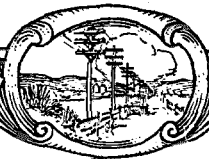# ELECTRICAL COMMUNICATION

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Sir Frank Gill, K.C.M.G., O.B.E.

By F. K. JEWSON

Assistant Vice President, International Standard Electric Corporation, London, England

THE English newspapers of June 12th, 1941, published the names of a number of people whose outstanding achievements have been rewarded by His Majesty the King, on the occasion of the celebration of his official birthday, by the award of various honours and distinctions. Amongst these was one of particular interest to all our readers; that of FRANK GILL, O.B.E., who was informed that His Majesty had been graciously pleased to give directions for his appointment to be a Knight Commander of the Most Distinguished Order of St. Michael and St. George for services in the development of the telephone industry and of international telephony.

Mr. Gill was born at Castletown in the Isle of Man and at the age of 16 entered the service of the United Telephone Company in London. After periods in Dublin, Liverpool and Blackburn, he returned to Dublin as District Manager, and in 1896 became the first Provincial Superintendent of the newly formed Province of Ireland of the National Telephone Company. Thus at the early age of 30 and fourteen years after starting his career he had reached a position which in the case of many telephone men proved to be their 'ultima thule' but not in the case of Mr. Gill.

In 1902 he was called to London to fill the position of Engineer-in-Chief of the National Telephone Company during a period which proved to be the most difficult of its existence. A change in the policy of the Government had allowed Municipalities to enter into competition with the National Telephone Company and it had been decided not to renew the franchise of the Company when it would expire at the end of 1911. The British Post Office (which had maintained a competitive system throughout the period of the franchise of the N. T. Co., confined mainly to official services and certain small exchanges in a few towns) had also entered directly into competition on a large scale in London. With the end of the franchise in sight, economy in capital expenditure was indicated but to meet the competition material improvements in the equipment were desirable. The Company, largely through the wisdom of its General Manager, W. E. L. Gaine, before his untimely death in 1907, found means of satisfying both requirements and made arrangements with the Government enabling a restricted progress in the telephone art in the British Isles to continue. During the last 7 years of the license most of the important exchanges in Great Britain were replaced by up-to-date common battery equipments and the telephone line wires continued to be put underground, whilst loading coils were introduced to bring circuits within desired transmission limits and transmission studies were made for all large towns. Indeed, planning went much further than this, for the efficiency of the service was such that without material changes conversations over lines much longer than could be found in these Islands would have been possible.

On January 1st, 1912, the Post Office took over the whole of the National Telephone Company's system except the 12 senior executive officers of the Company. In conjunction with Mr. W. W. Cook, Assistant Chief Engineer of the N. T. Co., the firm of Consulting Engineers, Gill & Cook, was formed and engaged in telephone work in various parts of the world including the U. S. A., Brazil, Argentine, Portugal and Turkey.

During the 1914-18 War Mr. Gill served in various capacities in the Ministry of Munitions, ending as Controller of the Central Stores Department. For these services he was made an Officer of the Order of the British Empire (O.B.E.).

In 1919 he accepted an offer of the post of European Chief Engineer of the International Western Electric Company and shortly after that there was commenced the introduction of long distance telephone cables in Europe. On the name of that Company being changed in 1925 to International Standard Electric Corporation he continued in the same capacity until 1928. During this period he was, in 1925/6, Vice President in Charge of Operations for the Spanish Telephone Company (Compania Telefonica Nacional de Espana) and began the reconstruction of the telephone system in Spain. He was also a member of the Postmaster

General's Committee which initiated Trans-atlantic Telephony.

The International Standard Electric Corporation elected him a Vice President of the Corporation. In 1929 while on a visit to Tokyo to attend the World Engineering Congress and the World Power Conference he was called to Shanghai, China, where he acquired for the I. T. T. System the business of the Shanghai Mutual Telephone Co. and undertook the reconstruction of the telephone system of the Shanghai Telephone Company, remaining until 1934. He is at present: a Director and a Vice President of International Standard Electric Corporation; Chairman of Standard Telephones and Cables Ltd., Creed & Company Ltd., and International Marine Radio Company, Ltd.

In 1922 he was elected President of the Institution of Electrical Engineers of which he had been a member since 1891 and selected as the subject of his inaugural address Electrical Communications with particular reference to international telephony. He drew attention to the achievements of the American Telephone & Telegraph Company in long distance telephony and pointed out that if distances alone were considered, telephone conversations could be carried on to all parts of the Continent of Europe and beyond with equal facilities. Long distance telephony had been possible in the U. S. A. because there had been one planning and co-ordinating authority, whereas there were some 40 in Europe, all with different ideas. Unless the circuit had been planned throughout with the same electrical characteristics, reflection and other losses occurred wherever there were variations. He proposed three alternative plans for dealing with this situation; one of which provided for an international telephone organisation with supervisory engineering powers. Early in 1923 the Department of Posts, Telegraphs & Telephones in France called an international meeting, of Government officials only, to consider these proposals and in 1924 the International Consultative Committee of Long Distance Telephony (C. C. I. F.) was formed, based on Mr. Gill's third proposal. To the efforts of this Committee we owe the success of long distance telephony in Europe, but the formation of the Committee is due to the vision of Mr. Gill.

After the war period it became apparent that something should be done to stimulate telephone development in a manner comparable with other European countries. At that time, the Postmaster General had no allocation of funds for advertising, and Mr. Gill in collaboration with others and with the consent of the Post Office authorities conceived the idea of the Telephone Development Association, of which he was President in 1935 and is serving in the same office again this year. He has also taken a great interest in the International Chamber of Commerce as a means for stimulating the demands of business men for better telephone facilities abroad.

Sir Frank Gill is a member of the Institution of Civil Engineers; Past President (1922) and Honorary Member (1938) of the Institution of Electrical Engineers; past Chairman of the China local branches of the Institutions of Civil and Electrical Engineers; Fellow of the American Institute of Electrical Engineers; Honorary Member of the Institute of Royal Engineers; Member of the Societe des Ingenieurs Civils de France and of the Societe Francaise des Electriciens; and Past President of the Association of Supervising Electrical Engineers.

Since the announcement of the honour conferred on him by the King, Sir Frank has been feted by most of the associations with which he has been associated, including, on June 16th, his entertainment by the Postmaster General, supported by the Assistant P. M. G., the executive officers past and present of the Post Office and representatives of the Telephone Industry.

That his arduous work and wonderful achievement in the development of the telephone industry and of international telephony has at last been publicly acknowledged is gratifying to the numerous friends throughout the world whom he has made during his long career; particularly as he has always been so modest and content to do whatever came to hand with enthusiasm and singleness of purpose, considering that the achievement of a duty well done was sufficient reward.

We offer our hearty congratulations to Sir Frank and Lady Gill and wish them many years to enjoy the honour which they so richly deserve.

Airport Communications

By R. H. RIDDLE

International Standard Electric Corporation, New York, N. Y.

Introduction

THIS article outlines the principal communication requirements of an airport, traces developments meeting these requirements, and describes some of the most modern equipment now in use or soon to be adopted, with particular reference to the facilities at La Guardia Field, the Municipal Airport of the City of New York, including those provided by governmental agencies and the commercial airlines.

The communications facilities required at an airport fall naturally into four functional groups, namely:

(a) Internal communication;

(b) Communication with outside fixed points and with other airports;

(c) Communication with aircraft;

(d) Auxiliary services such as radio direction finding on land, instrument landing and radio beacons.

The first part of the article is consequently devoted to a general discussion of groups (a), (b), and (c), in which European and American practices are indicated, with comment on the respective specialized applications, relative advantages, safety aspects and economic considerations. This is followed by consideration of the requirements and the equipment used at La Guardia Field, and (d) by brief descriptions of the latest developments in instrument landing and radio direction finding on land.

Internal Communications

In a modern airport, a flexible and efficient communication system interconnecting various internal departments is obviously indispensable. Centralization and coordination of functions, speeding up of procedure and avoidance of excessive auxiliary personnel depend to an important degree on the adequacy of the communication facilities.

The internal telephone system, preferably utilizing a private automatic branch exchange (PABX) [1] should be of adequate capacity for immediate needs and for reasonable future expansion. It must be capable of rendering reliable and speedy service to all units comprised in the airport, i.e., from the control tower to a series of strategic points bordering the field, as well as interconnection of shops, hangars, offices of the official staff, offices of private aviation companies located at the airport, etc.

Where permanent and instantaneous intercommunications are required, such as between two or more functionally allied departments or offices, so-called interphones are indicated. The use of interphone systems, however, should be restricted to special cases since the particular advantages of such systems—especially personal and immediate contact—decrease with expansion of the number of telephones involved. Beyond a certain stage, an internal telephone system is essential. Experience indicates that interphone systems should be used to supplement, but never to supplant an internal telephone system.

For the transmission of general orders, announcements to passengers or the public, paging individuals, control on the runways, emergency reports, etc., a loudspeaker public address system is required. The system should be arranged for transmission of orders and reports from various control points of the airport, including the possibility of instant selection of groups of loudspeakers covering the departments concerned. Microphone circuits at the various control points should be arranged for automatic priority throughout the system in order to prevent operation of two or more microphones simultaneously.

Weather reports, messages or orders concerning aircraft traffic, passenger lists and similar communications, which it is desirable to file for record purposes, may be transmitted between neighboring departments by means of pneumatic tubes.

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[1] For numbered references, see end of article.

For greater distances, teleprinters are more economical. They offer an appreciable advantage, not only because of instantaneous transmission, but also because of the practicability of simultaneous reception at various points in and outside the airport. In addition, their ability to print several copies facilitates distribution from key points, either by hand or through pneumatic tubes.

Teleprinters of the usual type are suitable for this purpose. In certain cases roll or tape rather than page printing machines are to be preferred, according to the requirements of individual departments.

Teleprinter messages can also be transmitted by means of a perforated tape such as is used in automatic telegraph offices. The operator prepares the tapes on a perforator and places them in the transmitting machine as circuits become free. Transmission is effected automatically, the operator being left free to prepare other messages on tapes, or to supervise other circuits. Piling up of messages is thus avoided at points where the traffic load is irregular; furthermore, tape perforations are useful for the automatic re-transmission of messages to side routes.

Selection of lines in the case of teleprinters is effected through a switchboard, similar to a small telephone exchange but embodying certain special features. Manual switchboards are used as a rule inasmuch as the teleprinter operators can readily supervise them and line changes are infrequent.

For communication between the control tower and mobile equipment of the airport, such as fire engines, accessory equipment for instrument landing, snow plows, successful use has been made at times of small portable radiotelephone equipments of very low power, operating on ultra-high frequency bands between 100 and 300 megacycles (1 to 3 meters).

Communication with Outside Fixed Points and with Other Airports

Telephone service to outside fixed points is usually handled through a manual private branch exchange (PBX) of one or more positions with trunks to the public telephone exchange.

Such a PBX provides telephone connections to all rooms and other places patronized by passengers and the public in general, and also to non-official agencies of the airport. In addition, it provides official and allied airport agencies with connections to the public telephone exchange. Calls from official airport agencies should originate through the PABX referred to above.

For emergency calls, the PBX should have available a microphone with control over the public address system previously mentioned.

In addition to telephone service to points outside the airport, provision must be made for the installation of a public telegraph office, including subsidiary offices for public and official airport use.

Communications with the official meteorological services obviously are especially important. For the transmission of weather reports to airports, teleprinter circuits have been adopted practically universally. They enable the weather bureau to transmit, simultaneously and in a single operation, messages to the main airport, other airdromes and its own agencies. Thus, messages may be received in record form with copies, as required, for internal distribution. Important, also, is the provision of an independent standby circuit interconnecting the weather bureau of the airport with the flight direction office of the airport.

Other direct circuits—telephone, telegraph or teleprinter—may be required to link the operations offices of governmental controlling agencies and to connect the airport offices of the airlines with local and distant ticket, sales and reservation points.

In areas of heavy aircraft traffic, direct communication with nearby airdromes is of great importance and may become essential. Physical or ultra-high frequency radiotelephone circuits are preferable since they avoid congestion of radio communication bands employed for normal services.

Communication with other airports and airdromes on the main flying routes under certain conditions may be provided advantageously by physical circuits. Due partly to the existing congestion throughout nearly the whole radio communication frequency spectrum, radio circuits are not, as a general rule, provided between airports in the U. S. A.

In Europe, up to the end of 1939, a definite tendency was noted towards the suppression of radio communication for these services, physical

teleprinter circuits being used, the same as in the U. S. A.

In the U. S. A., however, the cost of long distance teleprinter circuits is still substantially more than that of an equivalent radio circuit. On comparatively short circuits carrying heavy traffic the use of the teleprinter circuit is economically justified, but on longer circuits where traffic is light the economic factor compels use of radio circuits. In countries presenting broad expanses of territory combined with relatively undeveloped communications networks the economic considerations in favor of radio circuits are even greater, and in some cases radio may be the only possible means of communication.

Installations providing such radio channels may be made by the companies themselves, or the necessary equipment and personnel may be furnished by governmental authority. The equipment, in either case, must meet the requirements of all commercial lines using the airport; that is, for their communication with airports serving as landing points, auxiliary emergency airports, official weather bureaus, weather bureaus maintained by the aviation companies, etc.

For airport inter-communications in the aeronautical service bands, account must be taken of the definition approved at the Second Inter-American Radio Communications Conference in Santiago, Chile (1940). That definition, which agrees with the findings of previous world and regional conferences, establishes that aeronautical service consists exclusively in the transmission and reception of information contributing to the safety of aircraft in flight. Messages of an administrative and private nature would not, therefore, be included in this category; these may be classified as "point-to-point service" to be transmitted in the bands assigned to this latter service.

Communications with Aircraft in Flight

Communications with aircraft in flight generally are accomplished by radiotelephone and radiotelegraph.

The airport must be equipped to maintain communication with aircraft within the perimeter of its particular zone. If individual equipments are not installed by the commercial air lines, alternative arrangements must be made for governmental or other agencies to render this service and to keep in contact with aircraft at least until the zone of the next airport is reached.

This latter practice was common in Europe, up to the end of 1939, where the more important air services were primarily international; that is, in most cases the plane left an airport in one country to fly directly to an airport in another country. Jurisdictional problems consequently arose, requiring solution by international agreement.

In the U. S. A. the problem is largely a national one and has been solved as such. All flight activity throughout the country is subject to instructions from Airways Traffic Control of the Federal Civil Aeronautics Administration.

Planes on the field or in the immediate vicinity of the airport communicate directly with the airport control tower. Outside these "local control tower areas" all communication with commercial planes is through the facilities of the airline concerned.

For communication with military and itinerant planes outside the tower zone, facilities are provided by the Civil Aeronautics Administration. For navigation between airports, all planes may use the radio beacons and markers which are also provided and operated by the Civil Aeronautics Administration.

Both systems, experience shows, involve certain disadvantages. European methods, covering practically integral control, are simpler but not easily adaptable to very heavy air traffic conditions. American practice, involving a multiplicity of radio circuits with strict control and perfect coordination, is better adapted to the needs of terminal airports or points of converging air traffic.

The number of radio installations required at an airport is dependent on actual traffic volume and the probabilities of near and longer term traffic growth.

The principal transmissions from an airport to an airplane include weather reports of a general or specific character, flight instructions, emergency calls or danger warnings, bearings for direction finding and instructions for take off and landing. From aircraft, the transmissions primarily concern bearings, changes in flying alti-
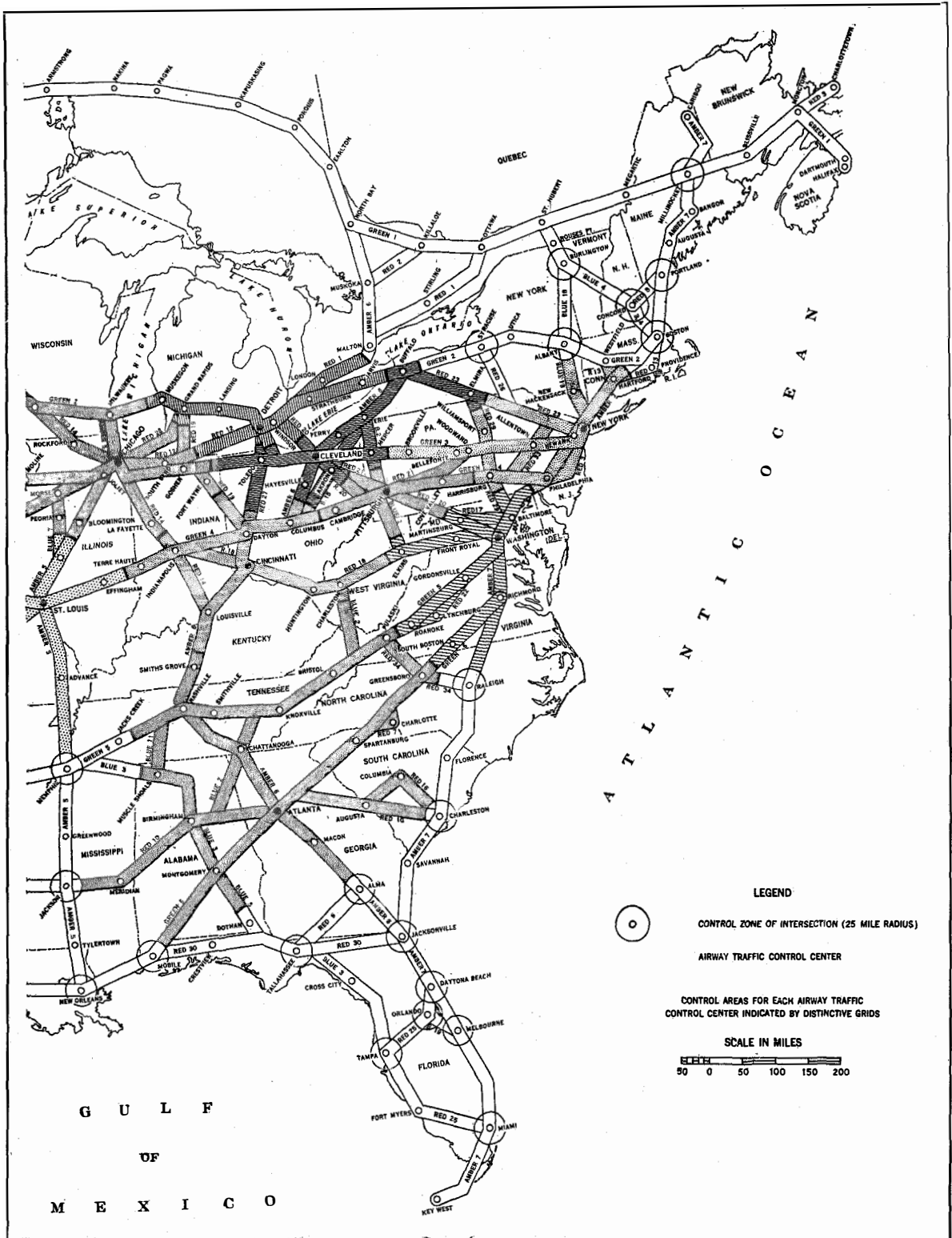
Fig. 1—Airway Traffic Control Areas of the United States and Canada.　(Territory east of St. Louis, Missouri.)　Reproduced from portion of map issued by Civil Aeronautics Administration, Department of Commerce, Washington, effective June 1, 1941.

tude, flying conditions, emergency calls, requests for landing authorization, etc.

At an important airport, where air traffic is or may become very heavy, separation of the receiving station from the transmitting station is in general desirable.

In Europe and elsewhere (partly due to lack of agreement on frequency standards), receivers frequently are located at or near the control tower of the airport. Since they are tuned by hand, contact can readily be maintained on medium or short waves with aircraft having equipment of the master oscillator type variable within the mobile or aeronautical service bands, and in many cases interference is avoided. Transmitters are placed at convenient distances, generally with manual control for starting, change in frequency and service, and are attended by personnel receiving orders by telephone. This arrangement has its advantages, especially in medium and long wave working, since the size of the transmitting antennas may present an appreciable flying hazard if placed near the landing runways.

In some instances, it has also been necessary to remove the radio direction finding installations from the airport. Modern Adcock radio direction finders, however, permit installation of their aerial system at a certain distance from the receiver so that this drawback has been reduced.

In the United States, control is unilateral and fixed frequencies have been assigned to all the services. It has thus been possible to provide automatic installations operated by remote control on pre-assigned frequencies, both for transmitting and receiving equipments.

LA GUARDIA FIELD (City of New York)

The preceding discussion deals with airport communications requirements in comparatively general terms. The following, (involving (1) the Civil Aeronautics Administration, (2) commercial airlines and (3) airport controls) is intended to present more specific and detailed information; it is confined to the systems and methods now used in the U. S. A., or, more particularly, to equipment now in operation or soon to be installed at La Guardia Field, Municipal Airport of the City of New York.

As a municipally owned airport, La Guardia

Field is under the Department of Docks of the City of New York. All communications facilities serving the airport as a whole, such as the control tower and the public address system, are therefore provided and operated by the Department of Docks.

Airlines using La Guardia Field include United Airlines, Eastern Airlines, American Airlines, Transcontinental and Western Air, Inc. and Canadian Colonial Airways, Inc. Pan American Airways operates from the Seaplane Base, also a part of the Municipal Airport; its facilities are not described in this article.

Civil Aeronautics Administration

GENERAL

For purposes of coordination and enhancement of safety, the Civil Aeronautics Administration delegated responsibility to Airways Traffic Control for dispatching and controlling all flying activity—commercial, military and itinerant—throughout the U. S. A. Through its Communications Division, the Civil Aeronautics Administration, in addition, undertook the gathering and distribution of information on weather conditions, flight control and progress reports involving the entire country. The Civil Aeronautics Administration also is responsible for the operation of radio beacons and markers.

AIRWAYS TRAFFIC CONTROL—NEW YORK AREA

The Airways Traffic Control office at La Guardia Field supervises flight operations within the New York Control area, which comprises the territory indicated in the map of Fig. 1. This area includes the airports of Newark (New Jersey), Philadelphia, Harrisburg (Pennsylvania), Middletown (New York), and the nearby Floyd Bennett, Mitchell and Roosevelt Fields (Long Island, N. Y.), all of which receive their flight instructions from Airways Traffic Control at La Guardia Field.

Instructions to commercial airplanes, while in flight *between airport control tower areas*, are relayed through the ground-airplane-radio facilities of the airline concerned. Contact with military and itinerant planes, however, is made directly from Airways Traffic Control by radio (as described below) until the plane comes *within the airport control tower area*.

Fig. 2—Operations Board—Airways Traffic Control.

AIRWAYS TRAFFIC CONTROL EQUIPMENT

For communication with other airports in the New York Control Area and for transmission of flight instructions to the communications centers of the airlines at La Guardia Field, telephone lines are used exclusively by Airways Traffic Control. In the case of the other airports, the lines are operated on a conference basis. Operators monitor the line at all points and come into answer when called. The local lines to the communication points of the airlines are operated on the usual ring-answer basis. A view of the operations board is shown in Fig. 2.

For communication with military and itinerant planes, Airways Traffic Control has its own radio receivers, installed near the operations board, and

transmits over the Airport "range and simultaneous broadcast" transmitter. This transmitter, supplied by the Federal Telegraph Co., operates on a fixed frequency of 209 kc. It is modulated continuously with tone at a level which permits speech to be imposed on it with adequate intelligibility. One receiver monitors 3,105 kc for reception from itinerant planes; another monitors 4,495 kc from military planes. In addition, the tone signal of the range transmitter is monitored (on 209 kc) and the local control tower on 362 kc.

WEATHER REPORTS

Adequate weather information must be received at the airport to enable the airlines and Airways Traffic Control to plan and control flights. As indicated above, the Communications Division of the Civil Aeronautics Administration is responsible for this service. The information is supplied by weather stations of the Weather Bureau of the U. S. Department of Commerce, except at points where there are no such weather stations, in which case employees of the Civil Aeronautics Administration are trained and authorized to make observations. Reports come to the Communications Office at La Guardia Field over several circuits and are relayed to its Airways Traffic Control as well as to the flight planning offices of all airlines at the field, to all other services in the locality subscribing to the service and to all connecting distribution circuits. Such reports, of course, include those supplied by the weather station and Airways Traffic Control at La Guardia Field.

EQUIPMENT FOR WEATHER REPORTS

The weather reporting service at La Guardia Field employs thirteen sets of teletype equipment, each set consisting of a printer with its associated reperforator and a transmitter. The reperforators associated with the printers are used when required to perforate a tape simultaneously with reception of the information in printed form on the printer. This tape may then be transferred to the transmitter for transmission of the reports to other distribution points and to local subscribers. One similar set of equipment is used for the flight control and progress report circuit. The typewritten copies received on the

printers are sent to Airways Traffic Control through a pneumatic tube system.

Airline Requirements

Each airline must have facilities for communicating with its planes in flight, for transmitting and receiving operating information to and from other airports on its routes, for relaying flight information from its planes to Airways Traffic Control, for relaying messages to and from the local reservations office and its reservations offices in other cities, and for intercommunication between its various offices at the airport.

As an example of the requirements and equipment used by a major airline in the U. S. A., the facilities of American Airlines at La Guardia field are described in the following paragraphs.

American Airlines, in general, was selected for this purpose in view of the fact that its general offices are located at La Guardia Field, which also is the terminus of the three distinctly separate routes flown by the line, with 122 flights in and out of New York daily, exclusive of extra sections. The extent of the operations carried on by American Airlines at La Guardia Field, moreover, demands what are perhaps the most elaborate facilities of any one airline at one airport, and it is thought that this very fact makes the installation of outstanding interest since the outlines of simpler systems are easily recognizable in such a relatively complex one. This fact should be kept constantly in mind, however, since correspondingly less equipment is, of course, required at the terminal airport of a single route or at an intermediate airport.

Fig. 3—Radiotelephone Operating Positions, Communications Center of American Airlines, La Guardia Field, North Beach Airport, New York.
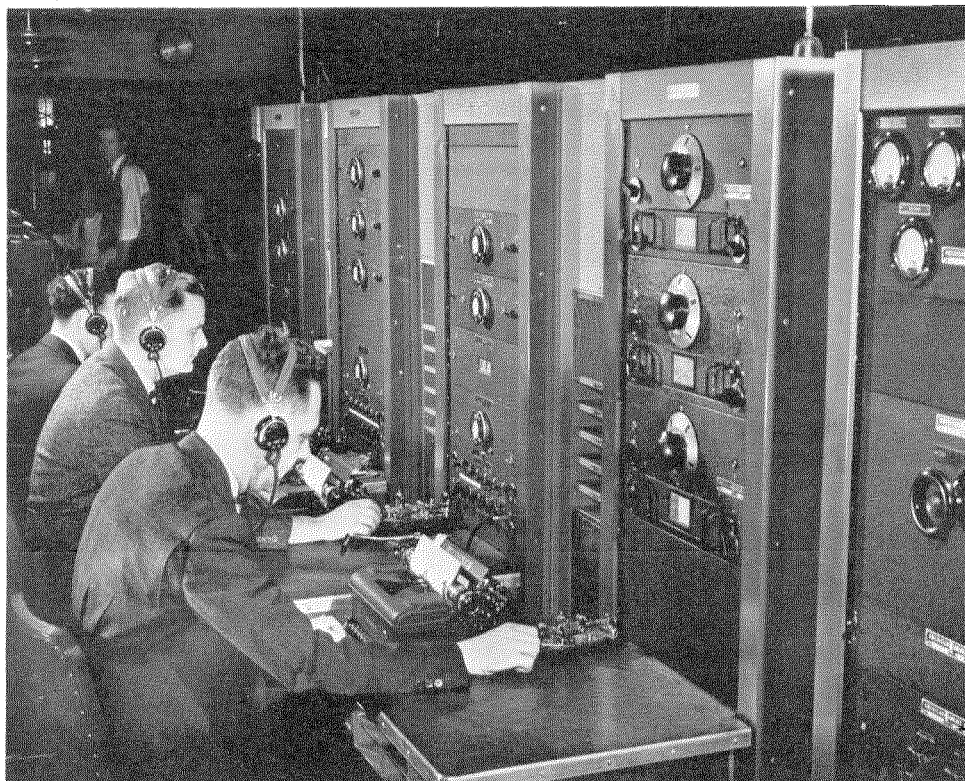
Fig. 4—Radiotelegraph Operating Positions, Communications Center of American Airlines, La Guardia Field, North Beach Airport, New York.

