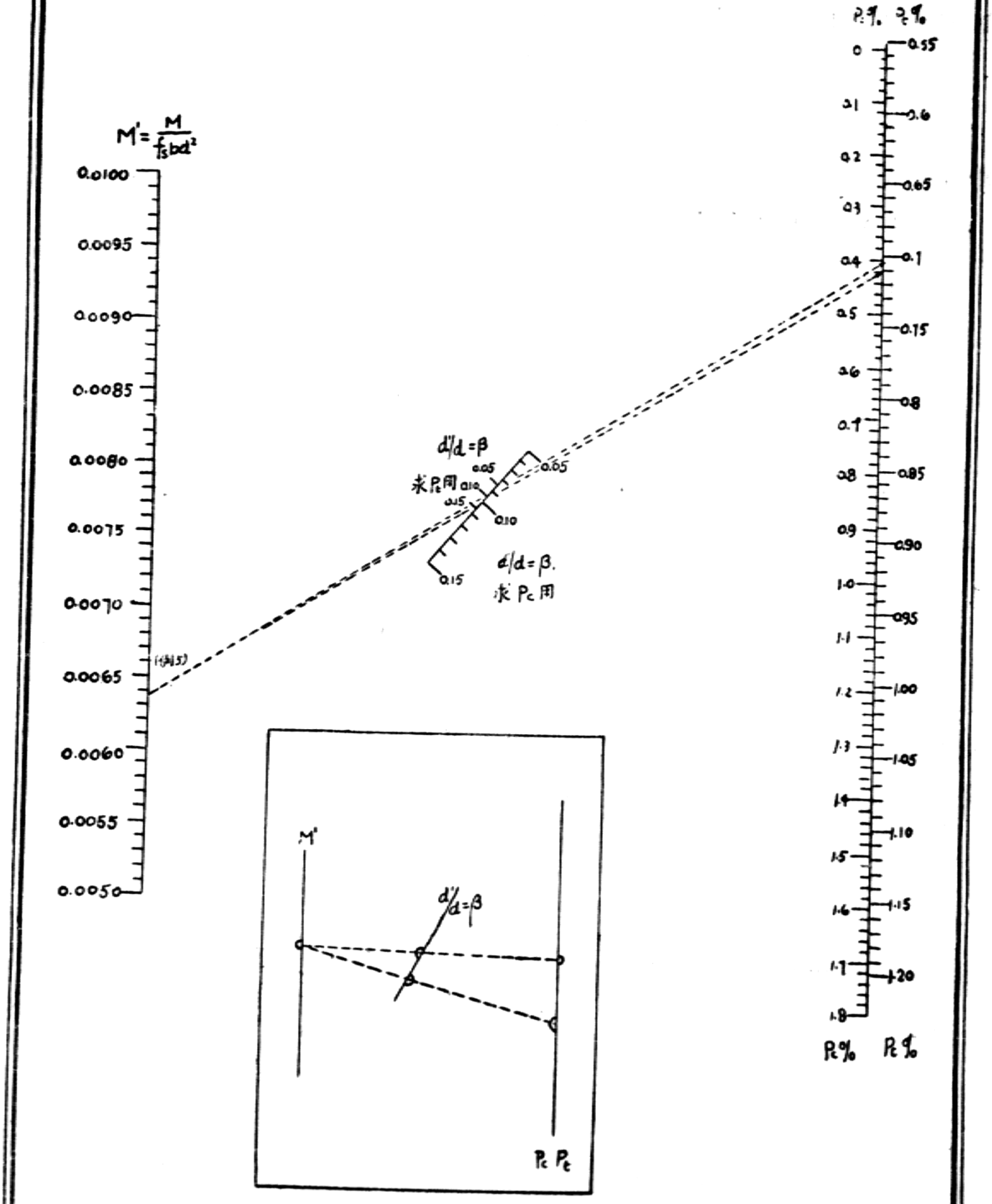
$P_c=0.42\%$

由是可知用圖表以求解答,其便捷較諸計算,何啻倍蓰而所起之差誤,又復極微.

(四) 結 論

本篇所附之圖表,其長處除能減省冗長之計算及撙節時間之外,尚俱有普遍之性質,無論所用之單位制度爲英制或公制,或爲市制,本圖表俱可應

計劃複筋梁用之圖表(其三)



用,今示一例如下:

例六. 已知　$M=64,000$ 寸斤(市制)　$\beta=0.10.$

$b=10$ 市寸　$d=6$ 市寸

$f_s=28,200$ 斤/市寸^2

$f_c=940$ 斤/市寸^2

求上下鋼筋之百分比.

解　$$M'=\frac{64.00}{28,200\times10\times6^2}=0.00644.$$

由圖表三讀得　$P_t=0.715\%$

$P_c=0.45\%.$

故作者以為欲決心改革單位制度,實非難事.如本篇所述之方法歸於單位制度所起之困難問題,消滅殆盡,無論何種制度均能適用,此點亦為本篇之特點.而圖表一舉,實為促進改革單位制度之急進先鋒,深幸我國工程界諸先進,起而圖之.

本篇因專就關於複梁之計算方法上着點,故不克附有良好而完善之實例,以明其步驟,深引為憾.但對於該項計算上所起之問題,大致俱可解決.故如能明瞭以上之步驟及方法,則在實施應用時,已足敷應用矣.又歸於施用圖表之解法,則每一例題,即在該圖表上用虛線表示其徑途,此項步驟,可不辯自明,故不贅述.惟該項圖表製成之方法,則因限於篇幅,不克序述,俟他日另有機緣,再行另立題目,專述此事可也.

本會編輯部啟事

下期(六卷二號)工程,專載本會在瀋陽東北大學舉行年會時,所集各種論文,稱為年會論文專號.該稿付印在卽,約於明年二月杪,可以出版.此啓.

十九年十二月

整理東北水利芻議

著者: 朱重光

(一) 概　論

東三省——遼寧吉林龍江,——位於我國東北隅,東控沿海州,以出日本海,南附朝鮮半島之背,以瞰日本,北扼黑龍江,以阻俄人東下之路,西控蒙古跨長城,以制中原,西南據遼東半島,以控黃渤,隱握東西兩洋之關鍵,此地理上之位置也.若以幅圓論之,東西廣約二千八百餘里,南北長約三千餘里,面積三百六十餘萬方里,較日本三島,幅圓約大二倍有半.其境內有最大之山嶽,——內興安嶺——,最大之川流,——黑龍江——,最大之平原,——內蒙古——,最良之海港,——大連,營口,葫蘆島——,其礦產約計六百處.林產有面積六萬方里,約占三省總面積六分之一.農產計十餘萬方里,約占三省總面積三分之一.他若水產,畜產等,亦無一不備.苟開發而利用之,卽此一隅之經濟,足以抵抗日,俄帝國主義之侵略,而况擁有百餘州之富乎?故論東北建設事業,凡我技術同志,亟應起而圖之,本各人之專長,盡個人之職責,抱互助之精神,謀國力之富強,豈東北一隅之福哉?重光服務東北水利事業有年,因就管見所及,草擬整理東北水利芻議,以就正於同志諸公,幸辱教焉!

(二) 河流之性質——國際河流,國內河流

東三省當蒙古高原之東,擁有三百餘萬方里之面積,其南北二部有最大之山脉,盤繞其間,故川河交錯,流域綿長,爲我國第三大河流,查東省與日,俄接壤,多以河流爲界,故東北河流有國際及國內之分.今將其較大河流,而有關於交通農利者,略述如下:

(甲)國際河流　(1)黑龍江流域——額爾古訥河,黑龍江,混同江,烏蘇里江(2)圖們江(3)鴨綠江

(乙)國內河流　(1)松花江,嫩江,牡丹江(2)遼河,柳河,渾河,太子河(3)大凌河

以上國際河流中,除鴨綠江外,均無海口,航行我國本部之輪船,不能駛入上述之河流.而該河流內之我國商輪,亦不能駛至中國本部.故東北貨物之運輸,非假道於中東鐵路,由海參威出口,即借路於南滿鐵路,由大連出口.每歲運費損失之鉅,不問可知,此就商業而言.若論及國防,危險尤甚.查東北江防軍艦九艘,困守松花江內,不能越三江口一步,黑龍江之江防,從未過問,此何故耶?蓋缺少海口,萬一與俄發生事故,我海防各艦,不能援助,孤軍無援,不得不示退讓也.

(三)　整理國內河流

東北國內河流之犖犖大者有三,即松花江,遼河,大凌河.後二者均有海口,故遼甯省貨物之運輸,可不假道於人.陸路由平遼鐵路直達關內.海道由營口以達四方.吉.黑兩省,則不然.陸路無直接關內之鐵道,水道缺直接入海之海口,貨物運輸,不假道於南滿,即借路於中東,利權外溢,年以千萬計,若不挽救,兩省必至受經濟之壓迫,至於民窮財盡而後已.挽救之道何如?實現總

理之實業計劃,開鑿松花江及遼河間之運河,爲治本之維一善策.蓋將來鑿成之後,其利益之點甚多,略述如後:

(1)黑龍江流域各河流,均有直接入海之海口

(2)吉,黑兩省之貨物,均可由水道運輸,運費比鐵道爲廉.

(3)可以振興營口之商業,與大連,海參威競爭.

(4)可以打倒日,俄之鐵路侵略主義.

(5)可以聯絡海防江防,鞏固我邊陲.

至於運河之路線,參考日人濱井松之最新滿洲全圖,在東遼河與伊通河之間:(一)由東遼河流域內之十屋地方起,經懷德縣城至大嶺鎮,與伊通河合流約長三十六公里.(二)由十屋上流雙城堡起,經三道崗,至大嶺鎮下流萬家橋附近,與伊通河會合,其長亦不過三十六公里.其工程費假定每公里十九萬元,(據孫哲生部長去歲雙十節發表之建設大綱草案新開運河經費預算每英里三十萬元).共需國幣六百八十四萬元.區區建設費,或由兩省分擔,或由中央建設經費項下支出,想易爲力也.對於黑龍江流域之河流,如松花江,嫩江,牡丹江等開濬工程,均歸東北水道局辦理.遼河,柳河,渾河及太子河等之整理工作,均歸遼河工程局辦理.分工合作,三五年後,行見最重要之運河,最流長之幹河於東北,豈不快哉?至大凌河之工程,將來可歸開闢葫蘆島商埠工程局辦理,蓋該島在大凌河口,有直接關係在也.

(四) 整理國際河流

吾人對於國際河流,偶不注意,強鄰將佔爲己有,譬如黑龍江,乃中,俄兩國之國際河流.今俄艦向兩岸可以自由行動,而我艦不但不能至俄地,併我國河流不能駛入,不平等何如?不自由何如?況整理黑龍江之經費,中,俄各半,由黑河中國海關支付.工程人員均係俄人,而中國方面河流,是否年年修濬,向無報告,中國官廳亦未過問,權利旁落,宜乎俄人之野猴自大矣.今爲爭自由

平等計,首先停給修濬經費,工程歸東北水道局負責,且將修濬經費,以補該局工程經費之不足,是則望於東省當局者也.黑龍江問題如能解決則混同江,烏蘇里江,及額爾古納河均可迎刃而解矣.

鴨綠江爲中韓之國際河流,上流有極大森林,下流有不凍港口,日人將在安東添築商港,以壟斷鴨綠江.今爲抗制日本侵略主義保護我國領土計,依照　總理之實業計劃,將安東闢爲漁業港,爲唯一補救之策.

圖們江爲中,韓及俄,韓之國際河流.上流爲中,韓合流,下流爲俄,韓合流.我國竟被俄,韓封鎖入海自由,喪失殆盡,此誠外交上之傷心史也!此江爲吉林入海最近之道,且與吉會鐵路平行,北滿貨物之輸出入,均可由此江轉運,商業之發達,可與俄之海參威及韓之清津爭霸.今欲達到此目的,非將江之左岸(自江口溯上三十里)之地恢復不可,如我國以革命外交爭之,或有一線之望,此則非我技術同人之責,乃執政諸公之任也.

(五) 結　論

整理東北水利,旣如上述,但茲事體大,實行談何容易.其最困難之處,有下述數點:(一)東北介居兩大之間,外交棘手,一舉一動,易起衝突;(二)因政治關係,經濟更受影響,建設進行,遂被阻止;(三)東北人士,素抱門羅主義,不論人之才學如何,不顧本地有無人才,非我者去,爲客者逐,技術同志,每多却步;(四)主持行政者,往往爲腐敗官僚,工程經費,藏而不用.有此種種原因,故東北建設事業之前途,整頓實未易言也.愚意東北河流,或屬國際,或屬兩省,整理之權,應歸中央管轄,由中央建設委員會主持辦理,則事權統一,旣可免兩省之爭,(遼吉爭辦東北水道局甚劇),而　總理實業計劃,亦於此可以完成矣.敢貢區區,倘希諸同志有以教之,幸甚!

THE DESIGNING OF HIGHWAY CONCRETE FRAME STRUCTURES FROM A PRACTICAL POINT OF VIEW

By Wm. H. F. Woo, M. S.

Synopsis. — Compared to other types of structures used in highway constructions either to bridge streams, or for grade separation, the concrete frames are little used, and judging from my personal knowledge, such a structure is not classified as a standard structure. Like railroad turnouts, no two frames are of exactly identical design, this being on account of the difference in physical and geological conditions in the locations where they are built, difference in the loading they are designated to carry, and several other factors affecting the design.

This paper deals with and discusses the methods commonly employed in the design of frames and the arrangement of members and reinforcement, attempting to throw some light on the practical side of the design. Discussions in this paper are written primarily to apply to frames when such are used as highway structures, but, as will be found, a great part of them can apply with equal force to similar structures designed for other purposes.

Generol Considerations. — A frame is a structure consisting of a girder or girders and columns, the ends of the girder being so rigidly connected with the columns supporting it, that deflection of one will cause deflections of all other members thereby inducing stresses in these members. The columns may be designed as, and built with fixed, free ends or any state intermediate between these two limits. Like a simple structure, the girder is the first member to take the load the structure is designed to carry, which then traverses through the joint, pass the footing, and then reach the foundation.

The use of frame structure as a highway bridge type is so far limited to those appearing in the forms of viaducts and overhead structures used in grade spearation. For bridging over streams of normal magnitude, it has not been much adopted due to its unsightliness and difficulty of its construction at such locations, and danger of being disturbed for being near the water.

Frames as overhead structures are very common, and in fact some railroad companies in the United States specifically desire that only such be the type built over their tracks for grade separation.

Frames as viaducts are also common. They are adopted not only due to the saving and economy it offers as compared to the similar concrete structures, but also due to their stiff resistance to longitudinal and lateral deflections. This latter property owned by some types of structures is gradually receiving attention and appreciation of highway engineers on account of the great number of fast moving vericles travelling on highways at the present time, whose speed constitutes a better agent of attacking on less rigid structures.

Whether a frame is an economical structure or not depends to a considerable degree upon the way in which the floor system is arranged. The types of floor system commonly adopted to such structures are three: (a) slab type in which the beams are omitted, the load being directly transmitted from the slab to the girder, (b) slab and beam construction in which the floor beams are arranged perpendicular to the roadway supporting the slab and and resting on girders, (c) like (b) only stringers are added. In several of the actual designs, the writer had occasions to investigate each of these arrangements and compare their relative economical value and reach the following conclusions:

(1) The use of (a) system is limited to those frames with short spans in which the dead load alone does not form a great part of the total moment from which the section is determined. The omission of floor beams necessitates that a thicker slab be used and therefore brings more dead load to the girder than in the case when the floor beams are used.

(2) Under any circumstance, type B is the most economical arrangement, and with skillful arrangement of the girders and floorbeams, the panel of the slab enclosed on the four sides by girders and floorbeams can be made to approximate a square, and therefore a doubleway reinforcement can be used. Any load that comes on the slab is distributed among and carried by the two systems of reinforcement. Thus a thinner slab may be used, and therefore a deduction in dead load is the result. It should be added, however, that by using the double system more steel is required, but the thickness of the slab is greatly reduced. Considering the prices to be paid for each, the amount saved, expressed in terms of money, through the adoption of thinner slab under ordinary circumstance is more than that to be spent for the additional steel resulted from the use of double reinforcement. The thinner slab contributes a lesser dead load to the structure, thus indirectly affecting a further saving in the cost of entire structure, a factor demanding

notice for long spans frames, say over 50 feet. (c) The use of stringers in addition to the floor beams system that was mentioned above is not general on account of the added expense to pay for the complication of form that result. The sections of the stringers with the lengths that are commonly designed are generally governed by the allowable shear at the ends and when this is the case, it explains itself that much concrete is wasted at sections where the allowable shear is not exceeded.

In general it may safely be concluded, that the floor system of a frame structure unlike that of a simple structure cannot be economically designed without a consideration of the arrangement of the other members with which it acts as a single unit. Under some circumstances the type of floor system cannot be choosen at randem to fit economy or to suit the wish of the designer and is dictated by the local conditions. Thus lack of head room, unfavorable foundation conditions are some among the governing conditions.

The designing of a highway frame structure is a problem requiring sound judgment in addition to precision in computations. The arrangement of the structure, that is the manner in which the columns, girders and floor systems are connected to form a unit, is very much determined by local physical requirements and geological conditions, and the success of the design depends upon the degree of thoroughness with which these matters are investigated.

Good subsurface foundation is one of the chief elements favored to the erection of a frame structure. It is a fatal policy to try to build a frame on foundation whose bearing value is low or nonuniform. Poor foundations cause settlement of the structure and if the settlement is anything but uniform, it is detrimental to the structure, for it causes tremendous stress in the entire structure even for a slight unequal settlement, the magnitude being dependents upon and varies with the rigidity of the members connected to form the structure.

As a foundation for frames and for every kind of structure there is nothing that is better than sound rock. The allowable bearing value of this kind of foundation is usually no less than the working stress of the concrete of the columns resting on it. In such a case, spreaded footing is theoretically unnecessary. If the distance of the rock below the ground level is not too great to prohibit the arrangement, on account of economical reason, the columns should rest directly on top of the rock or be keyed into it according to whether they are designed as with hinged or fixed ends.

As has been said, the foundation conditions dictate to a great extent the locations of the columns. As we all know, there is seldom a case in construction where the foundation under the ground is so uniform in character that it does not offer an economical problem in connection with the design of the structure. Rock, for instance, has sharp drops and steep slops, and it is entirely common that two borings located only several yards apart find the difference in elevation of the rock to be several tens of feet. Therefore a profile giving full details of the information of the subsurface condition should be in the hands of the designer who after careful consideration of it should determine the places where the foundation alone permits the location of the columns.

The columns should be placed at points so that they will satisfy every designing and physical requirement. When the frame is a grade elimination structure, the columns should be located outside the boundary lines of the right-of-way of the tracks over which the structure spans. As for a viaduct structure the columns may be located in such a way as to produce greatest economy.

The arrangement of the columns with regards to the girders depends a great extent on how the floor system is arranged. In the usual type of construction where the girders and floor beams are used, there is placed one line of columns to every line of girder. Longitudinally, the girders and columns are connected to form the frame to carry the vertical load. Transversely, the tops of the columns should be connected rigidly by a cap, thus forming another set of frames to take wind and eccentric force from vehicles running on it. This arrangement is the most economical serving the purpose of transmitting such loads to the foundation.

Frames may be built of a single span or of multiple spans. The multiple span frame gains advantage over the single one in that the maximum positive moments at the center of the girders are less than that of the corresponding point of the single spanned one of similar design and therefore its girders require a smaller cross-sectional area. On the other hand, the former requires a better foundation, and if the foundation falls short of satisfaction, they should not be adopted.

Frames may be designed and built with fix-end columns or hinged end columns. The use of hinged-end columns concrete frames as highway structures is very limited on account of (1) the difficulty involved in making the hinge that will function as a hinge, (2) little economy that will derive from its use when compared to a simple structure (3) difficulty of construction and (4) greater deflection both horizontal and vertical as compared to a similar structure with fixed columns ends. However, when the foundation is subtle and if ever a frame is to be built on it the use of a hinged end column frame is preferred to a frame with fixed end column frame, for to the former structure, the effects of unequal settlements of the foundation are not as seriously as to the latter. This rule however only aplies to single-span structures.

Temperature stresses sometimes play such an important part in the entire structure that it may need careful consideration of the designer. Like in arches, the temperature stress is a function of and varies with the rigidity of the members and connections, and with the overall length of the structure. Temperature variation exerts greatest stresses at the connections of the end columns and girders, where the structure is the weakest, and therefore where it should receive most careful consideration. (It is not uncommon to have the temperature stress at these points some 20% to 30% of the d. & l.l. stresses combined). When the temperature stresses at these section are so high as to endanger the safety of structure, some means of reducing it is necessary. The most effective method of doing this is to reduce the rigidity of the end columns. By this is meant either to reduce the cross-section area of the end columns (or more exactly the moment of Inertia of the end columns), increase the lengths of the columns, thus making it more slender, making the ends of the end columns hinged if the original design is of fixed ends, or a combination of these. If these remedies still do not help to reduce the temperature stress as low as is desired, then the final step should be resorted to, namely that of disconnecting the joints of end columns and girders, thus making the girders simply supported at these points and reducing the temperature stress to absolute zero.

Preliminary design and dimensions. — After the arrangement of the frame and floor system is determined upon a rough design should be made next on the floor system to get the approximate thickness of the slab. In this connection, concentrated loads, instead of uniform, usually govern the design. The value of the thickness of the slab will be used in calculating the approximate dimensions of the girders.

The preliminary dimensions of girders may be either interpolated from a structure of like design and dimensions and carrying like loads, or determined through employment of approximate calculation. For this, uniform loads are to be employed for live load. For the coefficient of moment, a value of 1/12 to 1/16 may be used, depending upon the degree of the rigidity of columns. The width of the stem is usually governed by the number of bars desired to be placed in a row in it. Thus for a span length of 50' say, a width of 2'-0" is usually adopted, allowing seven bars to be placed in a row.

There is no frame with a span length of say 50′ and economically designed that can safely resist the load without the addition of haunches at the ends of the girder. The depth of the haunch is determined primarily by considering the total shear at the section and the unit shearing stress allowed. The value of total shear referred to above may be obtained by assuming the girder to be simply supported.

The width of column is usually made the same as that of the girder. The depth of this column is another uncertain matter requiring judgement. As will be noted later, the deeper the column the more close the girder acts as a fix-end beam, and therefore a more economical combination is produced.

If a multiple span frame is determined upon, it is advisable to have the spans of approximately same lengths. This rule is established on the assumption of course that the geological and physical conditions permit it.

If the span lengths in a multiple span frame are approximately the same, it is advisable to make all the girders of the same depth. By so doing, the process of designing is greatly shortened, and a great deal of labor required to detail the steel is reduced.

Methods of Analyzing the Frame Structure. There are in use several methods to compute analytically frame structures. The following are the ones more often used:

1. Slope and deflection method
2. Area moment method
3. Method of least work
4. Method reciprocity.

All of these, however, are based on the same principle, namely the principle of Elasticity, and for any given problem, they should yield the same result.

It is not within the scope of this paper to discuss the theories involved in each of the above methods. Neither should there be such an attempt, for almost every method mentioned above is well discribed in standard text books dealing with indeterminate structures. Technical periodicals sometimes also carry descriptions as to how these methods applied in the solution of actual problems.

Of all the methods suitable for the solutions of frame problems the slope and deflection method deserve special mentioning and recommendation as it is this method that has been developed to such a practical form and involves so many mechanical fool-proofing features that it earns itself the reputation as being the easiest to apply.

Nearly all the methods used in the solution of statically undeterminate structures involve the assumption that moments of inertia of the members composing the structure are of constant value. With a reinforced concrete frame, the moment of inertia varies from section to section in any individual member, on account of the variations in reinforcement and different effectiveness of the concrete in taking tension. Many argued that since the values of the moments of inertia are used only as a means of determining the relative rigidity of the members composing the frame, the reinforcement may be omitted from the consideration and that plain concrete sections may be used for the calculation of such values without introducing serious errors. This opinion finds the favor of most of the designers, and this method is greatly followed.

After the values of I, the moment of inertia, are ascertained, actual computations may be started, using any of the methods that a designer is in favor of. In order to determine the maximum stresses at different sections, influence lines should be drawn. The method called the "Fix point method," "Feste Punkle," is recommended to the designer for expediting the drawing of the influence line. Maximum moments and shear should then be calculated at regular intervals of the girder and curves should be draw connecting the extreme values. Such curves are of great service to the designer, and in important structures are an absolute necessity.

Details of Design. (1) *Column.* The cross sectional shape of columns most used in frame structures is rectangular. As has been said, the width of the column is generally made the same as that of the girder resting on it. By so doing, the form work is simplified and the steel can be more accurately placed.

For columns with fix ends the cross sectional area of the column is usually maintained constant throughout the length of its column. The fixity of the column at the ends is usually produced by keeping the footing into the rock foundation when it is within reasonable reach or by other means: such as capping on piles, etc. The depth of the column should be such that it will give a section great enough to carry the load. In general the more deep the column the greater is the economy, provided by so doing the stresses due to the dead and live loads and especially from temperature change are still kept within allowable limit, that it will not spoil the look of the entire structure and that the column is not too high.

The reinforcement in the column should be arranged as symmetrical about the gravity axis as is practical, so as to reduce the eccentricity to a minimum. For intermediate columns, this is possible, economically, for the stress there are mostly in the form of direct loads, the moment is generally small compared to the outside columns. In end columns, the moment is generally high and the direct stress low as compared to those of the intermediate columns. In such columns, a symmetrical arrangement of steel generally indicates a waste of steel, although a better structure is resulted. It is the job of the designer to determine that arrangement which is best to suit the local conditions.

The moment diagram of a column with fix ends due to dead load and live load is a straight line varying from + to —, with a zero value at a point 1/3 up the base of the column. The moment at the top of the column has the maximum value and is twice that at the base. The temperature change casues the maximum moment at the top of the column. Therefore at this section, the steel area should be more than at any other section of the column. At a certain distance downward from the section above referred to, a part of the steel may be stopped, to conform with steep slope of the moment diagram. By so doing, a great percentage of steel is saved.

When a column is hinged, the cross section area may be made constant or variable, increasing with the distance between the base of the column and the section to conform with the moment diagram which in this case, is a straight lino varying from 0 to the maximum at the top of the column. If the latter method is followed some concrete is saved but it is handicapped by the resulting complication of form work. A careful designer should adopt the one that is on the favorable side of economy.

The hinge of the hinge end columns may be either a mechanical provision or merely the result of manipulation of the steel in the column. Mechancial hinges are expensive for concrete frame structure, and are therefore little used. The latter method is generally followed. It is accomplished by stopping the steel in the column above the hinge section, and leaving only few to pass through the center of the column to connect it with the footing. The steel being at the center of the section, the section is unable to take moment, for concrete of the section, the section is unable to take moment, for concrete is not able to take tension, as is commonly assumed. After the structure is loaded, the concrete at the hinged end is cracked leaving the steel alone to take the shear. Such an arrangement is open to objection because the cracked concrete absorbs water easily which may do damage to the structure in time of freezing. To eliminate this danger, a curved plate may be used at the base of the column, through the center of which a hole is punched. The plate is concreted with the columns and rests on the prepared footing. The reinforcement in the column is allowed to run through the hole of plates and is then securely fastened in the footing. It will take the shear; but no moments. In this way, a much better arrangement is resulted. It is necessary that that part of the reinforcement exposed to the weather should be coated to prevent corrosion.

With the size of column usually employed the unit shearing stress in the column is usually so low that it will not modify the spacing of the hoops commonly adopted in simple columns of similar sizes.

The joint between the end columns and girders should be well protected with reinforcement on account of the high moment there that result from the dead and live load and temperature variation. If every part of the structure is designed with equal care and if ever a sign of weakness appears after the structure is built, such a sign most likely appears first at the corner above mentioned. The failure of the corner to take the load is not a local problem, for it disconnects the continuity of the girder and columns, thus causing the positive moment in the girder to increase and may finally be a cause of the collapsing of the entire structure. It is a job of a good designer to arrange the steel at this part of the structure to take care of the moment and direct load fully and economically. The following rules may be used as a guide to produce a good design:—

(a) Try to arrange the steel as symmetrically about the gravity of the columns as possible.

(b) Do not use too many short bars, for short bars usually produce undesirable stresses at the places where its ends are and where the stresses are high.

(c) Extend the bars far enough from the points where they are unnecessary and hook the bars at their ends. Steel spent this way is usually justified.

(d) Do not attempt to run he bars from the girder to the column for such bars are hard to place in the field and hard to hold accurately in place in the form.

(e) Be a little extravagant in using hoops and stirrups at this part of the structure. They prevent the main reinforcement from buckling when they are under stress.

(f) Be not liberal to let the stress exceed that allowed.

(g) Girders. The design of the reinforcement in the girder is similarly to that of a fixed end beam if the frame is a single span frame and to that of a continuous beam if it is a multiple span frame.

Before any actual design is started, it is best and advisable to have the maximum moment diagrams drawn, using any one of the methods mentioned in the foregoing. These diagrams give one the notion as to the amount of steel area required at different section and give indications as to where the steel may be bent, after the steel at the important sections is designed.

To save reinforcement, advantage must be taken to the limit in making use of the slab above the girder which two form a T-Beam. This is possible only in the design of positive steel, that is steel taking positive moment. For negative moment, the slab is on the tension side, and therefore only the rectangular section should be considered in designing the reinforcement.

As has been said before, haunches are necessary in almost every frame used as a highway structure to take care of the negative moment and reduce the unit shearing stress to within allowable. The depth of the haunch at the springing is usually governed by the latter. The bottom of the haunch may be a straight line or a conical arc, depending upon the desire of the designer. Although it enhances the looks to some extent, the using of curved bottom haunches is hardly justified. It complicates the formwork, and the bending and placing of steel, and therefore is more expensive than the straight haunch.

The design of shear reinforcement in the girder is the same as that for simple structure after the total shears at various sections are known. Bars of the main reinforcement may be bent up or down to take shear at points where they are not needed to take the bending stress. The ends of the bars disposed in the way are thus utilized in a most economical manner. A word or two, however, should be mentioned with regard to the bending of the bars in the view of making them to do the service as is expected. In bending the bars of simple beams, the bends are usually made long enough so that it will pass the neutral axis for a certain length, say a certain number of diameters, so that it will develop the tension through bond in the compressive area along that length. In the girder of a rigid frame, however, the positions of neutral axis are not definitely located and they change with different loadings. It is therefore reasonable that a greater length of imbedment than that mentioned above should be allowed to assure that the bars will work under any loading. A still better structure will be produced if the bars are extended to meet and then run side by side with the steel on the other side of the axis for a distance say ten times the diameter of the bars bent. With bents of this shape such bars will not only take the shear effectively but will function as stiffners in plate girders, and therefore are in one way a safeguard against distruction caused by the impact of the modern wheel loads.

DIRECT GENERATION OF ALTERNATING CURRENT AT HIGH VOLTAGES

By the HON. SIR CHARLES A. PARSONS, O.M., F.C.B., F.R.S., Honorary Member, and J. ROSEN, Member

(Continued from Page 544 Vol. V, No. 4)

The end-windings illustrated in Fig. 8 are composed of flat copper strip formed on edge and having a full radius on the edges. This formation gives a very rigid construction, enabling it to withstand the stresses set up on short-circuit. Additional mechanical support is given to the end-winding strips by fitting them into recesses formed in the impregnated-wood supporting clamps.

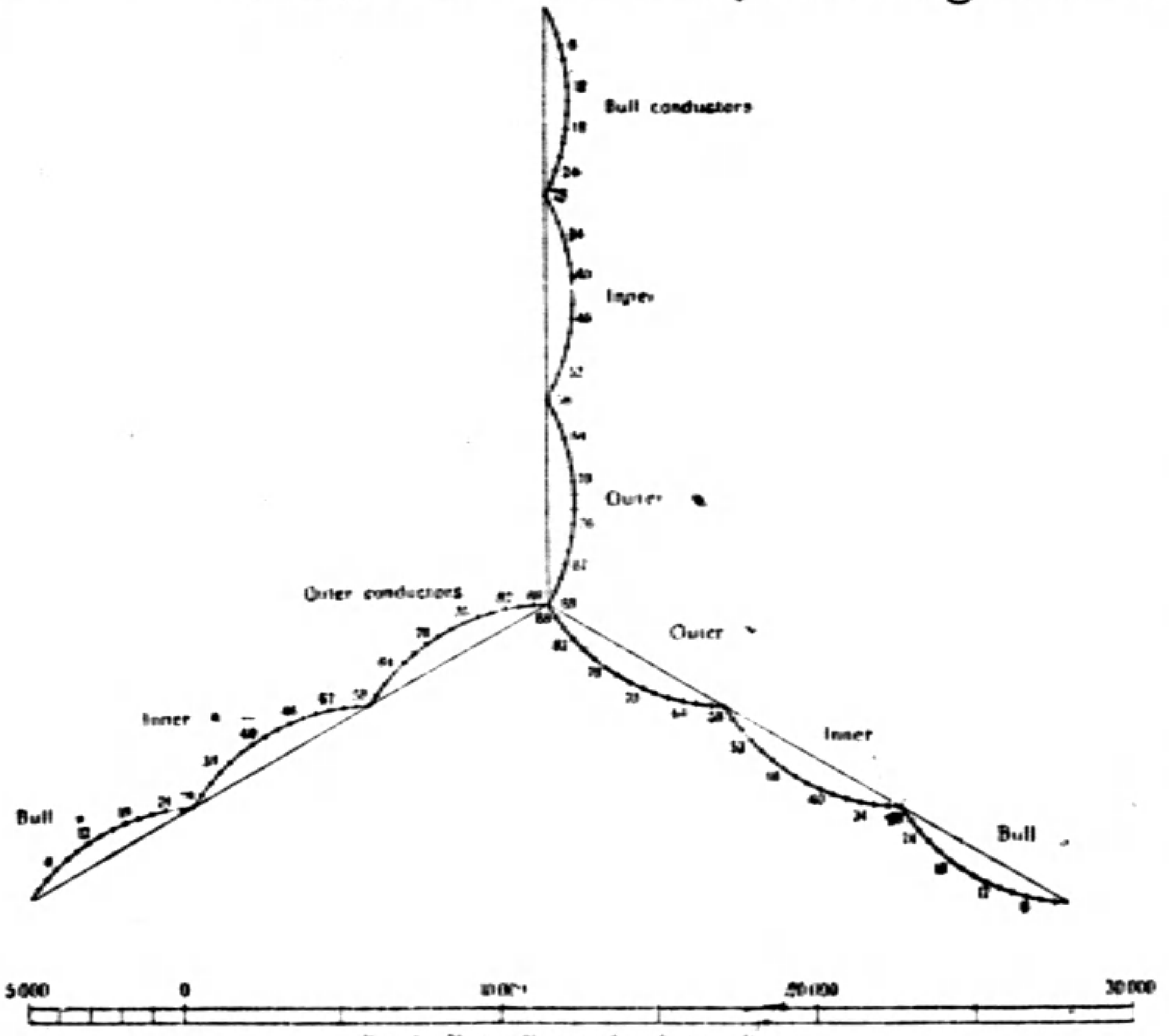


FIG. 5.- Vector diagram of conductor voltages

There are three banks of end-connections in each phase, corresponding to the "bull," "inner" and "outer" conductors. The cross connections between each bank are provided with removable links to enable each third of the phase to be pressure-tested separately. The link forms a ready means to fit between-turns protection if desired.

