SALES PROMOTION LETTER No. 1019.

COMPARATIVE NOTES ON THE ROTARY AND STEP-BY-STEP SYSTEMS.

Standard Telephones and Cables Limited

CONNAUGHT HOUSE, ALDWYCH, LONDON, W.C. 2.

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At the beginning of 1927 there were about one million lines of power driven "rotary" and "panel" equipment in actual service or in course of installation. The first panel line was placed in public service in 1922. The first rotary line was placed in public service in 1914. From 1914 until the end of 1920, the manufacture and development of rotary equipment was at a standstill owing to the closing down of the factory in Antwerp and to the entire depletion of that factory by the Germans during the period of occupation, including even the removal of the steam turbine upon which the factory depended for power. The real growth of rotary started in 1921. It will, therefore, be seen that the growth of power driven equipment has been extremely rapid. The main reason for this rapid growth is that the operating administrations who have chosen power driven systems believe that such systems can meet, with greater ease and accuracy than step-by-step systems, the more exacting requirements of modern telephone networks.

With regard to the decision of the British Post Office to adopt for London the Strowger system with the director, which decision was made in November, 1922, Colonel Purves in his able and interesting paper on this subject, read before the Institution of Electrical Engineers in London in March, 1925, did not claim any technical advantage for the step-by-step Strowger selector over the power driven panel selector. On the contrary, he did say that the Strowger System with the director could be made to give office prefix translation and flexible trunking along the lines of the panel system and it was because the director could do this that the Strowger system was considered.

At the time the decision was made the Strowger System had been manufactured for many years by at least two companies in England and, being old in the art, could be more easily taken up by other companies than could the manufacture of an entirely new system unknown in England. Had the panel system been chosen the initial equipment would have had to come from America which was something the British Post Office very much wished to avoid.

The rotary system was not offered to the British Post Office for consideration in London in 1920 when tenders were called for. As previously stated, the development of the rotary system had been unavoidably stopped by the closing down of and the depletion of the Antwerp factory by the Germans during the war. The valuable features of flexible trunking and office prefix translation which were then embodied in the panel system and subsequently copied in the director step-by-step system, had not yet been fully reduced to practice in the rotary system. The rotary system was not investigated by the British Post Office for use in London as it was not then being manufactured in England.

The largest Rotary exchange plants in service and on order and actually in service are as follows:-

IN SERVICE AND ON ORDER		ACTUALLY IN SERVICE	
Network.	Lines.	Network.	Lines.
Paris	104,000	Paris	20,000
Budapest	70,000	Brussels	68,000
Brussels	88,000	Oslo	40,820
Madrid	45,200	Hague	29,100
Oslo	43,200	Zurich	28,530
Barcelona	40,700	Madrid	30,300
Copenhagen	38,660	Marseille	19,700
Mexico City	37,000	Antwerp	22,500
Cairo, Egypt	16,000	Barcelona	34,700
		Budapest	26,600
		Copenhagen	24,660

In each instance cited above the step-by-step system contested the introduction of the power driven system.

The first system to be introduced into Holland was the Siemens and Halske step-by-step system installed in Amsterdam, but all subsequent automatic systems, that is, those introduced into Holland by the Municipalities of the Hague and Rotterdam and by the Dutch Administration have been of the rotary type. The National Telephone Company of Spain which had full access to the Strowger system chose the power driven rotary system for general use throughout Spain in no less than 19 cities, large and small. The Scandinavian people, who are among the most progressive in telephone matters seem to have chosen very decidedly in favour of power driven systems. Such systems are now in operation in the three Capitals, namely, Oslo, Copenhagen and Stockholm, all placed in service since the war. The two first mentioned are Rotary. Before the Norwegian Government decided to install the rotary system it made a world wide investigation of all systems, both in Europe and America, the final choice was made after a unanimous recommendation of a committee composed of the principal telephone authorities in the three Scandinavian countries.

SERVICE.

Good service is the password of modern times. If this controlling requirement cannot be met by a telephone system all other considerations are of no avail. That this quality belongs to the rotary system will be made clear by an examination of the data contained in the following extracts from a few official reports pertaining to certain of the more important rotary installations. It has always been the policy of the Company to encourage systematic service observations and at this time many Administrations operating rotary systems are giving this important matter serious attention. Without reliable service records, it is impossible to know what kind of service is being given and where to look for faults, unless, of course, they are so glaring as to make service observations needless.

The following citations are not the best nor the worst that could be said about the rotary system. Some are referred to because they have already been published and others because they are recent and immediately available.

GENEVA.

In an article by R. Mullar, Technicien de 1'Office Telephonique a Geneve which appeared in volume 3, No. 4 of the Bulletin Technique des Administrations des Telegraphes et des Telephones Suisses, the operation of the Geneva Mont Blanc automatic exchange, which is of the rotary type, is rather fully described. The Geneva network also includes the important manual office Stand. Calls from automatic to manual are handled on a call indicator basis and from manual to automatic on a semi-B basis.