American Airlines Facilities

Figs. 3 and 4 show, respectively, the radiotelephone and radiotelegraph operating positions in the communications center of American Airlines, from which telephone communication is maintained with planes in flight and telegraph traffic is handled with communications centers at some of the other airports. A block schematic of the system is shown in Fig. 5.

Four radio transmitters are located at the Jamaica Bay Station, approximately ten miles south of the airport. Two are multi-channel transmitters made up of a power unit, one telephone radio frequency unit and two CW telegraph units. Each of the radio frequency units is rated at 3 kw antenna output and is arranged for selection of six operating frequencies by remote control. The third transmitter is a single channel CW or telephone unit with an output rating of

1 kw, and is arranged for remote selection of ten frequencies. The fourth is a 250 watt unit for remote selection of six frequencies on CW telegraph only.

In addition, three auxiliary transmitters for telephone use only, rated at 50 watts and operating only on two frequencies, are installed near the operating positions in the communications center.

Seven receivers, each crystal controlled for two frequencies, are located at the station on nearby Rikers Island. Four similar auxiliary receivers are installed near the operating positions in the communications center.

As shown in the schematic (Fig. 5), all of the above transmitters and receivers are wired into a jack field at which circuits from the operating positions also terminate. Operating circuits are patched through as required; the remotely in-

stalled radio equipment is under the complete control of the operators through the remote control units at each operating position.

As mentioned above, the radiotelegraph facilities are used for communication with certain other airports on the routes of the American Airlines. In general, radiotelegraph circuits are used only to distant points, not involving heavy traffic. For the shorter distances and heavy traffic points, leased wire teletype circuits are used, supplemented by Telemeter and Teletype Exchange facilities.

The teletype operating section of the communications center is pictured in Fig. 6. The machines shown include the transmitter and the typing reperforator on the circuit to the reservations office in New York and the machine in the circuit linking the ticket offices, sales office, reservation office in New York and the general offices at the airport. Block schematics of the circuits in which these machines operate are given in Figs. 7 and 8.

Reperforators associated with each of the nineteen machines in the communications center at La Guardia Field (Fig. 8) are used to punch tapes for all messages from other points to the reservations office in New York. Messages from the New York reservations office are received on the typing reperforator, and the tapes are run on the circuit corresponding to the appropriate reservations office.

Teletype circuits also are used to relay flight information from airplanes to Airways Traffic Control. These machines are located at the three radiotelephone positions shown in Fig. 3, corresponding to the three routes flown by the Company. While the operator is receiving messages from the plane, he types them directly on the Teletype so that the message appears simultaneously in his machine and in the printer near the
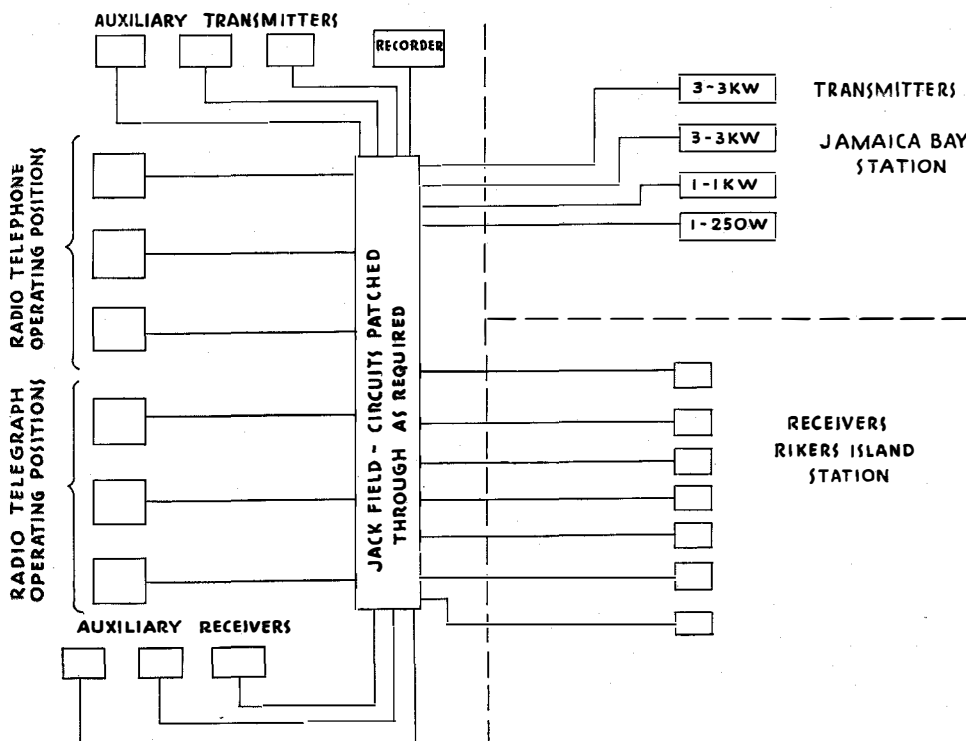

Fig. 5—Schematic of Radio Transmitting and Receiving Facilities, American Airlines, La Guardia Field, New York.

*Fig. 6—Teletype Operating Positions, Communications Center of American Airlines,
La Guardia Field, North Beach Airport, New York.*

operations board in Airways Traffic Control. The copy typed by the operator immediately is handed by him to the adjacent flight planning office of the airline.

In this flight planning office, weather reports also are received from Civil Aeronautics Administration lines. An hour before the scheduled departure of an airplane, the chief pilot, in collaboration with the flight planning supervisor, considers the flying conditions likely to be encountered and plans his flight, use being made of the latest information available through radio and teletype facilities.

Flight instructions are received in the flight planning office from Airways Traffic Control over a private telephone line.

For internal communication at the airport,

American Airlines employs a standard 300 line PAX. This is supplemented by a seven-position PBX with trunks to local central office exchanges.

A loudspeaker intercommunication system links the general offices, communication center, ticket center, agents, airmail and baggage offices. It is arranged for station-to-station operation or for broadcasting to all stations.

Multi-Channel Transmitter of United Airlines

Multi-channel radio transmitters for airline operation recently installed by the United Airlines at La Guardia Field represent the most modern developments and refinements in this type of equipment.[2] They were engineered and

manufactured by the Federal Telegraph Co. and are used by United Airlines for telephone contact with planes in flight and for point-to-point telegraph traffic.

Electrically and mechanically, this equipment is subdivided into four basic units similar in size and outward appearance, i.e., the power supply unit, modulator unit, radio frequency unit and central cooling unit (Fig. 9).

The power supply unit will operate radio frequency units individually or a limited number simultaneously. The modulator unit is capable of completely modulating a single radio frequency unit. Each radio frequency unit is a complete assembly capable of operation on a single frequency independently of all other radio frequency units. Control and switching are accomplished in primary power circuits, thereby eliminating troublesome RF switching.

The power supply unit together with a radio frequency unit constitutes the minimum equipment for single frequency telegraph service. The addition of a modulator unit provides single frequency telephone service. Individual modulator units may be associated with more than one radio frequency unit for telephone service on more than one frequency, but only one radio frequency unit may then be modulated at one time.

Provision is made for remote control of the following functions: (a) application of filament
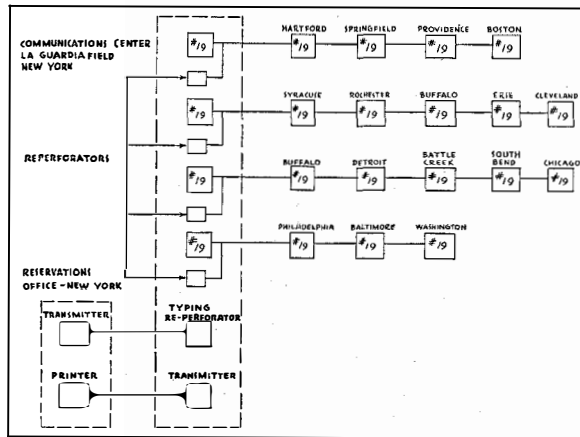

Fig. 8—Long Lines Teletype Circuits, American Airlines.

primary voltage; (b) removal of filament primary voltage; (c) application of plate voltage; (d) removal of plate voltage; (e) selection of any RF unit for operation; (f) keying of individual RF units for telegraph service; and (g) push-to-talk microphone switching for telephone service.

These remote control circuits are actuated by completing the respective relay circuits through a remotely controlled switching mechanism such as a telephone type of stepping switch. The same circuits may be switched manually by extending the circuits to a local control switching panel.

Control Tower Requirements (City of N. Y. —Municipal Airport)

As planes approach within 10 minutes flying distance, or approximately twenty-five to thirty miles of the airport, control of their flight is shifted from the airline or Airways Traffic Control, as the case may be, to the airport control tower. The control tower receives from commercial planes on the frequencies used for contacts with their respective communications centers. Commercial planes, however, call the tower on their night frequency during the day, and on their day frequency at night, in order to avoid interference with other planes of the line talking to their own communication center. Since military, police and itinerant planes also must receive their landing instructions from the tower, the transmitting frequencies of such planes must be available to the control tower. In addition,
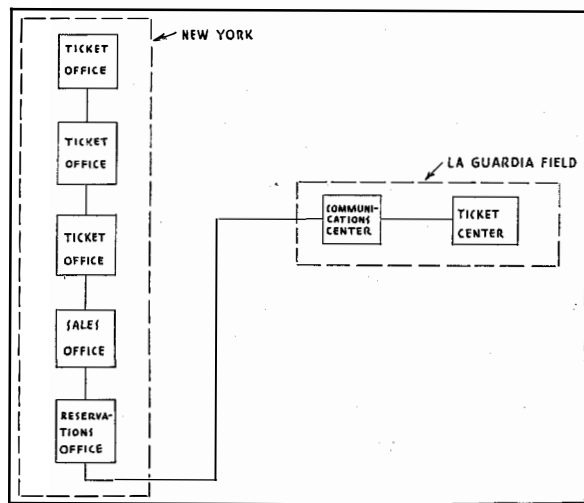

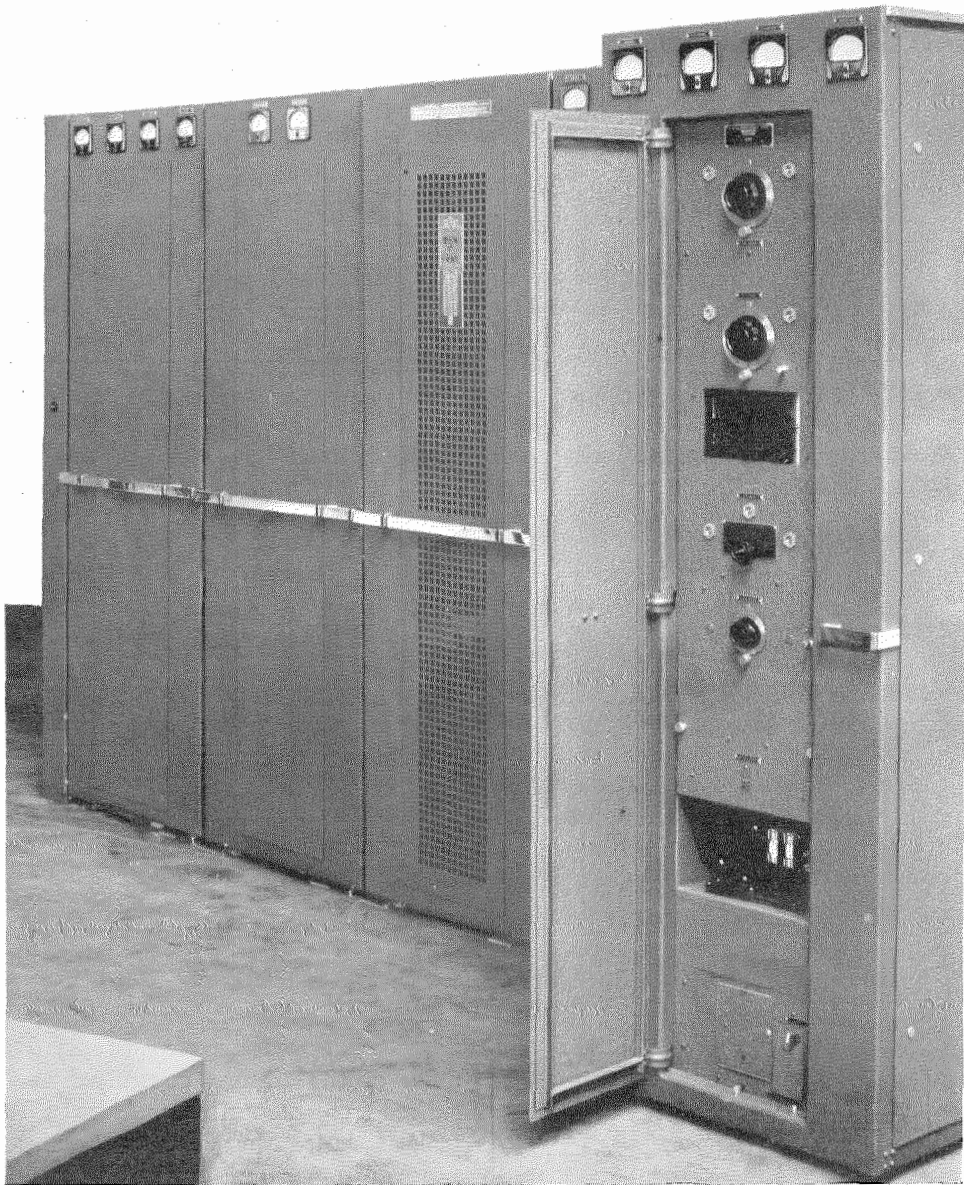Fig. 7—Local Teletype Circuit, American Airlines, New York.

Fig. 9—Five Kilowatt Unit Type Multi-Channel Federal Telegraph Company Transmitter.

facilities for communication with the Airways Traffic Control officer are required, as well as a system for instantaneous contact with the communications centers of all the airlines. Another essential item in the control tower is a microphone of the airport public address system.

Control Tower Equipment

Fig. 10 shows the interior of the control tower at La Guardia Field. In the center of the control console are the various wind direction and velocity indicating instruments, and airport lighting
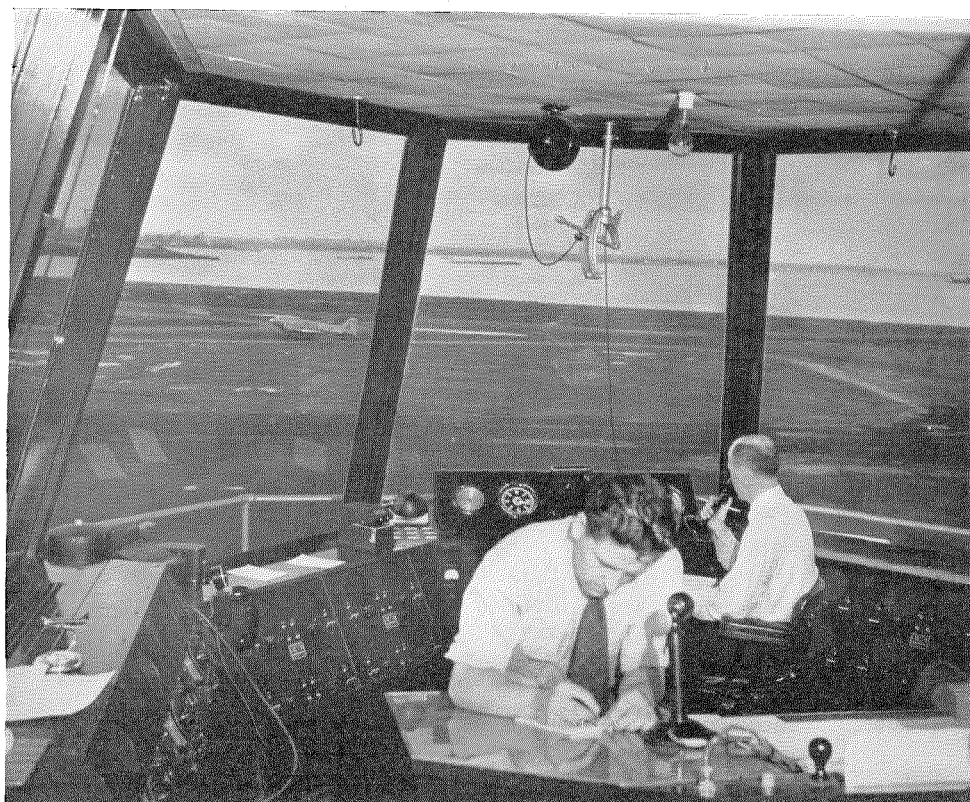
Fig. 10—Interior of Control Tower, La Guardia Field.

controls. On the left and right of the center panel are loudspeaker units from the remote receivers. At the extreme position on both wings of the console are the local auxiliary (emergency) receivers; directly below but not visible in the picture are transmitters and receiver line amplifiers.

Two transmitters operate at fixed frequency with 15 watts antenna output. The standard control tower transmitting frequency for the U. S. A. is 278 kc; La Guardia Field, however, is an exception in that it operates on 362 kc to avoid interference with the nearby Floyd Bennett Field. Ultra-high frequency for control tower operation is a recent innovation; a transmitter operating on approximately 130 mc is now in use at La Guardia Field simultaneously with a 362 kc transmitter. Both transmitters are modulated by the operator's dynamic microphone through a

line amplifier. While at present very few planes are equipped to receive and transmit on the ultra-high frequencies, it is expected that all control tower communication eventually will be shifted to this range.

A group of fifteen 23-A Western Electric receivers are installed at the remote station on nearby Rikers Island. American Airlines employs two on night frequencies, four on day frequencies; Transcontinental and Western Air, two on night, and one on day frequencies; United Air Lines, one day and one night frequency; Eastern Airlines, one frequency; and Pan American Airlines, one frequency.

One receiver is kept on the Army frequency of 4,495 kc and one on the itinerant frequency of 3,105 kc. The receivers are single frequency crystal controlled units with a highly effective

CODAN circuit (carrier operated device anti-noise) which operates to block the audio output of the receiver except in the presence of a carrier. Control equipment is provided to turn the receiver on and off, and to indicate by means of a light on the control tower console when the receiver CODAN operates (signal coming in). A submarine cable connects the equipment on Rikers Island with that at the airport proper. One pair in the cable is used for the output of each receiver including the above-mentioned control functions. One pair for each receiver also is used to disable the CODAN circuit at will. One additional pair is used for a wall type magneto telephone to provide communication between the receiver room and the traffic tower.

For reception from planes in the event of failure of a receiver or any of its associated equipment, six tunable receivers, each with provision for crystal control of two frequencies and equipped with crystals, serve as standby equipment.

The transmitters are located in the machine room below the control tower. They are duplicate units, capable of remote operation. One transmitter is connected with the control unit located in the control rack with the receiving amplifiers and control rectifiers; it is linked to the microphone placed over the console and to a jack on the key panel of the control operator's desk. The other transmitter is wired to the microphone and to a jack in the center section of the console. In addition to the overhead microphone, there are two desk stand microphones. All three are equipped with push-to-talk switches functioning as transmitter plate power controls. The receiver switching rectifier is operated by the press-to-talk switches of the remote transmitters so that the local receivers are silenced during transmission.

INSTANTANEOUS BROADCASTING

For instantaneous contact with the communications centers of all airlines at the field, a circuit has been installed in which reception at all points is on loudspeakers until the handset is lifted from the hook. Thus messages from the tower can be broadcast to all points instantaneously.

In the control tower, there is a microphone connection to the airport public address system but no loudspeaker connection. Interference with the many receivers being monitored there is consequently avoided.

Airport Public Address System

The La Guardia Field public address system is an elaborate Western Electric announcing system. Eighty-five loudspeakers in the Administration Building and on the loading platform broadcast announcements which originate at microphones located at fifteen different information centers.

From the control tower, information is conveyed on the arrival time of each flight. From the four ticket counters and information desk in the rotunda of the Administration Building, passengers are paged and the time and place of impending departures are announced. In offices at nine of the fourteen gates of the loading platform, microphones are used for the same purpose and also for calling taxis and porters.

Each microphone is equipped with a press-to-talk switch, and the system includes a relay arrangement which permits the connection of only one microphone at a time.

The specially designed loudspeakers on the loading platform have a 360 degree area of coverage and are arranged so that the output of one blends naturally with the others. The rotunda of the Administration Building is covered by three of the new type Western Electric "cobra" horns mounted in the dome. All other public rooms in the building are reached through wall speakers mounted behind ornamental grilles.

The system employs one type 119-A and two 116-A Western Electric speech amplifiers and four 118-A Western Electric power amplifiers.

Instrument Landing

Since the Bureau of Standards in 1929 produced the first complete experimental instrument system for the landing of airplanes, various solutions of the problem have been attempted. Standardization in any eventuality was recognized as a requisite since coordination of airplane and ground equipment dictated the adoption of a particular system in any one country or in connection with contacts involving international flights.

In line with a request by President Roosevelt, a special Committee of the National Academy of Sciences, in the autumn of 1939, made a thorough

study of the problem of standardizing instrument landing equipment. Early in 1940 it submitted a report which cleared the way for the installation of additional systems similar to the experimental and demonstration installation at Indianapolis, known as the Indianapolis System and developed by the International Telephone and Radio Manufacturing Corporation,* under the sponsorship and in accordance with performance specifications of the Civil Aeronautics Administration (C.A.A.).

Subsequent to the special Committee report, additional demonstrations were made to Army, Navy, airline officials and others, and standardization was effected in the sense of "a complete and unified system 'frozen' at a practicable stage of development in order to enable pilots and the industry to start accumulating first-hand knowledge of its technique and operation." In July, 1940, an order was placed by the C.A.A. with the I.T. & R.M. Corporation for the manufacture and installation of instrument landing systems at La Guardia Field, N. Y.; Municipal Airports at Chicago, Cleveland, and Kansas City; Mines Field, Los Angeles, and Meacham Field, Fort Worth.[3, 4, 5, 6, 7]

With the exception of experimental equipment, these landing systems will represent the first commercial installations in the U. S. A. and mark a decided advance in the application of ultra-high frequency radio to aerial navigation. In addition to enhancing the safety of flying, they will relieve congestion at busy airports due to delayed landings under unfavorable weather conditions. The system provides the pilot with complete guidance to the airport runway, both horizontally and vertically. Through beams of ultra-short wave energy transmitted from highly directive equipment at the airport, the pilot by means of a conveniently placed instrument on his instrument panel is provided not only with the exact line of approach laterally to the concrete runway but also with the exact line of descent, when five miles or more away, to the runway so that the airplane settles upon the latter as in normal landing. Further, two "marker beacons" are provided along the line of approach to the landing runway: one indicates to the pilot arrival at a certain point, some distance from the runway,

when he should be at a predetermined altitude and in line with the runway as indicated by the landing instruments; the other marker informs the pilot when he passes the boundary of the airport. With these facilities, pilots can land with consistent safety even when weather conditions are extremely difficult.

"Marker" or approach beacons operate at a frequency of 75 megacycles. Separate transmitters and antennas are used for the horizontal and vertical guide beams which are radiated on 109.9 and 93.9 megacycles, respectively.

The frequencies adopted for the C.A.A. (I.T. & R.M.) instrument landing system obviate the possibility of mutual interference between similar installations at different airports. This was found to be a source of difficulty in former systems.

Smaller antenna designs and greater effective directivity are achieved through the application of relatively higher frequency working. Potential obstacle hazards are reduced; and, further, the design permits placement of antennas beyond the danger zone.

Transmitter and antennas for the horizontal guide beam (locating equipment) are in general installed between 150 and 350 meters beyond the end of the runway; alternatively, they may be located below ground level at the edge of the runway. Underground installation does not affect operation other than by slightly reducing the range. Equipment for the vertical descent guide beam is placed some 400 meters to one side of the center of the runway; it cannot, therefore, be regarded as an obstacle.

Installation of a number of these new systems is well advanced and they doubtless will soon be in commercial operation at important airports, including La Guardia Field.

Short Wave Radio Direction Finding on Land

Up to the present time short wave radio direction finding on land in the United States has been confined principally to coast control stations for ocean flights. An advanced type of "azimuth indicating receiver," developed by the Western Electric Co., is now, however, available for operation in the 2.8–6.6 megacycle range, and it is expected that with completion of final tests and

* Formerly International Telephone Development Company, Inc.

refinements now in progress, equipment of this type will find wide application.

This azimuth indicator consists essentially of an antenna collector system, a remote controlled ten-frequency fixed tuned receiver, and a unit combining an azimuth indicating oscilloscope, operating controls, and the necessary voice frequency equipment.

As shown in Fig. 11 the antenna collector system, which is fundamentally of the elevated H fixed Adcock type, and the radio receiver are mounted on an outdoor supporting structure at the actual receiving site. The remote control and indicating unit is shown in Fig. 12 with side panels opened to show auxiliary adjustments.

The system employed is entirely carrier-operated. The collector system extracts the neces-sary directional information from the incoming carrier wave; this Adcock type of collector, as is well known, provides defense against polarization effects (so-called "night effect" or "airplane effect").[8, 9] In the radio receiver the directional information collected from the antennas is trans-lated into forms suitable for transmission on a two-wire line over a considerable distance to the remote indicator. The radio receiver also places on this two-wire line, which may have an overall attenuation as high as 30 db at 1,000 cycles, whatever intelligence in the form either of speech or tone modulation is imposed on the carrier, and the process of obtaining the bearing does not interfere with the reception of such intelligence.

An outstanding feature of the system is that this two-wire line also is utilized for all remote

Fig. 11—Antenna Assembly for Azimuth Indicating Radio Receiver.

control operations involved in frequency and volume selection of the radio receiver and control of a test oscillator at the receiving site.