Ample distance is provided between phases, so that it is unnecessary to provide insulating shields between the end windings, and adequate leakage surface is also provided over the impregnated-wood packings between the phases.

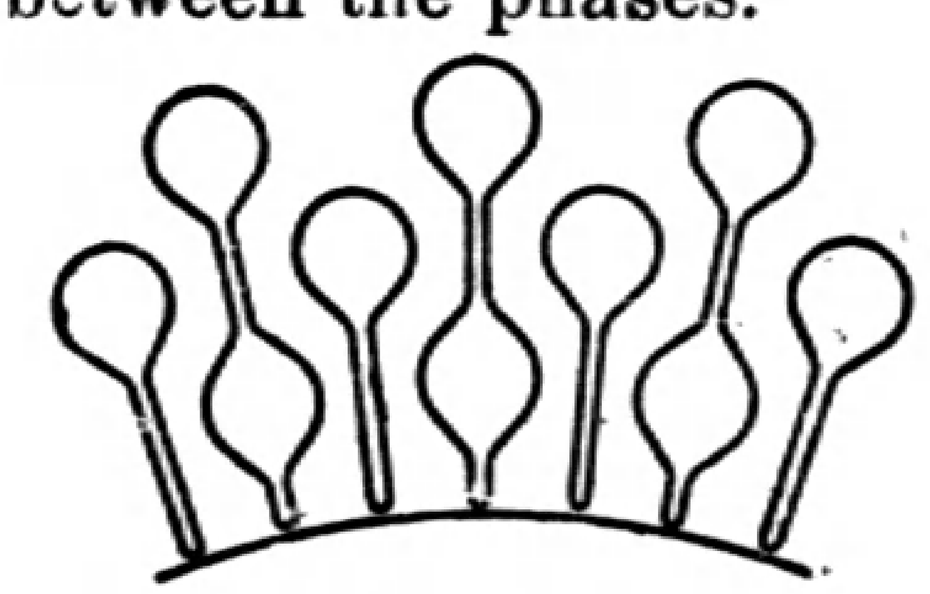


FIG. 6.—Conductor slots arranged in three rows.

In a normal design of alternator the full phase potential exists between banks in the end-windings. In the high-voltage alternator design the end-connections for the "bull" conductors of one phase are adjacent to the end-connections joining the "outer" conductors of another phase. The difference in potential between the phase banks is therefore less than the normal voltage between phase terminals. Thus the maximum potential difference in the end-windings between the adjacent conductor No. 1 in any phase and No. 58 in another phase is, from Fig. 5, referred to above, only 23,000 volts.

A 25,000-kW, 31,250-kVA, 33,000-volt, 3,000-r.p.m. alternator incorporating these principles was built for the North Metropolitan Electric Power Supply Co., Ltd., for installation in their new power station at Brimsdown, North London. It has been used as a basis in describing above the features of the winding. A part cross-section of the stator and elevation of the end-winding is shown in Fig 9.

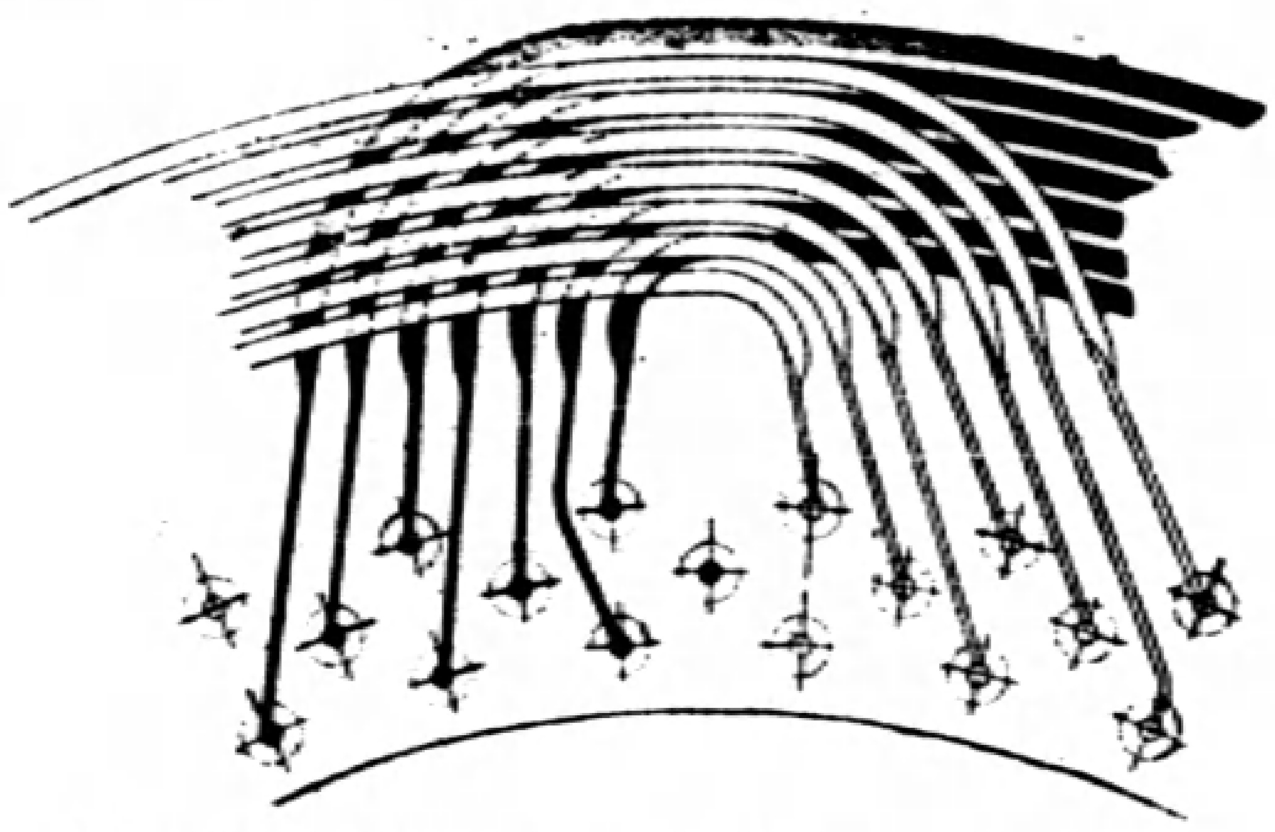


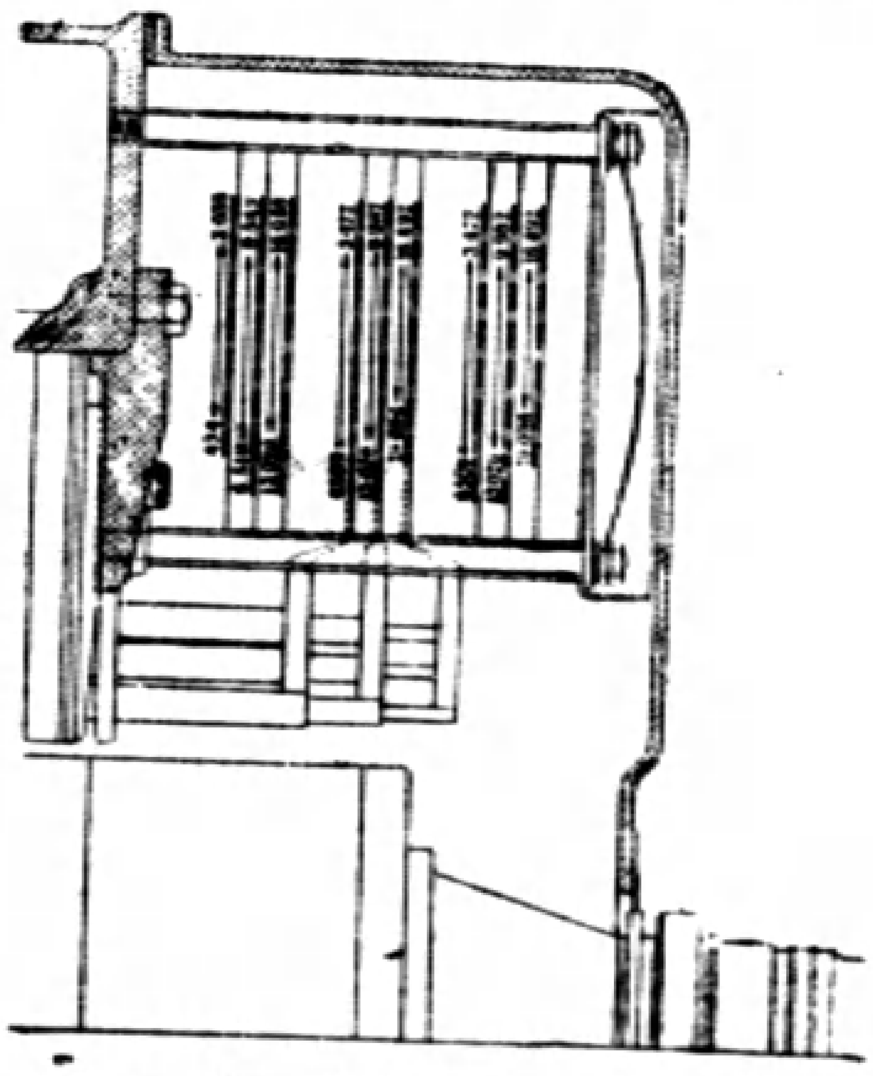
Fig. 7.—Position of highest-potential conductors relative to adjacent phases.

Apart from the stator windings and mechanical details, which have been modified in other to meet the special features in the design, this alternator is of standard construction.

A short account of some of the original experiments is given, together with a few notes upon the tests made during construction and on completion.

(7) An Outline of the Experimental Research Carried out in the Development of 33-kV Alternator, and Tests on the Completed Alternator, at Newcastle. Operating Experiences on Site.

Any departure from accepted design, however small, can only be accomplished successfully after extensive research. This is particularly so in large electrical apparatus, where, in addition, the proof of actual operation must be applied. A few of the tests previous to and during the assembly of the alternator are outlined below.



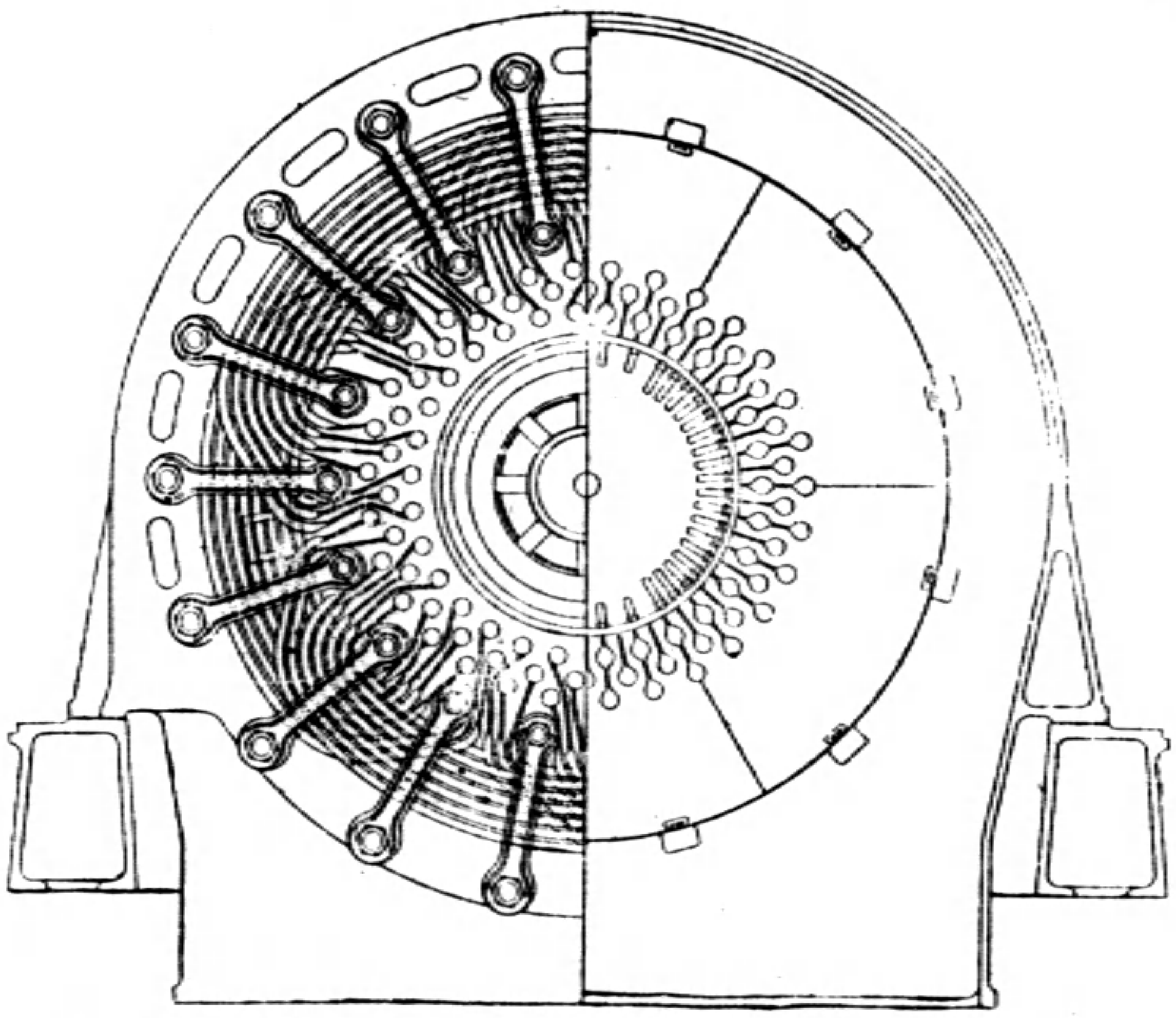
Gig. 8.—Diagram showing voltages of end-winding connections of 33000-volt altnator.

Stator tooth-heating test.—A section of the core plate was assembled and wound with a temporary winding in order to check the local heating which might result from the staggered disposition of the stator slots. The temperatures did not exceed those of an alternator of low voltage.

Pressure-testing apparatus.—A single-phase transformer with a voltage ratio of 440/110,000 was used for all pressure tests. Tappings were brought out at one-third and two-thirds of the maximum voltage.

In order to overcome the liability to flash-over at the pressure test of 10,0000 volts, individual bars while under test were immersed in a bath of varnish.

Test conductor bars were constructed, one set being un impregnated and a second set being impregnated after the application of each insulating tube. The latter bars, as seen from Fig. 10, had 30 per cent lower dielectric loss.



Elevation of stator end-windings. Part cross-section of stator.

FIG. 9.—33 000-volt, 3-phase, -pole, 3 000 r.p.m., 31 250-kVA alternator

The distribution of electrostatic capacity between the three conductors is given in Table 2.

The corresponding figures for a single conductor bar of an 11,000-volt alternator of similar output is 0.00024 μF per foot run obtained from test, the calculated value being 0.00028 μF per foot run.

Reliability tests extending over several months were made on the test bars, and an extract from the log is given in Table 3.

TABLE 2.

Capacity per Foot Run.

Position	Concentric bars	
	Measured capacity	Calculated capacity
	μF	μF
Between "bull" and "inner"	0.00018	0.00025
Between "inner" and "outer"	0.0008	0.0005
Between "outer" and "sheath"	0.00034	0.00046

The potential gradient across the in sulation in single-core and 3-core cables, with the same sectional areas, is given in Figs. 11 and 12. It will be seen that the maximum gradient is considerably less in the 3-core concentric cable. Flaws, such as cracks, or air pockets, are less liable to occur in the concentric cable, as the layers of insulation are much thinner.

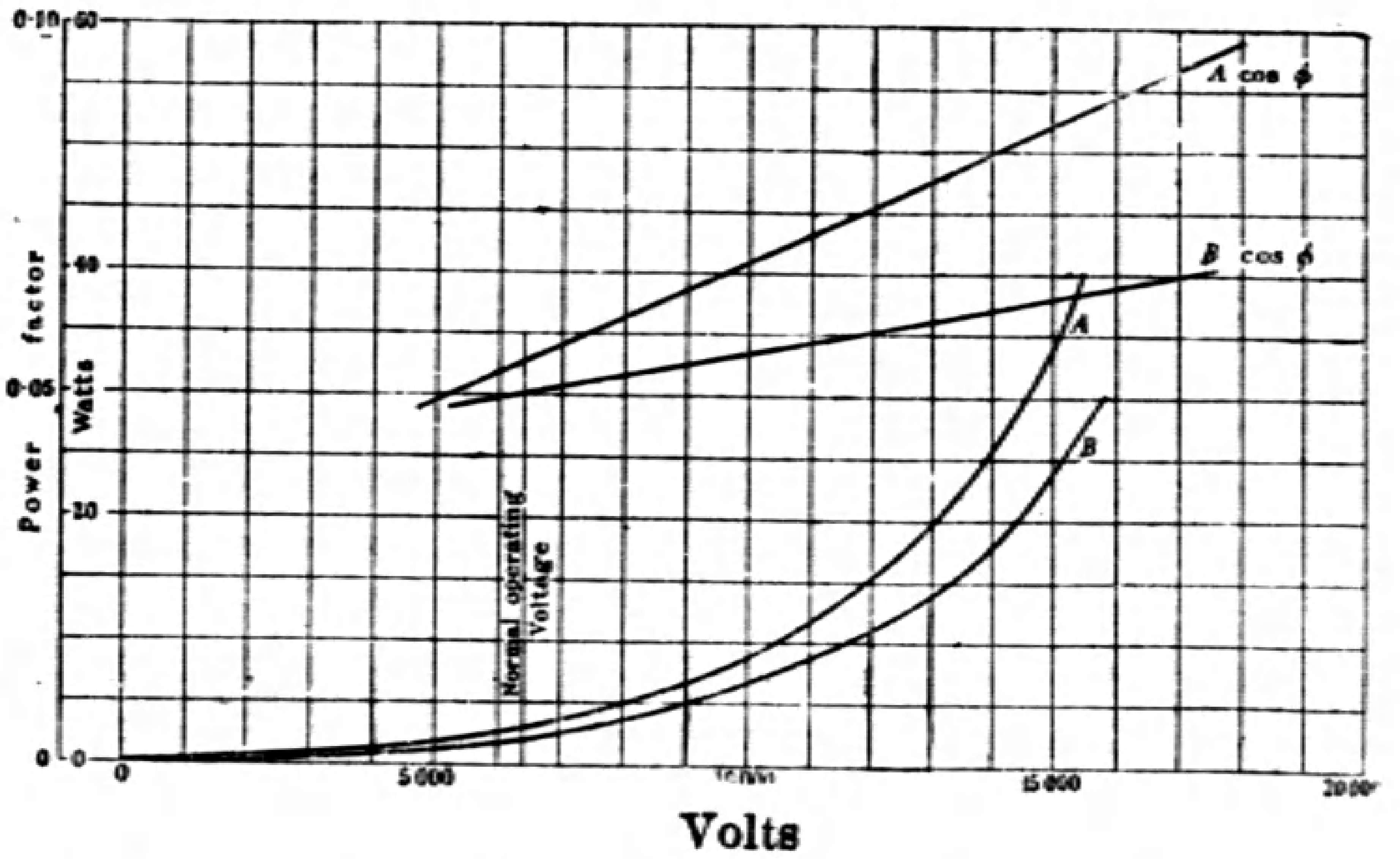


Fig. 10.—Comparative curves showing losses and power factors of concentric conductors at various voltages.
A. Un-impregnated. B. Impregnated.

Pressure tests.—On the completion of the winding the following pressure tests were applied:—

"Bulls"—67 kV between phase terminals and to earth.

"Inners"—45 kV between phase terminals and to earth.

"Outers"—23 kV between phase terminals and to earth.

Testing arrangements.—The alternator was erected in the shops on a specially designed test-bed. It was driven from an 800-kW steam turbine and coupled in paralled with a 750-kW d.c. motor driving through gearing. Either machine was capable of driving the alternator at full speed when fully excited. A completely enclosed air system, with a fan delivering 40,000 cub. ft. of air per minute, and surface air cooler, was provided for cooling the alternator.

Table 3.

Average Dielectric Loss in the Bar.

Test conditions	Voltage		Bar temperature		
			20°C.	60°C.	110°C.
33 kV on "bull" ... ... 22 kV on "inner" ... ... 11 kV on "outer"	174 per cent	Dielectric loss Leakage current	30 watts 0.008 amp.	105 watts 0.016 amp.	235 watts 0.03 amp.
19 kV on "bull" ... ... 12.8 kV on "inner" ... ... 6.4 kV on "outer"	Normal	Dielectric loss Leakage current	1.4 watts 0.001 amp.	18.8 watts 0.004 amp.	61 watts 0.008 amp.

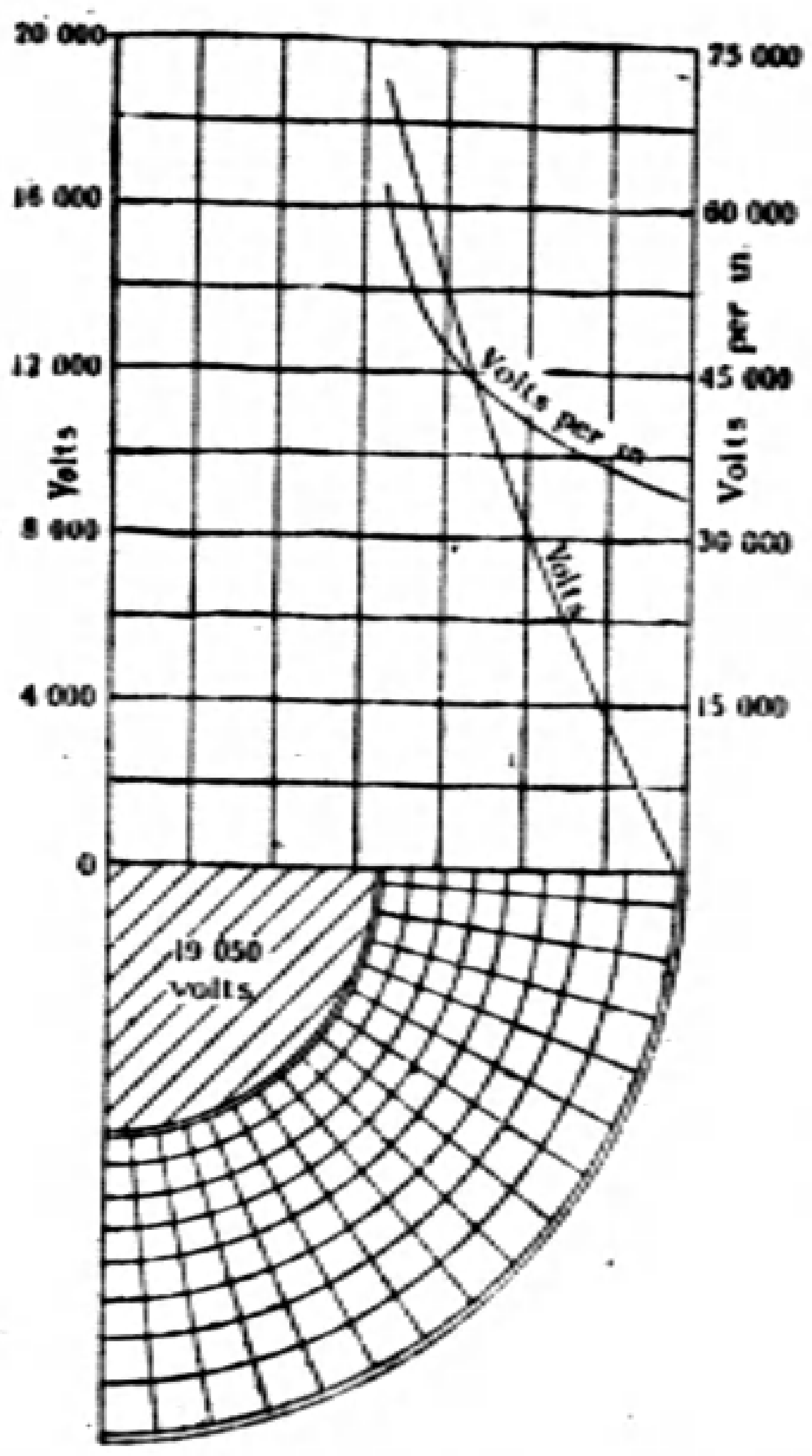


Fig. 11—Curves showing gradient and voltage-drop across insulation for a single-core conductor.

Temporary air ducts were constructed, to re-circulate the air. The excitation was provided by a d.c. generator.

The open-circuit and short-circuit characteristics are shown in Fig.13, and voltage oscillograms in Figs. 14 and 15.

Wave-form.—The voltage wave-form between phase terminals and between phase terminals and earth departs less than 1 per cent from a pure sine wave, and is free from ripples; no difficulty due to harmonics when operating on a cable network has been experienced.

Sudden short-circuit test.—The alternator was suddenly short-circuited by an ironclad, oil-immersed switch, and an oscillogram was obtained of the current in three phases, the curves being shown in Fig. 16. It should be recorded that after the test the end-windings showed no sign of movement.

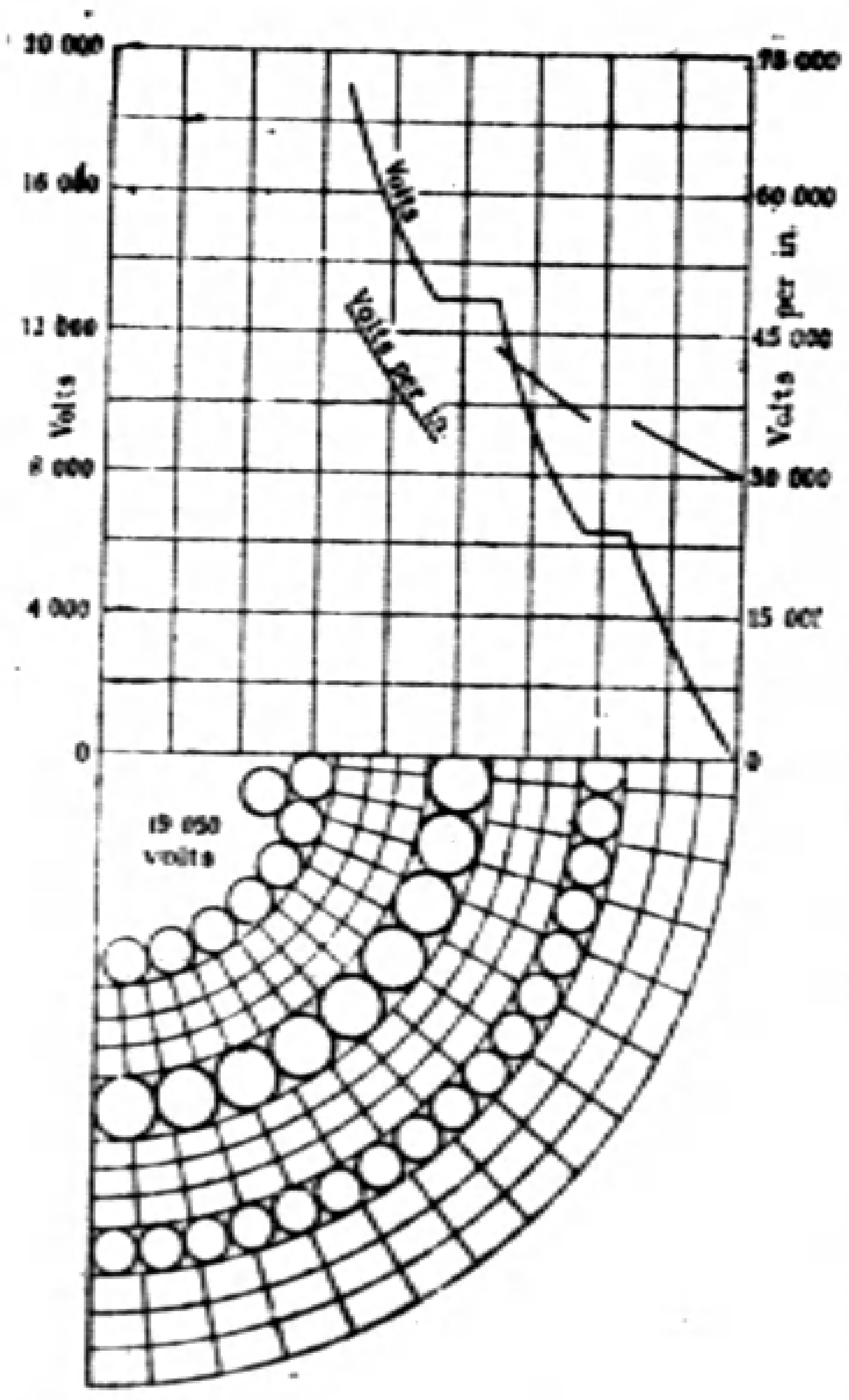


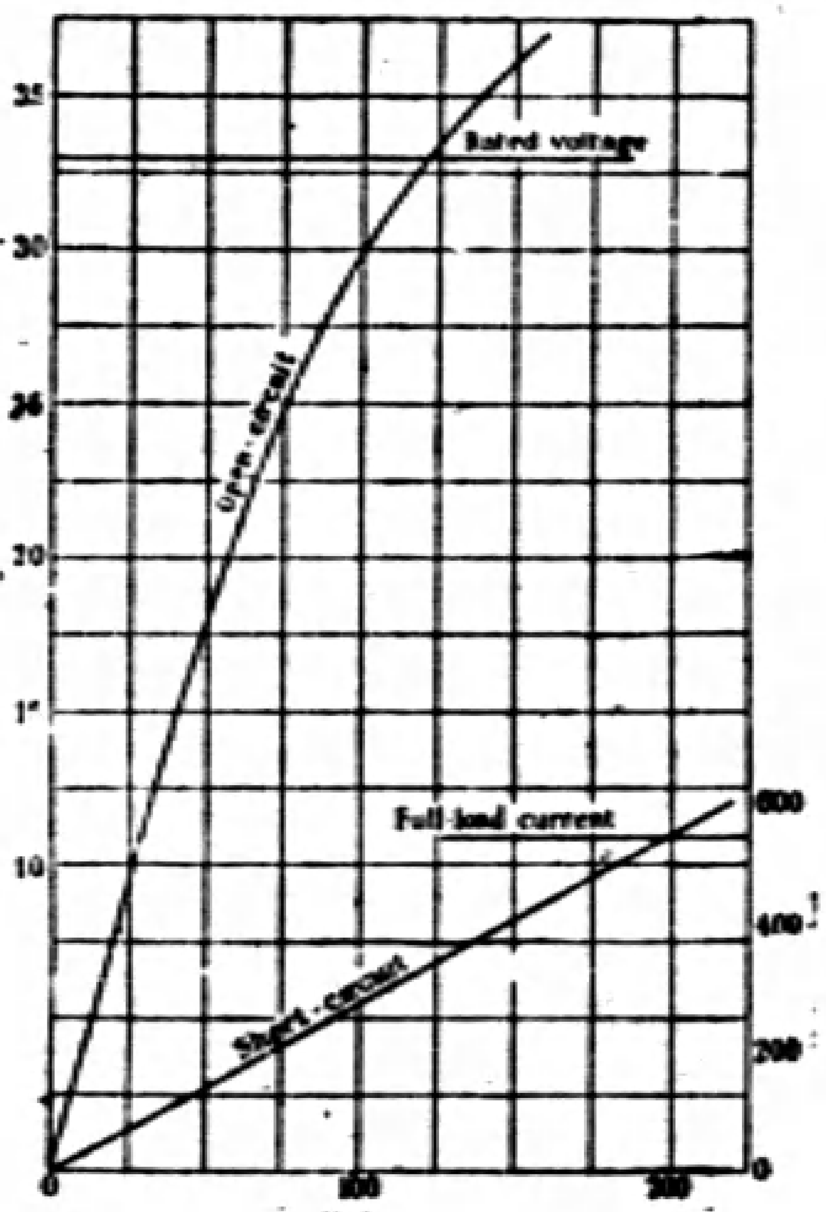
Fig. 12.—Curves showing gradient and voltage-drop across insulation with coneentric conductions.

Heat runs.—As it was impracticable to dissipate 25,000 kW at 33 kV, the windings were rearranged so as to circulate current, i.e. with the three sections of each phase in parallel. The difference in voltage between the "bull" section and the other two sections causes a circulating current which is controlled by a choke in the circuit. While the conditions do not represent the actual conditions of operation, they give a very good indication of the results to be expected on load.

The temperature-rises were moderate and very satisfactory, the figures on load being well within the estimated values.

During the open-circuit tests, a record of the leakage current per phase was taken. This figure was 80 mA at 33 kV at 60° C.

Efficicncy.—The efficiency of the alternator is shown by the cruve in Fig. 17. The efficiency is high at all loads, in spite of the restrictions imposed on the design owing to the fact that the machine had to be interchangeable as a whole with the low-voltage alternator.



Excitation current amps.

Fig. 13.—Actual open-circuit and short-circuit characteristics.

Reactance and mechanical stresses on sudden short-circuit.—The reactance of the high-voltage alternator proved on test to be approximately equal to the combined reactance of an alternator of normal design and a step-up transformer. The actual value obtained by calculation is 22 per cent, and that from the short-circuit tests is 21 per cent.