The following statistics are quoted from the above mentioned article:-

The following table gives the figures obtained for the month of January, 1925.

	Mont-Blanc to Mont-Blanc		Moat-Blanc to Stand (Call Indicator)		Mont-Blanc to Special Services	
	Number	%	Number	%	Number	%
Successful Calls	1551	99.54	1612	98.78	408	100.00
Wrong Numbers	0	0.00	11	0.67	0	0.00
Incomplete	0	0.66	2	0.12	0	0.00
False Metering	0	0.00	7	0.43	0	0.00
Total	1560	100.00	1652	100.00	408	100.00

Checks may equally well be made at the call indicator positions. They give for the same month the following results:-

Successful calls	2845 or 98.55%
Total errors	49 or 1.65%
	2894 or 100.00%

In the figure of 49 errors there are included the faults, which are not negligible made by the subscribers themselves. The real percentage is therefore less than 1.65.

As regards the traffic Stand Mont-Blanc, daily observations are made on the semi-B lines by the monitors at the Stand central office. During the month of January 1925, checks were carried out on a total of 2142 calls and gave:-

Successful calls	2201 or 98.17%
Wrong numbers	1 or 0.04%
Premature releases	40 or 1,79%
Total	2242 or 100.00%

The results of other months are comparable in all points to those of January; by way of example, we give in the following table the average percentage obtained since the month of September, 1924.

	Calls from Monitor's Desk			Observations on the Semi-B Junction		
Month	Mont-Blanc	Mont—Blanc Stand	Mont-Blanc Special Service	Call ind. Positions	Wrong numbers	Incomplete Prem. releases. Miscellaneous
	% error	% error	% error	% error	% error	% error
September 1924	0.93	1.90	0.76	1.57	Observation	
October 1924	0.88	0.94	0.83	1.97	Oct. not yet	
November 1924	1.16	1.16	0.83	2.04	installed	
December 1924	1.37	1.33	0.46	2.35	0.14	1.88
January 1925	0.66	1.22	0.00	1.65	0.05	1.78
February 1925	1.25	1.82	0.35	none	0.19	1.88
March 1925	1.05	1.05	0.35	1.08	0.24	1.35
April 1925	0.94	1.16	0.70	none	0.41	2.17

HAGUE NETWORK.

The Hague network comprises 4 large central offices of the rotary type. The first offices were installed on a semi-automatic basis, but later on the major portion of the equipment was converted to full automatic, By the kind permission of the Hague Telephone Administration a description of this network was published in the April 1926 issue of Electrical Communication. Service observations are regularly made by a "trained operator at a service observation desk. The operator observes each call, which calls are real ones originated by subscribers, from the time it is originated until it is terminated. An English translation of a typical summary sheet (original in Dutch) received from the Hague Administration, for the Scheveningen office for December, 1924, is given in the fore-mentioned article and is reproduced with explanation hereunder.

"In the upper part of the Form, Column A gives the number of calls observed at each stage of a call, Column B gives the total time taken by all observed calls to reach each stage. Column C gives the average time per call to reach any stage, and Column D gives the average time for each call when passing from one stage to another. A total of six stages is taken as representing an effective connection.*'

Stage 1 - The arrival of a call on the connection circuit.
Stage 2 - The time when dialling tone is first heard and later disconnected owing to the subscriber having commenced to dial.
Stage 3 - The completion of dialling.
Stage 4 - The receipt of the ringing tone.
Stage 5 - The commencement of conversation.
Stage 6 - The release after an effective call.

In addition there are:-

Stages 7 & 8 - The release of the switches after a busy or no answer connection.
Stage 9 - The release of an uncompleted connection owing either to the Subscriber or to the equipment.

SERVICE OBSERVATION REPORT (Full Automatic)

Exchange: Scheveningen — Period: December 1 to December 31, 1924

	9.30 to 11.30 A.M.					1.30 to 3.30 P.M.			
	A Cases	B Total	C Average	D Diff		A Cases	B Total	C Average	D Diff
1 Call on Connecting Circuit	1006	766	0 76			766	577	0 75	
2a Dialling Tone Rec'd	1006	1421	1 41	(2b-l)		766	1092	1 43	(2b-l)
2b Operator answers	1006	3642	3 62	2 86		766	2827	3 69	2 94
				(3-2b)					(3-2b)
3 Dialling Last Number	1005	11242	11 19	7 57		764	8316	10 88	7 19
				(4-3)	B. C.				(4-3)
4 Ringing or Busy Tone	999	14676	14 69	3 50	and D.	759	10868	14 32	3 44
				(5-4)	Time				(5-4)
5 Conversation Starting	841	21711	25 82	11 13	in	658	16878	25 65	11 33
				(6-5)	Seconds				(6-5)
6 Release of Connection	841	106445	126 57	100 75		656	85375	130 14	104 49
				(7-4)					(7-4)
7 Release of Busy Connection	128	2569	20 07	5 38		73	1515	20 75	6 43
8 Release of No Answer Con-				(8-4)					(8-4)
nection	30	2051	68 37	53 68		28	2099	74 96	60 64
9a Release of By Sub-									
Uncom- scriber									
9b pleted Mechanical									
Connec- and Un-				(9b-3)					(9b-3)
tion classified	6	582	97 00	85 81		5	301	60 20	49 32

