Western Electric Company, Inc.
Central Regional Services
Technical Training Section

For Training Purposes Only

Lesson No. 1

FUNDAMENTALS OF TELEPHONY

This Lesson covers the basic theory of the Telephone and Telephone Switching, together with the general features of the various Switching Systems. Comparisons are drawn between the various Dial Systems and the Manual Switching System to assist in understanding the various Switching Machines.

Information contained herein is to be used only for training purposes.

CONTENTS

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Reissued July, 1964

Bibliography

Bell System Publications

Western Electric Company, Inc.
Central Regional Services
Engineering Personnel Development

Lesson No. 1

FUNDAMENTALS OF TELEPHONY

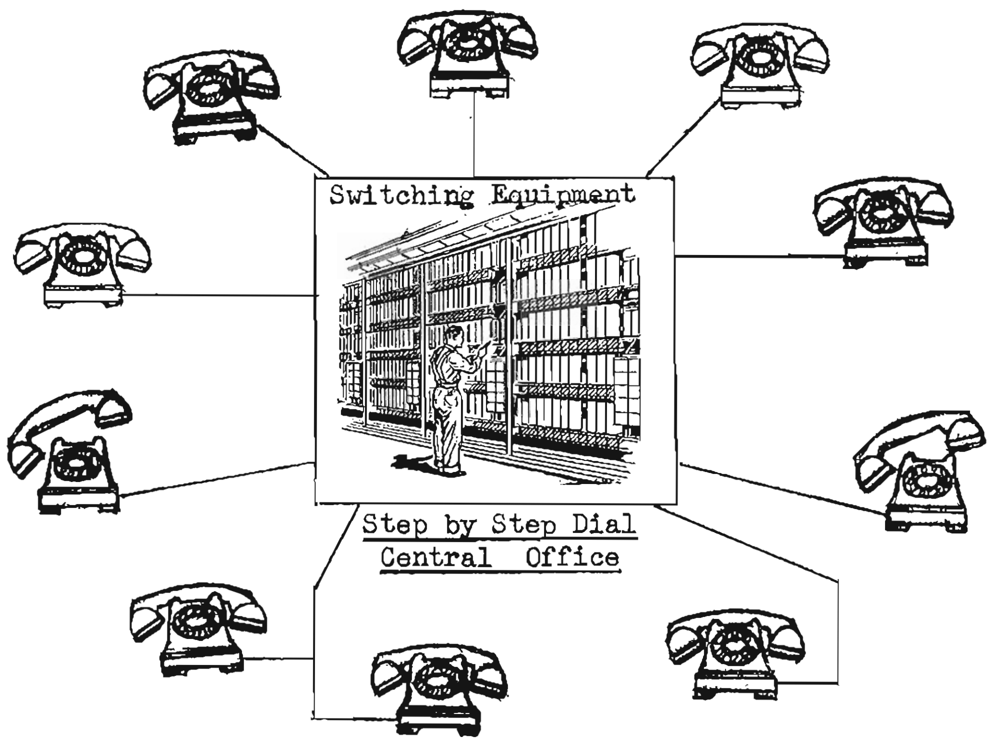
Section 1

Principles of Telephone Switching

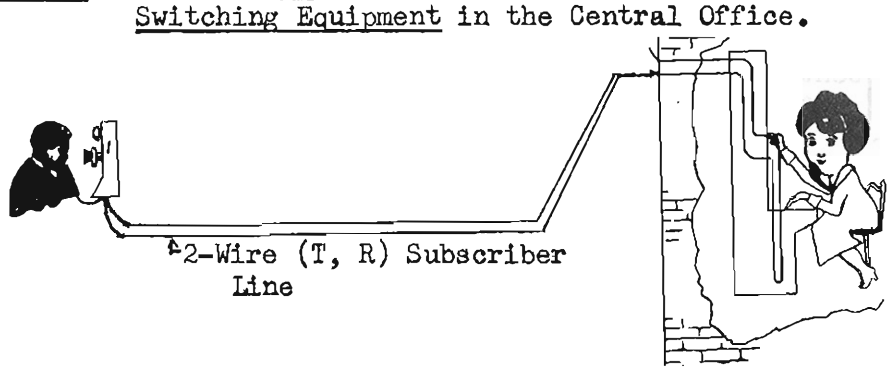
CONTENTS

PRINCIPLES OF TELEPHONE SWITCHING

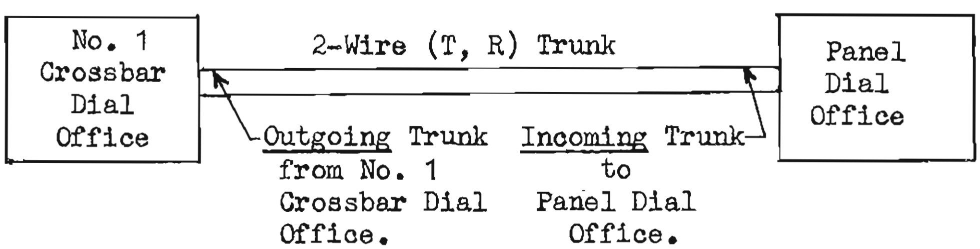
Function - The function of any Telephone Switching System is to connect together temporarily the Lines of any two Subscribers so they may talk.



Subscriber Line - A 2-wire Path between a Subset (Telephone) and the Switching Equipment in the Central Office.

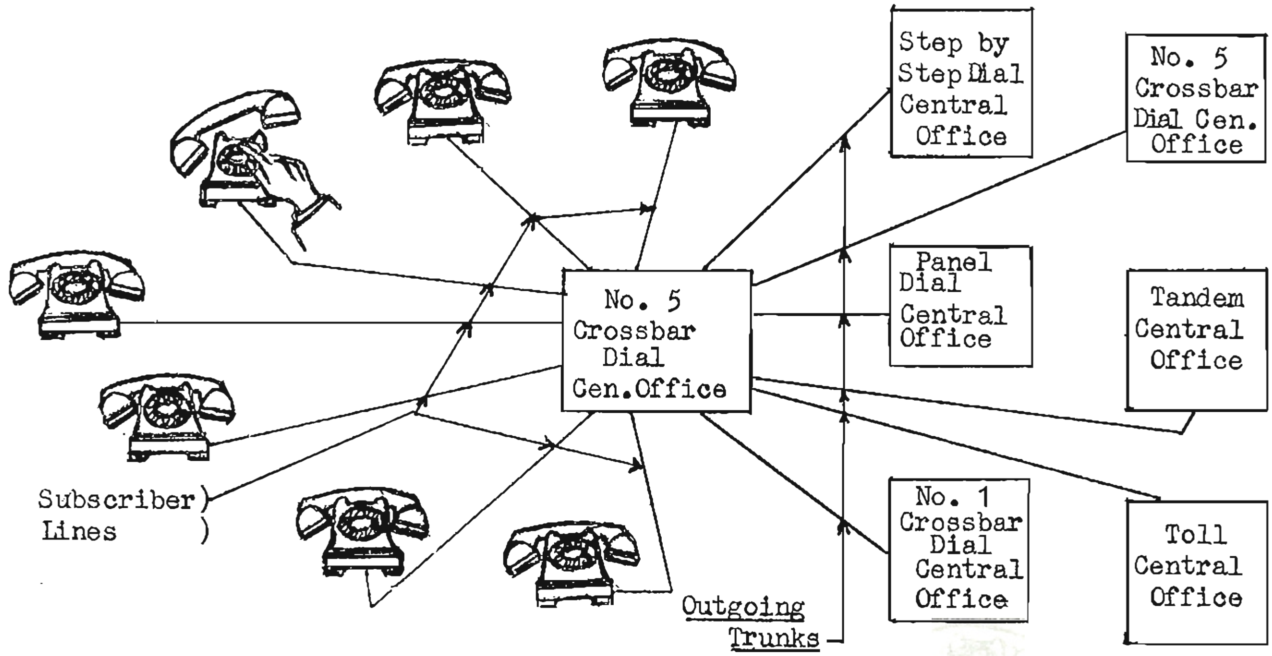


Trunk - A 2-wire Path (T, R) between two Central Offices.

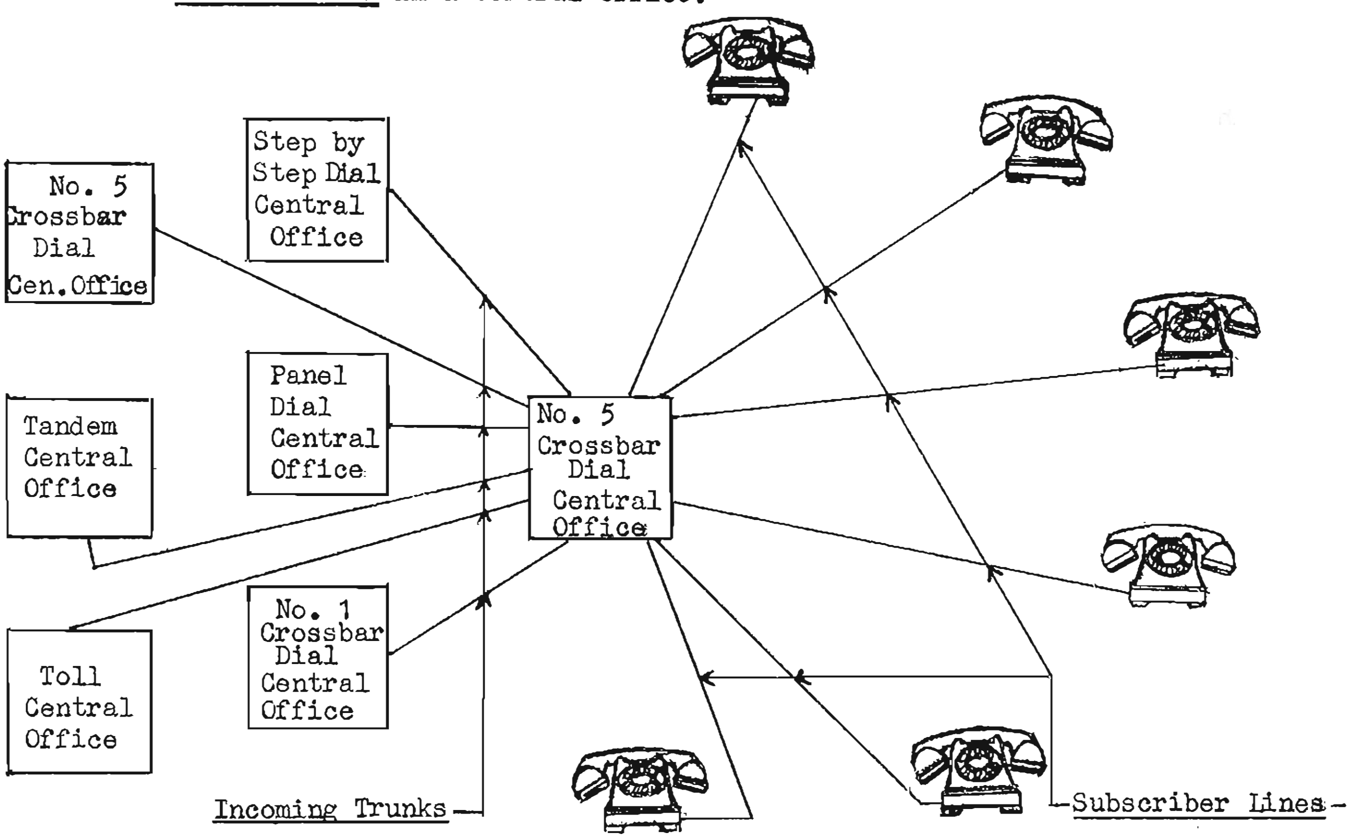


Requirements of a Telephone Switching System

1) Originating Calls - Each Subscriber Line must have access through the Switching Equipment to all other Subscriber Lines terminating in that Central Office, as well as to all Outgoing Trunks to other Central Offices.



2) Terminating Calls - Each Incoming Trunk must have access to all Subscriber Lines in a Central Office.

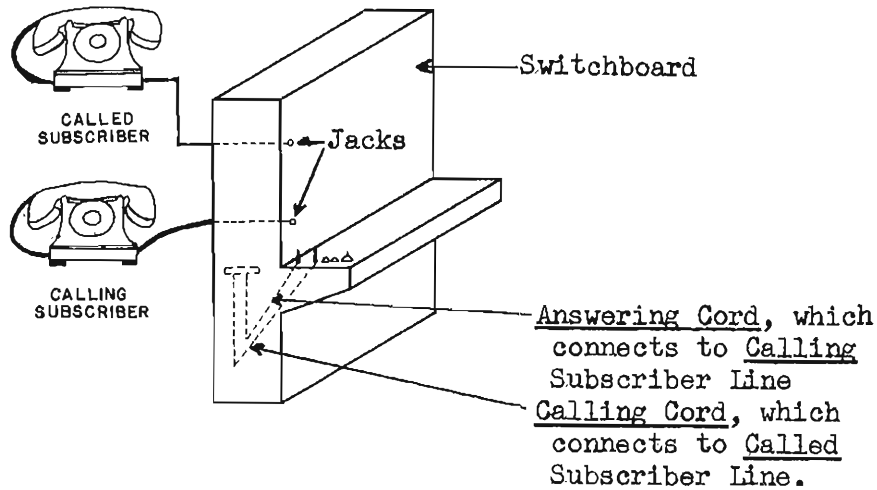


Tandem Office - A Central Office used as an intermediate Switching Point for traffic between other Central Offices.

Toll Office - A Central Office for completing Calls to destinations outside the Local Service Area of the Calling Station.

Telephone Switching Systems
1) Manual
2) Dial
   a) Direct Dial Control
   b) Common Control

Manual Switching System
1) Subscriber Lines are cabled to Jacks mounted on a Switchboard.
2) Operators connect Subscriber Lines together manually by inserting Plugs on the ends of Cords into Jacks.

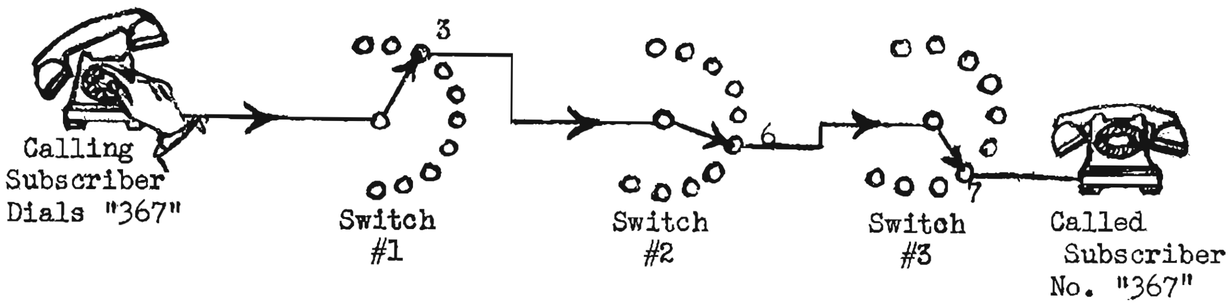


Dial Switching Systems

1) Subscriber Lines cable to electro-mechanical switches, instead of Jacks.

2) The Calling Subscriber operates a Dial, which transmits electrically the Called Telephone Number to the Switching Equipment in the Central Office.

3) Direct Dial Control - Switches respond directly to Dial Pulses as the Calling Subscriber dials the digits of the Called Telephone Number.

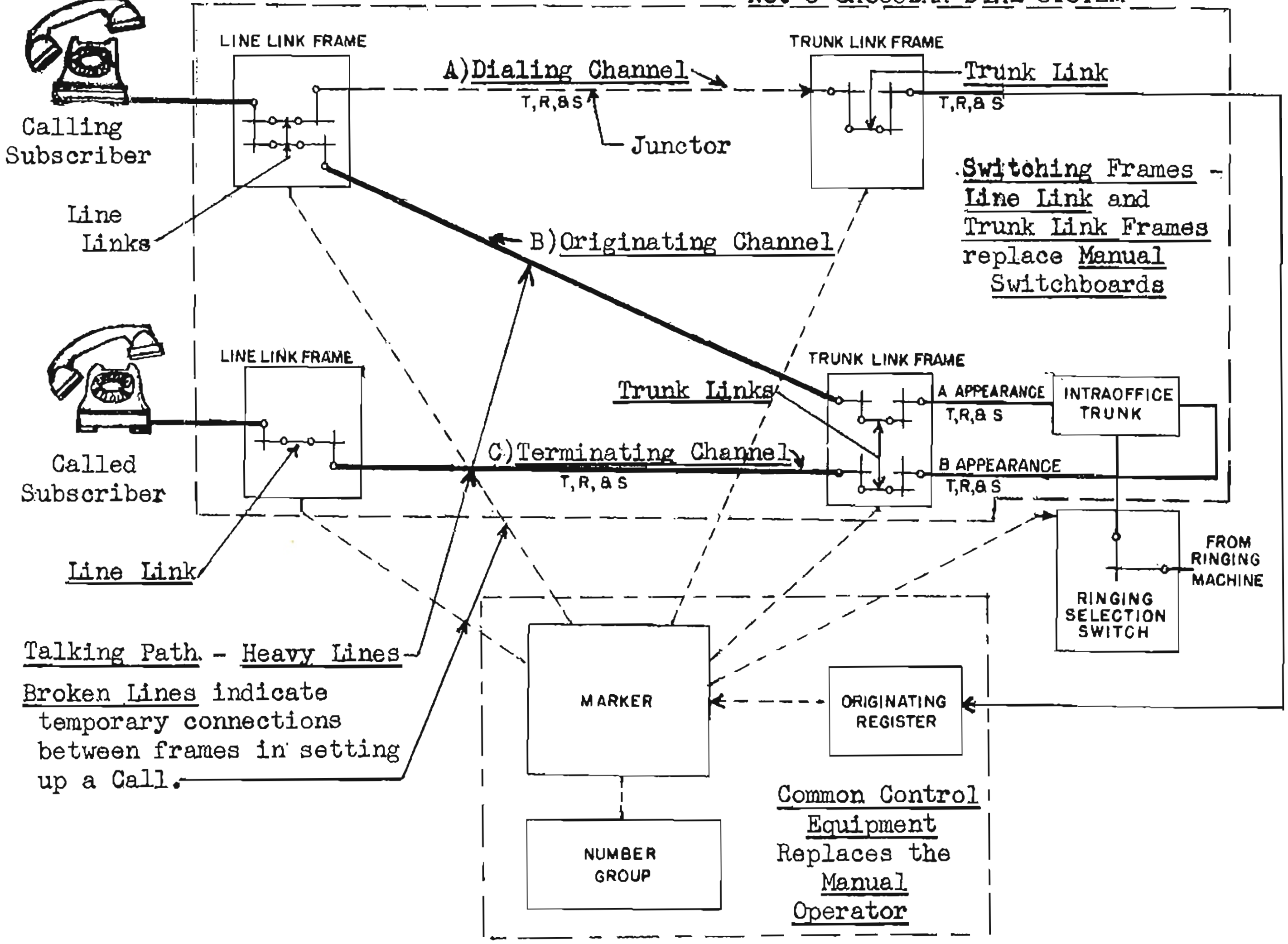


4) The Step-by-Step Dial Switching System is a Direct Dial Control System.

5) <u>Common Control Switching Systems</u> - The <u>dialed digits</u> of the Called Telephone Number are <u>registered</u> in the <u>Common Control Equipment</u>, which uses the <u>stored information</u> to:

1) <u>Select</u> an <u>Idle Talking Path</u>, through the <u>Switching Frames</u>, between the Calling and Called Subscribers.
2) <u>Close through</u> the <u>Talking Path</u>.
3) Then the Common Control Equipment <u>releases</u>, to be used in setting up other Calls.

- <u>NO. 5 CROSSBAR DIAL SYSTEM</u> -



A) <u>Dialing Channel</u> - Between the <u>Calling Subset</u> and the <u>Originating Register</u> - made up of:
1) Line Link,
2) Junctor,
3) Trunk Link.

B) <u>Originating Channel</u> - Between the <u>Calling Subset</u> and the <u>Intraoffice Trunk</u> - made up of:
1) Line Link,
2) Junctor,
3) Trunk Link.

C) <u>Terminating Channel</u> - Between the <u>Intraoffice Trunk</u> and the <u>Called Subset</u> - made up of:
1) Trunk Link,
2) Junctor,
3) Line Link.

(B and C) - <u>Talking Path</u>

4) <u>Common Control Switching Systems</u>:
a) Panel Dial
b) No. 1 Crossbar Dial
c) No. 5 Crossbar Dial
d) Crossbar Tandem
e) Crossbar Toll.

