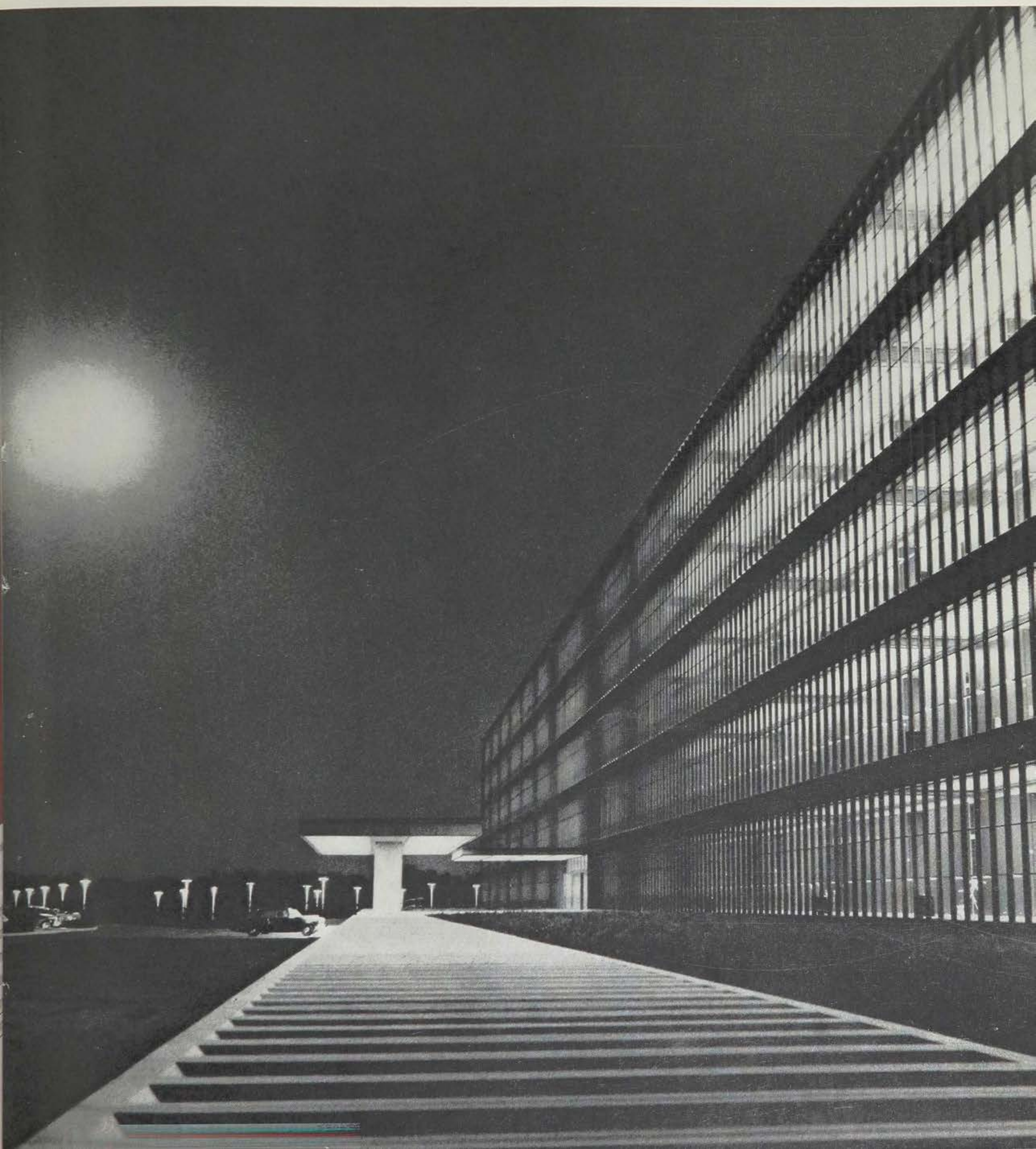
October 1962

Bell Laboratories
RECORD



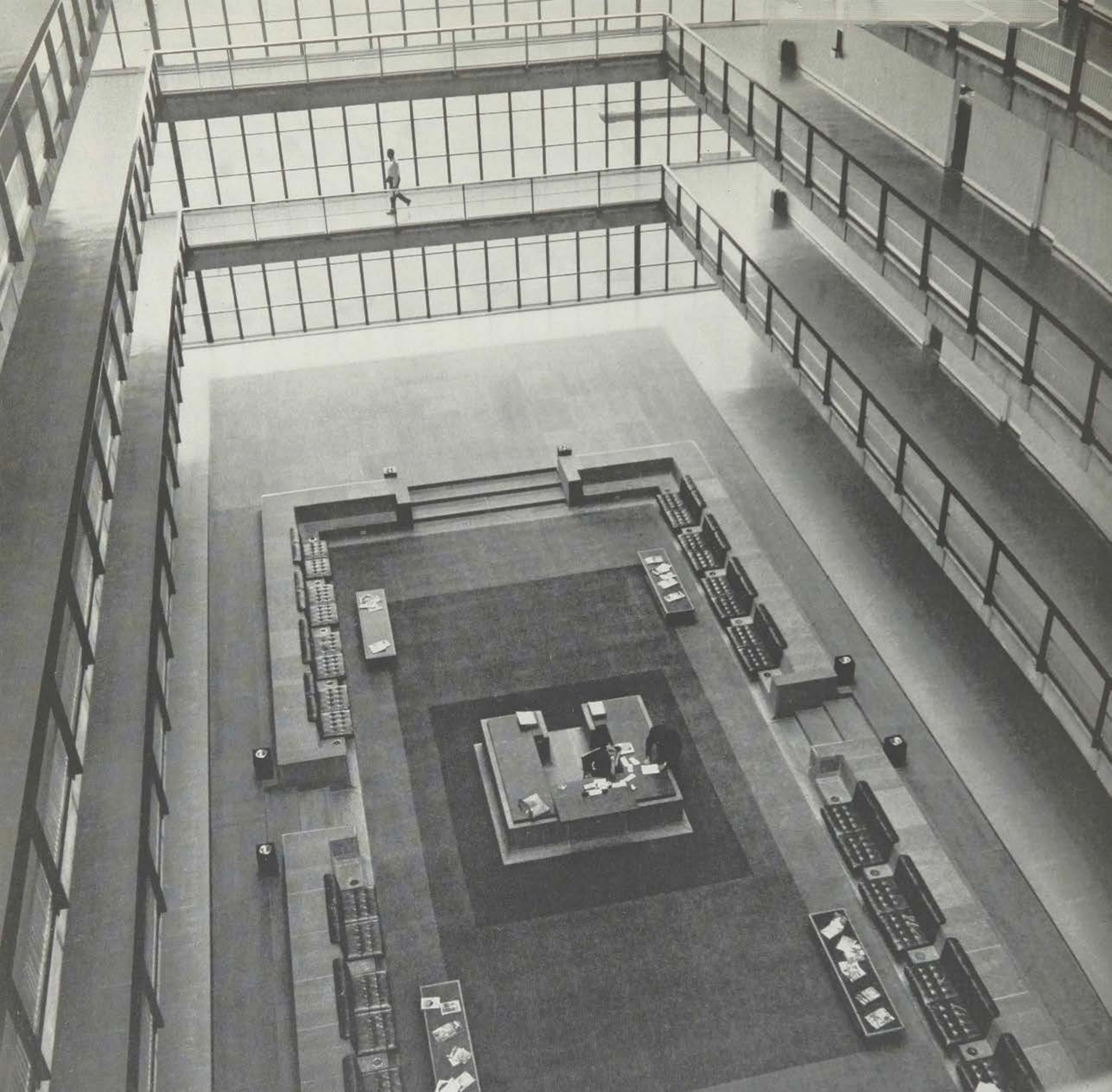
THE BELL LABORATORIES RECORD is published monthly by Bell Telephone Laboratories, Incorporated, 463 West Street, New York 14, N. Y., J. B. FISK, President; K. PRINCE, Secretary; and T. J. MONTIGEL, Treasurer. Subscription: $2.00 per year; Foreign, $2.95 per year. Checks should be made payable to Bell Laboratories Record and addressed to the Circulation Manager. Printed in U. S. A.

Bell Laboratories **RECORD**

Volume 40 • Number 9 • October 1962

Contents

Cover *Interior lights at the new Holmdel laboratory illuminate the surface of the concrete podium around the building, as the moon rises over the surrounding hills.* *(See page 316)*



Large lobby separates the two building sections at Holmdel. The lobby is ringed by balconies on the four upper floors and is topped by a skylight.

The HOLMDEL *Laboratories*

H. J. Wallis

During 1954 and 1955, M. H. Cook, then Vice President of Bell Laboratories, began a study of future growth and space requirements. The results of his study clearly indicated the need for substantial areas at both the Murray Hill, N. J. and Whippany, N. J., locations to reduce over-crowding and to accommodate further growth. The study further disclosed a changing ratio of office space to laboratory space, which had resulted in the use of substantial amounts of laboratory space for office occupancy.

Several factors indicated that a new major location would ultimately be required to meet our needs, instead of large-scale additions to our existing locations. The principal of these considerations were as follows:

1. The need for an adequate amount of suitable housing within reasonable commuting distances.
2. The problem of obtaining an adequate number of support personnel.
3. The factor of decreasing efficiency of operations as buildings at a location become more scattered.
4. The general impact upon the community in which we are located.

Having determined that a new major Bell Laboratories location was needed, a committee was formed to develop criteria for the new buildings and facilities, and ultimately to recommend an architect. The committee was composed of W. A. MacNair, H. T. Friis, H. J. Wallis, R. H. Kendall, and R. H. McCarthy (Western Electric Co.), under the chairmanship of M. H. Cook.

The first effort of the committee was to have the Plant Engineer make an engineering study, with the aid of the Executive Asistants at each location, on the problems which had been encountered in existing laboratory buildings. As might be expected, he compiled a substantial list of comments. No single potential design could possibly correct all the problems listed, but there appeared to be a considerable group which were soluble.

From these comments, the committee drew up a list of eight criteria which they felt were a minimum that any ultimate design should fulfill. They included:

1. Maximum flexibility in the use of space.
2. Centrally located common service facilities such as library, medical, personnel, restaurant, and reproduction.
3. Flexibility to make changes in laboratories, with minimum interruption of work.
4. Minimum traffic past offices and Labs.
5. Central air conditioning.
6. Minimum distance from parking lots to buildings.
7. Road system to eliminate pedestrian traffic across roads, plus minimum traffic problems on public roads.
8. Construction and operating costs as low as feasible.

The reasoning behind the various criteria are as follows:

1. *Flexibility in Use of Space:* Based on past experience, the ratio of laboratory to office space will constantly change. When Building 1 was erected at Murray Hill, for example, 26 per cent of the floor space was assigned to offices, with the balance reserved for laboratories. All essential services were built into the walls of the space designated for laboratories. When Building 2 was built seven years later, the floor space allocated to offices was 40 per cent of the total. Even this later proved to be inadequate, so Building 3, which was virtually all offices, was erected, bringing the over all ratio of offices to laboratories to 50:50.

Even within the over-all ratio, the proportions of space devoted to laboratory and office work vary as the functions of the department change. Thus, we would like to be able to alter this ratio conveniently, without having to use space equipped with expensive service facilities for office occupancy.

2. *Centrally Located Common Facilities:* In our present buildings at Murray Hill and Whippany, long walks are required in many instances to reach the library, medical department, and restaurants. With other facilities such as transcription, duplication, stock room, and shops, the need for nearby location has led to considerable duplication. This situation was to be avoided as far as possible in the new building.

Perimeter corridors, used for all major traffic, provide a continuous view of the countryside.

3. *Flexibility in Making Rearrangements:* Whenever a laboratory rearrangement is required in existing designs, the laboratory has to be shut down, and its occupants moved out for several weeks, while workmen change basic services and locations. Only then can the equipment be moved in and connected. Also, when new services are required, laboratories on floors below are often disrupted as the services are brought up through the walls from the cellar.

In the new buildings we wanted an arrangement in which a substantial amount of the work could be done outside the laboratory, ahead of the move, without disruption to any working space, with "hook-up" time cut to a minimum.

4. *Minimum Traffic:* With the buildings now being used, all traffic through an area must pass every laboratory and office, with the few exceptions of office wings where they exist. Obviously, if traffic could be reduced to only that directly concerned with the department itself, the distractions would be concurrently reduced greatly.

5. *Air Conditioning:* While this requirement would seem self-explanatory, at least two comments are necessary. Our experience over the past ten years has shown a rapidly changing technology requiring more and more air-conditioned laboratories to conduct our work properly. Not only is piece-meal addition of air conditioning extremely costly, but window units tend to destroy the appearance of our buildings. We also accepted the belief that air conditioning has a beneficial relationship to increased efficiency and output, as well as reduced absenteeism.

