F I N A L   R E P O R T

AIRWAYS OPERATIONS EVALUATION

CENTER ACTIVITIES

TECHNICAL DEVELOPMENT REPORT NO 413

Federal Aviation Agency

Bureau of Research and Development

TEST AND EXPERIMENTATION DIVISION

Atlantic City   New Jersey

This report has been approved by the Director, Bureau of Research & Development, Federal Aviation Agency Since this is a technical information report the contents do not necessarily reflect the official FAA policy in all respects, and is intended only for distribution within the Federal Aviation Agency.

FINAL REPORT

AIRWAYS OPERATIONS EVALUATION

CENTER ACTIVITIES

TECHNICAL DEVELOPMENT REPORT NO. 413

Prepared by Russell M. Andrew and Kenneth T. Ostrand

Reviewed by: Edward V. Kullmann
Chief, Approach and Landing Systems Section

Approved by

Chief, Evaluation Branch

Director

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NATIONAL AVIATION
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Atlantic City, New Jersey

FEDERAL AVIATION AGENCY
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

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Director
Bureau of Research and Development
Federal Aviation Agency
Washington 25, D. C.

Subject: Final Report on Technical Development Center Project 59-730 and AMB Project SA-1-111, Titled "Airways Operations Evaluation Center Activities"

Dear Sir:

Prior to the discontinuance of the Technical Development Center at Indianapolis, Indiana, it was decided to summarize the work accomplished by the Airways Operations Evaluation Center in a report.

The final report, Technical Development Report No. 413, titled "Airways Operations Evaluation Center Activities," is herewith enclosed.

Sincerely,

William S. Cowart, Jr.
Director

Enclosure - 1

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ABSTRACT

The various equipments, processes, methods, and studies performed in the Airways Operations Evaluation Center, under projects assigned by the Air Navigation Development Board and the Airways Modernization Board, are summarized in this report.

PURPOSE

The purpose of this report is to publish information on the activities of the Airways Operations Evaluation Center of the FAA Technical Development Center at Indianapolis, Ind. Those activities covered in Technical Development Reports are referred to briefly. Other activities are described in more detail, with illustrations.

SUMMARY

This report reviews the history and accomplishments of the Airways Operations Evaluation Center from its beginning in January 1953 until its closing in April 1959. Each of the major project tasks of the Airways Operations Evaluation Center is described. A bibliography of technical reports resulting from these activities is included. The project tests not covered by separate reports are described in more detail, with illustrations. Also included is a summary of the funding and personnel assigned to this program.

INTRODUCTION

In 1952, a project was proposed by the Civil Aeronautics Administration (CAA) for the establishment of an Airways Operations Evaluation Center (AOEC) at Indianapolis, Ind. The purpose of this facility was to permit operational testing and evaluation of new navigation and air traffic control equipments in a laboratory-type facility. On January 14, 1953, the Air Coordinating Committee approved the proposal. In this approval was a stipulation that the Air Navigation Development Board (ANDB) would provide funds to construct quarters and finance the project, which was designated as ANDB Project 1.4. At the outset, an environment including an Air Route Traffic Control (ARTC) Center, an airport traffic control tower, and an airways communications station were to be operated as one combined facility. The program was started early in 1954 when the Administrator of the Civil Aeronautics Administration produced a revised plan in which the AOEC would be a part of the Technical Development Center (TDC) and be constructed near an operating ARTC Center. Since the Center nearest TDC then was located at Cincinnati, Ohio, it was decided to use the Cincinnati Center's area for the AOEC environment and move the Center to Indianapolis, for the following reasons:

1. The AOEC would have access to all of the facilities and technical manpower at TDC.

2. The air traffic in the Cincinnati Center's area was a good, representative sample. It was not so heavy that experiments would be impeded, nor so light that the results would not be valid for high-density locations.

3. The ARTC area was surrounded by seven other ARTC Center areas

4. There were three major military bases located in the area, some equipped totally with jet aircraft.

5. The location was near Wright-Patterson Air Force Base (AFB) where several groups, including TRACALS, were engaged in air traffic control development and evaluation programs.

6. In addition to the military bases, there were several moderately large civil air terminals served by air carrier aircraft.

In the plan, the Indianapolis ARTC Center operated independently of the Technical Development Center but was staffed to provide rotation of control personnel into the testing laboratory of the AOEC when it was desired to control live flights operating under instrument flight rules.

Until deactivated in April 1959, the AOEC was active in developing and performing system evaluation of air traffic control equipment and procedures for centers, towers, and communications stations. Some of the equipments and techniques have been evaluated also in the New York, Washington, Boston, and Chicago areas.

This report was prepared to provide a summary of all project tasks undertaken by the AOEC and some details on those tasks not included in other Technical Development Reports. Detailed descriptions and illustrations have been omitted on the project tasks which are covered in separate reports.

FUNDING AND PERSONNEL

Project tasks and appropriations for the AOEC were provided by several sources. During Fiscal Years 1952 through 1955, all project tasks and funds were supplied by ANDB. Since Fiscal Year 1955, funding was obtained from the Airways Modernization Board (AMB), the Operation and Regulation (O&R) Budget of the CAA, and the Federal Aviation Agency (FAA). During this latter period, project tasks on in-service improvements were generated either within TDC or from the various operational, maintenance, and installation offices within the CAA. The longer-range programs were developed in cooperation with the AMB and the Air Force's TRACALS activities at Wright-Patterson AFB. An approximate breakdown of expenditures is shown below by fiscal year:

Fiscal Year	Total Expenditures
1952	162,600
1953	62,000
1954	93,900
1955	420,500
1956	1,250,000
1957	717,000
1958	1,114,000
1959	767,400
Total	$4,587,400

Approximately 1 million dollars of the above total was provided by the Air Force to establish certain radar, microwave link, and display facilities Approximately 30 personnel, not including personnel from the Indianapolis ARTC Center, were active in this program. The complement was arranged in a team concept, including engineering and airway operations specialists. This brought into each project task closer coordination of the technical and operational aspects of the problems.

Close cooperation was maintained during the AOEC program with the Air Force and Navy activities in the air traffic control field. A coordination team, including personnel from the Air Force's TRACALS group at Wright-Patterson AFB, AMB, and TDC, developed many of the program tasks and arranged for loans of equipments.

PROJECT TASKS

a. Panoramic Operations (PANOP) Display. One of the initial tests to be made in the AOEC was the use of a panoramic operations (PANOP) display, shown in Fig. 1, using a large-scale horizontal radar plotting table on which radar data were projected from an overhead projector. In the beginning, the display was on a horizontal table large enough to permit the use of variable scale maps from 2 miles per inch to 5 miles per inch. On this table top, the navigational map, similar to a Coast and Geodetic RF chart, was displayed by use of Chart-Pak tape, outlining the airways and the VOR navigational facilities. Attached to the table, or on portable consoles, were communications facilities. These included interphone 102A key boxes and receiver and transmitter air/ground radio controls. Enough interphone lines were terminated in these boxes to permit communication with all the agencies that would supply information to the particular sectors being simulated or controlled from the panoramic table. Air/ground communications included receivers and transmitters for frequencies used by civil, military, and air carrier aircraft. Emergency frequencies also were available.

The testing on the PANOP was simplified by using only two sector areas of the Indianapolis ARTC Center. In this arrangement, two controllers, two assistant controllers, one coordinator, and one radio air/ground operator were used (Fig. 1) All of these controllers were part of the normal ARTC Center complement. In addition, personnel from the Technical Development Center assigned to the AOEC project assisted in the coordination, wrote the test program, provided the equipment, suggested procedures, collected test data, studied the results, and prepared reports and recommendations on the test program.

The PANOP evaluation was carried out to determine its feasibility for combining tabular flight information with radar information. Small metal markers with paper inserts on which flight information could be written in abbreviated form were used. Only one insert was prepared per flight, whereas conventional flight strips would average approximately four per flight. Figure 2 shows the flight progress insert in a metal marker. Space for four estimates and four position reports was provided on each strip.

PANOP tests were made both with and without radar. The first tests were restricted to radar flight-following; then flight-following without radar was evaluated to prove that the system was fail-safe in the event of radar failure. Without radar, the markers were moved as time progressed. The study included an analysis of communications workload, both air/ground and point to point. Initially, measurements were made by simulating communication workload, then by communicating with VFR flights, and finally by performing all of the necessary air/ground communications with IFR flights. Measurements also were made of the number of flights that could be handled by one controller and one assistant, including the moving of flight markers and of scanning the board for conflicts.

After several weeks of simulated control and flight-following, actual control was taken over on VFR days. This activity gradually increased in scope and into increasingly inclement weather conditions. ASR-2 radar was used in some cases for flight-following; however, control was based upon standard time and altitude separation. When radar information was used for flight-following, it was projected onto the panoramic board through a Norelco TV projector and the SRD-1 bright tube display equipment[1] (Fig. 3). The primary radar information was supplied by the Indianapolis ASR-2 radar.

From questionnaires answered by the controllers, and data collected during the evaluation tests, the following conclusions were reached:

1. The panoramic display is more tiring to use than flight progress boards.

2. In a PANOP operation, the assistant controller can give more assistance to the controller since his clerical workload is less.

3. It was more difficult to spot potential conflictions on the panoramic display.

4. The panoramic display could be used without radar for controlling instrument-flight-rule traffic, if necessary.

a. Rockville ADC Radar. Since radar is employed for air defense as well as for air traffic control, the Air Force and the CAA agreed that an evaluation should be conducted to determine the feasibility of using defense radars for ATC purposes. Surveys of a number of Air Defense Command (ADC) radar sites were made in the coastal area from Norfolk, Va., to Boston, Mass.[2] It was obvious from this survey that certain differences in operation of radar equipment by ADC and the CAA, due to the nature of their missions, made it desirable to evaluate an actual joint-use operation. Accordingly, a project task was planned and activated in 1955 on the joint use of the ADC radar site at Rockville, Ind., a site 60 miles west of Indianapolis. To expedite the evaluation, the Terre Haute sector of the Indianapolis Center was decentralized and operated at the Rockville site.

To initiate the task, coordination with the military agencies, letters of agreement, procedures for operation, advisories to industries, and operations letters covering a decentralized operation were required. The CPS-6B radar data at Rockville were remoted by cables from the ADC control room to quarters in a vacant barracks where the decentralized ATC sector was established. During the period that the radar remoting equipment, communications equipment, flight progress boards, and radar displays were being installed and tested (Fig. 4), personnel from the Indianapolis ARTC Center and also from the Technical Development Center were trained, first in the TDC simulator and then in the AOEC environment, for the type of operation that would be carried on at Rockville.

The Rockville decentralized sector controlled IFR traffic from March 19, 1956, to June 30, 1956. During this period, traffic was controlled 16 hours per day, 5 days per week. In the beginning, the decentralized sector was quite small, including only that area surrounding the Terre Haute terminal. Later, this was expanded to include the

Lafayette terminal and the intervening space between Lafayette and Terre Haute.

The equipment used for displaying the radar information at Rockville included an SPA-8 plan position indicator (PPI), a scan-converted General Precision Laboratory (GPL) TV projection display on a panoramic board, and an Iatron display projected on the same panoramic board (Figs. 5 and 6). Neither the GPL nor Iatron projection units proved to be successful in this test and were not used for actual control of traffic for more than a few hours. The reasons these systems were not acceptable are explained in another section of this report.

The conclusions from operating a decentralized sector using the Rockville ADC radar were:

1. The coordination per flight handled by the remote sector was estimated to increase from 20 to 40 per cent. This necessitated additional facilities for coordination and flight data transfer.

2. Additional radio equipment was necessary to handle the direct communications.

3. The personnel complement was somewhat larger per flight handled because of radar control, radio communications, and the increased coordination.

4. The additional position reports and the requirement for changing frequency added to the pilot's workload.

5. Rockville base security regulations made it necessary for all personnel to have a clearance and an identification. This eventually was reduced to a routine but nevertheless, was a continual annoyance factor. All security clearances had to be sent to Division Headquarters which, in turn, forwarded them to Rockville.

6. Planned or surprise countermeasures against operation of the defense radar interfered with the ATC use of the radar data during such attacks.

7. The particular ADC radar equipment was not ideally sited for ATC purposes. Moving target indicator (MTI) was never available, ground clutter was a serious limitation, and radar coverage over the important nearby reporting points and airways was unsatisfactory.

8. The radar system was unusable more than 10 per cent of the time to perform routine and corrective maintenance

9. The Base Commander and all intermediate authorities were instructed by ADC that the ATC function was not to "interfere" with the defense mission. Although all concerned were cooperative, the absence of complete understanding and the reluctance of the military authorities to be responsible for interpreting the degree of possible compromise to the defense mission prevented full use of the radar's capability for air traffic control.

c. Narrow-Band Transmission Systems: To meet the requirement existing for the economical transmission of radar information from remote sites in the Indianapolis area to the AOEC, a narrow-band transmission system and equipment known as RAFAX was leased from its manufacturer, Haller, Raymond and Brown (HRB). The RAFAX first was tested as a slowed-down video (SDV) equipment to transmit secondary radar from Wright-Patterson AFB to the Technical Development Center, Indianapolis. This test was operated during April and May, 1956, the results of which were published in another report.[3] The report recommended the use of the beacon and devices such as RAFAX to remote beacon position data to provide immediate assistance to the high-altitude traffic control system

During Fiscal Year 1956, the AOEC procured a variable-parameter RAFAX system for extended tests of this device for transmitting radar information. Briefly, this system converts radar video to a narrow-band signal in the audio range. This bandwidth reduction is accomplished by storing the radar video on an intensity-modulated cathode-ray tube (CRT) with a J-type sweep. The CRT is scanned mechanically through an optical system and phototube. The bandwidth reduction is a function of the ratio of the writing rate on the CRT and the mechanical read-off rate. The radar azimuth and trigger information is combined with this narrow-band video and relayed over a single telephone or radio channel. A special indicator using a 12-inch CRT at the receiving end of the line displays the video at the slowed-down rate. In addition to being able to display radar information on a cathode-ray tube at the receiving end, it also is possible to record the compressed signals on magnetic tape and hence retain the radar information for reproduction at some other time. The RAFAX equipment was tested at Chicago, Indianapolis, and New York. The tests are covered individually in the following paragraphs.

(1) Chicago: During October of 1956, a RAFAX encoder and RAFAX decoder indicator were tested as linkage between the FPS-8 radar site on West 63rd Street, and the ARTC Center located 1 mile away on Central Avenue. Filter networks between the encoder and decoder were used to simulate the various line characteristics and lengths During these tests, slowed-down scan rates of 30, 60, and 120 scans per second were tried. By changing the frequency of the video carrier, resolutions of 100, 200, or 300 elements per scan could be obtained Photographic comparisons were made between the indicator of the RAFAX and the OA-99 indicators of the FPS-8 radar.

(2) Indianapolis· During the Indianapolis test in the AOEC in April 1957, the ASR-2 at Indianapolis and the CPS-6B Rockville data, remoted to Indianapolis by microwave link, were encoded by the RAFAX and filters simulating different line characteristics were tested. Various displays, including PPI's and projected radar through the GPL and Iatron systems, were compared with the presentation of the RAFAX decoder indicator. The targets of aircraft flying on predetermined patterns were flight-followed by operational personnel and the quality of target recorded for comparison. In addition to this, subjective opinions and photographic results were recorded for later study. The results of these tests did not reveal any outstanding deficiency in the RAFAX operation, although some azimuth shift existed during the tests. Results indicated that a line bandwidth of 15 kc produced the best presentation and 5 kc was the minimum acceptable for a 100-mile-radius picture and an antenna scan rate of 6 rpm. For a 30-mile-radius picture, such as from an ASR-2 or ASR-3 operating at rotation rates of 26 rpm, the minimum line bandwidth acceptable was 15 kc.

(3) New York. For several months prior to moving the RAFAX to the New York area, a test had been conducted using the Iatron for projecting the New York FPS-8 radar on a panoramic display. During this test, it was determined that the area for approximately 20 miles out from the FPS-8 site was seriously cluttered with MTI residue. The ASR-3 radars used by both the Idlewild and LaGuardia Towers did not have this problem and hence, the close-in presentation was somewhat improved. It was felt that by blanking out the first 20 to 30 miles of the FPS-8 radar and by inserting a display showing the ASR-3 radar, a composite picture could be presented to the Center controllers which would give the controllers complete coverage from the radar site to the maximum range of the long-range

radar. To accomplish this, the RAFAX encoder was placed in the Idlewild Tower and ASR-3 information transmitted over a 15-kc telephone line to the ARTC Center at the other side of the field, approximately 1 mile away. It was decoded and displayed through a second Iatron projector. The other Iatron, displaying long-range radar information, was blanked out for the first 20 miles and the ASR-3 information projected in this area of the display. At the end of 30 days, the RAFAX encoder was removed from the Idlewild Tower and installed in the LaGuardia Tower. The distance between the LaGuardia Tower and the Center at Idlewild was 9 1/2 miles. Here again a 15-kc line was used for a transmission medium. The same type of display, using the insertion of the LaGuardia ASR-3 radar information in a pattern of 20 to 30 miles near the center of the area covered by the FPS-8 radar, was used for this test. During both tests, the RAFAX equipment operated satisfactorily except for occasional azimuth trouble. The RAFAX tests extended over approximately 60 days, 30 days with the encoder in the Idlewild Tower and 30 days with the encoder in the LaGuardia Tower A report of the RAFAX test in New York was combined with the report of the Iatron test also conducted in New York[4]. This report also contains descriptions of the equipments.