Western Electric Company, Inc.
Central Regional Services
Engineering Personnel Development

For Training Purposes Only

Lesson No. 1

FUNDAMENTALS OF TELEPHONY

Section 2

Early Developments in Dial Switching Systems

CONTENTS

+Table I — List of United States Patents on Automatic Telephone Exchanges Issued During the Years 1879-1900, Inclusive.*

Number	Date Issued	Patentee	Application Date
222,458	Dec. 9, 1879	Connolly & McTighe	Sept. 10, 1879
223,201	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 11, 1879
223,202	Dec. 30, 1879	Westinghouse, G. Jr.	Oct. 13, 1879
224,565	Feb. 17, 1880	Westinghouse, G. Jr.	Oct. 27, 1879
237,222	Feb. 1, 1881	Westinghouse, G. Jr.	Feb. 7, 1880
248,138	Oct. 11, 1881	Buell, C. E.	June 15, 1881
255,766	Apr. 4, 1882	Buell, C. E.	Dec. 12, 1881
262,645	Aug. 15, 1882	Connolly & McTighe	Aug. 29, 1881
262,646	Aug. 15, 1882	Connolly, M. D.	Nov. 29, 1881
262,647	Aug. 15, 1882	Connolly, M. D.	Nov. 8, 1881
263,862	Sept. 5, 1882	Connolly, M. D.	Oct. 29, 1881
269,130	Dec. 12, 1882	Snell, F. H.	Sept. 6, 1882
281,613	July 17, 1883	Cardwell, G. A.	July 7, 1882
282,791	Aug. 7, 1883	Snell, F. H.	Feb. 28, 1883
283,806	Aug. 28, 1883	O'Donel, I. M.	June 5, 1880
290,730	Dec. 25, 1883	Bartelous, J. V. M.	June 15, 1882
295,356	Mar. 18, 1884	Connolly, T. A.	Apr. 10, 1883
310,282	Jan. 6, 1885	Jackson & Cole	Mar. 5, 1884
335,708	Feb. 9, 1886	Lockwood, T. D.	Sept. 26, 1885
349,975	Sept. 28, 1886	Bickford, J. H.	Nov. 25, 1885
349,976	Sept. 28, 1886	Bickford, J. H.	Jan. 18, 1886
367,219	July 26, 1887	McCoy, J. A.	Jan. 29, 1887
372,378	Nov. 1, 1887	Lockwood, T. D.	Apr. 11, 1887
381,938	May 1, 1888	McCoy, J. A.	July 6, 1887
408,327	Aug. 6, 1889	Smith, J. R.	Feb. 16, 1888
435,295	Aug. 26, 1890	Ford, W. H.	Dec. 31, 1889
442,734	Dec. 16, 1890	Smith & Childs	Sept. 27, 1889
447,918	Mar. 10, 1891	Strowger, A. B.	Mar. 12, 1889
457,477	Aug. 11, 1891	Hayes & Sears	Feb. 3, 1891
486,909	Nov. 29, 1892	Strowger, A. B.	Feb. 19, 1892
498,236	May 30, 1893	Clark, E. A.	Apr. 5, 1892
498,289	May 30, 1893	McCaskey, A. S.	July 29, 1892
498,291	May 30, 1893	McCaskey, A. S.	Aug. 25, 1892
499,748	June 20, 1893	McClaren, A. E.	June 13, 1892
510,195	Dec. 5, 1893	Serdinko, J.	Apr. 22, 1893
511,873	Jan. 2, 1894	Callender, R.	Apr. 24, 1893
511,874	Jan. 2, 1894	Callender, R.	May 12, 1893
511,875	Jan. 2, 1894	Callender, R.	Aug. 13, 1892
515,108	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,109	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
515,110	Feb. 20, 1894	Callender, R.	Nov. 2, 1893
520,246	May 22, 1894	Simoneau, L. E.	July 11, 1893
528,590	Nov. 6, 1894	Childs, W.	May 12, 1891
528,591	Nov. 6, 1894	Childs, W.	May 27, 1890
530,324	Dec. 4, 1894	Callender, R.	Dec. 18, 1893
533,893	Feb. 12, 1895	Hey & Parsons	Mar. 30, 1893
535,806	Mar. 12, 1895	Nissl, F.	Feb. 17, 1894
537,603	Apr. 16, 1895	Decker, W.	May 14, 1894
538,975	May 7, 1895	McDonough, J. W.	May 21, 1891
540,168	May 28, 1895	Keith, Lundquist & Erickson	Nov. 7, 1894
543,160	July 23, 1895	Shibata, W. Y.	Oct. 11, 1894
543,708	July 30, 1895	Shibata, W. Y.	Nov. 24, 1893
546,725	Sept. 24, 1895	†Berditschewsky et al.	Mar. 27, 1895
547,755	Oct. 8, 1895	Hutchins, G. K.	May 6, 1893
550,728	Dec. 3, 1895	Smith, J. G.	Feb. 18, 1893
550,729	Dec. 3, 1895	Smith, J. G.	Feb. 20, 1893
551,391	Dec. 17, 1895	Lounsbury, W. F.	Apr. 23, 1895
554,125	Feb. 4, 1896	Houts, W. A.	Dec. 24, 1894
556,007	Mar. 10, 1896	Freudenberg, M.	Jan. 10, 1896
561,377	June 2, 1896	Dean, G. Q. & J. Jr.	Aug. 3, 1895
562,064	June 16, 1896	†S. Berditschewsky	Mar. 23, 1896
570,840	Nov. 3, 1896	Brooks, M.	Jan. 26, 1895
573,859	Dec. 29, 1896	Callender, R.	Mar. 19, 1896
573,884	Dec. 29, 1896	Keith, A. E.	Sept. 16, 1893
574,245	Dec. 29, 1896	Houts & Nilson	Aug. 25, 1896
574,707	Jan. 5, 1897	Bowman, L. G.	July 18, 1896
582,578	May 11, 1897	Clark, Ellacott & Johnson	Sept. 28, 1893
584,384	June 15, 1897	Macklin, A. B.	Aug. 7, 1896
586,529	July 13, 1897	Davis, W. W.	Sept. 5, 1896
587,435	Aug. 3, 1897	Freudenberg, M.	Oct. 22, 1896
588,511	Aug. 17, 1897	Van Wagenen, A.	Apr. 30, 1896
589,798	Sept. 7, 1897	Strowger & Keith	Feb. 19, 1896
591,201	Oct. 5, 1897	Strowger, Lundquist & Erickson	July 17, 1895
597,062	Jan. 11, 1898	Keith & Erickson	Aug. 20, 1896
604,373	May 24, 1898	Decker, W.	Mar. 25, 1895
604,434	May 24, 1898	Stillwell & Barneck	Nov. 10, 1896
606,764	July 5, 1898	Lundquist, F. A.	May 19, 1897
611,974	Oct. 4, 1898	Nilson, L. G.	Mar. 9, 1896
612,681	Oct. 13, 1898	Snow, H. P.	Nov. 1, 1897
616,714	Dec. 27, 1898	Lundquist & Erickson	Mar. 28, 1893
624,666	May 9, 1899	Lundquist, F. A.	Sept. 20, 1897
626,983	June 13, 1899	Decker, W.	Aug. 3, 1896
632,759	Sept. 12, 1899	Slater, J. C.	May 23, 1898
638,249	Dec. 5, 1899	Keith & Erickson	Dec. 16, 1895
639,186	Dec. 12, 1899	Seligmann-Lui, G.	May 27, 1898

* Excludes village, house and factory systems. † Called "Apostoloff." Note:—No automatic telephone exchange patents were issued during the year 1900.

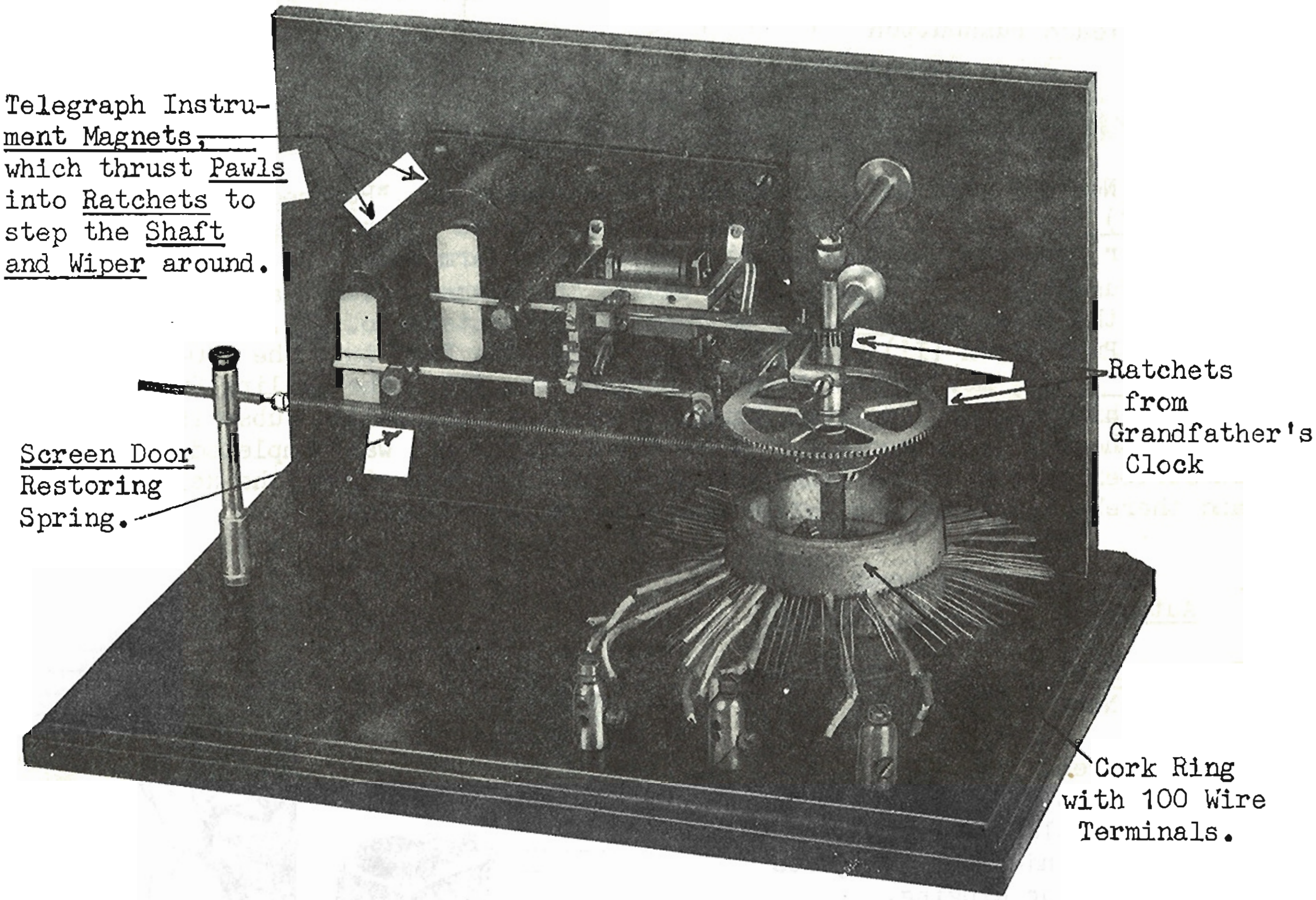
+ Taken from the Bell Laboratories Record January, 1953.

THE FIRST PRACTICAL AUTOMATIC TELEPHONE SWITCHING SYSTEM

STEP BY STEP DIAL

During the Jesse James Era, Almon B. Strowger of Kansas City found the undertaking business rather slow. Upon investigation, he discovered the local telephone operator was his competitor's daughter; therefore he developed the Step by Step Dial Switching System so that he might enjoy a more equitable share of that business.

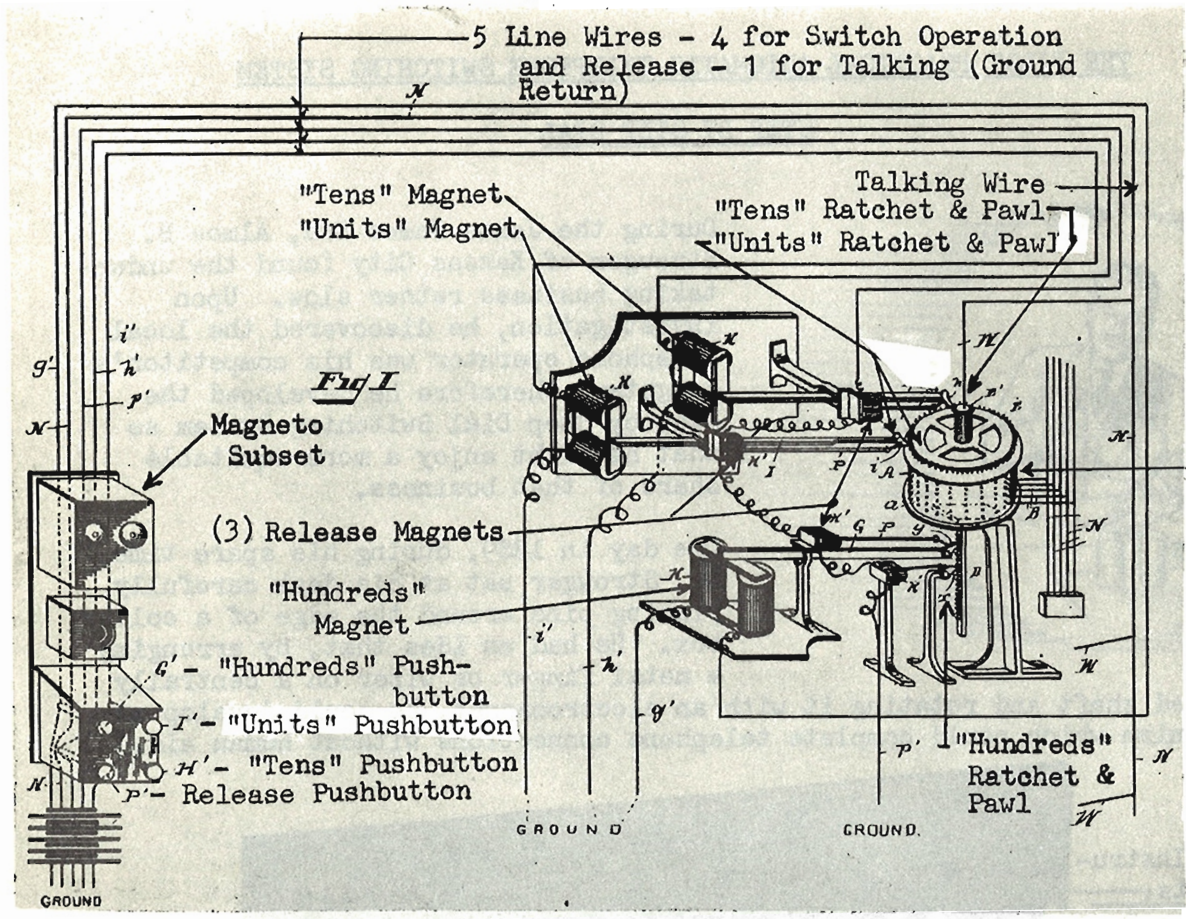
One day in 1889, during his spare time, Mr. Strowger sat at his desk carefully placing pins around the edge of a collar box. He had an idea that, by arranging a metal finger or wiper on a centrally located shaft and rotating it with an electromagnet, he could develop a mechanism which could complete telephone connections without human aid.



An Experimental Strwoger Switch - 1891

Mr. Strowger came to Chicago with his idea and an experimental switch. A company was formed known as the, "Strowger Automatic Telephone Exchange;" later reorganized as the Automatic Electric Company.

THE STROWGER PATENT #447,918, Issued March 10, 1891



Switch Cylinder - Talking Wires connected to Cylinder Contacts according to Telephone or Directory Numbers.

1000 Contacts
100/Horizontal Row
10 Rows, one above the other.

To call No. 315, the Calling Subscriber depressed the "Hundreds" Pushbutton (G') three (3) times, lifting the Shaft and Wiper three (3) notches, and bringing the Wiper opposite the third horizontal row of terminals. He then depressed the "Tens" Pushbutton (H') once, which caused the "Tens" Ratchet and Pawl Assembly to step the Wiper horizontally to Terminal or Contact No. 310. Depressing the "Units" Pushbutton (I') five (5) times forced the Pawl into the 100-tooth Ratchet five (5) times, moving the Wiper to Contact No. 315. The Calling Subscriber next cranked his Magneto, applying Ringing Current to the Called Subscriber Line to signal the Called Subscriber. After the conversation was completed, the Calling Subscriber depressed the Release Pushbutton (P'), energizing the Release Magnets and thereby restoring the Switch Shaft and Wiper to normal.

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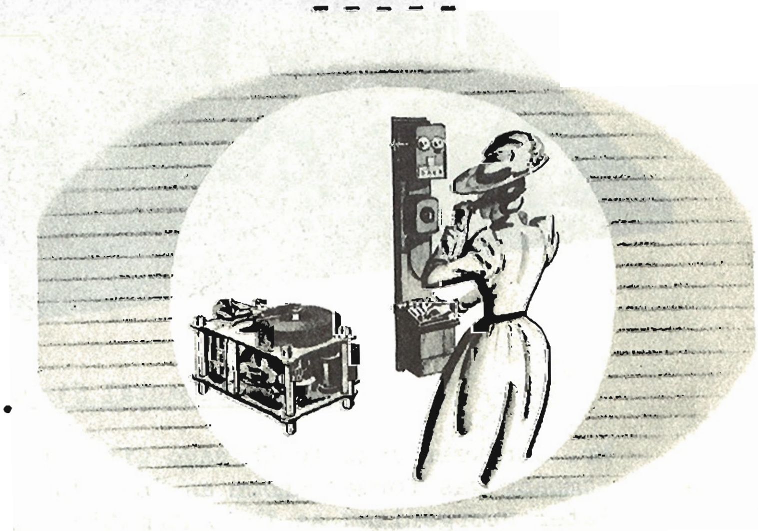
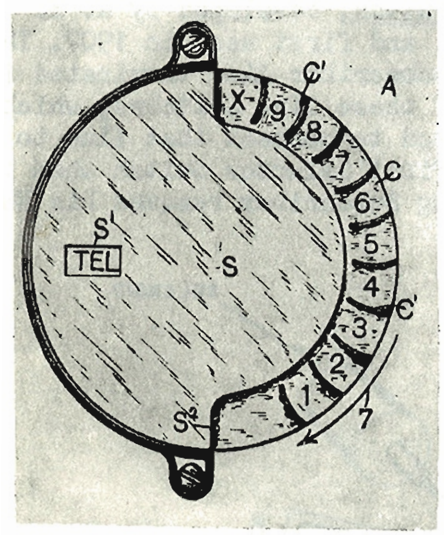
The First Strowger Automatic Telephone Exchange

Installed at La Porte, Indiana.
Cutover November 3, 1892.

5 Line Wires.
Pushbuttons for "Dialing" and Release.
Hand-Cranked Magneto for Ringing.
About 75 Subscribers.
Flat Rubber Disc Type Switch, with Rotary movement only, and one circular Row of Terminals.



The "Finger-Wheel" Dial Replaces the "Pushbuttons"



Finger-Wheel Dial Developed by
Strowger Engineers:
A. E. Keith,
John Erickson,
Charles J. Erickson
Patent #597,062, issued
August 20, 1896.
Finger Slots replaced
by Finger Holes in
Later Subscriber Dials.

Push-Button Dialing resulted in a high percentage of dialing errors and "Wrong Numbers," which made Subscribers very unhappy and unnecessarily wore out the Equipment.

- - - - -

Western Electric Company Meets the Competition by Developing its Own Version of the Dial

Makeup of Dial

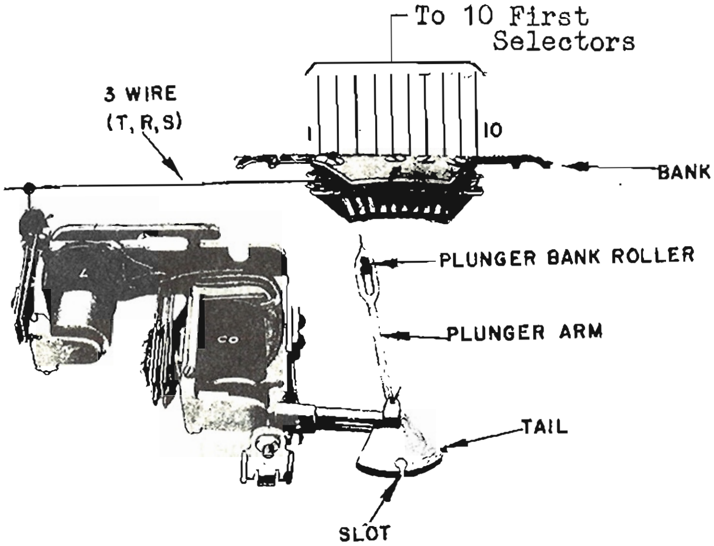
100 Holes drilled in an Iron Ring.
Any one Subscriber in the group of 100 could be selected by a single "pull" of the Dial.
Dialing was done by means of a Spring-Loaded Crank.

To Dial Subscriber #89

Insert the Peg on the end of the Chain in hole No. 89.
Pull the Dial Crank around to rest against the Peg and then release.
As the Dial Crank restores to normal, 89 pulses control the switching equipment in the Central Office to cut through to Subscriber No. 89.
A Pushbutton was furnished for Ringing the Called Station.