6. *Parking Lot Location:* A requirement with our existing buildings is that parking lots be separated by a considerable distance from the buildings, in order to landscape the property for appearance' sake. There seems to be little point in locating a new building in a rural or suburban atmosphere if the only view from a window is a sea of cars. On the other hand, no one wants to walk the excessive distance implied by a large green belt all around the building. Distance also involves the time of walking, during which an employee may be exposed to inclement weather.

7. *Road System:* The road system at existing buildings is far from ideal. Normally, there is too much cross traffic on our grounds as well as within the parking lots, under relatively unsafe and unregulated conditions, and too much "sorting" of traffic by destination after the automobiles have reached the public roads in the vicinity. Both situations lead to unsafe conditions among

ourselves and with our neighbors. Ideally, the road system at Holmdel should provide minimum cross traffic, and sort out drivers on company property, before releasing them to the public roads nearest the logical point of departure for their destination.

8. *Economy of Construction and Maintenance:* Once again, this criterion seemed to be self-explanatory, since both the cost factors of initial construction and maintenance had to be considered in any evaluation.

While formulating these criteria, the committee members visited various research and development laboratories around the nation, in groups and singly, looking at new construction and discussing the objectives behind each of the various designs, as well as determining the degree to which the designs were successful in meeting the objectives.

With these criteria and decisions, and even a tentative design, the committee then faced the problem of selecting an architect to carry out the aims. Ultimately, the unanimous choice fell on the famed architect, the late Eero Saarinen. Mr. Saarinen began work on the design in 1957. In 1959, when he completed the final design, Mr. Saarinen wrote:

"The challenge for us in the new laboratories at Holmdel was to make today the same advance in the science of planning research and development laboratories for our time as the Bell Laboratories at Murray Hill, built some years ago, did for their time. To that end, we tried to benefit from all the experience, technology and ideas of amenities in research centers arrived at during the past two decades. As a result, we have achieved an entirely new kind of plan and a new technical development in building.

"Investigating and re-examining the development of laboratory and office centers to date, we found of primary significance the fact that persons using these centers depend on air conditioning and efficient artificial lighting rather than on windows for their ventilation and lighting. As a consequence, the trend had been to use deeper space in buildings without windows, with only a few administrative offices with windows lining the periphery of the buildings. Even then, windows were usually obscured by venetian blinds or other forms of sun-shading . . . After much study, we arrived at a radically new plan. It is based on the idea of putting all laboratories and offices in interior space on short cross-block corridors and leaving the entire window-periphery free for main corridors.

"In its final stage, the Bell Laboratories will consist of four long-span separate building blocks, separated by a cross-shaped space with interior garden courts. Buildings and courts will be covered by one roof. The plan of each of the four

Photo shows typical conference room at Holmdel. There are twenty such conference rooms in the new laboratory, located at each end of both sections on the five upper floors, as shown on the floor plan.

units can be thought of as the gridiron of a football field. The main or trunk corridors run around the outside of the rectangle. The perpendicular lines represent alternating short corridors and structural utility walls.

"The advantages of this plan are many. Flexibility is at a maximum. Each of the cross-building cores is the width of seven six-foot modules. The entire core can be used as an open area, such as a drafting or typing pool, or it can be split into 12, 18 or 24-foot wide areas. . . . All service work can be done in the four-foot wide service cores without interfering with the occupants of a laboratory or office during change-overs or introduction of new equipment.

"The plan provides privacy for individuals in their offices and gives each the best controlled environment with the most efficient use of air conditioning and modern lighting, efficient and flexible storage-wall space and, particularly important in the laboratories, great flexibility in arrangements of instruments and laboratory furniture.

"The plan also ensures short, private corridors for easy internal communication. Since major foot traffic is relegated to the outside or periphery corridors in each building block, personnel will not be disturbed by movements of other employees.

"The plan also allowed us to take full advantage of the country site. Instead of offices and laboratories with small windows, covered with some sun-shading device, there can be continuous floor-to-ceiling glass walls for the corridors around each building block. Gone completely are the old claustrophobic, dreary, prison-like corridors. Emerging from concentration in laboratory or office, the individual will come upon the sweeping, uninterrupted views of gently rolling hills and formal planting and of the winter-garden interior court. At such moments of relaxation, walking down the periphery corridor, he can feel refreshed by the encounter with these views and really appreciate them.

"Obviously, we wanted to keep the continuous outside glass walls free of all window shading. We have all long wanted to encourage the manufacture of translucent wall materials that would act as a continuous transparent window from the inside but would, on the exterior, be a reflecting surface against the fierce heat of the sun. Steps in this direction have been taken by the manufacture of tinted glass. But now," wrote the architect in 1959, "we believe that the development of a new material will represent a major breakthrough."

Mr. Saarinen was referring to a new low-brightness reflective glass—a mirrored glass which would reflect 70 per cent of the sun's heat at 25 per cent light transmission. It is a laminate, with a thin film of aluminum bonded between the panes to protect the aluminum from the weather. As in the development of many new and forward-looking products, manufacturing difficulties were encountered in the perfection of this new glass. Rather than hold up building construction for an extended period of time, a sound alternative was to use a gray glass on the front and side facades. This material is also heat and glare resistant and, since it is not completely transparent, gives the building the form it would not have with clear glass. The reflective, mirrored glass, in spite of some irregularities in appearance, was installed on the rear facade. Several manufacturers are now working on various types of this mirrored glass, and the properties of these products are being evaluated.

As shown to the public this month, and as experienced by the 2,600 Laboratories employees who now work in this center, the new laboratory is a six-story building of reinforced concrete, enclosed by a wall of glass. The landscaping and roads around the building were designed and built to blend the strength and grace of the building with its 460-acre site and the surrounding terrain, and are ringed by wooded hills in Holmdel Township in the north central part of Monmouth County

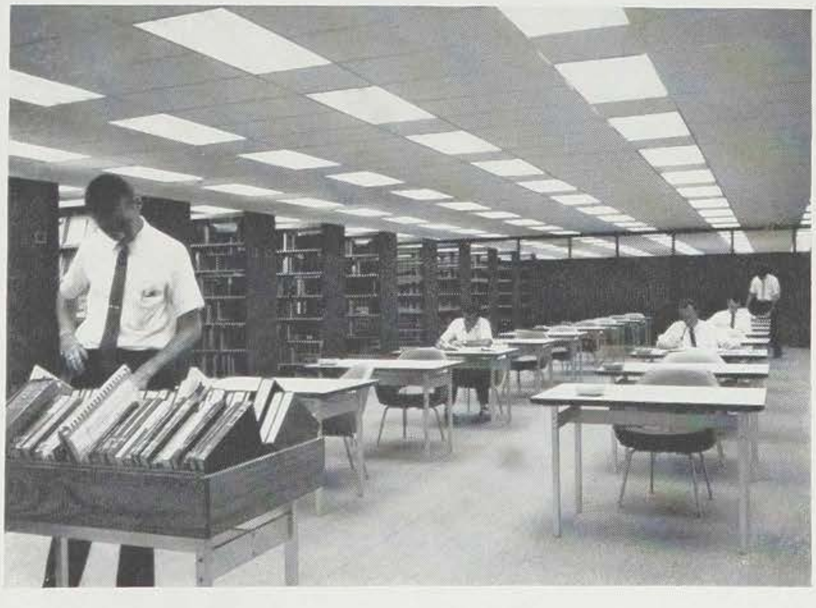
With the Western Electric Company in charge of the project, Frank Briscoe Construction Co. of Newark, N. J., was the general contractor.

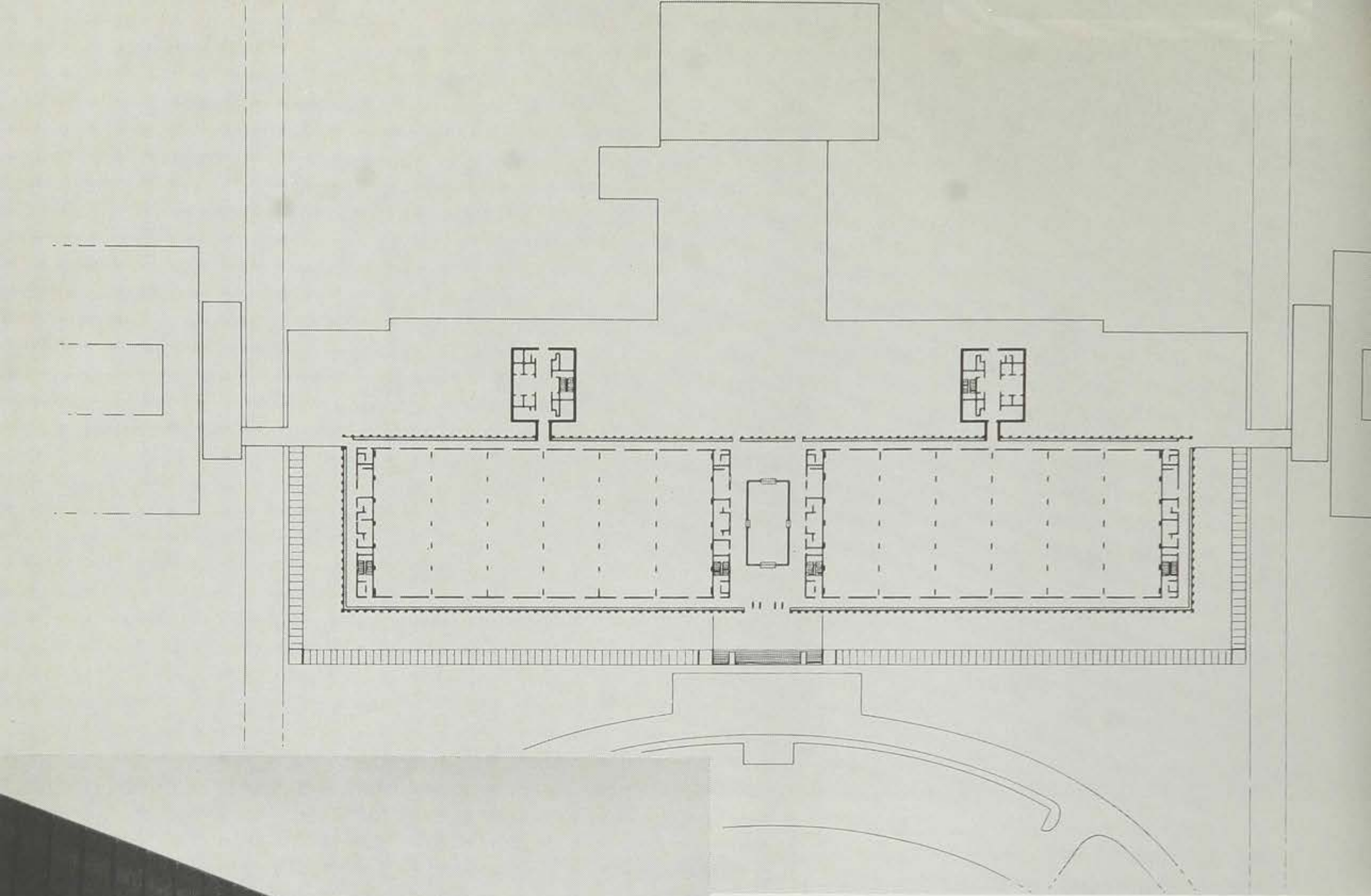
More than 50,000 cubic yards of poured concrete and 4,000 tons of reinforcing steel went into the reinforced concrete structural frame and floors. The building is built almost entirely on piles. The first floor of the structure is partially below grade. The five stories above grade rise above a surrounding concrete podium, which itself rises four to five feet above grade. Besides giving the appearance of a broad architectural base for the building, the podium also houses the intake and exhaust system for the building's air conditioning. The building is actually two separate, identical sections within the roof and glass wall which enclose the buildings. Nearly 100,000 square feet of glass, in 3′4″ by 6′6″ panes, are framed by more than 100 tons of black anodized aluminum mullions. The 4,500 panes are mounted in neoprene gaskets. A large lobby on the second floor separates the two sections, and is ringed by balconies on the four higher floors. The lobby is topped by a skylight.