After the above-outlined experience with RAFAX, it was concluded that the system was sound and basically trouble-free. It had two inherent problems, however, that caused it to be unacceptable for implementation. The first was that the resulting display had a picture renewal rate at the same frequency as the antenna rotation rate. In many applications, it appeared that the ATC application of the remoted display would not require data rates as high as the antenna rotation rate. Since this was inherent in the RAFAX design, it meant that the remoting circuit had to have a greater bandwidth than required to pass only necessary data. The second deficiency, which also was inherent in the RAFAX concept, was that a special indicator was required to display RAFAX data. None of existing CAA displays would handle the slow RAFAX sweep. In addition, because of the long period required to display RAFAX data, it was not practical to mix or time-share this information with normal radar data.

NEW YORK TEST OF IATRON PROJECTION DISPLAY

After preliminary tests of the Iatron tubes at the Technical Development Center, the first prototype console was delivered to the AOEC by the Farnsworth Co. in the early spring of 1956. This equipment was tested operationally at the Rockville decentralized sector in June of 1956. After additional tests in the AOEC at Indianapolis, an improved Iatron display was moved to the New York ARTC Center in the early spring of 1957. In the New York Center, the New York FPS-8 radar was fed to the Iatron and a panoramic display was evaluated by controllers in the New York Center This test continued at intervals over several months At a later date, a second Iatron was installed in the New York Center. During one period, while two Iatrons were available, the RAFAX was evaluated as noted in the preceding section. At New York, the Iatron projection indicator provided a 4-foot display on a table depicting the northwest sector of the metropolitan area from the three airports out to a distance of approximately 80 miles. At the white table top of the 4-foot display, the Iatron produced approximately 2.5 foot-lamberts of reflected brightness.

The 5-inch Iatron tube is the foundation of the projector indicator and consists of two electron beams, or guns, one known as the writing beam and the other the flood beam Both beams are projected onto a fine mesh metal screen supporting an insulated layer facing the guns. An aluminized phosphor screen on the back of the metal mesh becomes the effective display The writing gun scans the insulated layer, which has a high secondary emission ratio to the writing beam which deposits charges proportional to beam intensity. Since the insulator potential is negative with respect to the flood gun, the flood gun electrons cannot penetrate the insulator. Where the insulator has been positively charged by the writing beam, the flood gun electrons are bunched and passed through the aluminized phosphor screen to form the projected image. Thus, the video information which has been written then passes through the aluminized screen and is retained on the insulator until erased. This required that the screen be erased periodically to prevent accumulation of targets and clutter to an undesirable level. Various methods of erasing were tried, from the manual, where the operator erased the screen at his will by a push button, to a pulsing erase, varied in accordance with the rotation rate of the radar antenna. During the New York tests, it was found that the Iatron tube needed to be erased once each sweep of the slow, long-range (6 rpm) radar. On the higher rotation rate ASR-3, at least four rotations of the antenna could be tolerated before erase was necessary.

One of the desirable features of the Iatron projection indicator was that it could be offcentered to show any quadrant or portion of radar coverage that was desired. During the New York test, the northwest departure route quadrant of the FPS-8 radar was displayed. Early in the test it was found that the MTI circuitry on the FPS-8 left a residue that formed a clutter for the first 20 to 25 miles out from the radar site in which no aircraft targets could be tracked. To overcome this noncoverage, it was felt that the use of the ASR-3 tower radar, which had a better MTI system and antenna siting as well as circular polarization, could be used to fill the gap. The second part of the test used two Iatrons one covering the FPS-8, but being blanked out for some 20 to 30 miles, and another Iatron projection of the ASR-3 data filling in the blanked-out area with some overlap at the 20- to 30-mile radius from the site. The RAFAX equipment was used to couple the narrow-band telephone circuits to the Iatron projection unit using ASR-3 information from the Idlewild and LaGuardia Towers.

The evaluation of the Iatron in the New York Center demonstrated that it was not an adequate display for traffic control purposes. Poor target resolution, the lack of adequate gray scale, and buildup of noise and clutter obscuring the aircraft targets were the primary deficiencies. Extreme difficulty in obtaining display linearity due to the offset writing gun of the Iatron also was objectionable. The results are contained in another Technical Development Report.[4]

COORDINATION DEVICES

a. Light Guns: Light guns are pistol-shaped devices which can be pointed at an aircraft target to produce an identification mark on a repeater radar display for identification purposes. The identification mark is triggered by a photomultiplier tube energized by the light output of the target on the CRT. These equipments were used for coordination devices in the SAGE and VOLSCAN programs of the Air Force. Each light gun has independent controls for regulating the size of the marker and the distance that the marker will be displayed from the radar target of the aircraft. Under this program task, the TRACALS group of the Air Force provided the original light gun for testing in the AOEC environment During the summer of 1957, the light gun was installed in the LaGuardia Traffic Control Tower as a coordination device between the two radar approach control positions. After several weeks of testing by LaGuardia Tower operators in the IFR room, it was determined that:

1. The gun did not provide adequate resolution because it did not contain an optical system. Aircraft targets displayed close to each other could not be identified individually.

2. The photoelectric tube was not protected from stray light which caused spurious flashing and reduced the sensitivity of the system.

3. It was difficult to aim the gun accurately at a desired target

Based upon the experience gained during the test at the LaGuardia Tower, a new light gun was designed and built by TDC. This new light gun contained a lens system for improved resolution Stray light was eliminated by mounting the photoelectric tube inside the gun with a light-tight shutter between it and the outside port. Also, by pulling the trigger halfway through its travel, a beam of light was emitted to show where the gun was aimed. The light beam was positioned on the desired target and the trigger then was pulled through the balance of the travel. This action shut off the light beam and opened the shutter. When the next scan of the radar passed through the target, the photoelectric cell was energized and the associated circuitry caused a rectangular marker to be placed on the PPI adjacent to and just beyond the range of the target. Two identical guns were built so that a two-way system might be tested. Another report describes the engineering development of the TDC light gun [5]

The two guns constructed at TDC were placed in the Washington National Airport Tower IFR room in August 1958 and remained operational until December 1958 The test there was not especially successful due to the fact that manual coordination procedures had been developed by the Tower control operators to the point that electronic coordination was not needed. Details of this test are contained in another report.[6]

b. <u>Inditron Tube Coordination Device</u>: This coordination device was constructed at TDC for an evaluation in the Indianapolis Center to be used between the Patterson and Cincinnati Sectors. By the use of pushbutton switches, the controller at one sector could set up the altitude, identification, and estimated time over of the flight desiring to overfly the other sector. The equipment used in this test was contained in a large aluminum box placed at two sector positions in the ARTC

Center The boxes measured 30 inches by 9 1/2 inches wide by 5 inches deep, and were connected by cables containing 60 pairs of wires Coded push buttons were used with Inditron tubes to indicate numerical characters Selection was made by push buttons and the Inditron tubes on both panels were activated from either control position but only the receiving station could erase the characters. In operation, sector A selected the desired fix with a push button which turned on the desired fix light in both sectors. Sector A then punched in the last three digits of the aircraft number, the estimated time, and the altitude desired. These characters appeared on the Inditron tubes at both sectors as soon as the buttons were pushed Sector B could approve or disapprove the request by pressing the correct button If sector B pushed the "approve" button, a green light was activated on both boards Sector B then copied the time and altitude onto a flight progress strip and placed it on his board. When this was completed, he pushed the erase button, causing all the numbers and lights to turn off. In the event that sector B pushed the "disapprove" button, a red light was activated on both boards Sector B now made the changes by pushing other buttons to show a different altitude or time and a "suggested change" button which released the disapprove button, extinguished the red light on both panels, and lighted an amber light on both sector indicators If sector A pushed the "change accepted" button, sector B's suggested change was released, the amber light on both sectors was extinguished, and the white light appeared at both sectors When the coordination was completed, sector B, the receiving sector, pushed the erase button which caused all numbers and lights to be extinguished A fail-safe feature was built into this equipment in that corresponding lamps on each board were in series Parallel connections were required on corresponding Inditrons on each board due to the nature of their design This equipment was used in the Indianapolis Center for several weeks but was not satisfactory for several reasons:

1. The equipment was large and took up space required for other sector activity

2. The time required for setting up a request and receiving approval was greater than required for verbal coordination in most cases

3 Only one flight could be coordinated at a time which limited the capacity of the equipment.

c TV Marker Coordination Device During the early part of Fiscal Year 1959, a TV symbol generator was developed and connected to the TI-440 scan-conversion equipment in order to place a movable target marker on the television monitor The marker could be moved with a joy stick operated by the controller to encircle any desired target which appeared on the display Through circuitry, this marker also could be displayed on remotely located radar displays The purpose of this marker was to reduce verbal coordination during a radar handoff procedure

The equipment was tested in the AOEC by using teams consisting of both tower and center controllers who simulated radar handoffs under variable conditions, and then by obtaining subjective opinion, as well as time required, for the handoff process On December 15, 1958, this equipment was made operational between the control tower and the Indianapolis ARTC Center with the joy stick control located at the tower for handoffs to the Center of departing aircraft from Weir Cook Airport

The second half of this test permitted the controller at the Center to select either a display of the tower's ASR-2 radar, or through a mixing panel, the ARSR-1 long-range radar display. In this case, both radars were being displayed on the same TV monitor and the selection of which display was most satisfactory was a choice made by the controller The TV marker was well received and enthusiastically accepted. The detailed results of this evaluation are contained in other reports [7,8]

d Closed-Circuit Television Test Closed-circuit television appeared to offer aid in data transfer and coordination between sectors and between towers and centers. Beginning in September 1956, a closed-circuit television system was installed in the Indianapolis Center. The television system used in this test included an industrial Vidicon miniaturized camera manufactured by GPL to the following specifications· 525 lines, 60 fields interlaced, resolution of 500 lines, signal outputs composite video 1.4 volts peak to peak, and the modulated frequency was 0.1 volt across 75 ohms. The television monitor, Type C317A, was built by Conrac, Inc.

Originally, the monitor was installed on a small table adjacent to the receiving sector flight progress boards and was located at about the same level as the flight progress strip holders. In order to view the monitor, it was necessary for the controller to turn his head away from the board, which was an undesirable arrangement. To overcome this problem, the monitor then was moved to a position above the flight progress board. At the end of a 90-day test period, a questionnaire was circulated among the controllers who had worked with the equipment. The following is a brief summary of the results garnered from the questionnaire.

1. The closed-circuit television system tested was not adequate to obtain data on estimates, altitude assignments, actual times over fix, control release information, or new flight plans

2. Sixty-one per cent of the controllers did not believe that the system was adequate for clearing a flight without prior coordination.

3. The personnel were evenly divided in their opinions as to whether a perfectly readable system would be equal to or worse than an interphone system for transferring flight data from one sector to another.

4. Approximately one-half of the controllers thought that the necessary scanning of the monitor required more time than the transferring of information by interphone.

It was concluded that the industrial-type, closed-circuit television system tested in the Indianapolis ARTC Center did not have adequate resolution for this purpose. Details of the evaluation are contained in another Technical Development Report.[9]

STRIP PRINTING DEVICES

Several thousand flight progress strips are prepared daily in ARTC Centers to display flight data to the controller. In the past, these strips have been prepared by writing manually on the paper in front of the controller. Much of the information displayed is repetitive on several strips. An attempt was made to find a method or equipment to reduce the workload in preparing these strips by use of some equipment for printing the flight data. Equipments evaluated in the AOEC program included the Ditto duplicator, the IBM Cardatype, the IBM-650 computer, and the IBM-650/RAMAC computer and printer. The results of these tests are described in the following sections.

a Ditto Model D11 Duplicator. The Model D11 duplicator by Ditto was an off-the-shelf equipment which could be procured and, with slight modifications, used to print flight progress strips. Two Ditto duplicators were purchased with master writers, and the feed mechanism was modified to take 1- by 8-inch flight progress strips in place of standard-size typewriter paper.

A master copy for duplication was prepared by placing a standard flight progress strip in an open slot on the adapter plate of the master writer and writing in the flight data in its normal format A hard pencil or a fine-line ballpoint pen was required to pick up on the back of the strip carbon from the master writer roll. This master strip then was placed on the drum of the duplicator which, when operated, brought the carbon copy in contact with one new flight progress strip each rotation, thereby printing on each strip the information contained on the master copy. These machines were tested in the Indianapolis, Memphis, and New York ARTC Centers

The conclusions drawn from these evaluations were that the machine required an excessive amount of adjustment to obtain satisfactory operation. Poor positioning of the blank flight progress strip under the master resulted in excessive waste of strip material. The flow of fluid in the Model D11 duplicator did not operate satisfactorily for the narrow, 1-inch flight progress strips, even though the machine had been modified somewhat to provide for this small amount of fluid flow. Frequent reloading of the feed trays and the necessity to reset the guide adjustments after each reloading proved to be so time-consuming that it was felt that manual printing was more speedy than machine printing. A detailed report of the evaluation of the Ditto duplicator is contained in another Technical Development Report.[10]

b. IBM Cardatype System Beginning November 25, 1957, for a 60-day period, a Cardatype accounting system was tested for the printing of flight progress strips in the New York ARTC Center During the period of the test, approximately one-half of the departure flight plans for flights leaving the metropolitan area of New York were printed by the Cardatype machine. This included all of the departures from Newark Airport and all westbound departures from LaGuardia and Idlewild Airports. The equipment used in the test included IBM's 026 card punch, one 858

Cardatype accounting machine, two 972 auxiliary keyboards, and two 866 nontransmitting typewriters.

Outbound flight plans were received in the Center by interphone, and the assistant controller made one flight progress strip. This flight progress strip then was presented to a person operating the Cardatype equipment The operator selected one card pack, which had been prepared previously, from a total of 76 packs, and inserted the pack in the input card hopper of the 858 accounting machine. The operator then inserted the variable information such as flight identity, type of aircraft, ground speed, and proposed altitude through the auxiliary keyboard typewriter. The Cardatype accounting machine made the required number of flight progress strips using information from the card pack and the information inserted by the auxiliary keyboard device. The strips were cut from the perforated paper, inserted in strip holders, and delivered to the control boards It was found that a lead time of approximately 9 minutes was required to handle the proposed departure flight plan Since 15 per cent of the departing flight plans were filed with less than 9 minutes, these required manual handling. The 76 packs that were mentioned previously represented 76 different preferential routes which could be flown out of the metropolitan area, one card pack being required for each route of flight. The conclusions reached after this evaluation indicated that the accuracy and readability of the system were satisfactory, however, it lacked flexibility for variable routes and was too slow to take care of the New York departure problems. Details of the IBM Cardatype evaluation in the New York area are contained in another Technical Development Report.[11]

c. <u>IBM-650 Computer</u>. One of the machines evaluated for the printing of flight progress strips was the IBM-650 computer and associated equipment. This equipment was a product of the Electronic-Accounting Machine Division of the International Business Machines (IBM) Corp An IBM-650 was leased by the CAA and installed first in the AOEC and later in the Indianapolis ARTC Center quarters. The program for this machine was written during the last half of Fiscal Year 1956 Personnel from TDC, the Indianapolis ARTC Center, and IBM, working together, developed a program for processing both airways and direct flight plans. Considerable effort was required to fit the program into the storage capacity of the 650. This programming required about 2,100 man hours and 7 months to complete.

The equipment used during the programming and the first evaluation included four 826 card punch machines, one 533 input-output unit, one 650 computer console, and one 407 accounting machine printer

When the programming was completed, and space was made available in the ARTC Center quarters, the system was used for the production of flight progress strips for approximately 8 months, from April until December 1957. Another report[12] describes the Indianapolis program in more detail. During the 8-month period in calendar year 1957 when the IBM-650 computer was being used in the Indianapolis ARTC Center to process flight plans, an operational evaluation of the computer was conducted using a test period from September 5, 1957, to November 5, 1957. During the test, some of the findings indicated that the average time for processing a flight plan, from the time it was received in the Center until the flight progress strips were in front of the controller, was 4 minutes 21 seconds Since a number of flight plans are in various steps of preparation simultaneously, a number of other measurements also are important. For example, it was determined that the average interval between the average flight plans processed by the computer was 7.39 seconds for airway flights and 17.32 seconds for the average direct flights It was indicated that, in the Indianapolis Center, the computer theoretically could process 6.6 flight plans per minute.

The test period for this computer concluded that 80.1 per cent of all flight plans were airway flights, 15 4 per cent were direct flights, and 4.5 per cent were combination airway and direct flights. Of these, 52.2 per cent were air carrier, 33.9 per cent were military, and 13.9 per cent were itinerant. It also was determined that 3.88 flight progress strips were required for each airway flight, 3.94 flight progress strips were required for direct flights, and 2 26 strips were needed for combination airway and direct flights. Conclusions reached were that the reliability and accuracy were excellent. However, the type size for the identification, time, and altitude figures was too small on this particular machine The magnetic drum in the 650 without ancillary equipment did not contain enough storage capacity for the Indianapolis problem. Based upon these facts and findings, the 650 was deemed unsatisfactory. It was recommended that it be replaced with a larger machine with more storage capacity. It also was recommended that the Type 407 accounting machine be modified so that the printing wheels would provide larger figures for identification, time, and altitude columns. The replacement machine was an IBM-650/RAMAC. The description of this machine is given in a succeeding section of this report. An operational evaluation was not made on the RAMAC.

d. IBM-650/RAMAC Computer: Personnel of the AOEC, working with ARTC and IBM programmers, developed the logic and program for the new and larger-capacity machine. The IBM-650/RAMAC installation was completed on July 3, 1958. From that date until October 6, 1958, the program was "debugged" and tested for accuracy The first actual production of flight progress strips for the ARTC Center began on October 6, 1958. By November 20, 1958, theaairway and direct flights both could be handled. A more detailed Technical Development Report on this task is being prepared.[13]

FEASIBILITY OF USING A COMPUTER IN THE CENTRAL ALTITUDE RESERVATION FACILITY

One of the activities of the CAA Office of Air Traffic Control was the operation of the Central Altitude Reservation Facility (CARF) to perform advance processing of airspace reservations for military missions. CARF is responsible for coordinating between the FAA ARTC Centers and military units conducting flight missions in the United States and adjacent oceanic areas.