	9.30 to 11.30 A.M.		1.30 to 3.30 P.M.	
	Cases	Per cent	Cases	Per cent
10 Calls Observed	1006		766	
11				
12 Connections to "The Hague"		31.01		27.81
13 Connections to "Scheveningen"		46.42		48.96
14 Connections to "Marnix"		21.58		21.67
15 Connections to "Bezuidenhout"		0.99		1.56
16 Selecting Time to "The Hague"	3.58		3.44	
17 Selecting Time to "Scheveningen"	3.47		3.45	
18 Selecting Time to "Marnix"	3.85		3.54	
19 Selecting Time to "Bezuidenhout"	1.67		1.92	
20 Busy Calls.	128	12.72	73	9.53
21 No Answer Calls	30	2.98	28	3.66
22 Wrong Number (Subscriber or Operator)	8	0.80	9	1.17
23 Wrong Number (Mechanical and Unclassified)				
24 Uncompleted Calls			2	0.26
25a Interrupted By Subscriber				
25b Calls Mechanical and Unclassified	6	0.60	5	0.65
26 Premature Release	1	0.10	2	0.26

ZURICH.

With the kind permission of the Swiss Government some official data is given below which indicates clearly the high grade of service being given by the rotary system in Zurich. The Hottingen office in Zurich was one of the first of the rotary type and was cut over during the war under very trying circumstances. It operates in connection with 3 automatic satellites as well as with the old magnetic central offices Selnau.

Test Calls, Hottingen Exchange, March, 1926.

Full Automatic	No. of Cases	%
No. of test calls	8354	1.27%
O.K. Calls	8248	98.73
Faults: Wrong Numbers	24	0.30
Uncompleted	31	0.37
No Ringing	12	0.14
No dialling tone	5	0.06
False busies	4	0.05
Wrong metering	2	0.02
Continuous Rotation of Switches	21	0.25
Incomplete No. on call Indicator	1	0.01
Miscellaneous	6	0.07
Total Faulty Connections	106	1.27

Observed Calls Hottingen Exchange, March, 1926.
(Calls made by Subscribers).

	Cases	%	Total
Observed Calls	1000		
Effective Calls	768	76.8	
Busy Calls	77	7.7	)11.7%
No reply calls	40	4	)
Permanent Glows	5	0.5	)
Test Calls	0	0.0	)1.0%
Subscriber answers in error	5	0.5	)
Subscriber dials before dialling tone	4	0.4	)Operating fault due to Subscribers
Subscriber releases prematurely	33	3.3	) -7.8%
Subscriber does not send full number	12	1.2	)
Subscriber calls dead level	0	0	)
Wrong Numbers	32	3.2 (ca.2.9 (ca. 0.3	)
Subscriber does not get dialling tone	0	0	)
Uncompleted	12	1.2	)Machine faults
Interrupted	12	1.2	)-2.7%(incl, faults
Test faults	0	0	) in call. ind. and old manual switchboard.

SELECTING TIMES.

95	Special Calls	2.2	(R.D. Junction)
434	Local Calls	4.3	(Automatic)
380	Calls to Selnau	4.6/5.4	(Call Indicator)
26	Calls to Limmat	5.8	(" ")

No. of Subscribers in Service		
Full Automatic	Semi-Automatic	Total
1951	8319	10270

MAINTENANCE.

Maintenance may now be considered and in this respect the power driven rotary system has also shown up remarkably well.

The following are further extracts from the previously mentioned article on the Geneva Automatic Exchange. The toll board which is referred to is that serving the city of Geneva and consists of 60 toll positions and 20 recording and miscellaneous positions.

"The staff constantly at the Mont-Blanc Offices (automatic and toll) is made up of 2 electricians, 6 mechanics and 3 telephonists. Three of these mechanics detailed specially to the automatic equipment, ensure continuous attendance between 7 a.m. and 10 p.m. by taking turns alternating each week. Two others are engaged on mechanical maintenance, miscellaneous jobs, substitutes in case of absence, etc., whilst the last runs the jumpers at the main and intermediate frames, connecting up new subscribers, transferred and changed numbers, etc. As regards the telephonists, two amongst these take charge in turn of the service at the complaint desk and the Monitor's desk, the third tests periodically the different machines and when wanted helps her colleague of the complaint desk if she is overloaded."