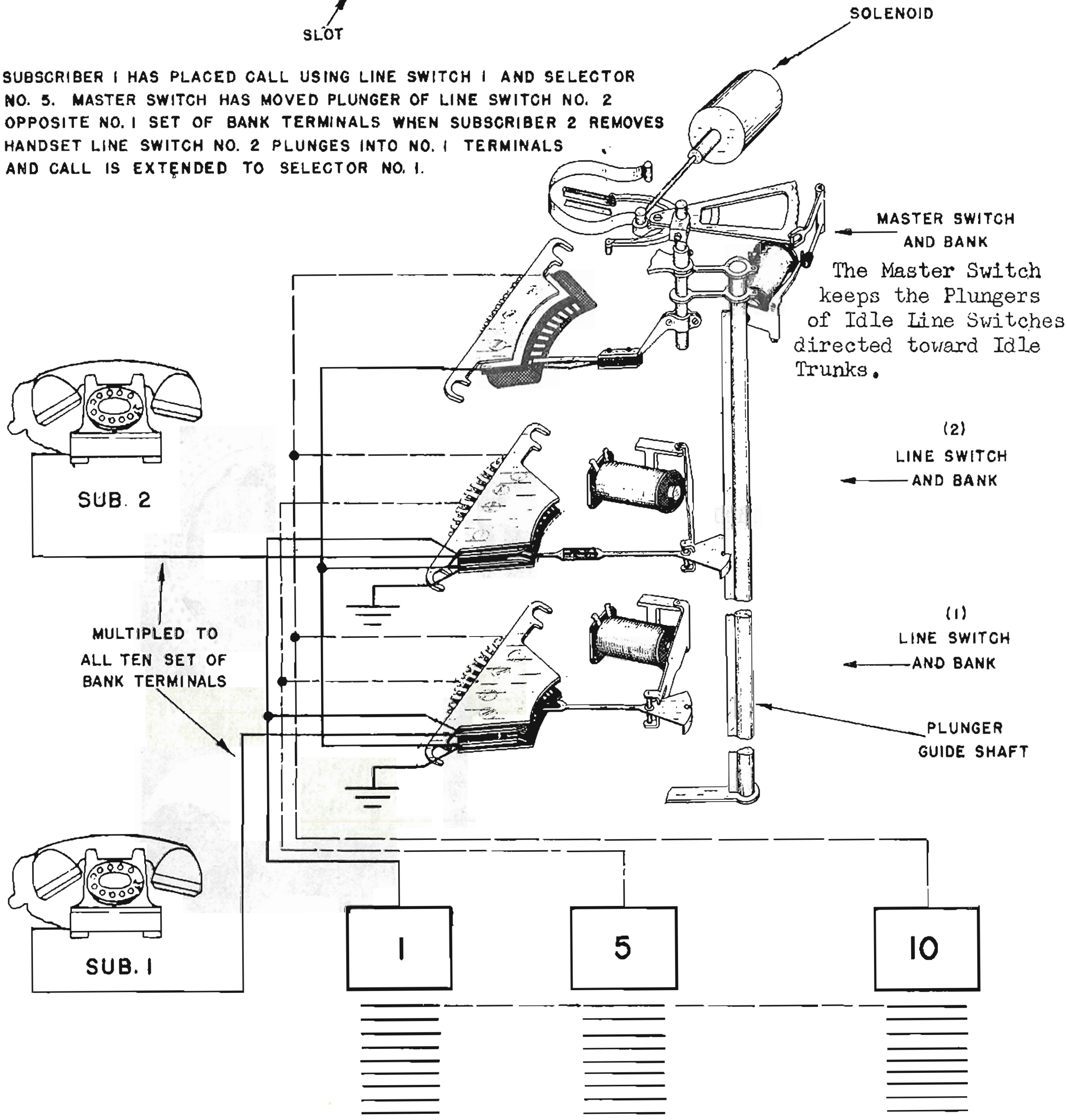
This type of Subscriber Dial was abandoned as the number of Telephone Subscribers increased over 100.

THE KEITH LINE SWITCH - 1907



The expensive Switch used for each Subscriber Line in early Strowger Exchanges was replaced by a smaller and more economical Plunger Type Line Switch, developed by A. E. Keith, and first used in 1907. Thus each Subscriber Line terminated in one of these Line Switches, which operated to connect that Line to an Idle First Selector Switch when the Calling Subscriber removed his Handset.

SUBSCRIBER I HAS PLACED CALL USING LINE SWITCH I AND SELECTOR NO. 5. MASTER SWITCH HAS MOVED PLUNGER OF LINE SWITCH NO. 2 OPPOSITE NO. I SET OF BANK TERMINALS WHEN SUBSCRIBER 2 REMOVES HANDSET LINE SWITCH NO. 2 PLUNGES INTO NO. I TERMINALS AND CALL IS EXTENDED TO SELECTOR NO. I.

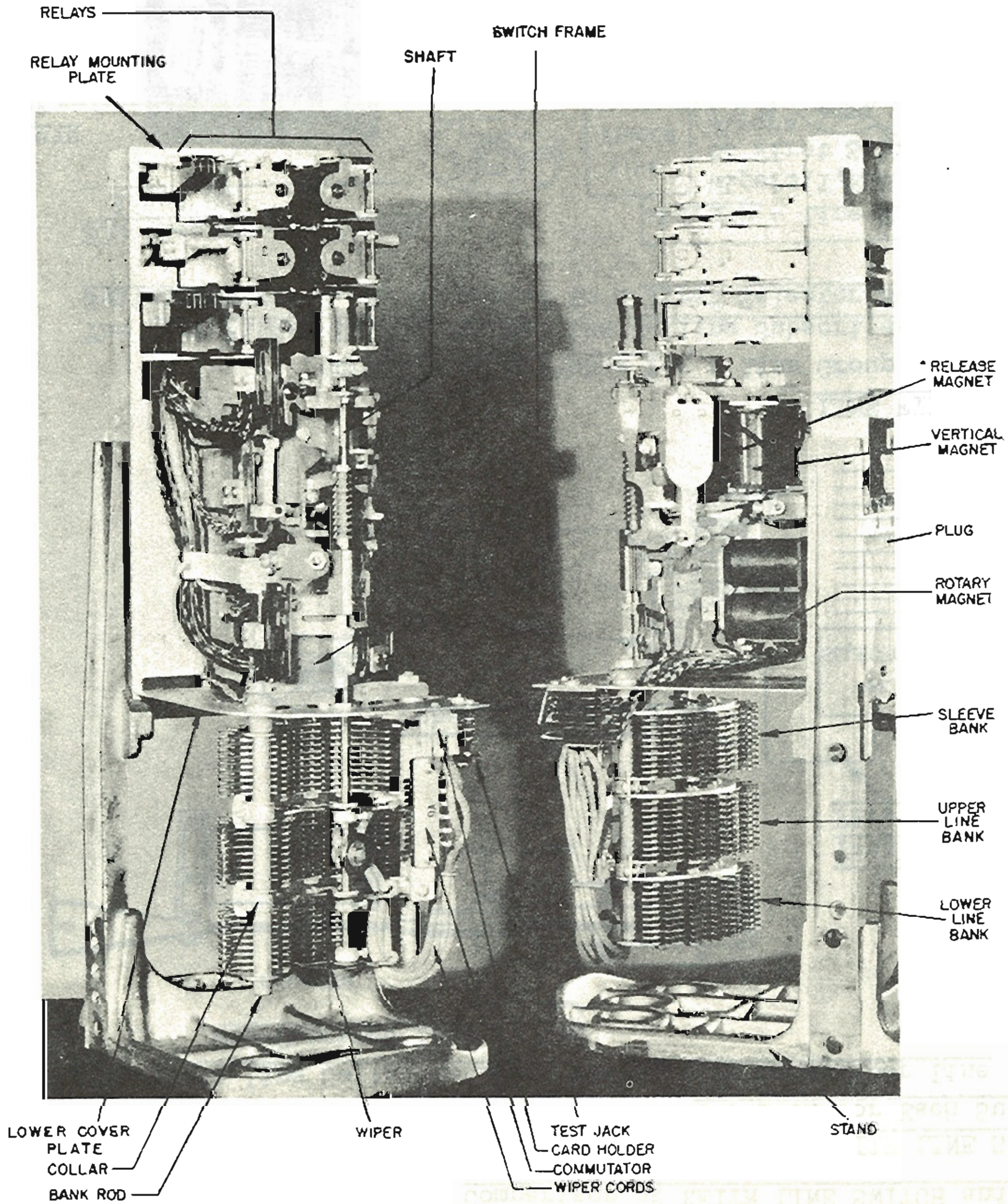


The Master Switch keeps the Plungers of Idle Line Switches directed toward Idle Trunks.

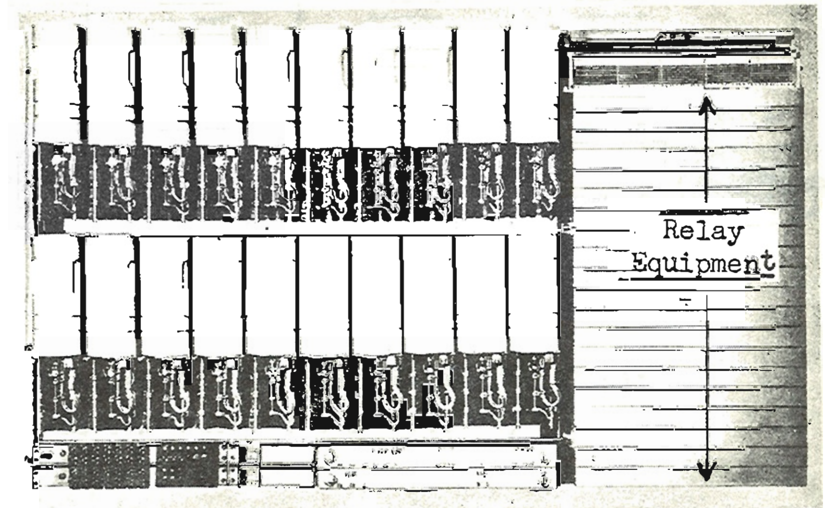
THE LINE FINDER SWITCH - 1927

The Line Finder Switch, serving 200 Lines, was developed, using the standard switch mechanism (the same as used in Selector and Connector Switches), to replace the Keith Line Switch required for each Line.

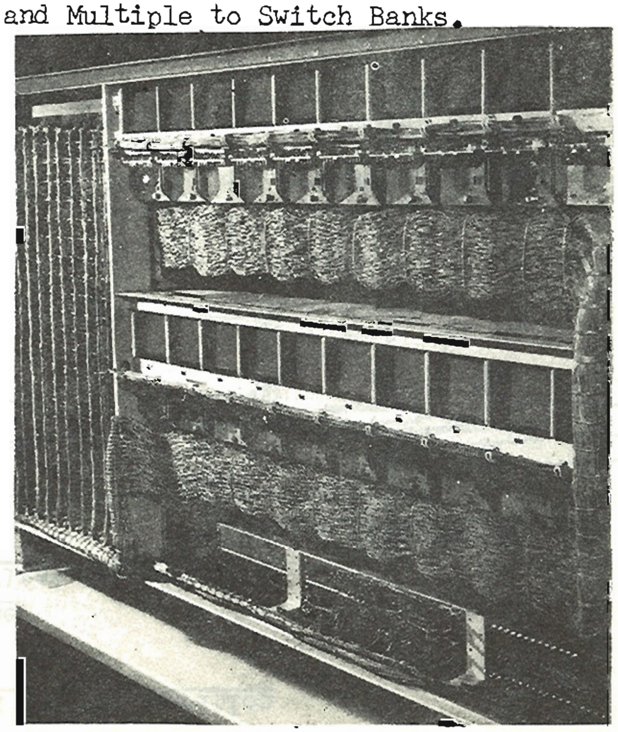
1927 - Line Finder Switches first installed in Brazil, Ind.



A Line Finder Unit, normally 20 Line Finder Switches, serves a Line Group of 200 Lines. Three (3) Units mount one above the other on a Line Finder Frame.



Below - Rear View of Line Finder Unit. Note Local Cable and Multiple to Switch Banks.



Comparison of KEITH LINE SWITCH and LINE FINDER SWITCH Operation

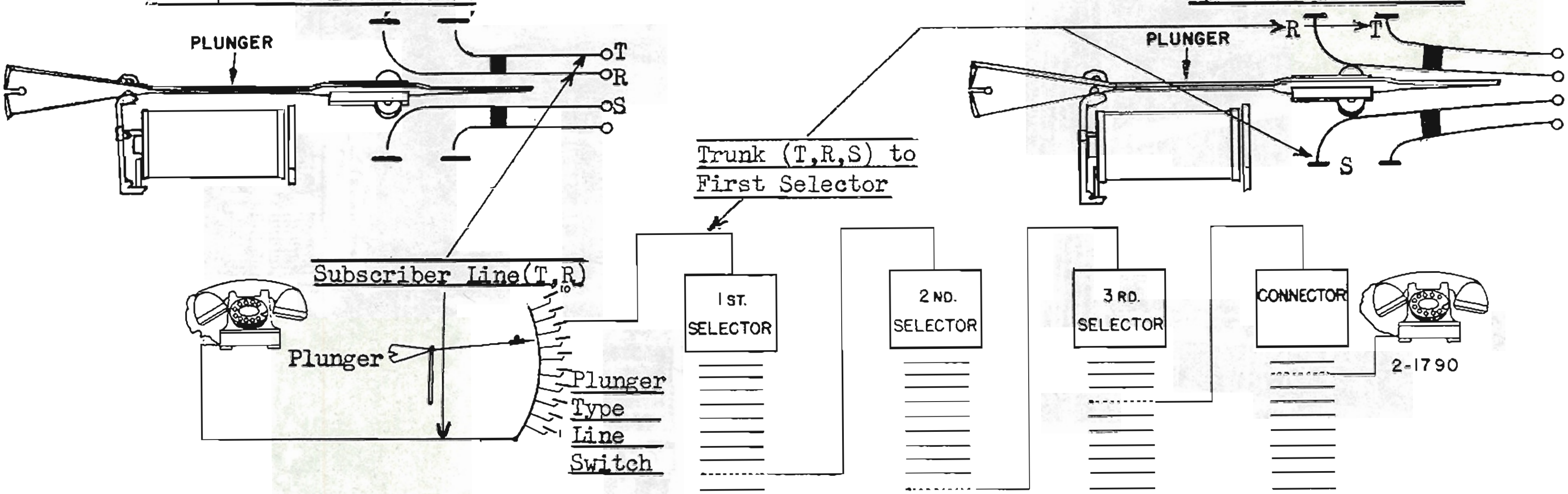
KEITH LINE SWITCH

1 Switch for Each Subscriber Line

The Keith Line Switch connects the Calling Subscriber Line to an Idle First Selector.

Non-Operated Line Switch

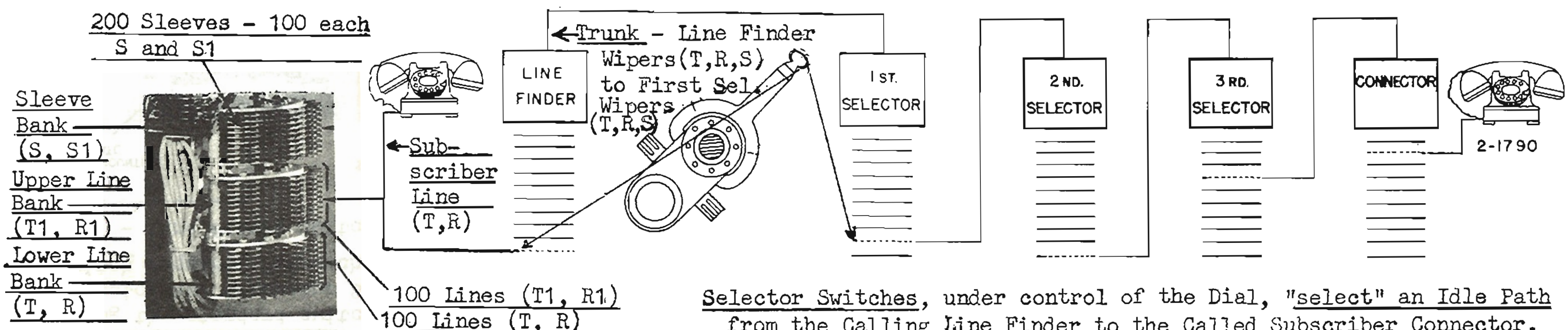
Operated Line Switch



LINE FINDER SWITCH

Normally 20 Switches for a Line Group of 200 Lines (198 Subscriber & 2 Test Lines)

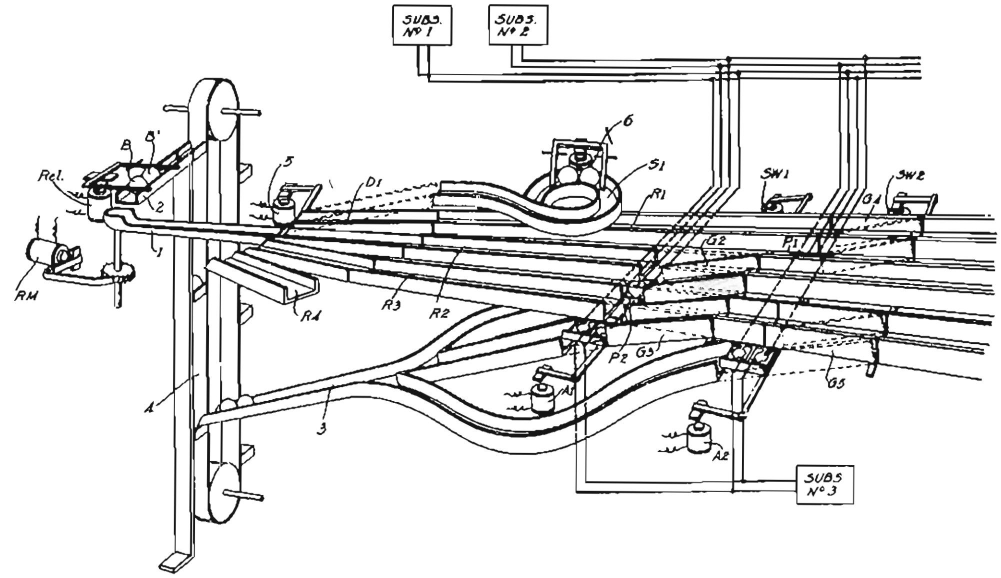
The Line Finder Switch "finds" the Calling Subscriber Line, wired to a set of Line Bank Terminals (T, R). Switch Wipers (T, R, S) cabled to a First Selector Switch.



Selector Switches, under control of the Dial, "select" an Idle Path from the Calling Line Finder to the Called Subscriber Connector. The Connector Switch, under control of the Dial, "finds" the Called Subscriber Line.

THE R. CALLENDER SWITCHING SYSTEM

Patent #511, 874
Issued Jan. 2, 1894
Never Used Commercially
System Capacity - 10 Subscriber Lines

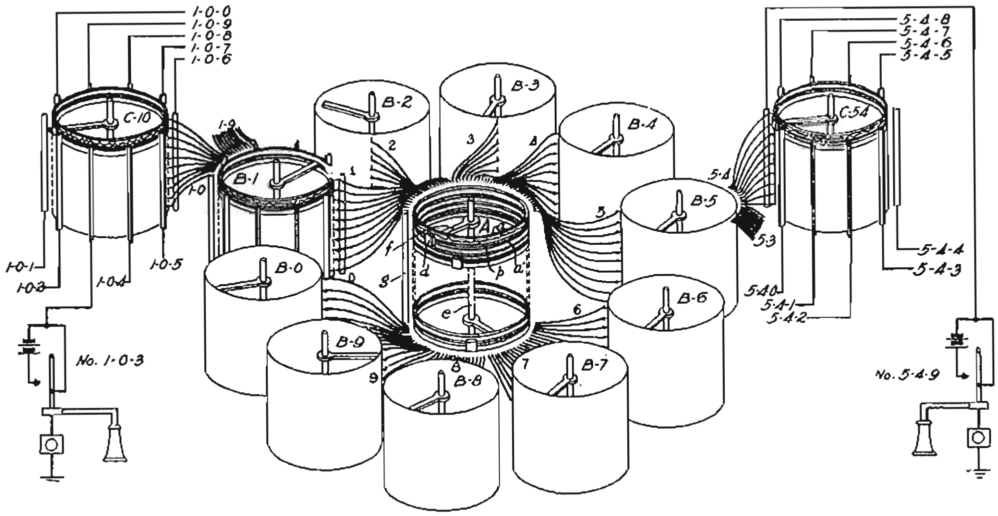


Operation:

1) Subscriber No. 1 wishes to Call Subscriber No. 2. He transmits two (2) impulses to the Central Office.
2) Rotary Magnet RM steps Switch Track 1 into alignment with inclined Runway R2.
3) Switching Magnet SW1 operates to depress Gate G2. The Path is now prepared for the desired connection.
4) Release Magnet Rel operates, releasing two steel balls B and B' from Storage Track 2
5) The two steel balls B and B' roll down Storage Track 2, out onto Switching Track 1, to Runway R2 (See No. 2), to depressed Gate G2 (See No. 3).
6) The two balls B and B' roll down Gate G2 and come to rest on the contacts of Cross-Connecting Plate P2 (Note detail of Cross-Connecting Plate for G5 - two pairs of contact members bridged by the two steel balls.), thereby establishing a Talking Path between the two Subscriber Lines, Nos. 1 and 2.
7) When the Subscribers finish talking, the Calling Subscriber "rings off," operating Magnet A1:
    a) Tilting Contact Plate P2 so that
    b) The two steel balls B and B' drop onto Return Runway R3 and roll down to Elevator Belt 4.
    c) Elevator Belt 4 returns the two balls B and B' to Storage Track 2, ready for establishing other connections.
8) A Storage Track is associated with each Runway R1, R2, etc., onto which the two balls may be deflected (Only Storage Track S1 has been shown.) if the Called Subscriber Line is busy:
    a) If Subscriber No. 1 is busy and another call originates for his line, Deflecting Gate D1, operated by Magnet 5, will deflect the two balls released for the second call to Track S1, where they will be held as long as Subscriber No. 1 Line is busy.
    b) When Subscriber No. 1 Line becomes Idle:
        1') Magnet 6 operates
        2') The two balls released from Track S1 roll out onto Runway R1 to set up the second Talking Path to Subscriber No. 1 Line.

THE J. W. McDONOUGH SWITCHING SYSTEM

Patent #538,975
Issued May 7, 1895
Never Used Commercially
System Capacity - 1,000 Subscriber Lines



System Makeup:

1 Central Switch "A"
10 Group Switches "B"
100 Terminating Switches "C"

Switch Makeup:

10 Pairs of Rings (horizontal) per Switch. One Ring of each pair bears a Phonographic Recording.
1 Contact Carriage per pair of Rings (10 Carriages per Switch) equipped with a Magnet, Levers, Catches and a Phonographic Transmitter. Carriage Contacts slide over outer surfaces of Rings.
1 Shaft per Switch mounted at the switch axis and rotated continuously by an electric motor.
10 Radial Arms per Switch (1 Arm per pair of Rings) to push the Carriage Assemblies around.
100 Gates or Vertical Bars (10 Groups of 10 each) for each "A" and "B" Switch
10 Gates for each "C" Switch
- (Carriage Contacts "make" with the Gates as the Radial Arms push the Carriages around.