The indicating device is a cathode ray oscillograph having a 360 degree azimuth scale around the periphery of the screen. In the absence of both signal and noise the light spot is centered with respect to the azimuth scale. As soon as a carrier wave reaches the collector system the spot is radially deflected toward the azimuth indication corresponding to the arrival azimuth of the wave itself with respect to any desired reference, such as true north. The indication is instantly and automatically unilateral, thus eliminating any 180 degree uncertainty. Moreover, and this is one of the most important features of the system, since no mechanical inertia is involved, indications may be obtained on signals of extremely short duration. The position of the spot can easily be read to within two degrees, which is approximately the accuracy of the system when receiving from planes up to a few hundred miles under favorable conditions. Errors of over four degrees are ordinarily rare.

The equipment is considered a medium range, medium accuracy device, but in operation its sensitivity is such that satisfactory indications may be obtained from planes carrying 50 watt transmitters in flight over land at distances up to a few hundred miles in the daytime and evening when transmitting in the 4–6 megacycle band. A few checks have been made on planes using 5 mc when well over 1,000 miles at sea.

The obvious application of a single radio receiver, equipped as described above with an azimuth indicator, located on an airway or at an airway terminal, is to verify that the plane is on course or to obtain an indication of its angular deviation from the course. Alternatively, a single receiver placed in an off-course position may be used to take bearings on a plane and thus indicate its advance along the course. However, there are other possible applications for a single terminally located receiver. It can be used to great advantage in case the pilot, under bad weather or visibility conditions, either becomes confused in the immediate neighborhood of the airport or overshoots the mark. Under such conditions the directional indication, especially in view of its rapidity, can be of great assistance to
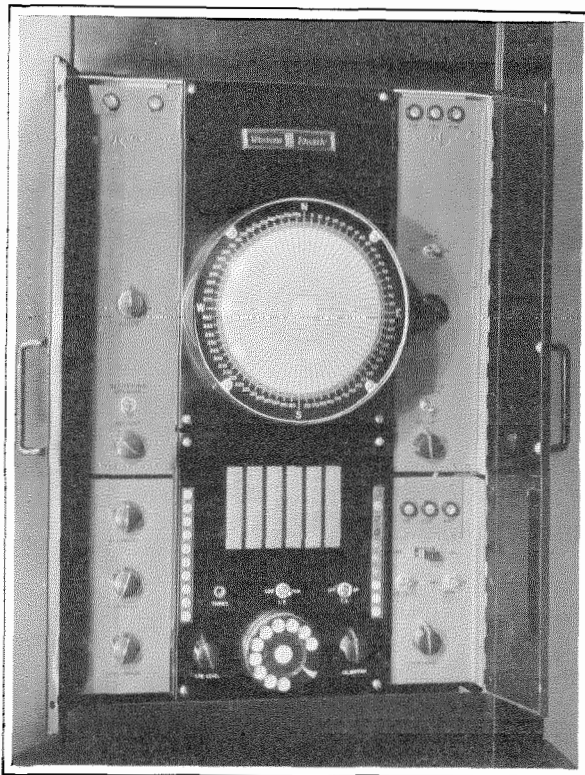

Fig. 12—Remote Control and Indicator Unit Showing Auxiliary Adjustments.

the ground crew in assisting the pilot to reorient himself for a landing.

If more than one azimuth indicating radio receiver is available to receive the plane's signals, position determination or triangulation immediately becomes possible, providing the collectors are strategically located with respect to the plane's course.

Several indicators may be operated from a single collector system if multiple indication is required.

Conclusion

The following summarizes typical communication equipment at La Guardia Field, together with indications of the functions involved:

Airways Traffic Control

Telephones Lines.—To other airports in the New York Control area on a conference basis. To the communications centers of all airlines at La Guardia Field on a ring-answer basis.

Radio Range and Simultaneous Broadcast.—Communication with military and itinerant planes.

Teletype.—Weather reports.

AMERICAN AIRLINES

Radiotelephone.—Communication with planes in flight.

Radiotelegraph.—Communication with distant airports not involving heavy traffic.

Teletype.—Communication with airports involving shorter distances and heavy traffic. Flight information relayed from planes to Airways Traffic Control. Network linking ticket, sales, reservations and general offices.

PAX.—Inter-office communications.

PBX.—Inter-departmental communications and connections to local central office exchanges.

Loudspeaker Interphone System.—Serving general offices, communication center, ticket center, agents, air mail and baggage offices.

MUNICIPAL AIRPORT

CONTROL TOWER

Radiotelephone.—Simultaneously on 278 kc and on approximately 130 mc for transmission to planes. Reception on various frequencies.

Special Telephone Circuit.—Loudspeaker reception at all airlines communications centers until receiver is lifted.

Public Address.—Microphone connection to the main public address system.

Separate from but closely allied to communications is the problem of airport illumination. An interesting example of a comprehensive illumination and field marker system is the recent Argentine Civil Aeronautic Authority's installation at the Presidente Rivadavia Airport, Province of Buenos Aires.[10] In addition to enhancing the safety of flying, it has effectively reduced air-time distances, particularly in the case of the longer journeys involving the problem of landing early in the morning or late in the afternoon under poor light conditions. Further, inauguration of night flying is under consideration in South America; if introduced, fully adequate airport illuminations, such as the Presidente Rivadavia installation, should prove invaluable.

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Rotary Automatic Telephone Service in Lima, Peru

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Introduction

THE Republic of Peru, situated on the west coast of South America, has a total area of 1,300,000 square kilometres and a population of more than 6,500,000. Lima, the capital, comprising over half a million inhabitants, was founded on January 18, 1535, by the Spanish Conquistador Francisco Pizarro, who named it "City of the Kings" in honor of the Spanish monarchs Ferdinand and Isabella. Lima today is a modern metropolis in which the beauty and historic interest of the colonial structures blend with the convenience and utility of modern avenues and buildings. Its growth during the last twenty years has been rapid so that the small towns of San Isidro, Miraflores, Barranco, Chorrillos and San Miguel, which formerly constituted entirely separate communities, are now merged as suburbs of Lima, forming a single urban area extending from the foothills of the Andes to the shores of the Pacific. Only twelve kilometres distant from Lima, is the city of Callao, the principal port of Peru, with a population of about 82,000.

Although the latitude of Lima is about 12° south, well within the tropical zone, the average temperature is 18.6°C.; the rainfall is only 3.3 millimetres a year, but the relative humidity is high, averaging 85.6% and frequently approaching 100%. This high humidity is one of the chief enemies of the telephone man who must devote constant attention to preventive maintenance in order to minimize low insulation troubles on all types of plant.

Conversion to Automatic

In 1930, when the Compañia Peruana de Telefonos Limitada became associated with the International Telephone and Telegraph Corporation, Compañia Peruana furnished telephone service in the Lima area through manual central offices in Lima, Callao, Miraflores, Barranco, San Isidro, Magdalena Vieja and Magdalena del Mar. Initial installations of 7-A.1 Rotary equipment,

however, had been started in two offices, namely, Washington (in the downtown area of Lima) and Miraflores.

The new management of the company completed the installation of the 7-A.1 equipment in Washington and Miraflores. The first cutover was effected in December, 1930, part of the southern section of Lima being transferred to the new Washington office. In November, 1931, the Miraflores office was opened, replacing an antiquated magneto switchboard. Concurrently, plans were formulated for an enlarged construction program with a view to providing automatic service throughout the area and, at the same time, renovating the existing outside plant.

Fig. 1 shows the general layout in the Lima area and the location of the central offices. The numbering arrangement is based on a standard 7-A type Rotary scheme for a 5-digit system and a capacity of 50,000 numbers. All odd levels, 1, 3, 5, 7 and 9, of the first group selectors are used as local levels, each corresponding to 2,000 lines; even levels, 2, 4, 6 and 8, correspond to units of 10,000 lines, while level 0 is reserved for special services. The numbers allotted to the sub-offices are taken in blocks of 2,000 from the numbers assigned to the corresponding main office. In the case of San Isidro and Barranco sub-offices, one level of the second group selectors is used for special service so that the numbering capacity is reduced from 4,000 to 3,800. Thus, with the present layout, the Lima area has an ultimate capacity of 49,600 lines distributed as shown by the following table:

Office Name	Type	Lines Installed	Numbering
Washington I	7-A.1 main office	4000	10000–13999
San Isidro	7-A.2 sub-office	1000	14000–17799
Magdalena	7-A.2 sub-office	600	18000–19999
Washington II	7-A.2 main office	9000	30000–39999
Washington III	7-A.2 main office	—	70000–79999
Callao	7-A.2 main office	1600	90000–99999
Miraflores	7-A.1 main office	2800	54000–59999
Barranco	7-A.2 sub-office	1000	50000–53799

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The Lima city area is served from the main Washington office which has an ultimate capacity for 30,000 lines of 7-A.2 equipment. The old section of the building housing 4,000 lines of 7-A.1 equipment, general stores and miscellaneous offices is constructed mainly of brick and adobe. For economic reasons it was decided to retain this building initially and to erect adjacent thereto a ferro-concrete earthquakeproof building to accommodate the first 10,000 line 7-A.2 unit, special service equipment and general offices for the staff of the telephone company. The old section of the building was reinforced to minimize risk of damage in the event of an earthquake; also the facade was reconstructed to line up with that of the new building. The appearance of the present structure is shown by Fig. 2, the old section being at the extreme right. Ultimately the older portion will be demolished and the ferro-concrete structure extended to accommodate three 10,000 line 7-A.2 units. The 30,000 line capacity of the Washington office includes two sub-offices at San Isidro and Magdalena with a capacity of 3,800 and 2,000 lines, respectively.

The Callao office (Fig. 3) serves the port district and surrounding residential suburbs of La Punta, Bellavista and La Perla. It is an integral part of the Lima flat rate area with direct trunks to other offices over 19 and 22 gauge cable pairs graded and loaded in accordance with supervision and transmission requirements.

The third main office serves the Miraflores residential district; the ultimate capacity is 9,800 lines, including 3,800 lines of 7-A.2 equipment in the Barranco sub-office. The plan is to transfer the 4,000 lines of 7-A.1 equipment from Washington to Miraflores in stages in accordance with growth requirements. Thus all 7-A.1 type equipment will be concentrated in one office (Miraflores) and all other offices will be 7-A.2 type.

Sub-offices

The sub-offices were designed for use in outlying districts where the ultimate demand will
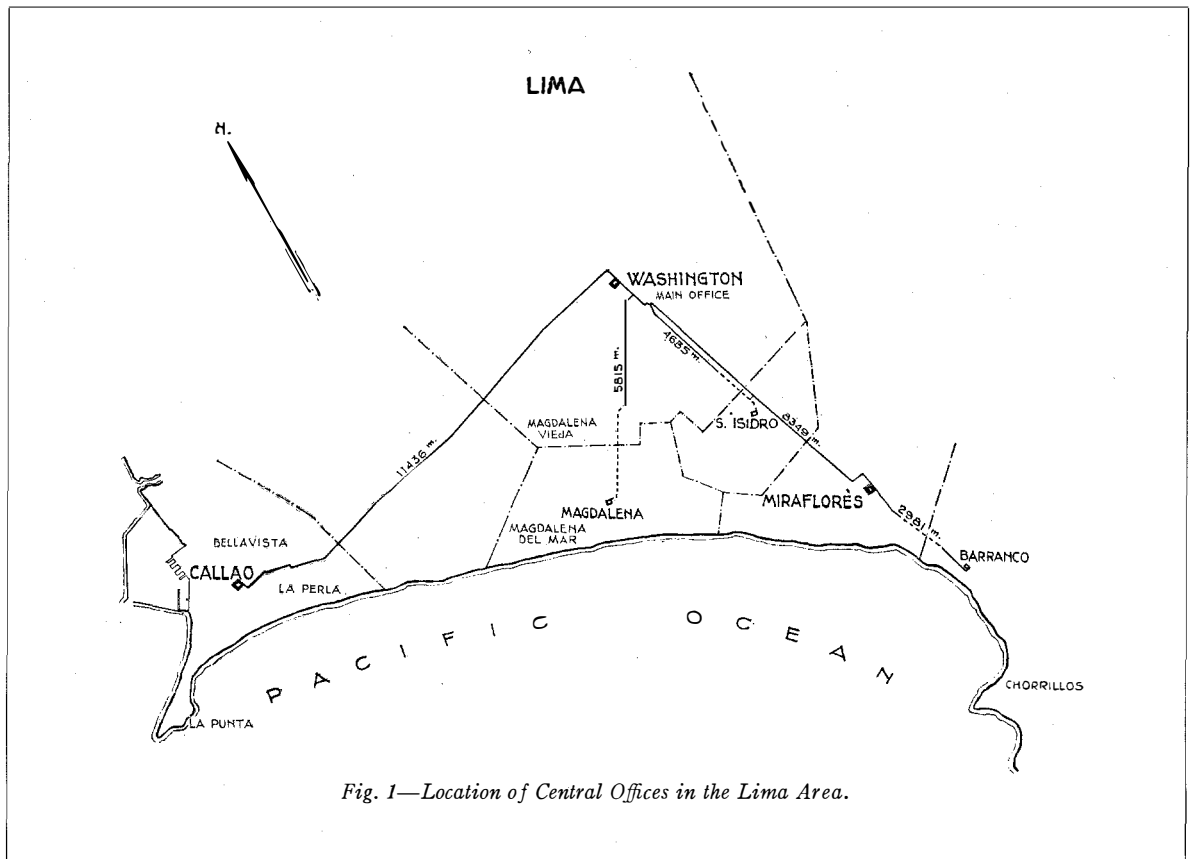

Fig. 1—Location of Central Offices in the Lima Area.

Fig. 2—*Washington Automatic Exchange and Headquarters Building of the Compañía Peruana de Teléfonos Limitada.*

not exceed 3,800 lines and the local community of interest is comparatively high. Since this type of sub-office is not in common use, a short description of the main operating procedure is given.

An originating call engages a link and register at the sub-office followed by a cord circuit and register at the main office. Dial tone is received over the junction to the main office. Dial impulses sent by the calling subscriber are received by the registers in the sub-office and at the main office.

In the case of a local call the junction to the main office is released and the connection is established via a fourth group and final selector under the control of the local register. The local fourth group selector is similar to the regular 7-A.2 fourth group selector used in the main office but is provided with a transmission bridge and controls the release of the connection.

When the call is not local, the register at the sub-office is released and the connection is established under the control of the register at the main office.

The register at the sub-office is designed for use either in 5 or 6-digit areas and will discriminate between one or two groups of 2,000 numbers. When only one group of local fourth selectors is installed, the level of the junction finder corresponding to the second group is used for special services, so that the capacity is for 2,000 numbers. When two groups of local fourth selectors are required, one level must be reserved for special services and thus the ultimate capcaity is reduced to 3,800 lines.

If all junctions to the main office are engaged, dial tone is given from the local register. A local call may be completed but, in the case of a call directed to another office, busy tone will be given by the local register.

Calls to special services not requiring a high

Fig. 3—7-A.2 *Rotary Equipment in the Callao Exchange. Main Distributing Frame and Test Desk Are in the Rear.*

efficiency junction or metallic through connection are routed via the common group of junctions to the main office. On calls to the toll board the local register breaks down the connection to the main office and routes the call via a group selector giving access to junctions which terminate on the toll board. Depending upon the class of the calling subscriber, levels may be selected giving access to junctions for non-restricted, restricted or coin box lines.

Incoming calls are completed via fourth group and final selectors, similar to those in the main office, except that the fourth selector contains a transmission bridge and arrangements for holding the connection over a 2-wire junction.

The sub-offices are not normally attended. With existing equipment not exceeding 1,000 lines, routine visits for maintenance inspection twice a week are found sufficient. Means are provided for extending fault alarms to the main office.

Centralized Special Services

All special services for the Lima area including toll, assistance, information, interception, service observation, repair and testing are concentrated in the main office at Washington.

While the Compañia Peruana de Telefonos Limitada owns no toll circuits with the exception of short haul circuits to the resort towns of Chosica and Ancon about 45 kilometres from Lima, subscribers can communicate with many of the provincial towns in Peru and with other telephone systems throughout the world by means of interconnection with the network of the Compañia Nacional de Telefonos del Peru and the facilities of All America Cables and Radio Incorporated. This service is handled on a 6-position No. 3 type toll switchboard.

The test bureau comprises a 3-position repair desk operated in conjunction with a 5-position test desk. Reports from subscribers regarding

physical plant troubles and actual or potential faults observed by the company's employees are routed direct to the repair desk via level 02, where they are recorded and passed to the test desk for immediate attention. The test desk is equipped with jack-ended trunk circuits giving access to test final selectors in each office. By means of a high speed key set the test clerk may set up via these circuits a metallic through connection to any subscriber's line. Incoming trunks from level 01 terminating on the test desk are arranged so that when a repair man dials this code from any subscriber's station a metallic through connection is established and the line may be tested without any further switching operation.

Subscribers' requests for assistance on account of service difficulties not involving physical plant troubles or emergency calls for public services, such as fire, ambulance or police, are routed via level '00' to an assistance operator on the toll board. The assistance operator has facilities for extending calls and for verifying the condition of any subscriber's line in the case of double number, 'don't answer' or 'busy' complaints.

Directory information service is handled on a 4-position desk comprising two double-sided tables equipped with key-ended trunks from level '03.' This desk is equipped with rotary files providing the operators with speedy access to the required information.

Interception services are handled on a 4-position test desk similar to and lining up with the directory information desk. Dead levels in automatic offices are connected to special circuits and calls made in error to such levels are routed to key-ended trunks on the interception desk. If a subscriber dials a number which does not exist in the Lima numbering scheme, the register automatically directs the call to the interception desk. To care for disconnections and changed numbers between directory issues, any subscriber's line may be connected to a changed number circuit arranged so that all calls to this line are directed automatically to the interception desk.

A 2-position observation desk is provided, the main function of which is to furnish facilities for observing the class of service being given from the subscribers' point of view. Observation circuits are provided giving access over one trunk to a group of subscribers' lines, and arranged so that the operator may identify the calling line, record the called number, etc. Facilities also are included for holding a faulty connection and speaking to the subscriber under observation; these facilities are used only for instruction purposes or when making special observations, the results of which are not included in the general reports.

A special unit is provided for 200 coin box lines in Washington and in Callao. At the present time, automatic prepayment single slot coin boxes for local service are used. The coin is collected when the called party answers or, in the case of an ineffective call, it is refunded when the calling party replaces the receiver. Calls to the toll board from a coin box are directed to a separate group of junctions appearing before the assistance operator, so that this operator may advise the calling party that coin boxes are barred from toll service or, if necessary, may complete the call; in this case, collection or refunding of coins is under the control of the operator. Fig. 4 illustrates the general arrangement of the toll and special service operating room located in Washington.

Power Plant

In the main offices, power plants are operated on a full float basis using shunt generators and automatic voltage regulators. The starting and stopping of the machines is controlled manually. Connections between batteries, power board and and machines are overhead; bare copper bars are used for the main circuits. This minimizes risk of breakdown in the event of damage to the building due to earthquake disturbances and facilitates repair if the plant is damaged. Permanent emergency plants are provided of sufficient capacity to maintain the office in service in the event of failure of the main supply. In Washington the emergency plant comprises a Diesel engine coupled to a generator with an a-c output which can replace the main supply to the battery charging machines, ringing machines, switchrack motors and lighting circuits. In Miraflores and in Callao the emergency plant comprises a gasoline engine coupled to a generator with a d-c output for charging the batteries and operating the duplex switchrack motors.

In sub-offices, power plants are operated on a 10% discharge routine under the control of ampere-hour meters with automatic voltage regulation. No permanent emergency power plant is provided but, in the event of failure of the main supply, the three offices may be maintained in service by means of a portable machine comprising a gasoline engine coupled to a d-c generator complete with control panel for battery charging. This machine is mounted on a trailer which can be towed to any office as required and placed in service on short notice.

Personnel Problem

When the enlarged construction program was undertaken, only a skeleton staff of competent supervisors was available so that one of the principal problems which had to be met was the recruiting and training of local personnel to undertake the construction and, subsequently, the maintenance of the new plant. The company engaged a number of recent graduates from technical schools for the purpose of preliminary training in the theory and practice of telephone work. Thus, by the time the first consignment of 7-A.2 equipment for Washington had arrived in Lima a crew of apprentice installers was available with a satisfactory knowledge of the fundamentals, including cable color codes, technique of soldering, trimming cables and mechanical adjustment of equipment. While instruction classes in the theory of circuits, switch adjustments and localization of troubles were continued, the students were employed on the installation of the equipment. Very satisfactory results were obtained and the first installation of 5,800 lines of 7-A.2 equipment was completed without difficulty by a local staff, which lacked previous knowledge of telephone equipment, under the control of one installation supervisor assisted by one experienced switch adjuster. During the course of the installation work a careful selection was made of the men who had shown the greatest aptitude; they were given special training in testing and other phases of maintenance work. By the time that the new Washington office was cut into service a nucleus of maintenance men was available, sufficiently expert to carry out routines and localize faults.

This plan of training the staff on the job combined with instruction classes has been continued for all branches of maintenance and construction work with very satisfactory results.

Earthquake Precautions

Lima being situated in a zone subject to earthquakes, special precautions were necessary with respect to the type of building construction and method of equipment installation adopted.

The buildings are constructed on the basis of a rigid framework of reinforced columns and beams. The outside walls comprise panels of reinforced concrete between the main columns. The inside walls are of light hollow tile. The complete buildings may be considered as boxes of reinforced concrete which may vibrate as a whole but which will not change their shape when an earthquake occurs.

The vertical channels of the switchracks as supplied by the factory were extended about 50 centimetres. These extension details were then connected together by steel 'U' beams and secured to a main steel framework, in turn fixed to the building columns. The switchracks and superstructure consequently form a solid framework fixed to the main building columns.

1940 Earthquake

On the 24th of May, 1940, at 11:35 in the morning, a violent earthquake totally destroyed the suburb of Chorrillos and caused extensive damage throughout the remainder of the city. During a period of 65 seconds a series of strong tremors caused many old buildings to collapse and seriously damaged those of more modern construction. The worst damage was in the port district of Callao and in the residential district of Chorrillos, particularly in the latter, where practically the entire population was left homeless. In Lima city, the most serious damage occurred in the central district where most of the old buildings, many dating from colonial times, are located. Some of the old churches suffered considerably, notably the church of Santo Domingo, the forty-metre spire of which was completely destroyed.

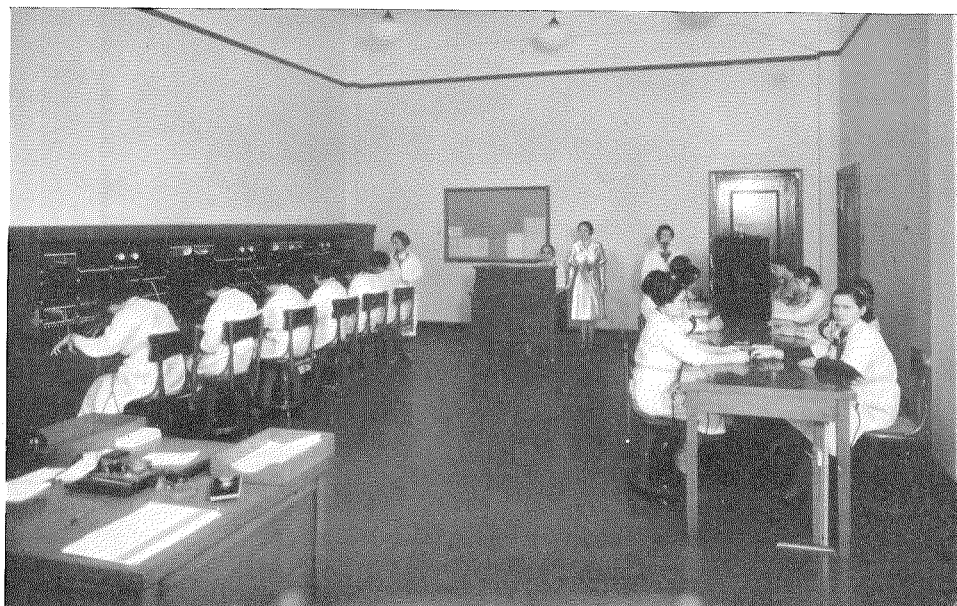As a result of the precautions taken in the construction of the telephone buildings, the robust-

Fig. 4—Toll and Special Service Operating Room in the Washington Exchange.

ness of the Rotary machine switching equipment and the method employed in installation, there was no interruption in the telephone service even during this major disaster. Damage to the central office buildings was limited to cracks in the old portion and to the ornamental parapet of the Washington building. The reinforced concrete structures suffered no damage whatever and the equipment continued to function normally during and after the earthquake. About 2,000 telephones were put out of service, including those due to buildings completely or partially destroyed or to damaged distribution cables. The traffic overload for several hours following the earthquake was very heavy due to the large number of people who attempted to use the telephone to communicate with their homes; also, because of the large number of permanent loops caused by damaged distribution plant, or telephones shaken from tables. Despite these abnormal conditions, no service interruptions occurred in so far as the central offices were concerned although, of course, dial tone delay was considerable, at one time exceeding two minutes. As a result of the excellent work of the local staff, adequate facilities for communication with the most seriously damaged areas were established rapidly and proved of very great value in connection with relief work. The effective aid thus rendered by the telephone company was the subject of special commendation by the authorities.
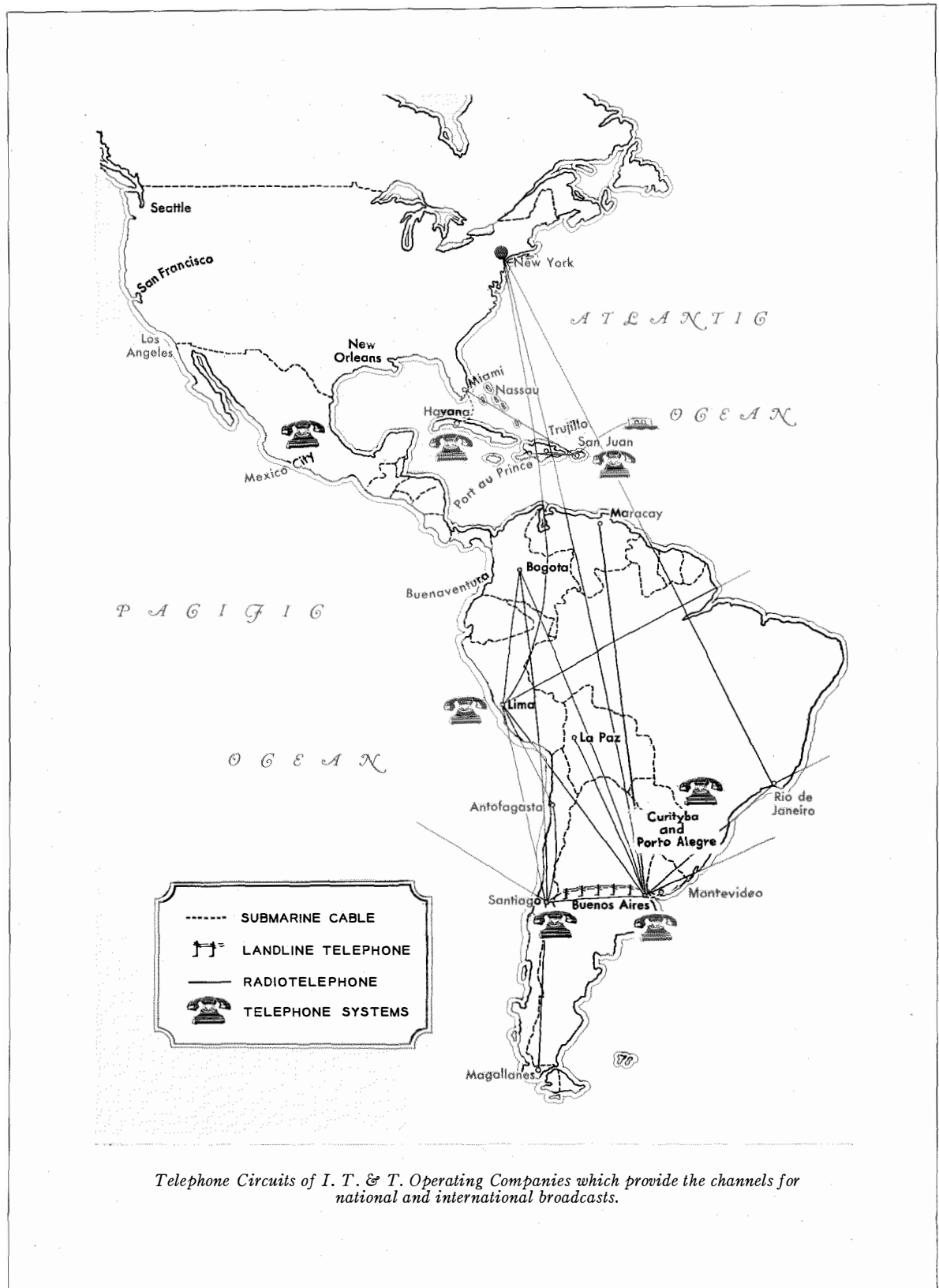
Telephone Circuits of I. T. & T. Operating Companies which provide the channels for national and international broadcasts.