The fault chart of the Scheveningen office in the Hague corresponding to the service observation chart previously given for the month of December, 1924, appears below. At the time this chart was made there were 3275 lines connected.

Facsimile of Service Observation Summary

	Installation Faults	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Not Including the Above Mentioned															
A	Sequence Switch and Registers				6		4	4	2	3						19
B	Line Finder and Selector				1				2			8				11
C	Multiple and Arcs			2				1								3
D	Relays			2	3		3	1	1			8				18
E	Wiring and cabling Lamps, Cords, Keys															
F	Miscellaneous				4							1		1	1	7
G	Total			4	14		7	6	5	3		17		1	1	58
	Extra Specification of These Faults															
H	Dirty Contacts			1	6		5	3	4	2		5				26
I	Power Drive (Slipping, Etc.							1								1
J	Adjustment				3		1					4				8
K	Breakage and Wear															

From the official Scheveningen fault reports for the year 1923 we obtain the following figures.

Total Automatic switches in use	1793
Total faults in switches for year	195
Faults per switch	0.109

This means that during the year 1923 there was but one fault for every 10 automatic switches in service.

An analysis of the 1923 trouble reports by automatic circuits is given in the following table. For comparative purposes are also given the latest figures available at that time for the Strowger system as given in bulletin No. 53 issued in March, 1923, by Automatic Telephone Manufacturing Company of Liverpool.

In the rotary system in Hague area there is not a separate first selector circuit. This selector is combined with the second line finder and with two sequence switches with the Strowger 2nd selector circuit and the final selector circuit may be compared with the Strowger 2nd selector circuit and connector circuit respectively. It is not clear that multiple wiring, relay, signal lamp and other miscellaneous faults are included in the Strowger figures, given in the above mentioned bulletin, but assuming they are, it will be seen that the ratio of the rotary faults to the Strowger faults is as follows:

2nd Selector	1 to 5.2
Final Selector (Connector)	1 to 3.2

SCHEVENINGEN OFFICE, THE HAGUE.

Faults per circuit per year for 1923

Circuit	Selector or Finder	Sequence Switch	Ribbon Cable & Arcs	Relays	Misc.	Total.
1st Line Finder	.0272	(A)	.0392	.0120		.0784
Connection Circuit (B)	.176	.334	.076	.255	.054	.895
2nd Group Selector	.072	.123	.028	.112	.012	.347
3rd Group Selector	.150	.210	.136	.110	.007	.613
Final Selector	.176	.213	.103	.101	.005	.598

(A) Circuit does not include Sequence Switch.
(B) Circuit consists of 1 No. 7001 Finder, 1 No. 7001 Selector and 2 No. 7001 Sequence Switches.

STROWGER SYSTEM
A.T.M. Co. Bulletin No. 53 March, 1924
Faults per Switch per Year

First Selector	2.03
Second Selector	1.80
Connector	1.91

Referring again to the article on The Hague, the total central office maintenance man-hours per line per year for the Marniz Office worked out at 6.5 including the clearing of all faults, routine testing and cleaning of the building. This figure will be reduced when the full number of lines are connected to the existing equipment.
The corresponding figure for the Zurich area at the end of 1924 was 4.5 man hours per line per year. Details concerning this figure are given below.
Number of subscribers lines in service at end of 1924 :

Hottingen semi-automatic lines	7811
" full automatic lines	947
Hongg full automatic lines	149
Cerlikon full automatic lines	244
Total	9251

Time spent weekly on maintenance :

	Man Hours	Percentage
1. Janitor service (cleaning of rooms)	8	1%
2. Power Plant	8	1%
3. Test Desk, incl. jumpering on M.D.F. and I.D.F.	216	27%
4. Routine Mechanical Inspection	168	21%
5. Routine Circuit Testing	176	22%
6. Fault Clearing, incl. subscribers' lines circuit troubles	208	26%
7. Tracing down false calls	16	2%
Total	800	100%

$\frac{800 \times 52}{9251}$ = 4.5 man hours per line per year.
With the time allotted for vacation and sickness, the above figure was increased to 4.6 man hours per line per year.

Power driven systems are not only economical for large offices but they are also economical for the smallest offices and a very large number of private exchanges and satellites, from 60 lines up, are now in successful service. The full automatic Hongg satellite at Zurich was put into service in January, 1923, with 115 lines connected. The satellite was constantly attended during the day time the first week only. Since that time the satellite has been regularly maintained by a visit of one-half day twice a week, namely, Monday and Thursday mornings. The principal work performed during that time is the charging of the batteries and the making of routine tests and clearing any faults thus found. Apart from these regular visits the Administration reported that during the first 8 months it was only once necessary to send a man to the satellite outside of the allotted mornings.

POWER DRIVEN VERSUS STEP-BY-STEP.