Inter-Switch Wiring:

10 Gates of each "A" Switch Group (Total 100 Gates) wired to 10 pairs of Rings on each of the 10 "B" Switches.
10 Gates of each "B" Switch Group (10 Groups per "B" Switch, 10 "B" Switches, Total 1,000 Gates) wired to the 10 pairs of Rings on a "C" Switch (Total 100 "C" Switches.).
10 Gates of each "C" Switch wired to 10 Subscriber Lines (Total 1,000 Subscriber Lines).

Operation:

A) Phonographic announcements inform the Calling Subscriber as to the progress of his call. This arrangement corresponds to the Revertive Pulsing used in the Panel and No. 1 Crossbar Dial Systems.

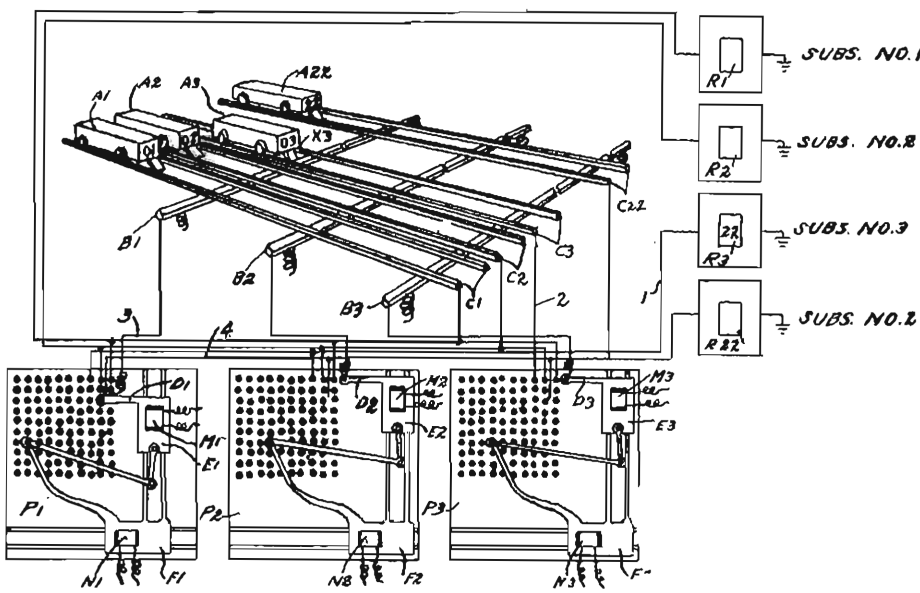
B) Subscriber No. 103 Calls Subscriber No. 549:

1) Subscriber No. 103 removes his Handset and listens to the signals, "101, 102, etc."

2) When the Calling Subscriber hears his own number, "103," he depresses a Pushbutton which stops the Carriage of his "C" Switch, connecting his Line to a pair of Rings on Switch "B1."
3) As the "B1" Switch Carriages rotate, signals "10, 11, 12, etc.," are transmitted.
4) Upon hearing "10," the Calling Subscriber again depresses his Pushbutton, stopping the "B1" Switch Carriages, and connecting his Line to an "A" Switch Gate (Vertical).
5) As the "A" Switch operates, the Subscriber hears the numbers of the Gates past which the Carriages move. Upon hearing "5," he depresses his Pushbutton, stopping Switch "A" Carriages, and cutting his Line through to a "B5" Switch Gate.
6) As Switch "B5" operates, the Calling Subscriber hears, "50, 51, 52, 53, etc.," and upon hearing "54," he again depresses his Pushbutton, causing the "B5" Switch Carriages to stop and cut through to a "C54" Switch Gate.
7) As Switch "C54" operates, the Subscriber hears, "540, 541, 542, 543, etc." When he hears "549," he depresses his Pushbutton once more, stopping Switch "C54" and cutting through to the Called Subscriber Line wired to "C54" Switch Gate No. 549.

THE MOISE FREUDENBERG SWITCHING SYSTEM

Patent #556,007
Issued March 10, 1896
Never Used Commercially
System Capacity - 100 Subscriber Line



A) General System Features: The Central Office Equipment of this system resembles a large railroad terminal freight yard. The cars required to switch the calls would be about the size of those for a 0-gauge tinplate toy electric train.

1) A metal Car or Wagon (A1, A2, A3, etc.), operating on an insulated metal Track, is required for each Subscriber Line.
2) Beneath the Tracks (C1, C2, etc.), and at right angles to them, is a number of metal Beams (B1, B2, B3, etc.).

3) Each Beam (B1, B2, B3, etc.) is wired to the movable Contact Member (D1, D2, D3, etc.) of an "X-Y" Coordinate Plate Switch (P1, P2, etc.).
4) Corresponding stationary Terminals of each Plate Switch are multipled together. A Subscriber Line is wired to each Multiple.
5) Each Plate Switch has an F1 ("X") Carriage driven horizontally along a Track, plus a second E1 ("Y") Carriage, moving at right angles to the first.
6) Contact Member D1 of Plate Switch P1 (also D2, D3, etc. of other Plate Switches) is supported by the E1 Carriage.
7) Links and Magnets M1 (horizontal or "X" drive) and N1 (vertical or "Y" drive) drive D1 over the entire Contact Field of P1 Plate Switch. A visible Register at the Calling Substation records the progress of the D1 Contact Member over the coordinate Contact Field.

B) Operation: Subscriber No. 3 Calls Subscriber No. 22:

1) Car or Wagon A3 is released electrically by the Calling Subscriber, No. 3, to hunt for an Idle B Beam.
2) A Projection X3 on the underside of Wagon A3 hits the first Idle B Beam (B1 in the diagram), and makes an electrical connection with it, swinging the B1 Beam downward, out of reach of any other Subscriber Wagon.
3) Plate Switch P1 is now connected to the Calling Subscriber, No. 3.
4) This initiates the operation of Plate Switch P1. Magnets M1 and N1 sweep the movable Contact Member D1 horizontally and vertically over the Contact Field.
5) The number of each Terminal ("1, 2, 3, 4, 5, etc.") over which the D1 movable Contact Member sweeps is recorded on the Calling Substation Register R3.
6) As soon as the desired Subscriber Number, "22," appears on Register R3, the Calling Subscriber releases a Pushbutton, which stops the D1 movable Contact Member on Terminal No. 22 of Plate Switch P1.
7) The Talking Circuit set up extends from Ground, through Subset No. 3, Wires 1 and 2, Track C3, Projection X3, Beam B1, Wire 3, Contact Member D1, Terminal No. 22 Plate Switch P1, Wire 4, through Subset No. 22 to Ground.

THE WESTERN ELECTRIC ROTARY SWITCHING SYSTEM

Developed About 1905
Dial Pulses Control Selections Indirectly
Used Only In Europe
System Capacity - 10,000 Subscriber Lines

A) Rotary Switching System Features:
1) Power-Driven Equipment - Horizontal and Vertical Driveshafts provide power for operating the Switches - A 2 H.P. Electric Motor is required for a 10,000-Line installation.
2) Switches have Rotary Motion only.
3) Switch Banks (To which Lines or Trunks are cabled) - Semi-Circular in shape - 200 Sets of Terminals, 20 Sets per Level, 10 Levels.
4) 10 Sets of Brushes per Switch - Only 1-Set "tripped" to "wipe" over the Terminals of 1-Level.
5) Selections controlled by Register Switches, positioned by pulses received from the Subscriber Dial. As the Selector or Final Brushes "wipe" over one Terminal after another, a Pulse is sent back (Revertive Pulsing) to the Register Switch for each Terminal contacted. When the Register Switch reaches normal, the Circuit is opened and the Brushes stop on the last set of Terminals.

6) Switches Used:

a) Line Switch - "Finds" the Calling Subscriber Line.

b) Selector Switch - Finds an Idle Trunk, under control of the Register Switch, from the Line Switch to the Final Switch serving the Called Subscriber Line.

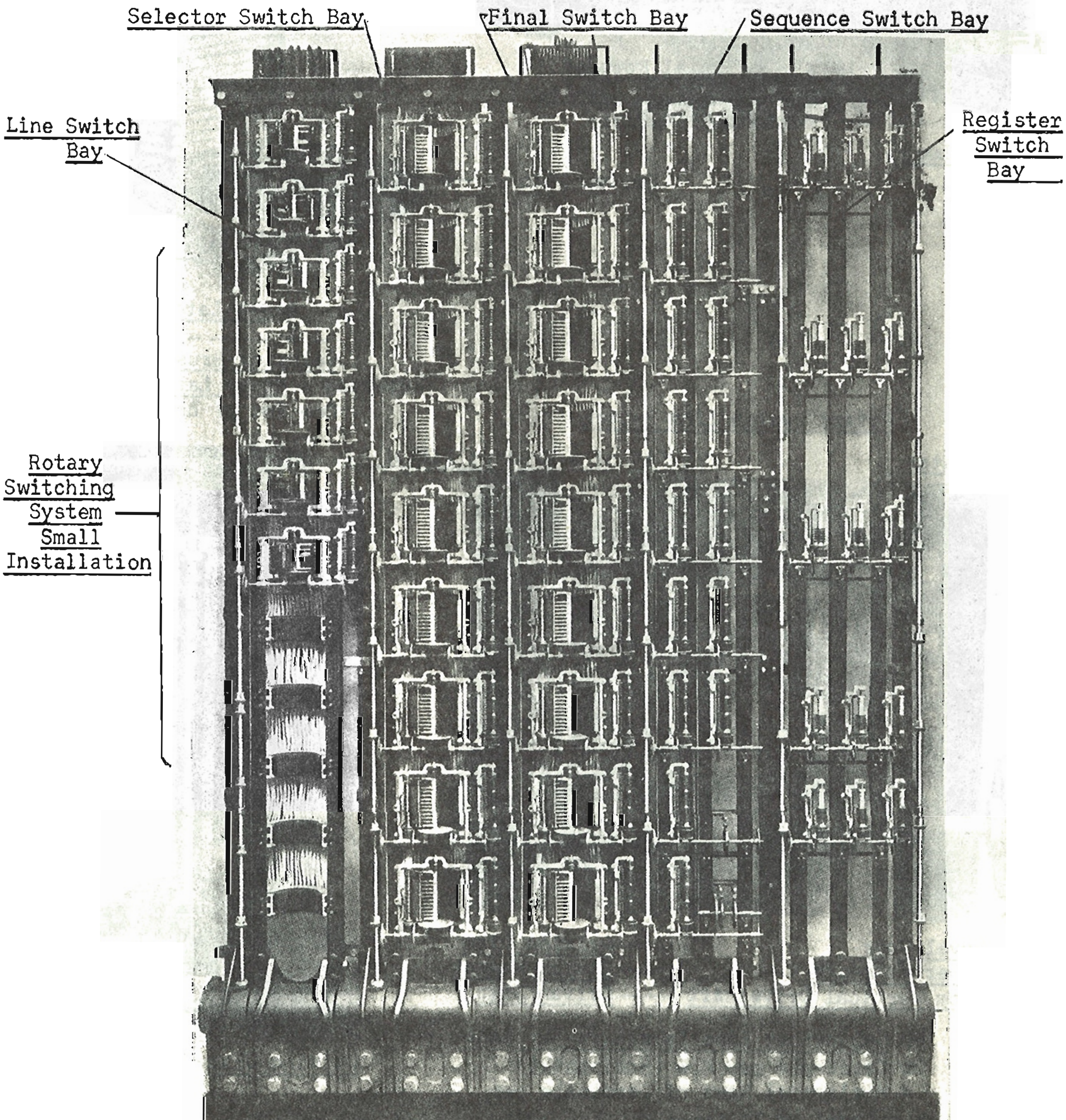
c) Final Switch - Under control of the Register Switch, finds the Called Subscriber Line.

d) Register Switch:

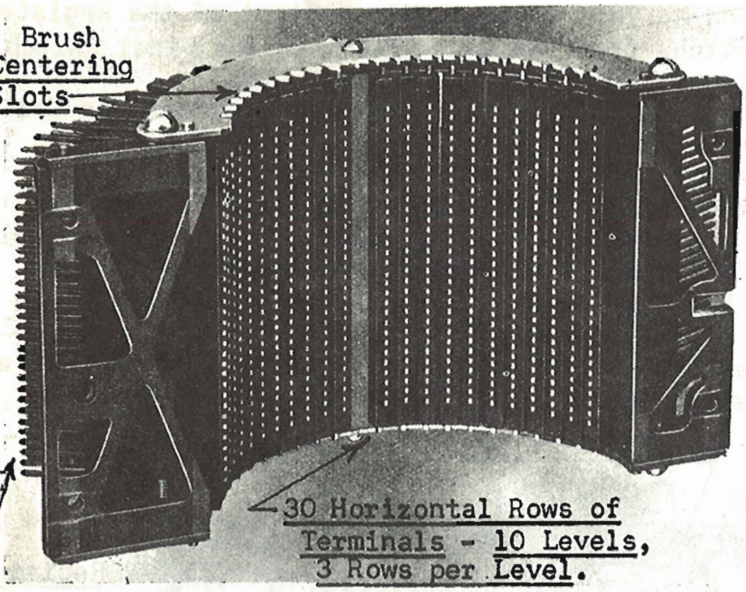
1') Stores the Digits dialed by the Calling Subscriber.

2') "Translates" or Converts the Dial Pulses received on a Decimal Basis (1-out-of-10) to a series of Pulses necessary to make Selections on the basis of 1 out of 20 (20 Sets of Terminals per Level).

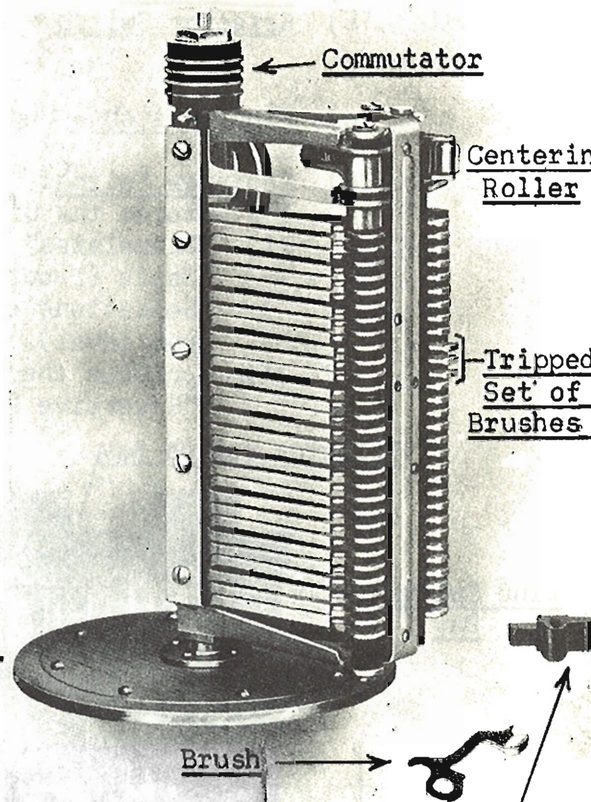
3') Controls the operation of the Selector and Final Switches on a "Revertive Pulsing" basis.



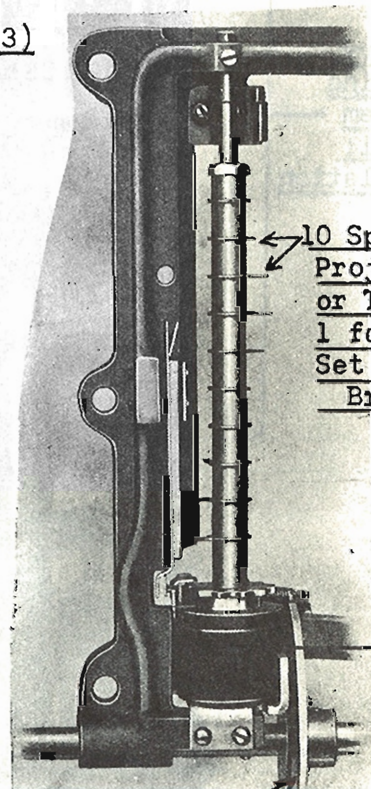
Rotary System Selector Bank



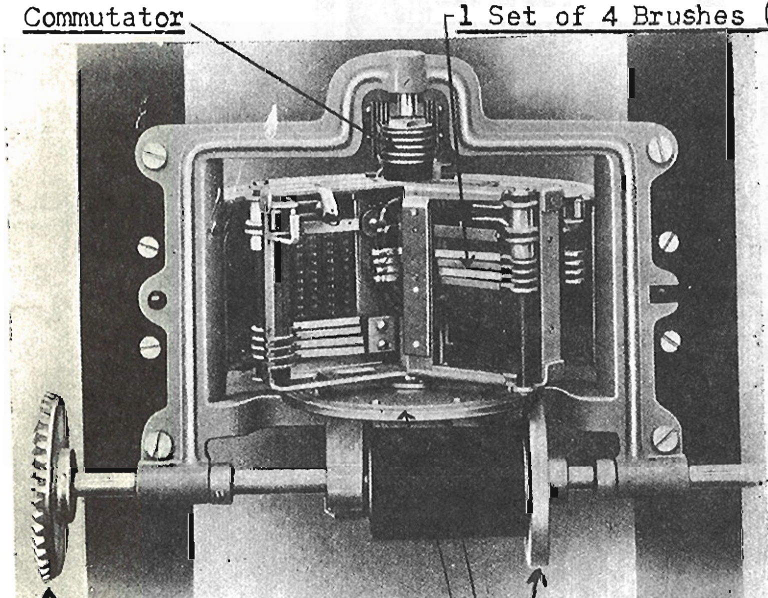
Rotary System
Selector Brush Carriage and Brush



Selector Brush Chooser
Releases a Brush Latch, "Tripping" One Set of Brushes.



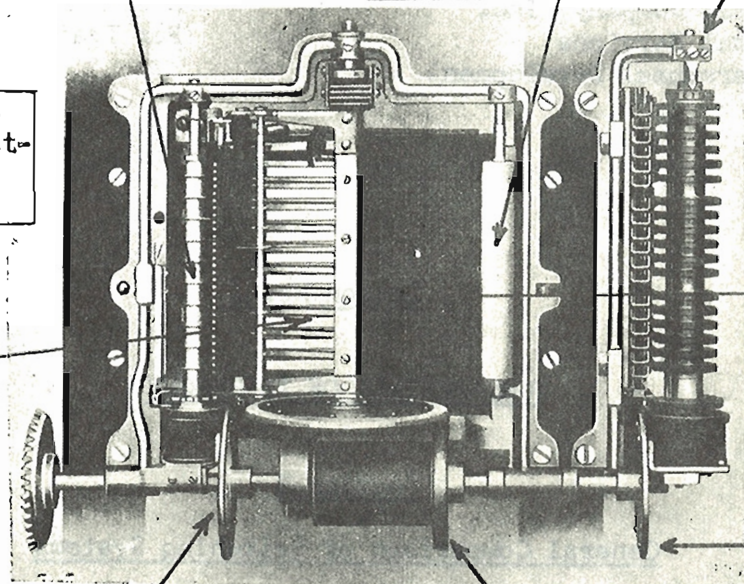
Rotary System Line Switch



60 Subscriber Line Terminals per Bank
20 Terminals per Row (Horizontal)
4 Horizontal Rows of Terminals per Level of 20 Lines.

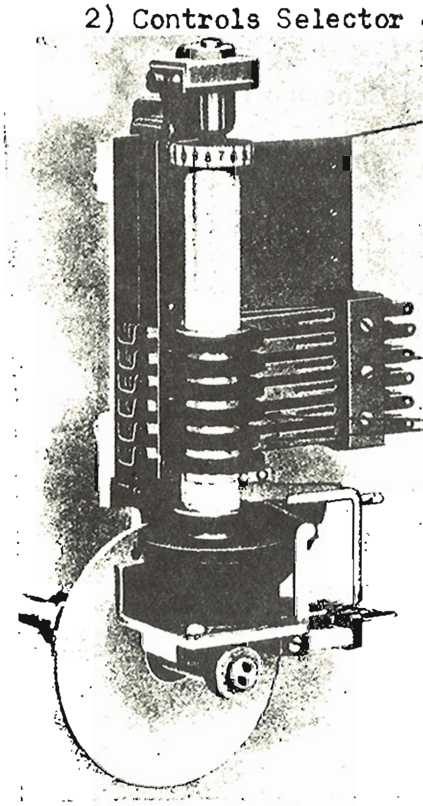
The Rotary System SELECTOR SWITCH

The Final Switch is similar in construction to the Selector Switch.



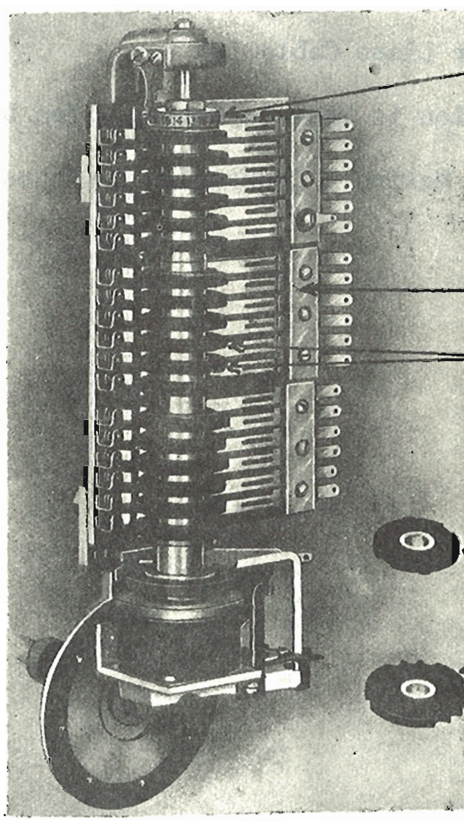
Register Switch

1) Registers Dialed Digits.
2) Controls Selector & Final Switch Operation.



The Register controls Selector and Final Switch operation (On a Revertive Pulse basis) as it restores to normal, after being advanced by Dial Pulses to the position representing the Digit Dialed.