Western Hemisphere Broadcast Networks

President Roosevelt's Fireside Chat of May 27, 1941

By JOHN W. G. OGILVIE

International Telephone and Telegraph Corporation, New York, N. Y.

SINCE radio broadcasting has reached a stage where its unique influence as an educational and cultural medium can no longer be questioned, private organizations largely responsible for its development under governmental regulation are becoming increasingly aware of their responsibility in fostering the Western Hemisphere ideals of democracy and mutual understanding. Consequently, in the past few years, international broadcasts originating in the Americas have become more frequent and interchanges of North and South American programs are a daily occurrence. Fortunately, in these broadcasts the handicap of time difference is present only to a minor degree, and English, Portuguese and Spanish are not unfamiliar to many listeners.

National or international programs to be effective must be available to all having broadcast receiving sets and reception must be reasonably free from static interference; further, listener interest must be aroused either by anticipatory interest based on past experience or suitable advance notice of appealing programs. These requirements are not met by powerful short wave broadcasts because of their hit and miss coverage, lack of adequate short wave receiving sets, etc.

Wide dissemination of programs of this character thus can be effected only through local medium wave broadcast stations to which every radio set owner is a potential listener. For adequate national or international hookups, furthermore, local stations must be served by high quality wire networks or radiotelephone circuits (inter-linked radio stations). It is, accordingly, a happy circumstance that the International Telephone and Telegraph Corporation, primarily due to its activities in developing local, national and international communications in the Southern continent, has at its disposal both wire networks and national and international radio-telephone stations for providing program transmission service to the broadcast stations in many of the important countries in the Western Hemisphere.

An outstanding instance of the potential scope of these facilities was presented by President Roosevelt's Fireside Chat of May 27th from the White House, Washington, D. C., in which he declared an unlimited national emergency. Members of the Diplomatic Corps representing American Republics in Washington, together with their families, were among the President's personal guests.

South American transmission in Spanish was effected over the radio circuit from New York to Buenos Aires where it was fed to an Argentine network through the lines of the United River Plate Telephone Company. From Buenos Aires, the program was conveyed to Uruguay via the submarine cable across the Rio de la Plata laid by I. T. & T. associated companies in 1928. Chilean broadcasting stations participated, both by means of the Buenos Aires-Santiago radio link and the transcontinental line and cable across the Andes Mountains. Bolivia received the program over the radiotelephone circuit from Buenos Aires, as did Bogota, Colombia, and Lima, Peru.

The President's message in Portuguese was transmitted over the New York-Rio de Janeiro radio circuit and was distributed to the entire Brazilian network. Transmissions to stations outside of the Rio de Janeiro and Sao Paulo areas were effected through short wave facilities of the I. T. & T. associated company in Rio de Janeiro.

Reports confirmed the excellent transmission quality and the interest evoked by the address. The South American network, giving coverage to an estimated ten million listeners, was the most comprehensive ever established on that continent for a single program originating in the U. S. A.

Plant Facilities of the Mackay Radio and Telegraph Company in the New York Area

By HARADEN PRATT

Vice President and Chief Engineer, Mackay Radio and Telegraph Company, New York, N. Y.

Historical

THE Mackay Radio and Telegraph Company first commenced the construction of its radio communication facilities at New York in 1928. Prior to that time, its operations had been confined to the Pacific Coast where its predecessor, the Federal Telegraph Company, in 1910, had inaugurated public domestic radiotelegraph and ship-to-shore services.

The famous old radio station, call letters WSL, built by a German company in 1911 near Sayville, Long Island, and enlarged by the U. S. Government in 1918, was leased from the Navy Department as the nucleus for a transmitting station. Property was acquired near Southampton, L. I., for receiving purposes, and a Central Operating Department was established at 20 Broad Street, New York, N. Y.

The first public service to be opened was ship-to-shore. It was established early in 1929, using transmitters installed at Sayville, receiving and operating facilities at Southampton, and a small harbor marine station located on the roof of the 20 Broad Street building. Various other public services were opened from time to time: to South America, the West Indies, Central America, Europe, and points within the United States.[1] The entire present day Mackay Radio System is shown diagrammatically in Fig. 1.

In 1931, the International System decided to locate the Operating Departments of its Cable and Radio Companies at 67 Broad Street, New York, in the International Telephone Building.

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[1] "The Mackay Radio and Telegraph Company Communications System," M. H. Anderson, *Electrical Communication*, Vol. 19, No. 4.
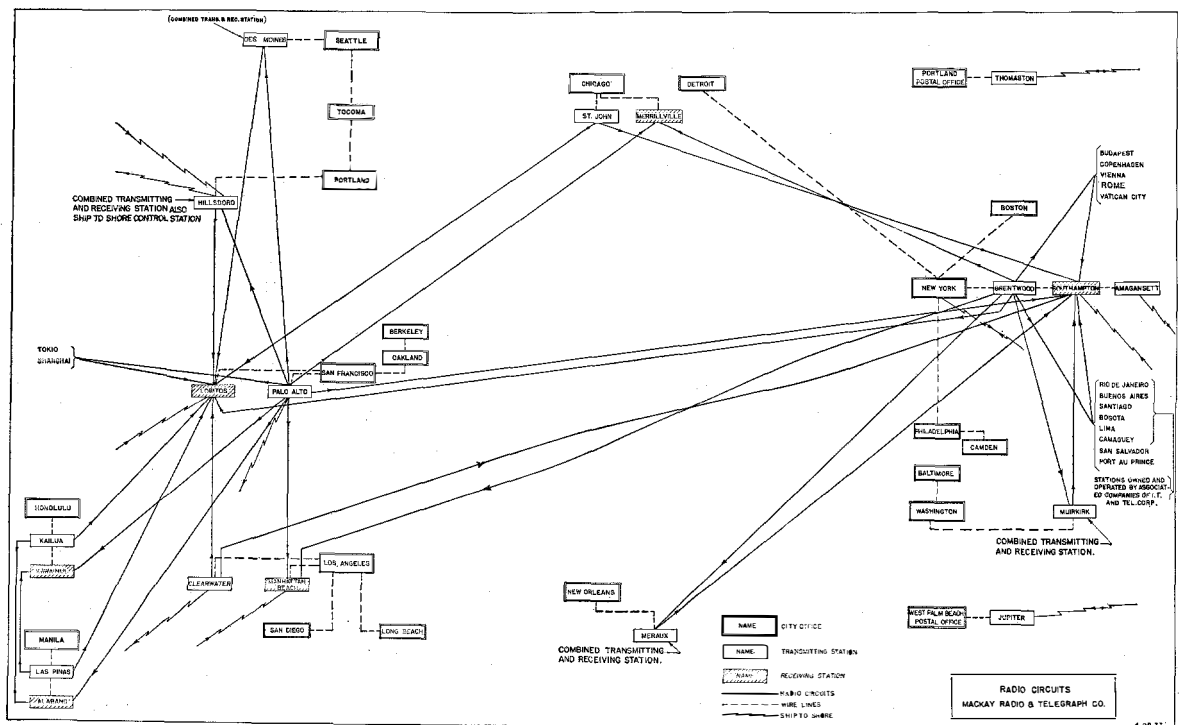
Fig. 1—Radio Circuits of Mackay Radio and Telegraph Company.

A — NEW YORK CENTRAL OPERATING DEPARTMENT AT 67 BROAD ST.
B — COMBINED CENTRAL MARINE BUREAU AND HARBOR STATION.
C — BRENTWOOD POINT TO POINT TRANSMITTING STATION.
D = SOUTHAMPTON POINT TO POINT RECEIVING STATION.
E = COMBINED MARINE RECEIVING AND OPERATING DEPARTMENT.
F — AMAGANSETT MARINE TRANSMITTING STATION.
1 = CONTROL LINES FOR AUTOMATIC KEYING OF TRANSMITTERS FROM OPERATING DEPARTMENT.
2 = CONTROL LINES TO AUTOMATICALLY PASS RECEIVED SIGNALS FROM RECEIVING STATION TO OPERATING DEPARTMENT.
3 = TELEGRAPH WIRES FOR HANDLING SHIP MESSAGES BETWEEN NEW YORK MARINE BUREAU AND MARINE OPERATING DEPARTMENT AT SOUTHAMPTON.

Fig. 2—Mackay Radio Stations and Operating Organizations in the New York Area.

Mackay Radio, consequently, constructed and placed in operation, during the latter part of that year, a new and improved Central Operating Department with space adequate for expansion to meet future growth. This department was located on the same floor with the Operating Departments of the Commercial Cable Company and All America Cables, Inc., all three being interconnected by message carrying belts and pneumatic tubes. The small harbor marine radio station was also moved to 67 Broad Street at the same time.

Due to the high attenuation of radio waves in the intermediate frequency band (near 500 kc) over Long Island ground, the operation of the ship-to-shore service, using the transmitters at the Sayville station, was found to be unsatisfactory. A new transmitting station for ship-to-shore operation was constructed near Amagansett, L. I. (Napeague Harbor), and placed in operation in 1932. Here, because of close proximity to Long Island Sound on one side and the

Atlantic Ocean on the other, losses due to ground absorption were negligible.

By the year 1933, the operations of the Company became sufficiently extensive to make necessary the construction of a new transmitting station, since the small size of the Sayville property restricted possibilities for expansion. In July 1934, construction was started on a new transmitting station, near Brentwood, L. I., where an 1100 acre site was acquired. In 1936, the Sayville station was discontinued, all point-to-point and shore-to-ship transmitters having been transferred to the new Brentwood and the Amagansett stations, respectively. The latter was enlarged to accommodate all transmitters for the ship-to-shore service.

To meet the Company's growing requirements, the receiving station property at Southampton was also extended and a new building erected, equipped and placed in operation in 1935 for the point-to-point services.

For some years the Company carried forward
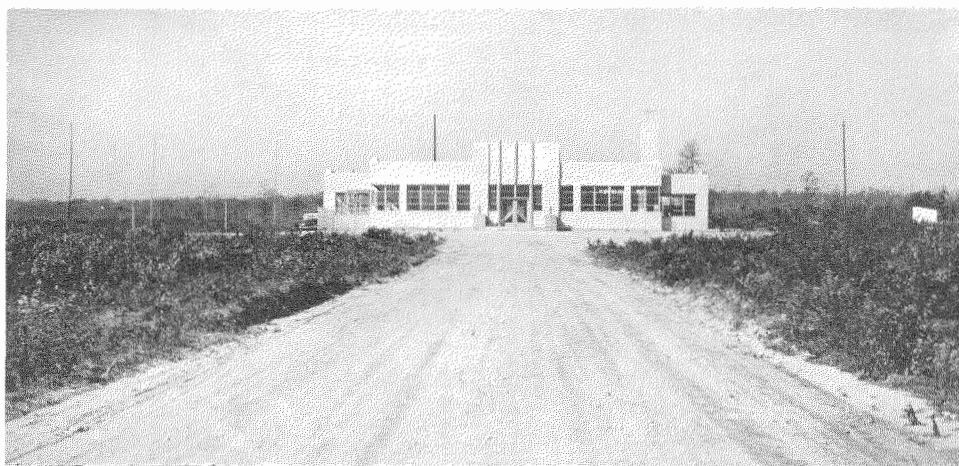
Fig. 3 A—Brentwood Transmitting Station, Main Building.

development work on a remote control system for conveying signals automatically between the Central Operating Department in New York and the transmitting and receiving stations, utilizing ultra-high frequency radio circuits in place of leased wire lines. Such a system was established and has been in successful operation for the past few years; it is, in fact, being expanded. At the present time, it is used for the control of all transmitters at Brentwood, and for a portion of the channels used to carry received signals from the Southampton receiving station to New York. Radio frequencies in the 100 megacycle region were first utilized. New allocations by the Federal Communications Commission required the rebuilding of the system in 1939 for frequencies near 135 megacycles; in 1940, the Commission again made new allocations, requiring another rebuilding to permit the utilization of frequencies near 160 megacycles.

Fig. 2 indicates the stations and operating organizations in the New York area and their interrelation.

Brentwood Transmitting Station

This property is situated near the center of Long Island north of the town of Bayshore. Here is located the main building (one story with basement) and auxiliary structures for the power substation, ultra-high frequency receiving apparatus, pump house, garages and storage sheds.

The main building and a floor plan are shown in Figs. 3 A and B. It houses 22 high frequency transmitters, ranging from 10 to 50 kw output (except one 2 kw unit), and all auxiliary apparatus. Direct current power for the anodes of amplifier tubes is supplied by 23 motor driven generators, ranging in output capacity from 3 kw at 3000 volts to 20 kw at 8000 volts, four small rectifiers at 3000 volts and six large rectifiers at 10,000 volts. Total capacity of all of these supplies aggregates 950 kw. Transmitter output amplifiers may be switched to more than one large rectifier; normally, several transmitters are served by one rectifier. A plug type switchboard permits any transmitter driver to be connected to any 3000 volt generator or rectifier. A system of locks and keys prevents interconnection of power sources. Cooling of tubes is effected by a water circulatory system equipped with two pumps (one a spare), each of 550 gallons per minute capacity; heat is transferred to the air through three large multi-fin cooling units backed by multi-vane blowers arranged so as to permit cooling the building in summer and heating it in winter. A continuously operating water conductivity measuring device is included in the cooling system.

Most of the transmitters consist of a 2 kw driver and an output power amplifier. Output amplifiers are of 10, 20 and 50 kw ratings. Each driver has three trays which roll out like file cabinet drawers, each tray containing a very low powered oscillator followed by some low powered amplifiers, permitting the setting up of three different frequencies. A selector switch connects the desired tray to the succeeding radio amplifier stages and to the amplifier power supply located within the unit. Other three position selector switches connect the proper pre-set tank
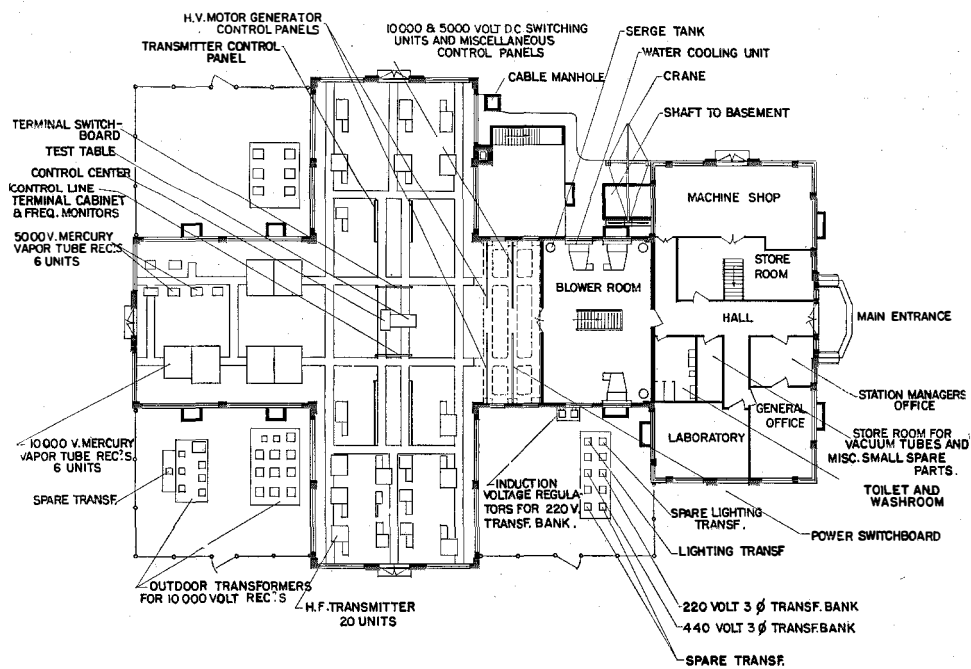
FLOOR PLAN — MAIN FLOOR
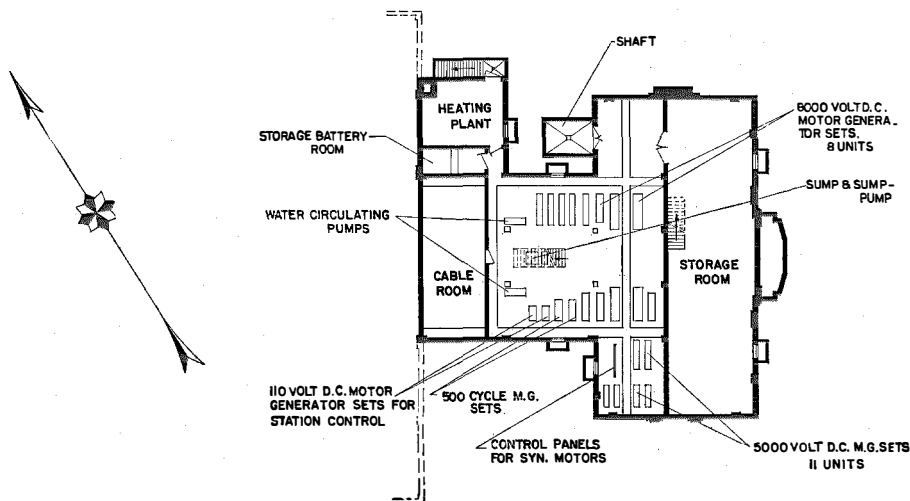
FLOOR PLAN — BASEMENT

Fig. 3 B—Brentwood Transmitting Station. Floor Plan of Main Building.

circuit inductance for these stages, final tuning being done by resetting condensers. Thus shifting from one frequency to another can be accomplished very rapidly. Two transmitters used for the morning and evening transition frequencies have only one driver tray. Two other transmitters have three trays between them. The single 2 kw transmitter, used for the circuit to Washington, D. C., consists only of a driver unit equipped with three trays.

Oscillators are of a non-crystal control type, located in temperature controlled ovens; their power is supplied from a constant voltage regulating transformer, one of which is included in each driver. All oscillator tubes and their oven heaters run continuously and, therefore, are available for use instantaneously.

Motor generators, pumps, heating plant, a 60 cell storage battery and a large stockroom are in the basement. On the main floor are located offices, laboratory, machine shop, small stockrooms, water cooling apparatus and, in one large room, all switchboards, rectifiers, radio transmitters, monitoring equipment and control apparatus. This large room is made up of four building wings arranged in the form of a cross, at the center of which is the control desk and its associated apparatus racks. All transformers for power supply and for the six high voltage rectifiers are mounted on concrete slabs out of doors.

Electric power is purchased at 23,000 volts, passed through a substation of 600 KVA capacity located at the west boundary of the property and carried to the main building through two 2300 volt underground feeders, each 3000 feet long. At the building, transformer groups of $37\frac{1}{2}$, 150 and 450 KVA supply power for lighting purposes, 230 volt and 460 volt loads, respectively. Voltage regulators are associated with the 230 volt supply so that vacuum tube filaments can be energized from a source not subject to line voltage variations. Communication circuits are available from the south boundary of the property through a multi-conductor underground communication cable. Water is secured from a deep well.

The station is provided with twenty-seven directional high frequency antennas, oriented to points in Europe, West Indies, South America and Central America, as well as to Washington,

D. C., New Orleans, Chicago, San Francisco and Los Angeles. Many of these antennas are provided with tuning networks, enabling them to be efficiently operated on any one of two or three frequencies without requiring any switching or physical changes other than connection to the desired transmitter. Several of the largest and most important antennas are provided with discriminating networks so that two transmitters, each working independently on a different frequency, may be operated simultaneously. Such operation has resulted in very marked economy in antenna costs, as well as in conservation of land area.

The special line impedance changing elements developed by the Company to accomplish these results, consist primarily of two types known, respectively, as re-entrants [2] and coupled sections.[3] The choice of type for a particular application is dictated by the conditions to be met, primarily frequencies used, the difference between them, and convenience in the physical disposition of the element at the point of application on the transmission line or its branches. In some cases, a single antenna will employ both types. The most flexible, however, is the coupled section. This device can be easily attached, has no electrical contact with the line, can be positioned and adjusted quickly, and produces no effect except for the frequency for which it is adjusted. Thus, by the use of this type of element on an existing antenna, line and antenna impedances can be matched for a new frequency without creating any mutual disturbances due to previously established set-ups for other frequencies operating on the same antenna. If re-entrant elements are used, they must be employed in conjugate relationship for multi-frequency operation.[2]

One mile and one mile and a half, respectively, from the main building are situated two small receiving stations, each equipped with two ultra-high frequency receivers, which are used to receive signals coming from New York and from the Southampton receiving station. One station is provided with 100 foot poles and the other

[2] "High Frequency Transmission Line Networks," Andrew Alford, *Electrical Communication* January, 1939.
[3] "Coupled Networks in Radio Frequency Circuits," Andrew Alford, *Proceedings IRE* February, 1941, pp. 55–70.

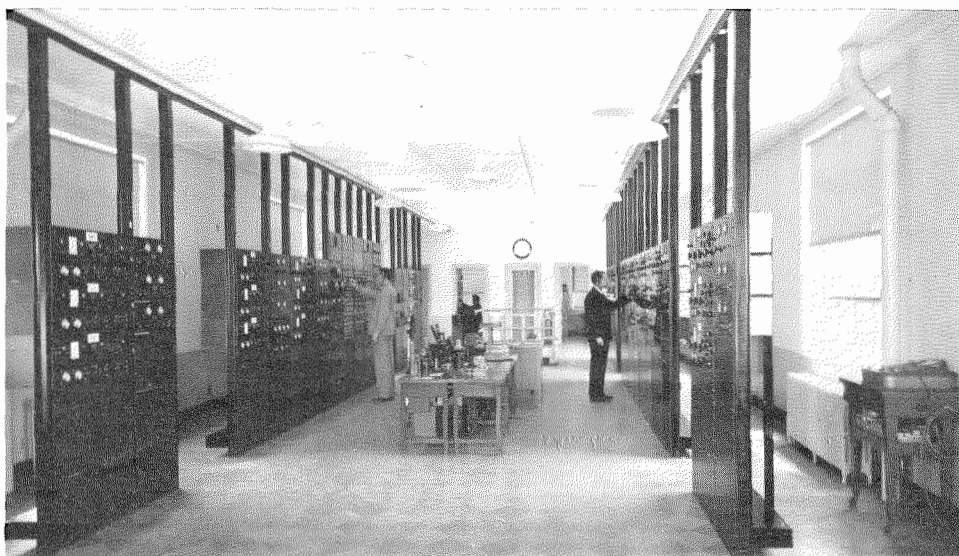*Fig. 4 A—Southampton Receiving Station, Point-to-Point Building.*

Fig. 4 B—Southampton Receiving Station, Point-to-Point Receiving Room.

with 200 foot guyed steel masts for supporting several ultra-high frequency antenna systems. Underground power and communication cables connect these points with the main building where the received signals are brought for connection to the terminal apparatus. The receivers are unattended and can be switched off and on from a control panel located at the operating center in the main building, at which place monitoring instruments are provided so that the operator in charge can check the operation of the receivers. This ultra-high frequency control system will be described in more detail hereinafter.

Southampton Receiving and Marine Service Control Station

Located north of the town of Southampton is the receiving station for both the point-to-point and shore-to-ship services. A one story and basement building houses the point-to-point equipment (Figs. 4-*A* and *B*). On the main floor are located the office, forty-seven radio receivers, a control board and a primary frequency standard including several associated receivers. In the basement are motor generators, storage batteries, charging equipment, heating plant, shop and ultra-high frequency audio terminal equipment.

Receiving apparatus is grouped in bays, each containing three receivers and one diversity keyer arranged as a unit for diversity operation. Switching facilities, however, provide complete flexibility, enabling the diversity groups to be made up of receivers and keyers regardless of location. Monitoring facilities permit listening in on any receiver or keyer output by means of an interlocking switch-key system. Two of the above mentioned receivers are associated with the ultra-high frequency remote control system.

The frequency standard, with its receivers, mixers and other devices, which enables any frequency between 15 kc and 165 mc to be picked up and accurately measured, is located in a separate room.

Connected with this building are fifteen high frequency antennas, including three for the frequency standard set-up. Most are of a directional aperiodic type; several receivers operating independently on different frequencies can receive signals from one antenna. For diversity reception, antennas are arranged in groups of three, being directed toward Europe, South America and the Pacific Coast of the U. S. A. Outdoor type transformers of a unique design, suitable for a 5 to 22 mc range, match open wire transmission lines from antennas to twisted conductor pairs having a characteristic impedance of about 125 ohms and low loss insulation. These twisted lines enter the building underground and reach receivers via a patching jack panel.

In another building of two stories and basement is located the Marine Receiving and Operating Department. On the main floor two low,

two intermediate and eight high frequency receivers are mounted on a table arranged in the shape of a "U," accessible to operators seated within the "U." These operators have the control of the ship-to-shore transmitters at the Amagansett station. Message traffic for this Operating Department is transferred to and from the Company's Marine Bureau at 67 Broad Street, New York, N. Y., over a telegraph circuit.

Low and intermediate frequencies in the bands allocated internationally for ship services are picked up by rotatable loop antennas located on the top floor of the building in conjunction with outdoor antennas supported above the building, permitting unidirectional reception from any direction. This arrangement aids in reducing interference from undesired signals and discriminates considerably against static which comes predominantly from a southwesterly direction.

Seven high frequency antennas are available for reception from ships, some of which are directed toward the North Atlantic ship lanes. Switching facilities available at each high frequency operating position allow selection of directive or non-directive antennas.

In the basement of this building are storage batteries, charging equipment, heating plant and storeroom.