The reason for the rapid development of power driven within recent years was necessity. In no other way could large capacity and robust structures be obtained. The Step-by-Step selector has remained what it is for the past 28 years because it has not been found possible by step-by-step movement easily to increase its range or capacity no matter how the various details were re-arranged or re-shaped. Some companies, notably Siemens & Halske, have found it advisable completely to re-design the old form of Strowger selector and during the past few years a large number of different forms of line switches or preselectors have appeared, all doing more or less the same thing. The standard step-by-step selector is still 10 levels of 10 lines each and it is futile to argue that larger groups, if they could be economically obtained, are not desirable. In any large exchange or network they are desirable. The very fact that so much time and study has been given to the grading of small groups substantiates this statement. The value of grading in increasing the efficiency of trunk groups is not contested but the fact that various manufacturers claim anywhere from 15 to 50 per cent, increase in efficiency, goes to show that the problem is a long way from being solved.

A step-by-step switch must have within itself sufficient power to drive the wipers or brushes over a certain distance in a certain time. This requires the use of powerful low resistance electro-magnets, which if they are to be self protecting must be specially constructed. Electro-magnets of sufficiently high resistance to be self protecting in the ordinary sense of the word may not be used because of the resulting high self induction, which would prevent the rapid operation necessary for reasonably high speeds in step-by-step switches. A group selector, for example, that selects the fifth level and then the fifth terminal in that level must make 10 complete steps, attracting its armature 10 times and releasing it 10 times, a total of 20 movements. Each movement offers a chance for error. In a power driven switch any distance may be covered by two simple movements, so far as the electro-magnet control is concerned. In a selector or a line finder we are not as interested in the time required to start as we are in the time required to stop. In power driven apparatus of the rotary type a very quick stop is obtained and at the same high resistance self protecting electro-magnets are employed. The flexible gear driven line finder, for example, hunts at a normal speed of 50 contacts per second. The controlling apparatus permits the speed to be increased to 75 contacts per second before under or overstepping takes place. By going to the extreme limits in the winding of relays or coils, as is now the case in step-by-step systems, the commercial speed of the line finder may be increased to 125. Such a speed cannot be approached by any step-by-step mechanism moving commercial brushes under commercial pressures. The fact that power driven equipment may be operated with such large margins of safety tends towards very great accuracy of selection and permanency of adjustment. It is also an indication of the accuracy of the controlling test relay and circuits.

Because the power element in a step-by-step switch must go through a complete cycle each time the brushes are advanced one step, and as wear is proportioned to use, it follows from the foregoing paragraph that wear in the motor mechanism of a step-by-step switch is very much greater

than in a corresponding power driven mechanism. The ordinary step-fay-step final selector moves on the average 5 levels up and then 5 terminals around. The pawl or pawls thus engage rack or ratchet 10 times. The pawl hits the ratchet or rack with great force and this violent motion is terminated by an abrupt "blow against a fixed stop, which stop is necessary for centering the brushes. In other words, to set the final selector brushes on the required terminal the pawl delivers 10 hammer blows. The pawl and ratchet must be made of the very finest materials, otherwise their life is short. Even the best constructed pawls are often replaced. A million revolutions in a step-by-step mechanism is considered very good. Life tests on flexible gears such as used in the rotary system, which correspond to the pawl and ratchet combination in a step-by-step switch show that after 18 million revolutions the end of their useful life is not even approached. No tests have been carried beyond 18 million revolutions. The statement is made with the full knowledge that any Administration operating the rotary system may easily check its accuracy by making similar tests. In the power driven system, therefore, it will be seen that the wear and tear on the mechanism which drives the brushes is very much less than in a step-by-step system. If step-by-step movement were not limited to light structures we would see it to-day applied to other motion producing electro-mechanical structures such as small motors. Violent reciprocating motion is always to be avoided in any structure.

The speed of selection in a power driven system is more uniform than in a step-by-step system. No two step-by-step switches operate at exactly the same speed and the speed of any given switch varies considerably with changes in battery potential. Power driven switches are driven by motors, which maintain a constant speed within the commercial limits of plus or minus 5%.

The matter of good electrical contacts between brushes and bank terminals is of great importance. In the rotary system both single and double brushes are used. A finder generally employs double brushes throughout, and a selector single brushes.

What is more important as regards "brushes and bank contacts in switch design is freedom from vibration. Vibration is set up in every step-by-step switch by the hammer action of the pawl and this vibration is the cause of microphonic disturbances in adjacent switches attached to the same fixed support. The Company has recently completed an investigation of many months during which a large number of step-by-step line switches of different manufacture were examined. The switches were mounted side by side and in various ways. They were all fitted with double brushes, and some of the brushes had double contact points, thus making a total of 4 contacts between "brush and terminal but in spite of all this, microphonic disturbances were noticeable in all switches when mounted adjacent to each other in the ordinary way. By a microphonic disturbance is meant a noise noticeable in a receiver due to a variation in the contact resistance between brush and terminal not to any actual opening of the circuit. These investigations were made because of complaints from users of small private exchanges employing standard line switches of the American type. To reduce the trouble to practical limits, it was found necessary to mount the switches on rubber or leather. The reason why disturbances are more noticeable in private exchanges of the step-by-step type than in large central offices of the same type, is because of the greater possibility of the simultaneous operation of adjacent switches in the former. The

period of disturbance due to the operation of an adjacent switch is generally very short and for this reason the trouble is generally passed over in central offices without comment. The reason why a test brush is often made double and the talking circuit brushes single is because a test brush comes into action while the switch is in motion or vibration.