Sequence Switch
(Power-Driven Relay)



As the Sequence Switch rotates only in one direction, it always opens and closes the circuits wired to its contacts in the same order or "sequence."

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FUNDAMENTALS OF TELEPHONY

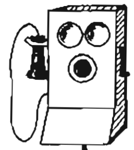
Section 3

General Comparison of Switching Systems

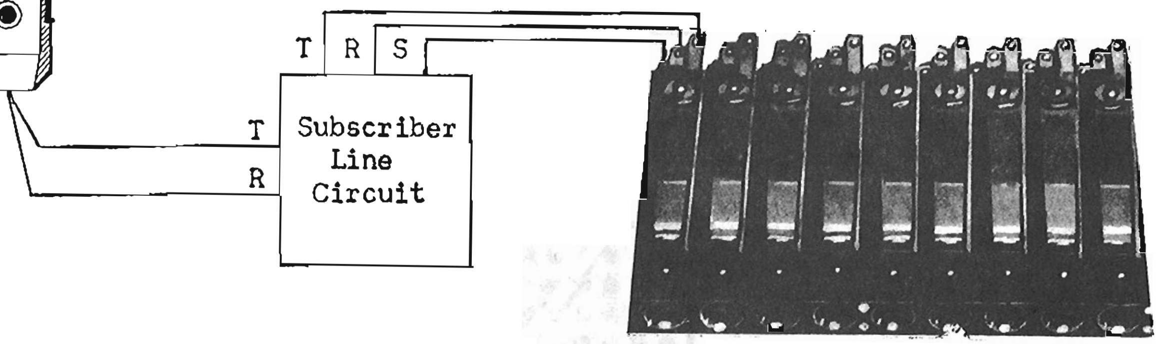
CONTENTS

GENERAL COMPARISON OF SWITCHING SYSTEMS

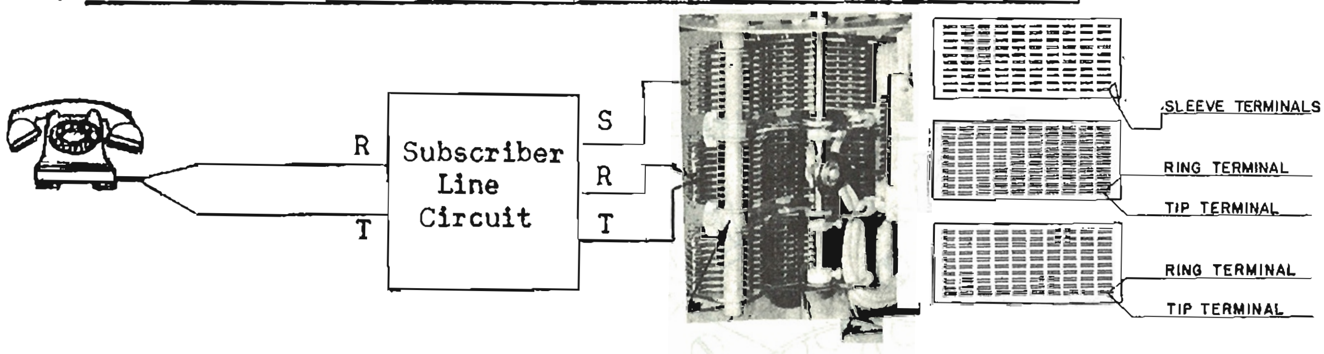
A) Subscriber Lines Cable to:



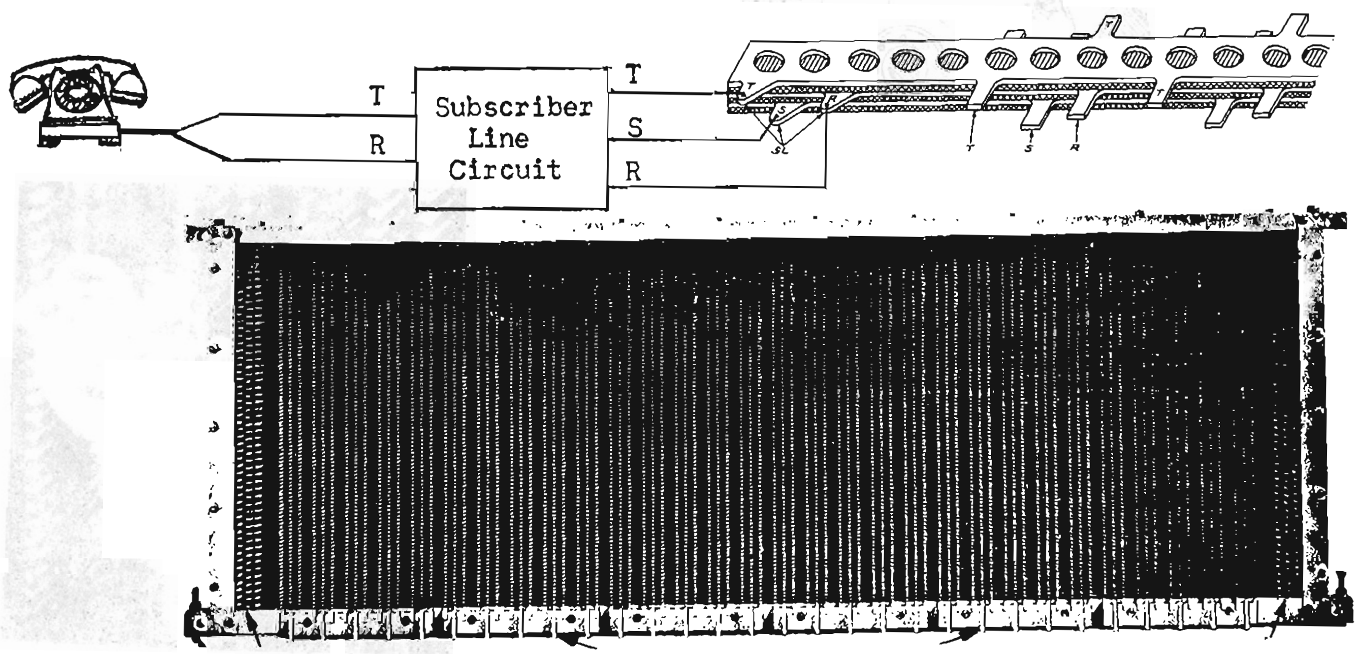
1) JACKS in the MANUAL System



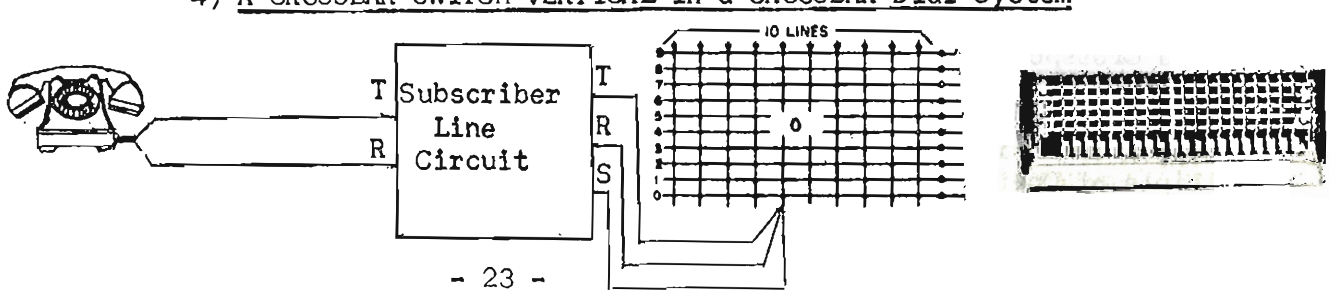
2) A SET OF SWITCH BANK TERMINALS in the STEP BY STEP Dial System



3) A SET OF MULTIPLE BANK STRIPS in the PANEL Dial System

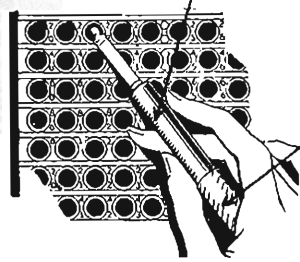


4) A CROSSBAR SWITCH VERTICAL in a CROSSBAR Dial System

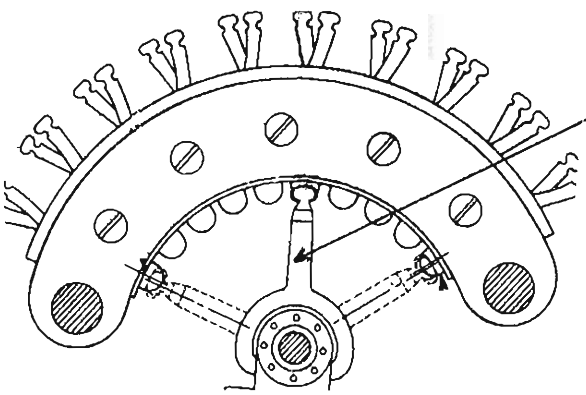


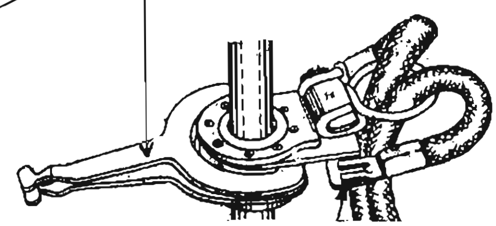
B) A CONNECTION is MADE in a:

1) MANUAL System - By a PLUG on the end of a CORD.

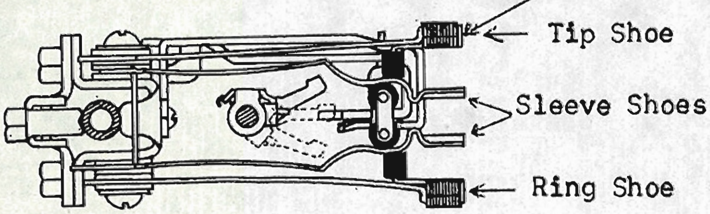


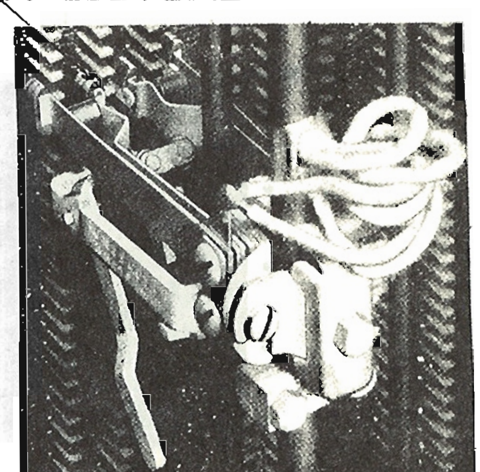
2) STEP BY STEP Dial System - By the SWITCH WIPERS.





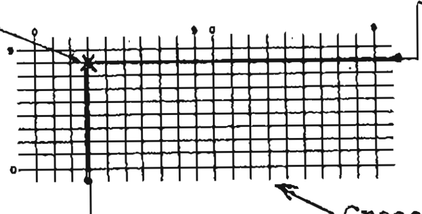
3) PANEL Dial System - By the MULTIPLE BRUSH SHOES.



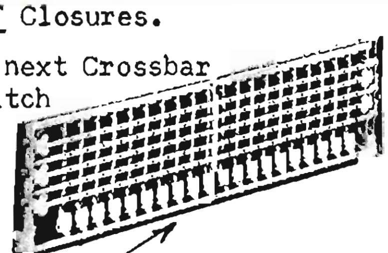


4) CROSSBAR Dial System - By CROSSPOINT Closures.

Closed Crosspoint
(T, R, S) Vertical
Multiple Stationary
Contacts to Horizontal
Multiple of Operate
Springs.



To next Crossbar
Switch

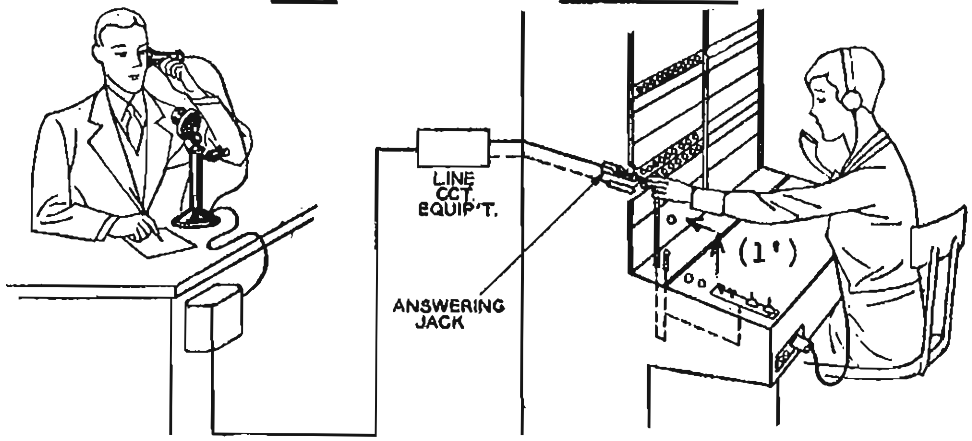


Sub. Line—(T, R, S)

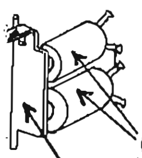
Crossbar Switch

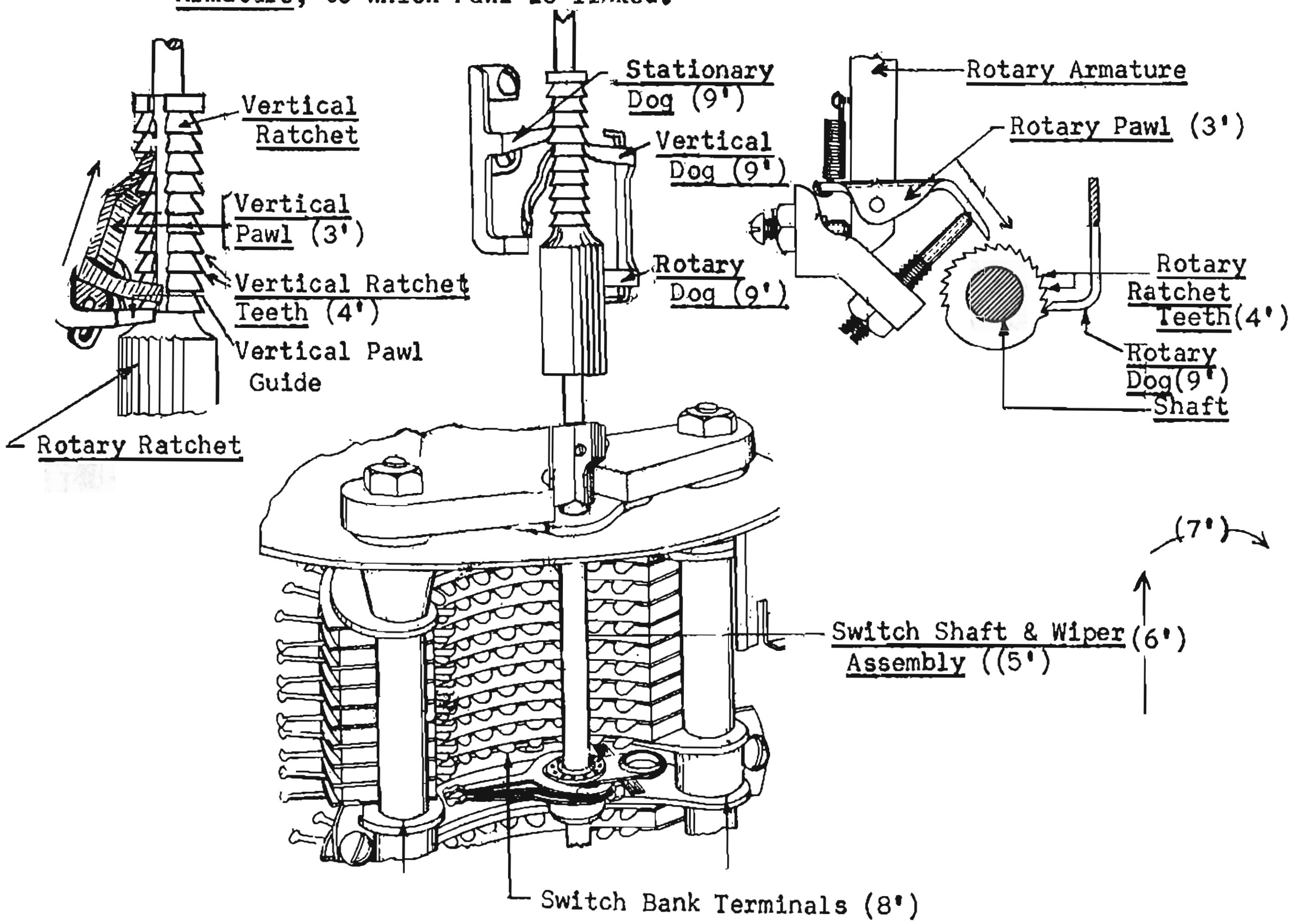
C) Method of MAKING A CONNECTION in a:

1) MANUAL System - The Operator picks up an Idle Cord and inserts the Plug of that Cord into a Jack.



2) STEP BY STEP Dial System - The Operator's Hand and Arm Movements (1') are replaced by a Stepping Magnet (2') thrusting a Pawl (3') into a Ratchet Tooth (4'), stepping the Shaft and Wipers (5'), first Vertically (6'), then Horizontally (7') or in a Rotary Direction to the desired Set of Switch Bank Terminals (8'). Each Step is held by a Dog (9').





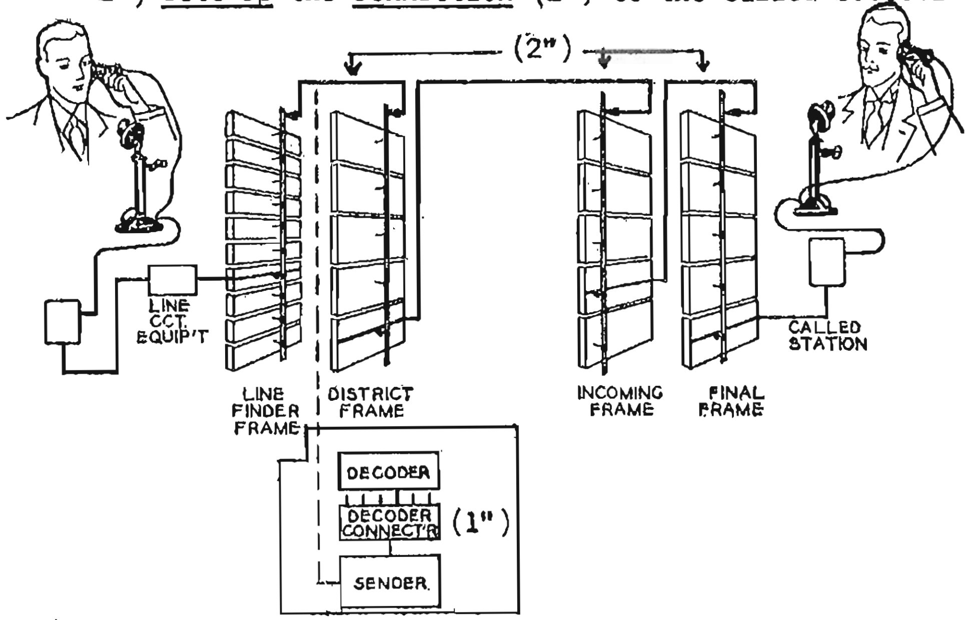
C) Method of MAKING A CONNECTION in a:

3) PANEL Dial System:

A') The Common Control Equipment (1"), which replaces the Manual Operator:

1') Registers the Digits Dialed, and

2') Sets Up the Connection (2") to the Called Subscriber Line.



B') The Operator's Hand and Arm Movements are replaced by:

1') An Electrically-Operated Clutch (3"), which

2') Forces a Rack (4") against a Rotating Cork Roll (5").

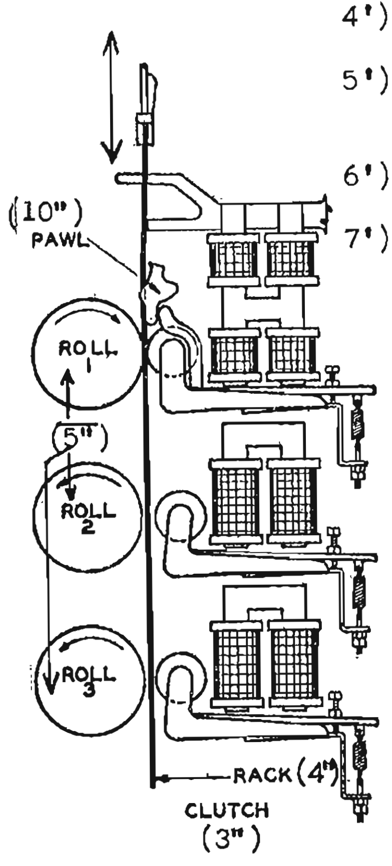
3') Friction drives the Multiple Brush Rod (6") Vertically.