Dr. S. L. Pearce, in his paper on "Prospective Development in the Generation of Electricity and its Influence on the Design of Station Plant," read before the Engineering Conference of The Institution of Civil Engineers in June 1928, draws attention to possible increased forces on the stator windings in a statement reading as follows:—"In the absence of step-up transformers, or ext rnal reactance coils, the reactance required for limiting the short-circuit currents to values within the rupturing capacity of the switchgear has necessarily to be inc rporated in the stator

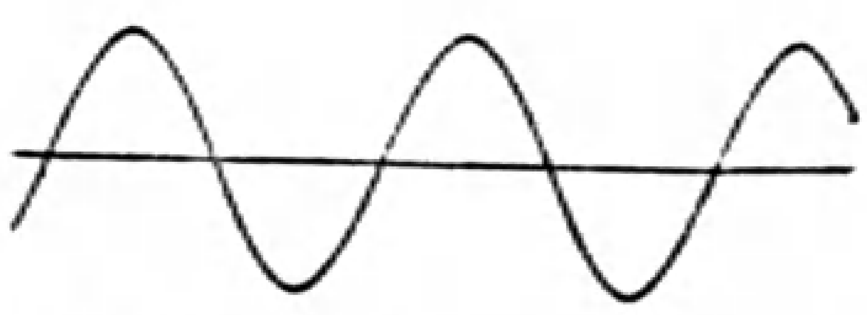


Fig. 14—Voltage wave-form between phase terminals.

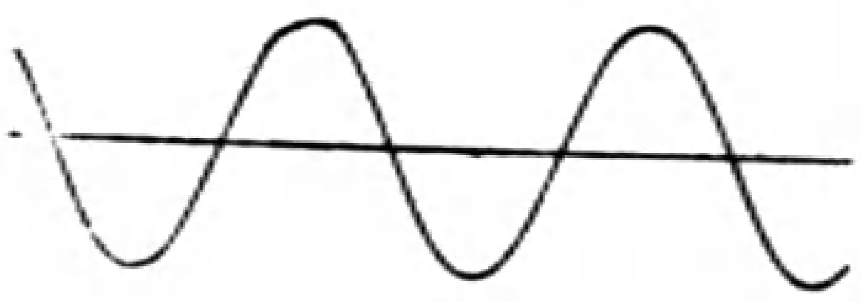


Fig. 15.—Voltage wave-form between phase terminals and earth.

windings, with the natural consequence that under short-circuit conditions, the mechanical forces on in'ierently weaker windings are appreciably increased." In the authors' experience, this dificulty has not arisen. The short-circuit tests carried out on the 25,000-kW, 33-kV alternator have proved that the windings are quite as robust as those of a low-voltage machine.

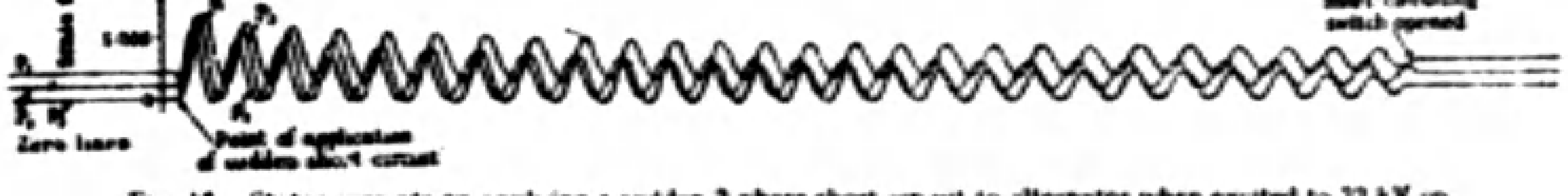


Fig. 16.—Stator currents on applying a sudden 3-phase short-circuit to alternator when excited to 33 kV on no load at normal speed

The arrangement and spacing of the end-connections of the 11-kV and 33-kV 25 000-kW alternators, respectively, are shown in Figs. 18 and 8. It will be seen that greater space is provided for the accommodation of the windings of the latter.

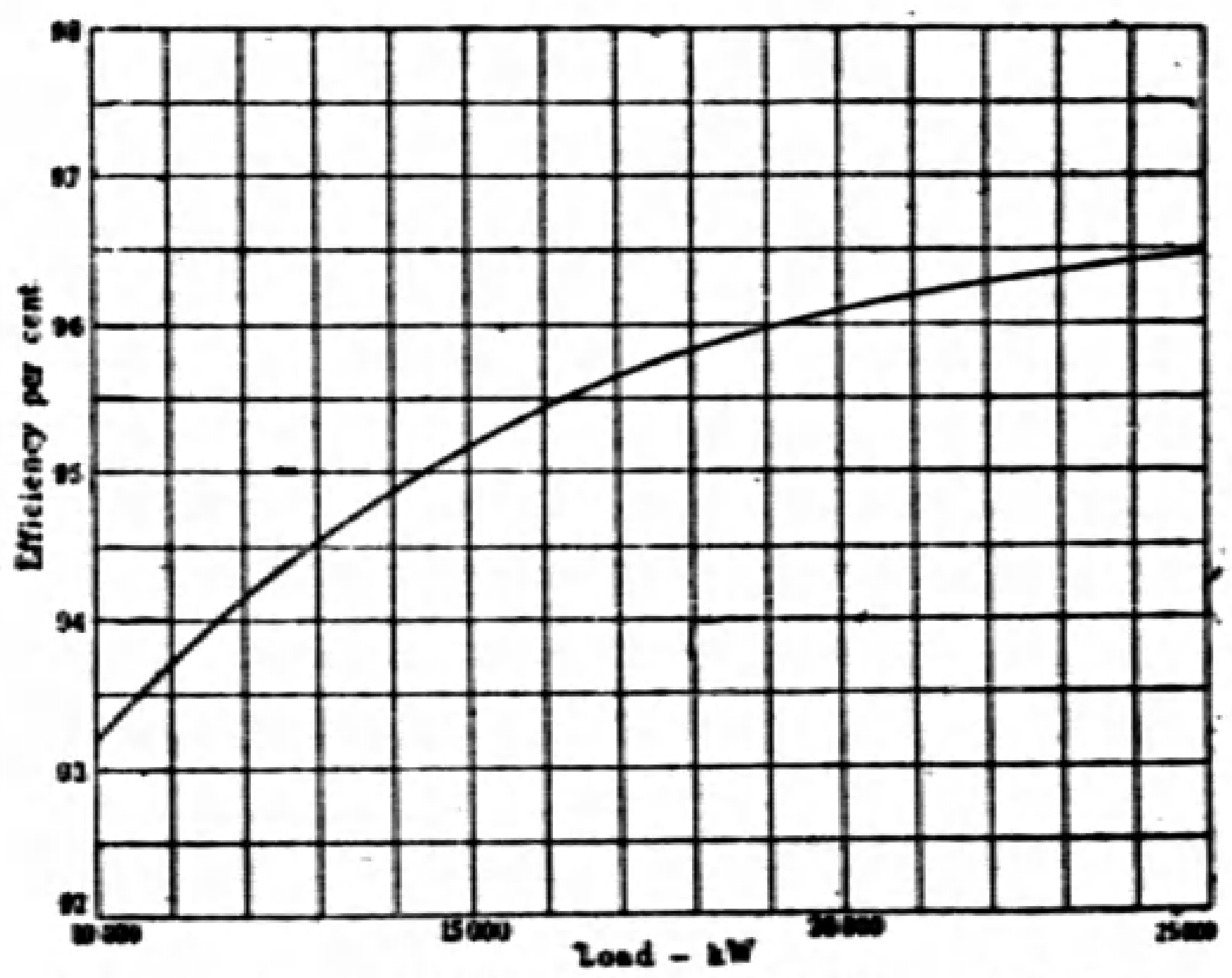


FIG. 17.—Efficiency curve of 25 000-kW, 33 000-volt, 0·8-power factor, 3-phase, 50-period, 3 000-r.p.m. alternator

In making a comparison of the forces between conductors under short-circuit conditions, it is assumed that the short-circuit takes place at the terminals of the high-voltage alternator, and at the secondary terminals of the transformer connected to the low-voltage alternator.

If a short-circuit occurs at the terminals of the low-voltage alternator, the stresses in the windings are increased nearly three times.

The number of ampere-conductors is approximately the same in each design, but the intensity of the leakage flux surrounding the end-windings is smaller in the high-voltage design, due to the longer magnetic path.

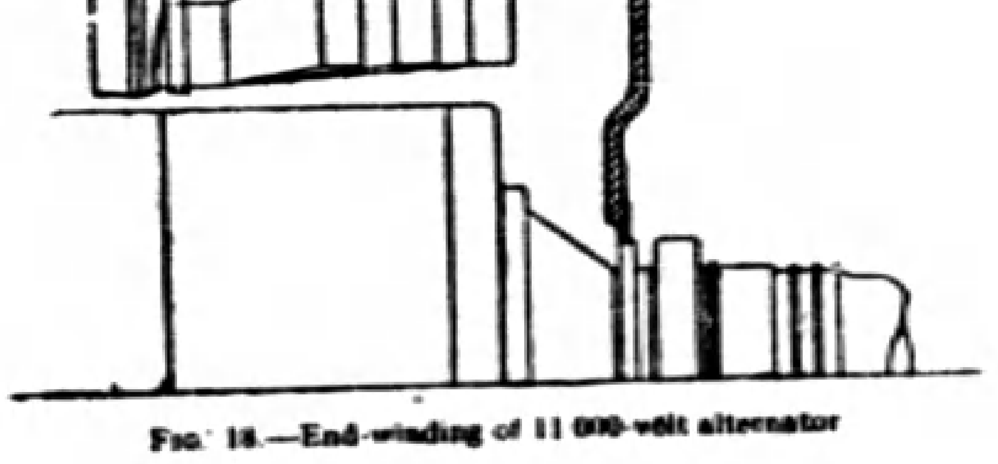


FIG. 18.—End-winding of 11 000-volt alternator

The conductor slots are circular and much wider than the reactance slots, and the intensity of the leakage field is low in the former. For these reasons, and owing to the lower current per conductor, the stresses between conductors both in the core and end-winding are lower in the high-voltage design than in the low-voltage design.

A comparison of the reactance and stress in the two designs is given in Table 4.

On site.—Since the plant was installed in August 1928, it has operated continuously up to its maximum load at voltages varying between 34,000 and 35,000, and it has withstood without any sign of distress the most severe faults on the large overhead and underground network to which it is coupled.

The control and regulation have proved eminently satisfactory in every way.

Some extracts from the station log are given in Table 5.

TABLE 4.

Forces on End Windings.

	25000-kW alternators	
	11000 volts	33000 volts
Inherent reactance of alternator...	12.5 per cent	21.0 per cent
Reactance of transformer	8.5 per cent	—
Total reactance	21.0 per cent	21.0 per cent
Current on short-circuit	4 75 × full-load current	4.75 × full-load current
Forces in windings:—		
(a) End-connections between phases ...	75 lb. per ft. run	17.5 lb. per ft. run
(b) End-connections between turns ...	14 lb. per ft. run	2.0 lb. per ft. run
(c) Between core conductors...	250 lb. per ft. run	140 lb. per ft. run

TABLE 5.

Extract from the Brimsdown Power Station Log. Surges on the System.

Date	Time	Generator on load	Remarks
31 August 1928	01.00	No. 2	Surge
31 August 1928	01.35	„ 2	Heavy surge
31 August 1928	18.25	„ 2	Slight surge
19 September 1928	08.30	„ 2	Heavy surge
12 October 1928	10.35	„ 2	Surge
2 November 1928	21.15	„ 2	Surge
5 November 1928	00.06	„ 2	Heavy surge
6 November 1928	19.41	„ 2	Surge
6 November 1928	20.14	„ 2	Surge
6 November 1928	21.01	„ 2	Surge
10 November 1928	16.15	Nos. 1 and 2	Short-circuit
16 November 1928	17.15	„ 1 and 2	Heavy surge
19 November 1928	03.26	No. 2	Heavy surge
19 November 1928	05.57	„ 2	Heavy surge
21 November 1928	06.09	„ 2	Slight surge
29 November 1928	17.29	Nos. 1 and 1	Heavy surge
6 December 1928	14.38	No. 2	Surge

Generator No. 2 is the 33 000-volt alternator.

(8) Conclusion.

Only the fringe of the possibilities has been touched; it certainly seems in the natural course of design that a reliable high-voltage alternator is essential to the rapid increase in size of power systems and their interconnections.

The paper is confined to generation at higher voltages, but other units of ever-increasing size, such as motors, motor-generators, synchronous condensers, etc., may be economically designed and coupled direct to the network without the use of transformers.

Although the purpose of the authors has been to give information and to promote discussion on the high-voltage machine, their primary object is to gain from engineers an expression of opinion on the possibilities, advantages and disadvantages of generating alternating current direct at voltages higher than those now recognized as customary.

The authors hope that they have shown that a definite advance has been made in the generation of electricity and in the design of large generators which may be used for connection to the "grid." If their work contributes to the problem of providing means for the more efficient and economical generation of electrical energy, and thus to some saving in the consumption of coal, they will feel that their efforts have not been wasted.

They wish to take this opportunity of paying tribute to, and to acknowledge the courage and foresight of. Sir James Devonshire, K. B. E., Chairman of the North Metropolitan Electric Power Supply Co., and the chief engineer, Captain J. M. Donaldson, M.C., of the same Company, in installing the pioneer high-voltage unit, and without whose co-operation it would have been impossible to undertake the work.

They also wish to acknowledge the assistance given by the staff and officials of Messrs. C. A. Parsons and Co., Ltd., who have made unstinted efforts in support of all investigations and in the compilation of this paper.

AERODYNAMICS AND AIRPLANE DESIGN

Paper presented to the Chinese Engineering Society in its Eleventh Annual Convention, Sept. 6, 1929.

By GEORGE C. CHOU, AERO. E. (周傳璋)

PART 1. INTRODUCTION

As is generally understood, aeronautics is a common name under which, aerodynamics, airplanes, airships, landing fields, airways, technical flying, air transportation, commercial applications, industrial application, military application, and so forth, each occupies a special field for specialization. Today it is more convenient to deal with only two topics in aeronautics, **Aerodynamics and Airplane Design.**

Before any subject is treated on its high spots, a general review or survey is always advisable. Let us survey the general mode of operation of an airplane. Figures 1, 2, and 3 are the usual drawings to express the main features of an airplane while the chief operation characteristics have to be tested in flight. Suppose the airplane is flying level like figure 1 which is technically known as in its cruising attitude. Attitude is term itself under which the airplane displays all its activities. The lift is equal to its weight so that airplane will stay in that particular level, the equation is,

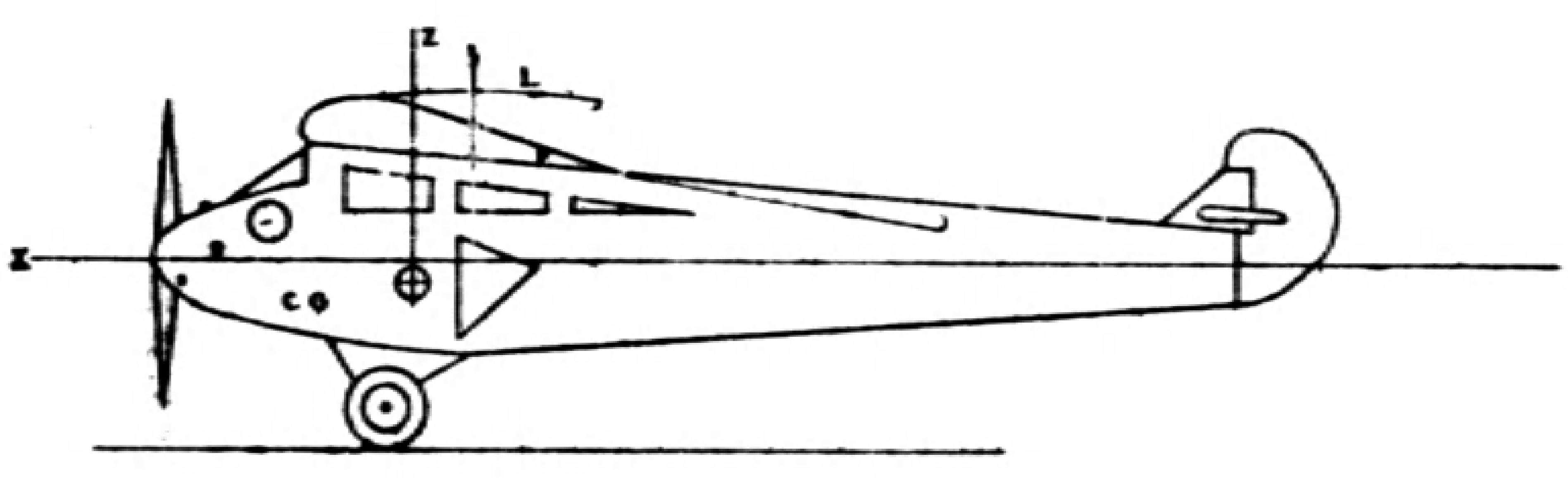


FIG. 1

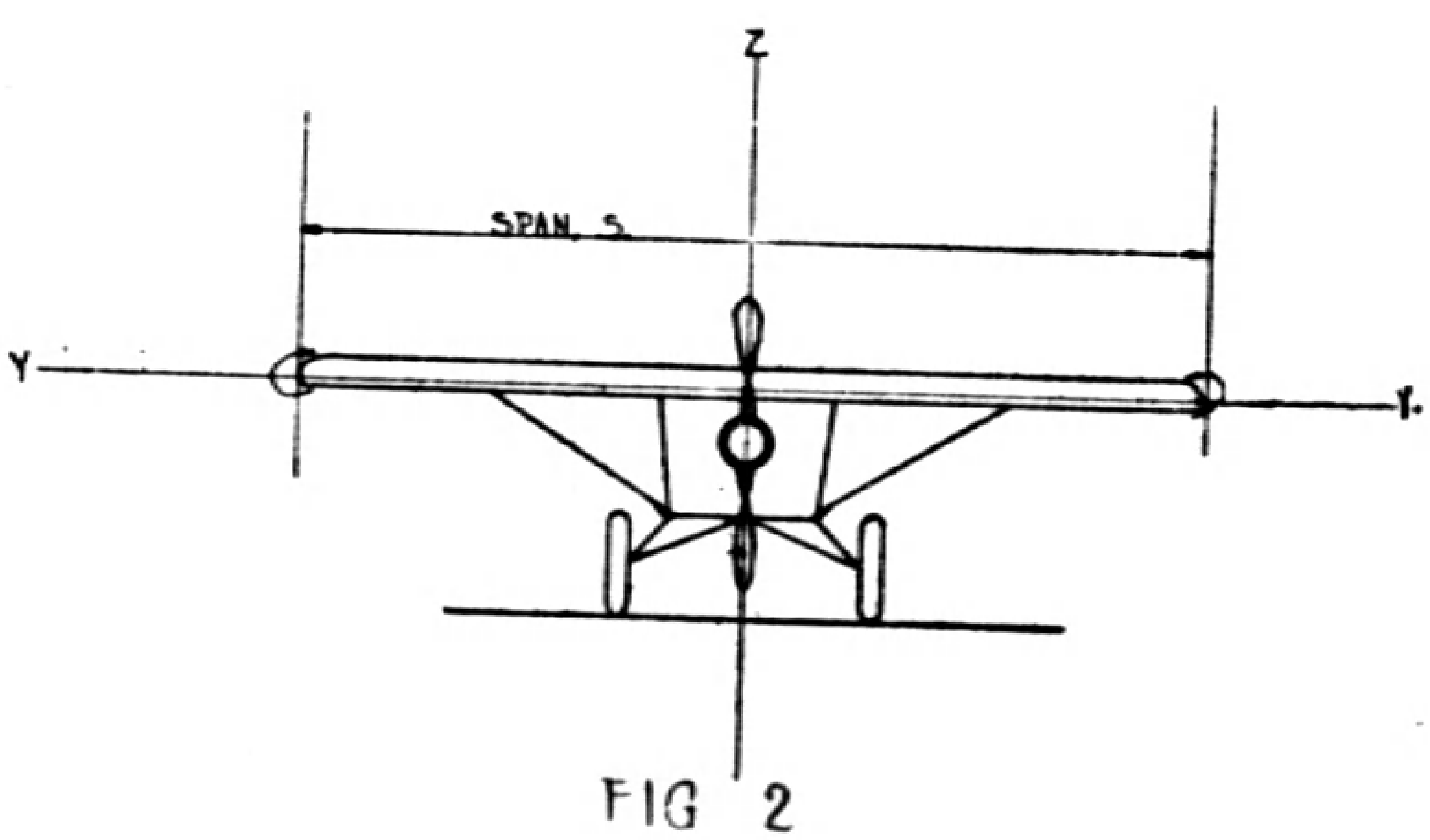


FIG 2

$$L = W = k_y A V^2,$$

Where L is the lift on the wings, W the gross weight of the airplane, K_y is the specific lift per

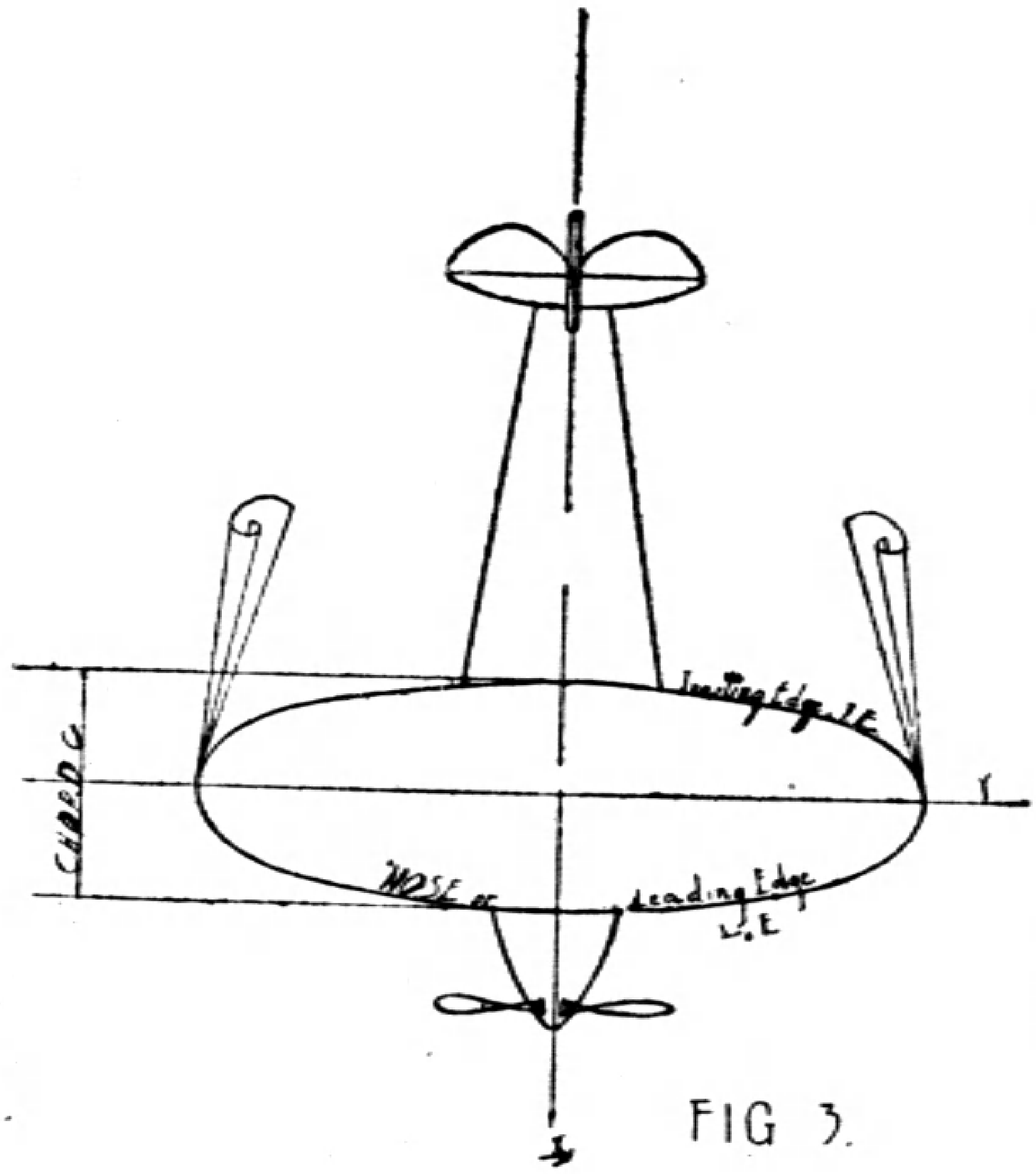


FIG 3.

unit area of the wing surface at unit velocity per unit time, A is the total area of the lifting surface, and V is the velocity of the airplane. The head resistance, technically known as the **Drag** D, is overcome by the thrust of the propeller, The drag of the wing alone is expressed by

$$D = k_x A V^2$$

where k_x is the specific drag coefficient of a certain wing. The thrust of the propeller must be equal to the entire drag of the airplane at uniform velocity. The development of the thrust will be dealt with later.

The level attitude of the airplane is maintained by the predetermined balancing elements expressed in the following equation,

$$M = o = M_w . M_t , M_b , M_p , \text{etc.}$$

where m is the total moment about the center of gravity of the entire airplane and must be equal to zero so that nothing will turn, M with subscripts w, t, b, p, etc., means the moments due to wing, tail plane, body, propeller, and so forth. A thorough explanation will be given later. For simplicity the total moment about the c.g. contains that of wing and tail only, which is accurate enough to determine the flying features of a machine. The above equations satisfy the law of motion at constant speed, as

$$\text{sum } V=o,$$
$$\text{sum } H=o,$$
$$\text{sum } M=O.$$

Now more information is to be sought in lift L, drag D, thrust T, and moments M of the various parts of the airplane.

Figure 4 is a crystallization of methods to study the main aerodynamical characteristics of a wing. The fish-like profile is the cross-section of the wing whose shape is maintained by means of wing ribs strung on the wing beams. The thickness of the wing section is called the camber, the length the chord.

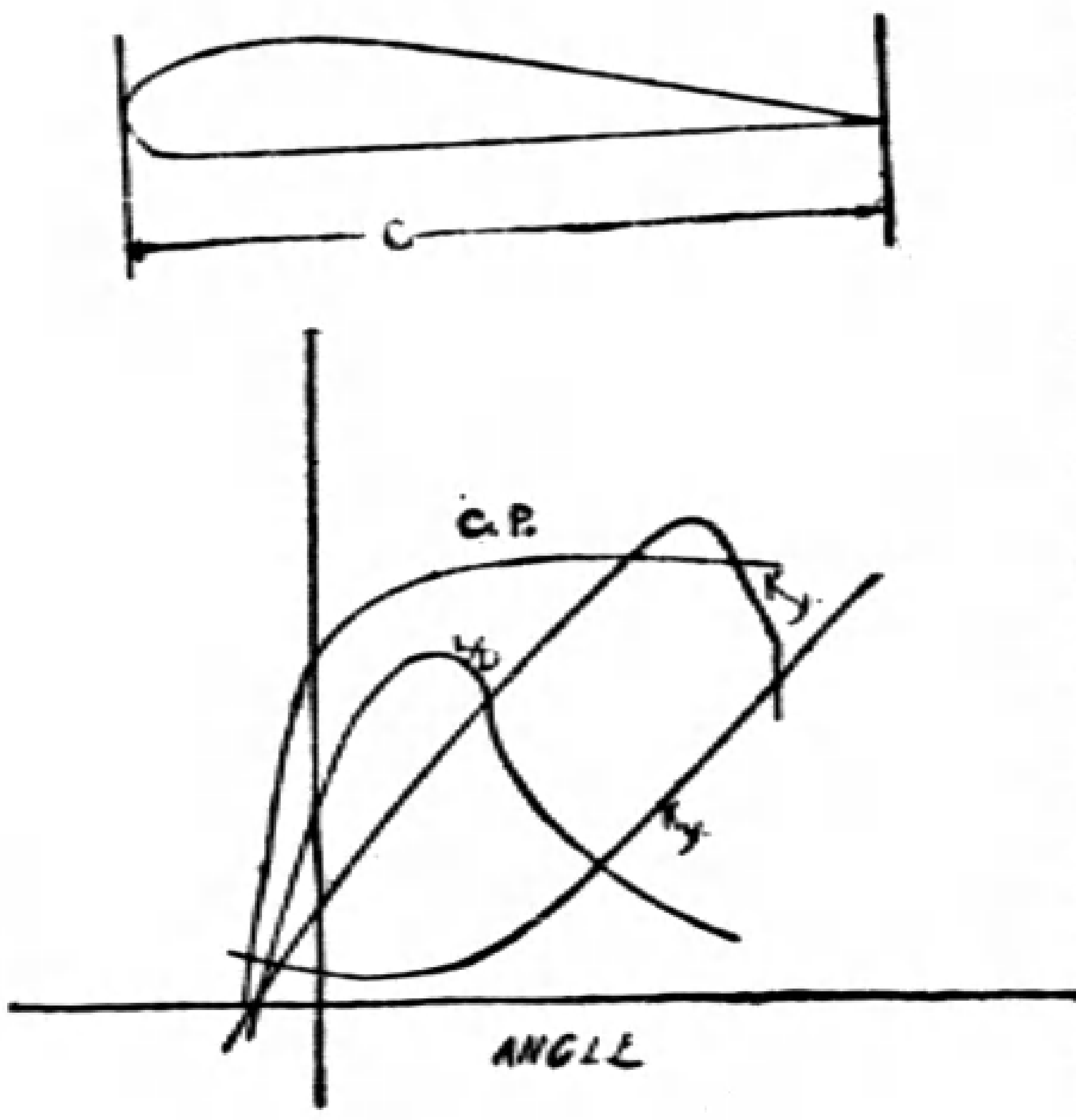


FIG. 4.

Curve k_y is that for specific lift which varies with the angle of the wing from the relative wind. The k_y curve is highest only at an angle of from 15 to 20 degrees and this point is also a one of dangerous consequences because of the sudden drop in lift. The curve of k_x is somewhat constant for one half the range of the k_y curve, then it rises more and more rapidly. The L/D curve is defined as the aerodynamical efficiency of the wings section in question. We have to get away from the idea of imput and output ratio for efficiency. The aerodynamical efficiency of a wing section is the ratio of lift over drag L/D.

The curve C. P. is the travel of the center of pressure of the wing section along its chord line (c in fig. 2 & 4). It is assumed a straight line along the length of the wing called the span. The curve is plotted in per cent of the chord line c either from rear edge (Trailing Edge T. E.) towards the front edge (Leading Edge L. E.), or vise versa. It is to be noted that the travel is forward on high angles and rearward on low angles of the wing against the relative wind.

These curves are of prime importance to the airplane designer. The k_y and k_x curves are sometimes plotted one against the other like figure 5 which is called the polar plot of the wing section. Curve a is a theoretical one parabolic in nature and curve b is the experimental curve.

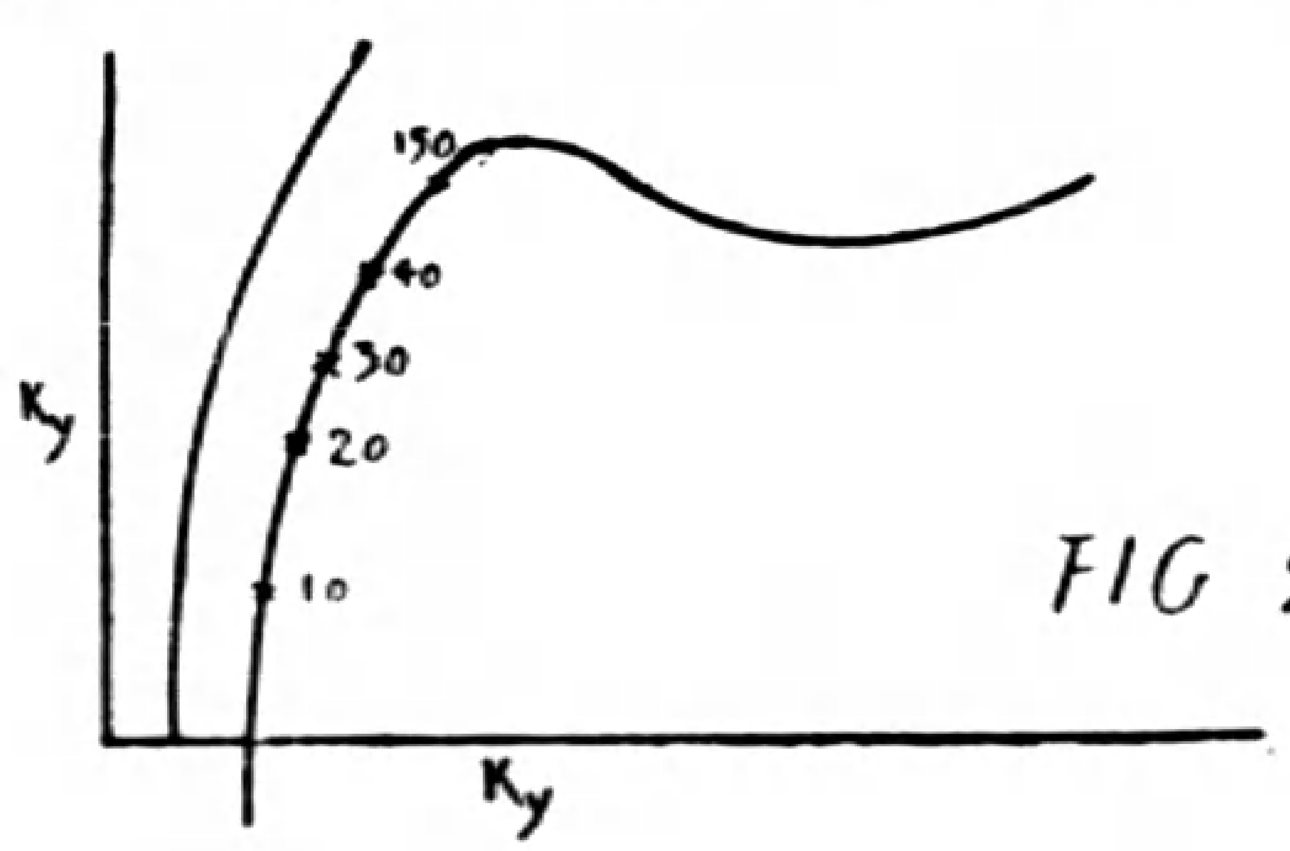


FIG 5

To illustrate the importance of these curves we take the airplane in its level flight condition. Since efficiency is the aim of flying, one must fly at the top of the L/D curve where gasoline will be comsumed the least and a long distance can be flown over. The C. P. at that point will assist the designer to divide the load onto the wing beams. The drag k_x at that point will give the designer how much power is needed to go. The size of the wing is determined by the maximum value of k_y and the equation,

$$A = \frac{W}{K_y \quad V_m^2},$$

where K_y is the maximum value of lift and V_m is the minimum value of flying speed. Higher k_y gives smaller wing and less construction work. Smaller V_m insures safety in landing or gliding down to land. Next we will find how thrust is developed.