Other small buildings provide for two ultra-high frequency transmitters, material storage and an emergency, gas engine driven power plant. The ultra-high frequency transmitting antenna is supported on a 200 foot guyed steel mast. The gas engine generating plant is capable of supplying all power requirements on the property. Power and communication conductors between buildings and to the utility companies are underground.

Amagansett Transmitting Station

This station (Fig. 5) is situated on a narrow neck of land between Long Island Sound and the Atlantic Ocean, located in a salt water marsh which floods at high tide. The one story building contains one 10 kw intermediate frequency transmitter, two 15 kw low frequency transmitters and three 10 kw high frequency transmitters. One 100 kw 10,000 volt and two 25 kw 10,000 volt rectifiers supply anode power for output ampli-
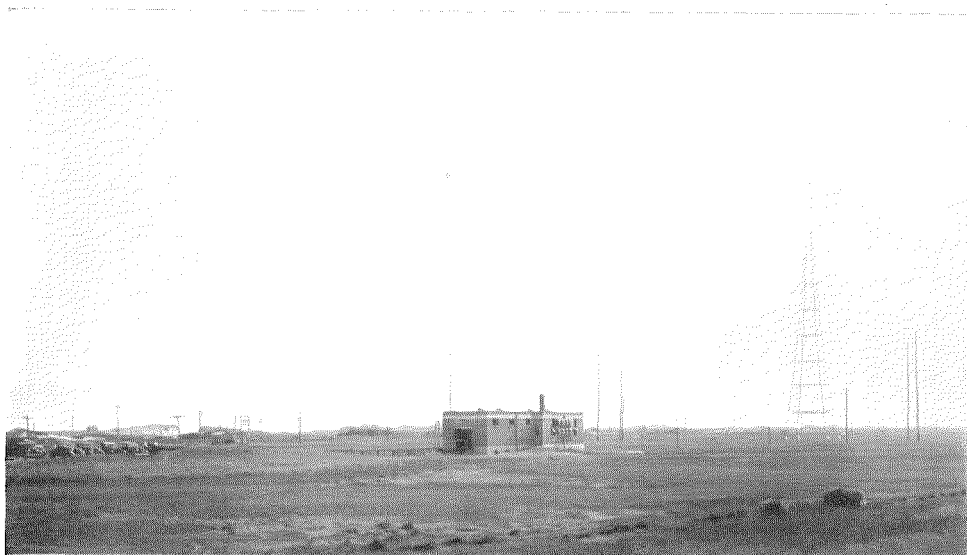
Fig. 5—Amagansett Transmitting Station.

fiers. Two 5,000 volt and two 3,000 volt rectifiers provide power for tubes in other amplifier stages. A flexible high voltage switching system permits connection of any combination of loads to any power supply. The central water circulating and cooling system for water cooled tubes is of the type described above for the Brentwood station, but of smaller capacity.

The high frequency transmitters each consist of one 2 kw, three tray driver, associated with two output amplifiers. This permits rapid frequency change inasmuch as the idle output amplifier can be pre-tuned at leisure for the frequency next to be employed.

Of the nine high frequency antennas, some are directional, others non-directional types. The operators at the Southampton control station select the antenna desired through a selective switching system, which also serves to shift the intermediate frequency transmitter from calling to working waves, or vice versa, at the will of the operator in control. The directional antennas are oriented to serve the North Atlantic ship lanes. The non-directional antennas radiate vertically polarized waves; some are stacked and fed with power to create radiation predominantly in the horizontal plane but tilted upwards in all directions at an angle favorable to the frequency and distance involved.

Two 300 foot non-guyed steel towers support one low frequency and one intermediate frequency antenna. Both are provided with means for melting sleet by circulating through their conductors large currents obtained from the 60 cycle power supply. A two frequency network arranged for 109 and 120 kc permits feeding the single low frequency antenna by both low frequency transmitters simultaneously.

Power is supplied from the Power Company's nearby substation at 4000 volts through two underground feeders. Communication lines also enter via an underground cable.

New York Central Operating Department

The sending and receiving of messages for the point-to-point services is performed in the Central Operating Department on the fifth floor of the International Telephone Building at 67 Broad Street, New York, N. Y. Messages arrive and leave via pneumatic tubes and belts which connect with the Commercial Cable Company, All America Cables and Radio, Inc. (all on the same

Fig. 6 A—Portion of Mackay Radio Operating Department, International Telephone Building,
67 Broad Street, New York, N. Y.
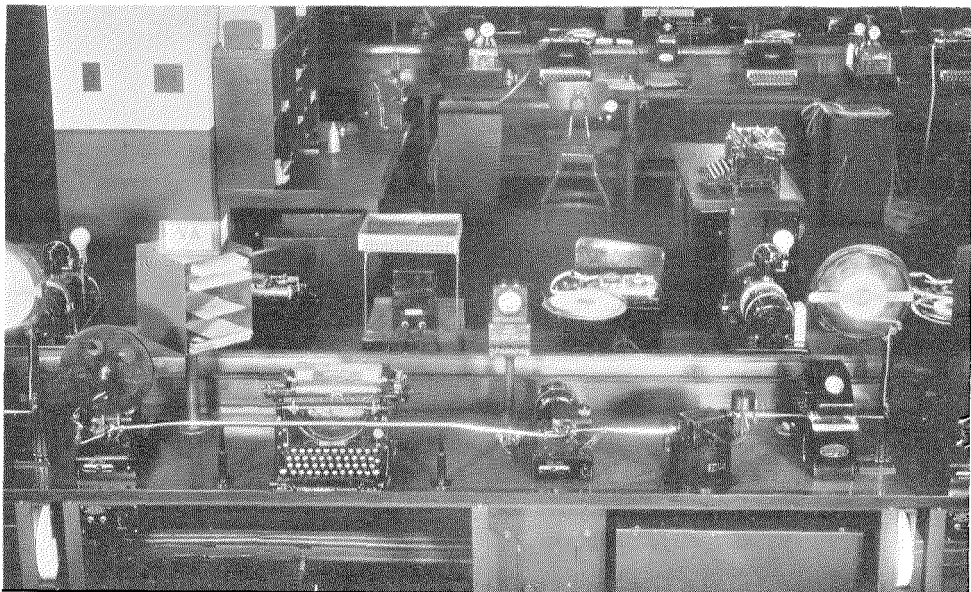
Fig. 6 B—View of Automatic Transmitting and Receiving Equipment, New York Operating
Department, 67 Broad Street, New York, N. Y.

floor) and the Postal Telegraph Company at 20 Broad Street. Tie lines, printer circuits and special telephone lines provide connections to many important customers.

The facilities directly associated with the radio circuits comprise groups of transmitting and receiving operating positions (Figs. 6, *A* and *B*). Each transmitting position is equipped with a keyboard perforator by means of which the sending operator spells out the message onto a paper tape in the form of perforations. An automatic transmitter translates the tape perforated message into the electrical dot and dash impulses which make up the telegraph code and which automatically key the radio transmitter at the Brentwood station. Each receiving position is equipped with a tape ink recorder which scribes a zigzag line, corresponding to the telegraph signals being received, on a moving paper tape. Paper reels, draw-off motors, and a tape guide in front of a typewriter provide the means that enable the receiving operator to transcribe the message contained on the tape to a message blank by typewriter. A time stamp automatically marks this tape at frequent intervals for providing an accurate record of time of receipt of messages. One or more transmitting positions are operated as a group with one or more receiving positions to terminate a duplex radio circuit permitting the flow of traffic in both directions simultaneously. As normally operated, corresponding transmitting and receiving position tables are located back to back with the operators sitting at them facing each other. Each receiving position has a hand key enabling the operator to break in on the transmitting position of the duplex circuit. When this hand key is depressed the transmitting circuit, which is being controlled by the automatic transmitter, is shifted to the hand key and a red warning light is illuminated on the transmitting position. A delay type relay restores the normal connections a short time after cessation of hand key manipulation. This arrangement allows the receiving operator to ask for repeats or give instructions to the other end of the circuit without delay.

The automatic equipment is capable of transmitting and receiving at speeds up to 200 words per minute, which is far beyond the capacity of one operator on each side of the duplex circuit.

For circuits involving traffic volume beyond the handling capacity of one man per side, positions are ganged up into groups of two or three. A three position group would have three sending and three receiving positions manned by six operators. The incoming signal is connected to all three receiving position recorders in sequence under the control of the operators by means of key switches provided with indicator lights. When an operator has finished transcribing the message on the tape before him, he waits for the end of the message being recorded and transcribed by one of the other operators. At this moment he moves his switch key which stops the writing of the recorder of this other operator and transfers the signal to his own recorder. At the next appropriate interval between messages the third operator will take over the recording in the same manner. Thus the received signals are passed around among three operators, who between them can keep up with the rate at which messages are arriving.

A similar arrangement for the three transmitting tables enables three operators to prepare punched tape at a rate sufficient to keep up with the speed of the automatic transmitter.

A special group of operating positions is associated with a radio concentrator for handling lightly loaded circuits that do not justify the continuous attention of individual operators specifically assigned to them. The concentrator permits the connection of a busy circuit to an unoccupied operator.

A monitor recorder, capable of making twenty four traces on both sides of a wide paper tape, records all outgoing radio signals. This record has been found invaluable from an operating standpoint in facilitating the identification of errors, equipment difficulties, etc.

The outgoing signals from the operating tables control tone keyers which are associated with the ultra-high frequency control system, the radio transmitters for which are on the roof of the building. Signals from the receiving station arrive as audio tone currents, which are converted by amplifier-rectifiers into direct current suitable for energizing the recorders.

The office is equipped with a total of 19 transmitting and receiving positions, and 6 com-

bination transmitting and receiving one-man positions associated with the concentrator.

A printer operating group terminates leased wires connecting with Philadelphia, Camden, Detroit and Boston.

New York Marine Bureau and Harbor Marine Station

Located also on the fifth floor at 67 Broad Street is the Marine Bureau (Fig. 7) which includes a telephone PBX board, telegraph connections to the Southampton Marine Operating Department, pneumatic tube connections to other carriers, and the receivers and transmitter controls for the small harbor marine radio station previously mentioned. Two unattended transmitters of one kw output each, located on the

35th floor of the building, provide service on the intermediate and low frequency bands used in the mobile service.

Ultra-High Frequency Control System

All transmitters at the Brentwood station are remotely controlled from the New York Operating Department through an ultra-high frequency radio transmitting and receiving link. Two ultra-high frequency transmitters operating in the band 156 to 162 mc are located in a small house on the roof of the building in New York with a power output of approximately 50 watts each. A control panel with monitoring instruments in the operating room provides remote starting and stopping of this apparatus which otherwise is unattended. One of the transmitters is a spare.
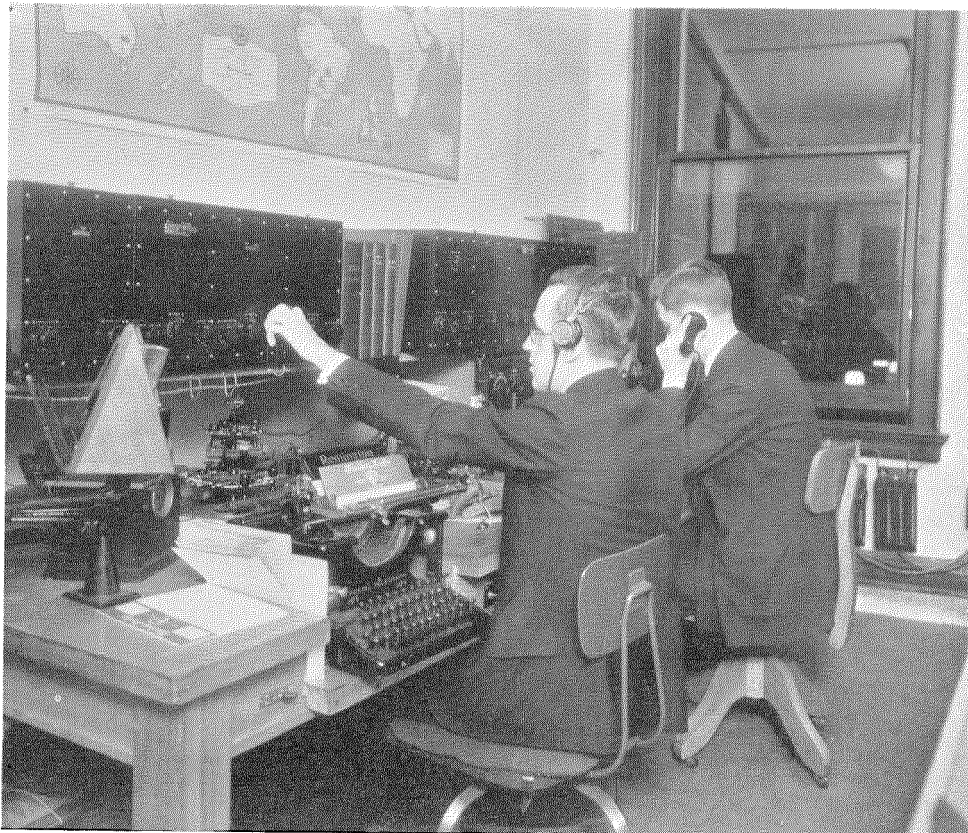
Fig. 7—New York Marine Harbor Station, Operating Positions.

The transmitter is arranged for modulation by 23 frequencies ranging from 200 to 12,000 cycles. These audio frequencies represent the individual telegraph control channels, each frequency being keyed by one of the circuit, operating table transmitting positions in the operating room. At Brentwood a receiver removes the carrier frequency, and the resulting low frequency currents derived from the receiver output are passed through filters and then converted into direct current. These direct current impulses are then individually used for keying the radio transmitters. Seven of these low frequency keying channels are for moderate speed operation, the pass bandwidth of the filters being approximately $62\frac{1}{2}$ cycles. The other 16 channels are for high speed keying with pass bandwidths of the order of 300 cycles.

A similar system operates between Brentwood and Southampton, and is being used for carrying six channels of received signals from Southampton to Brentwood, where they are repeated and passed over leased wire circuits to the New York Operating Department. This system is being expanded and, at the present time, similar facilities are being provided between Southampton and Amagansett to enable transmitters in the Amagansett station to be remotely controlled from the Marine Operating Department at Southampton.

The system between New York and Brentwood has been in successful operation for several years and that between Brentwood and Southampton for the past two years. It is of interest to note that this ultra-high frequency system was of considerable value at the time of the 1938 hurricane, during which period there was considerable damage done to the wire line plant on Long Island. Temporary installation of ultra-high frequency facilities between Southampton and Amagansett at that time made possible the resumption of service a number of days prior to the restoration of the wire line system normally used.

The Company has carried on considerable development work on ultra-high frequency antenna systems, and is successfully using array types with gains of the order of 9 to 12 db, designed to minimize the effects of sleet. During a severe sleet storm in the spring of 1940, one of these array type antennas operated successfully for several days while heavily coated with ice.

Neither the New York-Brentwood, nor the Brentwood-Southampton antennas are in a line of sight. The propagation path in each case crosses several groups of Long Island hills.

A Street in Colima After Partial Clearance.
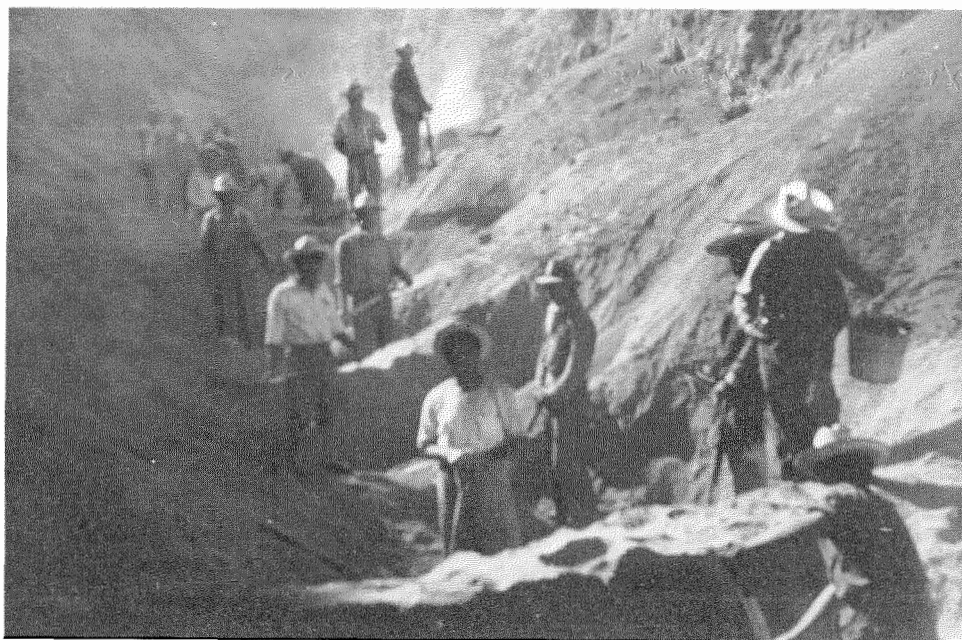
Railroad between Guadalajara and Colima Buried Five Meters as a Result of Landslides.

Earthquake—Colima, Mexico

By M. MEHL

General Plant Superintendent, Compañía Telefónica y Telegráfica Mexicana

Editor's Note

This account of recent earthquake destruction of outside plant in a sparsely settled section of southwestern Mexico far from headquarters, and measures taken to restore the telephone service is based on the author's field notes. To reach Colima as rapidly as possible he traveled by automobile, mule back and on foot over regions where roads had disappeared, vast dust-laden torrid deserts and dried up lakes, sleeping under freight cars and suffering from weariness, blistered feet, hunger and thirst. The record provides another instance of the high determination of the communications worker to maintain communications notwithstanding difficulties imposed by man or nature.

ON April 15th, 1941, at approximately 1 p.m. a severe earthquake shook the southwestern part of Mexico. While considered equally severe in Mexico City both as to intensity and duration, the resulting destruction in the Capital was relatively unimportant due to the character of the subsoil.

Routine checking within Mexico City showed that none of the Mexican Telephone and Telegraph Company plant had suffered damage. It was soon found, however, that all the Company circuits between Guadalajara and Colima, a pole line distance of 259 km, were out of commission. The telegraph service also was interrupted and the railroad between the two towns was destroyed. The afternoon papers reported that Colima and Tuxpan, with populations of 24,000 and 1,500, respectively, had suffered severely along with small neighboring villages.

In view of the seriousness of the situation, the author immediately left for Colima via Guadalajara, Sayula, and Ciudad Guzmán, arriving there after three days of travel by automobile, mule back and some 50 kilometers on foot. Normally, the train trip from Mexico City
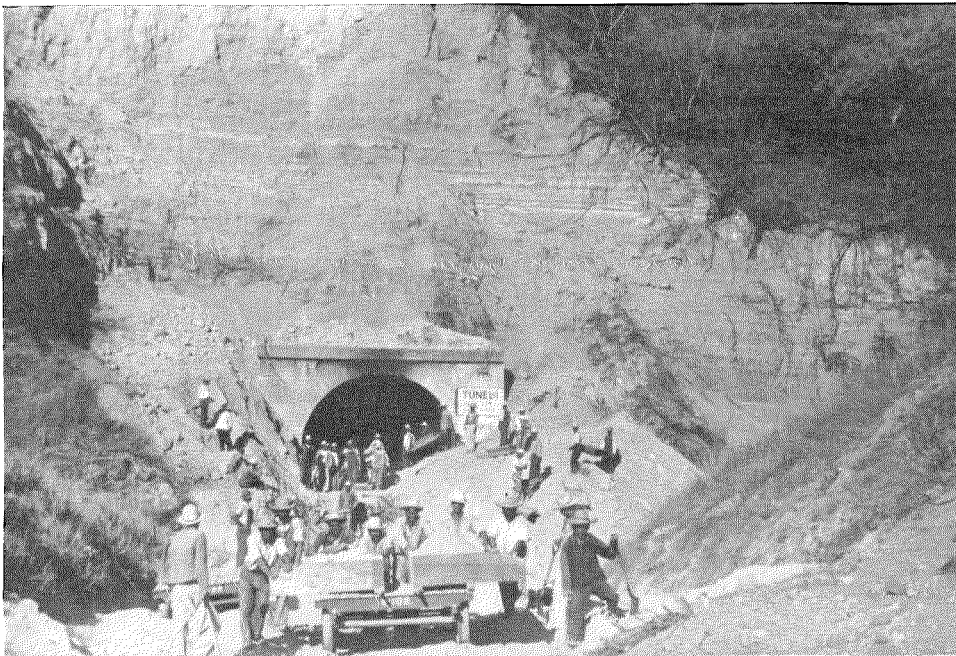
Clearing a Tunnel Head After Complete Obstruction by Landslides.

45

to Colima, a distance of about 450 miles, takes 20 hours.

Reaching Colima after dark and traversing the ruins of the city with the aid of a flash light, the author found the telephone office only slightly damaged. But the general aspect of the city was deplorable: the houses in general being of adobe were in ruins, and the streets were completely blocked with debris. Martial law had been proclaimed and the inhabitants were living in the public squares and gardens. Light and water services were unavailable. Telephone toll circuits were severed in numerous places between Colima and Guadalajara, due mainly to landslides. Work to re-establish service was immediately started, but progress was retarded due to set-backs occasioned by landslides and blasting by railroad repairmen. On Sunday, April 20th, five days after the catastrophe, a telephone call was completed from Colima, via Guadalajara, to Mexico City.

News of re-establishment of telephone service and consequent resumption of contact with the outside world occasioned great excitement. Long queues were formed by people desirous of getting in touch with families in neighboring towns.

The local outside plant was found to be practically totally covered by wreckage. It was mainly of special block construction consisting of small iron poles attached to the roofs of houses; cable messengers and cables were suspended from the poles. When the houses collapsed, the cables parted and were almost a total loss. Drop loops also were damaged but were repaired and re-used.

Local service to the Government, Police Force and hospitals was almost immediately restored by running drop loops from temporarily erected poles.

The question arose as to whether Colima should be rebuilt on its present site or moved elsewhere. The residents, in general, preferred the present location, but decision was deferred pending arrival of the President of the Republic who was expected as soon as railroad service could be
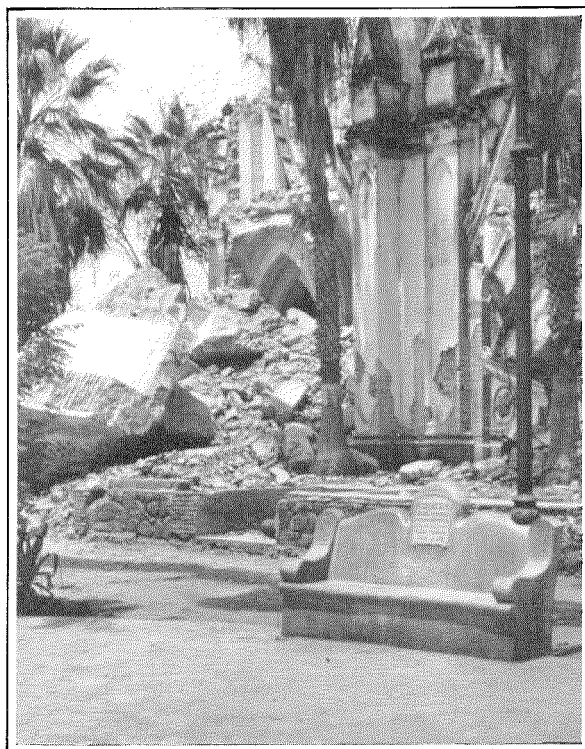
Colima Cathedral in Ruins.

resumed. On learning that the majority of the people wished Colima restored on its present site, the President acceded to their views.

Prior to returning to Mexico City, the author visited the towns of Tuxpan and Zapotiltic, both of which had been completely destroyed. These towns are relatively small and the resulting loss of life and property fortunately was not great. It is claimed that the tremors in this section were more intense than those of the San Francisco earthquake of 1906.

Prior to the earthquake the Company had 248 telephones in Colima. By June 23d, 187 telephones had been restored to service and 36 installations were being deferred pending reconstruction of buildings. The balance of 25 telephones was lost as a result of subscribers moving from the city or discontinuing their service.

Selenium Rectifier Characteristics, Applications†
and Design Factors

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Starting with a brief review of the general functions of a rectifier, this article describes the Selenium Rectifier (including static and dynamic characteristics), gives examples of applications in the power and communications fields and an indication of data required for specific rectifier designs. Subsequent articles will be devoted to: (a) novel applications of Selenium Rectifiers and (b) methods of rectifier design.

The Selenium Rectifier, due to its reliability, flexibility and economic advantages, is finding wide application in practically all branches of industry. The decision, made in 1938, to commence manufacture in New York was particularly fortunate because of the practically unlimited supply of selenium in North America.

THE importance of efficient, economical rectifiers results from the almost universal acceptance of alternating current for generation and distribution of power, coupled with increasing demands for direct current obtained from an a-c source. For a-c rectification, consequently, motor generators, rotary converters, vacuum tubes, liquid and vibrator types of rectifiers, as well as metallic-junction or dry plate rectifiers such as the Selenium Rectifier, have found wide application.

The Selenium Rectifier is an International Telephone and Telegraph associated company development; it was introduced in Europe in essentially its present form in 1928. (Latest available estimates of its acceptance abroad indicate that 88% of metallic-junction rectifiers in use are of the selenium type.) Application in the U.S.A. commenced in 1938 when the International Telephone and Radio Manufacturing Corporation,* New York, commenced its manufacture. An indication of its wide range of application may be obtained from Fig. 1, showing an oil-immersed, 6 volt, 1,000 ampere, three phase, full wave, center tap connected rectifier employing the largest size selenium plates available and, for comparison, held between the thumb and forefinger, a rectifier stack made up of four of the smallest size plates in regular production

in a single phase, full wave, bridge connected rectifier for an output of 12 volts, 150 milliamperes.

Basic Considerations

A rectifier is defined as a device possessing the ability to pass electric current freely in one direction while offering much greater or almost total resistance to the passage of electric current in the reverse direction. Thus crystal detectors may be classified as rectifiers, though their power capacity must be measured in microwatts, as compared with kilowatts handled by metallic-junction rectifiers of much greater effective rectifying surface. The ideal rectifier, if such existed, would offer zero resistance to the flow of current in the forward direction and infinite resistance to the flow of current in the reverse or blocking direction. Lacking ideal rectifiers, selection must necessarily be made from available types with due consideration of important factors such as first cost, useful life, annual charges, size, weight and efficiency.

Rectifier Plate Construction

I. T. & T. Selenium Rectifiers differ in their construction from other rectifiers of the metallic-junction type, principally in the electrodes themselves and in their semi-conducting layers. In these rectifiers the semi-conducting layer is derived from the metallic element selenium and consists of the thinnest practical coating (approximately 0.05 mm) of high purity selenium applied to one side of a processed steel plate, which serves as the back electrode. The selenium

coating is itself covered with an alloy, serving as a low resistance front electrode and providing uniform distribution of current throughout the active material. Further heat treatments create a layer between the front electrode alloy and the selenium, resulting in increased difference in resistance for currents flowing in the forward and reverse directions. Current flows readily from the back electrode to the front electrode, i.e., in the steel to selenium direction, but practically not at all from selenium to steel. Each plate thus constitutes a valve or half wave rectifier; full wave rectification is obtained with two or more half wave elements in one of the conventional single or three phase circuits.