Based upon the activity of this facility during a 1-year period from August 1956 to August 1957, using a 365-day year, the facility processed approximately 8 1/2 missions per day. An analysis of the missions processed during this period indicated that an average mission contained 30 fixed postings or route segments per mission.

The airspace reservation requests are received at CARF from ARTC Centers in whose area the mission will originate. From the flight plan received, CARF makes a plot of the proposed route of flight, the altitudes to be flown, and the control times. Refueling areas also are shown on the plot. After the plotted missions are compared with each other so that any confliction of altitude or airspace is detected, a study is made to determine the minimum number of changes that would be necessary to resolve the confliction. The resolution of mission conflict normally is based upon priority of mission, although there are other means of resolution, such as changing routes or altitudes to eliminate this confliction. Some conflictions are resolved by the operating agency at the suggestion of CARF. Other conflictions are resolved by CARF based upon the priority of operation This project task was designed to show whether or not it would be feasible to program the Remington Rand Univac Model 1 or the IBM-650/RAMAC computers to perform the necessary functions In addition to ascertaining if the storage capacity and the processing times were satisfactory, economic aspects also were considered.

In determining the feasibility of using a computer for this problem, it also was deemed advisable to determine if one computer could do the job for CARF and also the air route traffic control problem of the Kansas City Center. The conclusions reached in this evaluation are contained in a more detailed report[14] and are listed below.

1 The annual cost to do the job with a computer would be approximately twice that of operating CARF manually

2. Most of the problem of processing airspace reservation could be accomplished within present-day computer capabilities

3 The use of a computer is feasible if computer memory is used in lieu of manual plotting and if its computing functions are used to detect conflicts and suggest resolution of such conflicts based on altitude or time changes.

4. It did not appear feasible for the machine to suggest changes on alternate routings

5. It did not appear feasible to use one computer to attempt to do both the Kansas City ARTC Center and CARF jobs.

SCAN-CONVERSION (TI-440) EQUIPMENT

The Technical Development Center had a continuing task to improve radar displays for air traffic control. After considerable evaluation of the General Precision Laboratories' TV projection system and the Farnsworth Iatron system, a survey of industry was conducted in Fiscal Year 1957 to find the best radar displays available The use of scan-conversion techniques showed promise in this survey, and an equipment, built by Compagnie Generale De C.S.F. in Paris, France, and known as the Model TI-440 scan-conversion equipment, was obtained for operational evaluation. In the United States, the French company was represented by the

Intercontinental Electronics Corp (INTEC) The description of the equipment and the results of the technical evaluation are contained in another report.[15]

Briefly, the TI-440 equipment accepts video, trigger, and azimuth information from a radar and by using a two-gun electronic storage tube, converts this radar information into a television video and synchronizing signal. This composite output then is used to drive an ordinary television monitor for actual display purposes. In the AOEC, the scan-conversion equipment was used to display radar information on several different sizes of television monitors. Not only was this equipment used in the AOEC, but it also was evaluated in the Indianapolis ARTC Center and the Indianapolis Tower During Fiscal Year 1958, different methods of displaying radar were evaluated in the AOEC. These included different size TV monitors and positioning of monitors to display radar from the scan-conversion equipment. In the sections which follow immediately, each one of these displays is described briefly Detailed descriptions of these displays are contained in other reports.[16,17,18]

a. Superimposed Panoramic Radar Display (SPANRAD): One of the earliest applications of scan-converted radar to television was the use of a vertical TV monitor mounted perpendicular to a table top Above the monitor was a boom arrangement at the top of which was mounted a TV camera. The camera was focused to pick up anything that was on the table top. This TV camera picture then was mixed with the radar picture on the vertical monitor to form a composite picture. The purpose of this arrangement was to put flight markers on the table top, then, by viewing the TV monitor, the markers could be placed so as to coincide with targets on the monitor to give identification to the aircraft blips. This system, after being tried in the dynamic simulator, later was tried in the AOEC, after which an evaluation setup was made in the ARTC Center at Indianapolis and actually used for the control of traffic for a period of time. This remote tracking system was a new concept and not well accepted by controllers during the brief period of testing, although it proved satisfactory in the simulation tests.

b. Twenty-Two-Inch Horizontal Displays. Two different installations of the 22-inch flat-face tube were evaluated in the AOEC and the Indianapolis ARTC Center. The first consisted of a horizontal in-line console which occupied the space of five flight progress bays. The second used the 22-inch flat-face tube in an "island" arrangement which was the result of experimentation in the

AOEC with an original Washington design followed by a revised TDC design. In another application, the 22-inch flat-face tube was mounted in a console for use in the IFR room of the Indianapolis Tower

The advantages of the flat-face TV horizontal display were:

1. The display could be seen in near-normal room lighting.

2 The operation could be carried on using identification markers (small plastic chips comparable to those used with the VG indicators at New York, Washington, and Chicago ARTC Centers).

3 The brightness and resolution of the display were very good, and no noticeable heat was generated

The disadvantages of the 22-inch flat-face display were:

1. The implosion shield reflects light and images.

2. The maximum size of the display is 22 inches in diameter and cannot be changed unless larger tubes are developed.

3. The 22-inch flat-face is a special tube not in regular production.

The advantages of the island arrangement of the flat-face display are that three or more radar controllers can operate around each display. No camera chain equipment is required The console of the radar display is constructed so that control can be accomplished from a seated position. The disadvantages of the island display are similar to those listed above on the 22-inch flat-face display. There is one additional disadvantage· the arrangement does not lend itself to simplified coordination between sectors.

VERTICAL TV MONITORS

This part of the display evaluation was made using standard monitors ranging in size from 17-inch through 21-inch to 27-inch diagonal dimensions Different installations first were made in the AOEC by tilting the monitors at various degrees from the horizontal to the vertical. In the ARTC Center, these monitors were mounted in the bulletin board area and in the flight progress bay area by removing the flight progress bays to form an integral part of the in-line arrangement Controllers were not unanimous in their preference for size, some desired the 17-inch and others preferred the 21-inch. Some of the advantages of the vertically mounted displays were that:

1 The displays were easily visible to both the radar and the flight progress board controllers.

2 Little or no reflection of light or images occurred

3. Coordination between the radar and flight progress board controllers was simplified

4. The transition of scanning TV or flight progress board was easy.

5 No special lighting was required.

6. Flight progress strips could be read and marked by the radar controller when the vertical display was located in the A-3 board.

The disadvantages of the vertical display were that no memory help such as identification markers could be used. This limited the capacity of the controller and prevented him from handling more than three or four radar-separated aircraft simultaneously.

The evaluation of the SPANRAD 22-inch, flat-face, vertical monitors and slant scopes was carried on in the AOEC for about a year. At the end of this period, a number of radar controllers were called in to assist in the final analysis of these different displays. The results are detailed in another Technical Development Report[17] The conclusions reached in this report were

1. The scan-converted radar displays are bright enough and have sufficient contrast for use in ARTC Centers. By the use of light traps or other light controls, they may be used also in tower cabs and IFR rooms. Control of light is most important when using the 22-inch horizontal display.

2 The target trail or storage provided by the TI-440 equipment is excellent for control purposes

3 Resolution of radar targets on the scan-converted display is adequate

4 All radar controllers felt that tracking aircraft was a major workload and would require additional personnel to track targets The consensus was that the tracker should be a certified radar controller

5 Control personnel in general preferred the 22-inch flat-face indicator over all of the other displays tested

6. The in-line installation of the radar displays with flight progress boards generally was preferred over the island

7 The vertical monitors had only limited utility.

KELVIN-HUGHES RAPID-PROCESSING PHOTOGRAPHIC PROJECTOR

The Kelvin and Hughes equipment, Fig. 7, is a photographic display system which produces an enlarged projection of a radar cathode-ray tube or a Charactron shaped beam tube. The system is unique in the speed in which the film is developed Either a negative or a positive can be produced if required The negative is ready for projection in about 4 seconds, the production of a positive can be accomplished in about 12 seconds The speeds mentioned are made possible by the use of selected chemicals and heat. Hot air then is used for rapid drying

In operation, the Kelvin-Hughes camera equipment has the shutter synchronized in time with the rotation of the radar antenna. Ideally, the shutter of the camera is open for one rotation of the antenna plus 7 1/2° overlap. The shutter then closes for 1/25-second while the film is advanced The film frame which has just been exposed is advanced into development while the second frame is being exposed On the second advance of the film, the first frame is in projection, the second is in development, and the third is being exposed This cycle is repeated over and over

A 1,000-watt mercury vapor lamp provides the necessary light for projection. From a 35 mm film, a display of 4 to 6 feet across is available, as shown in Fig 8. Diameters of 10 to 20 feet are possible, but this would result in some loss of brightness and would not be sufficient for the normal ambient light in a room

The evaluation of the Kelvin-Hughes equipment in the AOEC was not completed nor was the equipment used to control live IFR traffic However, it was used for many hours by a large number of control personnel to track aircraft during radar flight checks, deviation from route measurements, and random aircraft tracking during demonstrations. From this experience, the following subjective opinions were drawn. The advantages of the system were:

1. A large panoramic display of either short- or long-range radars could be achieved.

2 It definitely was a bright display, bright enough to use under most room lighting conditions

3 The equipment was quite reliable when proper preventive maintenance was performed.

4. Targets were large enough to permit the use of aircraft markers on the order of 2 by 3 inches in size This permitted the combining of tabular information with range and azimuth data from the radar

5 A permanent record of radar data was available for file.

The disadvantages of the system were:

1. Film and chemicals were quite expensive. For 24-hour service, it is estimated that the cost of materials would approach 120 dollars per day

2. A maintenance technician must be at or near the equipment at all times

3 Considerable ceiling height must be provided if a horizontal display is required. To produce a display ap-aproximately 6 feet across requires 15 feet of projection distance.

4 A separate Kelvin-Hughes equipment would be required for each radar

5 No alpha-numeric data could be projected by the Kelvin-Hughes equipment unless it were written on the cathode-ray tube before being photographed.

6. The Kelvin-Hughes equipment requires connections for compressed air of approximately 60 pounds per square

inch and uses about 5 cubic feet per minute Power supply of 200 to 250 volts is required, a cold-water supply, as well as a waste pipe, is necessary, and a vent into the open air is needed for fumes. Although not absolutely necessary, a dark room is a desirable addition.

7. Duplicate units are required for fail-safe operation.

TIME-SHARED DISPLAYS

During Fiscal Year 1956, two ASR-2 radars at Indianapolis were used in a study of time-sharing This display of two radars on one indicator appeared to have application in traffic control areas where aircraft were handed off from one radar operator to another, each using different equipments.

The first experiments were conducted using the SPA-8 radar indicator A minimum of circuitry changes were required on this indicator due to a cursor circuit which could be converted to display a second radar input. During the second half of Fiscal Year 1956, while the decentralized sector of the Indianapolis ARTC Center was operated at Rockville, the SPA-8 indicator was used to time-share the CPS-6B radar which had two antennas on one pedestal. The vertical beams were oriented 146° in azimuth from the early warning beam. In time-sharing this radar, the sweeps on the indicator were separated by the same 146° in azimuth Inasmuch as only one trigger was used in the CPS-6B radar, the result was a synchronized display Since this was a synchronized display, the time-sharing was accomplished on a 1:1 ratio. This work is reported in another Technical Development Report.[19]

In addition to the SPA-8, another indicator of newer vintage, known as the UPA-35, also was used in this study. Most of this work was on the premise that no synchronization was required. The FPS-8 and the ARSR-1 long-range radars and the ASR-2 short-range radar were time-shared with each other. When time-sharing the ASR-2 with the long-range type radars, the long-range radar data were given display priority and the ASR-2, with a pulse repetition frequency (prf) of 1200, was blanked out whenever the long-range radar pulse was emitted. Figures 9 and 10 illustrate the time-sharing of these radars. A more detailed technical report of this work has been prepared.[20]

VFR FLIGHT ADVISORY TESTS

During the early months of Fiscal Year 1959, a 2-month evaluation test of the VFR Radar Advisory Service was conducted from the Indianapolis Tower. This test was completed August 23, 1958 During these tests, 61 per cent of the VFR flights in and out of Weir Cook Airport used the service during VFR weather, and for a period of 165 hours, data indicated that 719 aircraft were provided with VFR radar advisories During one 8-hour period, 87 aircraft were provided with advisories. Answers to two pilot questionnaires indicated that a large majority of pilots were in favor of a VFR advisory service. Many pilots indicated in these questionnaires that there was a need for altitude information on other aircraft. Pilots were not too favorable to inbound and outbound channelization except during marginal weather. They did indicate, however, that under these conditions they would be willing to accept some restriction such as corridors or radar vectors An earlier Technical Development Report covers the VFR Flight Advisory Service in more detail.[21]

ROOM LIGHTING STUDIES

Lighting of traffic control centers and traffic control towers became a critical problem when radar was introduced as a tool for the control of traffic. One of the earliest studies made in the AOEC was the evaluation of the British trichromatic lighting system Briefly, the trichromatic lighting system includes groups of three fluorescent tubes covered with colored plastic, one red, one blue, and the third green. This color combination produces an apparent white light which is deficient in the yellow-orange part of the spectrum

Three demonstration light booths were constructed in the AOEC in which three identical OA-99 radar indicators were located In each of the three booths a different type of lighting system was installed. These included polarized, broad-band blue, and minus green. In the booth being lighted by the polarized system, an overhead fluorescent fixture with glass diffusing was covered with a linear polarized plastic The radar indicator then was covered with a polarized plastic 90° from the source light. The resultant display from the OA-99 was a dark background with targets showing up brilliantly through the polarized plastic. The ambient light was sufficiently high to permit easy reading and writing of printed matter.

The broad-band-blue lighting system, developed by Ohio State University and adopted by many military bases, is achieved by covering a fluorescent fixture with a blue plastic material. The resultant ambient light is a deep blue which does not materially fluoresce the phosphor on a P-7 cathode-ray tube

The minus-green lighting system, developed by Franklin Institute Laboratories, used fluorescent tubes covered with two sheets of plastic, or in some cases, the tube was covered with one colored plastic and the diffusing glass plate covered with another color. The colored plastics used in this system were mauve and pea green When this system of lighting was used, a green filter was used over the cathode-ray tube Since the plastic shield over the cathode-ray tube tended to reflect light sources and light reflection from clothing or faces of operators, Franklin Institute Laboratories had this cover plated with a thin (5500 angstroms) zero reflection coating. The coating reduced the specular reflection to zero at one wavelength with reduction somewhat less than zero at other wavelengths. This coating was quite expensive, as it cost approximately 60 dollars to plate a 10-inch-diameter filter. The coating was soft and very easily scratched In addition, fingerprints once marked or applied to the surface were difficult to remove Most materials which would remove the fingerprints also scratched or marred the soft surface.

In addition to the systems for ambient lighting the space around radar indicators, considerable experimentation was carried on with such things as back-lighting of charts, in which opal glass was placed over several fluorescent tubes which were backed by reflective material to make a complete deflection system for back-lighting of film or thin paper charts Another approach to this problem was to build a box with lights at the edge of Plexiglas covers When the charts or maps were placed over and against the Plexiglas, light was deflected into the film or chart so that it had the appearance of being back-lighted. For other types of lighting for charts and maps, the lines were drawn with fluorescent ink or paint and then illuminated with ultraviolet lamps, or in some cases, whole sheets of fluorescent material were covered with transparent maps and charts and then lighted with ultraviolet lamps so that the fluorescent material would shine through the lines on the chart. A third system of lighting charts was to procure luminescent panels Using positive and negative film, experiments were carried out to see which system gave the best type of presentation to the controllers. The adoption of scan-conversion so that television pictures were available for radar control eliminated to a great extent the need for lighting charts since the ambient light in the room could be increased to the point where printed matter could be easily read.

Considerable effort was expended to use polarized material to build what were called "light traps." These were useful in radar installations in the control tower where ambient light is changing continually due to the movement of the sun and the reflections which were never static Although it had been recognized previously that polarized material was especially helpful in eliminating reflected light from cathode-ray tubes, the polarized material itself was a reflecting medium for light falling on it By using a parabolic curve and shading the lower portion, it was found that light traps could be built which would eliminate practically all ambient light reflections and images such as are found in control towers and other well-lighted installations. Some of this effort is reported in another Technical Development Report.[21]

ARTC CENTER ROOM LIGHTING

Prototype models of light fixtures of the type recommended by Thomas B Bourne Associates for the new ARTC Center building were procured. Sixteen of these fixtures were installed in the two-story auditorium of Building 69 in the TDC area. The light fixtures were constructed to use four 40-watt fluorescent tubes with motor-driven shutters on each fixture. This permitted shading of the light from individual fixtures. In addition, controls permitted dimming of the light from banks of eight fixtures. The louvers and movable vanes were painted dull black. Preliminary tests of these light fixtures indicated 19 foot-candles of illumination directly below the fixtures at a distance of 18 feet. There was a noticeable difference in light intensity due to the voltage drop from one end of a row of eight fixtures to the other. Testing of these fixtures was not completed due to the termination of the program at TDC and they were shipped to NAFEC.