The development of the thrust of a propeller is similar to the lift of the wing. Figure 6 is my perspective drawing to show how the thrust is developed. Here we have the air velocity components, that due to the motion of the airplane and that due to the turning of propeller. The resultant velocity is represented by V_r. The large angle ϕ is the blade angle which the chord of the propeller blade section makes with the plane of revolution YY. The actual angle of flying corresponding to that of a wing section is designated by i and which is never to be too large. The actual section of the propeller should be cylindrical since the propeller revolves in a cylinder. But for practical purposes, the section can be assumed to be plane. Resolving the lift L to the OX direction will give the desired thrust for pulling the airplane through the air. The other components will be resolved to the OY direction which is nothing but a waste or a necessary evil. The ratio of thrust to the other energy wasted will be the efficiency of the propeller, at that section. By summing up a number of these sections the total thrust of the propeller can be found. The propeller is designed for that required thrust usually. Before I go any further, I shall sum up what has been said before in a brief manner.

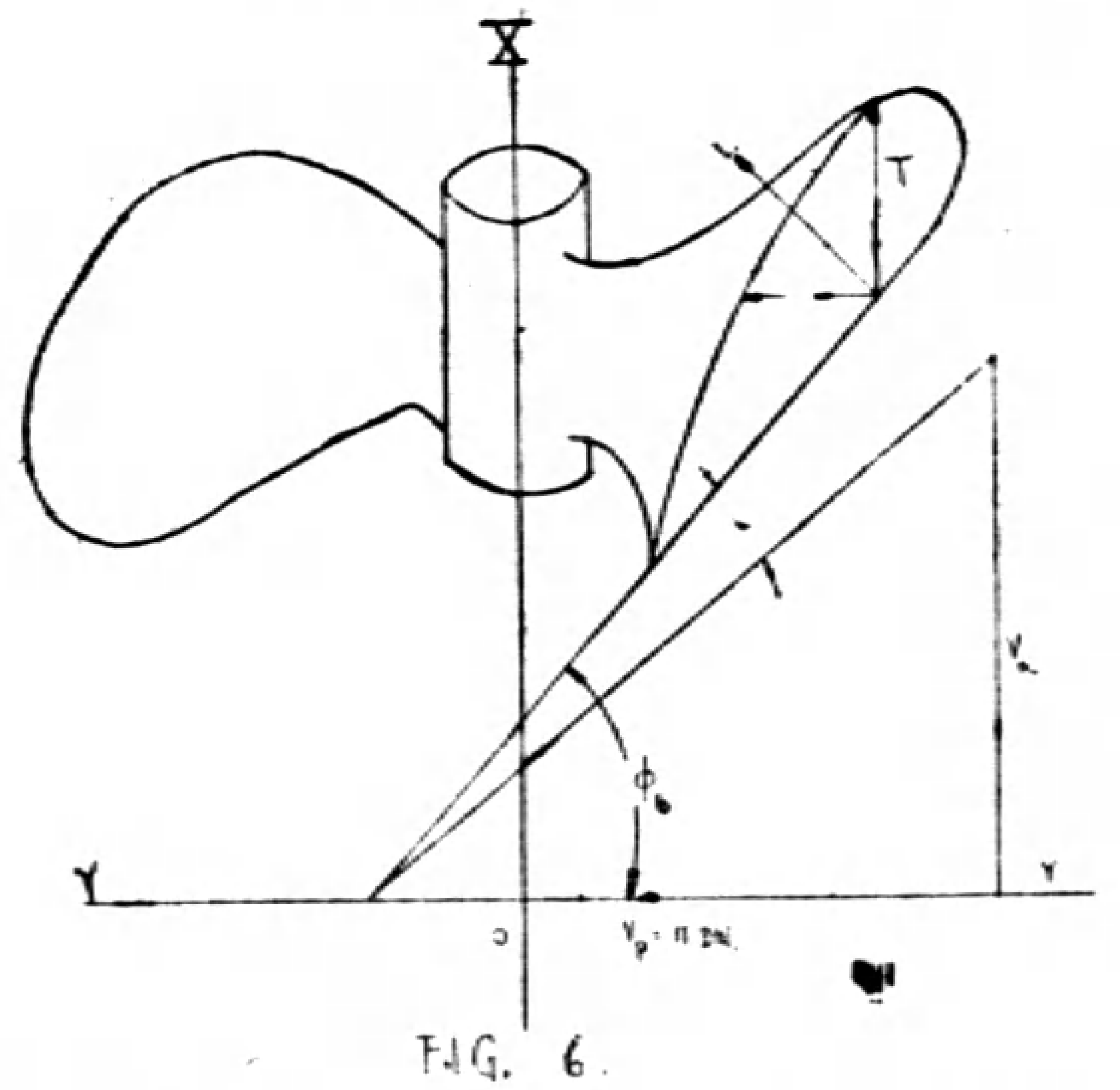


FIG. 6.

Figs. 1 & 2, some more items.—Referring back to fig. 1, some more elements of aerodynamics still exists but that's not all. Beginning from the propeller, the two tips of it are forcing the air to form what is called tip **Vortex.** Behind the propeller, the air is forced to go faster than the speed of the airplane and is called the **Slip Stream.** The slip stream does not go in a straight manner and the twist is called the **Rotational Mass.**

On top of the wing is a curve describing the air path which is smooth and then gradually develops into a turbulant form. By improperly elevating the wing, the turbulance will be excessive and called upon to drop the wing down (this is the burbling of the wing) Just behind the wing and tangent off from the trailing edge, the air is forced downward. On the tariling egde it is called trailing **Vorticity** and further back is called the **Downwash** This has some effect of the tail plane.

Fig. 3 has some arrows showing the directions of the air at the wing tip which is called the wing **Tip Vortex** similar to that of the propeller. This offers the reason why a short wing does not give enough lift for flying because the tips are drowned. A longer wing will be more efficient. A tapered wing is just as good. The ratio of the length of the wing (span) to the width (chord) is the **Aspect Ratio** of the wing and ranges from 6 to 8. The larger the better if construction permits. Next I shall begin to talk about the turning and maneauvering of the airplane.

Rise & Dip of the Airplane.—Considering our time being an age of specialization, I don't wonder if most of us here have not the slighthtest idea of how airplanes move around. In the same time I am not to blame for not knowing how banks are operated. Fig. 7 shows the linkage through which the airplane is controlled in its vertical plane. Pulling back the stick S will cause the air to strike downward on the tail T. Thus the airplane will go upward through the pull of the propeller. The airplane will slow down somewhat. The pilot P is shown in outline. In a similar manner, pushing the stick forward will cause the air to strike the tail from below and push it upward affecting a descending attitude. The airplane will go faster due to the pull of the propeller and gravity. You can well imagine what a change is going in the balancing moments of the equation and curves.

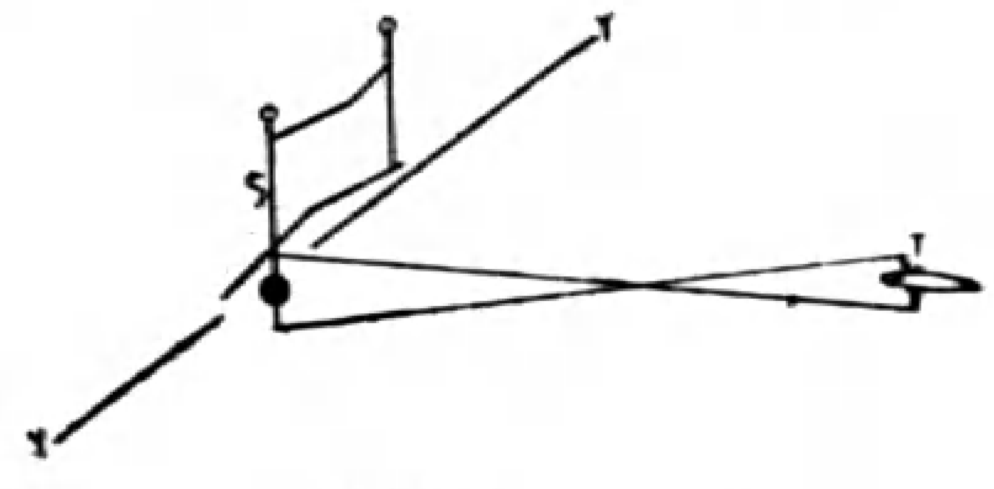


FIG. 7.

Bank & Turn. Fig. 8 is the inside view, of an airplane to show how the contols work for a turn, and fig. 9 the motion of the parts necessary to turn. The arrows show the directions the parts should move to. Looking at the aileron which is a flexible part of the wing, the upward motion of which will force the wing downward as the elevator tail does the tail of the airplane, and vise verse. Attention is called to fig. 8 that the airlerons are drawn in a plane of the controls in the cockpit. Moving the stick to its right will cause the right airleron to go up hence the wing down. The left wing will do the opposite. This is to get ready to turn to the right and providing for the plane to act against the centrifugal force. Fig. 10 is an instantaneous view of the airplane during a turn. The rudder control is shown below it which is very simple. Next you will be ready to be introduced to the more difficult subject of maneuvers of the airplane.

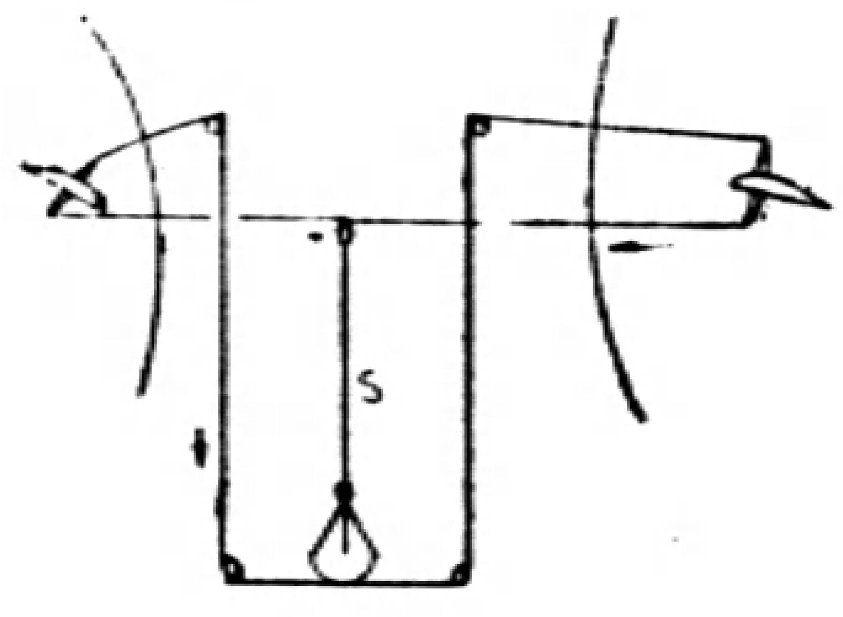


FIG. 8.

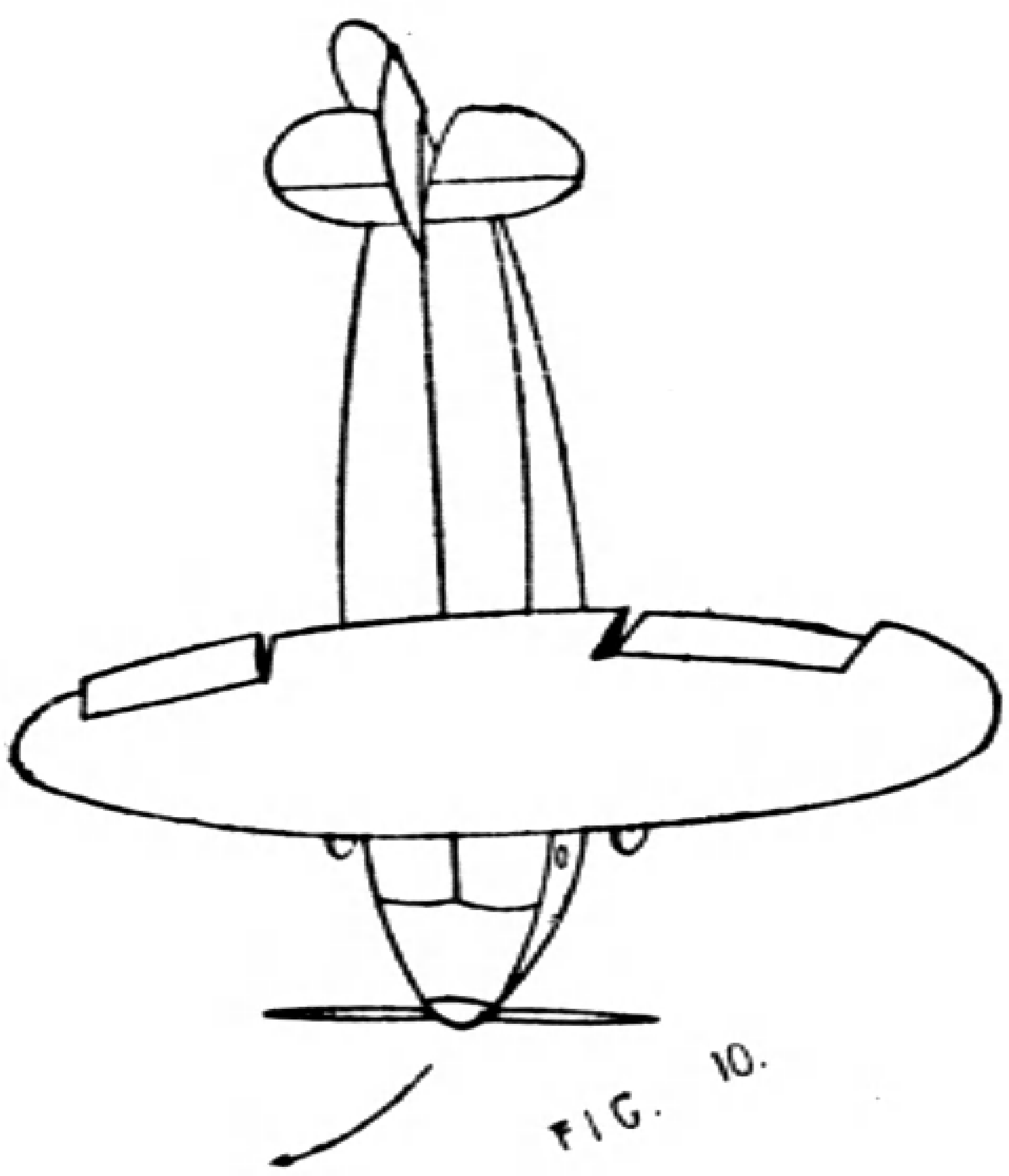


FIG. 10.

After understanding the motion of the airplane in level attitude, we shall touch some of the other more technical movements. It is easy and logical to follow the events, from start to finish.

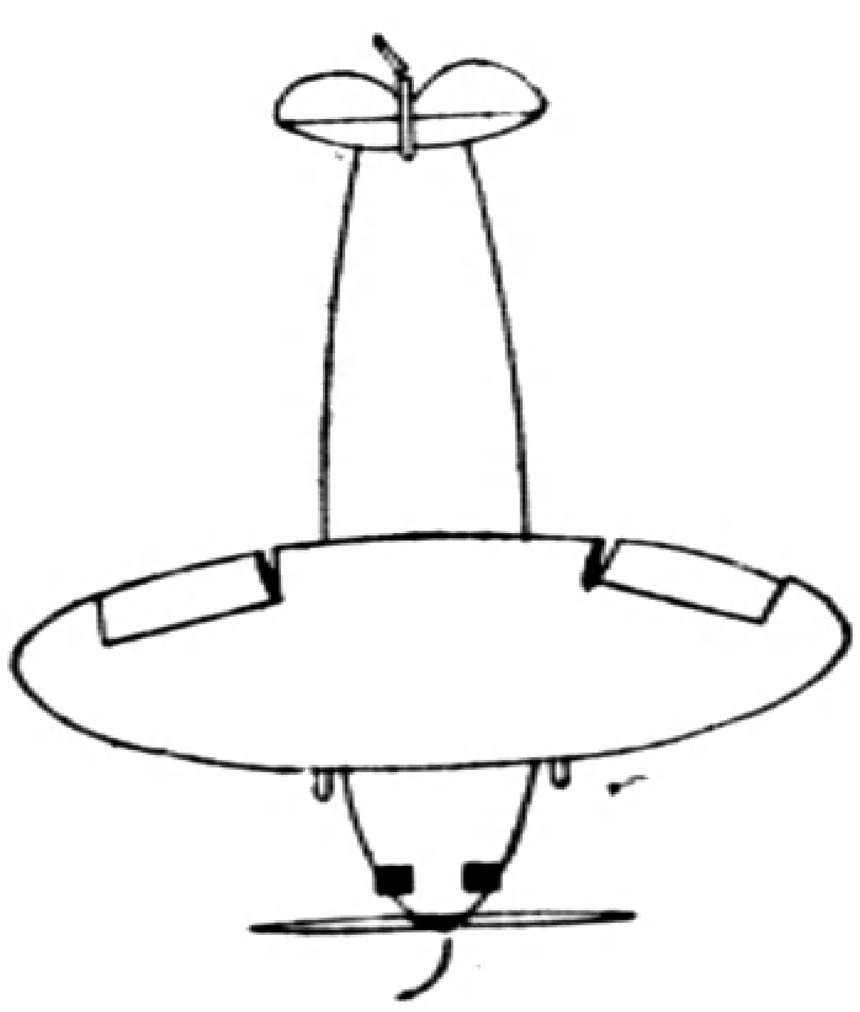


FIG. 9.

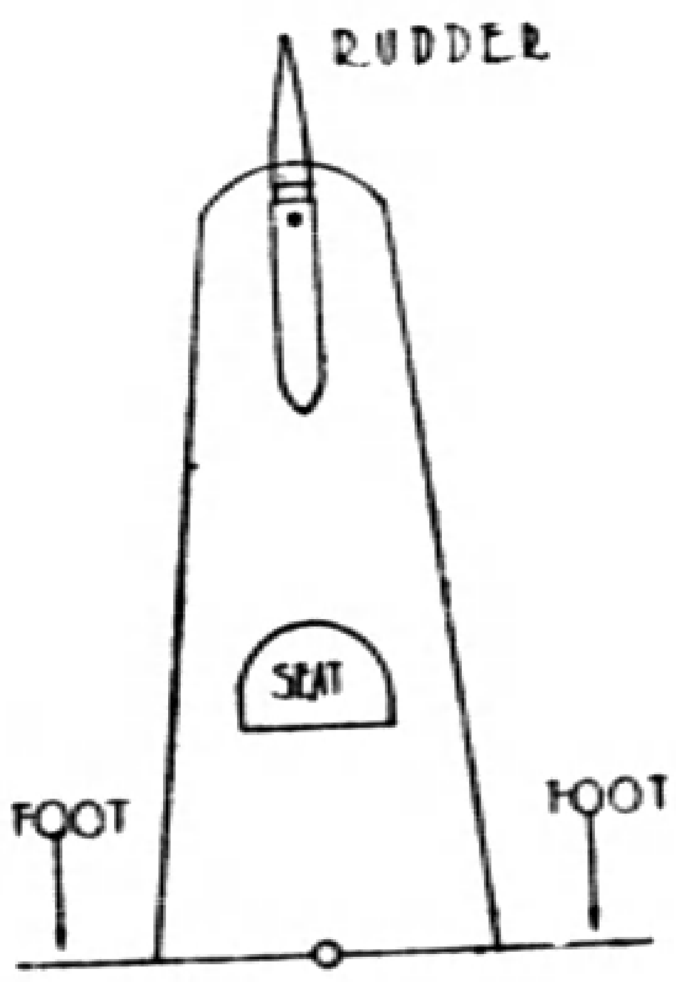


FIG. 11.

Take-Off

Fig. 12 shows an elementary almost childish picture of an airplane ready for take-off. Forgetting other precautions and technical point, we suppose that the engine is turned full power on. The tail must be pushed down to receive the slipstream for lift. The slipstream will lift the tail up till the plane is in a level attitude. This will be in a position offering least resistance to gather up speed. As the speed of the airplane gather up, the wing will begin to be responsive to the air. The equation of motion will be like the following, from F=ma, where F is the unbalanced force acting on the airplane, b is the mass of the airplane, and a the acceleration, the (F) part consists of thrust T, ground resistance on the wheel (fw, f is coefficient of friction and W the weight of plane) and the wing resistance due to flying which will develop drag in an aerodynamical manner, the (ma) part is $m(dx^2/dt2)$,

$$T - f(W - k_y AV^2) - k_x AV^2 = m\frac{dx^2}{dt^2} \text{ or } \tfrac{1}{2}m\frac{dV^2}{dx}.$$

The member with dt will give time and the member with dx will give distance of the airplane in taking-off. Gathering terms is the hardest task in any mathematical problem. The solution is then easy.

FIG. 12.

Climbing. To leave the grouund is so easy and so simple, as described in the previous page. Next thing is climbing. Climbing is one of the most dangerous stages in flying. (1) The wing is operating around the burbling point as can be remembered from the characteristic curves. (2) As the plane noses up, the speed gathered up from the take-off run will be lost to some extent. (3) Thus both the surface controls and the wing will lose some of their effectiveness in control and in lifting respectively. (4) As the airplane noses up, the gasoline in the tantanks will lose the potential head (hydraulic) relative to the carburetor which is usually put below the engine. (5) The propeller will lose of its speed in revolutions due to load and lack of sufficient head. Therefore (6) the motor has no reserve for any emergency since it is fully used up for raising up the weight of the plane and any attempt to do maneuvering will have serious consequences.

In case the engine stalls due to overloading, the best cure is to glide down immediately without any attempt to turn or side-slip which necessitates the expenditure of additional energy.

Cruising Granted that getting into the air did not entail any difficulties, the next move it to aim at cruising. Cruising. means to fly at the most economical speed at the service ceiling of the airplane. This is done by leveling out the plane from its climbing attitude. During this motion, the center of pressure of the wing has moved backwards and the tail must supply a down load to keep the plane in trim. So the tail-plane is sifted by moving down the stabilizer which is in front of the elevator. In this respect, the downwash of the air due to the wing decomes an asset.

Judging from the fact that any unnecessary inclination of the parts of the airplane will produce drag which reguires power to be overcome, crusing will need a very good balancing on all parts of the airplane. This is the job of the designer. It also involves the utilization of air currents to gain height and tail to save fuel or cover more resistance for a given amount of fuel. That is the job of the flier.

The pilot must also know what is the cruising r.p.m. of the engine so that he fly at that rev. Fig. 13 suggests the idea. The engine makers must supply the test data for brake horsepower against r.p.m. and fuel consumption against r.p.m. R.p.m. is an indirect measure of the airplane speed. The lowest point on the c curve (pounds of gasoline per horsepower per hour) indicates the most economical condition. The brake horsepower (b. hp.) will decrease due to lack of oxygen to burn the gas. The engine maker must test the engine in vacuum to give such complete data to the buyers. Here finishes the introduction to my talk. In the next few minutes we shall study what aerodynamics is composed of and landing will also be taken up.

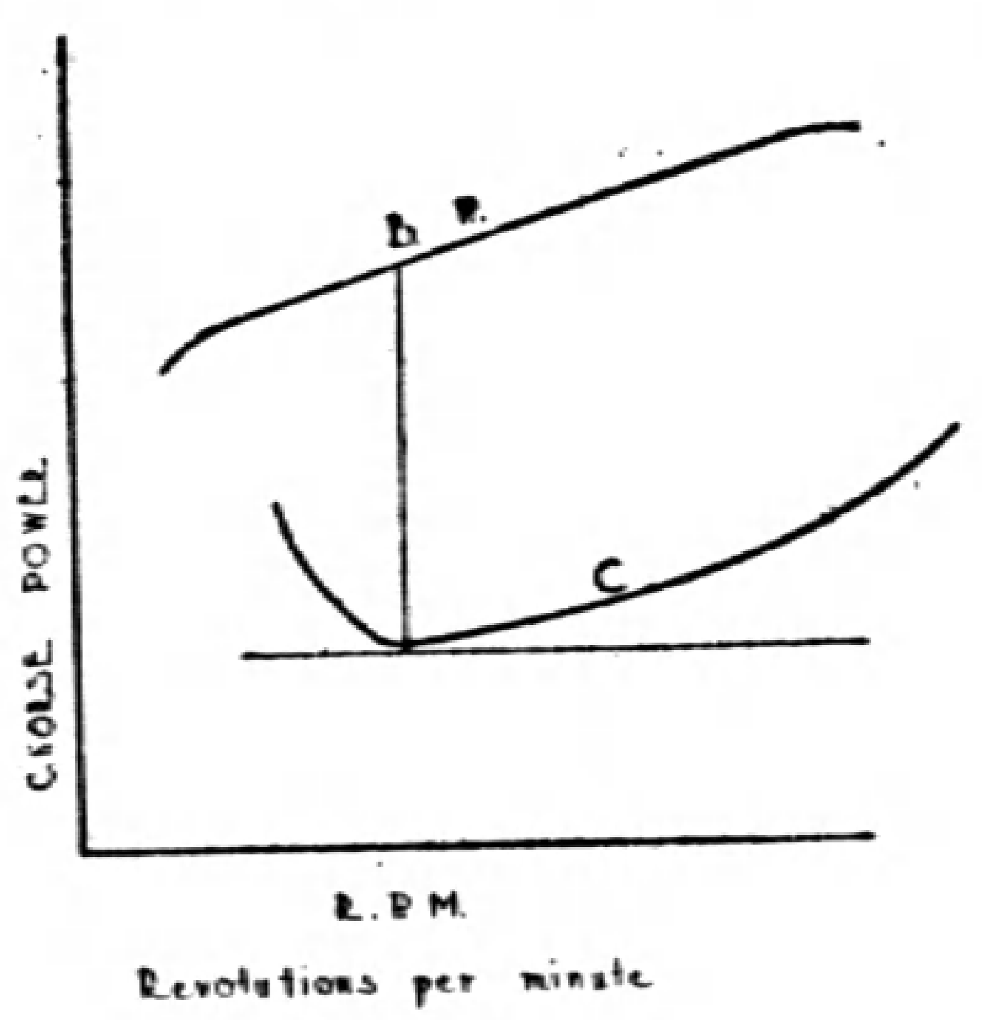


FIG. 13.

PART II. AERODYNAMICS

The Previous introduction had enabled us to follow a straighter channel on the subject of aerodynamics proper which is very wide and very old subject in its nature. Aerodynamics had been studied since time has begun. In a broader sense aerodynamics can be considered as that branch of science that deals with all possible contacts of any object with air. It is easy to imagine how wide and immense the field will be, perhaps wider than any magnetic field any radio station can set up. Coming down to specific things, aerodynamics deals with the following definite topics.

(1) general aerodynamics including hydrodynamics which is the basis for any aerodynamical analysis of skin friction, law of resistance, viscosity of air, standard atmosphere,
(2) theory of the wing sections, of dirigible shapes, of propellers, and so forth.
(3) Stability and dynamics of the airplane,
(4) Performance of the airplane,
(5) Maneuvers of the airplane.
(6) Controls of the airplane, and
(7) Miscellaneous topics.

Scientists have spent years of time with concentrated effort to study these subjects, engineers have put out enormous amount of energy to make apparatus for tests, and fliers paied their lives to help out the scientists and engineers in testing, only finding still more new phenomena and elements to be smoothed out for the benefit of mankind. A bibliographical list of the findings was prepared and occupies many a feet of paper in the governmental organs of various nations. Here I shall make it as short and brief as possibly can.

(2) *Theory of wing sections, of propellers.*

The wing theory is the first logical thing to be mentioned. The anscestor of the wing is the kite which philosopher Mei-Tze had made during Confucius's time. As our Chinese language lends itself less suitable than the Greek or Phoenician language in figure and mathematical anaylsis, so Newton had the first chance to formulate the equation on air pressure against a plate or plane surface in a moving stream of air,

$$P = \frac{d\ A\ V^2 \sin^2 \Theta}{g},$$

where P is the total pressure, d the density and V the speed of air steam, A the area of the plate, g the gravity, and Θ the angle between the plate plane and the direction of air. New ton had no experimental data nor paper to verify this law. So Euler, Raleigh, and Lanchester all had a chance to develop more exact equations. Now the equation stands like.

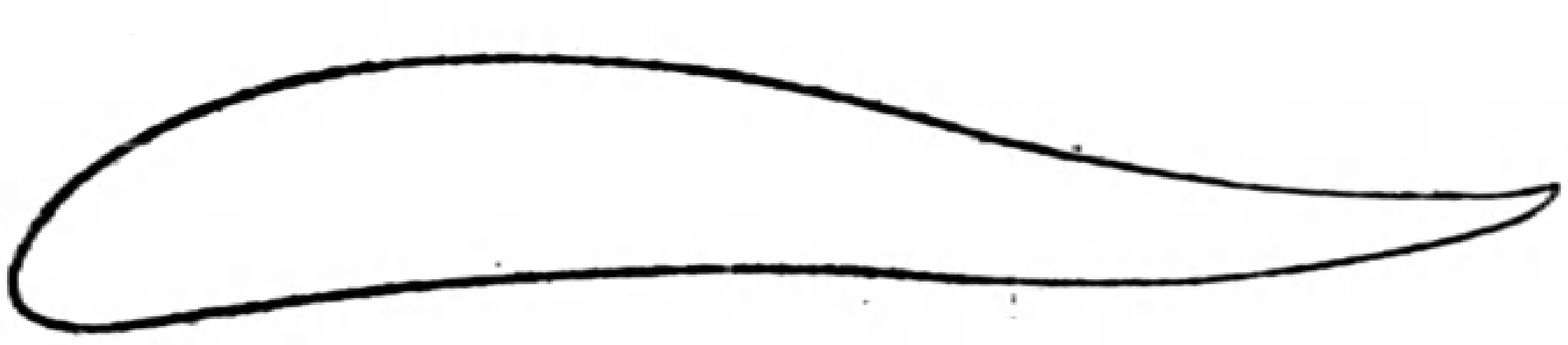
$P=0.0011\ A\ V^2$ for plate perpendicular to air, and
$P=0.00003\ A\ V^2$ for small angles of attack.

These are the rules for testing flat plates. The results will be used to compare with the resistnace of any wing section. In fact the resistance of complete airplane are usually reduced to that of a equivalent **Flat Plate.** Next we shall survey the field of modern wing theories.

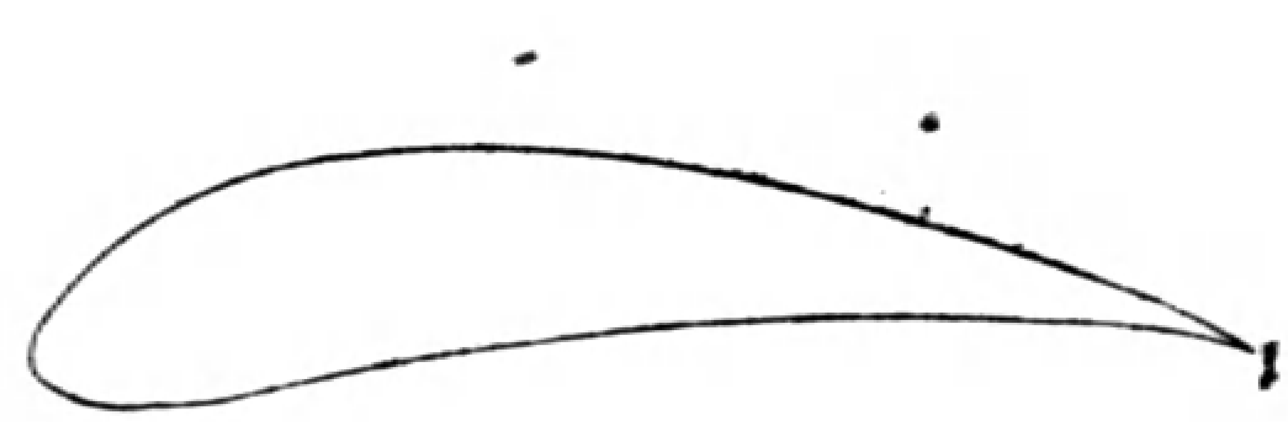
There are three 3 famous wing theories based on pure mathematics the most marvelous of which is that of J. Joukowski, then von Mises, and Max. Munk (also Glauert). The best wings are developed by actual trials.

(a) **Joukowski Wing.** This great mathematical accomplishment as well as aeronautical engineering starts first with streamline function and velocity-potential function which is nothing but Lagarnges' equations. All of us are familiar with magnetic fields which exists around a wire carrying a steady current in one direction. We are familar to with electrical fields which radiates outward from a wire with high voltage. Streamline function will be used on magnetic and potential function on electrical fields. The next step Joukowski took was to apply the methods in complex variables and then conjugate function (Greene's theorem). The final step was the application of conformal transformation which enabled him to change circles into ellipses and vise versa. The details of making such a wing section is simply geometry. This is not all. The air velocity around the Joukowski wing, the pressure the moment, and the drag can be all calculated and the results are verified by experiments.