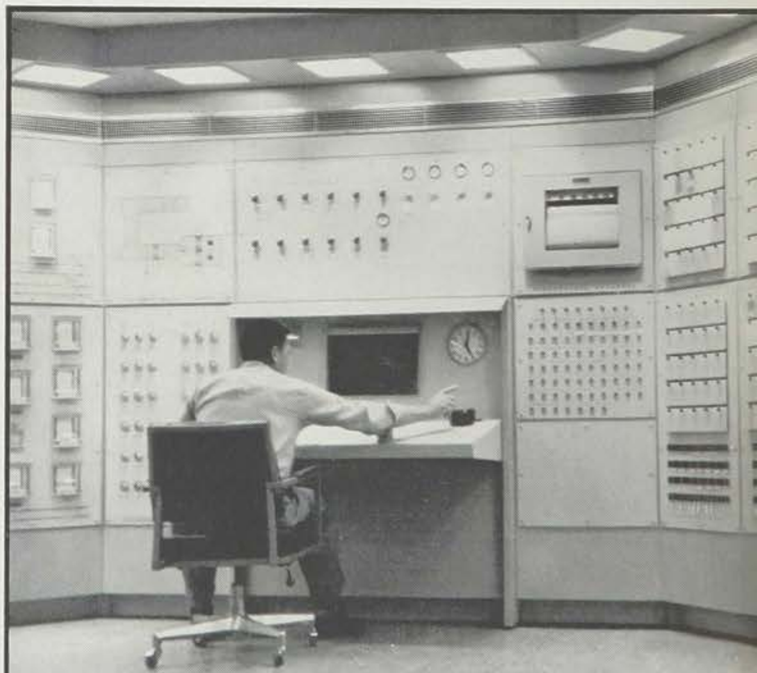
▲ *Computation center at Holmdel houses an IBM 7090 computer. The room is located on the first floor next to the auditorium, and extends out from the rear of the building.*

Drafting area is typical of the use of uninterrupted space made possible by modular construction. Such an area could be converted quickly into private offices or laboratories. ▶

The Holmdel library, also located at the rear of the first floor, has a present capacity of 14,000 volumes and some 500 periodical titles. ▶







From this console, the engineer can monitor and supervise all components in the air conditioning and heating systems.

◀ *View of corner gives indication of construction and shows how low transmission glass provides structural form*

Measuring 700 feet across the front and 135 feet deep, the building rises 70 feet above grade in the front. A concrete canopy shelters the front entrance. Two elevator towers, measuring 55 by 60 feet and 83 feet high, are connected, one to each section of the main building, by glass-walled bridges at the rear of the building. The towers each contain three elevators with provision for a fourth. Extended to the rear with the elevator towers is the part of the first floor which is above grade. This area includes maintenance, mechanical and equipment, shipping and receiving, and mail rooms. Between the towers is a large lecture hall and computation center.

The building has a gross area of 715,000 square feet, of which about 360,000 square feet are assignable as work space.

One unusual construction feature on the first floor is the use of 90-foot prestressed reinforced concrete beams to span the shipping and receiving areas as well as the boiler and air conditioning areas at each end of the building. Also, the entrances to these areas are beneath the side entrances and below the front grade, making them virtually "out of sight."

A restaurant extends out past the elevator towers and the first floor at the center of the rear of the building. Capable of holding about 1,000 people, the restaurant is also enclosed by a glass curtain wall and provides a view of the surrounding landscape. Foliage-filled planters and exposed concrete columns divide the room into sections.

This use of exposed concrete is a recurring feature in the building. The bush-hammered concrete appears on the podium wall and elevator towers, at the entrances, and in the lobby, lecture hall, dining area and other locations.

Also on the first floor is a library with a present capacity of about 14,000 volumes and some 500 periodical titles. The first floor also has shops, air handling equipment, stockrooms and other services.

As mentioned in the architect's original report, all main corridors are on the perimeter, with a grid of six cross-aisles in each section (or 12 on each floor) connecting the front and rear main corridors. Laboratories and offices are located on these cross-aisles. Major foot traffic is confined to the perimeter corridors. There are conference rooms and toilet facilities at each end of both sections on the upper five floors, with a total of 20 conference rooms.

The distance between front and rear perimeter corridors is 120 feet and the cross-aisle area, in-

Operator checks pressure gauges in boiler room. Installed capacity of the three steam generators is 52,000 pounds of steam per hour. Control room (opposite page) is on mezzanine in this room.

cluding laboratory, aisle and office is 42 feet wide. A six-by-six-foot modular grid prevails in the laboratory and office space areas. The aisle is normally situated so as to provide 24-foot-deep laboratories on one side and 12-foot-deep offices on the other.

Laboratories in one cross-aisle area are back-to-back with those in the next, with a walk-in service core between. In this service core are distributed the various mechanical and electrical services, such as piping for liquids, drains, and compressed gases; exhausts; ac and dc electric power bus ducts and telephone cables; as well as the conditioned air for ventilation of each room. These services are extended into the laboratories as needed.

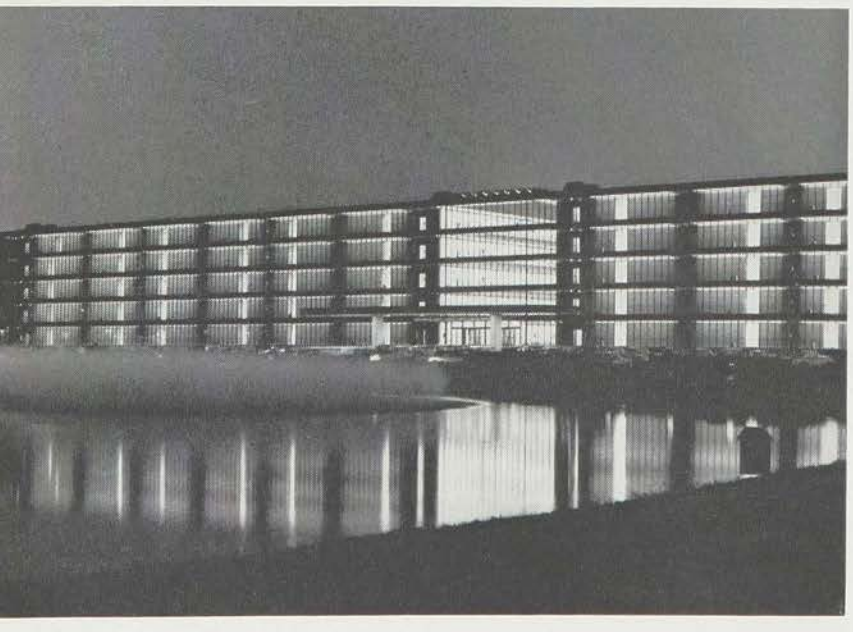
Similarly, offices are back-to-back. Columns are spaced approximately 46 feet apart and occur in the service core and between the backs of offices so that each 42-foot-by-120-foot cross-aisle unit is unobstructed.

The interior was designed for great flexibility in the utilization of space and for maximum ease for making rearrangements. The 6-foot-by-6-foot grid is delineated by an inverted channel which supports the acoustic ceiling and the lighting fixtures. This channel is permanently available to receive the top of the metal office partitions with the assurance of a good acoustical seal.

The steel wall partitions can be moved easily and economically to provide small or medium sized private offices, or group offices. Large or small laboratories can be set up by shifting partitions. Glass panels on the upper part of the side and aisle partitions give a feeling of spaciousness.

Flexibility in the offices is featured by a rear wall which is composed of interchangeable furniture components such as wardrobe closets, shelves and file cabinets. The arrangement of these components can be selected as the occupant prefers. Closet doors and blank panels are finished in an attractive leather textured vinyl.

Holmdel Laboratory at night, reflected in its pool.



Since the offices and labs have no outside windows, they depend on efficient fluorescent lighting and air conditioning exclusively. Lighting is provided by some 9,000 fluorescent fixtures, which serve a double purpose. In general, alternate fixtures provide outlets for air conditioning through small perforations in the fixture. Most rooms have individual thermostat control. The constant volume, dual-duct air distribution system is designed to maintain a temperature of 75 degrees F, with relative humidity not to exceed 50 per cent.

Conditioned air for each building section originates in air handling units located in the mechanical equipment rooms on the first floor. Outside air is drawn from the podium ringing the building, mixed with return air, conditioned and delivered through a network of ducts to risers in the service cores.

A return air system was designed with return air shafts located in the corners of each building section. Air is exhausted from offices and labs into the aisles through transfer boxes at the top of aisle partitions. A proportionate amount of air is intercepted by ceiling return air grilles in each cross-aisle and transported to a partitioned masonry shaft. The remaining air is allowed to pass through the perimeter corridors for supplemental cooling or heating and is intercepted by floor-to-ceiling return air grilles affixed to the return air shaft.

Additional heating and cooling is provided for the perimeter corridors through the use of floor-level finned-tube radiation and individual recirculating air fan-coil units. Total air circulation exceeds 500,000 cubic feet per minute. Installed air refrigeration capacity totals 2,400 tons. The installed capacity of three steam generators totals 52,000 pounds per hour.

Electrical power is received from the Jersey Central Power & Light Co. through an outdoor substation. The transformer capacity of the substation is 15,000 KVA at 34,500 volts via two power feeds. The power is distributed to substations inside the building at 13,200 volts and is reduced to 480/277 volts for utility power and lighting and 208/120 volts for laboratory power.

Water is supplied by three deep wells triangulated on the property. All water is treated at the water softening plant located in the service building, and is piped into the building and to the 300,000 gallon storage tank, located on a graceful tower at the main entrance roadway. The tank is 127 feet high and provides a dependable water reserve for fire protection as well as serving to maintain a constant pressure for the building. The fire loop is connected to the water main through two protective check valves.

Landscaping is an integral part of the over-all design. More than 7,900 shrubs and trees have been planted around the site. Four reflecting pools blend with the landscaping. The largest, in the esplanade at the front of the building, covers about six acres and holds some six million gallons of water. This water, through a fire pump connection, serves as a fire-fighting reserve. An attractive spray system in the pool also serves a practical purpose—to provide evaporative cooling for water from the air-conditioning system without using unsightly cooling towers.

A second pool in front, separated from the first one by a road, takes in about three and one-half acres. Two smaller stream-fed ponds of about an acre each face the side entrances.

The site has three entrance roads, which feed into two circular roads running around the building and leading to parking lots and service areas. Each circular road carries traffic one way. Features of the system are that pedestrians never have to cross a main traffic artery to enter the building, and traffic is sorted according to destination before it leaves the site.

Two employee parking lots at the side entrances have a capacity of about 2,000 cars. The longest distance from a building entrance to a car in the adjoining parking lot is about 600 feet, of which 250 feet are covered by a canopy that extends from the side entranceway. A visitors' parking lot, near the front entrance, has a capacity for some 150 cars.

In addition to the main building, there is a 35,000 square foot service building. This is used as a garage and general storage area, as well as for housing controls and equipment associated with the water supply and sewage system for the development. The aeration-type sewage disposal plant is large enough to handle an average community of 750 homes. It disposes of laboratory waste as well as sewage, processing the material to avoid pollution of neighboring streams.

Construction of the Holmdel development center began in August, 1959. The service building was occupied in January, 1960. Initial occupancy of the main building was in October, 1961. The building was completed in June, 1962.

Future plans call for another two-section building to be added to the existing main building. It would be identical to the main building and would be built onto it, connecting via bridges to the opposite side of the elevator towers. Starting and completion times for this addition are indefinite.

President Kennedy Signs Satellite Communications Bill

On August 31, the Communications Satellite Act of 1962 was signed into law by President Kennedy. In signing the bill the President said that it "promises significant benefits to our own people and to the whole world. Its purpose is to establish a commercial communications system utilizing space satellites which will serve our needs and those of other countries and contribute to world peace and understanding."

He added that the bill provides "many safeguards and protects the public interest. No single company or group will have the power to dominate the corporation." He stated that "the general public, the communications industry and the federal government will all have a voice. All will contribute their resources and all may reasonably hope to benefit. In this way the vigor of our competitive free enterprise system will be effectively used in a challenging new activity on the frontier of space.

"The benefits which a satellite system should make possible within a few years will stem largely from a vastly increased capacity to exchange information cheaply and reliably with all parts of the world by telephone, telegraph, radio, and television. The ultimate result will be to encourage and facilitate world trade, education, entertainment, and many kinds of professional, political, and personal discourse which are essential to healthy human relationships and international understanding."

The President will appoint incorporators to serve as the board of directors until the first annual meeting of the private corporation which will administer U.S. participation in the world satellite communications system. The bill provides that the incorporators will "arrange for an initial stock offering and take whatever other actions are necessary to establish the corporation, including the filing of articles of incorporation, as approved by the President."

Half the stock of the new corporation will be available to private communications carriers and the other half will be available to the public for about $100 a share. Directors will represent the public, government, and industry. The Federal Communications Commission will be responsible for regulating the satellite communications corporation.

PBX attendants at Chase Manhattan Bank, in New York City. The modern attractive CENTREX *office at the top, equipped with the new compact consoles has now replaced the cord switchboards below.*

A new concept of PBX service for modern business was recently introduced by the Bell System. It uses telephone company equipment as a combined central office switching system and PBX.

George Spiro

CENTREX Service with No. 5 Crossbar

Private branch exchanges (PBXs) have served the diverse communications needs of business customers for many years. Originally conceived as, in effect, small, self-contained switching systems, they were designed to serve situations in which most calls were internal, with relatively few into or out of the system. That concept is still tenable for small installations. The complex operations of many of today's businesses, however, pose traffic problems that challenge the traditional PBX.

The need to alter the traditional concepts of PBX switching system design was indicated by the first market trials of direct distance dialing (DDD) service. These trials showed that it would be desirable to convert the entire telephone network to DDD operation. To accomplish this objective properly, DDD service must be furnished to all PBX stations.