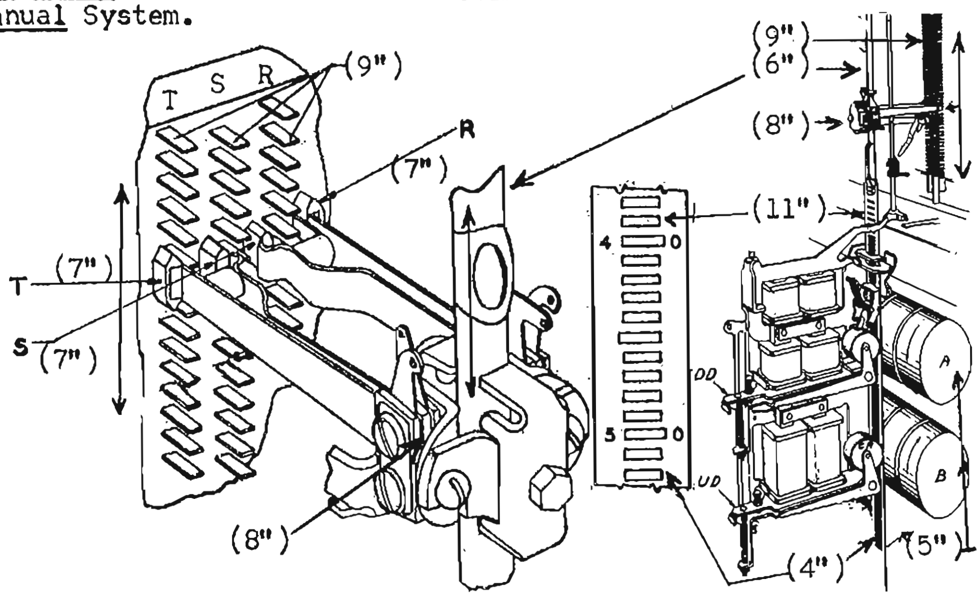
4') The Shoes (7") of a "Tripped" Multiple Brush (8") "wipe" over Multiple Bank Terminals (9").

5') The Clutch is released by the Common Control Equipment when the Multiple Brush Shoes make contact with the desired Set of Multiple Bank Terminals.

6') A Pawl (10") drops into a Rack Slot (11") to hold the Multiple Brush Rod in position.

7') The Multiple Brush Shoes in contact with the Multiple Bank Terminals correspond to the Plug inserted in a Jack of the Manual System.





GENERAL COMPARISON OF SWITCHING SYSTEMS

C) Method of MAKING A CONNECTION in a:

4) CROSSBAR Dial System (Method of Switching a No. 1 Crossbar Call shown below.):

A') SWITCHING FRAMES, on which the Talking Path is built up, replace the Manual SWITCHBOARDS.

B') COMMON CONTROL FRAMES, which replace the Manual OPERATORS:

1') Register the Digits Dialed.

2') Set up a Talking Path (1") to the Called Subscriber Line. Only Line Link and District Link Frames shown below.

C') In Handling a Call, the COMMON CONTROL EQUIPMENT:

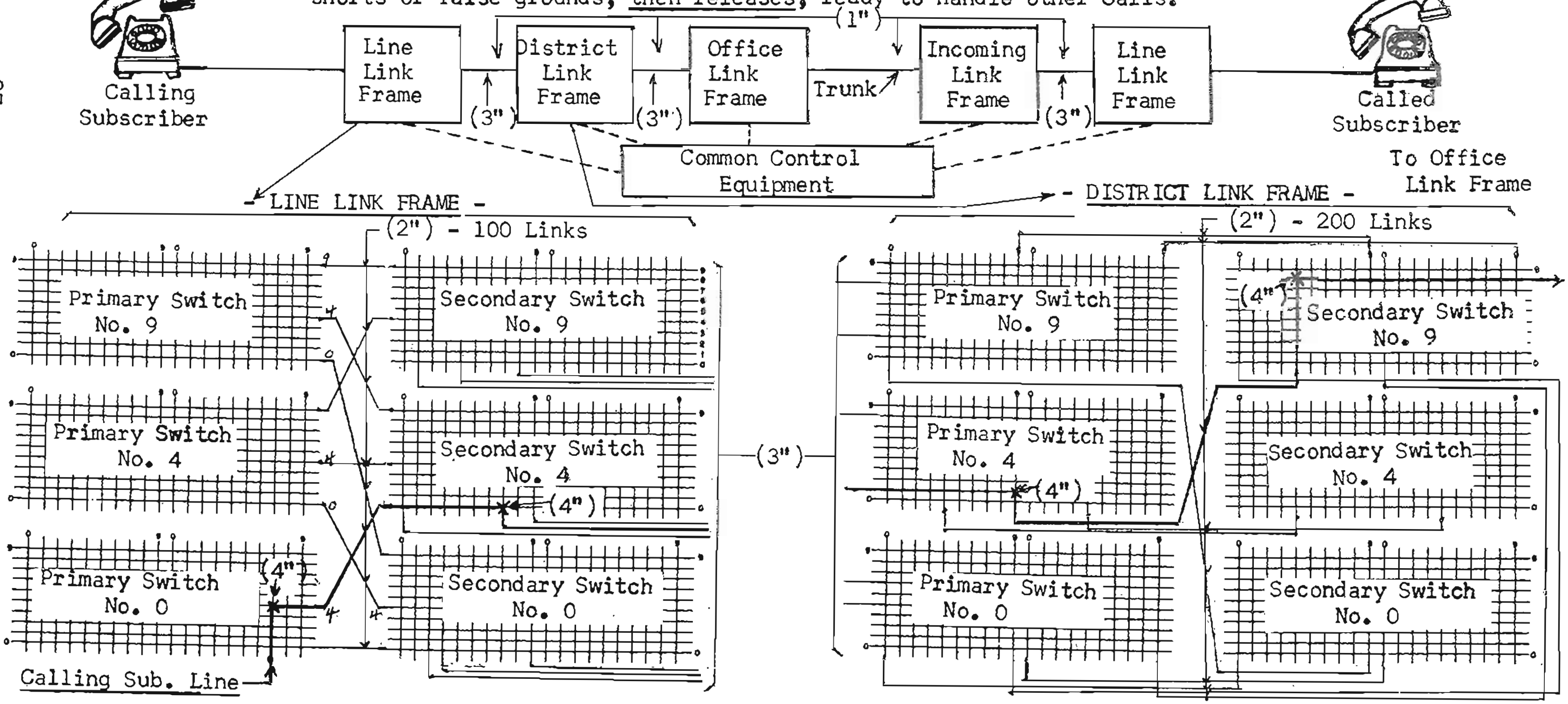
1') Selects an Idle combination of Paths through the various Switching Frames.

a') A Path between two Crossbar Switches on the same Frame is a LINK (2").

b') A Path between two Crossbar Switches on different Frames is a JUNCTOR (3").

2') Closes the necessary Crossbar Switch CROSSPOINTS (4") on the various Switching Frames to cut through a Talking Path between the Calling and Called Subscribers.

3') Checks the continuity of the established Talking Path to insure there are no opens, shorts or false grounds, then releases, ready to handle other Calls.



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FUNDAMENTALS OF TELEPHONY

Section 4

Subscriber Station Equipment

CONTENTS

SUBSCRIBER STATION EQUIPMENT

Subscriber Station or "Substation" - A Subset (Subscriber Set) installed and in service for telephone communication.

Substation Equipment - 1) Subscriber Set or "Subset" - An instrument designed for originating and receiving Telephone Calls.

2) Substation Protector - Mounts:

a) Protector Blocks (Lightning Arresters) - High voltage protection.

b) Fuses (7 Ampere, Tubular) or Lead Spacers - Excess current protection.

1) SUBSET

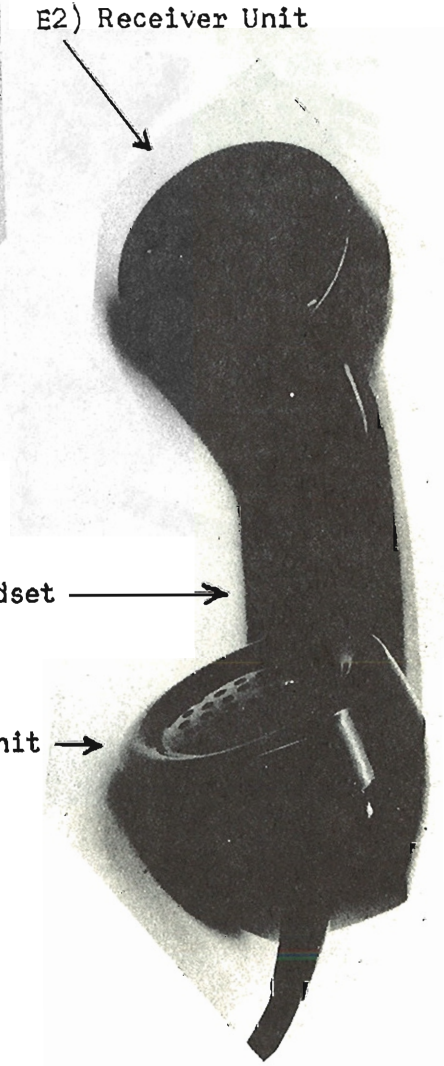
500-TYPE SUBSET
Front View

1) SUBSET

Ringer Volume Adjustment

500-TYPE SUBSET
Bottom View

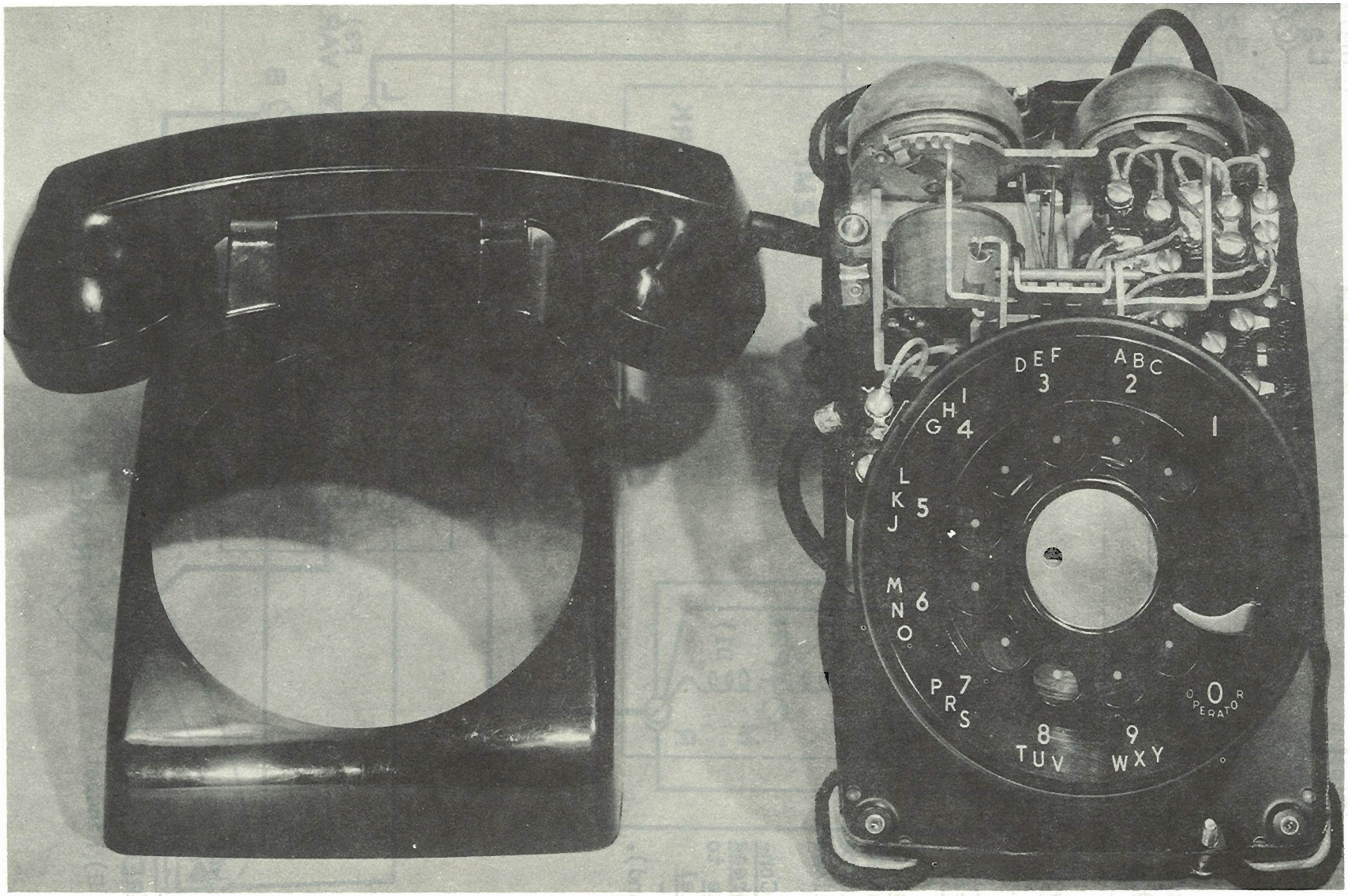
E2) Receiver Unit



E) 12-Oz. Handset

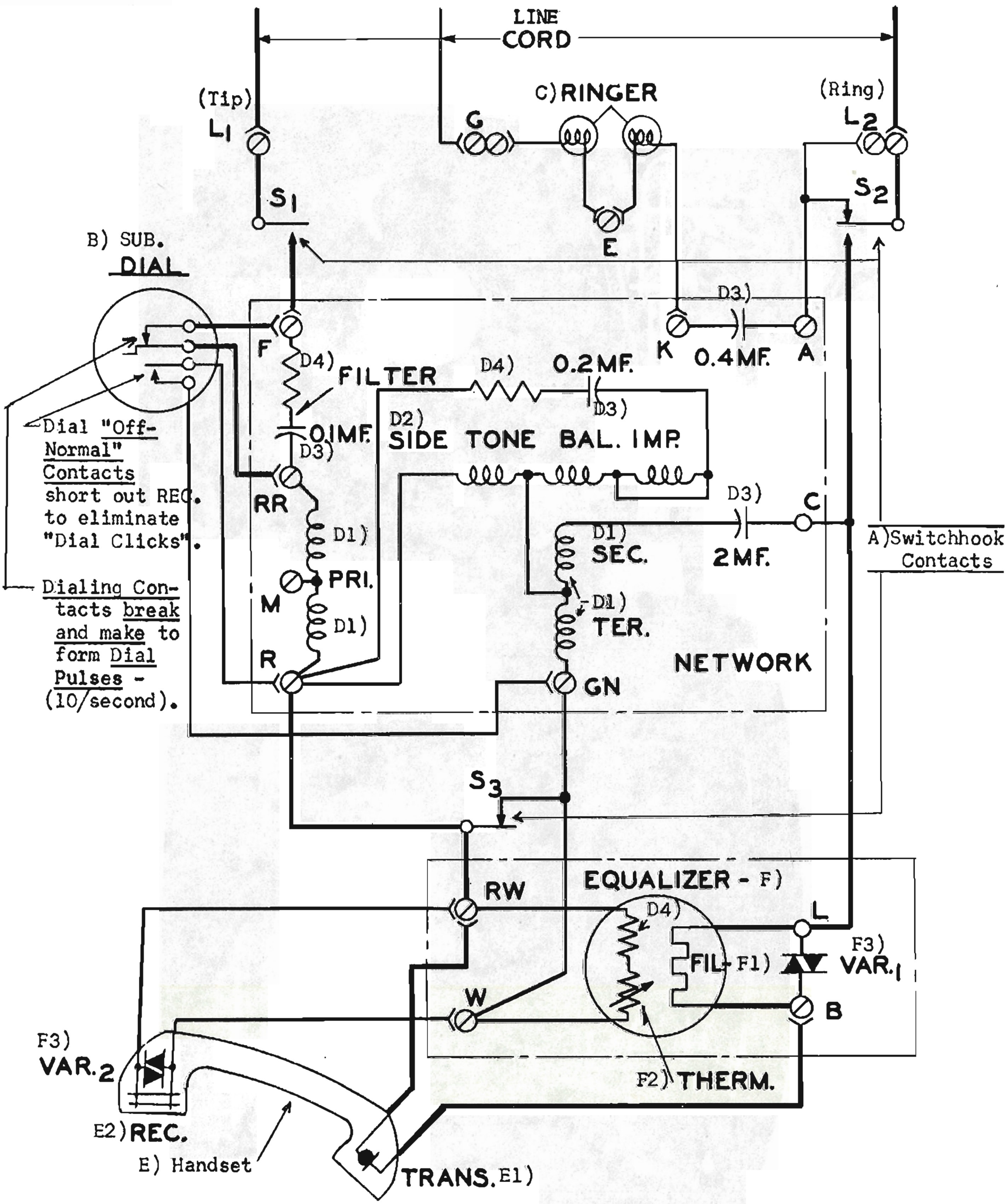
E1) Transmitter Unit

1) SUBSET



500-TYPE SUBSET
With Housing Removed

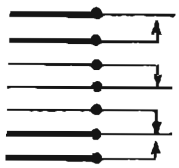
1) SUBSET



LINE CORD
(Tip)
L1
C) RINGER
(Ring)
L2
G
S1
S2
E
B) SUB. DIAL
D3)
F
D4)
FILTER
D4)
0.2MF
K
0.4MF
A
D3)
0.1MF
D3)
D2)
SIDE TONE BAL. IMP.
RR
D3)
C
D1)
D1)
SEC.
2MF.
A) Switchhook Contacts
Dial "Off-Normal" Contacts short out REC. to eliminate "Dial Clicks".
M
PRI.
D1)
TER.
D1)
Dialing Contacts break and make to form Dial Pulses - (10/second).
R
NETWORK
GN
S3
RW
EQUALIZER - F)
D4)
L
F3)
FIL - F1)
VAR.1
W
B
F3)
VAR.2
F2) THERM.
E2) REC.
E) Handset
TRANS. E1)

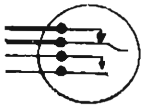
1) SUBSET - COMPONENTS

("A," "D2," "F3," etc., refer to Photo and Schematic on preceding pages.)

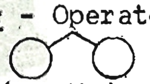


A) Switchhook - 1) Turns ON the Subset when the Subscriber removes the Handset from the Cradle.
2) Turns OFF the Subset when the Subscriber replaces Handset in the Cradle.

B) Subscriber Dial - Opens ("breaks") and closes ("makes") the Subscriber Loop (Line) to the Central Office 10 or more times per second to direct the Switching Equipment in setting up a Call. An apparatus blank mounts in place of the Subscriber Dial for Manual Service.

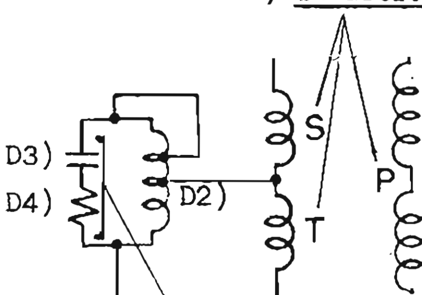


C) Ringer - Operated by 20-Cycle A-C Ringing Current from the Central Office Ringing Machine to signal the Called Subscriber.



D) Network - Made up of:

D1) Induction Coil - A Telephone Transformer to strengthen the voice currents.



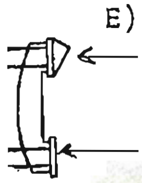
D2) Sidetone Balance Coil - Maintains a constant balance (flat response) over the voice-frequency range.
Sidetone - The reproduction by the Receiver of voice sounds and room noises actuating the Transmitter of the same Subset.

D3) Capacitors - A Capacitor is a device (two conductors separated by a Dielectric or insulator) which blocks d.c. (such as Talking Battery Supply), but transmits a.c. (20-Cycle Ringing Current).

D4) Resistors - A Resistor is a device for controlling the rate of current flow in a circuit

D5) Filter - A 50-Ohm Resistor in series with a 0.1 mf. Capacitor and the Induction Coil Windings to suppress radio receiver interference resulting from "breaks" and "makes" of the Dialing Contacts.

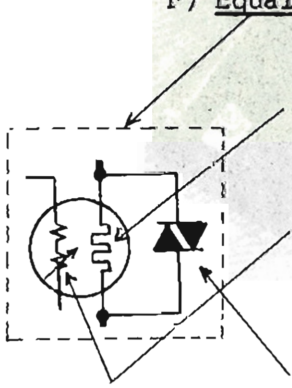
E) Handset - Includes the Transmitter and Receiver Units:



E1) Transmitter - A device which converts the mechanical energy (air pressure variations) of sound waves into electrical energy (varying electrical current - Talking Current.).

E2) Receiver - A device which converts electrical energy into the mechanical energy of reproduced sound waves.

F) Equalizer - A device for controlling reproduced voice volume or level, with variations in Subscriber Loop length, and with different Talking Battery Supplies.



F1) Ballast Lamp - A Current Regulator with a tungsten Filament, connected in series with the Transmitter Unit. The Filament resistance increases rapidly as temperature rises, to maintain a constant current.

F2) A Thermistor - A temperature-sensitive Resistor bridged around (shunting) the Receiver Unit, and connected in series with a loss-limiting Resistor. The Thermistor is heated by the Ballast Lamp Filament to introduce loss automatically, thereby avoiding excessive voice level on short Subscriber Loops.