FLIGHT PROGRESS BOARDS

Flight progress boards first came into use in 1939 for traffic control purposes. An evolution has continued since that time. In 1954, when the Cincinnati Center was moved to Indianapolis, there was not a sufficient number of Pittsburgh-type boards available to outfit the Indianapolis Center The Pittsburgh board, which was two-sided or made for back-to-back operation, located the A position on the opposite side of the board from the D position An experimental board, which had been designed by CAA engineers, was in blueprint form To meet the needs of the new Indianapolis Center, it was decided to construct an adequate supply of the new boards, which were known as the IA-1 type This type of board is illustrated in Fig. 11 and was the subject of an evaluation report written by the Indianapolis ARTC Center in 1955. In this evaluation report, it was recommended that a revision in design be built into future flight progress boards. As a result, the Technical Development Center constructed one of these boards for the ARTC Center. It was known as the Louisville board because of its location at the Louisville Sector in the Indianapolis Center. Figure 12 depicts this board

The Bell Telephone Laboratories, on contract for the Air Navigation Development Board, engaged Henry Dreyfus and Associates to design a flight progress board which would be designed for human engineering practices and fit the needs of air traffic control personnel. Figure 13 illustrates the Dreyfus board which was used at Rockville during the time that the decentralized sector was in operation at that location

One concept of a flight progress board was to make modular units of two- and four-bay units which could be mounted side by side to give any configuration that was necessary for Center use. Figure 14 illustrates one of the later types of modular boards built for the AOEC.

The A-3 and A-4 flight progress boards, which were designed in Washington, contained many features which were the result of experimentation, demonstrations, and conferences between AOEC and Washington personnel. Figure 15 illustrates the A-3 board which is being used in the Indianapolis ARTC Center. The A-4 flight progress board is the A-3 modified by adding more lights to the top of the flight progress board. AOEC personnel were instrumental in designing plans for the modification of the A-3 and A-4 flight progress boards for the installation of in-line radar displays. This included the 22-inch flat-face console for horizontal display as well as the 21-inch vertical display consoles.

The New York and Washington ARTC Centers used VG radar indicators upon which were mounted small sections of flight progress board for accommodating approximately 10 or 12 flight progress strip holders From this concept, it was deemed desirable to build an island arrangement for the use of television displays when scan-conversion equipment was introduced The first prototype of an island to accommodate a television flat-face display at each end was built at the Technical Development Center This construction was made from Washington's sketch No. 24 At a demonstration of this prototype, it was determined that some revisions were necessary and these were made at TDC Figures 16 and 17 illustrate these different island configurations.

FLIGHT PROGRESS STRIP HOLDERS

In the traffic control center and tower, the flight information is posted before the controller on paper board or cards which are 1 inch wide by 8 inches long. These cards, commonly called strips, are held on the board in a metal or other type container known as flight progress strip holders The earliest strip holders were made of sheet steel. In 1944, an aluminum strip holder was designed Since that time, a number of different materials have been used to fabricate flight progress strip holders. Materials have included several types of rubber, nylon, and Fiberglas. The AOEC, working with Indianapolis ARTC Center personnel, evaluated the different types of strip holders as they were made available. Technical Development Reports[22 23] covered the evaluation of the black rubber plastic and nylon strip holders.

Several thousand strip holders are used in busy centers each day There is a considerable workload involved in loading and unloading the strip holders to keep the information current. In 1957, when the first computer was introduced into the ARTC Centers, it was found that the speed of printing these flight progress strips was approximately 50 strips per minute. This speed required that several persons be assigned to load the strip holders with the output from the computer printer As a result, personnel of the AOEC conceived the idea of building an automatic or mechanical strip cutter and loader. The Technical Development Center's Engineering Shops designed and built a shop prototype model which was capable of loading strips at a rate of approximately 30 per minute. This model proved that the idea of loading the holders mechanically was feasible Future development programs on this equipment are being handled by the Bureau of R&D. Figure 18 shows the prototype strip stuffer that was built at TDC

TARGET MARKERS

Historically, target markers have been used in traffic control since 1936 when the first ARTC Centers were implemented These first markers were brass blocks 1 1/4 inches long by 3/4-inch wide by 1/4-inch thick. Grooves were provided in the top surface to permit the use of teletypewriter perforator tape for insertion and for marking with pencil These were discontinued in Centers about 1940. With the advent of radar in Centers, a need for markers to identify radar targets again was encountered. This need was met by the use of a small plastic marker of clear material upon which the identification could be marked with a China marking pencil. The size of this marker varied with the size of the radar display and usually was scaled to measure 3, 5, and 10 miles. These plastic markers were used in the New York, Washington, and Chicago Centers on the radar displays At the Technical Development Center, attempts were made to project radar information using various equipments, and to keep the identification and other flight data of tabular form coordinated with the radar blip. In the beginning, these markers were made of sheet aluminum turned up at the sides so that heavy paper could be used for a writing medium. The evolution of these aluminum markers became a machined block of cast aluminum with altitude wheels and attachments for indicating climb and descent arrows on the side. Figures 1, 2, and 8 illustrate some of these markers Figure 19 shows plastic markers in use on the TV radar displays covered in a previous section of this report.

Many people were of the opinion that a self-powered marker, which could be adjusted to move at a scale speed commensurate with the actual ground speed of the aircraft, would eliminate much of the labor of keeping the tabular information updated with the actual moving blip on the panoramic display Accordingly, a contract was initiated with the United States Time Corp. to develop such a self-powered marker In writing the specifications for this marker, it was necessary that the size of the marker be kept to a size commensurate with the scale used on the display. The size specified in the contract was 3 inches long by 2 inches wide by 1 inch high. The height later was altered when a decision was reached that the thickness of the marker was not critical. United States Time Corp was unable to meet the specifications, and eventually the contract was cancelled.

CONVEYORS FOR FLIGHT PROGRESS STRIP HOLDERS

Another project task involved the development of conveyors for the ARTC Center at Indianapolis to carry the flight progress strip holders from the IBM computer room to the individual sectors where the strip holders would be used. The complete installation of 13 individual belt conveyors is the outgrowth of approximately 18 months of study by AOEC personnel. The first conveyor used an aluminum channel with a smooth-surface belt It was found that the aluminum channel, when rubbed by the belt, turned black, and the resulting dirt coated the strips and personnel handling them The belt was slippery, and the holders did not adhere to the belt well enough to be transported up the slopes necessary for lifting the strip holders above the flight progress board After a considerable amount of experimentation, stainless steel carriers were developed These carriers were equipped with three-ply rubber. The surface is a series of small rubber beads, called "Ruff-Top," which grip the flight progress strip holders and carry them up grades of approximately 25°. On these three-ply belts, a better splice was developed than had been used previously and only one break was experienced in several months of continuous use. The linear speed of these belts was approximately 233 feet per minute A study was made to develop a return carrier belt which would convey the used flight progress strip holders back to the flight data position or the IBM computer room for stripping and re-loading The results of this project task are covered in detail in another Technical Development Report.[24]

TRAFFIC FLOW STUDIES

The AOEC made several intensive surveys of air traffic flow. Most of these studies were made from information available in the Indianapolis ARTC area. Some of the results obtained concerned

1. The number of flights per day per operator

2. The number of times each altitude level was occupied

3. The number of direct, airways, and combination direct/airways

4. The number of flight plans by speed categories (50-knot increments).

5 The number of flights from the seven adjacent centers from which the flight plans were received.

6. Traffic breakdown by 3-hour peak period and 1-hour peak period

7. During 1-hour peak periods, further breakdown was made to show:

a. The number of direct flights.

b. The number of airway flights.

c. The number of combination flights.

d. The number of characters (alpha or numeric) in the identification and in the aircraft type.

e The number of route segments contained in flight plans.

f. The number of revisions to estimates, routes, and altitudes.

g. The number of position reports received.

h. The number of compulsory position reports that were not received.

The results of these studies and surveys were made available to the various CAA offices concerned with programming computers and/or other problems.

Figure 20 indicates the traffic flow through the Indianapolis ARTC area in one 24-hour period. The solid lines indicate over-traffic based on point of origin to point of destination. This is depicted as a straight line and falls in the Indianapolis area because of airway configuration. The broken lines indicate aircraft taking off from or landing at terminals in the Indianapolis area.

INTERPHONE COMMUNICATIONS EQUIPMENT

A part of the AOEC environment included air/ground and landline communication facilities adjacent to the Indianapolis ARTC Center. Bell Laboratories, working with and through the Indiana Bell Telephone Co., engineered and installed a flexible system of landline communications facilities known locally as the patch panel. The Third Regional Office installation crew, following the same pattern of installation, installed patch panels for the air/ground and recording equipment.

Figure 21 illustrates the telephone patching panel equipment The left-hand panel of the illustration is the line termination patching panel which permitted each local and longline circuit to be terminated in a series of jacks An associated series of jacks on the same panel were arranged to correspond with each A and D position in the ARTC Center It thereby was possible to connect any incoming line to any key in a 102A keybox at the desired sector or sectors This permitted any combination of lines to be terminated at any control board in the center

At the top of the second panel from the left the position pairing (or splitting) patching panel is located This position pairing patching panel provided for pairing any two positions in the Center as A and D positions with the A always monitoring the associated D position. Patching was accomplished by cables with plugs which were wired to each other in such a way that the plug marked A was cross-connected to a plug marked D. The receptacles for these plugs or jacks were connected electrically to individual keybox positions in the Center's operating room. The advantage of this position pairing patch panel was the added flexibility enabling Center personnel to change the location of A and D positions without losing the monitoring characteristic

The second set of jacks on the panel, second from the left, is the prime answering patching panel. The prime answering patching panel had a series of jacks connected to relays on each incoming line terminating in the Indianapolis Center. Another series of jacks were wired to the attention signal lamps at each operating position in the control room. By using the patch cords, the incoming signal from any line could be connected to the auxiliary position signal lamp of the A or D position which would be responsible for answering that particular line Signals from two-tone dialing circuits also could be controlled by this panel. The advantage of this patching panel was that the prime answering responsibility could be transferred from one keybox to another.

Another feature unique to the Indianapolis Center was the override patching panel shown on the lower part of the second panel in Fig. 21. The override patching panel consists of a series of jacks which were connected to the headset circuit at each operating position in the Center A second series of jacks were connected to the intracenter 740 PBX equipment Each jack of this second group was assigned a two-digit code and activated by the PBX only when the pertinent number was dialed A two-digit code was assigned to each operating position in the ARTC Center and the AOEC. When a controller wished to converse with another controller, the calling controller depressed the PBX key and dialed the number associated with the called controller's position. This connected the two headsets and lighted a green beehive lamp at the called position. As the term "override" implies, the two headsets were connected, whether the called position was busy on another line or not. The patching panel on this flexible installation permitted the use of the same code number for a sector regardless of its physical location along the flight progress board

During calendar year 1956, at the request of the AOEC, the Indiana Bell Telephone Co. made a tentative survey of the relative costs of installing 18 interphone positions in the normal manner versus 18 interphone positions equipped with patching panel. It appeared that the patch panel equipment and plug-in cable terminations increased the installation and monthly charges approximately 30 per cent.

AIR/GROUND EQUIPMENT

Figure 22 illustrates the air/ground patching panel with the open Christmas-tree racks on the right and the telephone patching panels in the left background Thirty-two receiving channels and 28 transmitting channels were made available to the ARTC Center and the AOEC through the patching panel. This flexibility permitted frequencies to be transferred from one sector to another in the ARTC Center, and for operation or monitoring in the AOEC, by patching into the portable consoles, as described below. The 32 receiving channels and 28 transmitting channels mentioned above included all of the frequencies assigned to the control tower, the communications station, and the ARTC Center at Indianapolis.

In the AOEC, the air/ground channels and the interphone terminations all were terminated in a portable console, shown in Fig. 3. This configuration of communications equipment included 12 channels of radio, 20 channels of interphone, the central office line telephone, and a three-lamp signal light. An automatic switching device was used on each of these consoles so that if the controller was using radio regularly and the interphone circuits only occasionally, the switch could be placed on automatic, which then permitted the operator to listen and talk on the radio at all times with no interference to the interphone circuits However, if an interphone key was moved to the ON position, this automatically switched the headset from the radio to the interphone circuitry.

AIR/GROUND ANSWERING DEVICE

Several Mohawk message repeaters were purchased by the AOEC for experimentation in the field of automatic answering devices. The Mohawk message repeater consisted of a short magnetic tape recorder with playback available in the same instrument. AOEC personnel prepared closed loops of the magnetic tape on which special messages could be recorded. One application was the recording of regular broadcast weather. In this case, the Mohawk machine was installed in the communications station, and the operators were asked to record the regular 15- and 45-minute-after-the-hour broadcasts prior to broadcast time. The broadcast then would be made at the desired time by merely starting the playback of the Mohawk message repeater This test operated several weeks but was not considered satisfactory due to the fact that the equipment needed to be monitored, and oftentimes a special weather item would come in just prior to broadcast time which should have been inserted into the broadcast tape but could not be because of the time element. Another factor was that the recording was done in the normal operating room and the background noise caused by conversation and teletype machines was quite high

During calendar year 1958, at the request of TDC, a number of equipments derived from the Mohawk message repeater were installed in the Air Traffic Communications Station (ATCS) by CAA Third Regional personnel so that 12 units were available and were used for a continuous broadcast of selected weather information. This device broadcasts over the low-frequency radio range at Indianapolis. Normally, the weather at nine stations was broadcast, plus the Indianapolis winds aloft and a short weather summary.

Another application of the Mohawk message repeater was an installation in the equipment room of the ARTC Center In this case, a closed-loop tape was made which broadcast the same message each time the equipment was activated by pushing a button at the control sector in the

Center operating quarters In this experiment, which lasted approximately one year, a single message was broadcast each time the button was pressed and informed the pilot that the controller was busy and to please stand by on that frequency. A survey of usage indicated that this equipment was used an average of six times each day At the end of this test period, it was concluded that the device did not reduce the number of personnel required in a facility Its main benefit was derived from the fact that the pilot was answered when he called with a stand-by message which told him that his equipment was working

MICROWAVE LINKS

The Air Navigation Development Board sponsored the installation of a microwave link between the Air Defense Command radar at Rockville, Ind., and the Technical Development Center at Indianapolis The equipment used was manufactured by Motorola and the system was equivalent to the Motorola MRR-3. TDC leased the use of this microwave link for approximately two years from the Indiana Bell Telephone Co., which was responsible for the maintenance of the equipment. An evaluation of this wide-band radar remoting system was written by TDC at the end of the contract period.

The conclusions reached at the end of the evaluation period were that the microwave link has satisfactory frequency response, amplitude, linearity, resolution, and crosstalk characteristics It was found that the 2.5-Mc beacon channel was satisfactory for transmission of Mark 10 beacon decoders. It was found that special test equipment is required to provide acceptable performance. The details of this evaluation are contained in another Technical Development Report.[25]

A further study of microwave characteristics and performance was started in 1957 when a link was built between West Enon, Ohio, and Indianapolis, Ind Motorola MRR-6 equipment was used and installed by Motorola personnel. The MRR-6 link was approximately 127 miles long with three relay stations. This was a two-way, wide-band microwave link, with five channels from West Enon to Indianapolis and one channel from Indianapolis to West Enon. The MRR-6 equipment operated in the Government band of 7,125 to 8,000 Mc. Channel spacings were 160 Mc with each channel having a video bandwidth of 6 Mc. Although this microwave was not in operation over any prolonged period of time, a number of engineering studies were made of the equipment and of the characteristics. Signal-to-noise studies indicated that the loss of radar range was negligible This equipment was shipped to NAFEC for further use

SOUND-SUPPRESSION TESTS IN THE INDIANAPOLIS ATCS

AOEC personnel conducted an evaluation of noise suppression in the Air Traffic Communications Station at Indianapolis during the months from November 1958 to February 1959 This test was brought about by a suggestion to eliminate interference between two broadcast positions by the installation of a wall or curtain The study began by taking measurements of the sound level at one broadcast position which would indicate the amount of interference coming from the adjacent position This, of course, actually was the ambient noise measured at one broadcast position A study of the sound sources indicated that large 12-inch loud-speakers, mounted on the wall back of each broadcast position, caused some interference Talking at locations around or near either of the broadcast positions added to the ambient noise

Originally, it was suggested that a curtain, drapery, or wall be considered in the study of noise reduction However, based on noise-level studies previously made, it was suggested that in this particular application, due to the short distance between positions, a curtain or drapery would not be satisfactory. Therefore, curtains were not tested, and a wall was considered the most logical solution.