(b) **Von Mises Wing.** The Joukowski wing has this disadvantage that it has large C. P. travel and thin trailing edge which is hard to manufacture. The von Mises wing is an improvement that the trailing edge is turned up (fig. 14.) This turning up of the rear edge will neutralize some of the C. P. travel the other wing has. But the difficulty of making one is



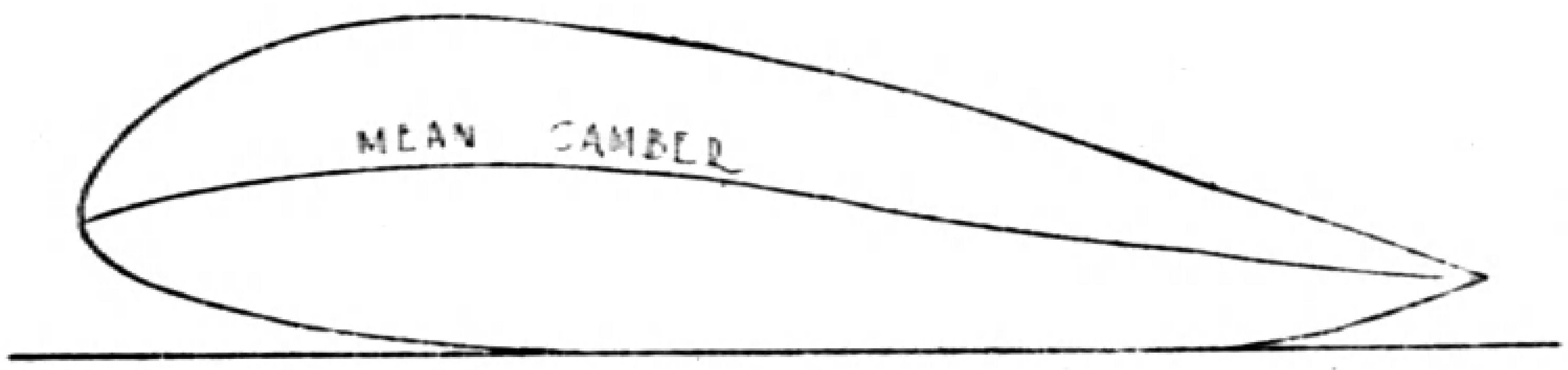
VON MISES WING' FIG. 14



JOUKOWSKI WING

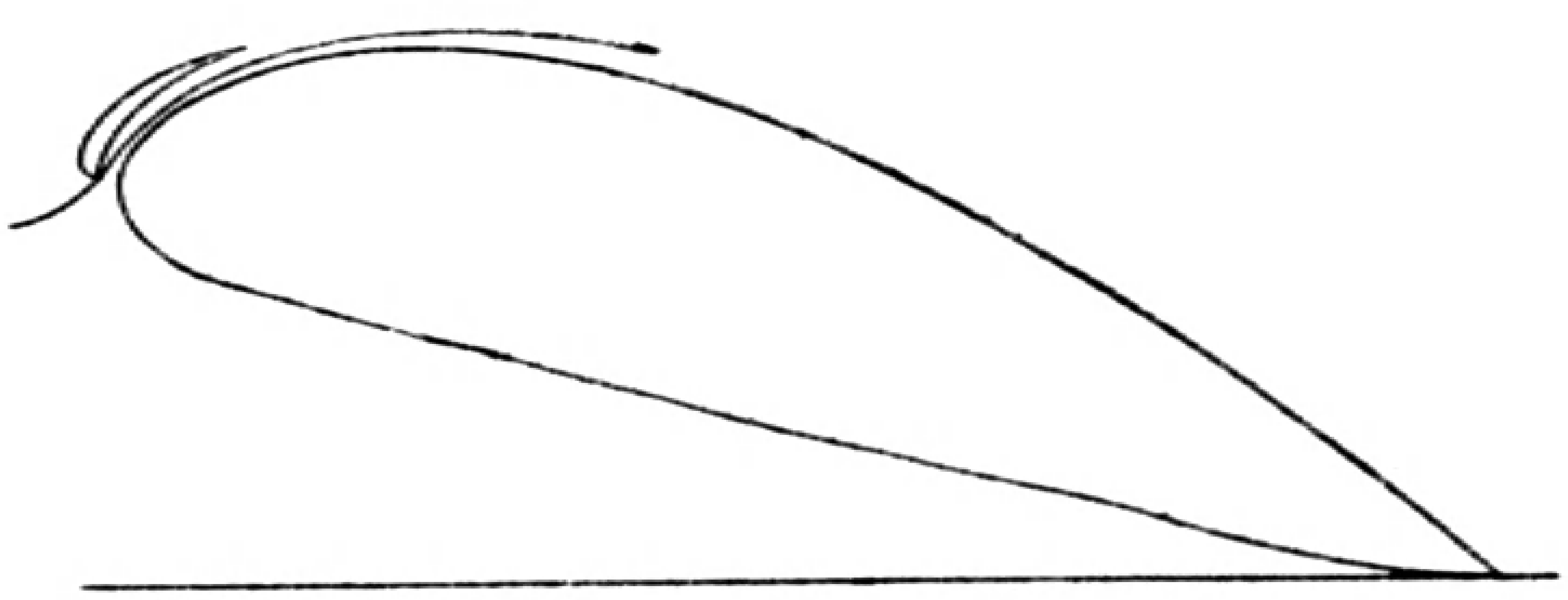
intensified. The mathematics of the wing is similar to that of the other save one more term is added during the development of a Fourier series.

(c) M. Munk Theory Munk's wing (also Glauert) differs from the other two in that this wing is based simply on the properties of straight or curved lines expressed in Fourie's series and representing the mean thickness of the wing (camber), fig. 15. The properties of the section are left to wind tunnel tests. In fact all the wing sections, when to be applied in making airplanes, have to be tested in order to have certainty. Therefore the theoretical developments does not put aside any of the wing sections developed by tests like that of Col. V. E. Clark, a friend of Mr. H. K. Chow. They really encouraged the use of wing sections based on tests as the latter will greatly facilitate manufacture.



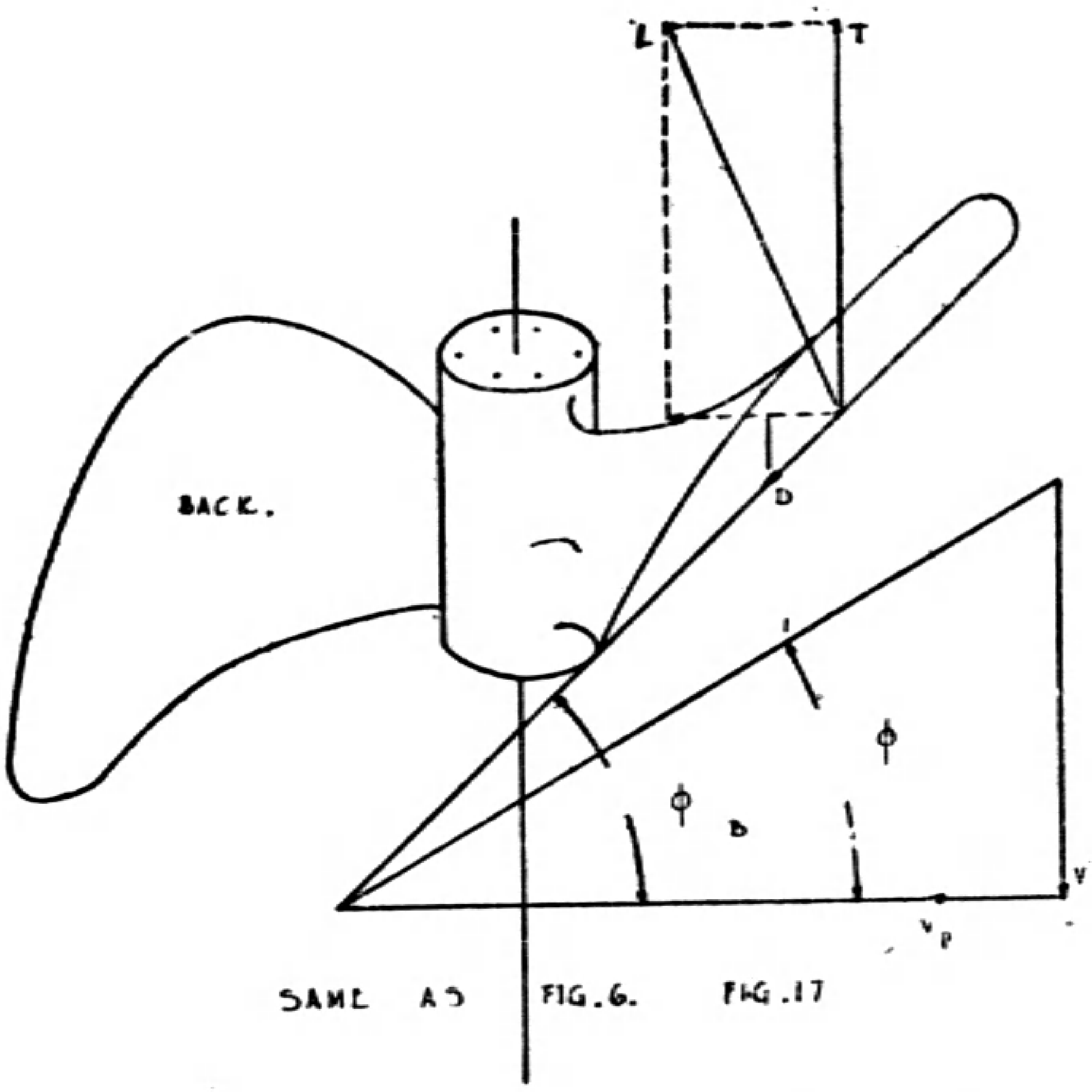
MUNK DEVELOPMENT. FIG. 15

The slotted wing of Handle Page is entirely empirical, fig. 16. Knowing that the air will get disturbed when the wing is elevated to too high an angle, he put a winglet in the nose of section to deflect the air down so as to make air flow smooth and graceful. It has been rated as the first great step forward in aviation. Troubles are still left in the fact that each wing has its own slot.



HANDLEY PAGE SLOTTED WING FIG 16

Propeller Theory. With the aid of marine propeller design, the propeller theory has been thoroughly treated somewhere else. Here it is is intended to give a very brief survey just as what was done to other parts



of the subject so as to make way for further study if you are interested in aeronautics. Some definitions:—

Aspect ratio, radius width, is blade angle, Viewpoint from cockpit, is $\tan^{-1}$ (V/nD), V is air velocity, D is diameter, Back of propeller is cambered, Plan view of propeller is its back, A section cut anywhere is assumed plane (actually cylindrical), Pitch is forward distance of one revolution of propeller, Geometrical pitch is pitch at 2/3 the radius, Experimental pitch is forward distance in one revolution resulting in zero thrust, (this is like a screw going into wood). Constant pitch is one whose sectional pitches has varying angles so that the forward advance is constant, Varying pitch propeller can have sections making any angle desirable.

The above definitons will greatly simplify the study of the propeller. The simple theory is developed by Drzweicki Fig. 17. The figure is almost self-explanatory as to how the thrust is developed by resolving the lift of the wing section to the forward direction of the propeller hub which is in line with X-axis of the airplane. The other components will be resolved into direction perpendicular to the propeller hub and is wasted, as a useless torque Q.

$$\text{Efficiency } e = \frac{\text{useful work of } V\ T}{\text{imput of } 2\pi N Q} \text{ of each}$$

section of the propeller. By studying the various sections set in arbitrary intervals, the complete thrust and imput needed can be determined by graphical integration.

The Drzweicki theory of the propeller is not complete because it neglected the change of air velocity after the propeller strike it and sends it flying back very fast. Also the rotational velocity of the air is not considered in finding the imput necessary. The Froude theory will then help out the situation.

Froude Theory Propeller. Fig. 18 suggests the idea of how the air is under going change of momentum due to the propeller. The Bernoulli equation is, at point A.

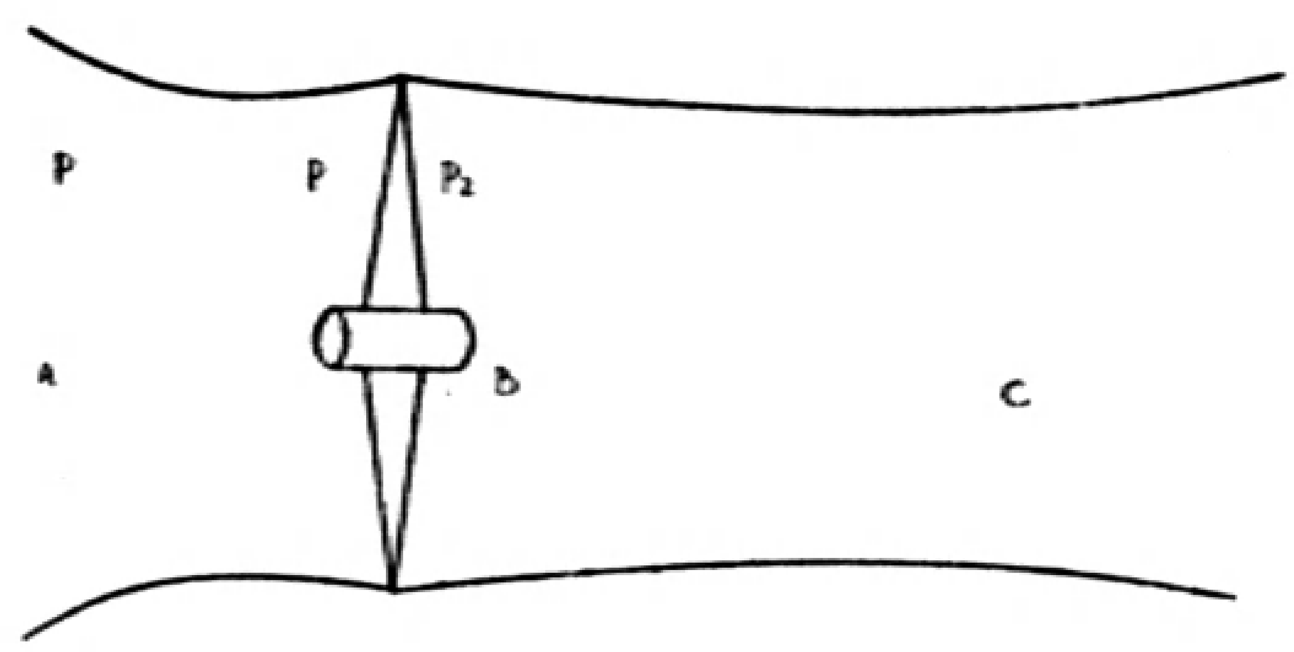


fig. 18

$$P_1 + \tfrac{1}{2}dV^2\,(1+a)^2 = P + \tfrac{1}{2}dV^2,$$

(d = density of air), and at B

$$P_2 + \tfrac{1}{2}dV^2\,(1+a)^2 = P + \tfrac{1}{2}dV^2\,(1+b)^2.$$

$$P_2 - p_1 = \tfrac{1}{2}dV^2\,((1+b)^2 - 1).$$

The momentum equation is, from mass of air and change of speed,

$$d\,A_a\,V_a = d\,A_b V\,(1 + a) = d\,A_c\,V\,(1 + b).$$

where A is area and V is velocity of air at sections A, B, & C, a, b are change of air speed,

$$A_A = A_B\,(1 + a) \text{ and } A_C = \frac{A_B\,(1 + a)}{(1 + b)}.$$

The thrust T is a force of mass times acceleration,

$$T = A_B\,(p_2 - p_1) = d\,A_b\,(V + v\,a)\,b$$
$$= \tfrac{1}{2}\,d\,A_b\,V\,[(1 + b)^2 - 1], \qquad b = 2a.$$

But sometimes acceleration b is assumed as 3a. Few knows the intricacies of the actual condition existing in air. From the above considerations, it is seen that the efficiency is

$$e = \frac{1}{1 + a}.$$

Propeller design is a mighty complicated subject. It is wise to stop here.

(3) *Stability and dynamice of the airplane.*

.. More fortunate are the mathematicians who worked out the stbility of airplanes than those who worked on the wing theories. There are two kinds of stability about bodies moving in fluids, the statical and dynamical stability. The stability equation I put out at the beginning of the talk was that for statical stability during level flying. Instead of going into mathematics I shall brieflq state the conditions. Since the balancing of the airplane requires the interconnection of the wing force and the tail force, there is differential calculus in the development of that inter-relationship. There is also differential calculus in treating the thrust and its relation to the center of gravity of the entire airplane. The slip-stream and downwash play an important part too. Fortunately, when the airplane is balanced in these statical conditions they will be dynamically stable at certain range of speeds.

Dynamical Stability. The dynamical stability deals with two phases of the problem, the longitudinal and the lateral. Since the former is more important, I shall briefly state the problem. The following table is convenient for a ready reference in visualizing the directions and forces,

Axis	Moment	Motion	Ang. vel.	angle	velocity	Force	Torque
x	L	roll	p	Θ	U	X	M_p
y	M	pitch	q	Θ	V	Y	M_q
x	N	yaw	r	ψ	W	Y	M_r

Since the airplane is free to move in hree dimensions, it can go forward and backward (not easily), right and left, up and down. It can also climb and descend, roll and yaw like a ship in sea. When translation is made there is developed an air resistance to oppose the translation. When rotation is made, there is resistance due to air developed to resist the motion. The forces thus developed are called the resistance derivatives. There are three translation motions and three rotational motions. So there will be six forces acting on the airplane when it is moving freely in all directions, and the derivatives will have reference vectors of six. Thus thirty six simultaneous equations will result. Among the thirty six unknowns seven can be measured in the windtunnel. So the problem is still unsolved.

However expert mathematicians have spent plenty of time in succession to study the motion by taking small changes of velocity called the step-by-step method and calculate the motion for a few seconds. During the process of analysis, some terms will be ignored on account of being higher orders of derivative. Aided by the method of determinants, the complete motion is reduced to a bi-quadratic equation with proper coefficients of twenty three. The form is like.

$$Ax^4 + Bx^3 + Cx^2 + Dx + E = 0.$$

Routh has made known of a factor called Routh's Discriminant,

$$R = BCD - AD^2 - EB^2$$

which must be positive for good stability. The solution of such an equation is rather complicated. But Bairstow has factored out the equation into two quadratic equations one of which represents a fast oscillating motion, the other a slow oscillating motion The equation is like the following,

$$(x^2 + B/A + C/A)\,[x^2 + (D/C - BE/C^2)\,x + E/C] = 0.$$

The first factor represents a quick oscillating motion and the second a slow one.

Similar equations are derived for the lateral motion of the airplane but will be omitted for convenience.

(4) *Performance.*

The performance of the airplane varies with the purpose of the design. Commercial airplanes require long voyage economy while racers needs speed and climbing capabilities. I shall make known the list of items usually calculated from equations in standard text books,

Take-off time and distance,
Rate of climbing at various altitudes,
Maximum speed attainable at service ceiling,
Cruising speed at service ceiling,
(Service ceiling is place where airplane will climb 100 feet per minute),
Calculation of absolute ceiling where airplane cannot climb any more due to decrease of power.
Stalling speed when airplane will not lift the weight,
Landing speed (similar to stalling speed),
Gliding speed with power on and power off.
Landing distance and time after wheel touches ground,
Endurance (time to stay in air),
Range (maximum distance the airplane can go).

Engineers working on performance usually occupy a special department of considerable size. Their job is to predict performance to avoid waste for the company.

(5) *Maneuvers of the Airplane.*

Maneuvers of the airplane is a subject of the aeronautical engineer but the carrying out depends upon the flier. The measure of maneuverability is the time to make a 180 degree turn, in other words to reverse the direction of flight, at a certain given speed. Commercial airplanes are hard to maneuver because they are made too stable and smooth flying. Military airplane are made short, small, and fast, so that the maneuverability is very high. High maneuverability means extra strength required. While the excessive wear of racing automobiles is on the tire and track, the excessive force on the maneuverable airplane is on the wings. Diving down the airplane at very high speeds, and suddenly pull it out by making the wing nearly perpendicular to the relative wind, the airplane will slow down but will suffer a sudden deceleration. Thus wings often came off due to this load. A list of the names of maneuvers seems interesting, for reference,

Pulling out of dive,
Loop, inside and outside loops,
Inverted flying,
Immelmann turn,
Roll, barrel, Dutch, spiral,
Wing over,
Falling leave,
Flat spin,
Tail spin,
William's turn.

Explanation of each can be asked any body in the airports, so I shall pass on to the next topic.

(6) *Controls of the Airplane.*

With the rise of commercial airplane industry, control of airplane became a special branch of study, because slower speeds need better controls. The first designs of control in the commercial airplanes are based on military results. Very soon it was found the rule does not work. At present there is no data for the proper design of airplane controls. The candidate aeronautical engineer has to gather data from various successful airplanes. The tail area, the rudder area, and the aileron area, are usually expressed in percentages of the wing area with special reference to their center of loading from the center of gravity of the entire airplane. This is very similar to the proper location of the center of pressure of the wing from the c.g. of the plane. Rough figure are this,

aileron........8—12% of wing area,
Horizontal tail area, 14—20%,
vertical „ „ 4— 5%.
20% increase for flying boats and amphibions.
20% increase for any special slow speed airplane.

Controlling big airplanes must be done by one man and the load on the control surfaces are very great. So balanced controls are devised. This is done by making the surface well distributed on either side of the turning hinge, leaving just a little over balance for the pilot to work on. Automatic controls have been designed in Germany already but the use of mercury electrodes and electric motors are rather heavy.

Another difficulty with controls is when the control is moved the air is disturbed sometimes to dangerous conditions. Then comes the slotted controls where the motion of the control will not disturb the air so badly as to make other parts of the airplane lose their effects.

(7) *Miscellaneous Topics.*

A list of the topics will be enough to incite interest,
wind tunnel studies,
air motion around large erections like chimneys, buildings, etc.,
air above rivers and lakes,
air around cliffs and surrounding canyons,
meteorology,
air in clouds,
winds around hill-sides,
and so forth.

PART III. DESIGN OF THE AIRPLANE

Like any other designing work, airplane design involves a lot of changes on account of the sad limitations. There are points best in aerodynamics but impossible of design like great aspect ratios and other things. The wing can never be designed like that of bird. Still the airplane industry is prospering if we go within those limits. The following steps will guide any designer from going astray.

(1) Purpose of the airplane, to be commercial, military, racing, messenger, farm dusting, photographic, or others.

(2) Free hand drawing to carry out the main feature of patentable specialities.

(3) Weight estimates for the empty airplane and the contents, and the balance about the entire center of gravity.

(4) Scaled drawing in three views with outlines of contents like pilots, passengers, baggage, gas tank, oil tank, and other important items.

(5) Study of wing sections and decision on one.

(6) Decision of the engine to be used.

(7) Preliminary performance estimates.

(8) Preliminary stress analysis.

(9) Arrangement of controls.

(10) Stability estimates.

(11) Changes of design to suit aerodynamics or vise versa, to avoid bulky members, and so forth.

(12) Control of weights, not t be over the estimated value to any too great extent.

(13) Final aerodynamics and tress analysis and completion of design.

Since all airplanes look alike, if one just draws up the outline of an airplane from common sense, it is most probable that it will fly after it is designed and built. So in this part of my paper, I will just point out what kinds of loads are coming on to the airplane, so that the plane will be designed to stand those loads.

The most important groups of the airplane that take up the loads are the wing group, the body group, the controls, the tail, the engine mount, and the landing gear. For simplicity, a monoplane will be taken up which has only one wing with the body hanging down from its middle.

Loads on Wing. Since the airplane is supported by the wing, the air load on the wing is distributed. So the wing is like a cantilever beam carrying air load and concentrated loads due to the body and contents.

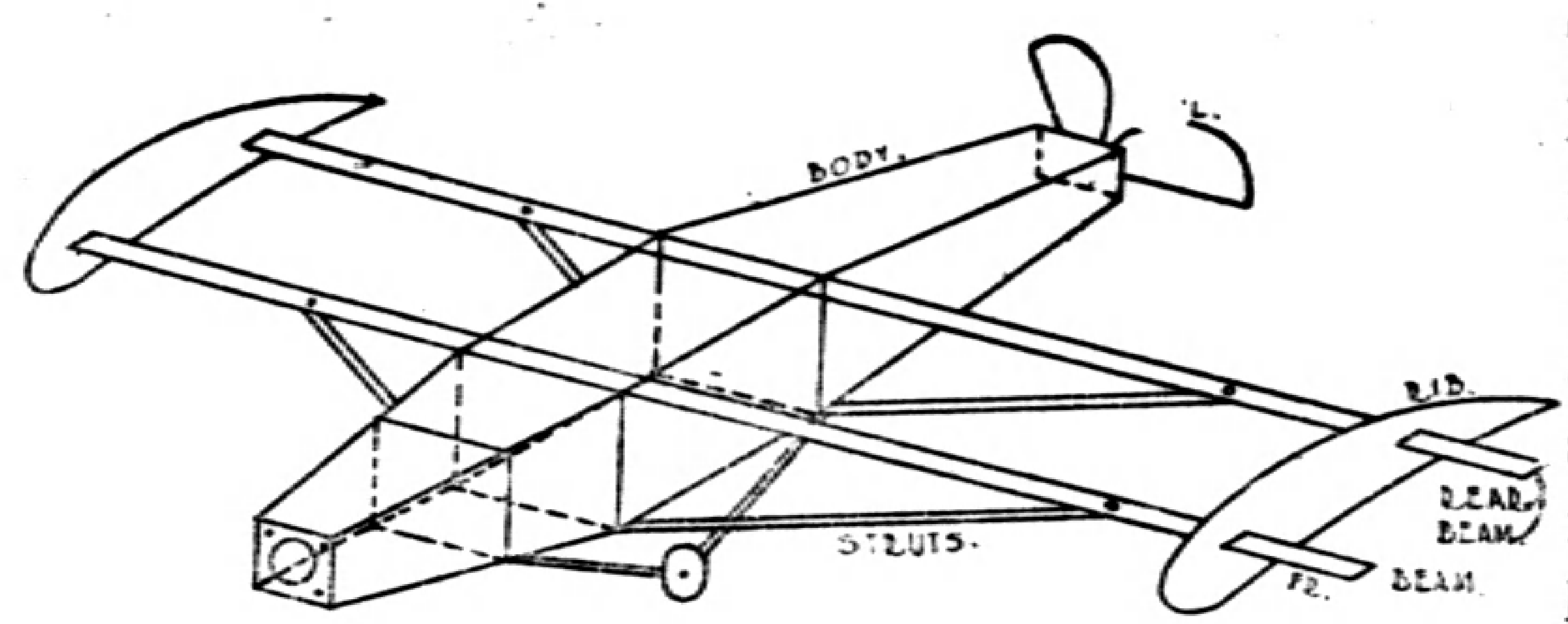


FIG. 19

To secure lightness and keep the wing section in comformity with the theory, above figure shows roughly how the skeleton of the airplane is built up. The ribs keep the wing section while the wing beam transmits the load on the ribs to itself together with the body load. Two wing beams are the least we can use, one front beam and one rear beam. How the air loads come onto the wing is analized as follows,

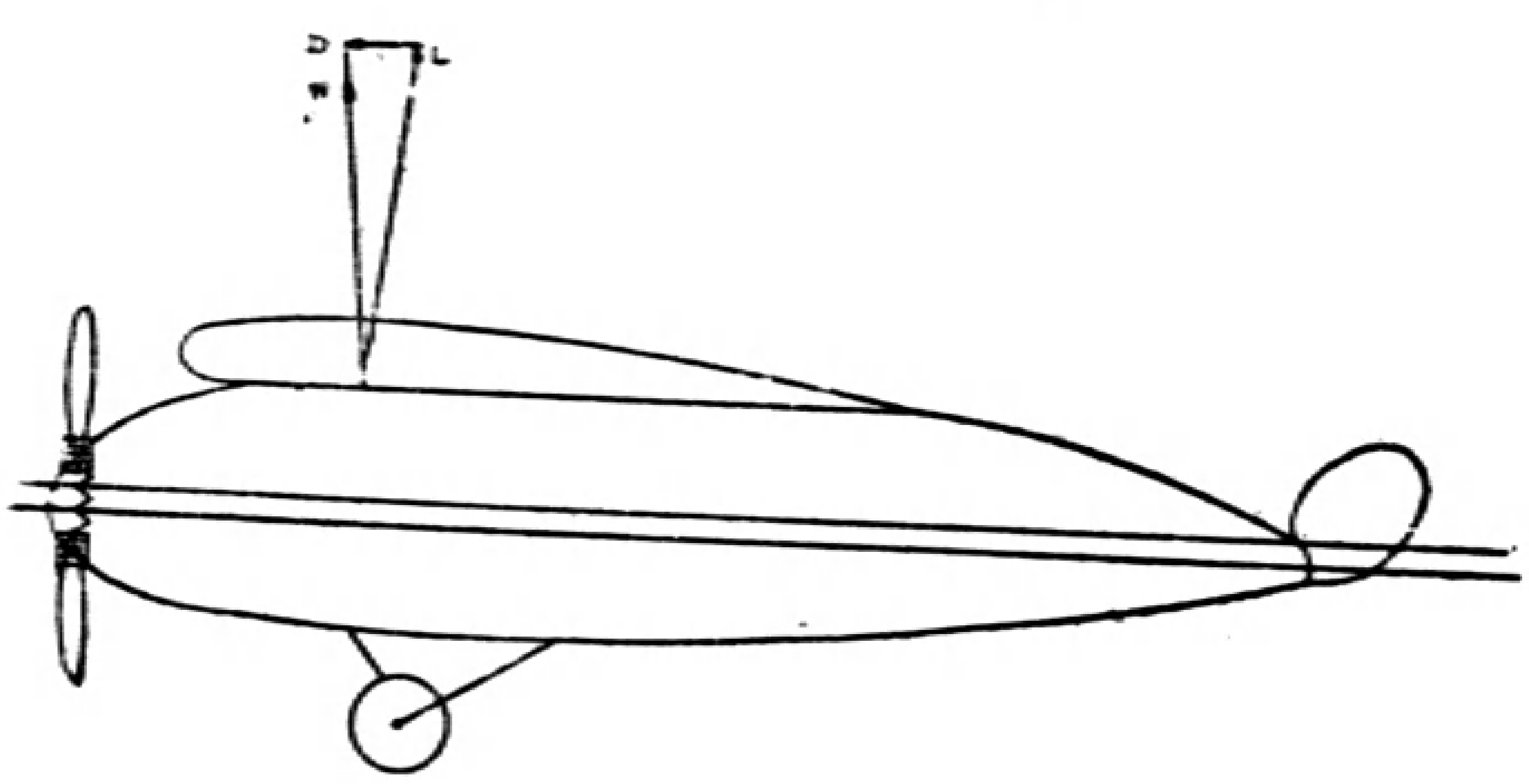


FIG. 20

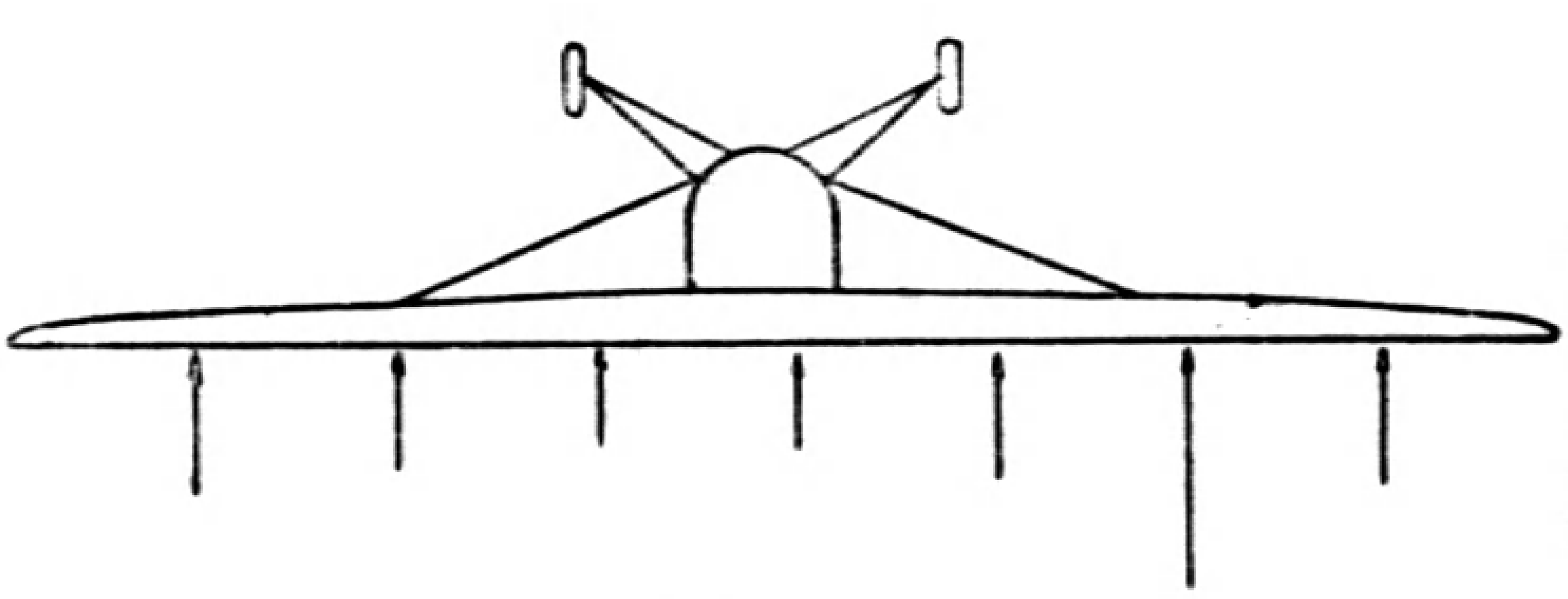


FIG 21

(1) High angle (or climing) flying when the load is near the front beam.

(2) High speed flying when the load is near the rear beam.

(3) Inverted flying when the load changes direction.

(4) Nose diving when the wing is twisted somewhat.

Figures at left are self explanatory.

The wing loads are expressed in pound per square foot of wing area. For stress analysis, the load is in pound per in. of wing span. This load is multiplied by a load factor for the four conditions,

condition (1) 6.5 x load per inch, (i.e. design load),

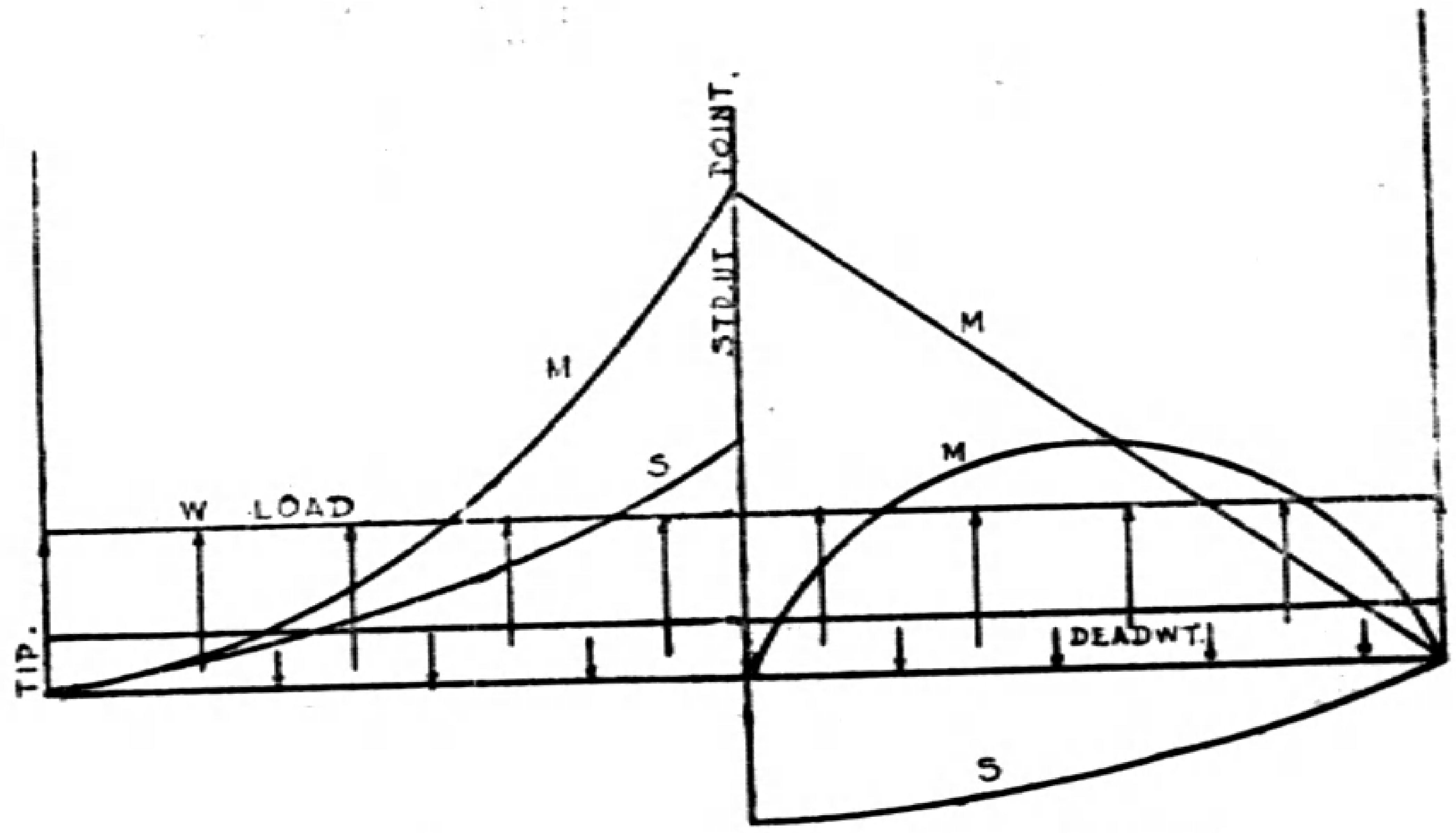
(2) 65% of (1),

(3) 40% of (1),

(4) below is the ex planation.