At first, attendants at dial PBXs had to complete and terminate connections between PBX stations and the DDD network. Now, a more advanced type of service has been developed by the Bell System. Called CENTREX, it provides direct inward and outward dialing for any station in a PBX. Thus, while it offers all the service features required by a large, complex business, CENTREX gives PBX customers service that is comparable to individual line business service in speed, flexibility, and efficiency. To achieve this, Bell Laboratories has developed new PBX switching systems, modernized old ones, and modified the designs of local central office, tandem, and toll switching systems. This article will describe one of the most important of these developments—CENTREX service using the No. 5 crossbar system as a combined PBX and central office switching system.

The need for this new system was created largely by the concentration of many companies in metropolitan central office exchange areas. Construction has boomed since World War II, especially in business buildings. New office buildings, industrial parks, factories and airports have become familiar scenes on the country's landscape. Like small communities, these complexes have large volumes of telephone traffic, both internally and to and from distant points. And it is apparent that, like individual line customers in small communities, the businesses within these complexes will benefit from shared central office facilities. For one thing, they will save valuable office space and power. For another, their service will be improved through a central office level of maintenance and through the ease with which central office equipment can be rearranged to accommodate new needs in business communications.

An early attempt to improve PBX service was made at the Air Force Academy in Colorado in 1958. In a communications building built by the Air Force, the Mountain States Telephone Company installed No. 5 crossbar equipment to serve both central office customers and Air Force Academy telephones. It was equipped with local automatic message accounting (AMA) and arranged for nationwide dialing. The part of the No. 5 equipment that served the Air Force Academy permitted Academy stations, all of which had 2-letter, 5-digit numbers, to receive incoming calls directly. Calls between Academy stations are made by dialing the last four digits. On outgoing charge calls—which are dialed directly and handled like calls from individual line customers—the local AMA equipment records the calling station's number.

In January 1959 a similar office was installed to serve the Dow Chemical Company at Midland, Michigan. It consisted of a No. 5 crossbar central office in an operating telephone company building about 3 miles from Dow Chemical. Operating telephone companies in several parts of the country provide this kind of service.

The features of these offices were retained in the CENTREX system. However, like many early systems, they had certain limitations which had to be overcome before the aims of nationwide DDD service could be achieved. One drawback was that these systems could serve the stations of only one PBX customer on a direct line basis. It would, of course, be prohibitively expensive to provide a No. 5 crossbar office to any PBX customer who wanted the features of the early systems. A second difficulty was that cord switchboards had to be used and attendants had to handle calls manually. Still another limitation in these early systems was that direct inward dialed (DID) calls could not be transferred from a called station to another station or to a tie line.

CENTREX service overcomes these limitations. The No. 5 crossbar office can serve as a common switching medium for as many as 100 PBXs. Most CENTREX installations will be served by attendants using cordless consoles to which calls are automatically distributed. However, the No. 5 cross-

New compact console designed for PBXs served by CENTREX. It can be conveniently placed on a desk top and used by an attendant, or by a company receptionist.

bar system arranged for CENTREX service has a number of special service features the older offices did not have. The basic features now include:

- Direct inward dialing (DID) to extensions;
- Identified outward dialing (IOD) using AMA;
- Intra-PBX calling;
- Incoming call transfer.

The PBX attendant can handle:

- Calls to the listed directory number;
- Transfer calls;
- Dial "O" assistance calls from PBX stations;
- Conference calls;
- Tie-line calls;
- Intercepted calls.

A PBX customer can choose any combination of these features for each station in his system. For example, a station may have unrestricted dialing privileges, or it may be restricted to intra-PBX calling only, or to intra-PBX calling with access to the attendant (dial "O") to complete outward calls. There are available 20 possible variations of originating call treatment and several terminating restrictions. To make the proper distinctions between stations with different restrictions and privileges, the No. 5 crossbar equipment was modified to generate and recognize 100 class-of-service marks and 20 rate (or routing) treatments. Class-of-service marks identify the PBX; rate treatments identify the dialing restrictions for each station — each variation requires a separate rate treatment. Because any rate treatment can be used commonly by all customer groups in a central office, each customer can select freely from the 20 that are available.

With DID, a customer needs a smaller number of PBX positions, and therefore, fewer attendants. In some PBXs arranged for DID, up to 90 per cent of the incoming calls are dialed directly to the stations, thus by-passing the attendant. This leads to improved transmission, because fewer switching and switchboard circuits are involved in the connection. DID also gives faster service, because it takes about 30 seconds less time to complete a directly dialed call than one which must be handled by an attendant, a significant saving in holding time for trunks and switching facilities. Also, the fact that an attendant does not come in on the call insures the privacy of a business conversation.

IOD, in a sense, consolidates the gains the PBX customer achieves with DID. Each station receives individual line service on the No. 5 crossbar equipment, and so does not have to go through the attendant unless its outward service is restricted. Details of all charge calls are recorded by local AMA equipment and reported to the customer by individual station billing.

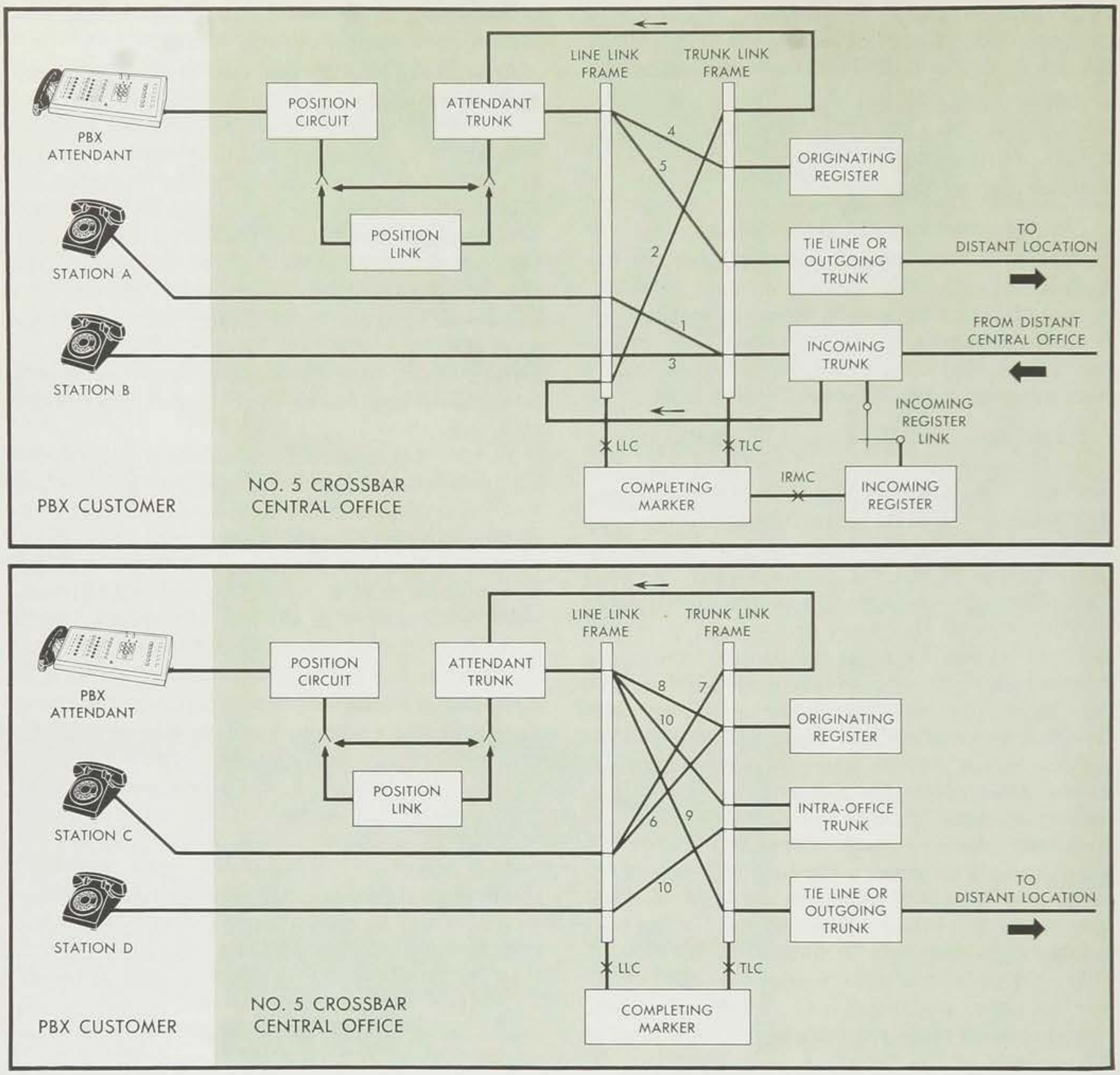
Calls made within the PBX are not charged. They are usually made by dialing the last four digits of the station number. However, because 0, 1, and 9 are used for reaching the PBX attendant, tie lines, and outside access, respectively, they cannot be used for first-dialed digits. Therefore a single office code is limited to the numbers between 2000 and 8999 for PBX stations. Some central offices will serve more than 7000 PBX stations and in these cases 5-digit dialing will be used. The third-digit of the office code, or an arbitrary digit, will extend the range of usable numbers to any 40,000 in the series from 20000 to 89999.

The No. 5 crossbar system uses only two switching frames to complete talking connections—a line link frame and a trunk link frame. CENTREX incoming trunk circuits appear on both these frames so that any incoming call to the PBX can be connected to either a station line or an attendant's trunk and, with the PBX attendant's assistance, calls can be transferred between stations.

The drawing on page 330 shows how this is done. Let us assume that an incoming call has been routed to station A over path 1. The completing marker shown in the drawing stores the class of service of station A in the trunk along with a mark indicating that the station may have calls transferred. To transfer this call to station B, the station A user merely flashes his switchhook. The incoming trunk circuit recognizes the flash, checks that transfer privileges can be exercised on the call, and instructs a completing marker to set up a connection to the attendant. This instruction is sent via the incoming register.

The completing marker now reads-out the stored class of service, say customer group 47. It then connects the incoming trunk circuit at the line link frame to the trunk link appearance of an attendant trunk circuit for the customer group. This is path 2 in the drawing. When it is seized, the attendant trunk circuit makes a connection to the attendant through the position link and position circuits. If the PBX has only one attendant position, the position link is by-passed.

At this point the attendant takes over and supervises the transfer. First, she operates a key which signals the incoming trunk circuit over path 2 to release the connection to station A over path 1. Then she keys the last four digits of station B's number into the incoming register. Again, the completing marker matches class of service marks to see that station B is in customer group 47. If the classes agree and station B is



Routing calls over the No. 5 crossbar system to a PBX. *The top half of the drawing shows how calls may be dialed directly to a station and how they may be transferred to another station with the attendant's assistance. The bottom half shows how the attendant may assist in completing calls.*

idle, a connection is made over path 3. When the connection is made and conversation begins, the attendant releases path 2 and all the equipment involved in transferring the call. The call can be transferred from station B to any other station in the group, and from that station to any subsequent one. Charges are made from the time the first station called answers until the calling party disconnects.

Incoming calls may also be transferred over a tie line to another location or to an outgoing trunk to a distant location. This operation is the same as the one described for transferring a call between stations in the same office up to the point where the attendant releases station A. In transferring to another location, however, station A can stay on the connection. Call transfer then proceeds pretty much as before, except that the attendant keys the distant station's number into an originating register rather than an incoming register. This is shown in the drawing above as path 4 from the attendant's trunk over the line link frame to the register. At this point, the completing marker sets up the call to an outgoing trunk or tie line over path 5. The incoming call is connected over paths 2 and 5 to the distant location and stations A or B can be bridged on the connection over paths 1 or 3.

On a call to a tie line, the marker matches class of service to restrict the routing to a tie line that belongs to customer 47. On an outward charge call, AMA records are used to bill the call to customer 47.

There is no charge for calls between stations in one customer group, hence they are not transferable; each call is dialed. To make certain that all non-charge calls are confined to the single customer group, class-of-service matching takes place on all intra-PBX calls.

Probably the largest volume of traffic handled by the PBX attendant in a CENTREX served office consists of calls to the listed directory number. Incoming calls are routed to the attendant over an incoming trunk using an incoming register and a completing marker that recognizes it as a call to the listed directory number. A cross office connection to the attendant trunk is established with the incoming trunk at the line link frame. The drawing opposite shows this connection as path 2. A distinctive lamp signal on the attendant's console indicates that the call is to the listed directory number, and she answers with the company's name. The attendant can extend the call to any station in the group (path 1 to station A in the drawing) or she can complete it to an outgoing trunk or tie line (paths 4 and 5).

Key pulsing and control are the same as those used in transferring calls. The completing marker matches classes of service to confine calls to stations or tie lines of the group. Any PBX station can initiate a transfer request.

The drawing opposite also shows how the attendant assists stations in placing calls. Say that station C has received dial tone from the originating register over path 6. If the station C user wishes attendant assistance, he dials "O" and the completing marker connects him to an attendant trunk (path 7). The attendant can now complete the call through an originating register (path 8) over a tie line or outgoing trunk (path 9) or over an intra-office trunk (path 10) to another station (say, D) in the group.