A wall or partition posed several problems. These included passageway for personnel from one position to the other as well as access by supervisors and maintenance personnel, the interchange of information on paper such as weather sequences, where only one copy was available for both operators, and in some cases, verbal coordination

The corrective action taken by TDC was to construct a partition, replace the large 12-inch loud-speakers with small 6-inch speakers close to the operator, and change the position of these speakers so that there was less interference caused by directional characteristics

The original room containing the two broadcast positions was 12 1/2 feet long, 11 feet wide, and 8 feet high. Two of the walls and the ceiling of this room had been treated with acoustical tile One wall contained two doorways with a glass partition between this particular room and the teletypewriter room At the rear of the room, behind the operators, there was a large window approximately 4 feet square which separated the operations room or broadcast positions from the office space

The wall or partition, which was constructed between the two broadcast positions, was constructed of two-by-four studs with plywood applied to both sides and both sides covered with acoustical tile. In this partition was a 30-inch-wide by 7-foot-high doorway. At the request of the chief communicator, no door or covering was made for this opening A pass-through slot or opening 12 inches wide by 4 inches high also was made in the partition within reach of the two operators This pass-through slot was covered with a piece of Plexiglas which could be moved to the side to permit pass-through Figure 23 illustrates the partition in place as viewed from the rear of the room. Sound-level measurements were made at a broadcast position after the partition or attenuating structure had been completed.

The large 12-inch speakers, which can be seen on the wall in Fig. 23, still caused interference after the partition was completed. The next step taken was to replace these speakers with 6-inch speakers mounted in small wooden boxes and placed close to the operator at each position This permitted the operator to work with less volume from the speaker.

Following the above changes, there appeared to be some interference reflected by the large window at the rear of the two broadcast positions. The sound from one booth seemed to be reflected into the other booth by this path. To attenuate this noise, a drapery material was placed over this window on the broadcast-booth side of the glass

The accurate measurement and interpretation of complex noise patterns and their annoyance factor is difficult to achieve. One assumption that is frequently used is loudness, and some reasonably satisfactory measures of loudness have been developed These can be measured by standardized types of test equipment, such as the General Radio sound level meter, Type 1551-B, used in these measurements The operational details of this instrument are contained in Manufacturer's Handbook No. 27, "Handbook of Noise Measurement," by A.P E. Peterson and L. L. Beranck, General Radio Co., Form 811-A, April 1953.

The measurements were taken with the sound meter near the center of the operating desk and with the pickup microphone about 9 inches from the right ear of the operator The data shown in the following tabulation are the average results of a number of observations

TABLE I

MEASUREMENT OF NOISE PATTERNS

Condition of Treatment	Meter Switch Positions 40 (db)	70 (db)	Flat (db)
Before Treatment	73	77	84
With Partition Only	65	70	75
Partition and Small 6-Inch Speakers	60	65	76
Partition, Window Draped, and Small Speakers	58	64	75
Reduction of Interference	15	13	9

From the above table, it can be seen that the total reduction in sound pressure levels for all modifications is approximately 9 db. Insofar as the ear is concerned, the sound level was reduced effectively between 13 and 15 db, depending upon the loudness level (40 db or 70 db) being considered.

It is concluded that the construction of attenuating structures, use of draperies, and careful attention to speaker location can be very effective in reducing interfering sounds and the over-all ambient sound level at the broadcasting positions A more detailed study than this one can be even more rewarding, but each must be patterned for the particular location involved, since very few locations resemble each other. Any partitioning of operating positions has to consider coordination requirements and the problems of cooling, heating, and ventilation.

TRANSISTORIZED REGULATED OUTPUT AMPLIFIERS

Another task undertaken to modernize communication facilities was the development of amplifiers containing the latest components. In 1958, the Centronix Manufacturing Co., under contract with TDC, constructed 20 transistorized audio amplifier assemblies (five channels per assembly) and related power supplies Figure 24 shows the standard CA-1503/1529 amplifier on the right, with five of the new ATR-1 amplifiers mounted in one panel on the left.

The Centronix ATR-1 regulated output amplifier provided high gain with automatic regulation and maintained a constant output level over a wide band of input levels. When operated between the limits of 300 to 4,000 cycles, amplification was linear with less than 4 per cent of harmonic distortion The amplifier operates on approximately 0 25 ampere A Centronix Model PS-596 dual power supply consists of two power supplies and an automatic transfer system. Output is filtered and regulated at 13.0 volts, 0.5 ampere.

The amplifiers are being evaluated in the Indianapolis ARTC Center on an in-service basis.

Controller-Computer Updating Equipment: Early in February 1959, TDC made a short evaluation of a controller-computer updating equipment fabricated by the Control Data Corp as a prototype Figure 25 shows the display with 13 windows for reading visually the characters which would be inserted into the computer The same display would produce a readable line of logical data from the computer. Also shown is the Key-Pack with 19 key switches which permitted control personnel to compose messages for insertion into the computer. The stepping switches and relays were contained in a metal cabinet shown in Fig 26

Two sets of prototype equipment were used in the tests These equipments were mounted in two different configurations for comparison Figure 26 shows one of the displays and Key-Pack mounted on an A-3 flight progress board. In this case, the display was mounted low, that is, in the communications panel area, with the Key-Pack portable and movable to any location on the shelf area. The other display was mounted high; that is, above the flight strip holder bays in a prototype A-5 flight progress board In this second installation, the Key-Pack was recessed into the shelf area. During some of the tests, the Key-Packs were modified from 19 keys to 14 keys by masking some of the keys with tape. The characters from the five masked keys were reassigned.

The tests consisted of making measurements of the time required for inserting a fixed number of different format messages into the equipment. In addition, the accuracy of composition was recorded by making a count of errors detected by the operator and those errors that were entered into the computer Three controllers from the Indianapolis ARTC Center were the subjects used in all tests

The results indicated that controllers could enter information somewhat faster with the display in the low position with a comparable number of detected errors (errors detected by the controller). Undetected errors (errors not detected by the controller) were somewhat higher with the display in the low position The test monitor felt that this increase in undetected errors was caused by overconfidence on the part of the controllers since the display was easier to read in the low position. Although the controllers were given time and practice in the use of both the 19 and 14 key configurations, controllers entered information faster and more accurately with the 19 Key-Pack than they did with the 14 Key-Pack.

One test consisted of measuring the time and accuracy when flight data were inserted on the Key-Pack and later transcribed onto a flight progress strip. Conversely, the data were written on the flight progress strip and then inserted in the computer. The results indicated that information was handled 1 6 per cent faster with 24.1 per cent greater detection of errors when writing the data on the flight progress strip first, then inserting it into the computer. However, undetected errors increased

The consensus of the controllers and AOEC personnel administering the tests indicated that

1. The display should be in a low position close to the Key-Pack

2 A single-character erase feature would be desirable

3 The speed of the equipment should permit a message of 14 characters to be inserted in 4 seconds or less.

4. The Key-Pack should be movable instead of fixed.

As a result of these tests, the following specification requirements are recommended:

1. The Key-Pack should conform to the pattern shown in Fig. 27, that is, 17 keys

2. The Key-Pack should be portable.

3. The equipment should accept at least 4 characters per second

4. The last character erase should be incorporated if no additional keys were needed.

5 The display should contain 14 visible character indicators.

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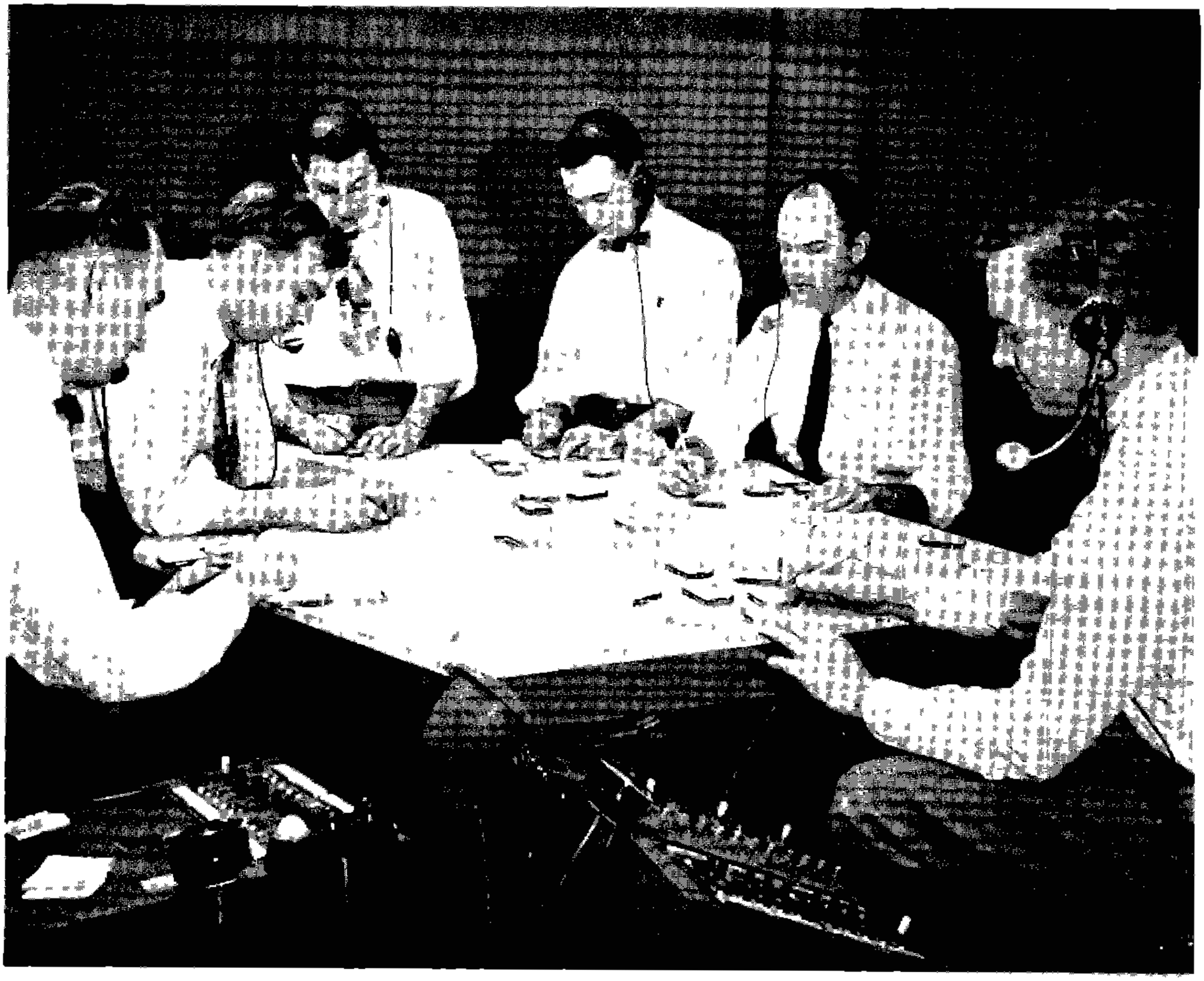
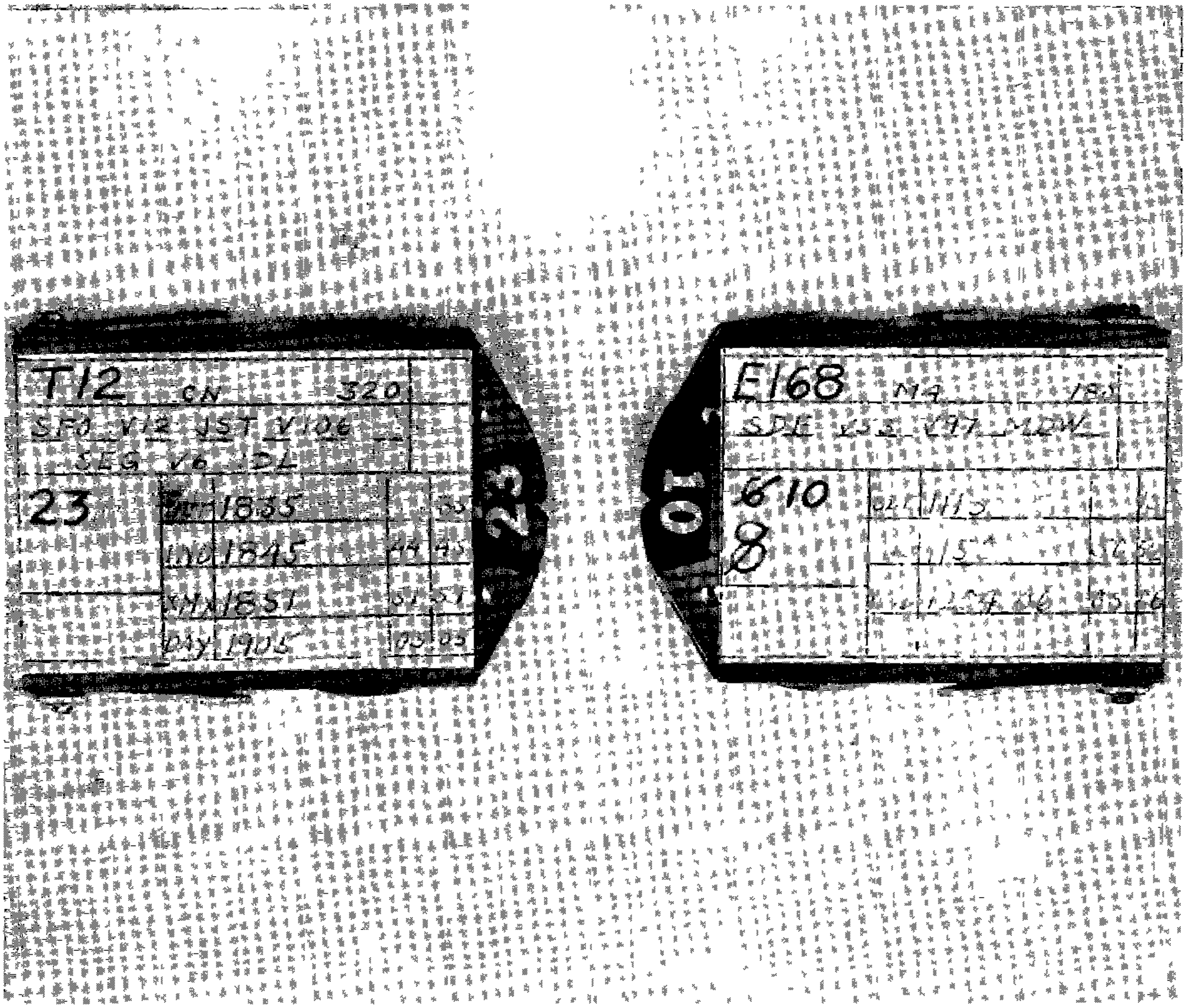
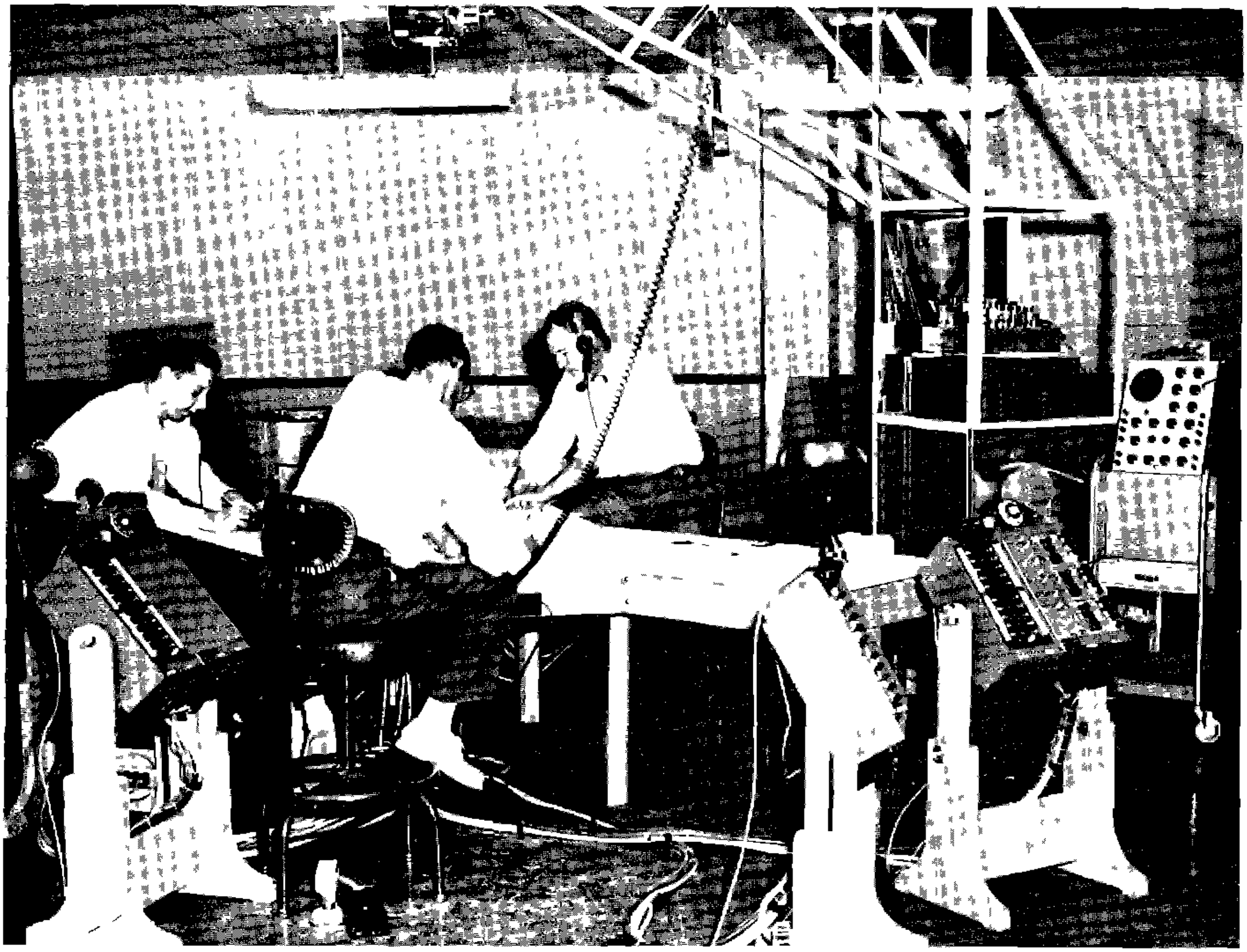