If the strength of the wing beam is stronger than the design load, the extra strength is called the margin of safety.

Wing Beam Design. In designing the wing beams, a loading curve curve for one pound per inch is the proper start. Figure at left shows the idea where w is the load per inch, s the shear at different sections, m the bending moment at the various sections.



INCHES BEAM FROM TIP FIG. 22

But the design load of the wing has to be divided between the two beams. The division is made by the following method. Refering to figure at left, Front spar F. S. will take the larger part of load at high angle while rear will take the larger load at high speed, since the c.p. is moved, fig. shows F. S. takes 70% of condition (1) and rear spar takes 70% of condition (2). For inverted flying, the high angle C. P. is used. For nose diving condition fig. 25 will be used to illustrate. The L. E. of wing is supposed to be under down load (referring to c.g. of airplane) and rear edge of wing is under upward load. The balance is taken care of by the down load on the tail to keep diving straight. The drag loads must be equal that weight of

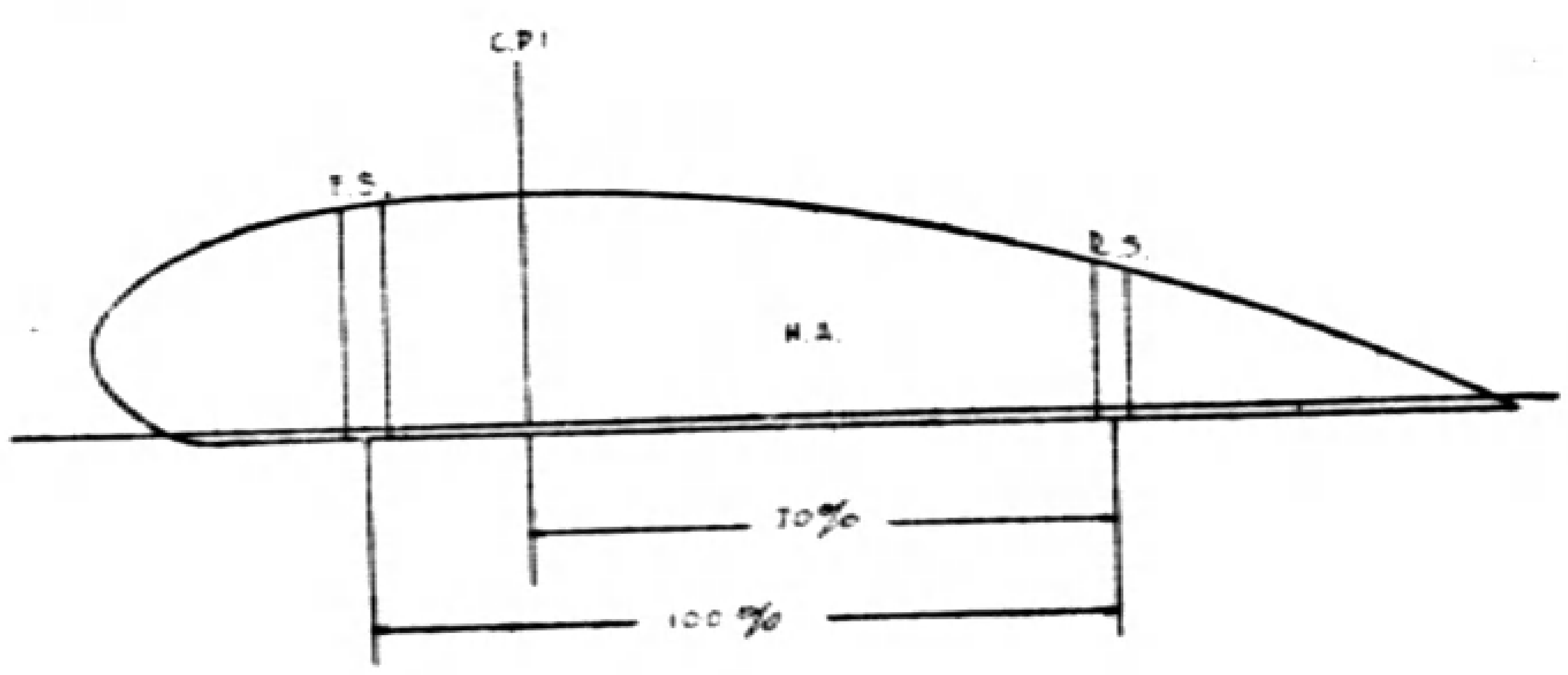


FIG. 23

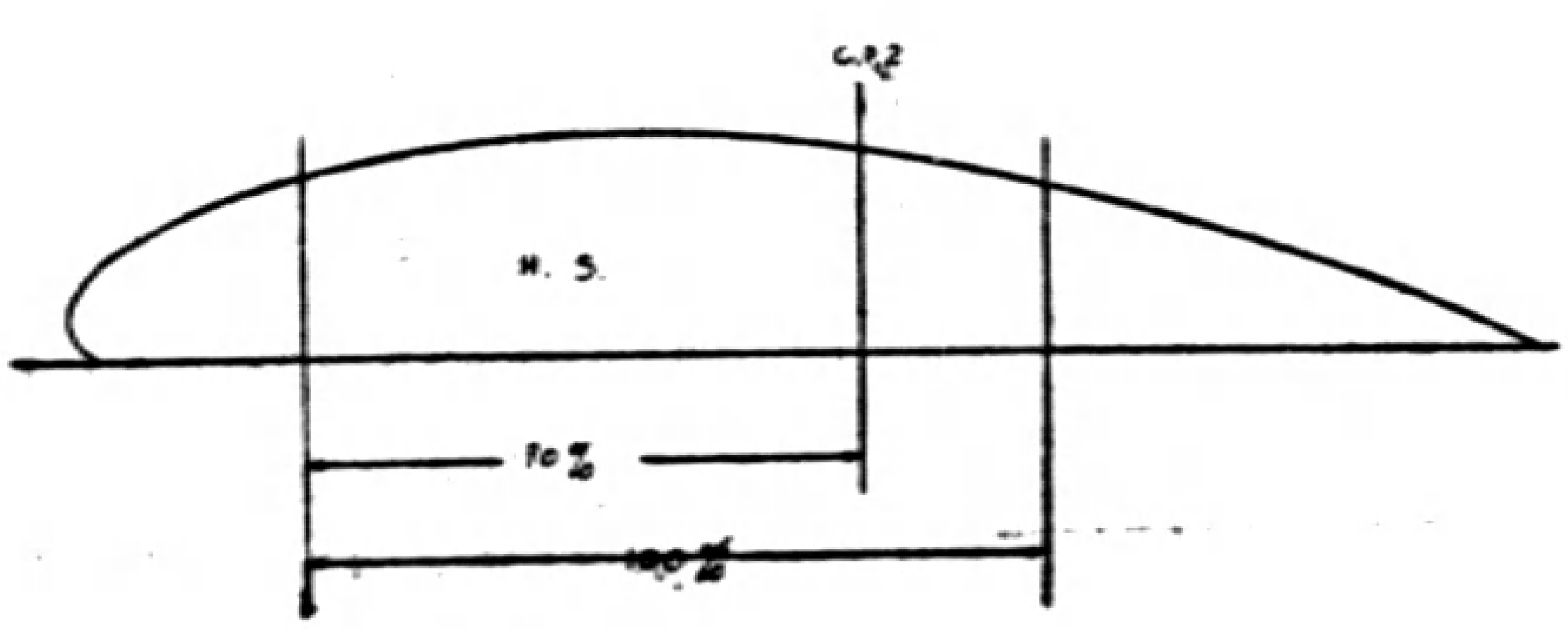


FIG 24

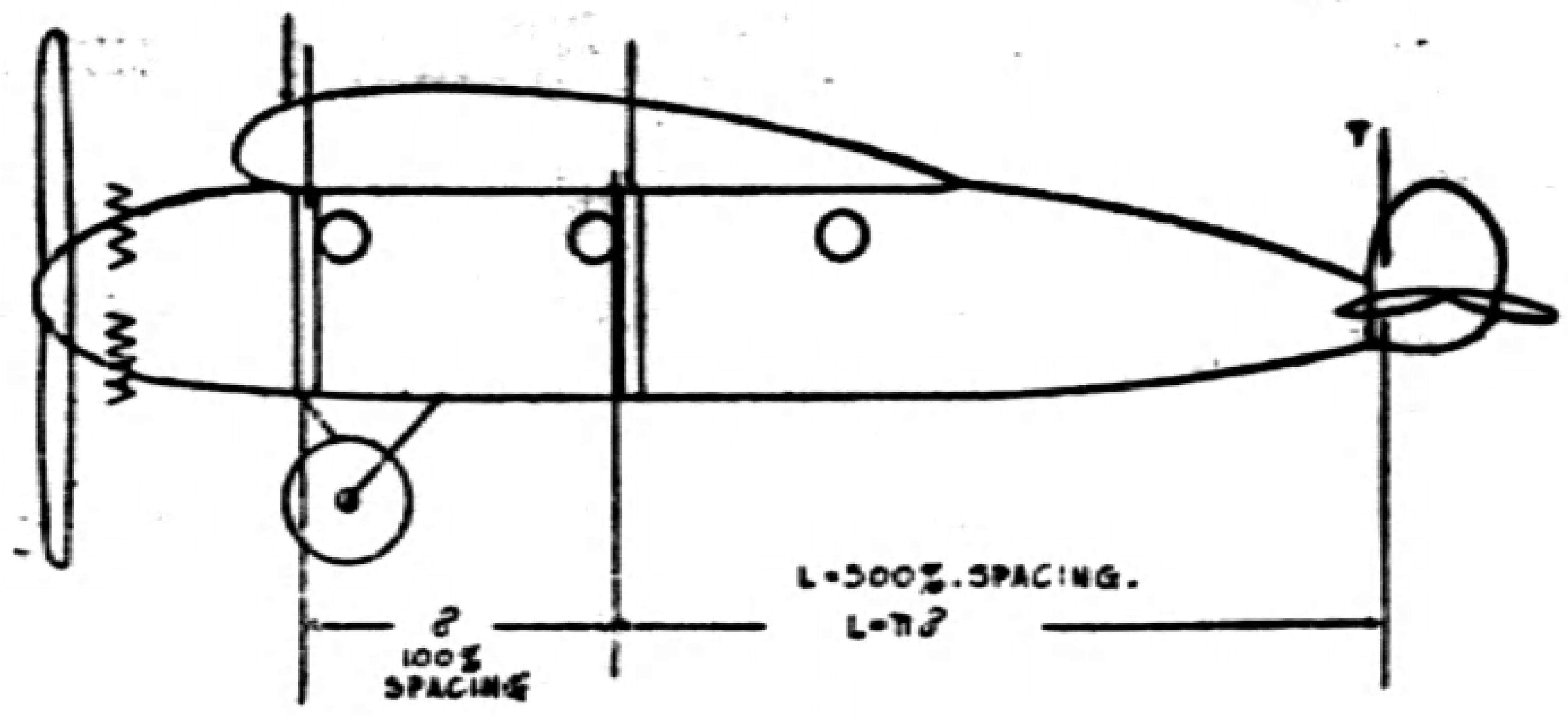


FIG. 25

entire airplane. The load will therefore be that of inverted for f. S. Tail load is gotten by taking moment about Rear Spar. Load on R. S. will be sum of that on F. S. and tail. Now the beam loads can be tabulated,

Condition	F. S. load	R. S. load
(1)	$0.7\times6.5\times$load/in.	$0.3\times6.5\times$load/in. w.
(2)	$0.3\times6.5\times0.65$ w	$0.7\times6.5\times0.65$ w
(3)	$0.4\times6.5\times0.7$ xw	$0.4\times6.5\times0.3$ w.
(4)	$0.4\times6.5\times0.7$ w	1.12 w+T

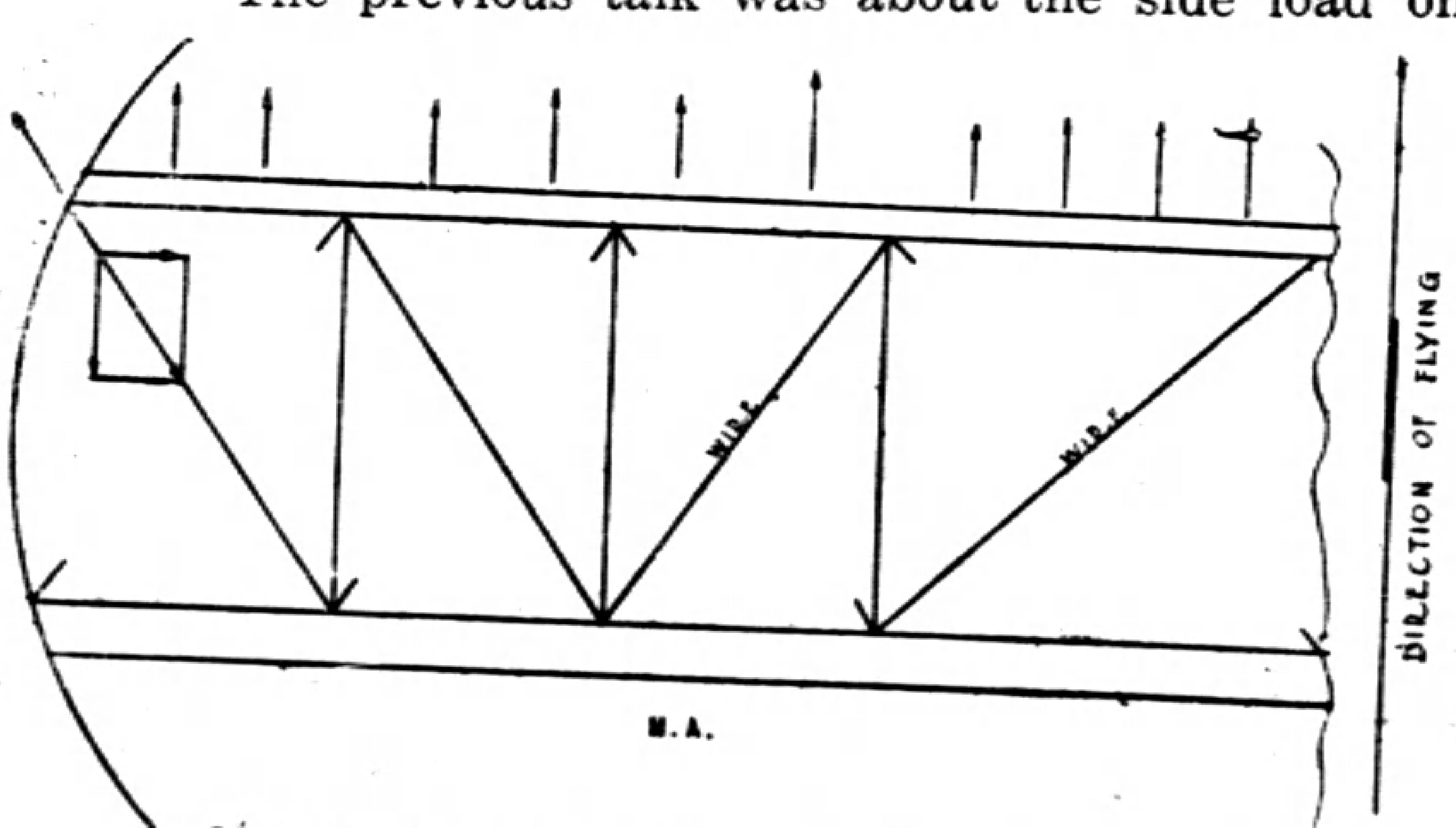
The bending and shear for the beam will be the above load multiplied by the values on the shear and bending curves.

There is another part of the air load not considered yet, i.e. the drag loads acting on the wing chord. This load is usually assumed to be 15% that of the beam load for condition (1) and (2). For (3) it is zero. For condition (4), the chord load C is the sum of condition (2), added 30% and modified by a constant k to be equal to the total weight. It is

$$K\times0.15(4{,}225)\times1.3=w \text{ in pounds per inch of span.}$$

It is to be noted that the dead weight of the wing must be subtracted from the air loads.

The previous talk was about the side load on the wing. The drag loads are carried to them by means of drag wires. Fig. at left shows the idea more clearly. The total drag load will act on the roots of the beams and will counter balance that due to the struts. Fig. 27 suggests the idea.



OMITTED WIRES ARE FOR OTHER CONDITIONS. FIG. 26

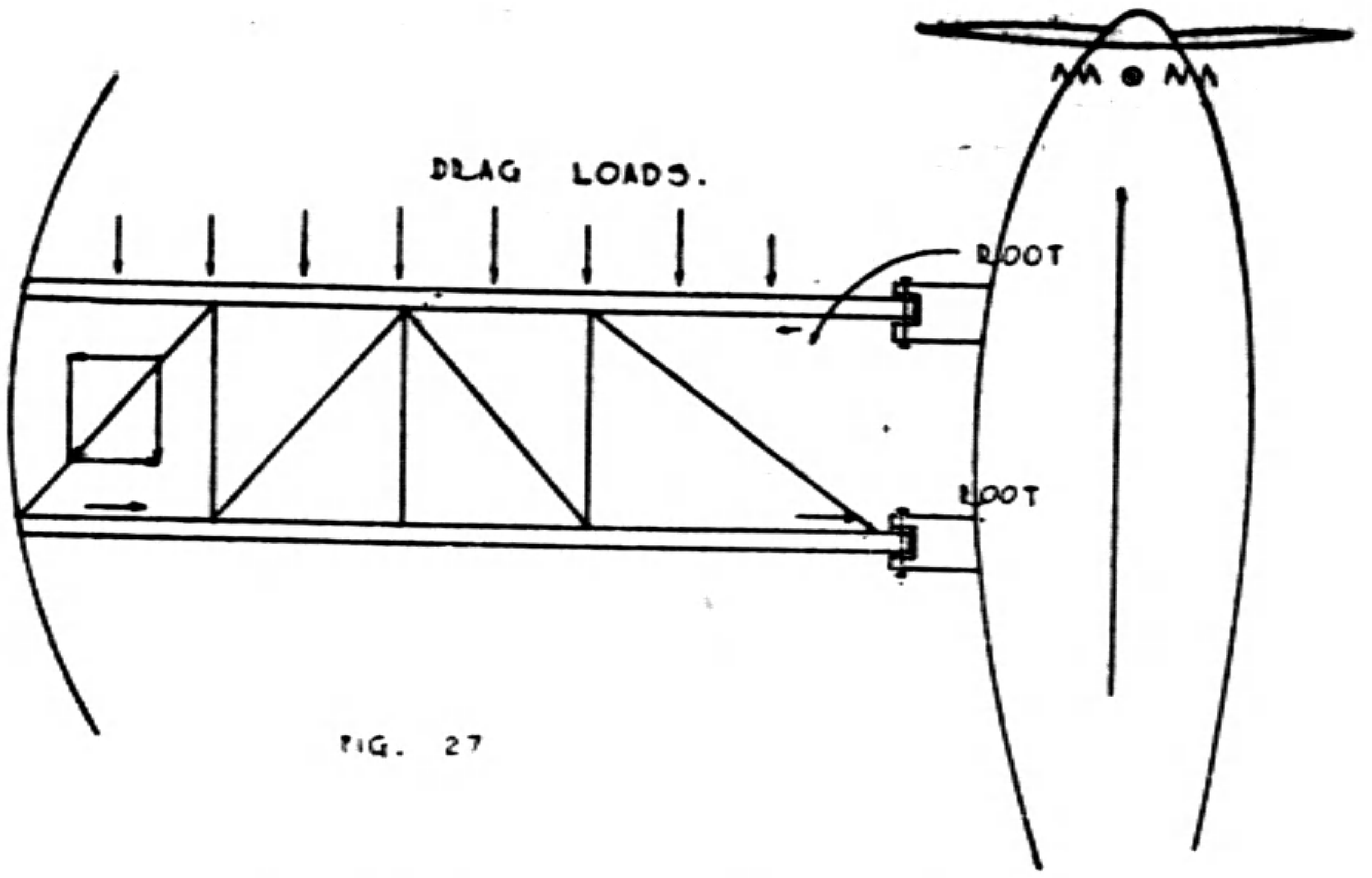


FIG. 27

It can now be summarized that there are the following loads on the beams,

the side loads, acting up and down,

the side loads action back and forth,

the axial compression due to wires or structs,

the aial tention due to wires on compression.

It is always good to define the sign of the loads before going too deep.

+ denotes load acting, up, back, out,

— denotes loads acting down, forward, in.

The nature of the loads have to be visualized for particular designs. After the loads are collected, then the beam can be designed for the most severe cases of loading. The components of the loads in all members must receive due attention. Thus the load component of a drag wire acts in three direction, one along each beam, one along the chord, and one in the wire. The components of the struts will have four, one along the struts, one along the beam, one along the chord, and one parallel to the Z—axis of the plane.

The rib design is a complete engineering unit itself and the usual manner of the rib design is hown as Fig. 28.

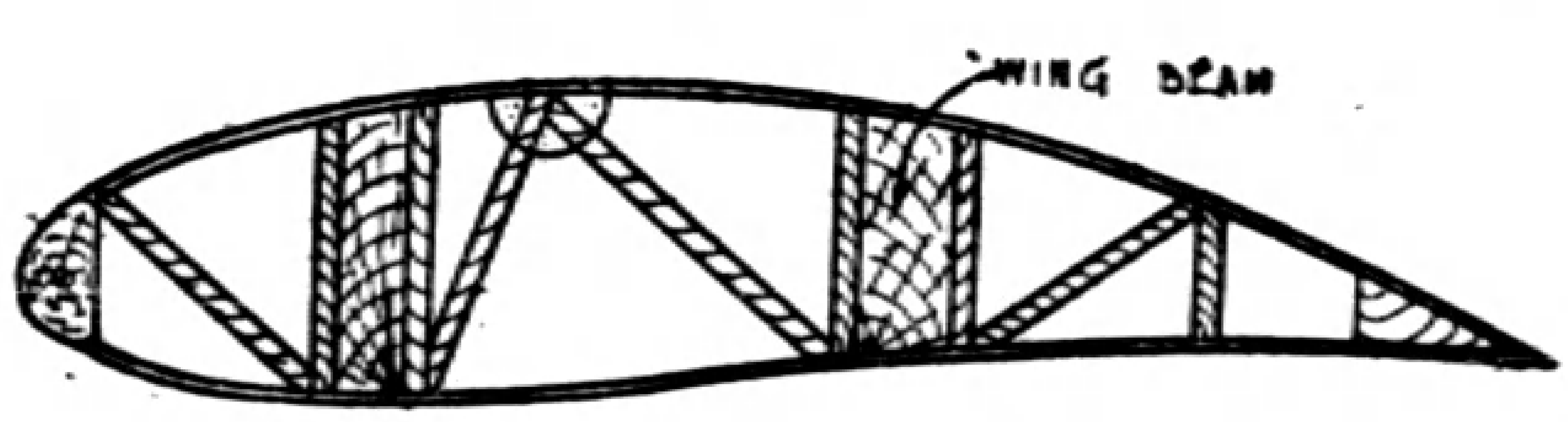


FIG. 28

The beam and strut design are finally the same for airplanes as for other structural members like that of a building, or rail, and so forth. Next we pass to the loads on the landing gear.

Loads on Landing Gear. The part of the whole chassis group that supports one wheel is usually in the form of an inverted tripod, the apex of which is attached to the hub of the wheel. For shock absorbing purposes, one member of the three has to slide along its own axis to absorb the shock while the other two will rotate about a common axis to them. The loads on them will be all compression or two compression and one tension depending on the direction of outer load. Same as for other members of the wing group, the components of the chassis members' loads must be duely treated. There are usually three conditions for the analysis of the chassis load,

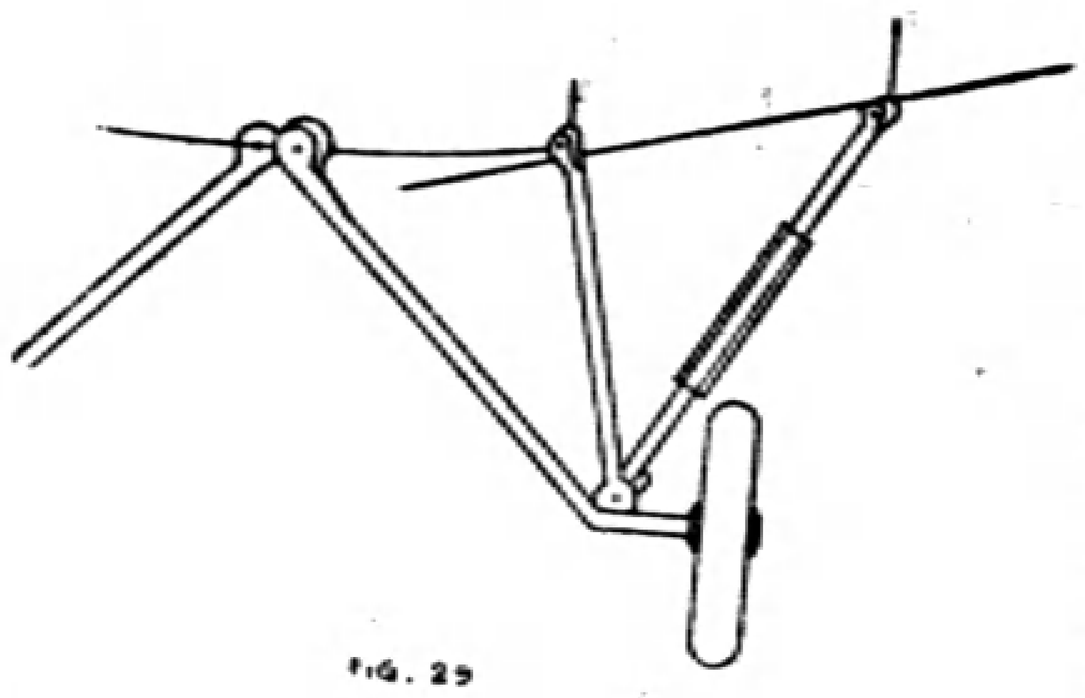


FIG. 29

three point landing,
two point landing (level landing),
one wheel landing.

The loads can be determined either graphically or analytically. The loads from wing analysis and chassis analysis are most important because the body analysis has to be based on these loads which are attached to it.

LOADS ON BODY

(1) First things to be done on the body are to plot the truss top, bottom, and side showing clearly where the joints are by center lines only.

(2) On these joints are placed the loads of the contents and the body's own weight.

(3) Assume the side truss to be in one plane and the loads on the joints are ½ (load factor) (unit loads).

(4) In distributing the loads in (2) the total weight must check the weights at the joints and the moment of each joint weight about the preliminary C. G. must check to zero. The preliminary C. G. was found in the preliminary balance by taking moment about a convenient point of reference so that the c.g. of the total airplane will balance at certain point of the wing section (usually at 33% from L. E.)

(5) C. G. of the airplane must be clearly put and dimensioned, from each joint, for all conditions of flying and landing. Because for flying the wing weight is not counted and for landing the chassis weight is not counted thus changing the C. G. to different places.

(6) Tabulation of the joint loads stating clearly the design loads for all conditions in flying and landing.

(7) Now the forces (or loads) due to flying and landing as found in the wing and chassis analysis have to have zero moment about the C. G. too. Usually they do not because of various arbitrary factors.

(8) In order to have (7) balanced, three simultaneous equations sum V, sum D and Sum M from the joint loads and the wing or chassis forces must be solved and a coefficient k introduced for balancing. The factor k is used to modify the wing or chassis forces.

(9) This step is to check the forces so that

in flying,

the lift of wing equals weight of plane,
the drag of wing equals thrust of propeller,
and the moment about c.g. be zero.

in landing,

the ground force up will equal weight down,
the ground resistance will equal inertia of plane,
and the moment about c.g. be zero.

(10) After the force systems are checked, a graphical solution of the side truss can be easily done.

After the above steps are taken the forces in the members will have various values. Only the greatest will be chosen for design.

(11) So a list of the members must be made and the loads due to flying conditions (1), (2), (3), (4), and landing conditions (5), (6), (7) to be filled in.

(12) But the rear part of the body will receive larger loads than is thought of. The rudder load usually give a large twist to the body's rear, and the elevators give a large bending force, that the top truss has to be analized for maxrudder load and the side truss under maximum elevator loads. These will be condition (8) and (9) for body.

(13) Also the nose of the body where the engine is usually put, will receive a torque when the engine starts. The nose is usually under severe load in high angle flying. So the side truss has to be analized for high angle load plus the load due to torque, Condition (10) for body.

(14) There may possible be special conditions for the body like hoisting into a steamer about some particular joints. This will occur for special designs.

The air loads that occur to the other parts of the airplane like the tail, and the airleron will be analized similar to that of the wing. The loads on the controls like the stick, the cables, the rudder bar and supports, are very simple and need no further explanation.

紡紗機之拖動法

著者: 費福燾

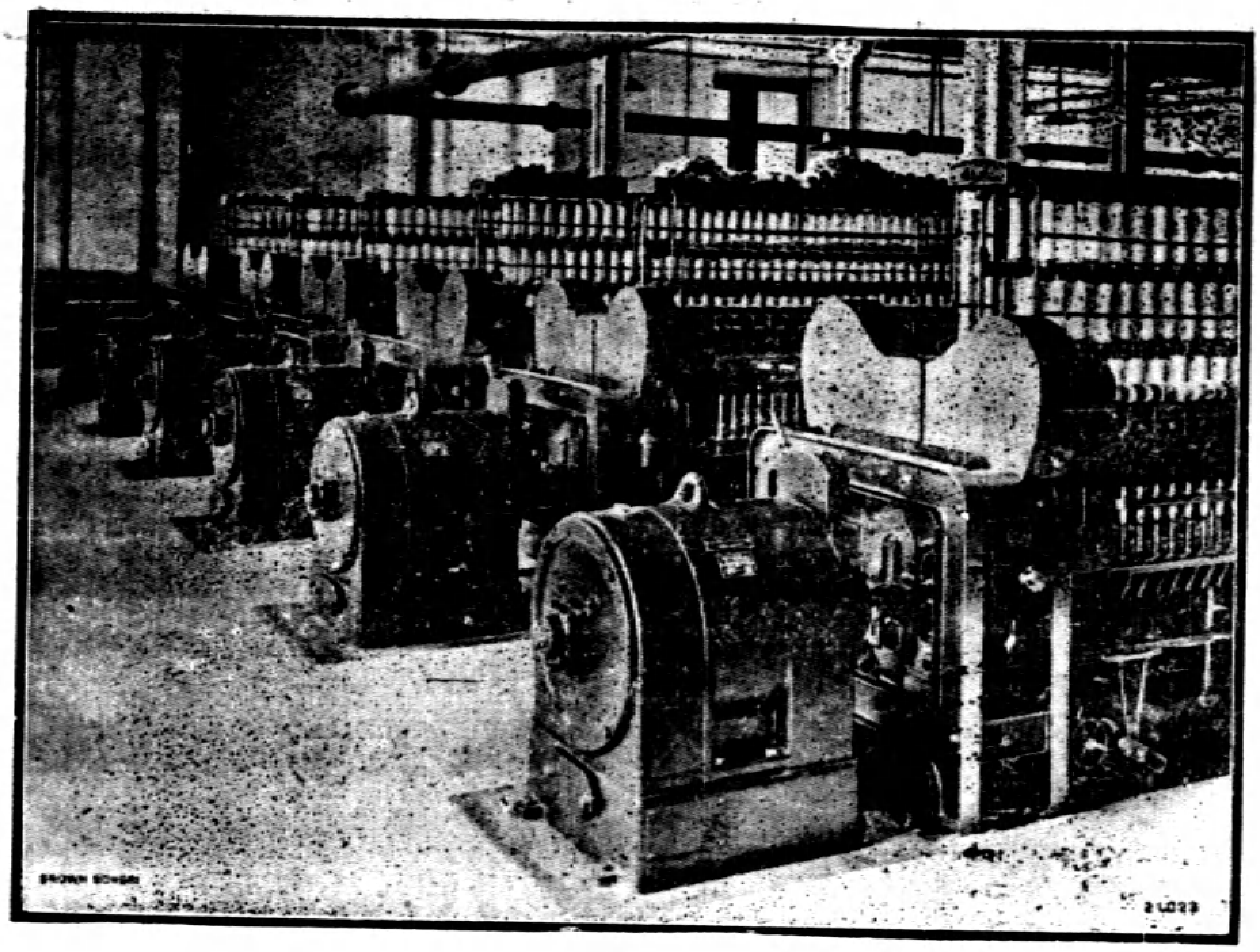
第一節　變速馬達單獨拖動法

自紗廠採取能變換速度之單相或三相更流電馬達拖動紗錠機以來,於今已二十年,該種制度之原理,係紗錠機紡錠子之時,馬達速度,能同時自動調節,俾維持紗線相當之拉力,紗線斷裂之弊,因之減少,而出品於以增多.方今各國大紗廠,採用該種制度者甚多.且應用於製蔴及紡毛機之拖動,亦極相宜.今將該種制度包括紡紗機(Ring Spinning Frame)馬達,及自動齒輪之關係,及互相配合法;述之如后.