Owing to the absence of hammer action in the power driven rotary system the contacts in this system are free from microphonic disturbances.

As regards contact pressures, the required pressures can be more easily obtained and maintained in a power driven system than in a step-by-step system because more substantial brush structures are permissible, thus insuring a greater range in wear and in the ease and accuracy of adjustment. It is often difficult to obtain the proper pressures and at the same time maintain a high speed when many brushes are used in a step-by-step mechanism. In a power driven switch any number of brushes may be used, each giving the requisite pressure.

It is not true that higher contact pressures may not be employed in power driven systems. The normal pressure employed in the standard rotary selector is from 40 to 80 grams. During rotation this pressure momentarily reaches 275 or more grams. The reason why such contact pressures may be used in a power driven switch is because, when necessary, a greater mass of the very hardest contact metal may be used than is possible in a step-by-step switch.

A very serious source of trouble in the step-by-step Strowger selector is the cord used to connect the moveable brushes to fixed terminals on the switch. These cords have a comparatively short life and are frequently replaced. They are often a source of intermittent trouble and also the cause of microphonic disturbances due to the partial opening of the conductors. That this point is recognised by Strowger manufacturers as a serious point is evinced by the fact that improvements have recently been made whereby the cords may be more readily removed and replaced. In the power driven system of the rotary type no cords whatsoever are employed, all contacts with the moveable brushes are made by means of substantial commutators and feeder brushes, long recognised as the best means of making electrical contact with a moving brush.

In step-by-step switches the tips of the brushes wear out and have to be replaced. This is because heavier materials may not be used without affecting speed or accuracy or increase in the size of the motor mechanism required to drive them. Repeated life tests on power driven finders of the gear driven rotary type show that the average useful life of the shoe tips before reforming or readjusting becomes necessary is more than two million revolutions, which is equivalent to a life of more than 50 years when used as a line finder, according to the practice adopted in the rotary system. In the power driven selector of the rotary type 10 sets of single contact brushes are used. As the wear is distributed over these 10 sets, it has not been possible, in any life test so far carried out, to determine the 1-ife of these brushes. Selectors have been rotated more than 3 million times under normal conditions and with no appreciable indication of any wear. It may, therefore, be said, that in the power driven system of the rotary type, brushes may be easily produced which do not require readjustment for 50 years or so.

As regards switch motors in power driven systems the small 1/8 H.P. motors so far provided for the rotary system have never yet been overloaded.

The total power consumed by a power driven exchange is not more than, if as much as, that consumed by a corresponding step-by-step exchange. The total power required to operate the switch motors during a day of 24 hours in a typical 10,000 line office is about 40 kilowatt hours, which is equivalent to 15% to 20% of the total power required to operate the switches and relays. As sequence switches are employed throughout the rotary system, the amount of energy required to hold a connection when once established, is much less than in a step-by-step system, which relies primarily upon the continued energisation of relays. A sequence switch when placed in position stays there without any further expenditure of energy. In small offices and private branch exchanges the motor runs only when it is needed.

One result of development and research work done by the Company was the development of the flexible gear drive. This drive has proven itself to be cheaper and better than any other form of drive and because of this, it has been introduced into all the switches made by the Company. The flexible gear drive is far easier to adjust and to maintain than any step-by-step drive, as witnessed by its accurate performance in the field. Two hundred and fifty gear driven finders were installed in Copenhagen to serve as incoming junction traffic distributors in a large manual exchange. At the end of 13 months continuous service not one case of switch readjustment or replacement was reported. The only apparatus fault was one open coil winding.

CONCLUSIONS.

A power driven selector or finder will establish a connection with less wear, with more margin and reserve as regards speed, with more margin and reserve as regards contact pressures and with fewer movements on the part of the motor mechanism. Also that power drive permits the engineer to design a more robust structure in all details, to provide the necessary mass to take up wear in all parts subject to wear, to provide the necessary power to insure the required contact pressure under all circumstances, to increase the size of the arc as economy may dictate and finally to avoid entirely the use of perishable parts in the sense that there are perishable parts in a step-by-step switch, such as pawls, ratchets, cords and delicate and thin brushes. From these conclusions it follows that a properly designed power driven switch in respect to a correspondingly designed step-by-step switch is:

(a) more accurate
(b) more reliable
(c) more economical in the use of the junction plant
(d) affords better service since faults are fewer
(e) reduces maintenance, first, because there are less faults per individual piece of apparatus; second, because of the larger arc capacity, there are fewer pieces of apparatus.