Electrical and Physical Advantages

Fig. 2 illustrates the construction of a Selenium Rectifier plate in cross section, but does not re-present the relative thicknesses of the various layers. Besides serving as a back electrode the sturdy steel plate provides rigid support, giving the strength necessary to withstand physical shocks, vibration and stresses. The steel also provides the necessary surface for convection cooling under all normal operations. Rectification takes place entirely within this one-piece sturdy plate.

The plates range from $\frac{3}{4}$ inch to $4\frac{3}{8}$ inches in diameter, seven sizes in all; they may be assembled in compact stacks consisting of the plates, contact discs, spacers, insulators, terminals and a center stud with or without mounting brackets. The flexible, petal-shaped contact discs are of brass and make contact with a considerable area of the rectifier plate. Contact terminals are brought out from the plates in various arrangements for series or parallel con-
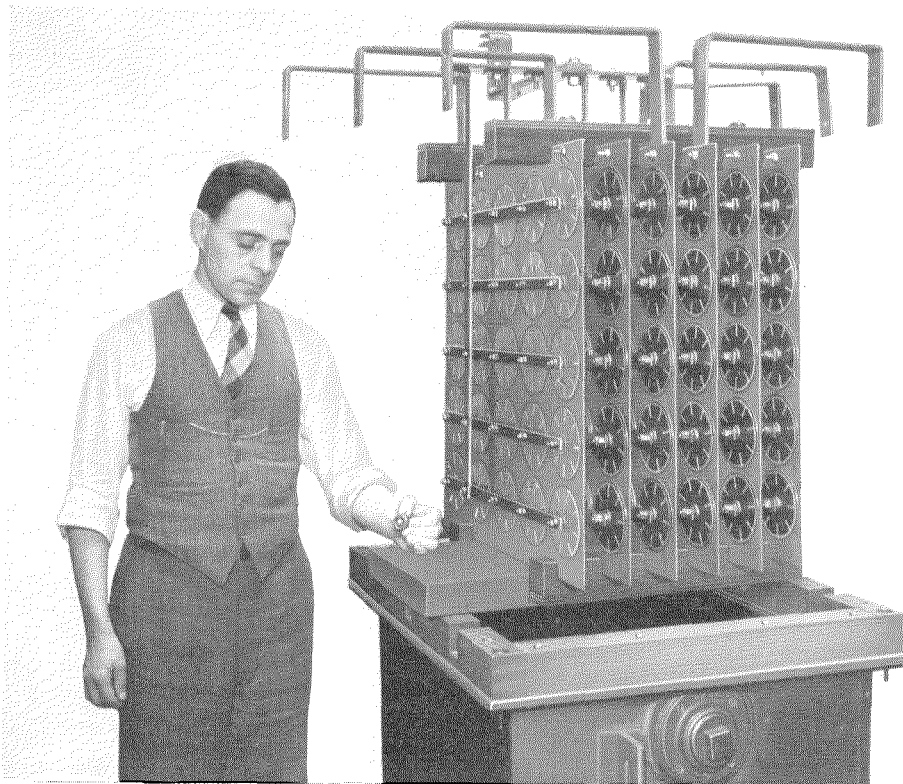
Fig. 1—Oil Immersed 6 v, 1000 amp., 3 Phase, Full Wave, Center Tap Connected Rectifier (Shown Out of Its Oil Tank Below) and 12 v, 150 ma, Single Phase, Full Wave, Bridge Connected Unit.

nection of the plates, as required. Since each plate is a complete rectifying element, pressure is not required beyond that necessary to establish electrical contact and the rectifier therefore is not critical to pressure changes. The electrical parts of the stack assemblies are completely insulated from the stud and mounting brackets. If necessary, high potential tests of individual stacks may be applied up to 3,000 volts a-c, thus exceeding A. I. E. E. requirements. Parts of a rectifier stack are shown in Fig. 3.

Unlike thermionic rectifiers which depend upon heat to produce electron emission, the d-c output from a Selenium Rectifier is available immediately upon application of the alternating voltage, avoiding the delay of a heating-up period. The materials of Selenium Rectifiers do not deteriorate during normal operation. Since Selenium Rectifiers are electronic devices their life is not limited by chemical action or thermal elements which may wear out. They have in fact been in continuous service over a period of many years without showing any signs of deterioration and hence are assumed to possess unlimited life. There are no moving parts or materials requiring maintenance or renewal.

The rectifier stack is essentially an assembly of compact, light metal parts ruggedly built to outlast associated equipment. An assembled I. T. & T. Selenium Rectifier stack is shown in Fig. 4. It will be noted that the rectifiers are designed for mounting with the assembly stud in a horizontal position so that normal air convection provides for all but unusual cooling requirements.

With proper protection of metal parts Selenium Rectifiers can be used under highly unfavorable atmospheric conditions and the normal separation of electrical parts permits their use at high altitudes. For most applications the output is sufficiently stable as a function of time and temperature not to require compensation, and the device lends itself readily to use in circuits with manual or automatic adjustment.

High permissible reverse voltages and high permissible working temperatures make it possible to obtain high power output with a small quantity of plates. These factors permit light, small rectifier stacks. Relatively large unobstructed cooling surfaces permit the use of small diameter plates. Simplicity of design, light hard-
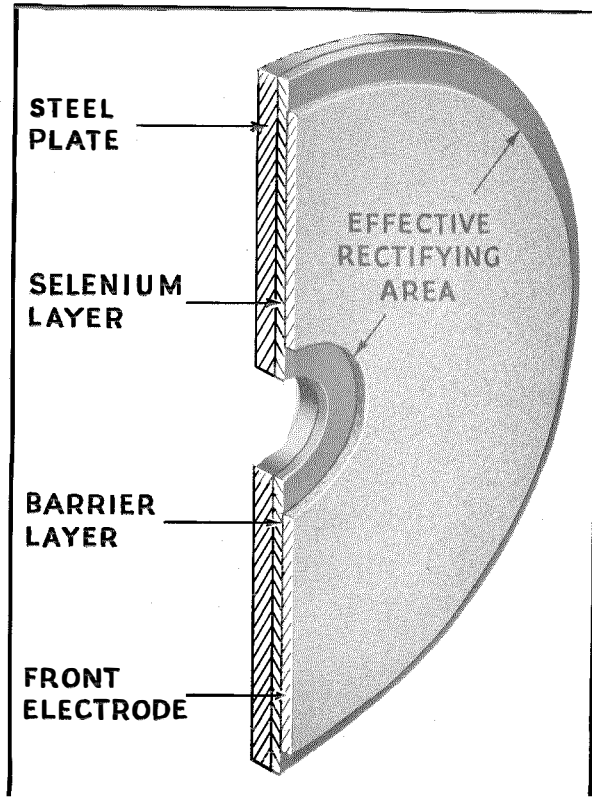

Fig. 2—Cross-Section of Selenium Rectifier Plate.

ware and compactness of the units, added to flexibility in mechanical and electrical arrangements, permit easy installation of Selenium Rectifiers and their adaptation to unusual requirements.

Rectification occurs over a wide range of applied frequencies.

Static Current Characteristics

Static forward and reverse characteristics of a Selenium Rectifier are shown in Fig. 5. Attention is directed to the fact that the reverse current is plotted to two scales because of its low values. The ordinate for the dotted reverse current curve is only 1/100th of that used for the solid line. The curves represent the static characteristics of a Selenium Rectifier plate of one square centimeter effective area. The characteristic always passes through the origin with the current increasing rapidly for low values of forward voltage and finally becoming almost linear. Due to its very low resistance in the forward direction and
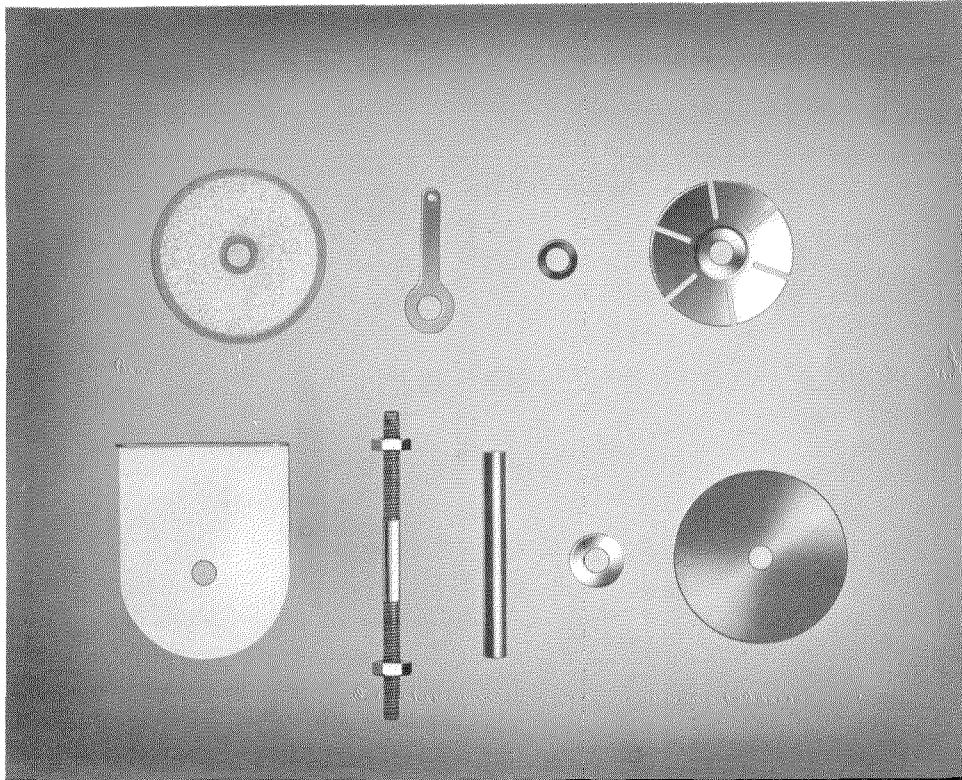
Fig. 3—Components of a Rectifier Stack.

Top Row, Left to Right: Selenium Rectifier Plate; Terminal Lug; Pressure Limiting Washer; Petal-Shaped Contact Disc.
  Bottom Row, Left to Right: Mounting Bracket; Center Stud; Insulating Sleeve; Spacing Washer; End Insulator.

high resistance in the reverse or blocking direction, a high rectification ratio with good regulation is attained.

Applications of Static Characteristic

The negligible reverse current or "back leak" shown as a solid line in Fig. 5 finds a valuable practical application in battery charging rectifiers through the elimination of equipment for disconnecting the battery from the rectifier when the rectifier is turned off or the a-c supply is interrupted. This characteristic also makes possible the use of one or more single plates connected as a valve between an automobile or airplane generator and its associated battery in place of the usual cutout relay. When the gener-

ator voltage exceeds that of the battery, current flows through the valve to charge the battery, but when the engine driving the generator slows down or stops, the high back resistance of the valve prevents battery discharge through the generator.

A further example of valve action is presented by the connection of a rectifier plate of appropriate size across an inductance in a d-c circuit for quenching the arc across a disconnect switch or contactor. The valve is so connected that it does not pass the d-c impressed on the inductance, but when the d-c circuit is broken, the inductance discharges through the low resistance path of the valve with practically no increase in the voltage across the inductance. Resistance may

be inserted in the valve circuit to adjust the rate of current decay.

Translation of the static characteristic curve into resistance values (Fig. 6) shows that the single plate valve has a negative resistance characteristic in the forward direction closely approximating an exponential curve. The forward resistance increases sharply from a low value at the normal operating current to a maximum as the voltage approaches zero. If two valves are paralleled with their conducting directions in opposition, the device becomes a variable resistance shunt for an applied a-c and has proved effective as a volume limiter or acoustic shock reducer in telephone circuits subject to severe inductive interference. The double valve unit is connected across the telephone receiver or other portion of the circuit to be protected. For normal speech currents of low voltages, the shunting effect of the valve unit is negligible. For high voltages due to inductive "kicks" the valve resistance drops instantaneously to low values, thus effectively limiting the voltage across the telephone apparatus; consequently, the sound output level is not injurious to the ear of the telephone listener.

Dynamic Current Characteristics

The dynamic forward and reverse current characteristics of Selenium Rectifiers may be
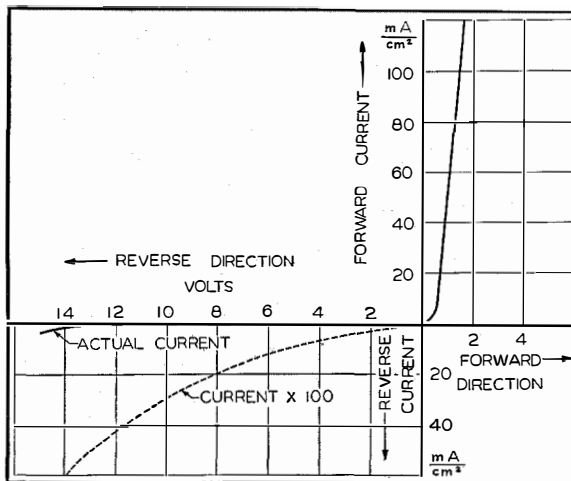
Fig. 5—Typical Static Forward and Reverse Current Characteristics. Reverse Characteristic Shown to 2 Scales.
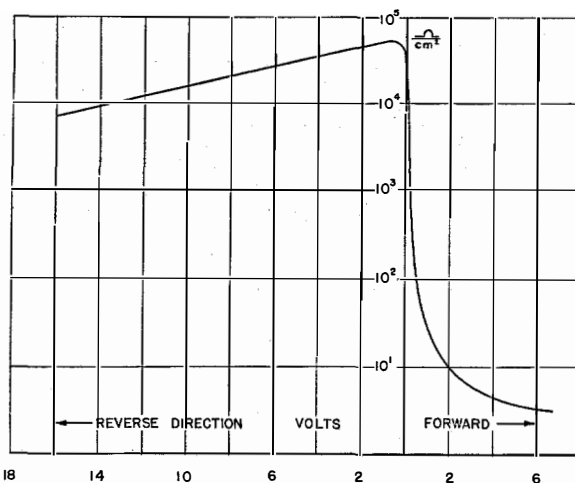
Fig. 6—Typical Static Resistance—Voltage Curve of a Selenium Rectifier Plate Having an Effective Surface Area of 1 cm².

graphically observed and studied with the aid of an oscillograph. Fig. 7 shows the wiring diagram employed for such studies and the accompanying description indicates the technical procedure followed. Figures 8 and 9, respectively, are reproductions of oscillograms of the dynamic forward and reverse current characteristics of a single Selenium Rectifier plate.

Unlike most electrical apparatus, the forward resistance characteristic of the Selenium Rectifier as a function of plate temperature has a negative slope. The resistance decreases rapidly
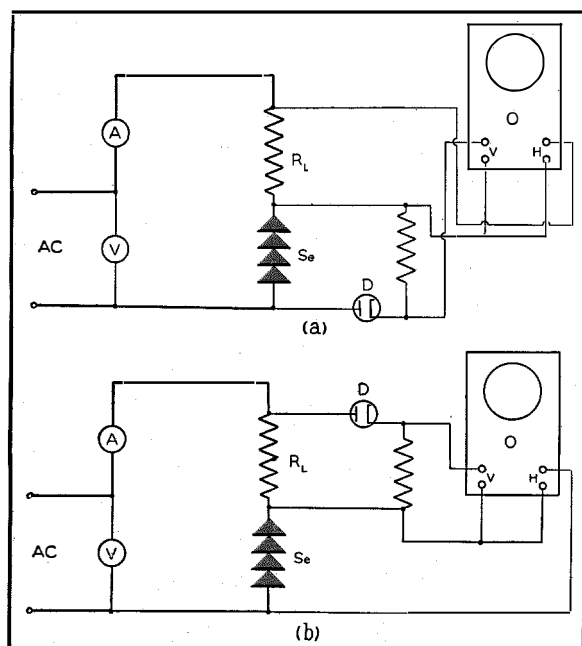

Fig. 4—I. T. & T. Selenium Rectifier.

Fig. 7—Connections for Obtaining Dynamic Characteristics of Selenium Rectifiers: (a) Forward Characteristic; (b) Reverse Characteristic.

Rectifier, Se, is connected in series with an alternating current supply, AC, and pure resistance, R_L. Since the overall characteristic involves large changes in voltage and current values depending on whether the Rectifier, Se, is blocking or passing current, the circuits above give means of recording the passing and blocking characteristics separately.

For the forward characteristic, the oscillograph, O, is connected as in (a). The voltage across the resistance, R_L, is so connected that the horizontal deflection of the oscillograph is proportional to the valve current. The high voltage peaks of the valve voltage in the reverse direction are suppressed by the diode, D, and this voltage is then connected to the oscillograph so that the vertical deflection is proportional to valve voltage.

For the blocking characteristic the oscillograph is connected as in diagram (b). The high blocking voltage of Se is now connected for producing horizontal deflection. The voltage across R_L, due to reverse current, is impressed on the vertical deflectors through the diode D. The vertical deflection hence is proportional to the reverse current.

By connecting several valves in series, the average characteristic of the several valves is then obtained with little distortion due to the diode D.

as the temperature increases from very low values, but only slightly in the usual range of working temperatures. The upper curve of Fig. 10 shows the relative drop in voltage across a plate, or its decrease in resistance, with temperature rise, for a constant full load current density. It should be noted that the total rectifier forward resistance is only about 10% of the total load circuit resistance; hence, the change in the rectifier voltage drop is a quite negligible percentage of the value of the output voltage.

Furthermore, rectifiers which must operate at unusually low temperatures generally also must be designed for high temperature operation and their rated current or current density decreased in accordance with Fig. 11 which is fully discussed later. Thus the relative change in internal voltage drop compared to a normally loaded rectifier is decreased; the lower curve of Fig. 10 shows this change for a current density corresponding to one-tenth full load. In actual service, the negative temperature coefficient of the rectifier resistance is largely counter-balanced by the positive temperature coefficients of transformer, choke and load resistances.

Variation in reverse resistance at 2 and 18 volts, respectively, is indicated in Fig. 12 for the same range of plate temperatures. Actual resistance values are different but, in order to show the form of the two graphs on one illustration, both the 2 volt and 18 volt reverse currents are assumed as unity for a rectifier temperature of 25° C. It is obviously of fundamental importance that the reverse resistance be and remain high even under extreme temperature conditions.

Applications of Dynamic Characteristics

The relatively small change in reverse current with temperature contributes not only to the high efficiency of the rectifier and extends its usefulness over a wide range of temperatures, but it also is of value in protecting a rectifier load including an e.m.f. such as a battery from inadvertent discharge. In railway signal use, for example, groups of batteries and their associated trickle chargers, such as the type shown in Fig. 13, are housed along the right of way, usually in black-painted, weather-resistant cabinets with restricted ventilation. While this arrangement serves to maintain the ambient temperature inside the cabinet well above the outside temperature in cold weather, the inside temperature may rise to excessively high values during sunny summer days. Under such conditions it is a prime requisite that the rectifier reverse resistance be maintained as high as possible.

Power Factor

From a dynamic standpoint, the negative resistance characteristic of the Selenium Rectifier tends to produce a forward current wave shape in

which the successive half wave pulses deviate very slightly from true sine wave form because of the minute changes in forward resistance which follow the cyclic change in input voltage. Although current and voltage pulses are in phase in the rectified output, the measured wattage does not exactly equal the product of the measured effective current and voltage due to the harmonic content of the output. Thus the measured rectifier power factor differs slightly from unity and is found to be of the order of 97% to 99% in single phase, depending on conditions of use.

Stability of Output

Both the forward and reverse resistances of the Selenium Rectifier increase with age, causing a higher internal drop and consequent decrease in output voltage, which is offset to some extent by the smaller loss in the reverse direction (Figs. 14 and 15). Aging usually takes place within the first 10,000 hours of full rated continuous operation. In intermittent or light load operation this period is longer; in extreme cases, 40,000 to 50,000 hours. A new rectifier will show no change in output for a considerable length of time, and,
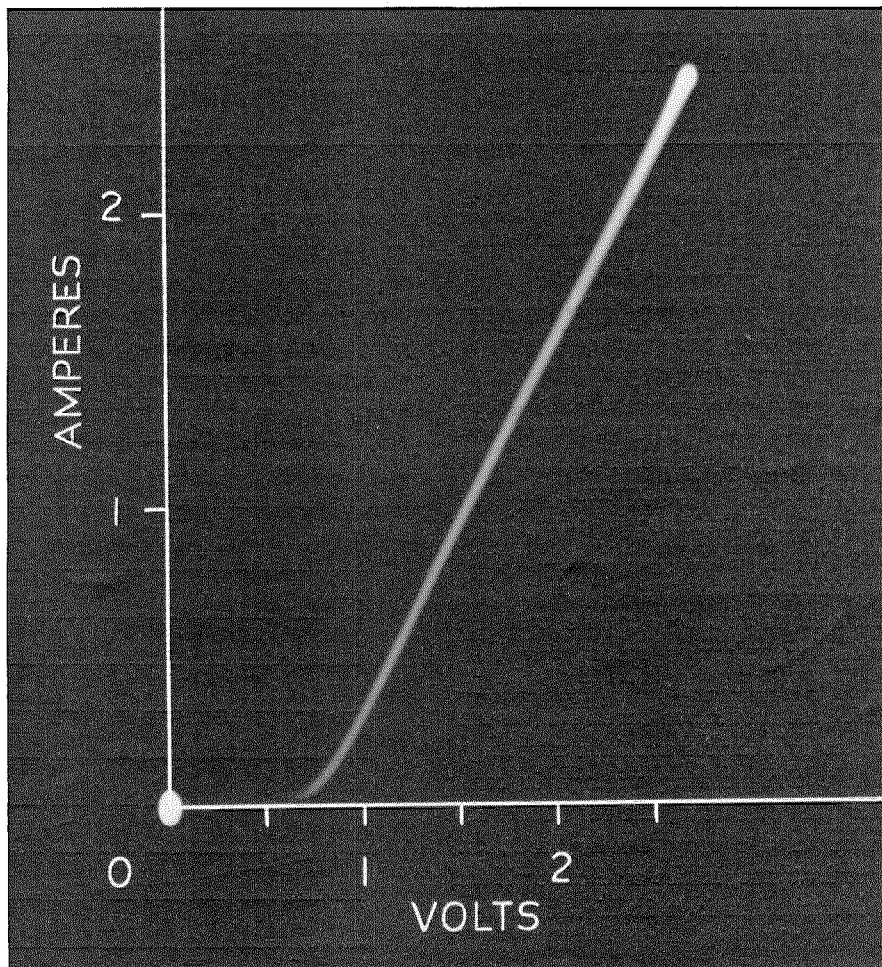
Fig. 8—Oscillogram of Dynamic Forward Current Characteristic.
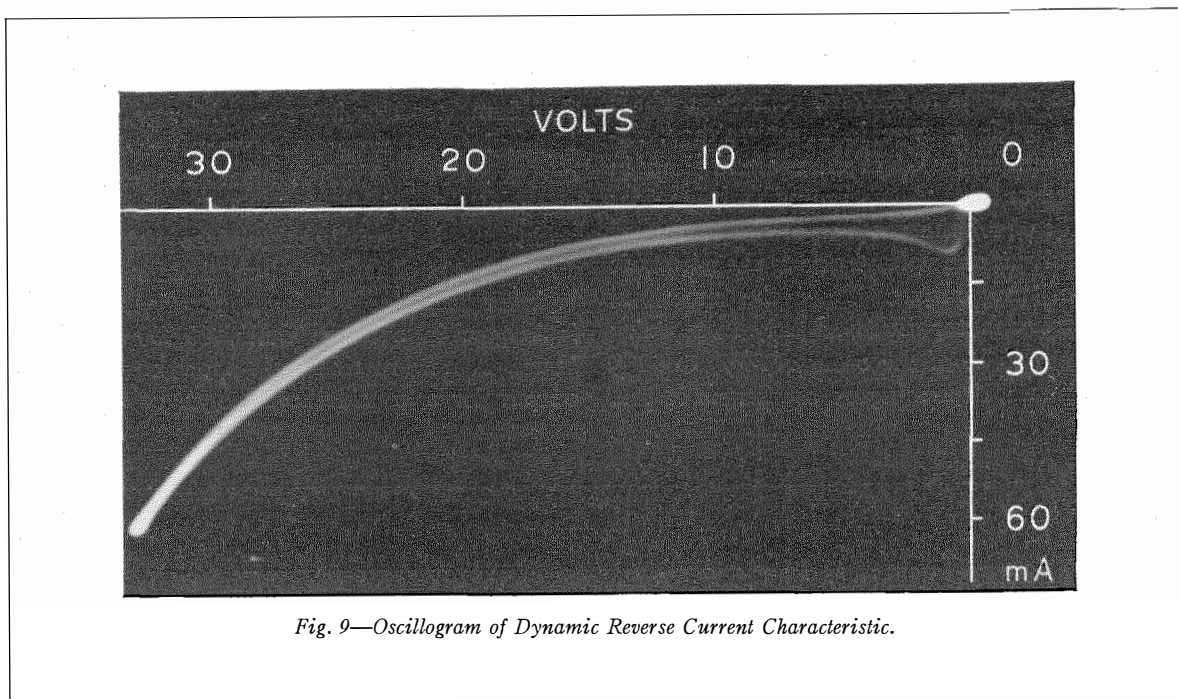
Fig. 9—Oscillogram of Dynamic Reverse Current Characteristic.

once it has fully aged, no additional changes in output occur. The shape of the aging curve and the time required are functions of the specific conditions of use and cannot readily be predicted. Experience shows that in the majority of cases aging can be entirely neglected.

If full compensation is required, the a-c input voltage may be raised after aging to restore the d-c output to its original value. For normally spaced rectifiers without supplemental cooling fins, the amount of this increase in a-c voltage usually does not exceed 5%. With wide spacing of plates or cooling fins the increase may be as high as 10%, and at least two 5% taps should be provided on the transformer secondary. Fan cooled units may require 15% compensation in extreme cases. These values are based on the use of the rectifier at or near its maximum voltage per plate. Where the working voltage is considerably under the maximum, the required percentage increase in a-c may be higher than indicated as, for instance, in the case of rectifiers operating at decreased ratings in high ambient temperatures.

Cooling and Temperature Considerations

Selenium Rectifiers are designed with adequate self-cooling facilities utilizing normal air con-

vection. Forced draft cooling may be employed and operation under oil is practicable for both protection of metal parts and cooling.