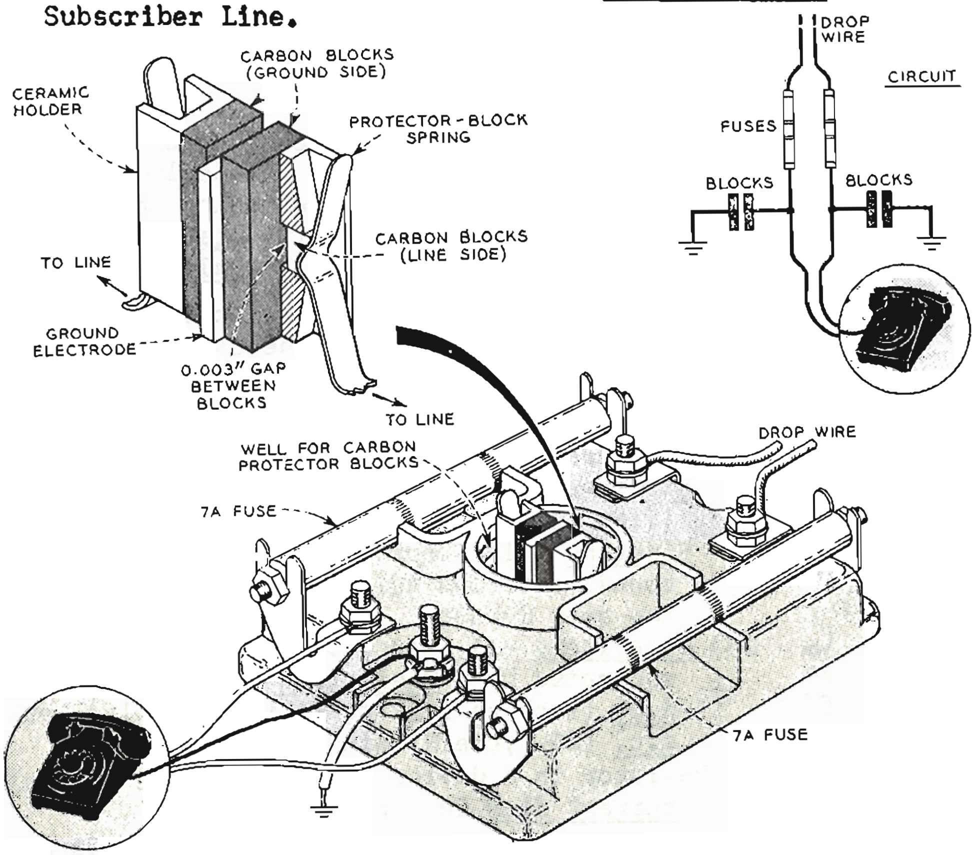
F3) A Varistor - A variable Resistor (Resistance decreases as impressed Voltage increases), shunting the Ballast Filament to limit current flow through it.

2) SUBSTATION PROTECTOR

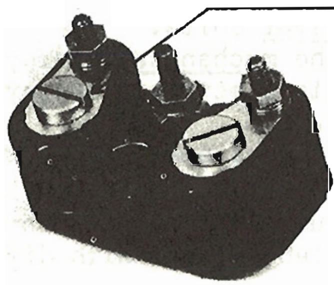
The Substation Protector is made up of:

a) Protector Block Assembly (Lightning Arresters) -- One per Subscriber Line Wire - Operated by high-voltage on Subscriber Line.

b) Fuse - 7-Ampere Cartridge Type; Lead Alloy Spacers on 111A - One per Subscriber Line Wire - Operated by excess current flow through the Subscriber Line.

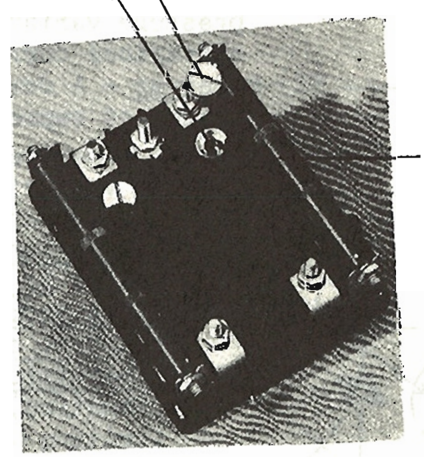


98A SUBSTATION PROTECTOR



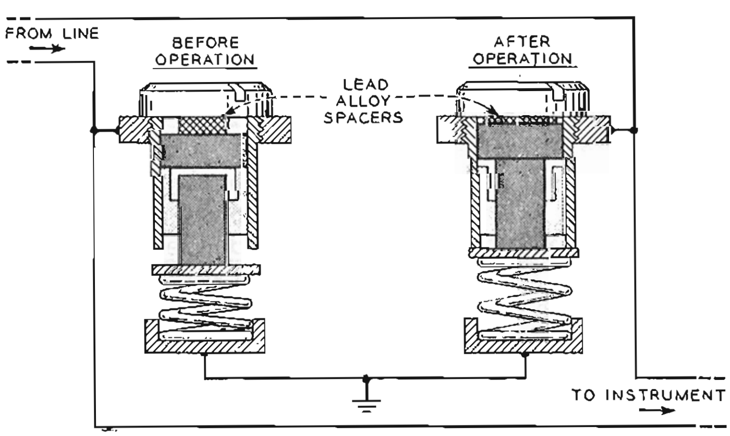
Mounted in Well
(Under Spring Tension) Well
Protector Blocks
Carbon Disc.
Carbon Rod in Porcelain Tube.

Cap Screw



Fuse

111A SUBSTATION PROTECTOR



106A SUBSTATION PROTECTOR

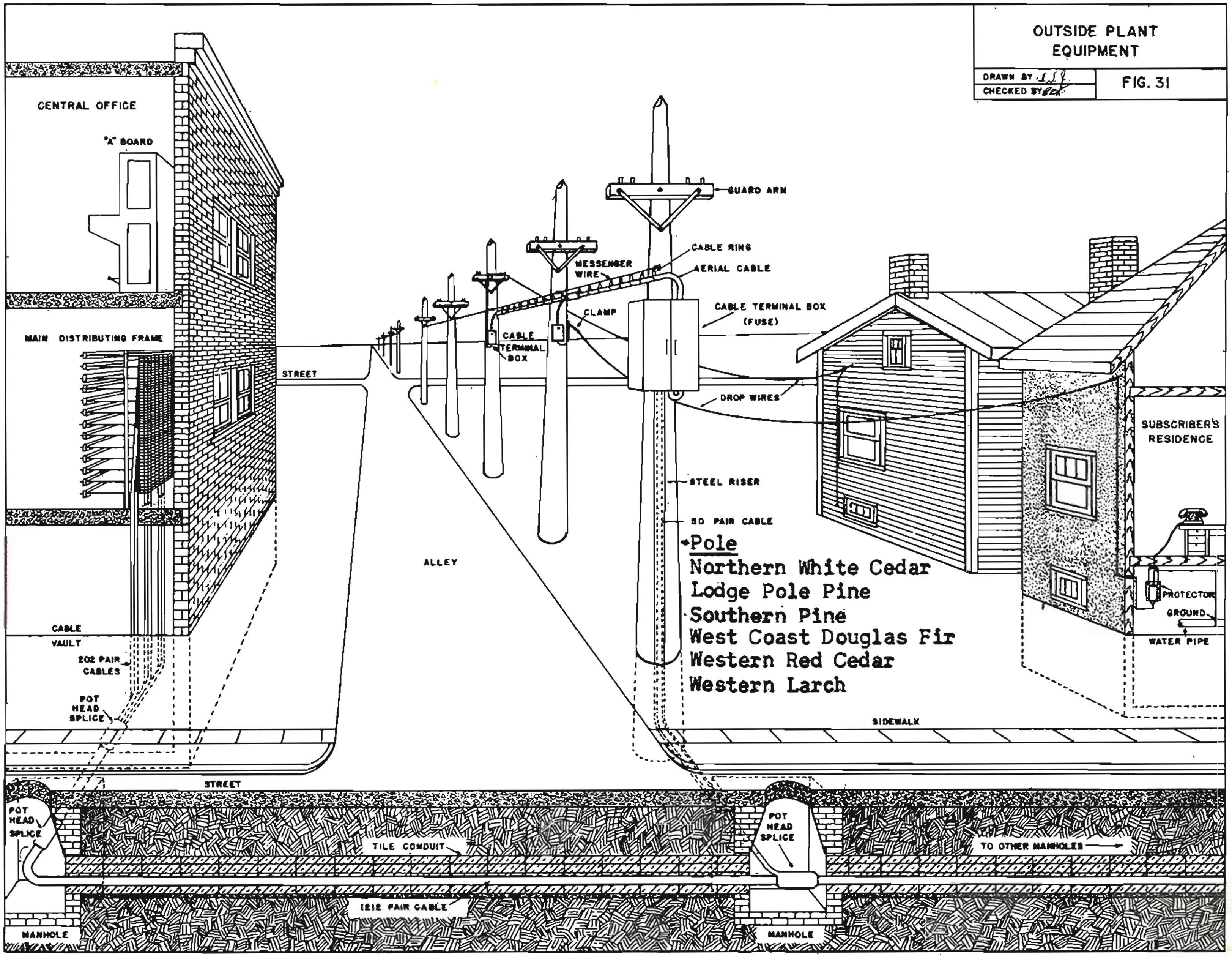
Lesson No. 1

FUNDAMENTALS OF TELEPHONY

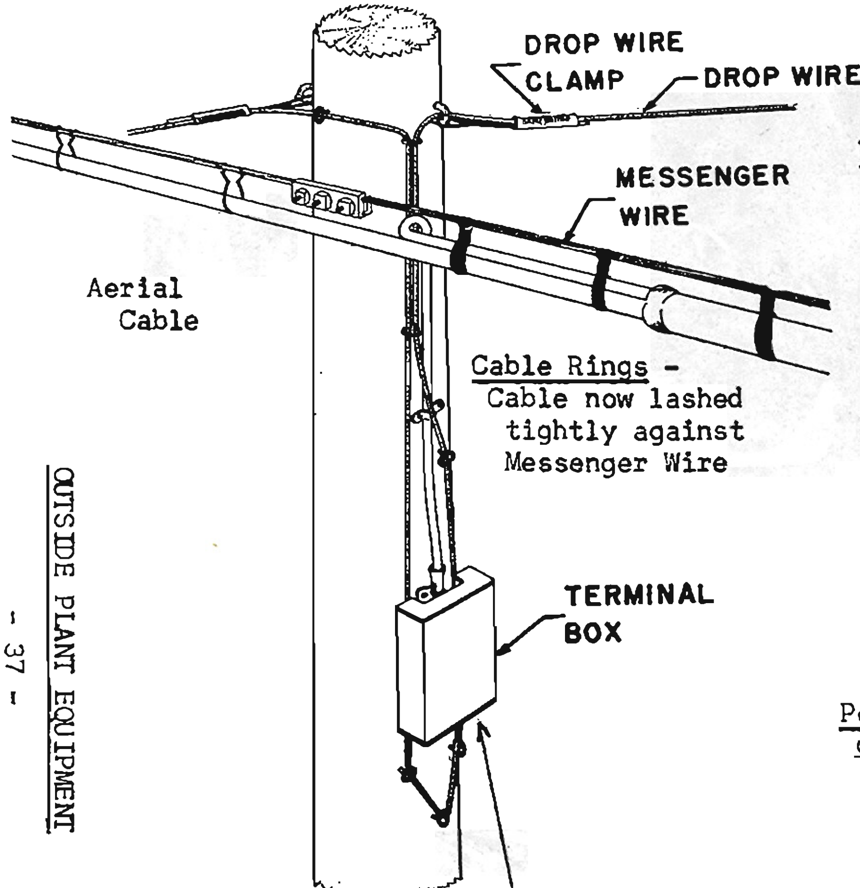
Section 5

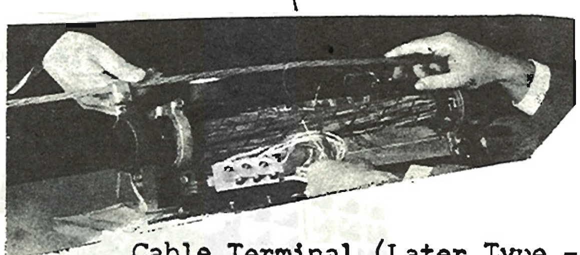
Outside Plant Equipment

CONTENTS



Outside Plant Equipment Required between the Central Office and a Substation



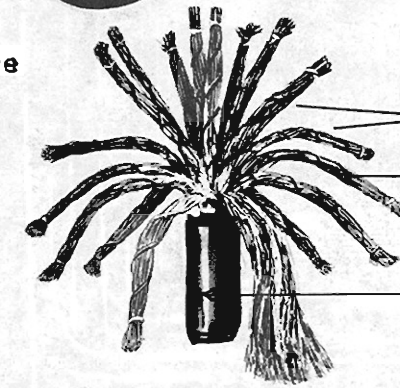


Cable Terminal (Later Type - Mounted on Cable instead of Pole.)

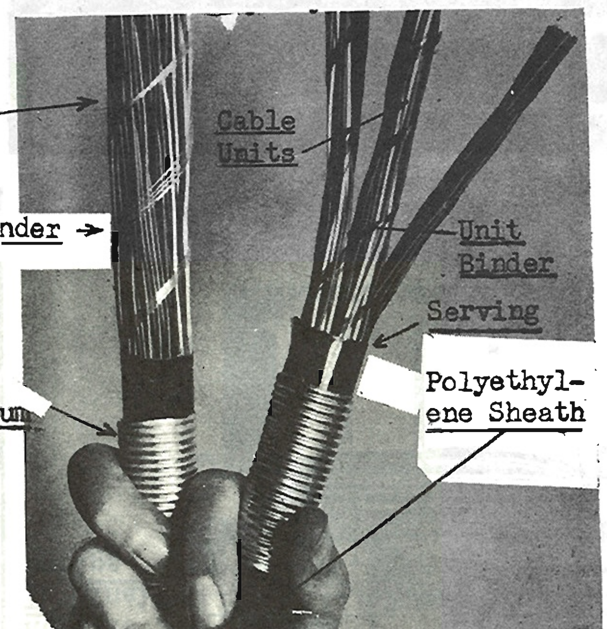
Types of Exchange Cable

Lead Covered
Lepeth)
Alpeth)-From Core
Stalpeth) Outward.

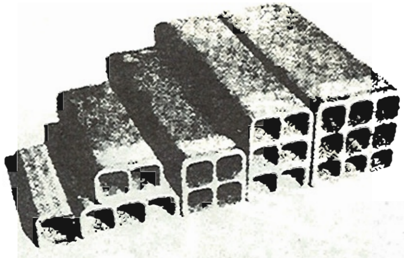
Al - Aluminum
Le - Lead
St - Steel
Peth - Polyethylene.



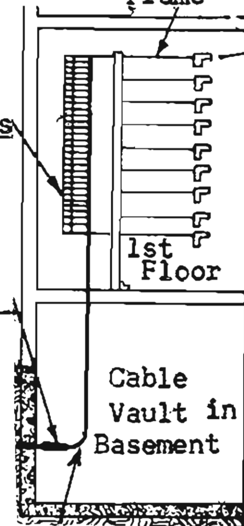
Exchange Cable

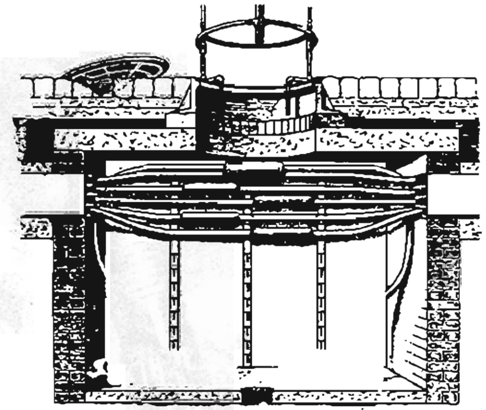


OUTSIDE PLANT EQUIPMENT

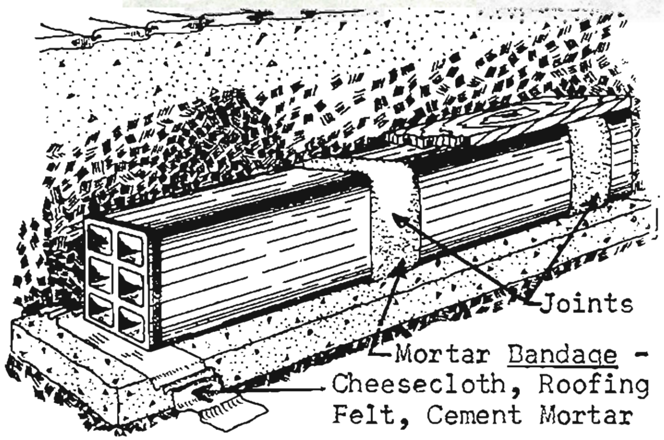


Tile Conduit
Concrete Conduit also used.

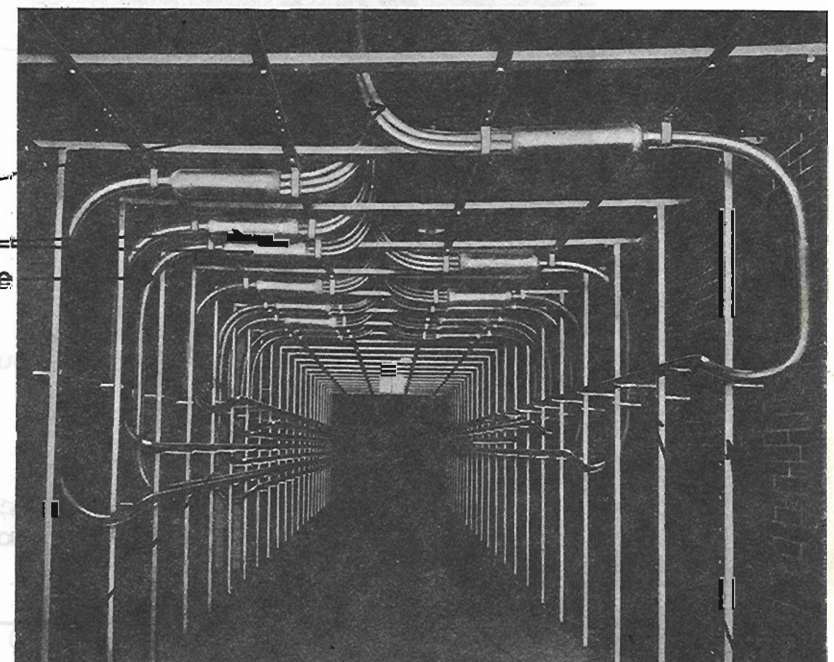




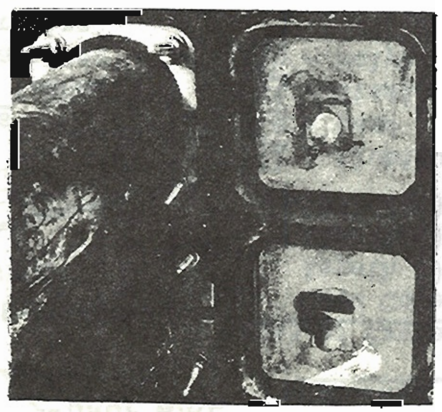
Typical Manhole
(6' X 4' Wide X 5' High)

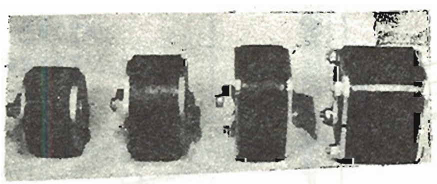


Method of Laying Conduit



Central Office Cable Vault





Rubber Duct Plugs Used in Manholes and Cable Vault to Seal Out Water and Gas.

OUTSIDE PLANT EQUIPMENT

Lesson No. 1

FUNDAMENTALS OF TELEPHONY

Section 6

Central Office Distributing Frames and Cabling

CONTENTS

<u>IDF</u> - <u>Intermediate Distributing Frame</u>

1) <u>Not used</u> in Crossbar Central Offices.
2) For re-locating Lines on Switching Equipment in Manual, Step by Step and Panel Offices.
3) 3-Wire Flameproof Jumpers from HIDF to VIDF.

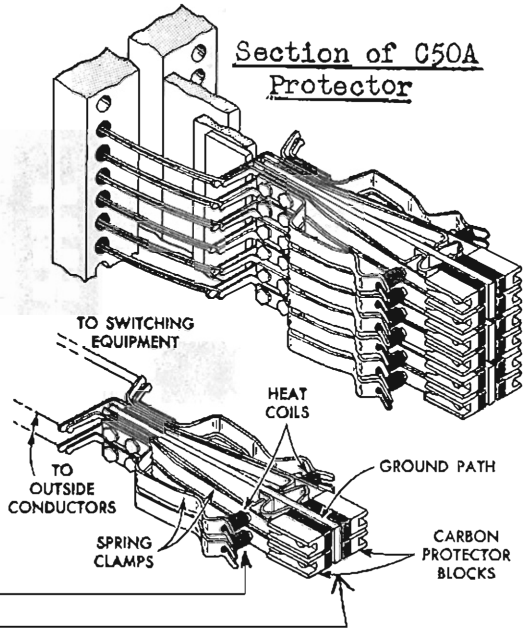
<u>MDF</u> - <u>Main Distributing Frame</u>

1) Outside Subscriber Lines and Trunks terminate on the VMDF.
2) Central Office Equipment cables to the HMDF.
3) 2-Wire Jumpers from VMDF to HMDF.
4) Switchboard Cable from HMDF to HIDF.