Calls dialed to stations which have been temporarily disconnected or whose numbers have been changed are also routed to the attendant. These intercepted calls are controlled through cross-connections in the central office. Vacant or disconnected numbers in a customer's series are routed to an announcement.

To help the attendant handle these calls efficiently, Bell Laboratories has designed a new cordless console (see photograph on page 328) with illuminated keys and a pushbutton keyset. A large customer may need several consoles, and in this case a distributor or position link circuit in the central office directs calls to the various positions.

A modified 608A switchboard may be used in place of the console. However, at this board attendants must answer, initiate, or complete calls with cords. Thus, the 608A switchboard is bulkier and less efficient than the console.

Today there are more than 6700 Bell System PBX customers with 200 or more stations. CENTREX service should appeal most strongly to these customers because of its economic benefits and because of the improved speed of communications it offers. A number of additional features such as inward dialing to PBX satellites, station controlled dial transfer, add-on conference calling, and dial hold are being studied and developed. All of these are directed toward still further mechanization of PBX service and, hence, to the fastest and most reliable service that can be developed.

Crewmen working on a CENTREX exchange being installed for the New York Telephone Company.

The Industrial Designer— His Role and Purpose

Henry Dreyfuss

The industrial designer has frequently had a hand in the design of communication equipment. How does such a person operate? Henry Dreyfuss, noted industrial designer, discusses his work in this invited article.

There is a man in Detroit who is reputed to have said that one day it will be possible to feed every known curve and contour, every angle and plane, into a computer, and then, by merely pushing the proper controls, produce the design of a new automobile.

It is true that we are acquainted with the mathematics of an infinity of planes and curves —and a computer could doubtless be devised to compose and arrange them scientifically. But what of the human factor of good taste—and the "magic" that lies in the disciplines of the designer to assemble and relate those planes and curves in a balance that is both serviceable and pleasing?

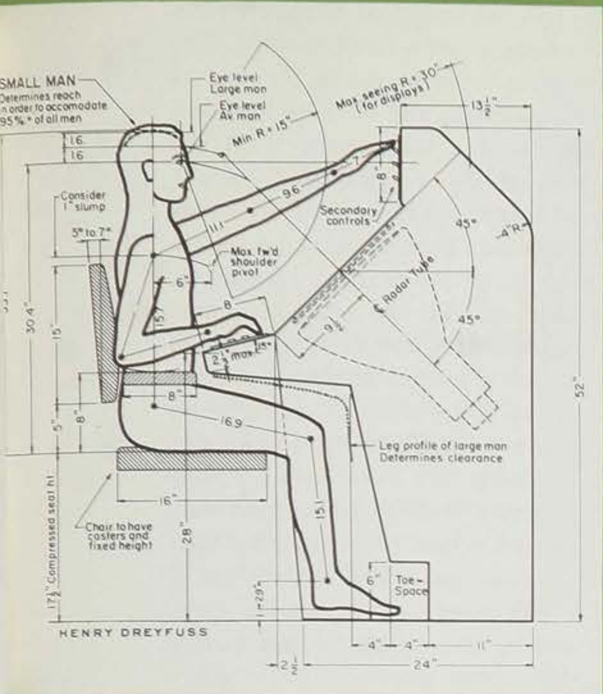
Industrial design cannot claim to be an exact science that can unequivocally prove its merits. Designers must still rely on what they call an "educated hunch"—an intuition resulting from education, experience, research, recognition of engineering problems, understanding of product usage and, finally, a sense of timing.

While the designer is guiding his client in changing a product's appearance, he must be aware of the real danger of being so far in advance of public acceptance that the product is rejected by the consumer! Paradoxically, however, design often begins many years before the product is to be introduced. Therefore, the designer must have an awareness of the pace of change in public taste; then the product will find its natural place in the market at the date of its introduction. The industrial designer must be sure of his ground and have the confidence of his client so that there will be complete accord on design aims.

Purity of design must be everyone's goal, and obsolescence planned solely for merchandising purposes is deplorable. On the other hand, obsolescence resulting from new engineering or technological developments is sound progress, and such advances should be expressed in the design and appearance of the product.

Ideally, when the function has reached perfection, the form is beyond criticism. A very few objects have achieved such excellence—the ball, the wheel, the plowshare are among these, as are some aerodynamic and nautical forms which have been affected by the forces of the elements.

In most cases such extreme simplicity is not possible; many components are needed for the function, and these must be integrated into practical and pleasing forms. Simplicity, however, is



Industrial designers use data from anthropometrical figures (left) in designing consoles such as that shown at right. Console is used in the Nike control van, nerve center of a Nike missile site.

still a constant objective. Beauty, on the other hand, while important, is not a primary objective of the industrial designer. Much more basic to the design process is the enormous concern with the ultimate user of an object.

Except for some few examples that perform entirely unattended, devices in general are used or operated by humans; hence, the industrial designer is preoccupied with human factors. Knowledge of anatomy and of psychology are two of the most important tools he has within his reach. For example, important measurements in the design of a telephone handset are the "modal distance"—the distance from ear to mouth—and the cheekbone clearance. Design for a "solid grip" provides a feeling of security and comfort, while the weight is minimized to reduce user fatigue. However, an experienced industrial designer must not only be acquainted with the anthropometrical figure, but must also be familiar with the pressures each of the body's extremities can exert. In addition, environmental factors, such as the effects of colors and sounds on the senses, are among the many considerations which the industrial designer must respect.

A good design must start with an understanding of the man, woman or child who will eventually use the object. In a broad sense, we say we must fit the machine to the man—not squeeze the man into the machine.

Our work with Bell Laboratories engineering personnel on the consoles for the U. S. Army's NIKE HERCULES system, shown above, is an interesting example of the application of human engineering studies in industrial design. One of the primary problems in developing design criteria for these consoles stemmed from the fact that there were several different companies participating in the contract, and each had its own design philosophy. Consequently, each contractor's design had to be reviewed carefully in its relation to the optimum system that was our objective. We stressed especially the need for consistency in typeface and lettering size, control positions and the manuals relating to the associated displays.

Our earlier work on the BMEWS console was extremely helpful in the NIKE HERCULES development program. For the new system, our goal was to put in front of the operator convenient controls, grouped and located according to related function and sequence of operation. We wanted an uncluttered panel layout to avoid operator confusion and to satisfy all considerations of reach and vision. Also stressed was the importance of nonreflective surfaces, as well as the intensity of illumination of the displays. To reach this end, we made many studies, concentrating on the operator, his capabilities, and his environment. A diagram indicating some of the critical measurements is shown above, contrasted with the actual console in use.

This description is necessarily brief, and no attempt has been made to present all of the human engineering and industrial design aspects of the NIKE HERCULES system consoles. However, the program is of particular interest because it relates to other work that we have done in industry. For instance, the redesign of a turret lathe was comparable in two main areas:

1. MANUALS CONTROLS — These were studied for their location, organization, and handling ease as determined by the human limitations of reach, muscular strength, natural limb motion, speed of action, hand grip characteristics, fatigue and mental habits.
2. SPEED SELECTION AND INDICATION—Here, position, organization, type of information and the needs of legibility were studied in relation to eye level, form and color, maximum reading distance, eye motions, head motions, and color contrast.

On the redesigned turret lathe, shown in the photo below, the controls have been so grouped as to be within the operator's reach without requiring excess stretching or body movement. A comprehensive study of the hand movements required to start the original lathes under normal conditions indicated that sixteen hand movements were needed—the hand movements for starting the redesigned lathe were reduced to only seven. In addition, the operator does not need to move from his normal working position.

The uninitiated may consider the industrial designer's contribution to be a superficial one, similar to the application of cosmetics. Nothing could be farther from the truth. The industrial designer strives toward these five considerations:

1. *Safety and convenience of use*: Protection against loss of life and limb may sometimes require the use of guards, but often better protection can be achieved through placing dangerous components intelligently. The industrial designer tries to make the use of each component obvious, and studies the comfort of the user in his interaction with the shape of a knob or the height of a step.
2. *Ease of maintenance*: This is often overlooked. It is essential that repairs be easily made. All parts must be readily accessible, easy to clean and oil. To the ultimate user, it is just as important to be able to remove the dust from the vacuum cleaner quickly and neatly as it is to be able to change the engine nacelle on a jet airliner expeditiously.
3. *Cost*: Industrial designers have been accused of reading cost sheets with more understanding than they show when they scan a blueprint! It is, however, pointless to produce a product which will prove so expensive that no one can afford it, or so underpriced as not to permit a reasonable profit to the manufacturer. Good design need not increase cost.
4. *Appeal*: This can best be interpreted as quality — the elusive, indefinable attribute that can sway a person to *want* the product. Realistically, it is the difference between the "feel" of closing the door of a Model T Ford and that of a Cadillac—the satisfaction of operating a well-designed control rather than a poorly engineered one.
5. *Appearance*: This item is placed last on the list, because if the preceding goals have been achieved, the product will automatically approach good appearance. It is then left to the industrial designer to apply his knowledge of line and form, proportion, texture and color, and integrate them into a pleasing whole.

Turret lathe, redesigned on basis of human capabilities and limitations, reduces operator effort.

The industrial designer is often found in unexpected places. He has contributed to the development of farm machinery and oil well drilling rigs, to industrial machinery, meters and valves, and to every form of transportation. He has been applying himself extensively to the improvement of the control centers and ground equipment systems that monitor our rockets and missiles. He is employed in government defense efforts on items as varied as the interiors of armored tanks and the capsules that will eventually land man on other planets.

The story is told of the industrial designer who was in his client's showroom, observing reactions to a newly produced tractor. A farmer and his wife were circling the machine and the farmer said, "If that works like it looks, I think we'd better have one." The designer had succeeded in

Each of the variety of telephones shown was designed to perform a specific function. The variety itself indicates the need for the industrial designer as an important member of the development team.

one of his most important functions—to reflect outwardly the excellence of the engineering, the capabilities of the product and its safety and comfort, and had visually conveyed the integrity of the manufacturer.

Raising the level of public taste must be one of the prime responsibilities of the manufacturer. He is abetted in his efforts by both the engineer and industrial designer. The taste-setting potential that exists within the area of the telephone, for example, is incalculable; no other product reaches so many people so often. The frequently-used residential telephone instrument alone has an enormous effect on public taste. Not many years ago the telephone was a necessity grudgingly accepted on an office desk and often hidden in polite homes. Today this essential apparatus is a decorative accessory which has influenced design and color trends. Its function approaches perfection, and the telephone has become a vital part of our lives.

In this sense, Bell Laboratories is a leader of public taste, possibly as much so as in scientific development. Long before industrial design was considered one of the important factors in manufacturing—perhaps before the average man knew what the term meant—the men who were then directing Bell Laboratories had the foresight (and the courage) to seek industrial design aid, and selected our organization. The long-term association has been an exceptional example of exchange of influence. We have profited by the patient understanding and explanations of the engineers, and our efforts hopefully have guided their understanding of the philosophies of industrial design.

It has been our experience that close coordination between the industrial designer and the engineer, from the conceptual stage until the product is released for manufacture, can produce the optimum result. Over the years a mutual respect has developed between the engineer and the industrial designer. The former is rightfully preoccupied with the details of "making it work," and his collaborative industrial designer brings to the problem his "educated hunch" plus an objective outside point of view.

When the engineer automatically applies the precepts of human factors and good taste to his efforts, and when the industrial designer becomes knowledgeable and sympathetic to the problems of engineering, an additional dividend results from their association, to the benefit of the consumer or user, the ultimate judge of all products.

technical News Briefs

Brief accounts of recent technical developments at Bell Telephone Laboratories

SIMPLIFIED EPR TECHNIQUE DEVISED

Scientists at Bell Laboratories have devised a simple and fast electron paramagnetic resonance (EPR) technique for studying the structure of organic molecules. The new procedure does not require that samples be in the form of single crystals and does not require as extensive data analysis as some previous methods.

Using this technique, the scientists have demonstrated for the first time by EPR that the most stable form of several organic molecules contains two unpaired electrons. (Unpaired electrons are electrons which have magnetic spin moments which do not cancel each other.)

The simplified EPR method will make it considerably easier to investigate the electron structure of some paramagnetic materials which occur during many biological and chemical processes.

The scientists involved are W. A. Yager, R. M. R. Cramer, E. Wasserman, R. W. Murray, and A. M. Trozzolo, all of the Chemical Research Laboratory.

NEW SYNTHETIC CRYSTALS ARE PIEZOELECTRIC AND FLUORESCENT

A new series of crystals which are both piezoelectric and fluorescent has been synthesized. A. A. Ballman, Metallurgical Research Laboratory, has grown small, single crystals of rare earth, aluminum-borates and rare earth, chromium-borates by slowly cooling a molten solvent saturated with the component oxides. The crystals are unusual in that they combine optical and electric properties not usually present in the same crystal.