Since the forward resistance of a Selenium Rectifier is not zero (Fig. 5), the forward flow of current generates heat. The very small flow of current in the reverse direction also adds to the heat generated within the plate. The alloy employed as the front electrode has a lower melting temperature than the selenium; the
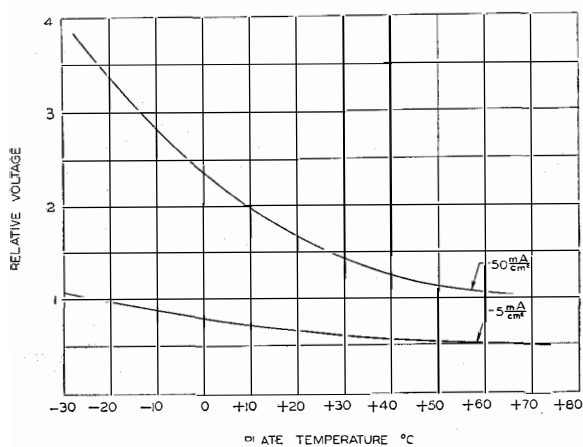

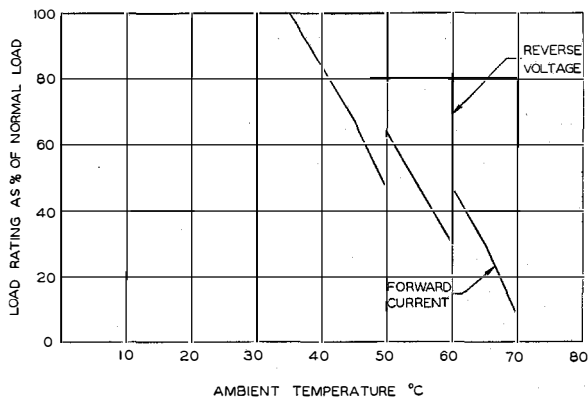*Fig. 10—Forward Voltage Change with Temperature for Full Load and One-Tenth Full Load.*

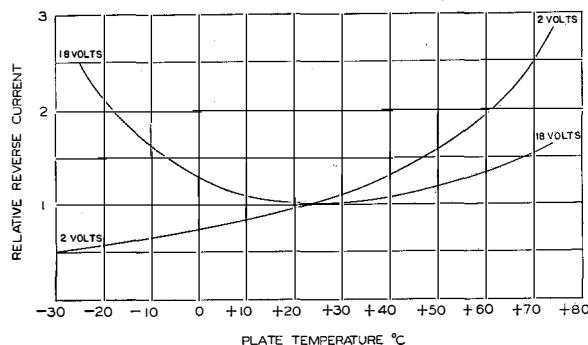Fig. 11—Load Rating vs. Ambient Temperature.

Fig. 12—Reverse Current vs. Plate Temperature for Normal Voltage and a Fraction of Normal Voltage.

melting temperature of the alloy, therefore, sets the *absolute maximum* temperature at which the rectifier plates may be operated. Considerations of safety require that the temperature rating of selenium plates be established with an ample margin of safety below this limiting maximum temperature.

Ambient Temperature Range

Like most electrical power equipment, Selenium Rectifiers are designed for a temperature rise of 40° C. above an ambient temperature of 35° C. (95° F.) for continuous operation. Their maximum safe plate temperature of 75° C. (167° F.), for aged plates, affords an ample safety factor for the metallic coatings of the plate and at the same time permits the use of the rectifier over wide ranges of ambient temperature.

Extremely low ambient temperatures of the order of −40° C. (−40° F.), or lower, are favor-

able to I. T. & T. Selenium Rectifier operation since they offer a larger margin between temperature of the surrounding air and the maximum safe operating plate temperature.

When the rectifier must operate in ambient temperatures above 35° C., the rectifier power output must be decreased or the size of the rectifier increased so that the sum of internal forward and reverse losses will not raise the plate temperature beyond a maximum of 75° C. Since the reverse losses are a function of the applied a-c voltage and the forward losses vary with load current, both voltage and current ratings are decreased as the ambient temperature increases towards 75° C.

The percentage of decrease in ratings necessary when the ambient temperature exceeds 35° C. is represented in Fig. 11. It will be noted that at 50° C. and 60° C. either of the corresponding pairs of ratings may be used, the choice being determined by economic considerations or the physical dimensions of the respective designs.

The high temperature at which the Selenium Rectifier can be operated permits many unusual applications, including outdoor use and condi-
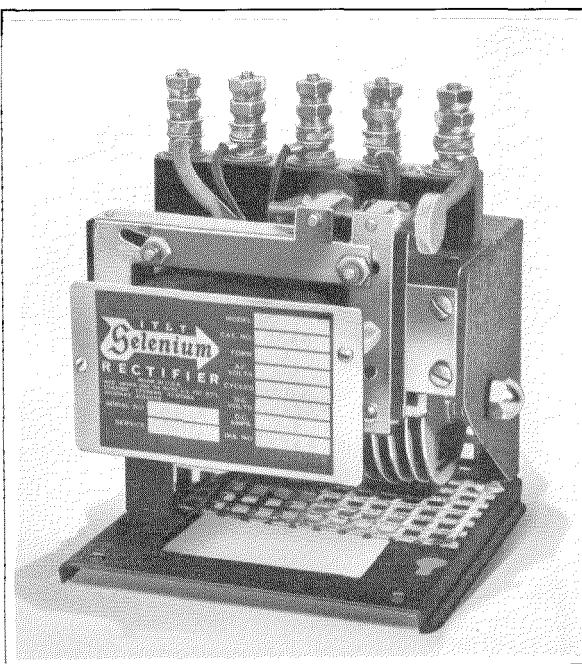

Fig. 13—Battery Charging Rectifier with Case Cut Away to Show the Selenium Rectifier. (Courtesy of Fansteel Metallurgical Corporation.)
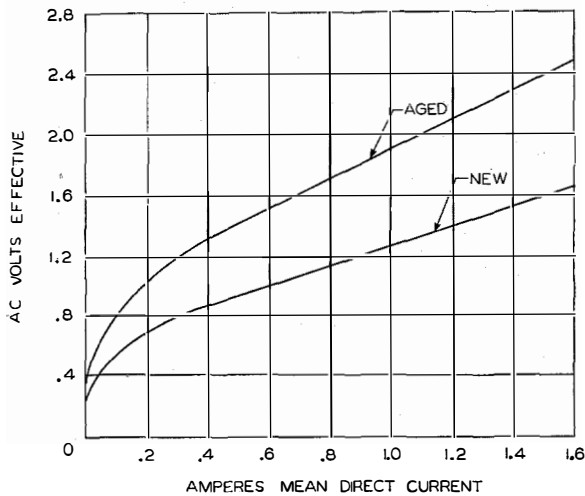
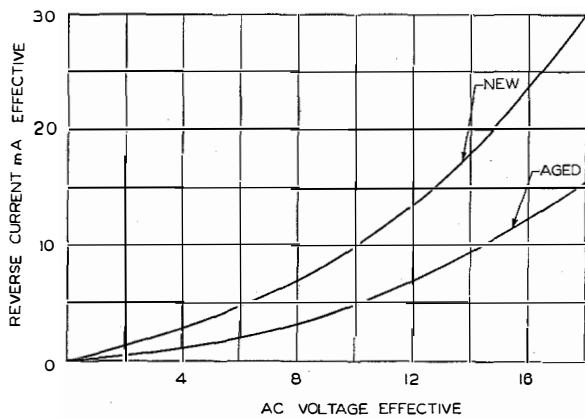Fig. 14—*Typical Forward Voltage Drop and Direct Current Output Curves for a New and an Aged Rectifier.*

Fig. 15—*Typical Reverse Current—Voltage Curves for a New and an Aged Rectifier.*

tions involving restricted ventilation in close association with equipment generating heat.

Applications at High and Low Ambient Temperatures

An interesting example of extreme temperature operation is afforded by the application of the Selenium Rectifier to the coaxial cable amplifier, Fig. 16. The amplifier is housed in a sealed, non-ventilated metal case which also includes thermionic tubes, transformers and resistors contributing to the internal temperature rise. Some of these amplifiers are located in manholes, others atop poles where direct rays from the sun add to

the internal heat. The rectifier is used for anode supply for the tubes and was designed for continuous operation in ambient temperatures of $-40°$ C. to $+68°$ C. As compared with a mercury vapor rectifier tube for this application the Selenium Rectifier, in addition to unlimited life, has the advantage that it operates instantly at $-40°$ C. ambient temperature whereas mercury would solidify.

Fig. 17 pictures a vacuum tube plate supply rectifier for use in an unattended radio transmitter station. The unit is designed to operate in an ambient temperature range of $-40°$ C. to $+60°$ C. With an input of about 3,000 volts single phase a-c, this rectifier supplies 2,300 volts, 180 milliamperes at the output of the associated filter.

Cathodic Protection

An unusual outdoor application of the Selenium Rectifier for unattended use is in forced drainage or counter-electrolytic cathodic protection of underground pipe lines, telephone cables, water tanks or other equipment subject to electrolysis.
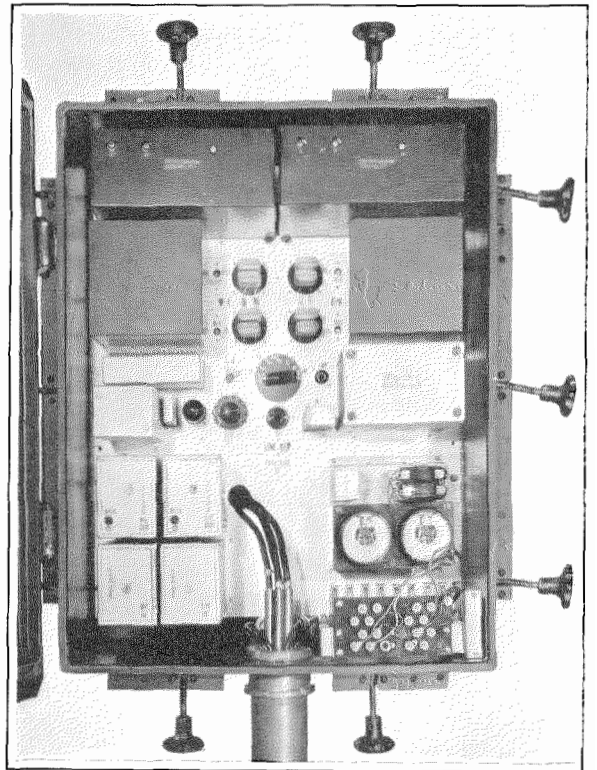

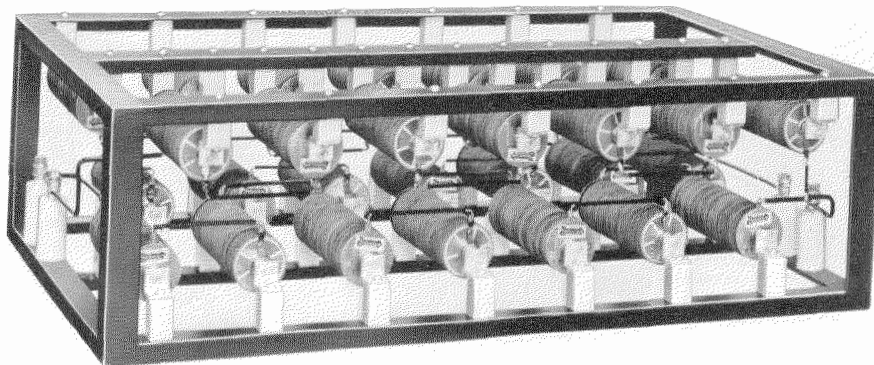Fig. 16—*Coaxial Cable Amplifier.* (*Courtesy of Bell System Technical Journal.*)

Fig. 17—Anode Supply Rectifier for Use in Radio Transmitter. Single Phase Bridge Circuit for Output from its Associated Filter of 2,300 Volts, 180 Milliamperes, in Ambient Temperatures of — 40°C. to + 60°C.

The usual scheme applied to pipe lines is to more than neutralize the e.m.f. generated by the pipe as a primary cell by forcing a larger current between pipe and ground in the direction opposite to the locally generated current. The rectifiers are located along the pipe line at selected intervals; they are mounted on poles which also carry a telephone line, one side of which may serve as an a-c power conductor with the pipe as a return. A typical cathodic protection rectifier is shown in Fig. 18.

Reverse Voltage Limitations

The blocking resistance in the reverse direction decreases with increasing voltage up to the point of breakdown of the barrier layer. Under normal operating conditions the permissible maximum reverse voltage which may be impressed on a single plate is, in most cases, 18 volts r.m.s. for a sinusoidal wave shape or about 25.5 volts peak. When an applied voltage greater than this value is necessary, more than one rectifier plate must be used in a series connection.

Operating Limitations

From the foregoing it is evident that the amount of reverse voltage which may be im-pressed upon an I. T. & T. Selenium Rectifier is limited only by the breakdown voltage in the reverse direction. The current output, similarly, is limited only by the maximum permissible plate temperature produced by the combined internal losses of the rectifier plates, largely forward current loss. A current density of about 50 milliamperes per square centimeter is permissible continuously in the forward direction, corresponding to about one volt drop per series plate. For most applications the important design factor is insuring ample margins for operating within the permissible plate temperature limit of +75° C. (determined by power output) down to any low temperature value where the limitation is solely one of voltage regulation.

Reverse Voltage Blocking Characteristic Changes

A peculiar characteristic of the Selenium Rectifier is that the longer the rectifier is operated at a low reverse voltage the less it will withstand the *sudden* application of higher reverse voltages, thus requiring that the change to higher voltages be gradual. This blocking characteristic is change-able over protracted periods of time and must be considered when the rectifier is used alternately
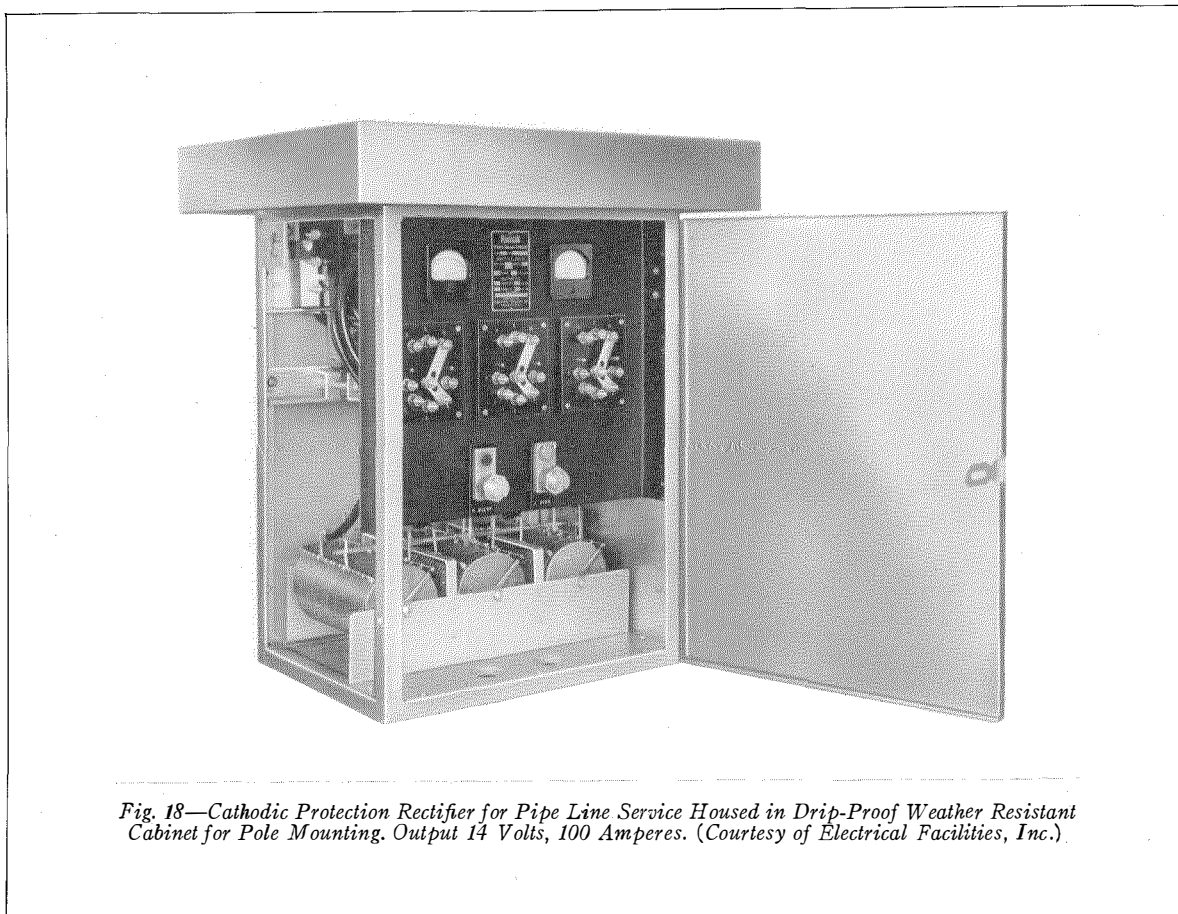
Fig. 18—Cathodic Protection Rectifier for Pipe Line Service Housed in Drip-Proof Weather Resistant Cabinet for Pole Mounting. Output 14 Volts, 100 Amperes. (Courtesy of Electrical Facilities, Inc.)

at different voltages. The decrease in reverse resistance takes place very slowly after the voltage is reduced, becoming noticeable only after several days. When the voltage is increased, however, the reverse resistance increases very rapidly, becoming noticeable within a few minutes. When this characteristic is observed in action with an oscillograph the restoration of reverse resistance becomes dramatically visible as it progresses from second to second. Rectifiers which have been used at very low reverse voltage for some time and are then connected to a much higher voltage will, for a few minutes, show an abnormally high leakage current, which thereafter assumes normal value.

This characteristic is also noticeable after a rectifier has been lying idle for a considerable period. When restored to service, the a-c potential should be started at a low voltage and increased gradually to the required value. Occasionally

crackling sounds occur as the electrostatic stresses reach an equilibrium but this phenomenon can be entirely disregarded as it has no effect on the life or performance of the rectifier.

Heavy Permissible Overloads

Since the permissible current output of the Selenium Rectifier depends entirely upon its ultimate temperature, no theoretical limit can be placed on its current handling capacity. A unit which is initially cool can supply many times its normal continuous current during the time required to bring it to its limiting safe plate temperature. At this point the load must be decreased to a value which does not exceed the normal continuous rating. The relation between load and operating time for a temperature rise of 40° C. is shown in Fig. 19, which applies to cases where there is a sufficient interval between successive load applications to permit the rectifier to cool
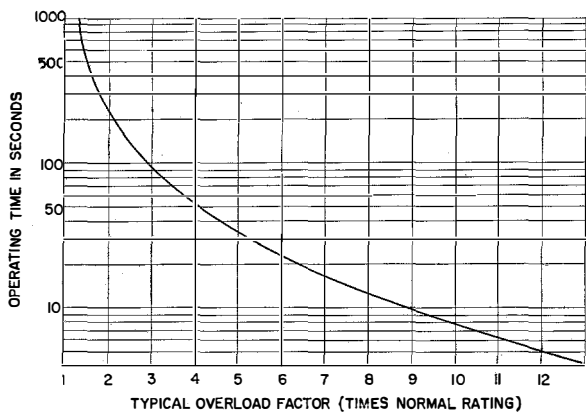
Fig. 19—Typical Short Period Overload Capacity of a Se-
lenium Rectifier. (The curve assumes a half-hour period of
idleness between operations to allow the rectifier to cool.)

Fig. 20—Overload and Operating Time for
Intermittent Operation.

to its initial temperature of 35° C. If the rectifier
is started at a lower temperature, a somewhat
longer application of overload is permissible. If
the starting temperature is above 35° C., the
overload must be decreased in accordance with
Fig. 11.

Fig. 20 shows similar curves for intermittent
operation when the intervening idle periods are
too short for cooling to the surrounding tempera-
ture. One curve shows the relation between
percentage operating time and permissible over-
load; and the other, the corresponding maximum
operating time in seconds. It should be noted that
intermittent use does not permit application of
voltages above the normal continuous ratings.

While there is no limit to the current which can
be supplied by a Selenium Rectifier for short

periods, it must be remembered that the rectifier
is a resistance device so that the higher its
current output the higher also will be its internal
voltage drop. Where the actual operating time is
short, the rectifier temperature may not rise
appreciably above its surrounding temperature.
Fig. 21 shows a typical heating curve for a
convection cooled Selenium Rectifier assembled
with normally spaced plates without cooling fins
and operated at its normal full load rating. The
shape of this curve can be changed by altering
plate spacing and cooling facilities. Choice of a
suitable rectifier design for extremely short
period operation is therefore determined by the
permissible voltage regulation or at least by the
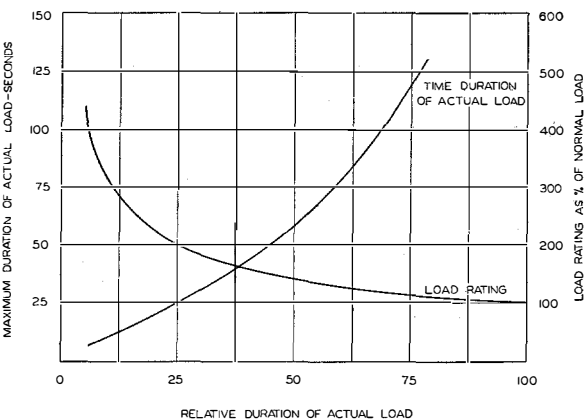minimum operating voltage required at the load.

It is usually possible to compute the tempera-
ture rise and so design rectifiers for intermittent
operation provided the duty cycle can be defined.
In cases where the cycle is not recurrent or is too
complex to permit ready description, laboratory
checks under actual operating conditions may be
required, the ultimate plate temperature of the
rectifier and its output voltage under load being
the determining factors.

Applications of Overload Characteristic

In practice, rectifiers are frequently used for
intermittent service in elevator operation, alarm
equipment and many control circuit applications.
For such uses the rectifier has a distinct advantage
in that its standby losses are small compared to
rotating machines, and it is not injured by
sudden high overloads which would rapidly
destroy thermionic devices dependent upon a
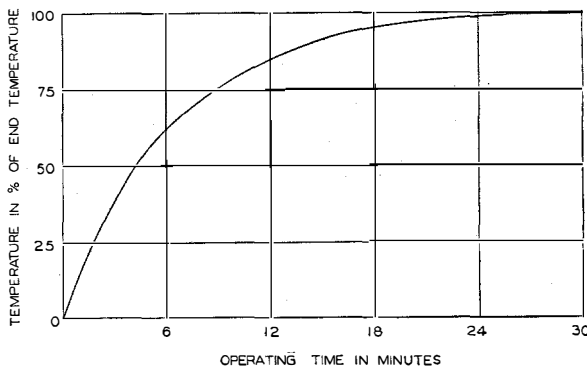heated element to produce an electron stream.

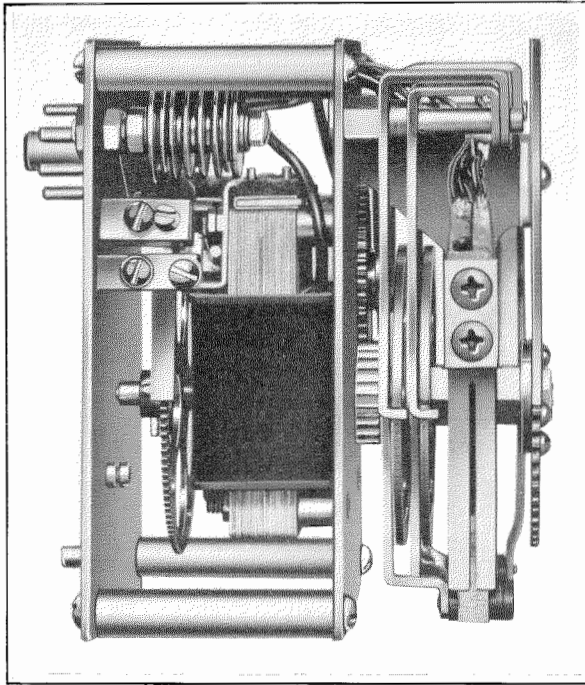Fig. 21—Typical Temperature Rise vs. Time Curve.

Fig. 22—Code Transmitter for Operating an Alarm Circuit.
(Courtesy of The Holtzer-Cabot Electric Company.)

Program clock and bell services, such as required for schools, represent an interesting form of intermittent operation. Here the rectifier must operate a number of clocks which are stepped ahead each minute by the application of the rectifier output for perhaps one second per operation as determined by a master clock. At other intervals, which may or may not coincide with the clock operation, vibrating bells may be operated for various lengths of time and single stroke bells operated one or more times. A code transmitter for operating an alarm circuit is shown in Fig. 22.

Plate Types and Ratings

Selenium Rectifier plates, because of adequate cooling surface, inherently do not require cooling fins. However, such fins are often used to extend the current capacity of the largest size of plate as well as to obtain current values intermediate between the normal ratings of smaller plates. While the relationship of plate spacing to diameter is chosen for optimum cooling at normal current rating, an increase in rating can also be obtained by increasing the spacing between plates. The determination of plate size, and whether or not cooling fins or wider spacing or both should be used, are governed by the economics of each specific case. Forced ventilation, rather than the addition of fins, may also be economical under certain conditions.

Table I lists basic types of Selenium Rectifiers and their ratings. The normal full load output current in amperes is given for each type on the basis of one plate (or several in series) in each branch of the listed rectifier circuits. Output currents can be increased by the connection of plates in parallel. Plate reverse voltages, outside diameters and d-c valve ratings are included in the table. The forward currents permissible for d-c valve use are higher than the equivalent half wave rating for a-c operation because there is no simultaneous heating due to reverse current. As noted for rectifiers used at low reverse potentials, it is not recommended that valves be operated for long periods with forward current only. Occasional applications of reverse potential should
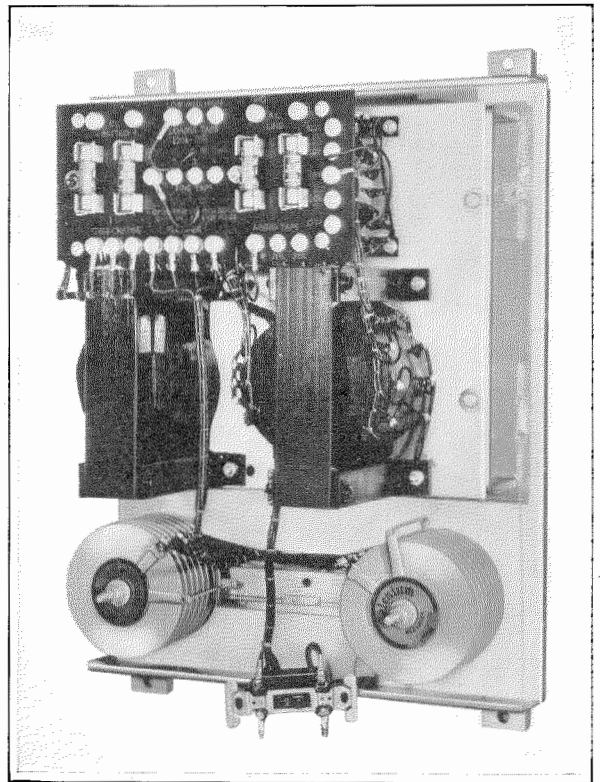

Fig. 23—Saturable Core Reactor Type Regulating Rectifier for Telephone Central Office Power Supply. (Courtesy of The North Electric Manufacturing Company.)