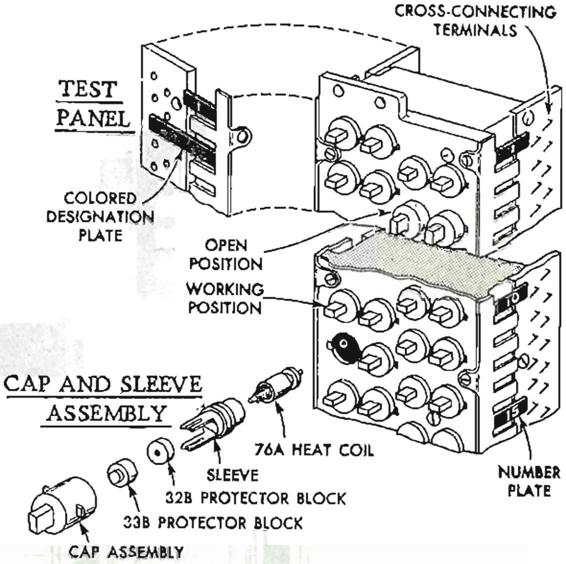
<u>CENTRAL OFFICE DISTRIBUTING FRAMES</u>

VMDF EQUIPMENT

Section of C50A Protector

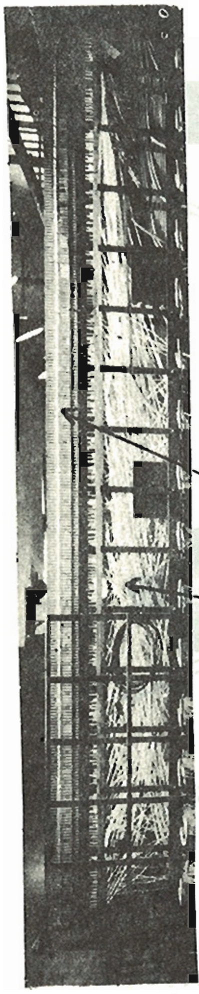


New
300-Type Connectors



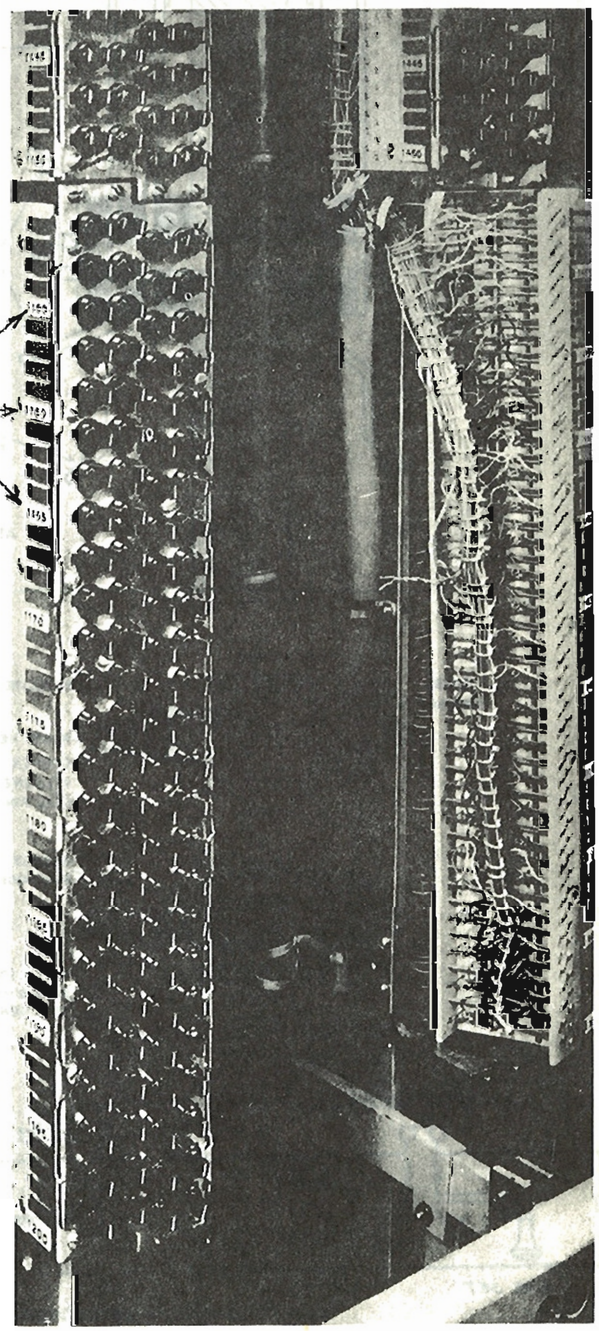
Protector Blocks - High-Voltage Protection

Heat Coils - Excess Current Protection



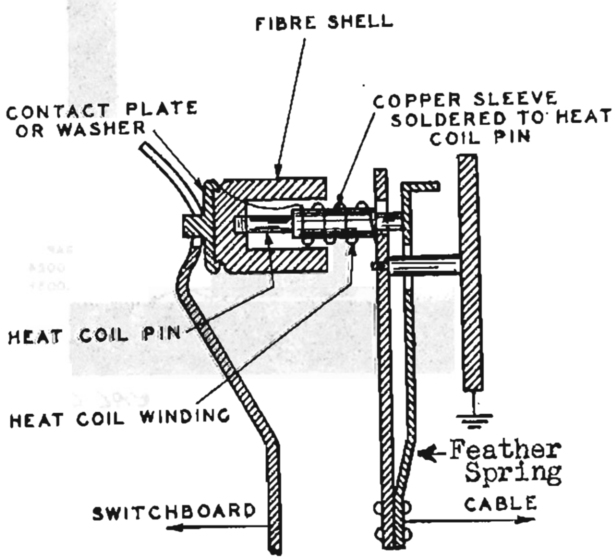
VMDF Vertical Column of C50A Protectors

2-Wire Jumpers (T, R) VMDF to HMDF



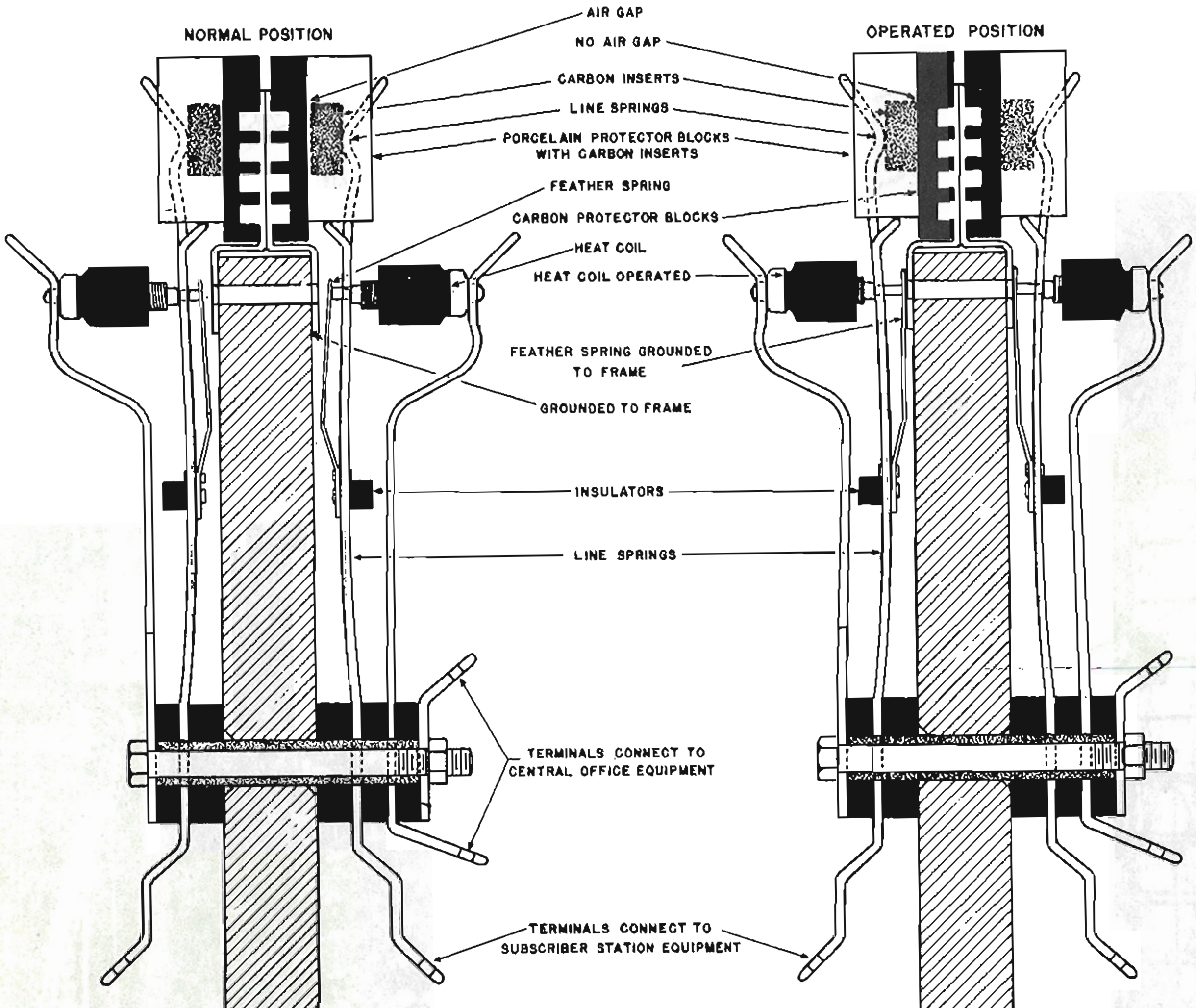
Number Plates
Cable Pair Numbers

300-Type Connector Unit

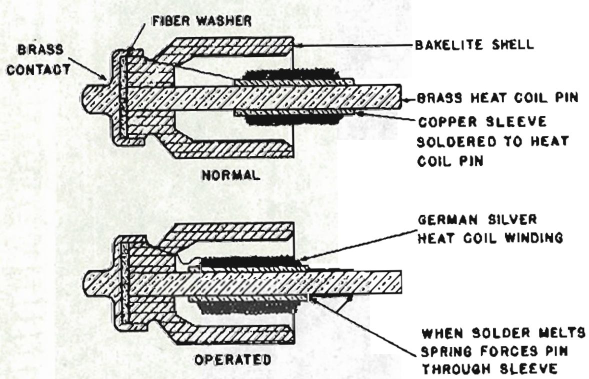


Cross-Section of Type 76A Heat Coil

Protector Blocks and Heat Coils

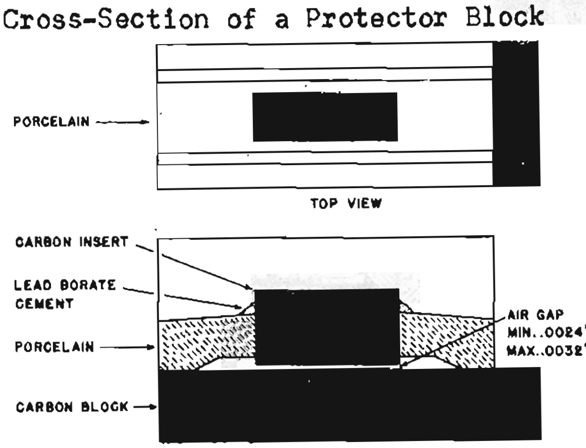


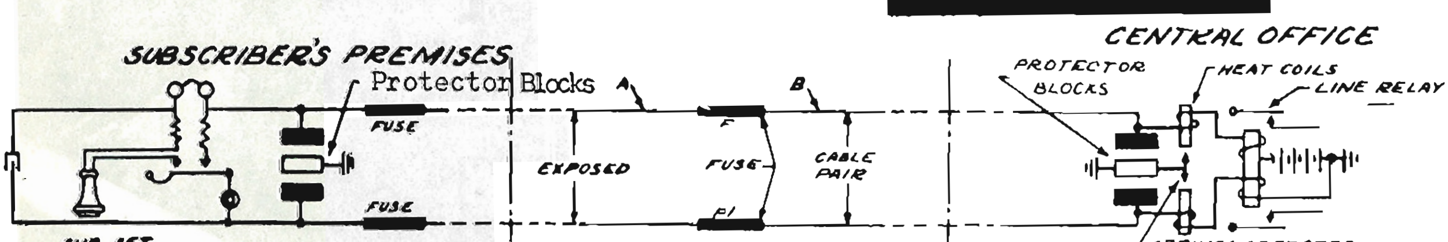
ASSEMBLED "B" TYPE PROTECTOR



CROSS SECTION OF A HEAT COIL

Cross-Section of a Protector Block

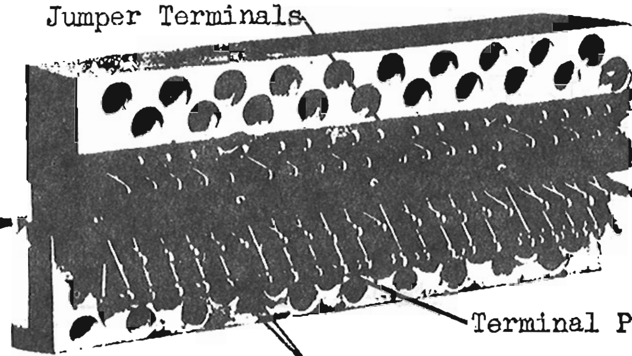




SCHEMATIC OF LINE CIRCUIT

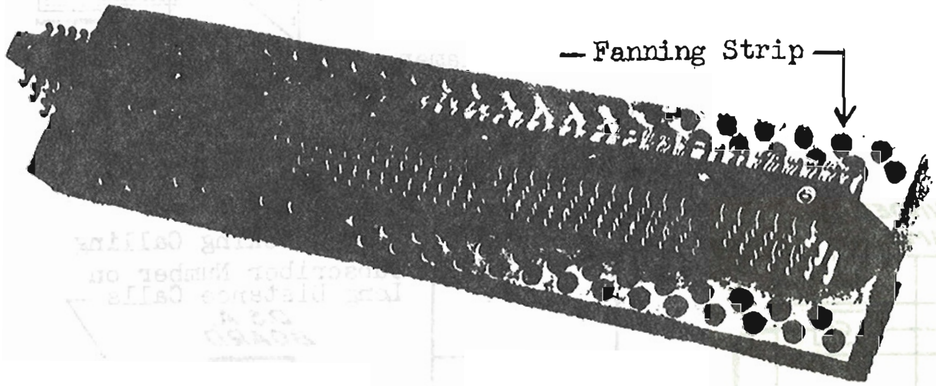
OTHER DISTRIBUTING FRAME EQUIPMENT

Terminal Strips - Mount on the HMDF, HIDF and VIDF, as well as on Switchboards, Units, Frames, etc., to facilitate necessary changes in wiring, assignments, cross-connections, etc.

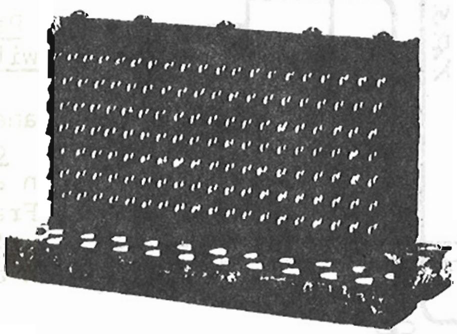


HMDF Terminal Strip
Terminal Punchings for hand-wrapped connections.

VIDF Terminal Strip



HIDF Terminal Strip



All of the above Terminal Strips are assembled by hand.
Newer Type Terminal Strips have the Punchings cast in a Resin Compound block, which is attached to a Wood Fanning Strip by means of self-tapping screws.
Many new Terminal Strips are arranged for Gun-Wrap Wiring.

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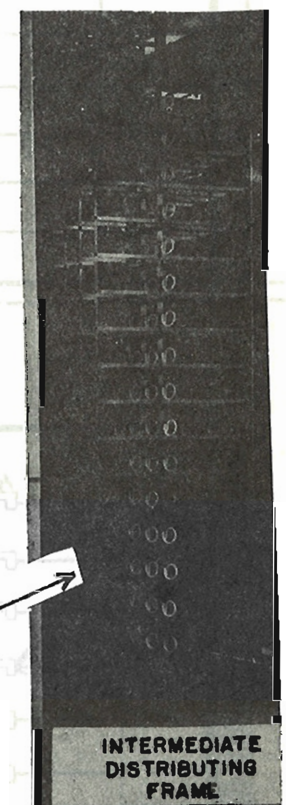
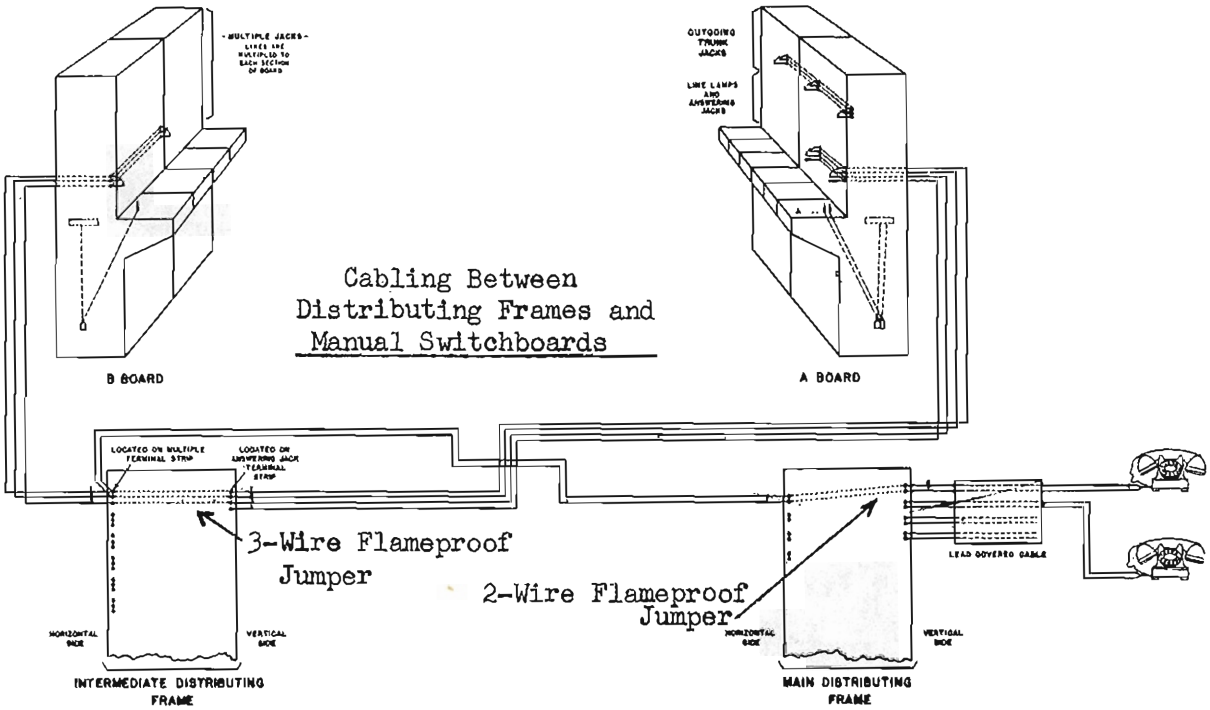
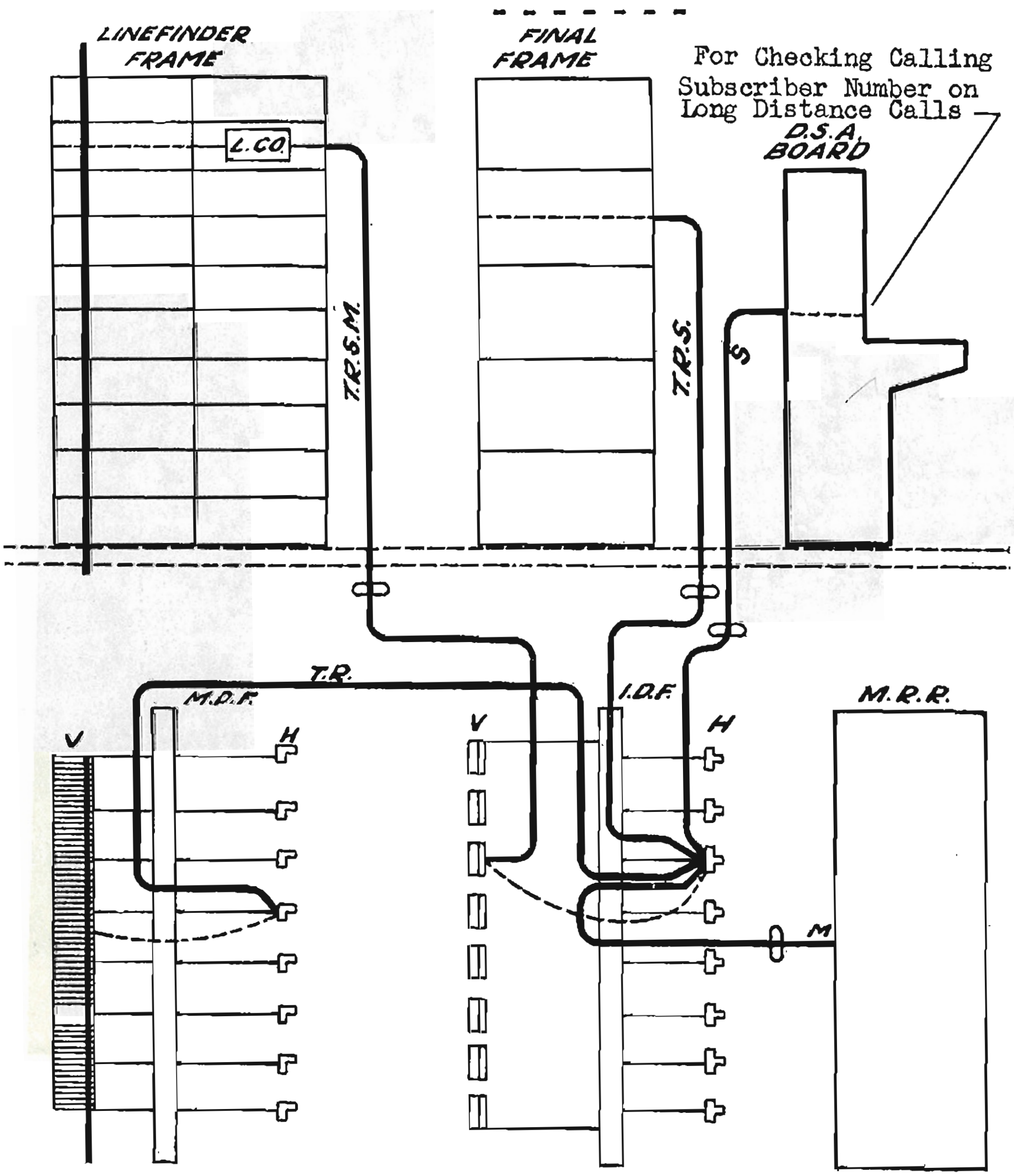


Distributing Rings
Mount on Verticals of Distributing Frames.
The Rings are finished with a viterous enamel paint, which acts as an insulator in case the Jumper insulation is defective. Rings prevent the Jumpers from becoming wedged in the Framework.

CENTRAL OFFICE CABLING



Cabling Between Distributing Frames and Manual Switchboards



Cabling Between Distributing Frames and Panel Dial Switching Frames

Panel Dial Call originates on a Line Finder Frame and terminates on a Final Selector Frame