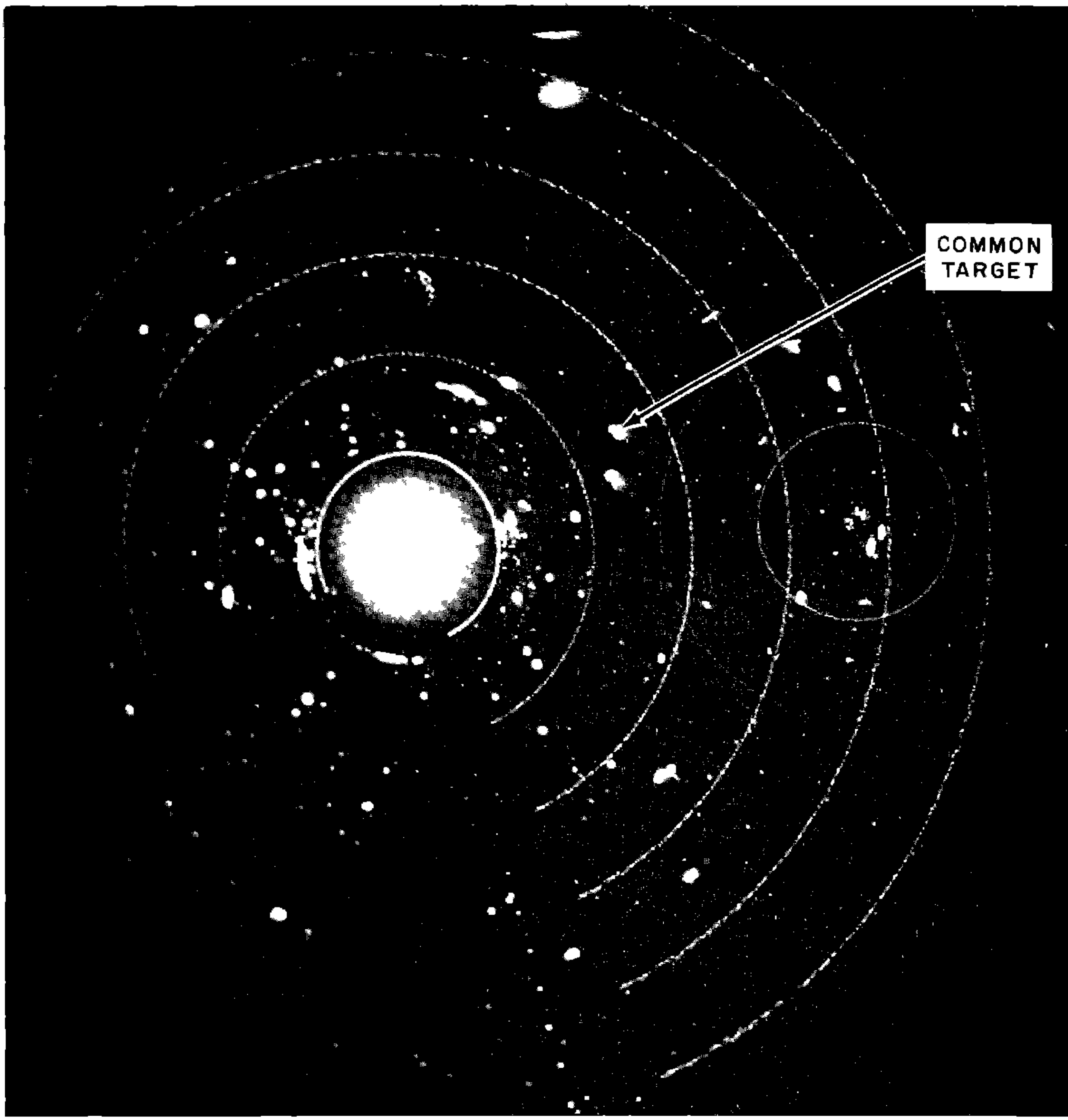
PANORAMIC DISPLAY IN AIR TRAFFIC CONTROL



FLIGHT MARKERS WITH PAPER INSERTS AND STRIP MARKING



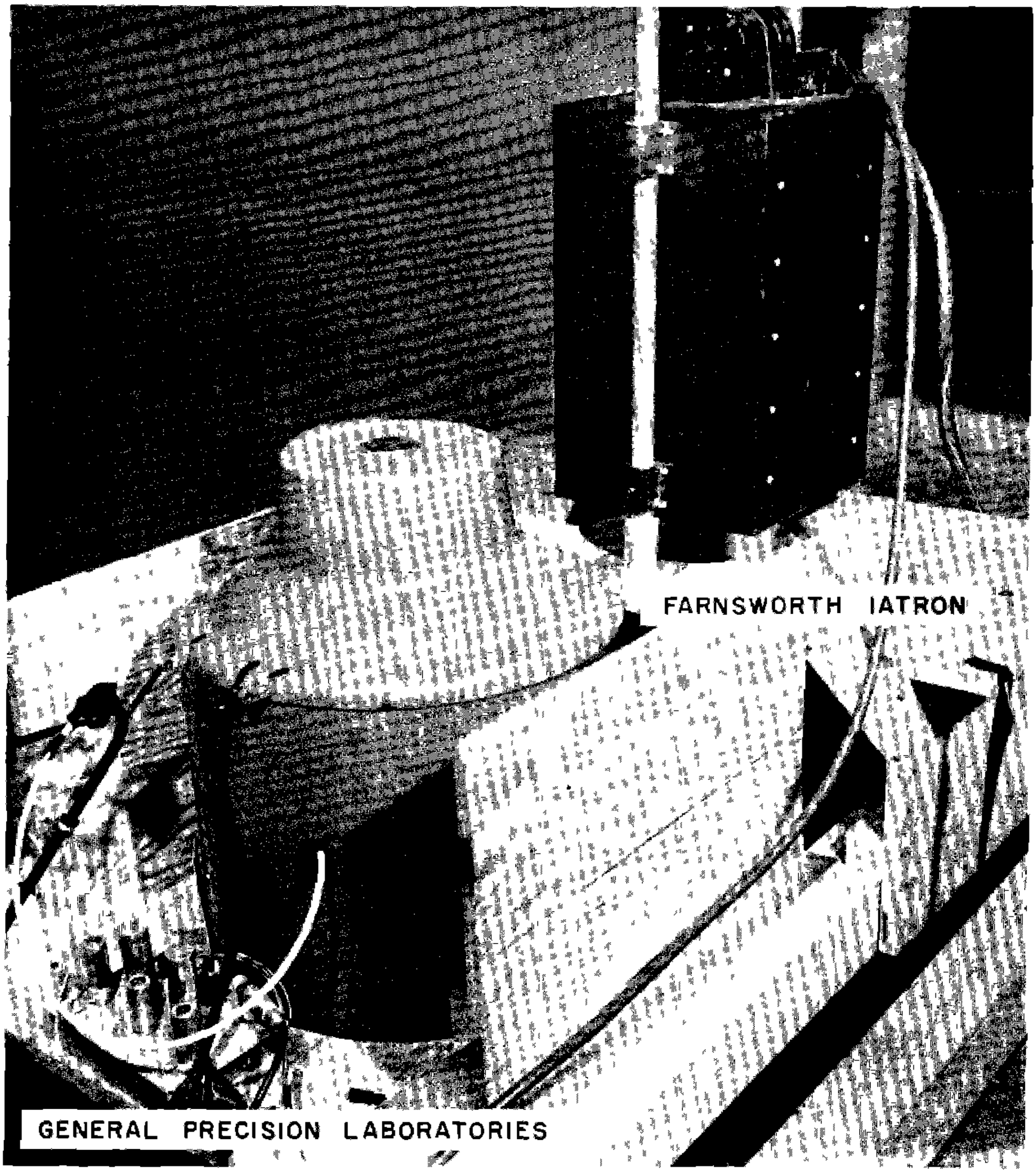
ATC DISPLAYS AND COMMUNICATION CONSOLES



TIME SHARING RADAR DISPLAY ON SPA-8 INDICATOR

NOTES

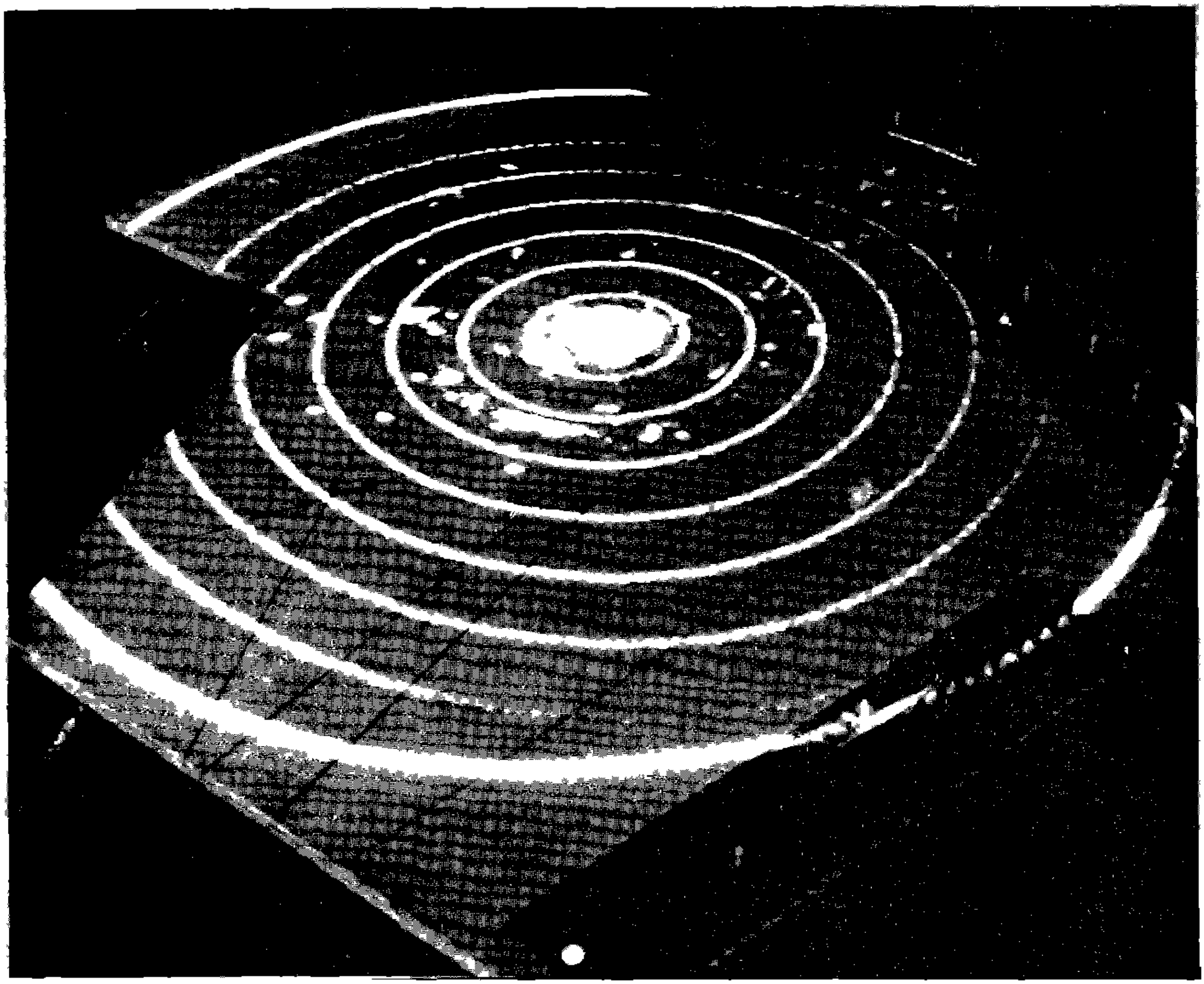
UNSYNCHRONIZED CP6-6B RADAR (ON LEFT)
UNSYNCHRONIZED ASR-2 RADAR (ON RIGHT)



RADAR PROJECTION HEADS

NOTES

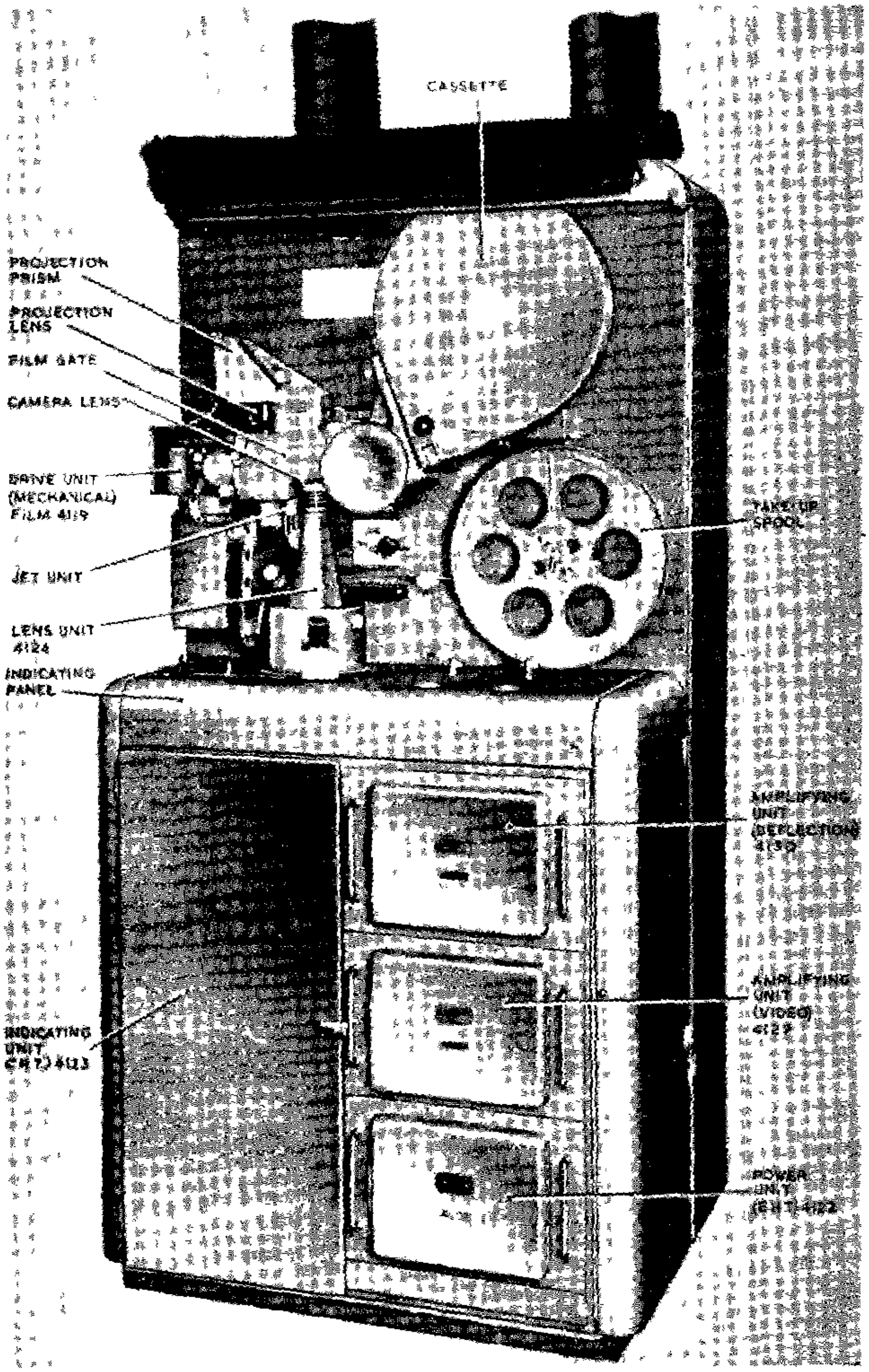
GENERAL PRECISION LABORATORIES (POINT TO LEFT)
FARNSWORTH IATRON (POINT TO RIGHT)