自動調節速度之機關,爲兩個桃子盤(Cam),其動作則用適當之聯合;傳自紗錠機.該兩個桃子盤之動作,復傳到馬達之調速柄.緣上述之傳動,馬達整流子上電刷之地位,可以移動,而得所需要之紡織速度.至該兩桃子盤之責任其中之一,務使錠子始紡(Copping)及紡畢(Doffing)之時,速度較平常爲低.故在該兩種時間內,線紗之拉力減低,而線紗斷裂之虞;亦因之減少.其另一桃子盤則在紡紗機之鐵圈軌(Ring rail)每一起落之時;轉動一次.馬達之速度,因該桃子盤之作用在紗線紡在錠子上最小直徑之時,其速度減少.俟錠子之直徑,紡到最大時,馬達速度,亦增到最高點.

因上述之傳動法,紗線始終能維持其適當之拉力.用該種傳動,紡軸之平均速度.亦較一般用固定速度拖動之法爲高.其結果則紗錠機上每日之出品增加.當紡同樣質地之紗線,用變速傳動法則纏繞(Twist)較少,而所紡紗之堅久力,能與須纏繞較多之固定速度法相等.今請舉一例,有時用質地較軟之紗線.其纏繞須較少.若用固定速度拖動法,因紗線質地較軟之故,紗軸之速度,須減到極低度,以免紗線在紡織時之斷裂,倘用卜郎比變速拖動法,

則其速度與出品均皆較高.附圖一爲*瑞士卜郎比變速馬達,在歐洲某紗廠之攝影.今將其緊要項目述之.每馬達爲六•八輪製馬工率,四百伏而特,五十周波,每分鐘一千轉.該項馬達係單相制,但平均分佈於三相線上.其速度調節,可自每分鐘六百轉增至一千二百轉而

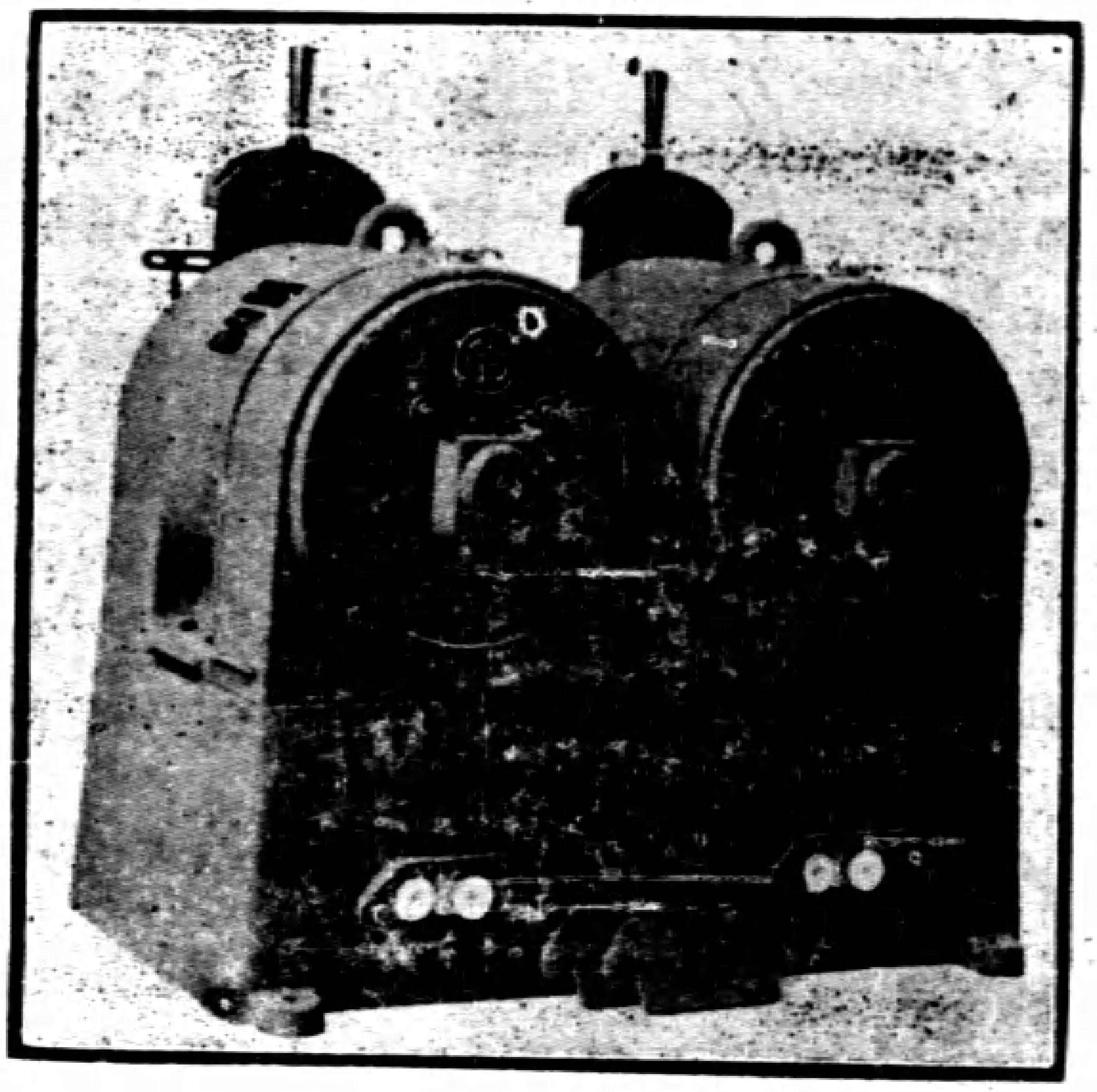


第　一　圖

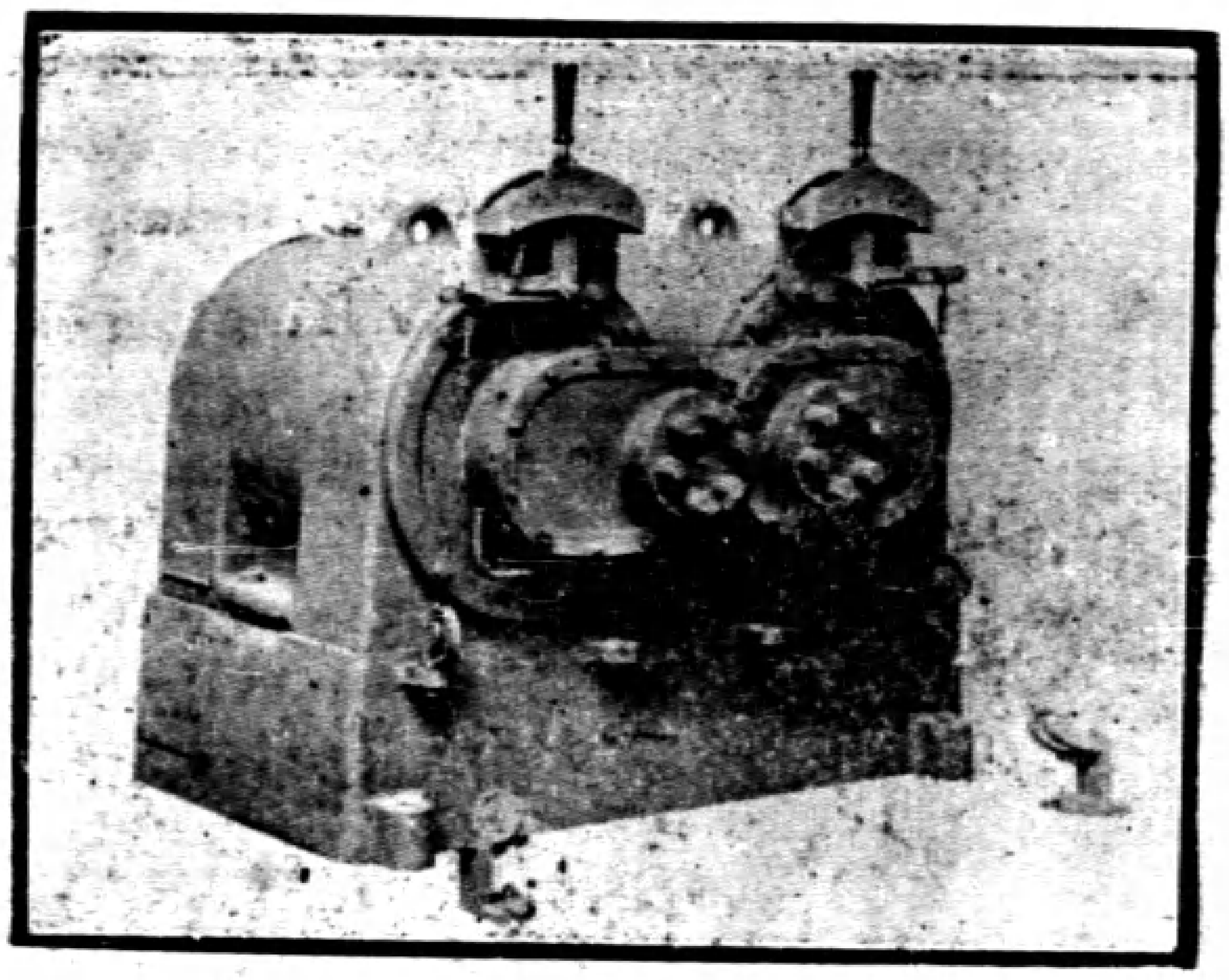
並無電損.每紗機裝五百錠子.其所紡線紗支數,自四•五至廿四支.(Counts)因紡該項粗紗之時間甚短,故除自動調節齒輪之外,尙裝一完全停止紗軸之機關(Full Bobbin Stop Motion)直接傳到馬達之起動柄而使馬達停止,當該廠採用該種變速馬達第一批共十部,結果甚爲圓滿.前後復添辦二十部.至用該種馬達之成績,則出品較該廠所用之別種拖動法,增加百分之七.除單獨馬達拖動紡紗機外,(見圖一)該種馬達製造上稍事改變,應用於他種工業甚多.如雙架紡毛機,常裝有兩個滚筒,故應用雙馬達拖動法.(見圖二)又馬達位於一底座之上,而每個馬達之速度,各被其自動齒輪所調節.

有時雙架紡機之滚筒相距太近,而仍欲採用雙馬達拖動制度;則可裝置

*瑞士卜郎比電機廠在中國獨家經理者爲上海九江路二十二號新通貿易公司



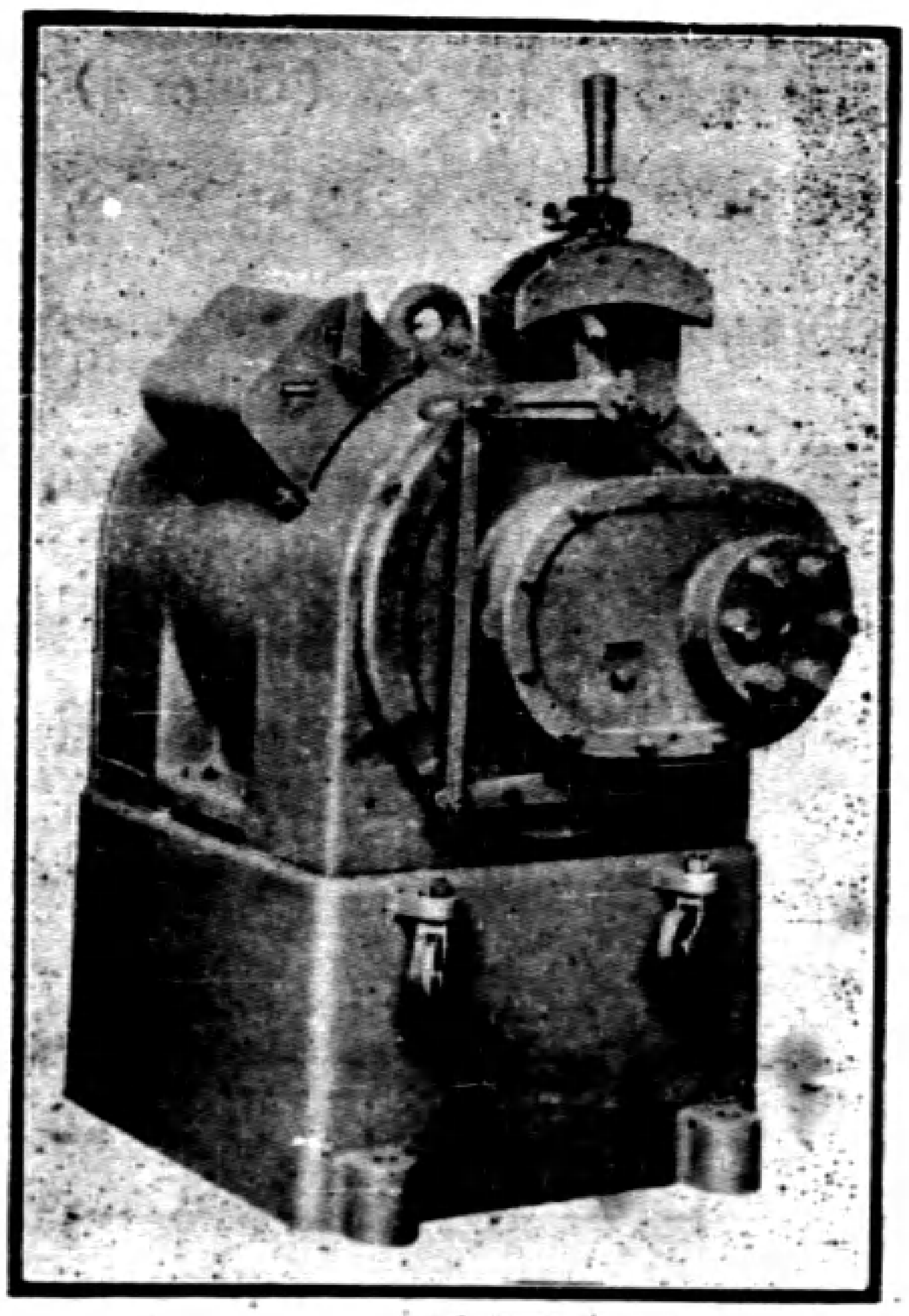
第二圖



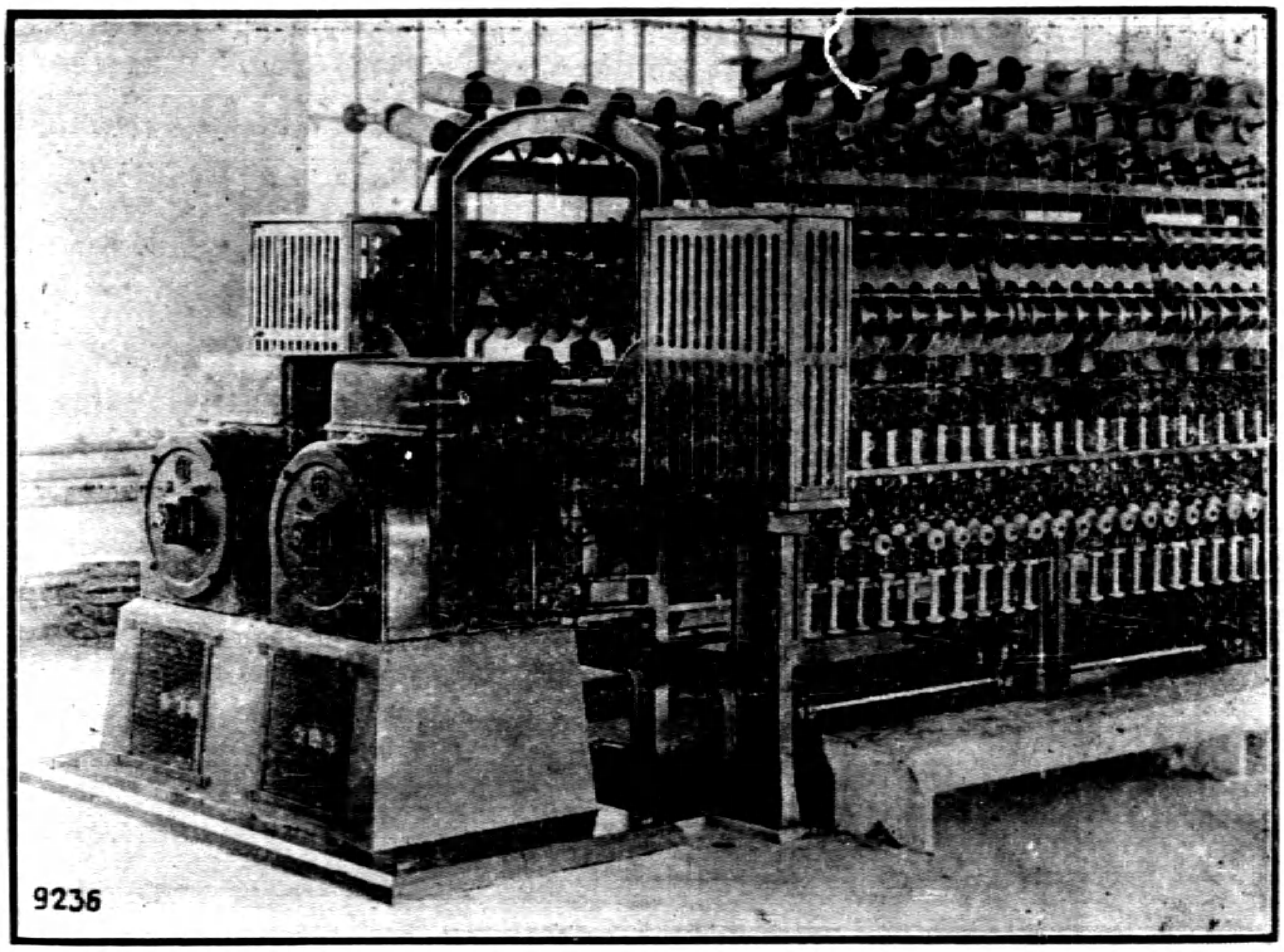
第三圖

高效率之變速齒輪.該齒輪在一油缸內轉動,故永得滑潤.(見圖三)

倘紡機之錫滾筒(Tin roller)較馬達之普通速度爲低.可利用變速齒輪配合;俾適合任何紡織機之速度;而同時又得最適宜之馬達特性.倘紡紗機速度之調節更須增廣,可加裝固定子變換鑰.(Stator Change Over Switch)(見圖四)該圖並表明變速齒輪之裝置至該種馬達之冷却法係在廠房內地板下裝設風道.新鮮空氣自廠外引入,經過馬達內部之後,其熱空氣復導至廠外.有時熱空氣散在廠內亦無妨礙.如圖五所示,係三相整流子變速馬達拖動紡蔴機.馬達裝在鐵櫈之上,而所通過之空氣,經過馬達後;散在廠房之內.



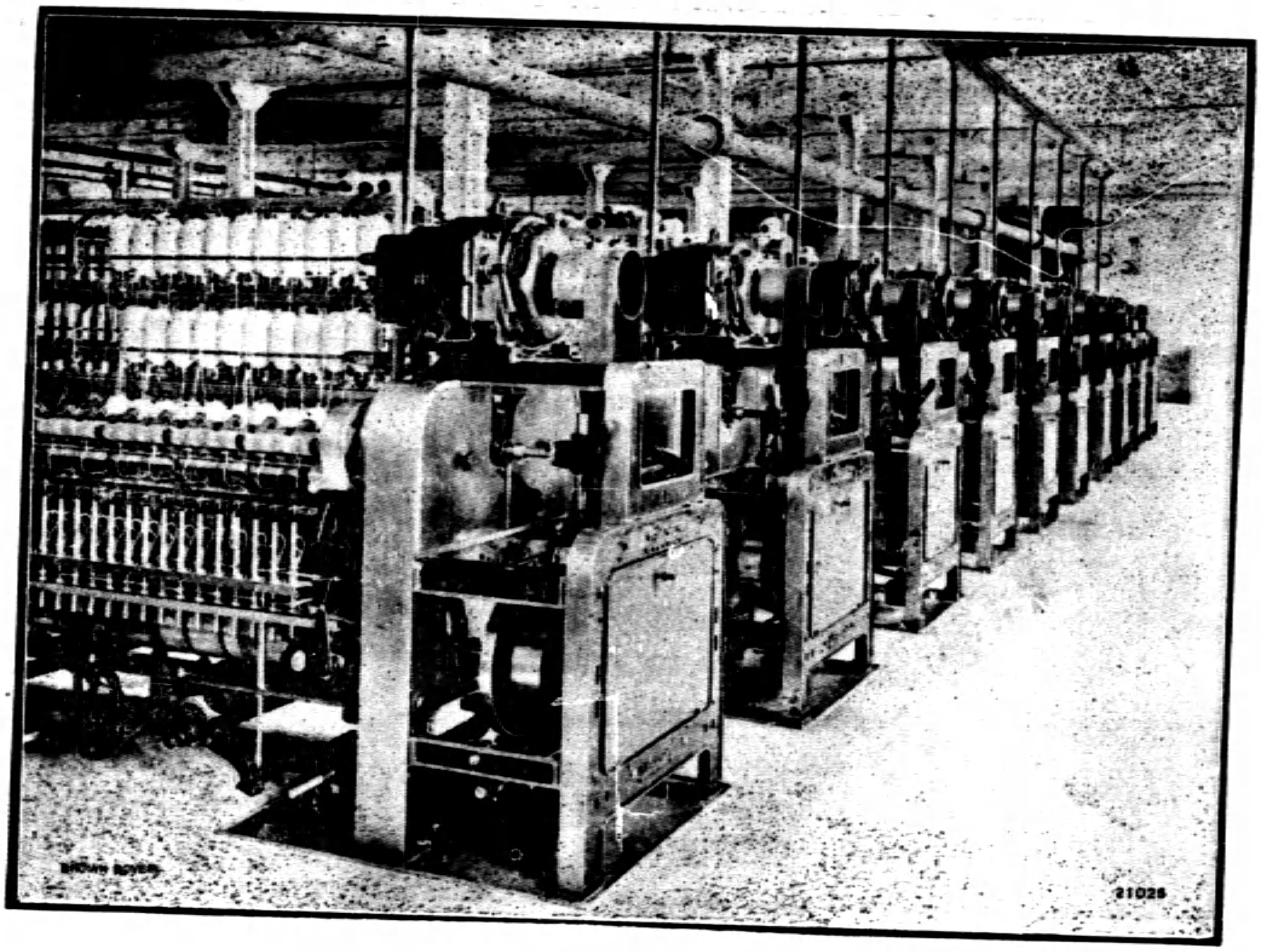
第四圖



第五圖

第二節　價值較廉之松鼠籠式馬達單獨拖動法

紡織廠中,有時因所紡紗線之性質,對於自動變速馬達制不甚合算,則可採取價格較廉之松鼠籠式馬達單獨拖動制.如圖六所示,該種馬達係松鼠籠式亦名短接式(Squirrel cage type)裝設鋼珠軸領,馬達兩端有孔,其內則裝設特製風扇,故馬達之繞線得以冷却,而同時因該種特製風扇之轉動,將黏在馬達上之棉塵吹去,而不至鑽入馬達內部,馬達之壽命及安全於以保障.(作者曾參觀瑞士魏廷根紗廠.試將小棉團塞入馬達孔內,立時爲風扇吹出)如圖六所示,卽係該項馬達裝在紡紗機之端,而位在一鐵架之上.占地既省,視察亦易,較之用架空拖動法,所省地位甚多.且廠內光線亦因之不受影響.該項馬達,因用特種皮帶盤(Jockey pulley)傳動,故皮帶甚短而傳動之效率甚高.該種皮帶盤尙有一利,卽錠子始紡之時,可將皮帶暫時扳鬆;俾錠



第　六　圖

子軸之速度在此時稍減;而紗線之拉力亦因之稍低;故紗線斷裂之虞得以減少.故用該項拖動制較之用架空傳動法等之平均速度爲高,而出貨因之較多.松鼠籠式馬達拖動制雖不能如第一節所述法之盡善盡美,但價格較廉,且勝於他種拖動法實多.至所述兩種拖動制之採用,須權衡出品及經濟情形而後取決之.

本刊職員易人

九月杪,本會舉行年會於瀋陽東北大學,總務一席,由黃炎,姚長安,楊錫鏐三君依次當選.旋三君因故先後堅辭,由本會商請支秉淵君擔任.工程季刊自本期起,凡印刷,廣告,發行等事務,概由支君負責.

SMALL REFRIGERATING PLANTS FOR MAKING ICE CREAM

The manufacture of ice cream cannot be carried on with any prospect of success unless a fairly large daily turnover can be reckoned with. This is an essential condition, because of the relatively high cost of acquiring the necessary plant, and because only a very small quantity of ice cream can be sold in winter. The allowance for annual depreciation must therefore be earned in a comparatively short time, i.e. principally during the few hot months in summer. The problem is therefore in the first place a purely commercial one, depending solely and absolutely on the prospects of selling the manufactured product, so that for the moment the only plants which have any likelihood of being profitable are those situated in districts, where a sufficiently large daily demand for ice cream can be reckoned on.

A plant for making 165 gals. of ice cream per day has been put in service by the Industrie du Froid S.A., Cairo (fig. 1). The cold required for the plant is supplied by a vertical Sulzer compound ammonia compressor rated at 48,000 B. Th. U. per hour at an evaporating temperature of 22 deg. F. and a condensing temperature of 96 deg. F. The compressor can be seen to the left in fig. 2; the other compressor seen in the illustration serves for ice-making and the two Sulzer Diesel engines of 40 and 120 B.H.P., installed in the same room, drive generators which supply the light and power required. In contrast to other plants for making ice cream, no special store rooms are provided for keeping the ice cream, but there are two hardening rooms, kept at a constant temperature of 11 deg. F. The two freezers, fig. 1, and also the refrigerating systems in the hardening and other rooms, work with direct evaporation, whilst the cream cooler and the ice cream ageing vats are worked with cold brine taken from an existing ice tank.

Ice cream is essentially a sweettend frozen cream. In addition to the cream and sugar, about ½ of 1 per cent. of gelatine is nearly always added in order to prevent the formation of large ice crystals; aromatic substances are also added. Here there is endless opportunity for variety, as not only fruits can be added in the form of extract or juice or grated, but also all the other various kinds of flavouring matter hitherto adopted in making sweets and cakes. Nevertheless a certain number of standard makes have been evolved, of which the principal are vanilla, pine-apple and lemon ice creams.

In particular kinds of ice cream other substances are added, such as eggs, for example, the mixture being heated up to 175 deg. F. before being frozen, in order to curdle all the white of egg; starch-flour and other substances are also employed.

After being prepared, the raw materials are mixed and pasteurised, the mix being passed through the homogenising machine and then over a cooler to the ageing vats which are fitted with a stirring mechanism. In these vats the mix is allowed to stand generally for 24 hours at a constant temperature of 40 deg.F. in order to "age." The function of the homogenising machine is to break up the fat globules into still smaller globules that no cream can form on the surface. The homogenising machine works on the principle of forcing the warm milk and cream at a high pressure, and therefore at a great velocity, through a very narrow aperture. This causes strong eddies, which break up the fat into very small globules. The homogenising process works the ice cream into a uniform mass and also prevents the mix turning into butter under the subsequent churning action in the freezer.

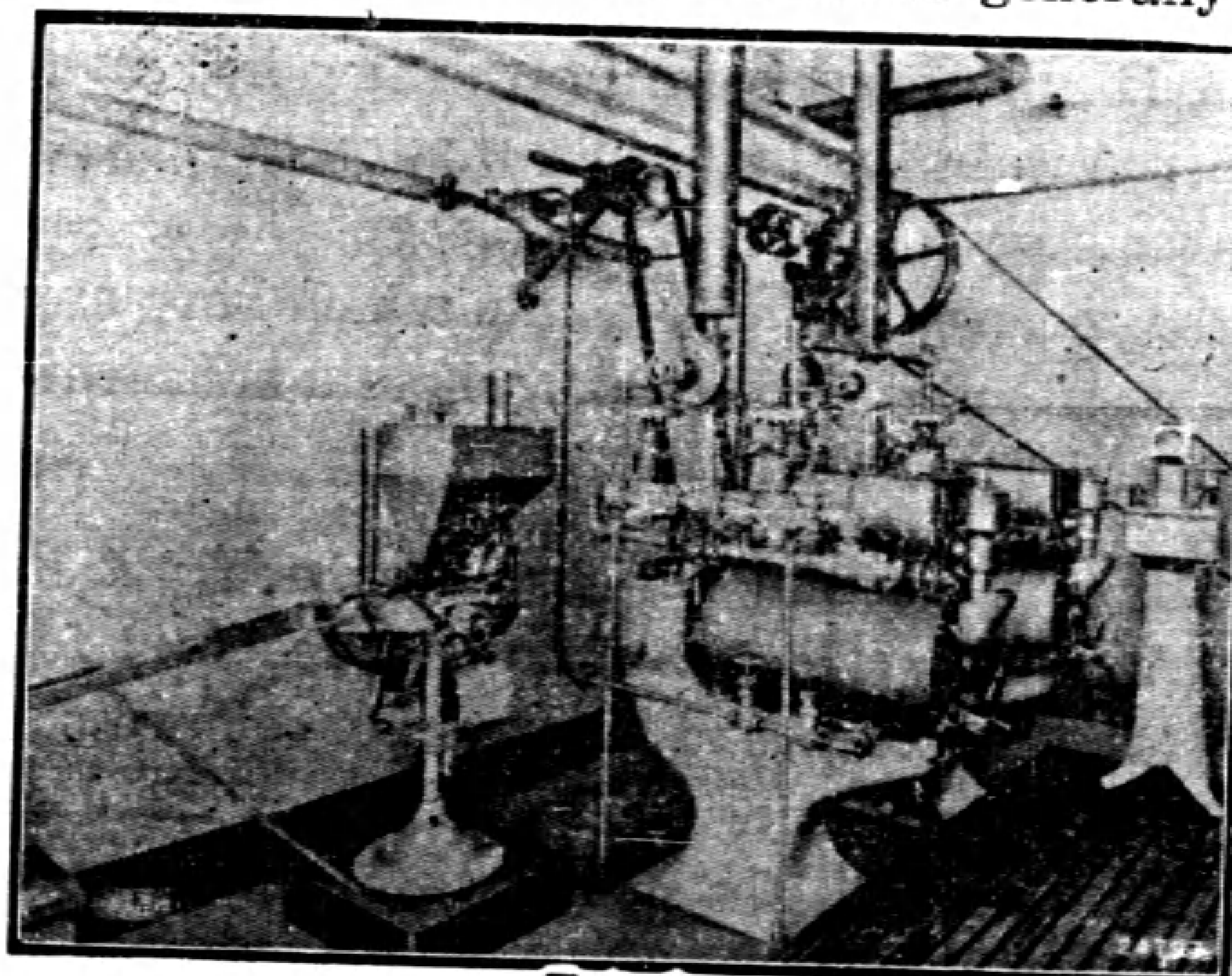


FIG. 1.
Refrigerating apparatus for making ice cream.

After the mix has aged sufficiently, it is run into the freezer and then the aromatic and colouring substances are generally added, when such are to be used. In the freezer, which is fitted with a cooling jacket, the mix is simultaneously beaten and frozen, the final temperature being 27 to 25 deg.F. This operation requires abt. 20—30 min., depending on the size of the freezer. It results in a great frothing, to such an extent that up to 2 gallons of ice cream can generally be obtained from 1 gal. of mix. This increase in volume is technically known as "overrun" or swell. Its amount is important, as on it depends to a great degree the quality of the resultant product and also the commercial efficiency of the manufacture. Ice cream should be "light," but there is also a limit beyond which it becomes soggy and unpalatable. This limit lies with an overrun of abt. 100%; it is not advisable to go beyond that.

The mix is now left in the freezer until it is absolutely hard, but shall still be in a semi-liquid state when it leaves the machine. It is then run into pre-cooled cans, or immediately into moulds, which are then placed in the hardening room. This is a room kept at a very low temperature, and there the ice cream becomes consistent, so that it can be cut with a knife. The temperature of this hardening room should be at least +5 deg.F., but better still is —4 to —13 deg.F. The ice cream generally remains here for 24 hours after which it is transferred to the general storage rooms, where it is kept at a temperature of abt. 14 deg. F until distributed. The purpose of the hardening is to solidify the water contained in the ice cream as quickly as possible. It is necessary to do this quickly, in order to keep the ice crystals as small as possible. The slower the rate of freezing, the larger will be the ice crystals, and the coarser the texture of the ice cream. The hardness of the ice cream depends on the completeness with which it is frozen.