EFFECTS OF DUST ON APPARATUS.

Because it is not under the direct control of a subscriber's dial the rotary system employs apparatus of a very solid construction which enables all the rubbing contact surfaces to be built very rigidly. The action of a heavy phosphor bronze brush passing over the bank contact secures a very high degree of electrical continuity and the grinding motion therefore eliminates all possibility of allowing particles of dust to rest on the contacts.

This feature is of no small importance where the system is installed in areas which are subject to abnormal accumulation of dust in the atmosphere.

SIMPLICITY AND ADAPTABILITY.

Simplicity may always be obtained by sacrificing adaptability. Simplicity may be examined from an apparatus point of view or from a point of view of system. Piece for piece power driven automatic apparatus is simpler, or may be made simpler, than corresponding pieces of step-by-step apparatus. For example, compare the rotary power driven line finder, which is rather fully described in Part iii, volume 3 of Electrical Communications, with a preselector such as manufactured by any of the large Strowger manufacturing companies. In the power driven switch the rotating brushes come into contact with a given set of terminals when the armature is lifted by an electric-magnet, thereupon the flexible gear under its own tension engages the driving gear.

The brushes rotate in one direction and at a fixed speed and will do so indefinitely until the armature is released. Prom start to finish, we have therefore, but four mechanical movements in the driving mechanism:

(1) attraction of armature, (2) movement of disc gear under its own tension,(3) release of armature, (4) disc gear forced out of engagement with driving gear.

In a corresponding step-by-step line switch such as is standard in America and England, we have a multitude of mechanical motions when an appreciable hunting is involved. (1) the attraction of the armature(2) the movement of the pawl into a position for engagement with a tooth on the ratchet wheel, (3) the openings of the interrupter contact when the armature is nearly fully attracted, (4) release of armature, forcing pawl with ratchet tooth against a back stop, (5) closing of interrupter contact,(6) check spring falls into position to prevent the return of the ratchet when pawl is withdrawn. This process is repeated for each step or terminal passed over by the line switch. Thus in an advance of 10 steps 60 mechanical motions are involved. Each complete revolution in a step-by-step line switch of the small capacity of 25 lines, therefore, requires 150 mechanical movements.

In the power driven finder the comparatively few springs and brushes involved have definite tensions and the airgaps, operating and non-operating of the electro-magnet are fixed. In the step-by-step switch of the preselector type, a very slight, that is an almost imperceptible change in the adjustment of the interrupter contact or in the tension of the retractile spring makes a big change in the behaviour of the switch. In a 10,000 line exchange with an average calling rate of one 2-minute call per line per busy hour 10,000 preselectors, of the type referred to, are required against 1000 power driven rotary line finders. It will, therefore, be seen that in the usual form of step-by-step system there are at the outset very many more switches and each of a more delicate structure.

A similar comparison may be made between the simple uniform rotary motion of the power driven rotary selector and the 2-motion Strowger selector with its series of pawls and connecting links. The gear driven rotary selector has two simple controlling electro-magnets, one for rotating the brushes and the other for tripping the desired set of brushes. All rotation is in the same direction. In a Strowger selector of the ordinary type there are three magnets; a vertical pawl operating magnet; a rotary pawl operating magnet and a release magnet. In addition to these parts there is a link or links kicked or forced into and out of position, holding pawl or pawls and retractile springs for resetting the moving parts.

When we consider an automatic system as a whole, not merely the individual pieces of apparatus separately, we have a very different problem to face and in this connection, adaptability must also be considered. A Strowger circuit for a simple office is probably easier for a beginner to follow than the corresponding circuit for a simple power driven system employing a register. This does not mean, however, that the latter system is any more difficult to maintain. In may respects the power driven system with a sequence switch is much easier to maintain because of the sequence switches which indicate, by position number, the exact stage to which a call has progressed. The maintenance man-hours previously given for such multi-office areas as the Hague and Zurich are conclusive proof that the rotary power driven system is not difficult to maintain.
It is not without reason that power drive has been responsible for most, if not all, of the major improvements in automatic telephony in recent years. It introduced office prefix translation, flexible trunking, call indicator working to manual positions and high speed direct trunking from manual to automatic. These advancements in telephony have been or are now being introduced in the Strowger system. As a result of the above mentioned differences in design and principles of operation of the two systems, the following are the outstanding features of the rotary system.