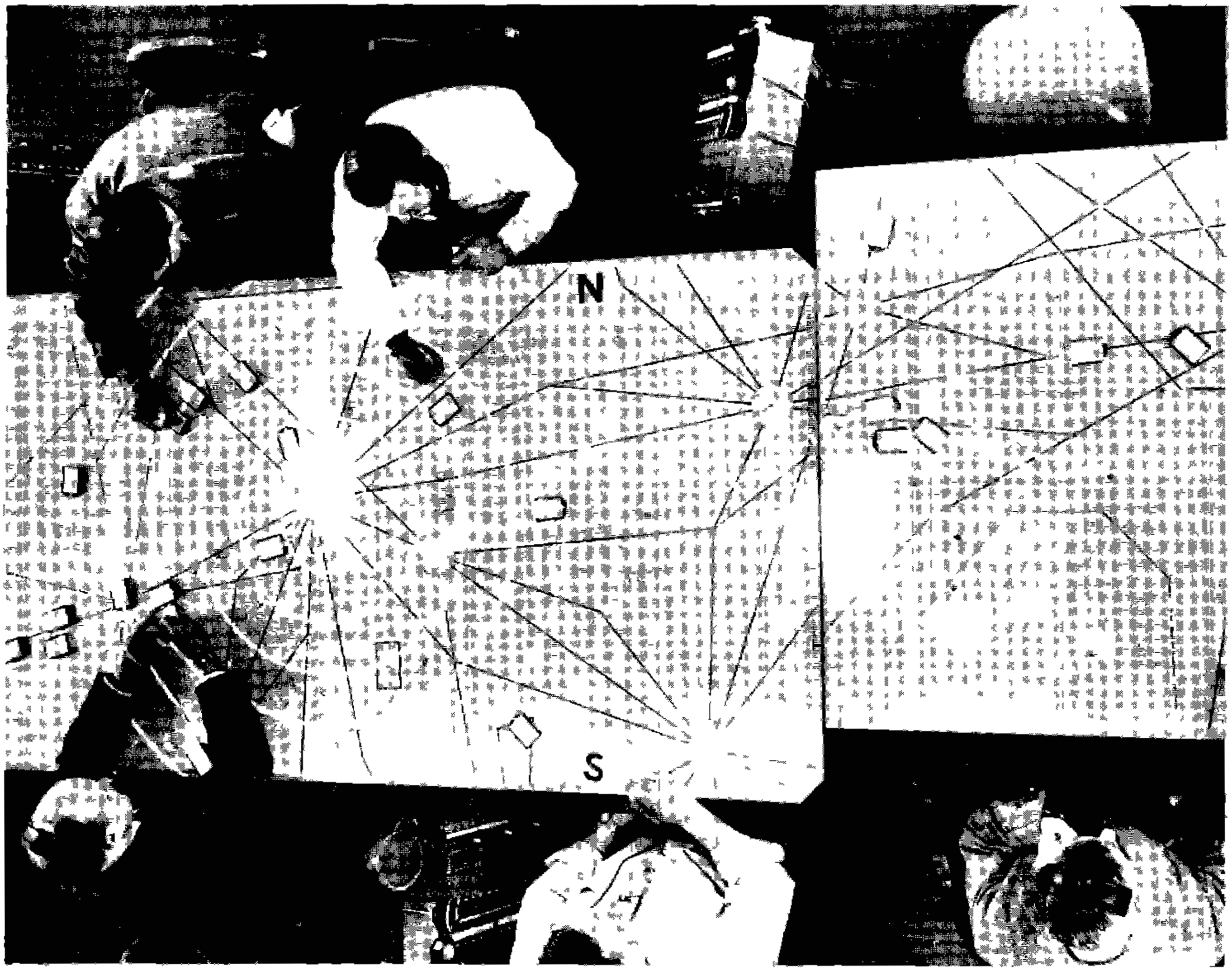
IATRON RADAR PROJECTION DISPLAY

NOTES

INDIANAPOLIS UPPER RIGHT LAFAYETTE UPPER LEFT



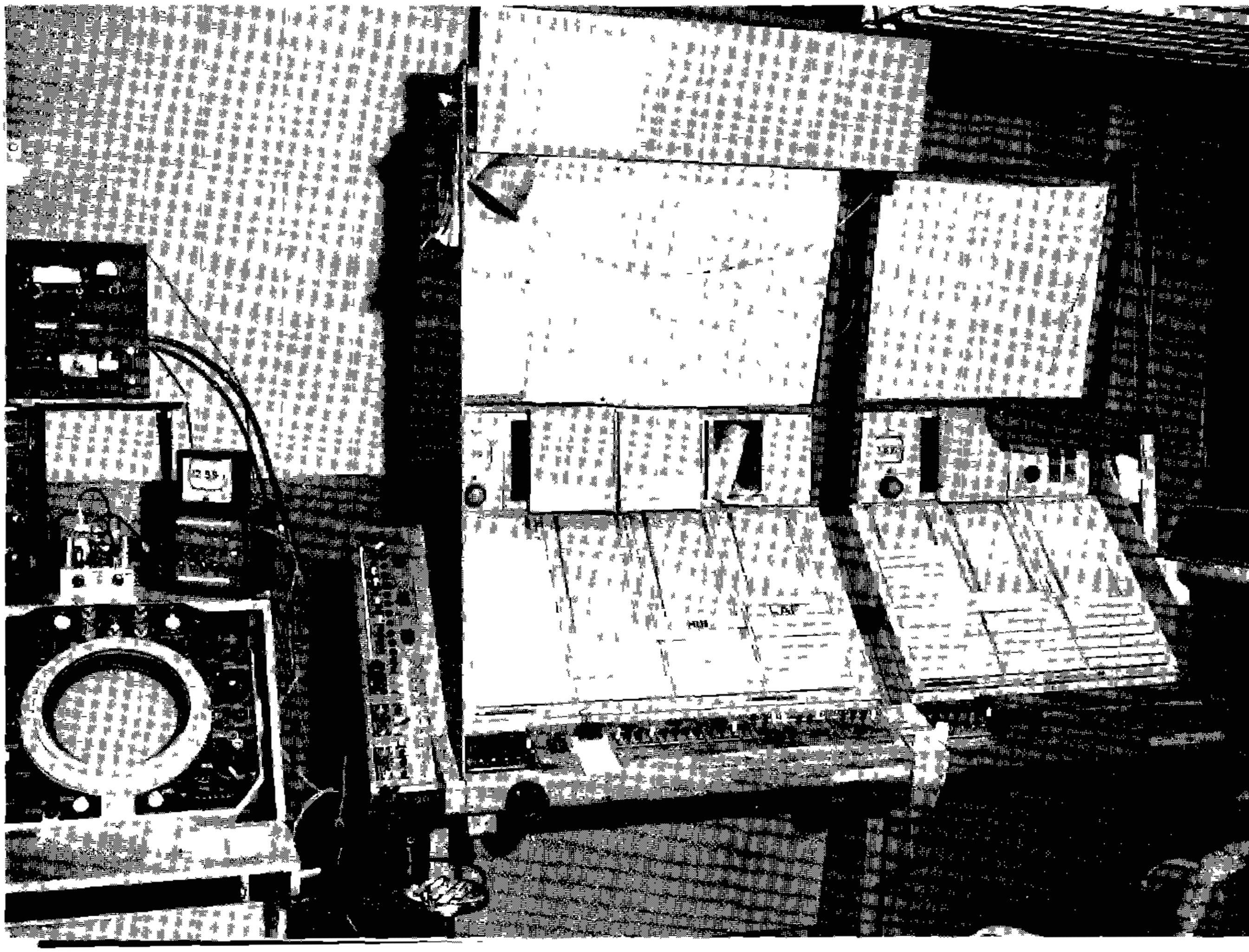
KELVIN AND HUGHES PHOTOGRAPHIC PROJECTION UNIT



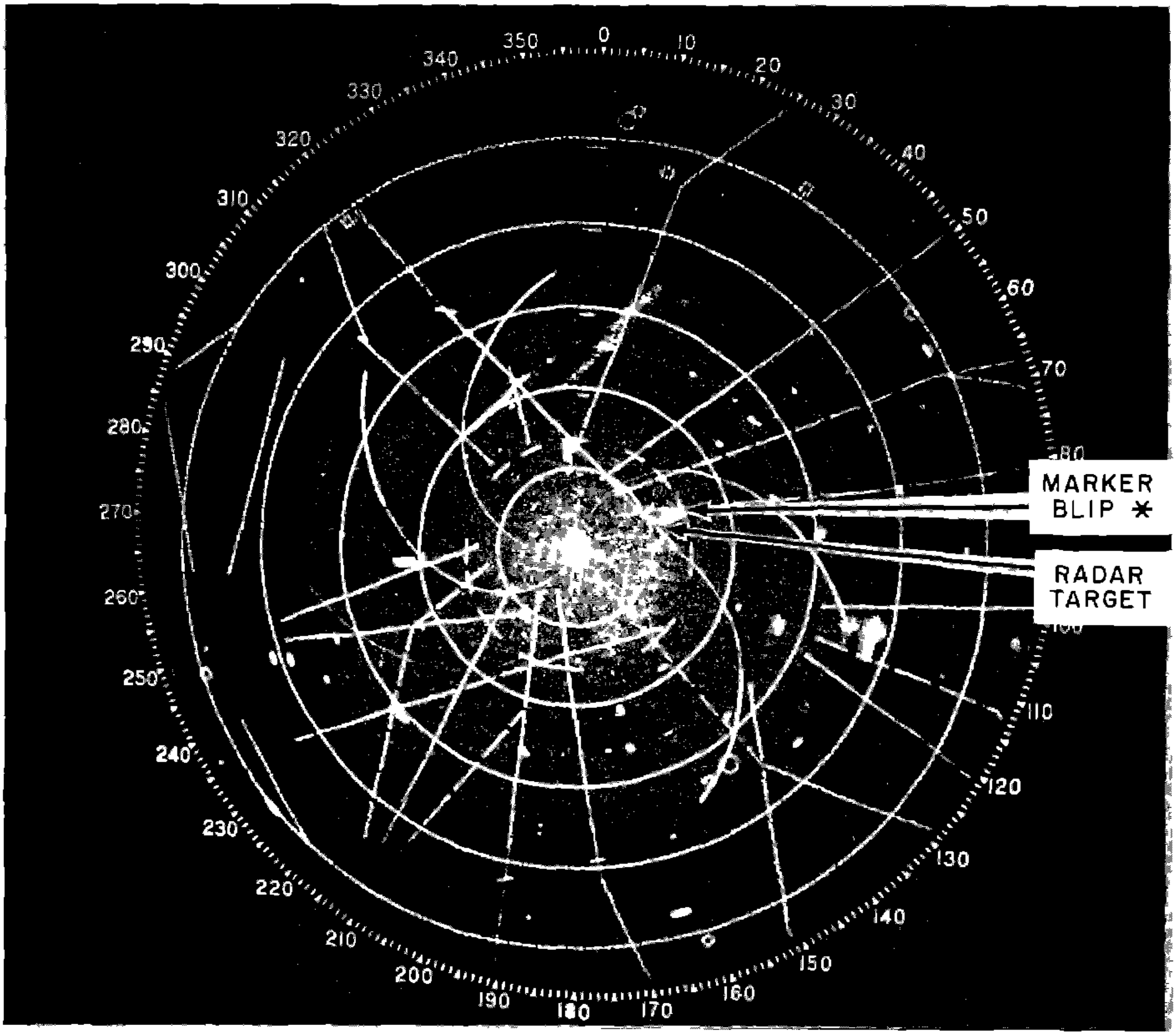
KELVIN AND HUGHES DISPLAY ON PANORAMIC BOARD

NOTES

PICTURE DISPLAYED FROM POSITIVE FILM



OPERATING EQUIPMENT, ARTC DECENTRALIZED SECTOR, ROCKVILLE, INDIANA

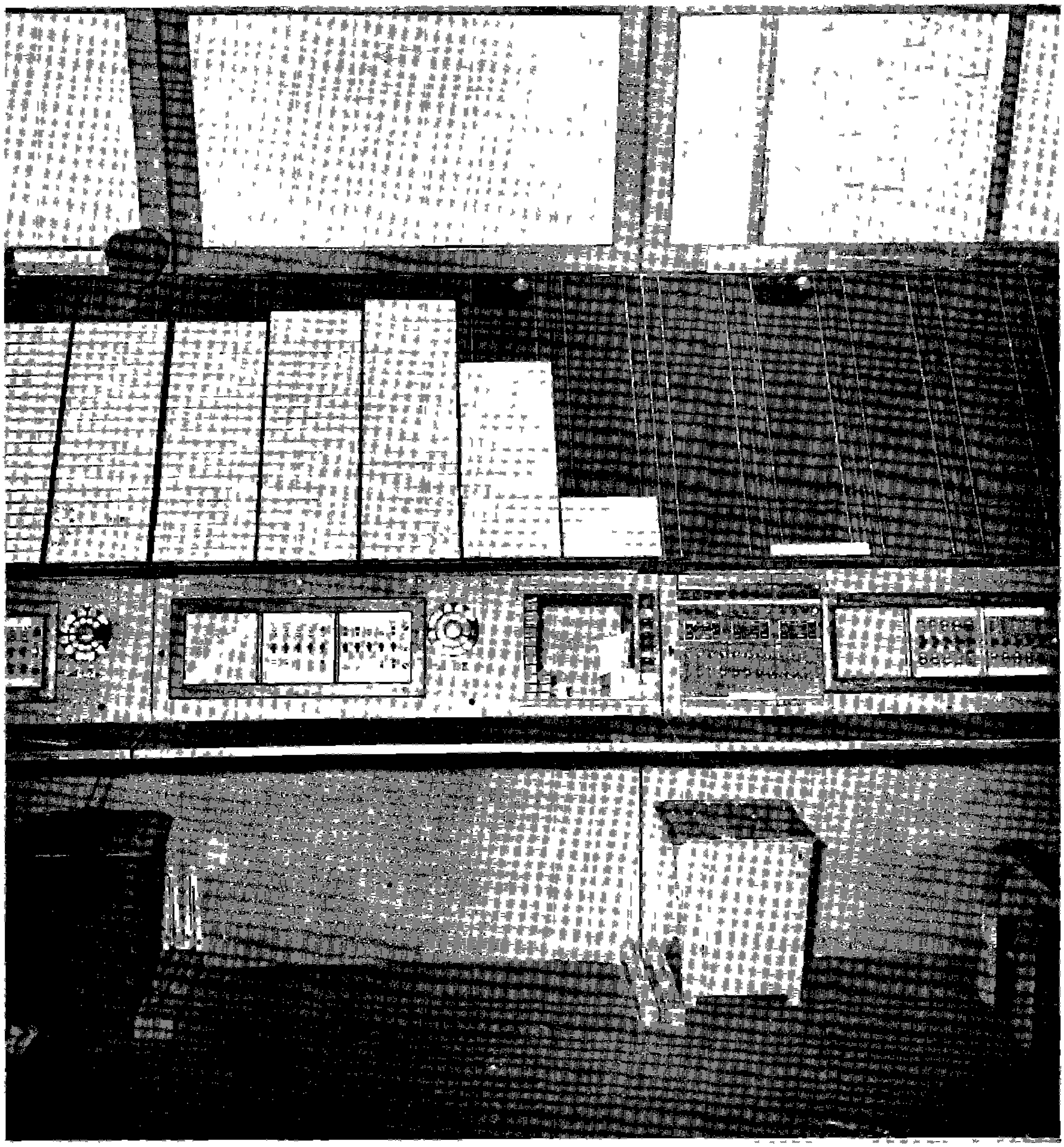


TIME–SHARING RADAR DISPLAY ON UPA–35 INDICATOR

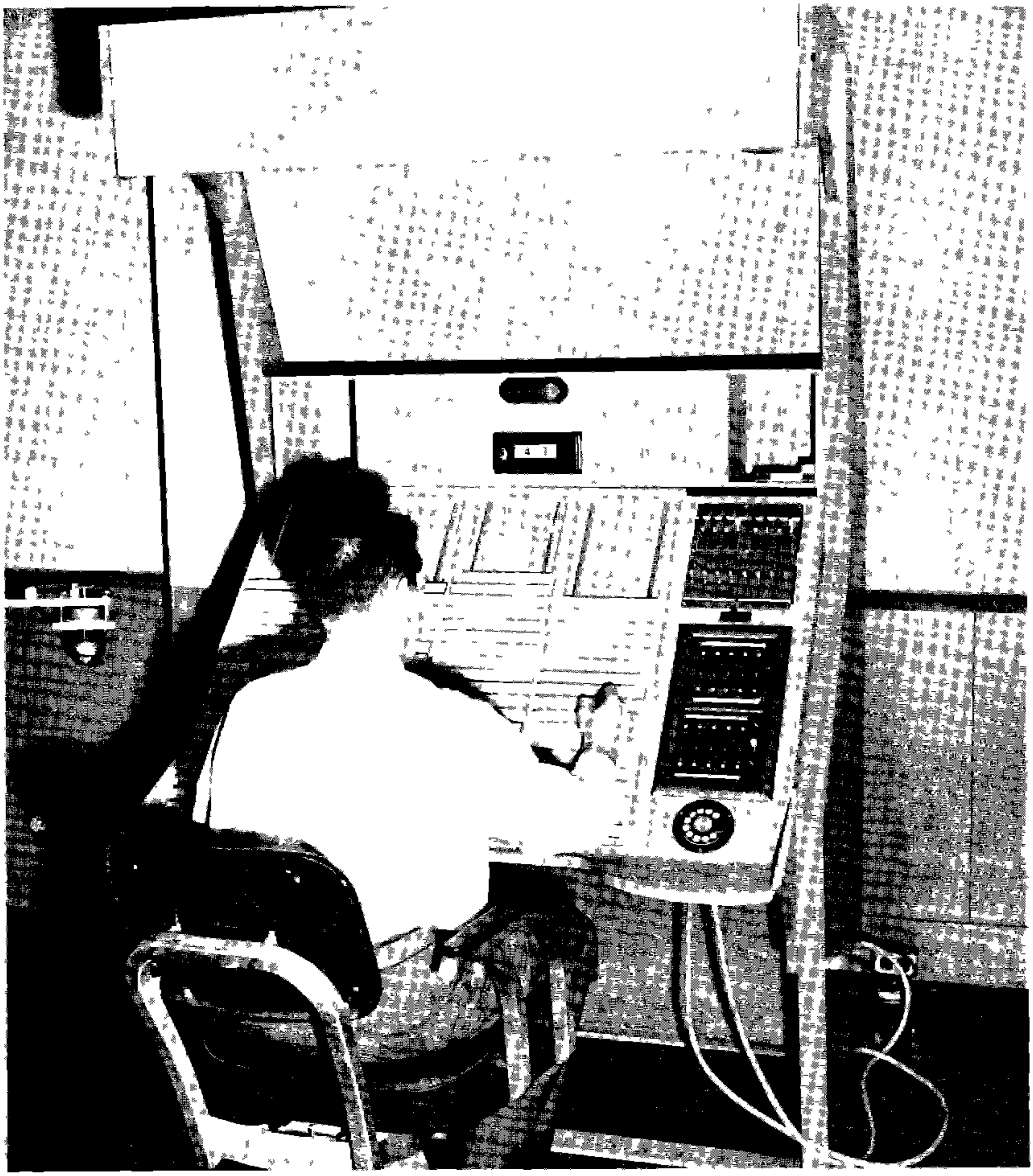
NOTES

ARSR–1 AND ASR–2 RADAR INFORMATION DISPLAYED

* – A MARKER BLIP GENERATED BY A LIGHT GUN OPERATED AT A REMOTE ASR–2 RADAR INDICATOR FOR HANDING OFF A TARGET FROM AN ASR–2 RADAR TO AN ARSR–1 RADAR