CLOCKS ON TWO CONTINENTS SYNCHRONIZED BY TELSTAR

Clocks in the United States and Great Britain were synchronized on August 25, via Telstar satellite. Experiments were conducted at the transmitting and receiving stations at Goonhilly Downs, England and Andover, Maine by the National Physical Laboratory, Teddington, England and the U.S. Naval Observatory, Washington.

Signals were sent simultaneously from Andover and Goonhilly. By noting the time of arrival of a pulse from the other station and comparing it with the transmitted pulse, it was possible to determine both the time of transmission of the signal and the difference in time of the clocks at the two transmitting stations.

By eliminating custom engineering, manufacture and installation, costs of No. 5 Crossbar offices can now be competitive for all central office sizes, even down to 500 lines.

For No. 5 Crossbar - - A Packaged Central Office

J. E. Greene

The flexibility which common control switching provides for present and future services, as well as for growth, is just as desirable for small telephone offices as it is in the larger switching centers of the national network. Unfortunately, even the minimum amount of common control equipment becomes a major factor of cost in a small office, and this has tended to eliminate common control systems from consideration in engineering such offices.

About three years ago, a seven man task force was set up to study means of solving this problem. Representatives of the American Telephone and Telegraph Company, Western Electric Company and Bell Laboratories were assigned to determine what cost reductions could be accomplished in No. 5 Crossbar through additional standardization and packaging. Their conclusion was that costs could be reduced for small offices by eliminating custom engineering, custom manufacture, and custom installation. This implied fixed sizes of offices without options, and with fixed floor plans.

The first No. 5 Crossbar packaged office, "pre-engineered" by the task force, was shipped in August, 1960. At the present time, the Western Electric Company is manufacturing and installing similar No. 5 Crossbar packaged offices at a rate of about two per week. By the end of this year, package offices will be installed in 45 of the 50 states and in Washington, D. C.

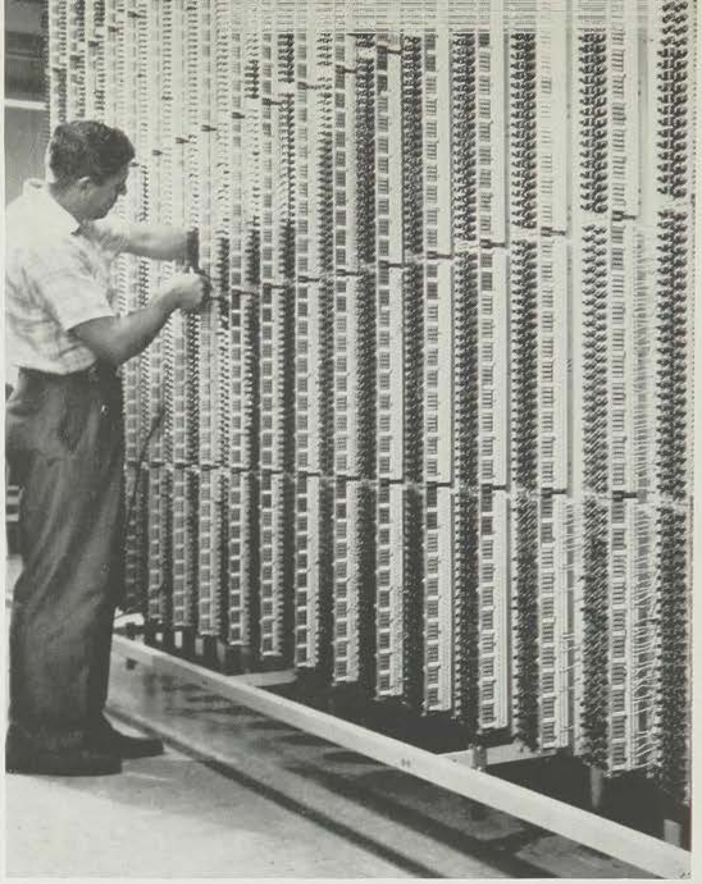
The packaged offices are now available in four sizes, serving up to 580, 980, 1960 and 2940 lines respectively. Each office consists primarily of standard No. 5 Crossbar frames with features and options selected to serve the majority of new local office installations.

A standard floor plan was developed for each size packaged office, to show a fixed location for each piece of equipment. This permitted the inclusion in the package of standard details for ladders, lighting, framing and factory-prepared interframe cabling. The most economical power plant and small ringing plants were adopted for each of the packages.

The cost of common control equipment in the smaller packages was further reduced by replacing the master test frame and trouble recorder with a simple office test frame and lamp type trouble indicator. Also, relay rack mounting was

Exterior of New York Telephone Co.'s packaged central office at Hampton Bays, N. Y.

Power equipment for the packaged central offices can be ordered with a single "J Code."



Henry Makowski, New York Co., works on main distribution frame before cutover at Hampton Bays.

used for marker route relays, a smaller coin supervisory link frame was developed, and one incoming register link frame was arranged to serve both dial pulsing and multifrequency pulsing incoming registers. A new originating line identifier was developed to handle dial tone calls by making use of the excess capacity of a minimum of two completing markers, thus replacing the more complex dial tone markers. Universal operator office trunks were developed to permit combining several functions into one group of trunks, saving considerable outside plant between packaged offices and associated switchboards—especially important when these are widely separated.

Packaged offices have been assigned "J-codes" to facilitate ordering. Within each size of office there are choices of signaling available, depending upon the existing plant with which the office must operate. Cabling and associated details may be omitted from the package if the exact standard floor plan cannot be followed. Parts or all of the power equipment may be omitted if the package is to be installed in an existing building where power is already available.

From an economic standpoint, these packages are attractive compared to custom engineered central offices of the same size, even though additional trunks or additional features may be needed to satisfy the requirements of the particular location. The benefits of standardization were achieved by observing the old lunch-counter maxim of "No substitutions"—the quantities and features provided in the coded packaged equipment must be accepted without change on the initial order.

No. 5 Crossbar packaged offices are now recommended for the starting entity of any local office regardless of size or location. No limit is imposed on growth in frames, lines, numbers, or features by the packaged design. Any packaged office may grow to the maximum No. 5 office size and any standard No. 5 Crossbar features not included in the package—AMA, CAMA or ANI; foreign area translators; toll or tandem switching; coin overtime, coin zone dialing; TOUCH-TONE Calling; CENTREX; WATS; WADS; line insulation testing; automatic monitor; or service observing —may be added when needed, just as in any standard No. 5 Crossbar office.

The results of the recommendations of the task force, with a relatively small amount of new development, have exceeded the most optimistic expectations. Common control offices—No. 5 Crossbar—are now feasible on a competitive basis for the entire range of central office sizes, including those as small as 500 lines. Just a few years ago this was thought to be not even remotely possible. Needless to say, the packaged concept has met with complete and enthusiastic acceptance by all telephone companies.

Locating Open Conductors In Multiple-Line Wire

I. M. McNair, Jr.

Multiple-line wire is a telephone term referring to multipair wires often used in rural and suburban distribution systems. It consists of pairs of plastic insulated copper conductors spiraled around a support wire. Because there is no sheath, or outer covering, the conductors are more susceptible to damage than the conductors of standard sheathed cable. Such things as lightning or gun shot may directly sever a conductor, or mechanical damage to the insulation during installation may allow a conductor to corrode where it is exposed to the atmosphere. Such breaks, or "opens," in the wire result in the loss of transmission.

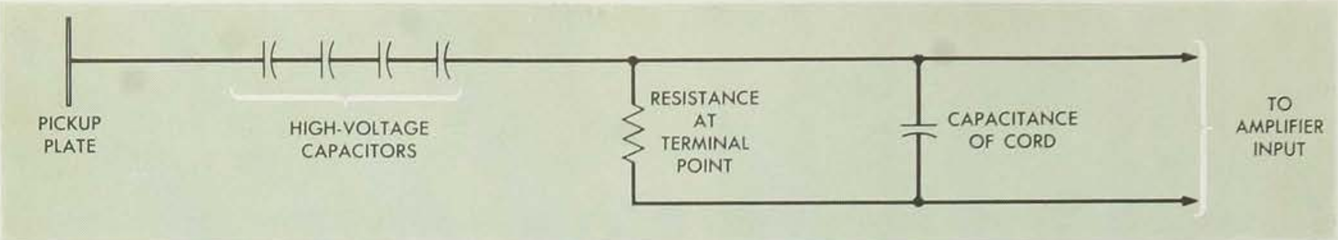
Previously, a telephone craftsman had to climb several poles in checking for a 500-cps signal that was applied to the open conductor. In so doing, he had to go back and forth along the pole line until he localized the break. This resulted in excessive time and effort in pole-climbing to locate the opens with existing equipment, and these factors led to the development of the 111A Test Set.

This test set is basically an electrostatic probe mounted on a five-foot rod. The rod has extension sections so that a craftsman can probe the multiple-line wire from the ground. Because of its frequent use on joint-use lines, the set is designed to withstand accidental contact with power line potentials as high as 10,000 volts with complete safety to the user.

The absence of a metal shield on multiple-line wire actually facilitates the location of breaks in the conductor. An ac voltage is applied between ground and the open conductor. The craftsman checks for breaks in the conductor by holding the probe against the wire at intervals along the route. An audio signal in the craftsman's headset indicates the presence of the voltage signal. A break in the conductor is found at the point where the voltage drops off abruptly. The probe uses capacitive coupling to detect the ac voltage. This obviates puncturing the insulation, and avoids possible future conductor corrosion at the puncture.

The 111A Test Set is used in combination with a small battery-powered amplifier (type 147) and a voltage source such as the newly developed transistorized 500-cycle oscillator (114A Test Set). The amplifier is approximately 1.5 x 1 x 4 in. and is easily worn on a belt. The 111A Test Set is used to pick up the voltage on the open conductor, and the amplifier boosts the signal voltage to produce an audio signal in the head receiver. A 500-cps voltage source modulated at approximately 10 cps produces a signal that is easily distinguishable even in the presence of noise.

The procedure for locating an open may be best understood by the following example: Assume that there is a break in one conductor of a multiple-line wire. A craftsman first connects the voltage source (between the open conductor and ground) at a convenient terminal point. He also connects to ground all the spare pairs and the good conductor of the pair in question. Next, he grounds all spare pairs and the pair with the



Schematic diagram of high-voltage capacitors, cord capacitance, and resistor in the 111A Test Set. These components form a simple filter to reduce 60-cps signal pickup from nearby power lines.

open conductor at another convenient terminal beyond the break. This minimizes the voltage developed on the spare pairs because of capacitive coupling. Working circuits are not grounded because this would mean taking them out of service.

After the craftsman makes these connections, he probes the line with the 111A Test Set coupled to the amplifier and the head receiver. In so doing, he holds the 111A Test Set against the multiple-line wire near the terminal where the voltage source is located. The signal picked up by the probe varies in intensity because of the spiral lay of the conductors and also because of the position of the open conductor with respect to the over-all diameter of the wire. He then adjusts the gain of the amplifier so that he barely hears the 500-cps signal in the head receiver when the probe is at a point where the signal pick-up is a maximum. Adjusting the volume to the lowest level possible accentuates the reduction in signal when the probe passes a break.

John Apgar uses 111A Test Set to check for signal voltage on multiple-line wire in Chester, N. J.

The next step is to check for the 500-cps signal at intervals along the wire, probably every two or three pole spans. The absence of the signal indicates that the craftsman has passed the open conductor and that he must backtrack to locate it. In most cases, he can find a position where the signal is audible at one point, and not audible six inches away. In a few cases, usually in long lengths, the signal may not drop off completely. However, if the gain of the amplifier is set low originally, the telephone craftsman experiences no difficulty in determining the point where the signal drops off significantly.

To mark the location of the open conductor, the craftsman temporarily hangs the 111A Test Set on the wire with the hook on the handle of the probe. Then, he either lowers the wire to the ground or uses a ladder truck to reach the wire. In most cases, the open is obvious upon close visual inspection. Sometimes, however, the insulation may be continuous, but the wire inside is open. In these cases, the craftsman uses a capacitance probe (such as the 513A Tool) to locate the correct wire and localize the break to within a section only an inch long.

Safety was a paramount factor in developing the test set. The set is intended for use with several extension handles so that it can be held against the multiple-line wire from the ground. Thus, it may accidentally come in contact with power wires that are on the same pole line or that cross the telephone line. For this reason, the set is designed so that contact with voltages as high as 10,000 volts will not injure the user of the set. To achieve this, Laboratories engineers developed apparatus which limited the current to less than 1 milliampere, the threshold value for shock sensation. Under test conditions, with the cord grounded and the exposed metal parts at 10 kv 60 cps, the current is 0.6 milliampere. Although higher currents could be tolerated, it is desirable to eliminate any shock sensation because the resulting reactions could cause a telephone craftsman to trip or fall.