(1) The rotary system is fundamentally a register system which operates on a " No lost call " basis.
(2) Switches with capacity to hunt over 30 trunks in a group are used, thereby reducing the number of switches required to carry a given traffic.
(3) The use of line finders and large group switches both tend to keep the number of mechanisms to be maintained to an absolute minimum.
(4) Sequence switches give great latitude in the working of the system and as regards running cost, are economical, in that they do the work of several relays and do not require current to hold them in the operated position.
(5) A very economical, method of direct trunking from "A" positions without the need for cordless " B " positions, can be used.
(6) Being power driven, it has been possible to make the switches very robust without losing the advantage of quick operation. There are no weak or delicate parts to wear out or require frequent attention.
(7) No flexible connections, such as cords, are used with the switch gear.
(8) Being driven from continuously rotating shafting, there are no vibrating parts to introduce microphonic disturbances into the talking circuits.
(9) The method of mounting the switch gear enables complete bays of equipment to be assembled in the factory, so that installation and extension work can be done without a large force of specialists.

(10) The power driven apparatus as used in a rotary system is of much more rugged construction with a consequent reduction in maintenance cost and interruptions in service than the step-by-step type. This is particularly true as regards the driving clutches of the rotary equipment as compared with the stepping magnets of the step-by-step apparatus.
(11) The multiple banks of the various selectors, line finders and rotary switches used in the rotary equipments are also of markedly better construction from the standpoint of ruggedness and ease of maintenance than the corresponding banks used in the step-by-step equipment.
(12) The ribbon cable used for connecting the banks in multiple is better from a maintenance standpoint and presents a much better appearance than the loose wire connections used between multiple banks in the step-by-step equipment.
(13) The claims made by some manufacturers of step-by-step Equipment that power drive, which requires the continuous operation of driving motors and shafts, is not reliable, is untenable in view of the many offices using power drive that have been in service for 10 years or longer without any serious interruption in service and with no indication of wear on the motors of shafts to indicate that such an interruption can be expected, until long after the useful life of the associated telephone equipments has been reached.
(14) Registration of Dial Pulses and the Control of Selectors by the Register versus Straightforward pulsing from the dial to the various selector switches.

The fundamental circuit design of the rotary system where the dial pulses are received in a register which then controls the movement of the various selectors in connecting the calling station's line with the line of the called station, undoubtedly has very important advantages from the standpoint of annual charges and dependability of service over the system used in step-by-step equipments, where the dial pulses are received directly on each switch of the train required to establish the connection. These advantages may be listed as follows:—

(a) No set relation is necessary between the digits dialled and the actual selections made, that it, the digit dialled in a rotary system does not necessarily select the corresponding level in a group selector or the corresponding level and terminal number in that level in a final selector when a register is used. This permits an important degree of flexibility.

(b) Where a register is used for receiving the dial pulses a more stable adjustment of the stepping relay can be obtained and wider margins for variations in dial pulse characteristics is permissible than with a system where each selector is provided with a stepping relay. This permits of satisfactory dialling over longer subscriber lines. The standard loop resistance requirements for a rotary system is 1000 ohms, while with the step-by-step system this requirement is

750 ohms. Where lines of higher resistance than these limits are encountered it is much easier and cheaper to provide special long line equipment in the rotary than in the step-by-step equipment. Due to the fact that the stepping relays in the registers are the only ones that operate from the dial, the total number of relays that must be adjusted to meet the variations of the dials is much smaller than in the step-by-step equipment. This means that the reaction on service should be materially less and the cost of maintenance lower.

(c) In the rotary system the selectors are controlled by the register over fundamental circuits using a revertive battery method. That is, the movement of the power driven selector itself sends back to the register sets of impulses which are counted in the register and the movement of the selector stops when the desired level or terminal is reached. With this method the outstepping relays in the registers are the only ones that it is necessary to adjust for operation in the pulses. The only factor that would be a variable in the stepping circuit would be the resistance of the inter office trunks. However, by providing compensating resistances in the trunks at the different offices a uniform resistance is obtained so that a standard adjustment with wide margins can be given the stepping relays. This again is an assurance of uninterrupted service and results in lower maintenance than the direct pulsing circuits of the step-by-step system.

(d) Since all selectors are controlled by the register, the position of the various pieces of apparatus associated with the register circuit gives a direct indication of the status of the call at any stage of its progress. This is a very important advantage from a maintenance standpoint since a maintenance man knows immediately in the majority of cases of trouble, the nature and location of the trouble from the position of the equipment in the registers.

(15) Sequence Switch.

The sequence switches used in the rotary type equipment function to open, close or transfer circuits similarly to relays, and if they were not used large numbers of relays would be required. The sequence switches are power driven and actually consume power only while the clutch is in the operating position, that is, unlike the relays, no current is consumed in their holding position. The current drain requirements for a rotary office are considerably lower than for step-by-step machines. This, of course, reacts favourably on the maintenance cost, and on the floor plan requirements of central office equipment.

Sequence switches associated with the registers and with the various selectors are equipped with position indicators to show at all times what position the switches are standing in. As stated above, this is of material aid in maintenance work as a trained man can immediately tell from the location of the sequence switches, the position and nature of most cases of trouble.