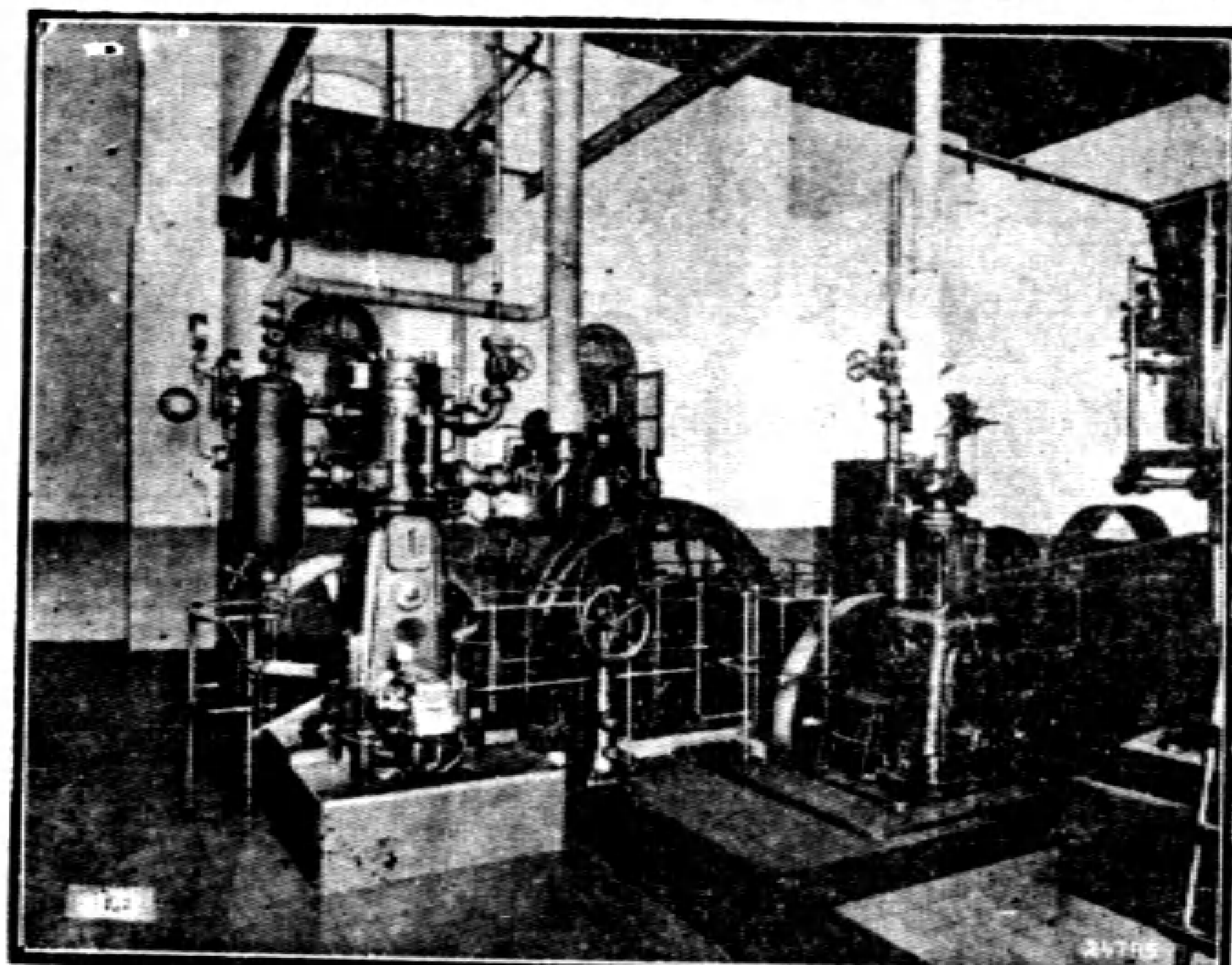


Fig. 2. Refrigerating plan of the Industrie du Froid S.A., Caira, comprising tmo Sulzer ammonia compressors; in the background, to the right, two Sulzer Diesel engines diving generators for supplying electric light and power

Certainly even the adoption of very low temperatures will not cause all the water to turn into ice, as the sugar solution becomes more concentrated as the water is frozen out. But, for the reasons given, it is desirable to use the lowest possible temperature, and in the United States the temperature of the hardening room is being always more and more lowered. About 20 years ago +14 to +15 deg.F. was thought satisfactory, but now —5 deg.F. is demanded and there are even hardening rooms in existence with temperatures of —20 deg.F.

Ice cream is generally dispatched in containers packed in a freezing mixture of ice and salt and, when well insulated, can be sent to a comparatively great distance. The best containers are those in which the ice cream is packed in tightly closing metal boxes. The temperature of the freezing mixture can be adjusted as desired down to a temperature of abt. —10 deg.F. by varying the amount of salt.

The question of keeping ice cream in retail shops deserves a chapter for itself. It is a costly matter to supply the retailer daily with ice cream, and for this reason it is always advisable to get him, whenever possible, to acquire a cold cupboard fitted with mechanical refrigeration.

國外工程新聞

德國柏林市之道路概況

柏林市現有之道路約八千條,共長約2,900公里,總面積約計爲23,500,000平方公尺,總價估計約330兆馬克,平均每市民應攤76.3馬克.其中61%爲磚石路,29%爲瀝青與柏油路,6%爲碎石路,其餘爲他種道路.

柏林市築路經費頗爲支拙,其原因,大半由於該市每年汽車捐稅收入,約23.8兆馬克,大部分爲德政府支用,能分配於該市築路之經費,僅2.34兆馬克,不過總數十分之一.故雖有建築新路,便利交通之議,曾於數年前計劃建築放射式道路十九條,環繞式道路三條,及其他重要聯絡道路多條,因限於財力,未克舉辦.其尚能於去年(1929)以18兆馬克之經費,築成道路165條,亦可謂極盡其力矣.在此種困難情形之下,柏林市現在所定之築路方針,僅以完成交通幹路爲限,其次要交通道路,及居住道路之修理,雖亟待舉辦者,亦不得不暫緩從事焉.

柏林市修築之道路,除行人道外,其路面擬分劃爲三部,卽電車道一條,與車馬道兩條.至於交通廣場,其通過之道路在四條以下者,採用直接穿過制;在四條以上者,則採用環行交通制.廣場之中央,仍主張設立寬闊之隔台;例如新築之 Alxander 廣場,中央亦設寬闊之草地,四週車道比較狹隘,雖對於交通,有不甚適宜之點,然亦不之顧也.

凡天雨時道路,往往發生泥濘,車輛往來,易生危險,交通極感不便.柏林市當局,有鑒於此,設法避免天雨時道路之泥濘,減少行車之危險,飭工務局改良道路之建築.築路方式,僅以瀝青柏油砂,混凝土,石塊等數種爲限.又爲減少掘路起見,已擬就埋設各種管纜之統一辦法,庶掘路工作得分段分期進行,道路交通,不致多受妨礙.

柏林市內之運貨汽車,裝載重量往往超越規定之數,甚至二倍以上,殊於道路之維持有礙,當局將釐訂嚴厲之罰則,以取締之云.

美洲分會附刊

第二期

中國工程學會美洲分會編輯出版委員會編輯

委員會主席　顧毓琇

書記　黃輝

目錄

鐵道電化及鐵道與人口

著者: 劉乾才

(一) 鐵道電化新聞二則

(1) 紐約與華盛頓間之鐵道電化

本雪物泥亞鐵道公司,於十月一號宣佈,與巴迪摩爾城議妥,完成紐約與華盛頓間之鐵道電化.

此項議約曾醞釀數年.其重要問題爲分站計畫,鐵軌改良,及巴城之雙軌山洞.此項問題一決,該公司遂可發展電氣鐵道,先從紐約至豫民頓.再至華盛頓首都.一切客車貨車皆可通行.預計五六年之間,山洞,新站,貨棧.交軌,以及電氣裝設,皆可竣功.

該公司已定造一百五十輛電氣機關車,作拖客車之用.價值合美金一千六百萬元.造完期限兩年.此項機車,由該公司及西屋奇異之工程師規定,其最高速度為每小時九十哩,馬力六千匹(兩機頭合併,以一小時為限)大過於現有之蒸汽機車馬力半倍.將來往返紐約與華盛頓之時間,由五小時縮短為四小時或四小時以下;自紐約至費勒德爾費亞城之行程由二小時減為一小時半而已.

(2)英國政府電化大不列顛鐵道之先聲

英國政府擬將全英領土之鐵道電化,藉以救濟失業工人.該項計畫,已於九月七日公佈,派定一委員會審查.委員會主席為威爾(Lord Weir of Eastwood)該會將來促英國中央電氣部之成立,以資統一.威爾曾聘請英國電氣專家多人,襄助一切.現任美洲加拿大國有鐵道局之總理湘頓(Sir Henry Thorton),亦有被請回國,任政府鐵道顧問之說.

(二)歐美之鐵道與人口

國名	面積	人口	每方哩人口	國有鐵道哩數	總線哩數	每千方哩哩數	每萬人哩數
奥國	32,368	6,535,363	201	3,608	4,128	123	6.3
Czechoslovokia	54,206	14,388,000	265	2,289	8,239	153	5.8
法國	212,736	40,960,000	193	6,907	26,872	126	6.6
德國	180,972	62,592 000	346	33,320	35,597	197	5.7
意大利	119,744	40,799,000	341	10,300	13,355	116	3.3
尼士蘭	13,213	7,726,072	577	......	2,254	171	3.0
西班牙	195,040	22,128,000	113	......	9,705	50	4.4
瑞典	158,525	6,087,923	38	3,877	10,110	64	16.6
瑞士	15,944	3,959,000	248	1,823	3,492	219	8.9
英國本洲	94,278	44,170,241	469	......	21,165	225	4.8
美國	2,973,774	120,073,000	40	......	249,131	84	20.8

HIGHWAY LOCATION

BY T. Y. YU (余宰揚)

Not until the advent of automobile in the closing years of nineteenth century has the highway development become one of the most important problems of the country. The romance of railroad location engineer has been played up so impressive that its glamour has overshadowed the highway work. Yet the annual expenditure on American highways is already in excess of annual sums spent on railroad work in its palmiest days. Of course any knowledge of railroad engineering is helpful to highway work if the engineer can correlate that knowledge with the requirements of highway. But ignorance of any of peculiar features of highway work would result in material improvement without adequate return. For instance railroad has spent large sums in acquiring long easy grade. In highway work, the consideration of grade is given less weight, and in ordinary design we expect to confirm to natural topography as much as possible, because the return due to excessive cut and fill for improving the highway grade is intangible, and the modern automobile is so designed as to be able to ascend steep grade. This is only one of the marked differences between railroad and highway location which should not be overlooked. The object of this article is to present these fundamental points to be considered in highway location.

Survey of Highway. The complete survey of a highway, quite similar to that of railroad, may be divided into following four steps:—

1. Reconnaissance
2. Preliminary survey
3. Location survey
4. Final survey

The former three involves the location and design of a highway, while the last one, to be made after the highway is completed, serves only to check engineer's construction estimates and needs not to be discussed here.

The reconnaissance is rough preliminary investigation of possible routes between two terminals of a highhway project immediately after reconnaissance, the preliminary survey are made for the purpose of collecting all informations along the routes as may be considered feasible in the reconnaissance. The informations collected are to be mapped, and a rough estimate of cost prepared. As soon as best lines selected on the paper, it is laid on the ground subject to minor changes if necessary, which procedure is said to be location survey.

Importance of prepliminary survey. The negligence of preliminary survey too often results in the expensive resurveys and readjustments after the construction is started. The trouble would be multiplied in the case of concrete pavement; its hard and fast lines can be hardly altered. The crooked locations, especially in pioneer district, are almost unsoluble withuot the help of preliminary survey. Therefore it is always a good policy to have painstaking preliminary surveys, and map in the field with contours and topography laid to the convenient scale. All items such as grade, alignment, drainage, foundation etc., should be analyzed in order to provide a sound basis for the paper location. These items are to be briefly discussed in the following paragraphs:

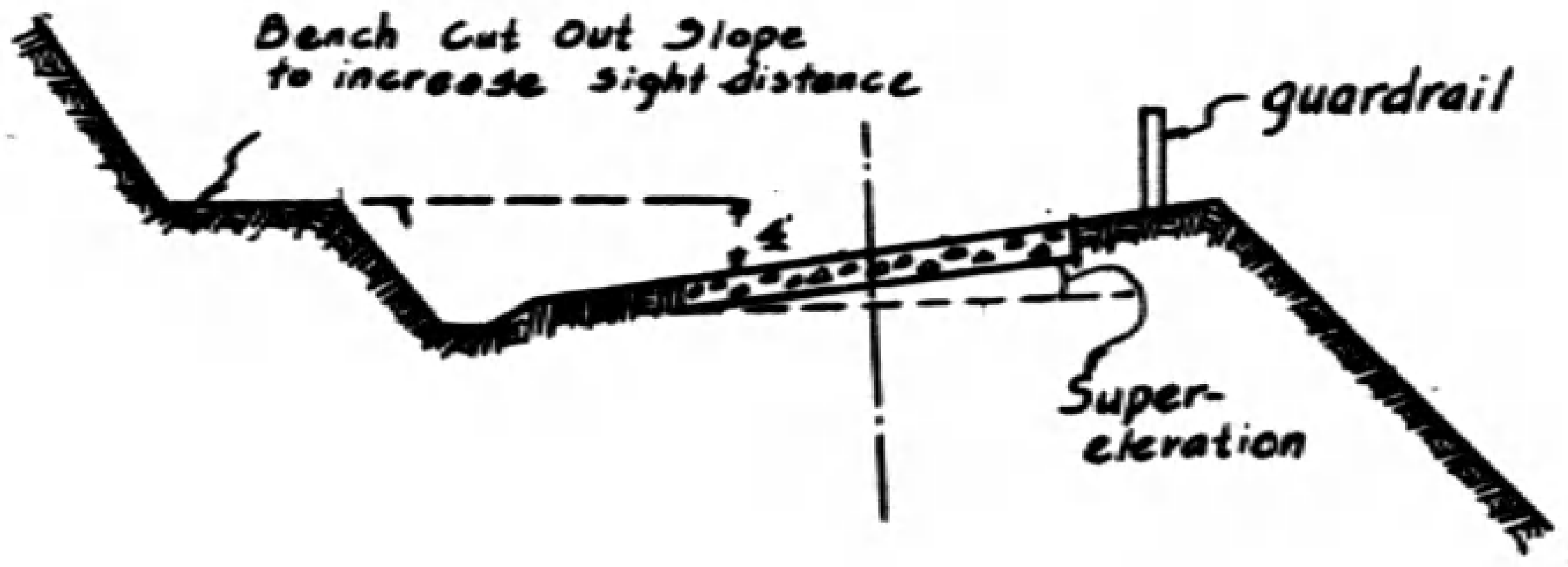
Maximun grades and grade reduction. Grade selection depends upon many factors such as safety, conveniencs, cost of construction and maintenance, and traffic operating cost. Not one of these is absolutely dominant without considering the others. The whole question of determining maximum grade depends upon experience and lies in the dicision of what is most reasonable for a specific case. For these roads where there are large percentage of heavy trucks or horse drawn traffic, the maximum grade should be kept under 6%, while for lighter traffic, a short grade up to 8% may not be objectionable. The soil condition, and the types of pavement and ditch have also great bearing on the grade, for the maintenance of shoulders, ditches, macadam or gravel road, increases in cost rapidly on grades over 6%. From the standpoint of maintenance, 6% can be said as logical maximum grade.

It is also important that the maximum grade should be correlated with other features of location. In securing lower grade, the engineer should notice that neither poor alignment, nor excessive cut have been introduced. If there are existing heavy grade between two terminals which can not be reduced. it will be unwise to spend large sums in securing less intermediate grades. In a word, the reduction of grade requires comprehensive preliminary survey and careful analysis of alignment and cost.

Aligement. Alignment affects safety, speed, ease and hauling power of the traffic, as well as construction cost of the highway. Mere theory is not sufficient in fixing the alignment, unless it is tempered by some practical considerations.

In well-settled communities, alignment is practically controlled by existing right of way except some minor relocations. In sparsely-settled communities, it is less handicapped by right of way difficulties. When the right of way can only be secured by paying heavy compensation, it is advisable to find a new location.

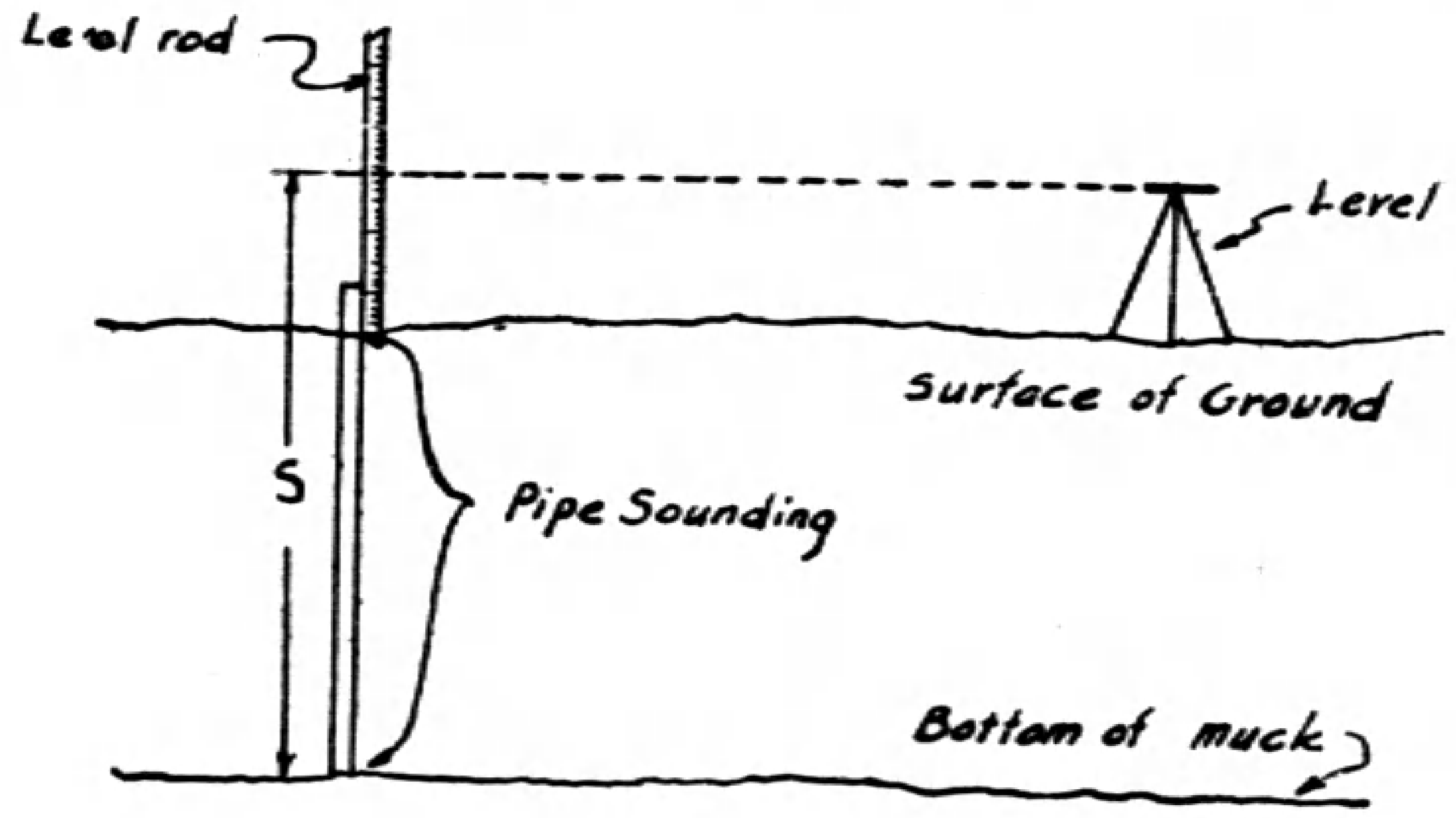
As a rule, curves of radius of less than 500ft. should be eliminated, and a minimum sight distance of 500 ft. be secured in both horizontal and vertical alignment, A curve concave toward a hill will preclude its use, unless a bench cut out of the slope can be provided at reasonable expense. The outline of the bench is shown in the following figure.



If the road has long tangents the curve should have longer radius than those crooked roads with shorter tangents, because in the former case traffic will attain higher speed. It seems to be a curious thing that more accidents happen on long straight road than the crooked. The reason is that people are apt to drive faster, and feel monotonous on the straight grades. Therefore an alignment composing smooth and safe curves, and yet straight enough to be free from undue amount distance, will be the most desirable one.

Foundation Experience has shown that poor foundation and improper drainage are responsible for the failure of many highways. Special attention must be paid to investigate the condition of soil over which the highway rests, as the design of future road depends greatly upon the results obtained. Due to the fact that soil condition changes abruptly, many engineers advocate station-to-station analysis. It is not infrequent that soft soil develops where road surface prevents fair appearance. Therefore as a matter of precaution, whenever there is suspicion of unstability, the sounding bars must employed, and a length of pipe is driven into the bottom of hole; the earth retained in the pipe showing what kind of soil it is. In short, any serious soil condition should be studied so that the projected line will not pass through any unstable place unadvisably. Sometimes a change of line to avoid the bad foundation is justifiable.

The rod used for subsoil investigation is ½ inch or ¾ inch gas pipe jointed in five-foot lengths. In case the rock underlies the road surface within short distance of surface, the road should be driven down to the bottom, and the elevation of the rock surface is ascertained as shown in the following figure, care should be taken to avoid the misleading due to presence of logs and stones. The results of soil investigation are to be tabulated under general soil classi-

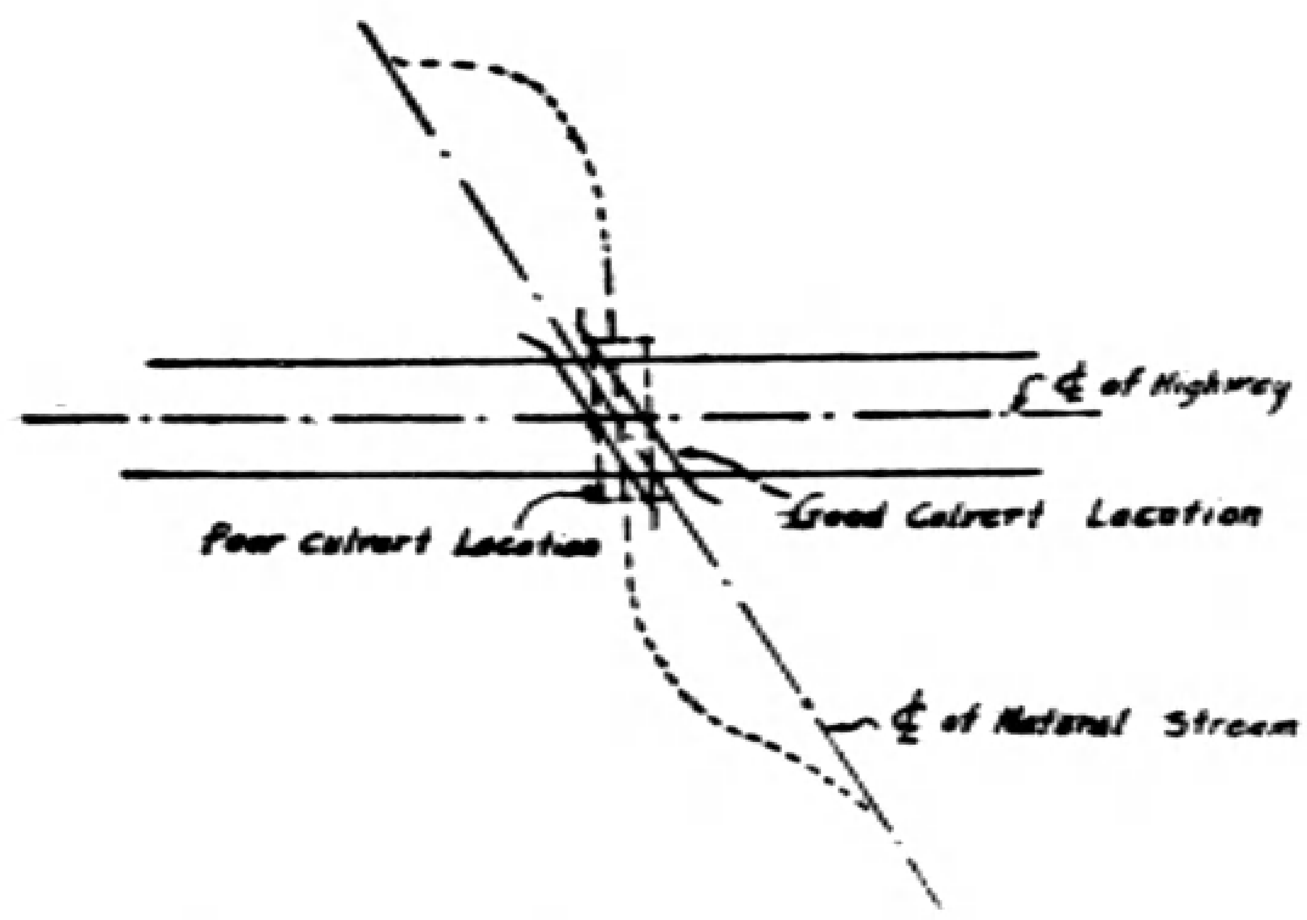


fication, that is gravel, sand, sandy loam, loam, clay, wet heavy clay and quicksand. The elevation of rock surface can be plotted on cross-section sheets.

Drainage. Adequate drainage is essential to the success of the highways. There are many factors which should be investigated in the preliminary survey, such as topography of stream crossing, height of banks, foundations, length of spans, distance of haul and cost of materials etc. Only the most important ones are to be discussed on account of lack of space. The foundation condition is determined by test pits and gas pipes in similar way described in the preceeding paragraph. If the soil condition seems to be not firm enough to support the structure, the piles will be recommended. Information concerning high and low water elevation is also extremely helpful, because these piles above the low water elevation should be either concrete, or creosoted to prevent decay.

Since the size of opening and elevation of bottom of superstructure depends upon the volume and velocity of stream flow and on clearance for ice and floating debris, a careful analysis of drainage area is indispensible, but details of which are too numerous to be mentioned here.

As to location of bridges and culverts, the common fault is the use of right angle location in very unnatural way, the capacity of drainage structure is thus reduced, and the flow of stream checked, resulting in excessive scour and silting. The following diagram shows the relative merits of two locations.



It is true that right angle location saves the length of the culvert, but the saving can hardly balance the above mentioned disadvantages. Considering the maintenance cost, the right-angle location for streams crossing the road on skew angle is unfavorable unless the stream channel can be changed for considerable distance when the skew of stream centerline is too big, or the stream approaches the road in an undesirable manner, a suitable plan of channel change should be worked out. A careful study of all informations gathered in the preliminary would lead to the recommendation of suitable types of structure. Then rough estimates are made for different types before final dicision is reached.

The underdrains also play important part in field of drainage. The engineer should bear in mind that, in case of poor soil condition, it is necessary to get the road bed three feet above the water table. This can be attained by raising the grade or by lowering the general level of water table. An open ditch, or tile drain will serve the purpose. Such ditches are to be surveyed and cross-sectioned for preliminary estimates. Special attention should be paid to locate the springs and seepages which are common sources of drainage trouble. The only remedy is relocation, or to divert them by ditch or tile.

Conclusion Due to broad aspect of the subject, this article barely covers some main points among which special emphasis is laid upon foundation and drainage. Every year the increasing traffic makes the railroad crossing a menace to safety of travel. Every effort should be made to reduce the number of crossings. If the crossing is unavoidable, grade separation and clear vision near the track should be secured. Another problem, which becomes greater each year, is the avoiding of streets in congested cities. Although the highway should be so located as to serve the greatest number of communities, the trunk line should not run through the center of large cities. The best policy is to run the line outside the cities with short branch roads running into them. The local material available and local environment are other two subjects which should receive due attention in locating a route.

It is obvious that the art of location rests on good common sense, and not entirely on engineering considerations.

The report prepared by locating engineer after preliminary survey should show clearly the relative merits and rough cost for the different routes. It should convey full informations, yet it is so concise that even the non-technical readers will grasp the situation easily.

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FROM BOSTON TO DETROIT

BY C. T. CHWANG (莊前鼎)

Early in last March I conceived the idea of taking an inspection trip through the United States. I sent a circular to various concerns, which I selected from the Condenced Catalogue of A.S.M.E. and the Chemical Engineering Catalogue. I received many letters of permission and not a few letters of refusal. In general, the manufacturing plants in the fields of mechanical, electrical, and civil engineering gave me a cordial welcome; while those in the chemical and industrial fields, which are very specific in nature, refused my inspection, for the sole reason that they never allow any visitors.

On account of my financial conditions, I was only able to see the industrial plants near the large cities that I passed. My trip was not complete; but it was successful. With about sixty dollars in my pocket I travelled over two thousand miles in three weeks.

Mr. J. T. Hu and I started from Boston. In Boston, we visited the Sturtevant Co., where all kinds of fans used in power plants and for heating and ventilation are manufactured; and the Walworth Mfg. Co., where all kinds of valves and pipe fittings used in power plants are cast out in a big foundry of cast steel, cast iron, and brass. In the field of fan-manufacturing, the Sturtevant Co. has its world reputation. This company usually admits five Chinese students to work in the Drafting Department for a period of twc years. In my opinion, they should be allowed to work for a while in the erecting floor and in the outside installation work. Perhaps we Chinese students perfer the white collar jobs to any work outside the Drafting Department. But it would be a mistake to think that a successful engineer can be made in office only.

We first drove to New York. The places of general interest such as the Woolworth Building, the Statue of Liberty, the Holland Tunnel, the Metropolitan Museum of Fine Arts, need no recount here. We visited the Worthington Pump in Harrison near New York. It is a plant, which manufactures all seizes of pumps, gas engines, and compressors. The company usually gives a training course, starting from June. Some-time ago a few Chinese students worked there. But the lack of trade relations between the company and China in the last few years and the dull prospect in the future serve as a good reason for the company to refuse to admit any Chinese student.

We went to the famous Edison Laboratory in New Orange near New York. To our disappointment, it is not wholly open to visitors. We were only able to see the office desk and chair in the room, where Mr. Edison used to work. We saw, also, on Mr. Edison's desk, the first phonograph and the photos of Mr. Coolidge and Mr. Hoover. We were guided through the Laboratory and the Edison Storage Battery Co., where the storage batteries using iron oxide and nickel oxide in potassium hydroxide electrolyte are manufactured for uses in the electric trucks.

From New York we proceeded to Bathelham, where is located the largest steel company in the world, the Bethelham Steel Company. This company employs 30000 to 40000 workers during the War and is now employing about 20000. There are sixteen blast furnaces, the largest of which takes 800 tons of ore a day and the smallest 400 tons. In making the structural steel, I-beams, girders, columns, channels, and angles, the open hearth process is used. We spent almost a whole day in the plant. The assistant sales engineer accompanied us and explained very clearly the whole process of manufacturing structural steel. To our surprise—and joy—we met a Chinese fellow, who has been working there since his graduation from the University of Illinois in 1925. This company gives a student course caled the "Probation Circuit," for a period of ten weeks. Usually it is very hard to get in, unless one has some help from the Chinese government.

We then went to Philadelphia, where we met the Nanyang men of the University of Pennsylvania. We had a good time. We visited the Leeds and Northup Company, where the electrical measuring and recording devices and meters are made; and the Cochrane Corporation, where the heaters and condencers for the powers plants are made.

We then passed to Washington D. C. In the capital we had the opportunity the see the Senate in session, and hear the eloquent discussion of a senator, charging President Hoover for allowing the capital to be "wet." We visited some places of general interest. By the way, one should never Miss Washington D.C. A trip through the chief cities can never be said to be complete without seeing the capital. A well-planned trip, including a visit of Washington D. C., can be carried out with the smallest expenditure by a group of interested people, who know how to drive a car carefully and how to repair it, in case any slight trouble should happen. A good partner in a car is most desirable. I was lucky to have Mr. Hu for my partner. But a friend of mine is more lucky: he has his bride for his partner. As I am writing this, they were "honeymooning" in their machine. Let us wish them "Bon Vovage!"

From Washington we went toIthaca and back to our Alma mater Cornell University. We met our friends and visited our old professors. Then we went to the Eastman Kodak Co., Rochester. There the cutting and rolling of photo films were clearly explained to us by the guide. However, we were not admitted to the so-called "No-man-room," where the film is manufactured in the automatic machine, designed and built by the Company. Since that machine has nevor been patented, it is not open to the visitors. The guide told us about the life of Mr. Eastman, the inventor of the film. The story is by no means new; it is the story of a man of patience and hard work.

On our way to Buffalo, we passed the Niagara Power Co., the largest hydro-electric power plant in the world. It generates power for the use of the industrial plants within its area of 300 miles. In Buffalo Mr. Hu took the train for California on his way to China. I, now left alone, visited the American Radio Comnany, and saw the wonderful process of enamelling and the officient methods of making radio castings. At Erio, I visited the Union

Iron Works, where large steam boilers are made. The process of rivetting, rolling, and forging were clearly explained.

The Westinghouse Electrical Company was the next place of my visit. It is as large as G.E. in Schenectady. But all the buildings of Westinghouse are connected, whereas those of G. E. are scattered. Both these companies employ from 18000 to 20000 workers. At present only one Chinese student is working at Westinghouse. He came from China direct.

Pittsurgh is a dusty city. But it is the real industrial capital of U.S.A. Around the city there are many iron and steel works, to which I did not have time to go. I visited, however, the American Bridge Co., at Ambridge. All the designing work of the company is done in the office in the Frick Bldg, Pittsburgh. In Ambridge, which is twenty miles from Pittsburgh, all the fabricating work on the structural steel, and the bridge work are done with the multiple punchers, drillers, rivetters. There, also the bridge members are put together in a horizontal position, and subjected to test before they are shipped out for erection.

From Pittsburgh I proceeded to Akron, the world's largest manufacturing center of rubber. (62% rubber supply in the world comes to Akron) The B. F. Goodrich Company is the first rubber company in the Midwest and the largest in Akron. It employs 16000 workers. It manufactures rubber tires, tubes, footwears, and household necessaries. The most efficient method of making footwears according to the wonderful conveyor system, which is used in the manufacturing of the Ford automobiles, interested me most.

Thirty-four miles away from Akron is Cleveland. At Cleveland I made hurried visits to the Machine Tools Exposition in the Public Auditorium, and the Warnor and Swasey Machine Tools Works. Then I hurried to Detroit to find a job in the Detroit Edison Company. I got it. Thus my trip came to an end.

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I have been deeply impressed by the fact that the army of workers has made the United States as she is to-day. It is not the soldiers, nor the diplomats, that may be considered as the backbone of the nation. For where comes mass production? There comes power and industry? One word is the keynote; that is work.

For a long time, China, while encouraging scholastic studies has despised the workmen. And that is, as we all know, the main reason why we are lagging far behind other nations in the development of industry. Before her industries are fully developed, China must experience three stages. The first one is the improvement of communications: the railway, the automoblic, the telephone, and the like should be more properly managed and widely used. With a strong central government, these can be done, let us say, about fifteen years. The second will be a stage of power industry. That is the development of the hydro-electric and steam power for various uses. The third will be the development of the industries of iron and steel, chemical acids and alkalies, and cement and structural materials.

Now is the time for China to prepare her students of engineering to come here to work in the different companies of various field. If our government can ever be induced to make some contract with the companies here for the sake of business relationship and co-operation, it will be easy, I think, to get their consent to admit the Chinese students to work. China needs her engineering students to come here to work for practical experience, but not her students to work for the vain titles of Ph.D., D.Sc., and M.S. The real value of research in the highly specialized field of engineering in this country lies in the fact that U.S.A. has got her industries fully developed and needs research to carry on further development. How about China? It will be a long time for her to come to such a state of development as we find here, I would say I shall send my grand-children here to work for Ph.D. or D.Sc., because at that time, let us hope, China would be in a better position to use such highly specialized men of engineering. If these friends of mine, who are candidates for the highest honor, should feel themselves offended by what I have said above, I should be very sorry. I regret that I spent too much time at college. It was against my will to do any research in a specialized field of engineering. Perhaps every engineering student will remember that a good engineer here is made outside school he is made from the real bottom. China has had enough engineering students; but she still needs real workers.