The design of the upper section presented a challenging problem because of the need for both good coupling to pick up the 500-cps signal and the need to limit current in case the pickup plate should contact high voltage. The guide assembly contains a flat plate in the bottom of the V-shaped guide to pick up the 500-cps signal. The plate is connected through four series capacitors to a cord that feeds the amplifier and headset. These capacitors are encapsulated in a tube below the pickup plate, and they provide a margin of safety so that if one capacitor in the group short-circuits, the current at 10 kv will still be less than 1 milliampere.

The guide assembly is insulated from the metal tubing at the base of the set by a fiberglass tube approximately five feet long. A cord from the capacitors in the guide runs down the inside of the fiberglass tube and is thus protected from mechanical damage. An external cord runs from the base of the tube to the amplifier at the craftsman's belt. Both cords are shielded and can withstand voltages of 15 kv, 60 cps. All the metal fittings on the test set, except the pickup plate, are insulated from the cord that connects the capacitors to the amplifier.

All 111A Test Sets are checked at yearly intervals to insure that defective models are either repaired or taken from service. At Western Electric repair centers, the sets are first tested at 10 kv, 60 cps, to determine that breakdown does not occur. Next, the capacitance is measured to determine that no capacitor has shorted. The dc resistance of the capacitor is measured to insure that it is within limits. The cords are visually inspected for defects.

A simple filter in the test set attenuates the 60-cps voltage picked up from overhead power lines. It makes use of (1) the four series capacitors, (2) the capacitance of the cord, and (3) a resistor at the terminal point between the internal and external cord. This triple combination results in a high-pass filter which has a response at 60 cps which is down 18 db compared to that at 500 cps.

The 111A Test Set and the testing method described here have been well received by field personnel. A small amount of apparatus is involved, the procedure is simple, safe, and the exact location of a break can be found in a straight-forward manner. Perhaps, the most significant feature of the set is that it can be used with a minimum of pole climbing.

TWX System Successfully Converted To Dial Operation

The Bell System's teletypewriter exchange service (TWX) was successfully converted during the Labor Day weekend from a manual service using operators and switchboards on a separate network to dial service over the DDD network.

The cutover, the first nationwide dial conversion in Bell System history, was the result of the combined efforts of all the operating telephone companies, the A.T.&T. Company, the Western Electric Company, The Teletype Corporation, and Bell Telephone Laboratories.

The conversion, which went into service 26 months after the start of development, required many new developments by the Laboratories. A new transistorized data set was developed which transforms teletypewriter pulses into tone signals to be sent over the DDD network. A new switchboard and operating room desks were designed to handle the calls which require the personal attention of the operators. In addition, new switching, transmission, and signaling designs were developed.

Since the cutover of the system, the A.T.&T. Company has gathered daily reports from all the operating telephone companies concerning the quality of the service being given. Continued improvement has been reported in the operation of the system as customers have become better acquainted with the operating procedures and minor trouble conditions have been rectified.

Fourteen Laboratories organizations, including groups at West Street, Murray Hill, Holmdel, Columbus, Merrimack Valley, Indianapolis, and Allentown were involved in the development. Mr. W. M. Bacon at West Street was responsible for the major development and overall coordination of the development aspects of the project. Mr. T. L. Dimond of Holmdel was responsible for the overall planning of the system. The change will mean faster and more convenient transmission of typewritten messages between the nation's 60,000 exchange teletypewriters. Now calls between machines may be dialed just as telephone calls are.

All TWX stations have been modified to work with the dial system. About 900 switching offices and most of the nation's major telephone trunk routes are involved. The Bell System first offered nationwide TWX service in 1931.

Two-Way Voice Channel Via Telstar Established with Compact Ground Station

Bell Laboratories demonstrated last month that a single two-way voice channel can be accomplished via Telstar with equipment which is simple and relatively inexpensive compared with the Bell System's Telstar ground station at Andover, Me. The ground station used in the demonstrations included a remodeled 18-foot dish antenna, together with other existing equipment.

In one of the two demonstrations conducted, a two-way telephone conversation was carried out. The path of the call was from the small ground station at Bell Laboratories Holmdel, N. J., location, to Telstar and down to Andover. From Andover, the call was sent back to Holmdel by regular telephone circuits. This showed that such a small ground station can be used in conjunction with a much larger installation such as the one at Andover.

In the other demonstration, a voice signal was sent from the small antenna to the Telstar satellite and back to the same antenna. This suggested that two small stations, separated by thousands of miles, could supply two-way voice communications via satellite.

Studies made more than a year ago convinced Laboratories engineers that a simple small ground station could make use of an orbiting low-level satellite, such as Telstar, for limited communications. On July 27, 1962, with a working Telstar satellite orbiting the earth, they decided to conduct an experiment to demonstrate that such a system was feasible. In two and a half weeks, they assembled existing communications equipment and built a comparatively inexpensive sending—receiving station at Holmdel.

The experiment was conducted under Warren E. Danielson, Director of the Military Research Laboratory, with Robert Lowell, John S. Cook, and Ira Jacobs of that Laboratory playing key roles in the organization and execution of the experiment.

While the capabilities of a small station like the one demonstrated at Holmdel are small compared with the installation at Andover, such a station could provide basic service where communications needs are limited. The Andover station can provide one television channel or 600 voice channels. The small system demonstrated provided only a single two-way voice circuit.

Much of the equipment used in the experiment was standard communications equipment that was on hand or easily acquired. The engineers were interested in simplicity and speed rather than compactness or design for maunfacture. The antenna was an inexpensive 18-foot expanded mesh dish which was mounted on a motor-driven World War II radar pedestal. This configuration had been previously used at frequencies near 1 KMC for the Project Echo equipment (RECORD, *September*, 1961). To prevent leakage of the higher-frequency 4 and 6 KMC signals required for Telstar, a layer of ordinary aluminum window screen had been wired in place over the expanded mesh. This makeshift dish performed very well; however, an appropriately designed 10 foot dish antenna would perform equally well. This should be contrasted with the 68-foot opening of of the giant horn antenna at Andover.

The method chosen for coupling energy to and from the antenna allows for simultaneous transmission and reception of voice-modulated microwave signals. A modified Bell System TH microwave transmitter was used in the experiment. Output from this equipment was further amplified to 850 watts (at 6 kmc) by an air-cooled klystron tube. The transmitter carrier frequency was 6384.58 mc. It was modulated over a radio frequency bandwidth of 66 kc. Width of the transmitted beam was 0.8 degrees.

Receiving frequencies for the experiment were 4165 mc or 4175 mc. A low-noise 4 kmc receiving system was used. To obtain the high receiver sensitivity required, two very low noise parametric amplifiers, one at room temperature, the other cooled to 77 degrees K to reduce the thermal noise in the system, were used in tandem. (The coolant is liquid air, easily obtained with an air compressor. It needs to be replenished no oftener than every ten days.)

Compact ground station used to demonstrate two-way voice communications via Telstar used simple, relatively inexpensive ground equipment. The 18-foot dish antenna was used for both sending and receiving; control equipment is in trailer.

The amplifier was originally built at Bell Laboratories as a reserve for the more sensitive maser amplifier now being used in the Andover horn antenna. When receiving a 4170 mc signal it provides an almost flat gain of 38 db over a 50 mc bandwidth. The cooled amplifier itself has a noise figure of less than 1 db. The heart of the amplifier is a hermetically-sealed gallium arsenide diode that has very low intrinsic noise.

An FM demodulator with negative feedback, slightly modified from the one used in the Project Echo experiment, reduces noise still further. The FM feedback circuit is an improved version of the one invented at Bell Laboratories in the 1930's. It acts as a very rapid automatic tuning device, tuning a narrow-band receiver to the exact frequency being received at any instant, although the signal varies over a wide band. Thus the receiver picks up background noise only in a very narrow band instead of the much greater noise that it would pick up without this feature. The signal to noise ratio at the output of the receiver is better than 44 db.

The compact ground station is nearly self-sufficient. In tracking Telstar, the antenna was controlled by a simplified version of the automatic tracking method used with the large horn antenna at Andover. The only outside help needed was orbital information for the initial positioning of the antenna. (This information can be predicted weeks or months in advance.)

The small antenna at Holmdel was pointed at a region in the sky where Telstar was expected to pass. As the satellite passed through the region, the antenna picked up Telstar's 4080 mc precision tracking beacon (which had been turned on by Andover). The autotrack system then "locked on" and positioned the antenna to follow the satellite to within a small fraction of the antenna beam width. (When the antenna tracks just a slight bit off the center of the satellite signal, the 4080 mc energy is propagated in a different manner through the waveguide leading from the dish. This change in mode of propagation is used as an error signal to correct the pointing of the antenna). The antenna has a beam width of about 1 degree when receiving the microwave signals from Telstar.

A system such as this might offer an opportunity for new and developing countries, whose communications needs are limited, to participate in satellite communication.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, G. F., Jr. and Padden, F. D.—*Transistor Multivibrator Circuit with Variable Impedance Operation Stabilizing Means*—3,051,850.

Alsberg, D. A. and Denton, E. C.—*Duplex Station Employing a Reflex Traveling Wave Amplifier and Frequency Conversion*—3,045,235.

Anderson, W. W. and Hines, M. E.—*Slow-Wave Broadband Nonreciprocal Microwave Devices*—3,051,908.

Andregg, E. R.—*Telephone Pay Station System*—3,048,660.

Andrews, E. G.—*Magnetic Storage Circuits*—3,050,716.

Atalla, M. M., Ross, I. M. and Smits, F. M.—*Semiconductor Tunnel Device*—3,045,129.

Averill, R. M., Jr.—*Magnetic Memory Array*—3,048,826.

Barnes, C. E.—*Broadband Polarization Rotator*—3,046,506.

Berkery, E. A.—*Surge Suppression for Power Supplies*—3,047,746.

Benson, M. L. and Breen, C.—*Registration Control Circuit*—3,050,588.

Bomba, J. S., Haller, N. M. and Kretzmer, E. R.—*Line Tracing System*—3,050,581.

Bonner, A. L.—*Negative Impedance Repeaters*—3,042,759.

Bosworth, R. H.—*Mounting Board for Electric Circuit Elements*—3,042,740.

Brass, R. L.—*Semiconductor Hall Effect Devices*—3,050,698.

Breen, C. and Michael, H. J.—*Morning Call System*—3,046,339.

Breen, C., see Benson, M. L.

Buhrendorf, F. G.—*Tape Drive Control System*—3,045,884.

Byrnes, P. A., Jr., Davis, T. E. and Mener, E. C.—*Bonding Apparatus*—3,048,690.

Carbrey, R. L.—*Bipolar Clamp for Pulse Modulation Systems*—3,050,587.

Cath, P. G. and Pferd, W.—*Impulse Transmitting Mechanism*—3,046,355.

Clemency, W. F.—*Loud Speaking Telephone*—3,046,354.

Courtney-Pratt, J. S.—*High Speed Shutter*—3,043,960.

Cutler, C. C.—*Stabilization of Earth Satellite Repeaters*—3,048,350.

Davis, T. E., see Byrnes, P. A. Jr.

Davis, T. E.—*Diode Impedance Tester*—3,048,779.

De Loach, B. C., Jr.—*Broadband Solid State Amplifier and Switch Using "Dam" Cavity*—3,050,689.

Deming, R. D., Jacobitti, E., Kennedy, J. B., Large, W. V. K. and Pruden, H. M.—*Supervisory Control System*—3,046,525.

Denton, E. C., see Alsberg, D. A.

Donoho, P. L.—*Spin Stabilization of Earth Satellites*—3,048,351.

Engelbrecht, R. S.—*Traveling Wave Parametric Amplifier*—3,045,189.

Engelbrecht, R. S.—*Up-Converter Amplifier Circuits with Isolation*—3,051,909.

Favin, D. L.—*Method and Apparatus for Synchronizing Oscillators*—3,049,675.

Fleckenstein, W. O.—*Variable Length Code Group Circuits*—3,051,940.

Fulmer, R. J.—*Failure Detecting Apparatus*—3,042,752.

Geyling, F. T.—*Stress Photometer*—3,041,923.

Gianola, U. F.—*Electrical Control Circuits*—3,045,215.

Glaser, J. L.—*Reduction of Quantizing Error in Quantized Transmission Systems*—3,048,781.

Gotthardt, M. R. and Lowry, T. N.—*Control Arrangement for Line Concentrator*—3,047,668.

Graham, R. E.—*Sequential Scan Television with Line Interpolation*—3,051,778.

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Gyorgy, E. M. and Scovil, H. E. D.—*Method of Suppressing Saturation Effects in Gyromagnetic Devices*—3,051,917.

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Harmon, L. D.—*Automatic Character Analyzer*—3,050,711.

Harmon, L. D.—*Output Selecting Circuit*—3,050,713.

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Helder, G. K. and Mayo, J. S.—*Detection and Measurement of Errors in Pulse Code Trains*—3,048,819.

Hellstrom, E. C. and Pollard, C. E., Jr.—*Switching Device*—3,048,677.

Highleyman, W. H.—*Function Generators*—3,047,747.