Type No.	Diameter Inches	Max. R.M.S. A.C. Volts reverse per plate	*Maximum continuous D.C. amperes for one plate per arm at 35° C. ambient, inductive or resistive load						Maximum Continuous D.C. rating as valve at 35° C. ambient		Maximum No. of plates per stack	Using Plate No.
			Single Phase			Three Phase						
			Half Wave	Bridge	Center Tap	Half Wave	Bridge	Center Tap	Amperes	Blocking Voltage		
1	¾	18	.040	.075	.075	.100	.110	.130	.06	15	36	1
2	1	18	.075	.150	.150	.200	.225	.270	.12	15	36	2
20	1	18	.11	.22	.22	.29	.33	.4	.17	15	28	2
3	1⅜	18	.15	.30	.30	.40	.45	.55	.23	15	36	3
21	1⅜	18	.23	.45	.45	.6	.67	.82	.34	15	28	3
4	1¾	18	.30	.60	.60	.80	.90	1.1	.45	15	40	4
10	1¼	18	.39	.78	.78	1.0	1.1	1.4	.58	15	28	4
9	2⅝	18	.58	1.1	1.1	1.5	1.7	2.1	.87	15	28	4
5	2⅝	18	.60	1.2	1.2	1.6	1.8	2.2	.90	15	40	5
11	2⅝	18	.78	1.6	1.6	2.1	2.3	2.8	1.2	15	28	5
12	3⅜	18	.90	1.8	1.8	2.4	2.7	3.3	1.4	15	28	5
13	4⅜	18	1.1	2.2	2.2	2.9	3.3	4.0	1.7	15	28	5
6	3⅜	16	1.2	2.4	2.4	3.2	3.6	4.5	1.8	12	40	6
14	3⅜	16	1.5	3.1	3.1	4.1	4.6	5.8	2.4	12	28	6
15	4⅜	16	1.8	3.5	3.5	4.6	5.2	6.5	2.7	12	28	6
16	4⅜	16	1.9	3.8	3.8	5.0	5.6	7.0	2.9	12	24	6
17	6″ sq.	16	2.7	5.4	5.4	7.2	8.1	10.0	4.1	12	28	6
7	4⅜	14	2.0	4.0	4.0	5.3	6.0	7.5	3.1	12	40	7
18	4⅜	14	2.6	5.2	5.2	6.9	7.8	9.7	4.0	12	28	7
19	6″ sq.	14	3.7	7.4	7.4	9.8	11.1	13.3	5.7	12	28	7
8	8″ sq.	14	5.0	10.0	10.0	13.0	15.0	18.0	7.5	12	28	7

* Note: These ratings do not apply to battery charging or condenser loads.

Table I—Sizes and Current Capacity of Selenium Rectifiers.

be made to maintain a high reverse resistance. A d-c valve which is chiefly used with blocking potential needs no such attention. It should be noted also that the maximum permissible d-c reverse potential is less than the r.m.s. a-c values.

With fan cooling at an air velocity of 55 feet per minute Type 7, for example, gives 150% of the convection cooled current ratings listed in Table I. If the air velocity is increased to 90 feet per minute the ratings are twice the values in the table and at 120 feet per minute, 2½ times the listed values.

In oil at 35° C., the Type 4 Selenium Rectifier gives 167% of the currents indicated in the table.

Regulation

Along with unusual stability of operating characteristics, the exceptionally good voltage regulation of the Selenium Rectifier results from its low forward resistance. Regulation from no load to full load for a single phase bridge rectifier with a resistive load is of the order of 15%. The addition of fins, or wide spacing, for obtaining increased current density may increase this value by about 5%; with highly intermittent use a further increase may occur if too small a rectifier is selected. Fig. 14 shows typical changes in voltage drop across a plate of a single phase bridge type rectifier as its current output is increased. The largest portion of the voltage change occurs from zero output current to some small value of current of the order of 20% of full load. From there on, the voltage change is almost linear and the regulation from, say, half load to full load is only about 6%. The use of a small additional load or bleeder resistance improves the regulation by preventing the output current from decreasing to zero.

Where close regulation is essential, various regulating devices may be employed. Fig. 23 shows a saturable core reactor type of regulating rectifier used for telephone central office power
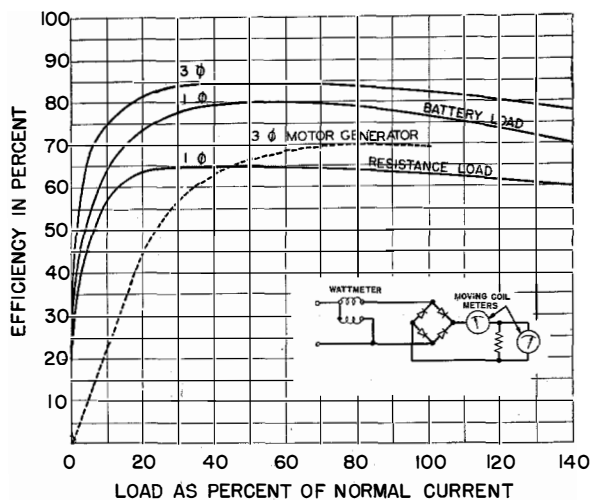
Fig. 24—Efficiency of Selenium Rectifier Operating at Full Load Voltage Compared to Average Typical Efficiency of a Motor Generator Set with Exciter.

supply. One winding of a small reactor is placed in series with the a-c input to the rectifier; the other, is connected in series with the d-c load. If the load current tends to increase, the saturable reactor impedance on the a-c side is decreased and the a-c voltage impressed on the rectifier is immediately increased so as to restore the d-c output voltage. Such rectifiers can be made to almost any small degree of regulation for extremely wide load changes. They serve a wide variety of uses besides simple control of load voltage; an example is the electric milk pasteurizer where the constancy of the pasteurizing temperature is controlled by a saturable core Selenium Rectifier circuit.

When compensation for line voltage fluctuations is desired, taps on the primary of the rectifier transformer may be used or regulation accomplished automatically by the use of one of the standard regulating transformers available. If a rectifier is required for laboratory or test work with variable output voltage, it is convenient to use a continuously variable input transformer to supply the rectifier, making certain that the permissible voltage of the rectifier will not be exceeded.

Efficiency and Economy

In order to take into account the various form factors which differ considerably with various types of load and rectifier arrangements, the efficiency of the Selenium Rectifier is considered to be its volt-ampere efficiency, obtained by a wattmeter measurement of input and a moving-coil voltmeter and ammeter measurement of output. Such measurements show the rectifier efficiency between 65% and 85%, depending on the nature of the circuit and the load. These efficiencies, shown in Fig. 24, apply to convection cooled rectifiers without cooling fins and operation at maximum voltage. The high efficiency is maintained with remarkable uniformity from about 20% to 150% of full load. The Selenium Rectifier differs in this respect from most electrical equipment which normally reaches maximum efficiency only in the neighborhood of full load current. Efficiency of the rectifier, however, is dependent on the operating voltage per plate. The aim of the designer, therefore, should be to provide an adequate but not excessive number of plates for each specific application.

In comparison with tube rectifying equipment, the Selenium Rectifier is usually found to have a higher efficiency for outputs of any current at voltages up to about 80 to 120 volts. Tube equipment ordinarily has a constant internal drop of about 15 volts, regardless of output voltage, whereas the total internal drop of a Selenium Rectifier must rise as its voltage, and hence its number of plates, is increased. Furthermore, tube efficiency is lowered by the filament or heater losses. The efficiency of the Selenium Rectifier therefore is higher in the range within which the loss due to its internal drop is less than the total losses of the tube rectifier.

Rotating machinery, such as the motor generator, compared with the Selenium Rectifier, is about equally efficient at full load, but its efficiency drops off rapidly as the load deviates from full load. With individual machine efficiencies of 80% to 85% or more, the overall efficiency of a motor generator set is about 64% to 72%. Small machines may be less and large machines more efficient.

The use of wider plate spacing or the addition of cooling fins to the Selenium Rectifier, while decreasing its efficiency by some 3% to 5% in most cases, is usually economical where size and first cost are of greater importance than

annual charges. This is also true of fan cooled rectifiers, the efficiency of which may drop as much as 10% below the convection cooling values.

Efficiency in Electroplating Applications

Uniformity of the rectifier efficiency with varying output currents suggested applications where the load current is not constant, such as in electroplating. Although electroplating generators possess high efficiency, they must usually be isolated from the plating tanks for protection against corrosion, thus involving long bus bars and considerable power losses due to the heavy currents handled. Since small individual generators are uneconomical, one large constant voltage machine is generally used for serving a considerable number of plating tanks, the voltage at each tank being reduced by a series rheostat with resultant large power losses. Thus the combination of bus and rheostat losses may reduce the overall efficiency of the plating plant to a maximum of some 40% to 45%. A solution of this problem has been effected by the use of compact, forced air cooled or oil immersed Selenium Rectifier units close to the plating

tanks to minimize bus bar length. By designing the plating rectifier (Fig. 25) for the required output voltage and using a regulator within the rectifier for close adjustment, tank rheostats can be eliminated. Higher starting costs for rotating machines, the cost of power factor correction and higher standby losses when idling are additional considerations favoring the use of rectifier equipment. Rotating machines, further, are larger in size and heavier than equivalent Selenium Rectifiers and usually require special foundations for supporting and anchoring them. In contrast to these disadvantages, the 1500 ampere Selenium Rectifier illustrated in Fig. 25 has been mounted on small casters so that it may be readily installed and moved at short notice.

Design Requisites

Choice of circuit schemes ordinarily may be left to the rectifier designer. Under certain conditions advantage should be taken of the fact that three phase circuits have a smaller ripple then single phase rectifier circuits and their higher frequency is easier to filter. The ripple in the output of a single phase bridge

CIRCUIT	SINGLE PHASE HALF WAVE	SINGLE PHASE CENTER TAP	SINGLE PHASE BRIDGE	3 PHASE HALF WAVE	3 PHASE BRIDGE	3 PHASE CENTER TAP
RECTIFIER CONNECTION						
RESISTIVE LOAD APPROXIMATE OUTPUT VOLTAGE WAVE SHAPE						
CAPACITIVE LOAD APPROXIMATE OUTPUT VOLTAGE WAVE SHAPE						
NUMBER OF PLATES IN SERIES — RESISTIVE LOAD (E=AC RMS VOLTS, V_p=RATED VOLTS PER PLATE)	$\dfrac{E}{V_p}$	$\dfrac{2E}{V_p}$	$\dfrac{E}{V_p}$	$\dfrac{\sqrt{3}\,E}{V_p}$	$\dfrac{E}{V_p}$	$\dfrac{2E}{V_p}$
CAPACITIVE LOAD	$\dfrac{(1+\sqrt{2})E}{V_p}$	$\dfrac{2\sqrt{2}\,E}{V_p}$	$\dfrac{\sqrt{2}\,E}{V_p}$	$\dfrac{(1+\sqrt{2})E}{V_p}$	$\dfrac{\sqrt{2}\,E}{V_p}$	$\dfrac{2\sqrt{2}\,E}{V_p}$
THEORETICAL RIPPLE	121%	48.3%	48.2%	18.3%	4.2%	4.2%
MAXIMUM THEORETICAL OUTPUT EFFICIENCY $\dfrac{E_{DC}\,I_{DC}}{E_{AC}\,I_{AC}}$	40.5%	81.1%	81.1%	96.8%	99.8%	99.8%

Table II—Basic Characteristics of Rectifier Circuits.

rectifier is about 48%. A three phase, half wave circuit produces an 18% ripple; for three phase bridge and center tap circuits, this value is as low as 4%. Inasmuch as the utility factors for three as compared with single phase circuits are more favorable, the resultant three phase rectifiers are smaller and less expensive. Moreover, since operation of the Selenium Rectifier does not depend on the generation of electrons through the agency of heat or the inclusion of contactors,
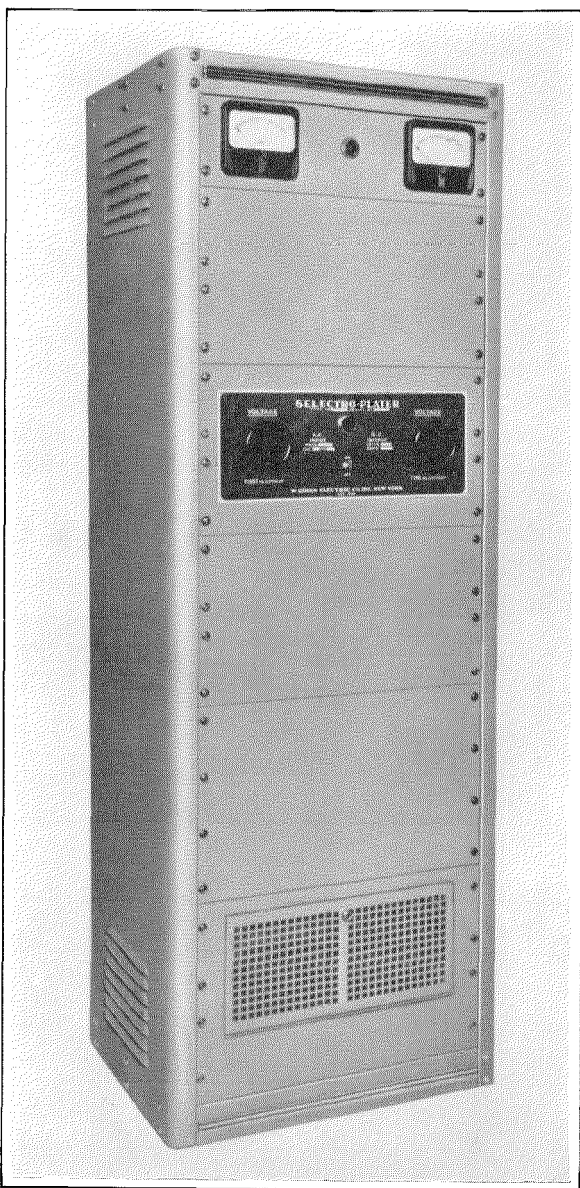

Fig. 25—Electroplating Rectifier, 6 v, 1,500 amp. (Courtesy of W. Green Electric Company.)

such as commutators, the ripple frequency spectrum, as might be anticipated, is confined to low multiples of the input frequency and does not contain either high frequency noises inherent in thermionic equipment or the transients of commutating machines.

Basic characteristics of the six most common rectifier circuits are listed in Table II.

The single phase half wave circuit is ordinarily not economical except for low voltage and current output since only one-half of the cycle is utilized. As shown in the oscillograms of Table II, the use of a condenser across the load maintains some current flow during the half-cycle which is suppressed by the rectifier. Rectifier reverse current flows through the load.

The single phase full wave bridge arrangement is perhaps most widely used. The ripple voltage has twice the frequency of the a-c supply and the rectifier back current does not flow through the load. If the load is highly inductive, switching on the a-c supply side permits the rectifier to act as an effective means of absorbing the rise in voltage across the load so that when the supply voltage is disconnected, the voltage across the load does not rise appreciably above its normal value. The rectifier may consist of a single stack, two identical stacks each having two bridge arms, four half wave stacks representing each of the four bridge arms, or series-parallel combinations. For a rectifier with a single 18 volt plate per arm, the output voltage is of the order of 12 volts.

The single phase full wave center tap arrangement provides the same performance as the bridge circuit but is only half as large. It is applicable to output voltages of the order of 6 volts or less and requires a center tapped transformer. If the output voltage is higher, the number of plates required will be the same as for the bridge connection and it is then more economical to use the latter circuit since it does not require a center tapped transformer.

The three phase half wave circuit differs from the corresponding single phase arrangement in that current flows through the load throughout the entire cycle due to overlapping of the output from the three phases. It is therefore commercially advantageous because of its higher effi-
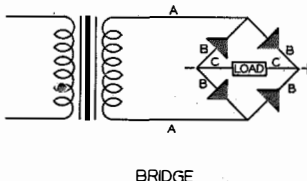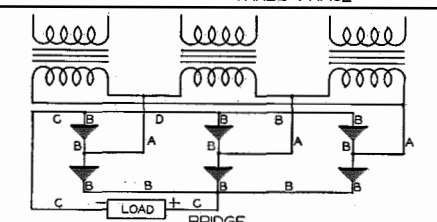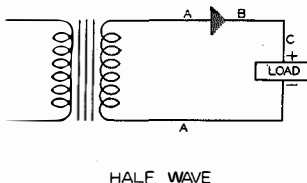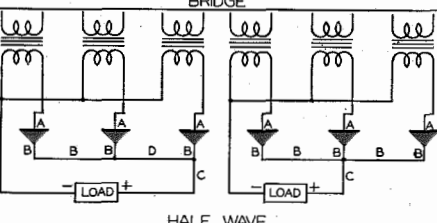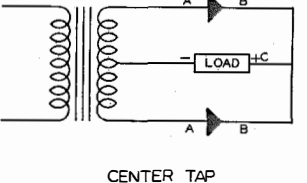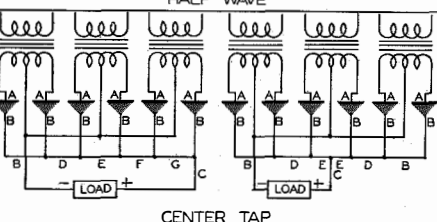
Table III — Approximate Current Factors in Rectifier Circuits.

SINGLE PHASE

Circuit	SECTION	RESISTANCE LOAD FACTOR	BATTERY LOAD FACTOR
BRIDGE	A	1.15	1.7
	B	.80	1.2
	C	1.15	1.6
HALF WAVE	A	1.80	2.5
	B	1.80	2.5
	C	1.80	2.5
CENTER TAP	A	.80	1.2
	B	.80	1.2
	C	1.15	1.6

THREE PHASE

Circuit	SECTION	RESISTANCE LOAD FACTOR	BATTERY LOAD FACTOR
BRIDGE	A	.85	.86
	B	.60	.61
	C	1.0	1.02
	D	.85	.86
HALF WAVE	A	.65	.70
	B	.65	.70
	C	1.06	1.08
	D	.86	.90
CENTER TAP	A	.46	.48
	B	.46	.48
	C	1.00	1.02
	D	.62	.64
	E	.75	.77
	F	.85	.87
	G	.95	.97

ciency and low ripple component. The ripple frequency is three times that of the supply line.

The three phase bridge circuit is one of the most useful for large power outputs; it has the highest efficiency and the lowest ripple voltage. The ripple frequency, six times that of the power supply, may easily be filtered out.

The three phase center tap circuit is similar in connection to the single phase equivalent. It offers the same performance as the three phase bridge connection but has a lower voltage output per plate. The number of arms in the rectifier is the same as for the three phase bridge circuit, yet the permissible forward current per plate is higher than that for the three phase bridge connection since the current of one phase returns directly to that phase from the load and does not divide between the other phases as in the three phase bridge rectifier.

Approximate current factors in these rectifier circuits, especially useful in the determination of wire and bus bar sizes, are given in Table III. With a known output current, the effective current in each section of the various circuits can be determined by multiplying the mean or average value of the output current by the appropriate factor.

Essential Design Data

In order to design a rectifier for a specific application, an outline of the limiting conditions is required. A circuit schematic including constituent electrical constants conveys the clearest definition of the operating requirements and frequently enables the designer to suggest alternate arrangements warranting consideration. Actual performance requirements and details of service conditions are preferable to the inclusion of arbitrary safety factors. While Selenium Rectifier ratings embody ample safety factors, careful design is essential in order that all limiting conditions may be met without sacrificing desirable margins or unduly increasing others.

Obvious requirements include d-c output voltage and current. Stated tolerances for each aid the designer, whose choice is limited to fixed current and voltage steps. First cost usually is a function of rectifier output and varies with the number of plates required, making it desirable

to hold size to a minimum. The number of phases of the power supply is important but the frequency is relatively unimportant except for capacitive loads or smoothing filter circuits inasmuch as the rectifier ratings hold for frequencies up to 1000 cycles per second. Voltage variation of the a-c supply line should be stated.

Upper and lower ambient temperature limits must be known as well as the duty cycle, i.e., whether continuous or intermittent. If the latter, details of current changes are required together with the length of time each value is to be maintained, as well as the length of each "off" period. Necessary also are voltage regulation limits between stated loads and details of switching, i.e., whether on the line or load side of the rectifier.

The nature of the load is an important design factor. Inductive and resistive loads are usually treated similarly, but capacitive loads and battery charging service require different designs. For capacitive loads, the value of the capacity and the supply line frequency must be known in order to determine the a-c input to the rectifier. If a filter is used, it is considered as an inductive or capacitive load according to whether its input section comprises a choke coil or a condenser. Battery charging should be defined as either taper or trickle charging. If the former, the maximum starting rate and the final cell voltage must be known. For trickle charging, similarly, the charging rate and cell voltage must be defined together with data on maximum cell voltage required if the battery is to be given an occasional "freshening" charge.

Atmospheric conditions require attention in order to determine whether or not a protective coating should be applied to the rectifier. Such a coating does not alter the rectifier rating.

The a-c voltage required for a given d-c output voltage depends on the circuit and load conditions. For a resistive or inductive load, the r.m.s. input voltage of a single phase bridge rectifier is of the order of 30% above the mean output voltage; for a three phase bridge rectifier, the input voltage is about 12% below the mean output voltage. Similarly, for a single phase, half wave rectifier the input voltage is about 180% above the output; and, for a three phase half wave rectifier, it is about 8% above the output. In a single phase bridge rectifier operating into a capacitive or trickle charging load, the input and output voltages are about equal numerically. While this may reduce the number of rectifier plates in series, the current capacity of the rectifier must be increased by about 12% as compared with a resistive or inductive load.

The rectifier designer, in addition to stated line voltage, ambient temperature and other known variables, must consider full compensation for aging as well as allowances for variation in ventilating conditions. The usual practice is to mount rectifier stacks at or near the bottom of the equipment housing so that they will receive an unrestricted supply of air at about the prevailing temperature. If two or more stacks are required in the rectifier unit, it is generally preferable to mount them side by side rather than one above the other.

The housing for the complete equipment should preferably be small in horizontal cross sectional area and as high as practicable in order to enhance "chimney" action for convection cooling.

Recent Telecommunications Developments

PORTABLE SWITCHBOARD.—Standard Electric NMS-10 local battery portable switchboard, providing facilities for ten lines and six connecting circuits, is specially designed to withstand rough usage in the field. Connections are effected by means of rugged switching keys, no cords being utilized. The apparatus required for each line circuit, i.e., binding posts, drop and switching keys, is mounted on an individual panel, arranged for convenient disconnection without disturbing other circuits and thus facilitating field maintenance.

The quartered oak protecting cabinet, finished in olive drab, is $15\frac{5}{8}$ inches wide, $13\frac{1}{4}$ inches high and 8 inches deep; its weight is 35 lbs.

Two switchboards can readily be interconnected and operated by one person when facilities exceeding ten lines are required.
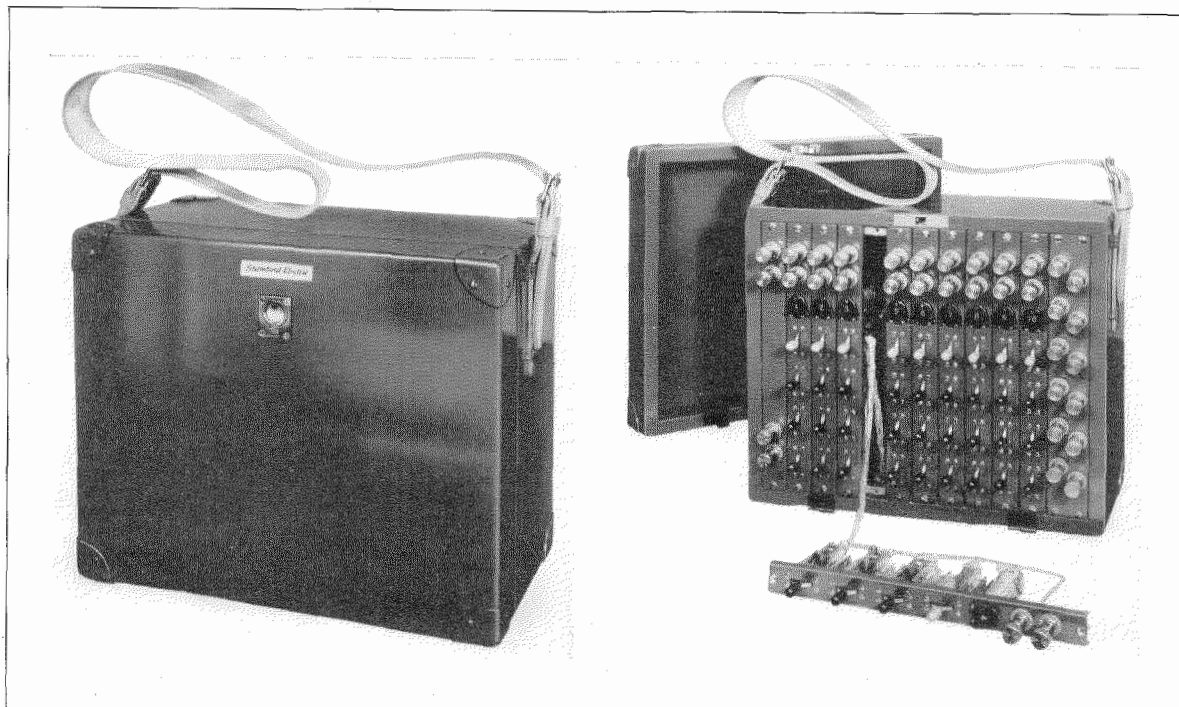
"NORMAS SOBRE RECEPTORES DE RADIO," a translation from English into Castilian of I.R.E. "Standards on Radio Receivers 1938" has been issued by the Sección Buenos Aires of the Institute of Radio Engineers, Inc. The following is quoted (in translation) from the foreword incorporated in the Castilian edition:

"On May 2, 1939, the members of the Institute of Radio Engineers residing in the Argentine, numbering 25, decided to form a local association for greater technical efficiency and collaboration.

"The association, which took the name, Centro Argentino de Socios del Institute of Radio Engineers, requested the central headquarters in New York to recognize it as an Official Section. This was accorded by the Board of Directors of the Institute at its meeting on October 4th of the same year.

"Recognized as an Official Section, the association as of that date chose the name 'Sección Buenos Aires' of the Institute of Radio Engineers.

"This Section is the only one existing outside the North American continent and is the first Spanish-speaking one. The Sección Buenos Aires, consequently, has felt itself called upon to translate into Castilian the standards prepared by the

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Institute, desiring thus to fulfill its fundamental purpose, which is to contribute to the dissemination of radioelectric knowledge.

"The present Managing Committee of the Sección Buenos Aires comprises:

A. T. Cosentino	*Chairman*
A. M. Stevens	*Ex-Chairman*
P. J. Noizeux	*Vice-Chairman*
G. J. Andrews	*Secretary-Treasurer*

E. E. Kapus ⎫
J. P. Arnaud ⎬ *Members*
A. Nadosy ⎭

"Translation of the standards was prepared by an Argentine committee, under the supervision of J. P. Arnaud and M. J. Kobilsky."

Copies of "Normas sobre Receptores de Radio" may be obtained from Revista Telegrafica, Peru 165, Buenos Aires, at a price of one Argentine peso.