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Hose, R. H.—*Automatic Card-Dialing Telephone Desk Set*—D-193,269.

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Hose, R. H. and Lince, A. H.—*Case for a Measuring Instrument*—D-193,481.

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Jurgens, W. C. and Treptow, F. W.—*Guided Cord Weight Assembly*—3,046,356.

Kaenel, R. A.—*Analog-to-Digital Converter*—3,046,543.

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Kennedy, J. B., see Deming, R. D.

Kibler, L. U.—*Capacitively Loaded Waveguide*—3,050,702.

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Kramer, H. P.—*Multiplex Signaling System*—3,046,346.
Kretzmer, E. R., see Bomba, J. S.
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Mayo, J. S., see Helder, G. K.
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Scovil, H. E. D., see Gyorgy, E. M.
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Wolfstirn, K. B., see Fuller, C. S.

* Not a Laboratories employee.

TALKS

Following is a list of speakers, titles and places of presentation for recent talks presented by members of Bell Laboratories.

Allen, F. G. and Gobeli, G. W., *Volume and Surface Effects in Photoelectric Emission from Silicon*, Intern. Conf. on Physics of Semiconductors, Exeter, England.

Bennett, W. R., *Plasma Masers*, Princeton Univ., Princeton, N. J.

Boyd, G. D., *Recent Developments in Optical Masers*, Laser Conference, Northeastern Univ., Boston.

Buchsbaum, S. J., *Solid-State Plasmas*, Princeton Univ., Princeton, N. J.

Buchsbaum, S. J., *Principles and Modern Application of Plasmas*, Rensselaer Polytech. Inst., Troy, N. Y.

Cave, J. H. and Warthman, K. L., *From Echo to Telstar*, Kiwanis Club, Chatham, N. J.

Cottingham, W. B., *Superconductivity—Its Application to Large Magnets*, Purdue Univ., Lafayette, Ind.

Courtney-Pratt, J. S., Hill, D. W., McLaughlin, J. W. and *Hett, J., *The Detection of Flashes of Sunlight Reflected from a Satellite*, Soc. Photographic Instrumentation Engrs. Symp., New York City.

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Critchlow, G. F., *Telstar—Communications via Satellite*, Human Factors Soc., Metropolitan Chapt., Murray Hill, N. J.

Deininger, R. L., *Telephone Information Services—People and Automation*, Human Factors Soc., Metropolitan Chapt., Murray Hill, N. J.

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Dietz, R. E., see Gershenzon, M.

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Hempstead, C. F., *Applications of Superconducting Magnets*, Gordon Research Conf. on Instrumentation, New London, N. H.

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Mason, W. P., *Absorption and Dispersion of Sound in Polymer Solutions, Polymer Liquids, Rubbers and Solid Polymers*, Enrico Fermi Italian School of Physics, Lake Como, Italy.

McAfee, K. B., *Effects of Structural Order on Atomic Diffusion in Silica Glass*, Gordon Research Conf. on Phys. Metallurgy, Meriden, N. H.

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Mitchell, D., *Satellite Systems for Telephone and Television Relays*, Am. Federation of Television and Radio Artists, Miami.

Mosing, L. W., *Telephone Sets—Industrial Design and Human Factors*, Human Factors Soc., Metropolitan Chapt., Murray Hill, N. J.

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TALKS

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Allen, F. G. and Gobeli, G. W., *Volume and Surface Effects in Photoelectric Emission from Silicon,* Intern. Conf. on Physics of Semiconductors, Exeter, England.

Bennett, W. R., *Plasma Masers,* Princeton Univ., Princeton, N. J.

Boyd, G. D., *Recent Developments in Optical Masers,* Laser Conference, Northeastern Univ., Boston.

Buchsbaum, S. J., *Solid-State Plasmas,* Princeton Univ., Princeton, N. J.

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Cave, J. H. and Warthman, K. L., *From Echo to Telstar,* Kiwanis Club, Chatham, N. J.

Cottingham, W. B., *Superconductivity—Its Application to Large Magnets,* Purdue Univ., Lafayette, Ind.

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AUTHORS

H. J. Wallis

H. J. Wallis, Assistant Vice President in charge of the General Staff Division, was born in Mitchell, S. D. He received the B.S. in E.E. degree from South Dakota School of Mines and Technology in 1934. Upon joining the Laboratories in 1937, he was initially concerned with trial installations and current engineering problems. After several years in equipment design work, he transferred to the Staff Division where he headed shops and general service departments. After a two-year assignment with Sandia Corporation, he returned to the Laboratories as New York Area Staff Manager. He was appointed to his present position in 1956.

Mr. Wallis, author of "The Holmdel Laboratories," is a member of Sigma Tau, Society for the Advancement of Management, and the American Management Association. He is currently serving as a member of the Planning Council for the Administrative Services Division of AMA.

George Spiro, the author of the article on CENTREX Service in this issue, was born and educated in New York City, receiving the BEE and MIE degrees from New York University in 1954 and 1959, respectively. Mr. Spiro served with the U.S. Army Signal Corps in the European Theatre of Operations during World War II. In 1946 he joined the Plant Department of the New York Telephone Company as a central office switchman. He advanced through various positions to staff engineer, and in 1954 was transferred to the Engineering Department of the Company.

In 1958, Mr. Spiro joined Bell Laboratories. Since then his major concern has been with systems engineering, first on No. 4 Toll Crossbar and later as supervisor of a group working on the No. 5 Crossbar system. Mr. Spiro was recently appointed Head of the Local Switching Engineering Department at the Holmdel Laboratories. He is a member of Tau

George Spiro

Beta Pi and Eta Kappa Nu, and is presently secretary of the Communications and Electronic Division of the New York section of AIEE. He is a Licensed Professional Engineer in New York State.

Henry Dreyfuss, author of "The Industrial Designer — His Role and Purpose," was born in New York City. He attended local schools, and at the age of 19 launched his career as a theatrical designer. Six years later, he began his new profession in industrial design, a pioneer in the field.

The Henry Dreyfuss organization, operating today from offices in New York and California, works closely in many fields in the development of a wide variety of products, including telephones, turret lathes, farm equipment, printing presses, kitchen and household appliances, instruments, and military projects. He has been a design consultant for Bell Laboratories since 1930.

Henry Dreyfuss, Fellow, Director and Past President of the American Society of Industrial Designers, was also one of its founders. He is a faculty member of the California Institute of Technology, and the University of California at Los Angeles, a member of the Board of Directors of the Ford Foundation—Educational Facilities Laboratories, and Benjamin Franklin Fellow of the Royal Society of Arts.

Mr. Dreyfuss has received a number of awards and honors, including the Architectural League Gold Medal (1951); the order of Orange-Nassau from Queen Juliana of the Netherlands (1952); a Doctor of Science degree from Occidental College of California (1953); the Distinguished Contribution Award of the American Society of Industrial Designers (1960); and the Design Award of the Philadelphia Museum College of Art (1962). He is also an honorary member of the Telephone Pioneers of America.

Henry Dreyfuss

J. E. Greene

James E. Greene, author of "For No. 5 Crossbar—A Packaged Central Office," was born in St. Marys, W. Va. He received his B.S.E.E. from Pennsylvania State University in 1925, and joined Bell Laboratories immediately on graduating. His work has been in equipment design for step-by-step and crossbar dial systems, and for airborne radar during World War II. He is presently located at the Columbus, O., branch laboratory.

Irving M. McNair, Jr. author of "Locating Open Conductors in Multiple-Line Wire" in this issue, was born in Fairfax County, Virginia and received the B.S.E.E. with honors from Pennsylvania State University in 1954. He joined the Laboratories that year and subsequently completed the Communications Development Training Program. Mr. McNair received the M.S. degree from Stevens Institute of Technology in June 1961. He supervises a group concerned with the development of test sets for wire identification and fault location in the Outside Plant. He is a member of Tau Beta Phi, Phi Kappa Phi, and Eta Kappa Nu. He is an associate member of the AIEE and a licensed N.J. Professional Engineer.

Irving M. McNair, Jr.

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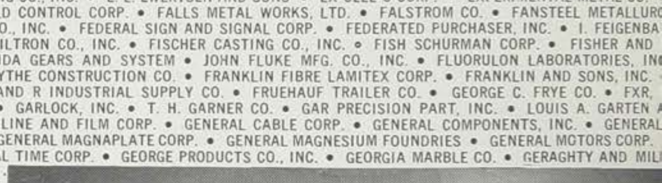

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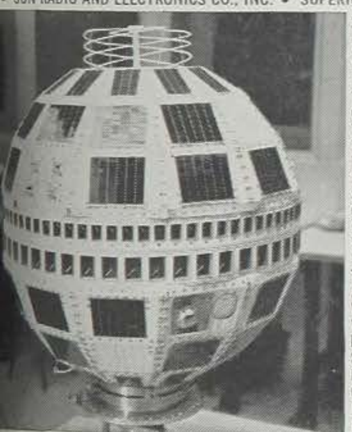

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THWING ALBERT INSTRUMENTS CO. • TOLEDO SCALE CORP. • TOOL SERVICE ENGINEERING CO. • TOOLS, INC. • JOSEPH TORCH • TRANSISTOR SPE-
CIALTIES, INC. • TREITEL GRATZ CO., INC. • TREMCO METAL PRODUCTS, INC. • TRENT, INC. • H. O. TRERICE CO. • TRIANGLE REPRODUCTIONS, INC.
TRIANGLE TOOL CO. • TRICON MFG. CO. • TRINITY EQUIPMENT CORP. • TRIPLETT ELECTRICAL INSTRUMENTS CO. • TRIPLEX MACHINE TOOL CORP.
TRI-POINT INDUSTRIES, INC. • TRI STATE PLASTIC MOULDING, INC. • GERALD E. TROUTMAN MACHINE SHOP SERVICE • TUBE DISTRIBUTORS CO., INC.
TUBE SALES • TUBULAR RIVET AND STUD CO. • J. M. TULL METAL AND SUPPLY CO., INC. • TURBOCRAFT, INC. • TURCO PRODUCTS, INC. • TURTLE AND
HUGHES, INC. • ULBRICH STAINLESS STEELS • ULTEK CORP. • UNEX WELDING SUPPLY • UNIFORM TUBES, INC. • UNION CARBIDE CORP. • UNION
SCREW CO. • UNITED AIRCRAFT CORP. • UNITED ELECTRONICS CO. • UNITED MICROWAVE CO. • UNITED SHOE MACHINERY CORP. • UNITED STATES
COMPONENTS, INC. • UNITED STATES DYNAMICS CORP. • UNITED TRANSFORMER CORP. • UNIVERSAL CYCLOPS STEEL CORP. • UNIVERSAL ELECTRONICS
CO. • UNIVERSAL MFG. CO., INC. • UNIVERSAL MICROWAVE CORP. • UNIVERSAL TOOLS AND MFG. CO. • U. S. MAGNET AND ALLOY CORP. • U. S. STONE-
WARE CO. • UTILITY BRASS AND COPPER CORP. • VACUUM ELECTRONICS CORP. • VALLEY TOOL AND PRECISION CORP. • VARIAN ASSOCIATES • VARI
L. CO. INC. • VECTOR ELECTRONIC CO. • VECTOR MFG. CO. • VEECO VACUUM CORP. • VEEDER ROOT, INC. • VERNITRON CORP. • VICKERS, INC. • VIC-
TORY ENGINEERING CORP. • VINCO CORP. • ARMAND A. VIOLETTE • VISIONEERING CO. • VITA VAR CORP. • VITRAMON, INC. • VITRO CORP. OF
AMERICA • VOLKERT STAMPING, INC. • VOLT TECHNICAL CORP. • E. W. WACKER CO. • AUGUST WAELDIN, INC. • WAGNER FOTO SCREEN PROCESS
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WARD LEONARD ELECTRIC CO. • WASHINGTON ALUMINUM CO. • WASHINGTON MACHINE AND TOOL WORKS, INC. • WASHINGTON SCIENTIFIC INDUSTRIES,
INC. • WATERSON X-RAY LAB • WAVELINE, INC. • WAYNE KERR CORP. • A. V. WEBER CO. • WEINSCHEL ENGINEERING AND MFG. CORP. • WM. WELSH
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Telstar—first satellite capable of cross-ocean relay of telephone calls, TV and data messages—is the work of many hands.

The Bell System provided technical leadership and underwrote the entire cost, which was about $50 million. The experimental satellite was launched at Bell System expense by the National Aeronautics and Space Administration.

But before that launching, 1249 different companies—most of them small businesses—participated, with billings of $100 or more, as subcontractors and suppliers on the project. Their contributions ranged from liquid nitrogen to special resistors, transmitters, waveguide components, telemetry and antennas. The companies themselves are located north, south, east and west. Each was chosen because of its competence in its field for the job required. Telstar, then, is a glowing tribute to the nation's private industry, and a dramatic example of industry and government co-operation to advance American technology.

Many shared its creation so that all might share its accomplishments.

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