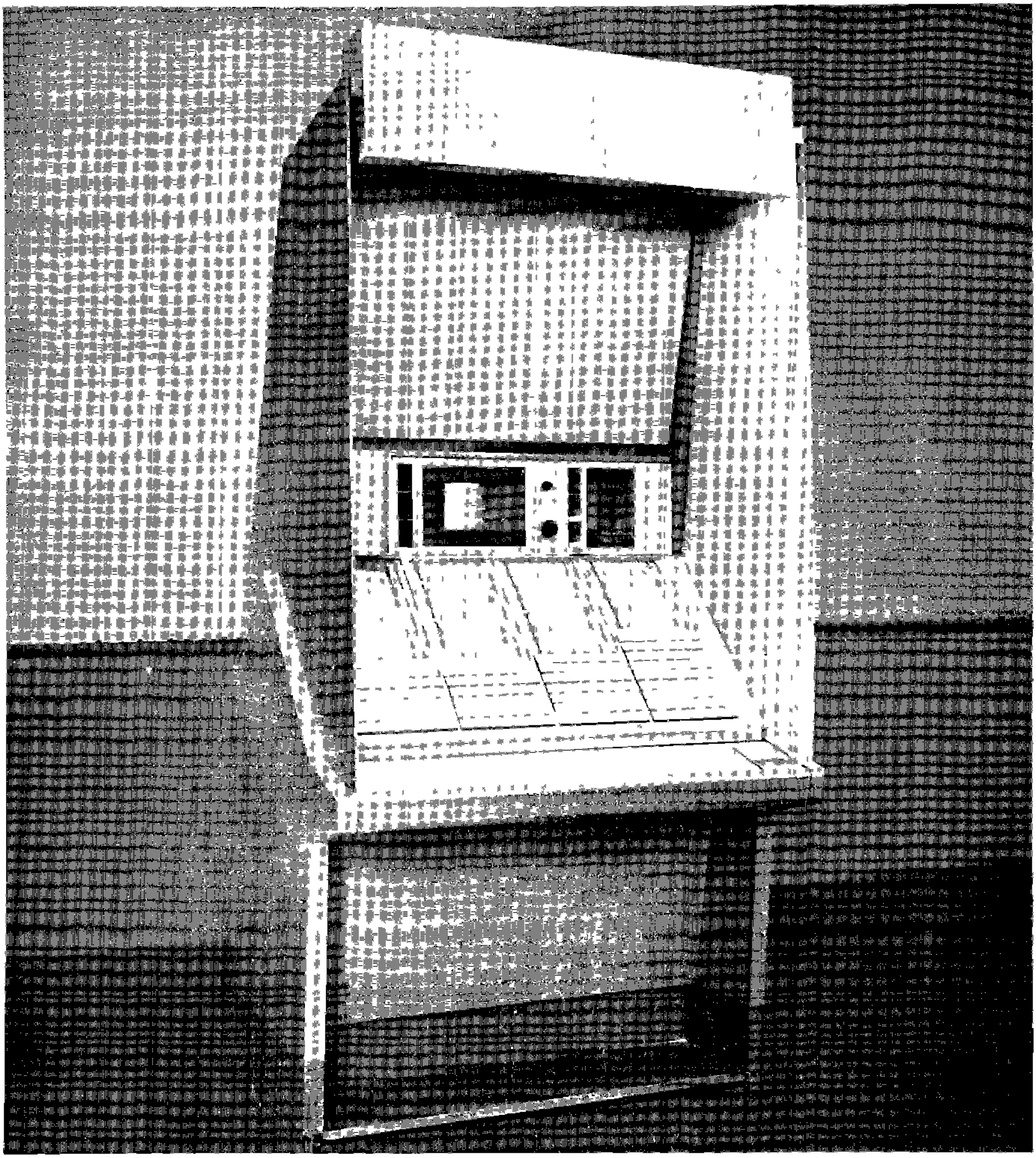
IA–I FLIGHT PROGRESS BOARD INDIANAPOLIS ARTCC



PROTOTYPE FLIGHT PROGRESS BOARD

NOTES

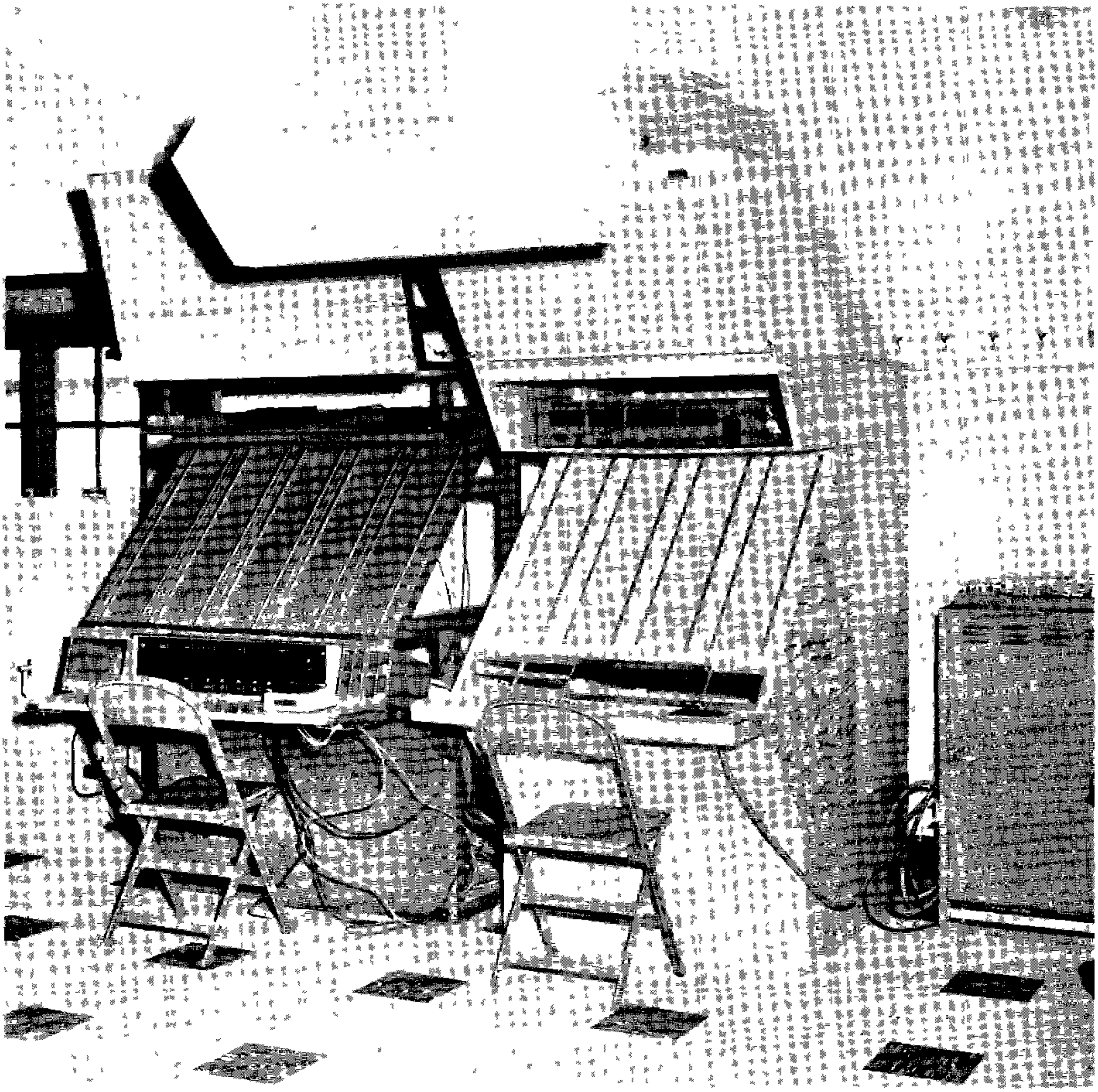
BUILT AT TECHNICAL DEVELOPMENT CENTER AND USED IN THE INDIANAPOLIS ARTC CENTER



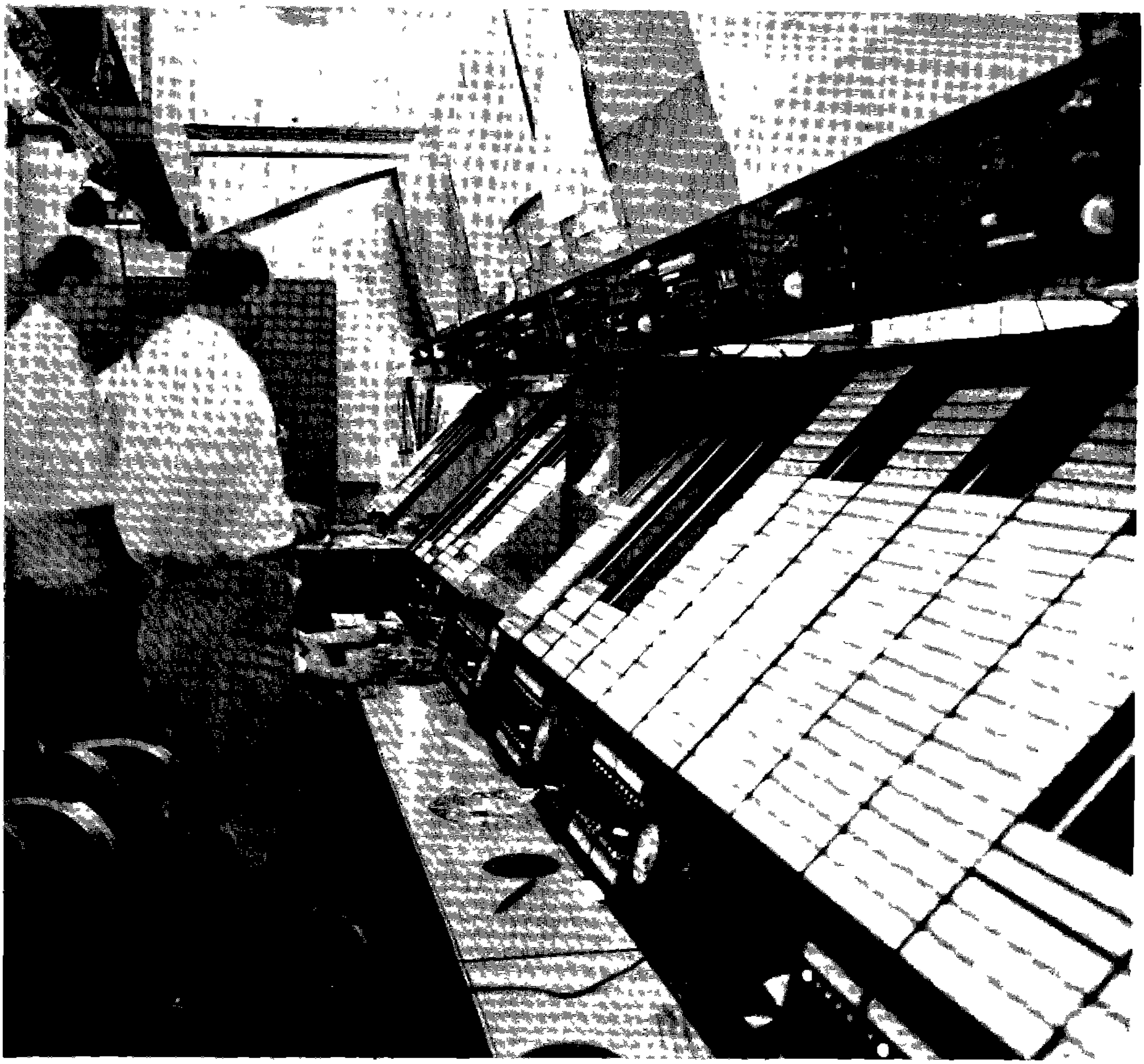
BELL LABORATORY (DREYFUS DESIGNED) FLIGHT PROGRESS BOARD

NOTE

BOARD SHOWN BEFORE COMMUNICATIONS WERE ADDED



A–3 AND MODIFIED A–3 FLIGHT PROGRESS BOARDS

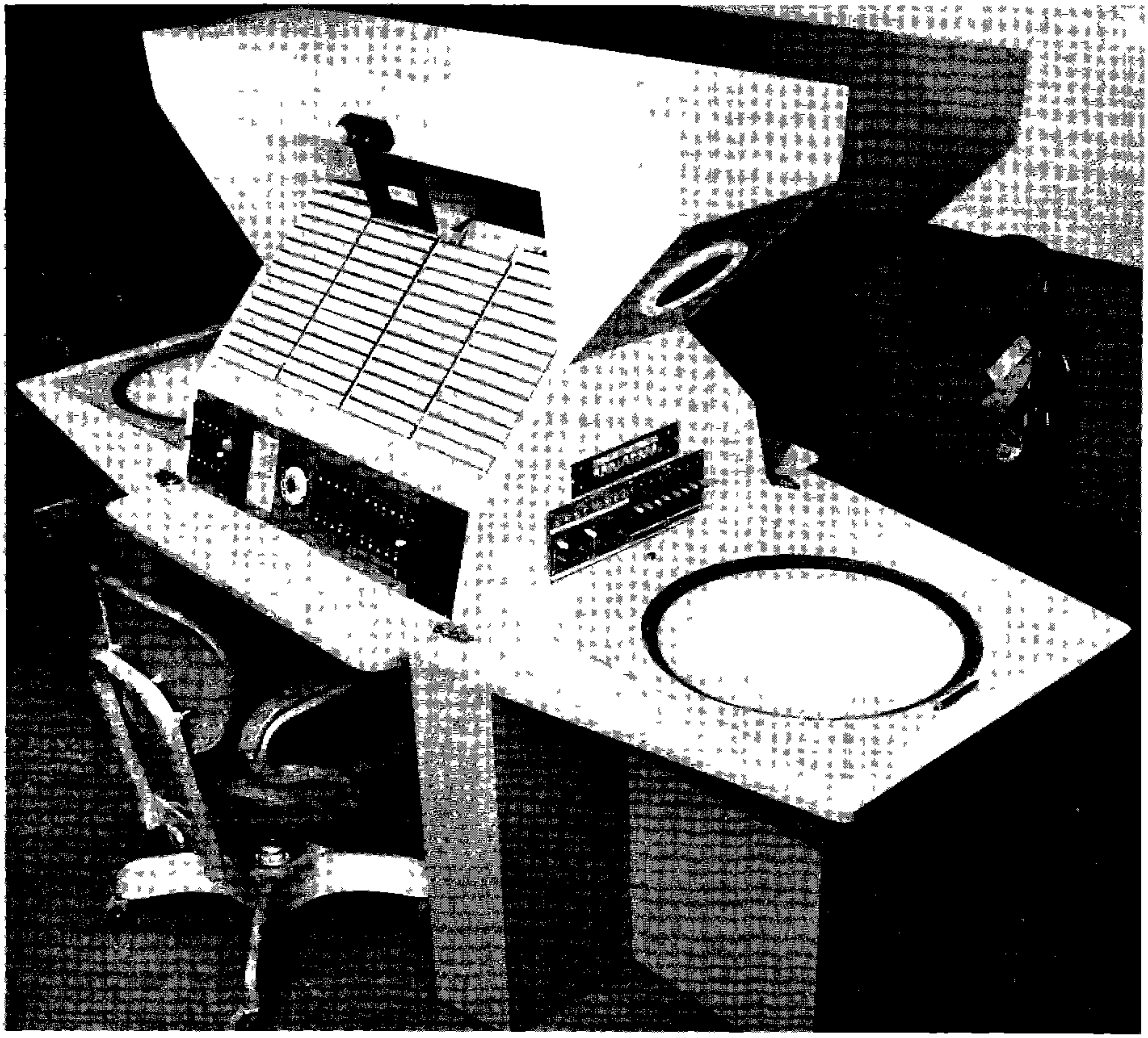


SCAN–CONVERTED RADAR DISPLAYS IN–LINE WITH A–3 BOARDS

NOTES

21 INCH VERTICAL TV MONITOR (CENTER)

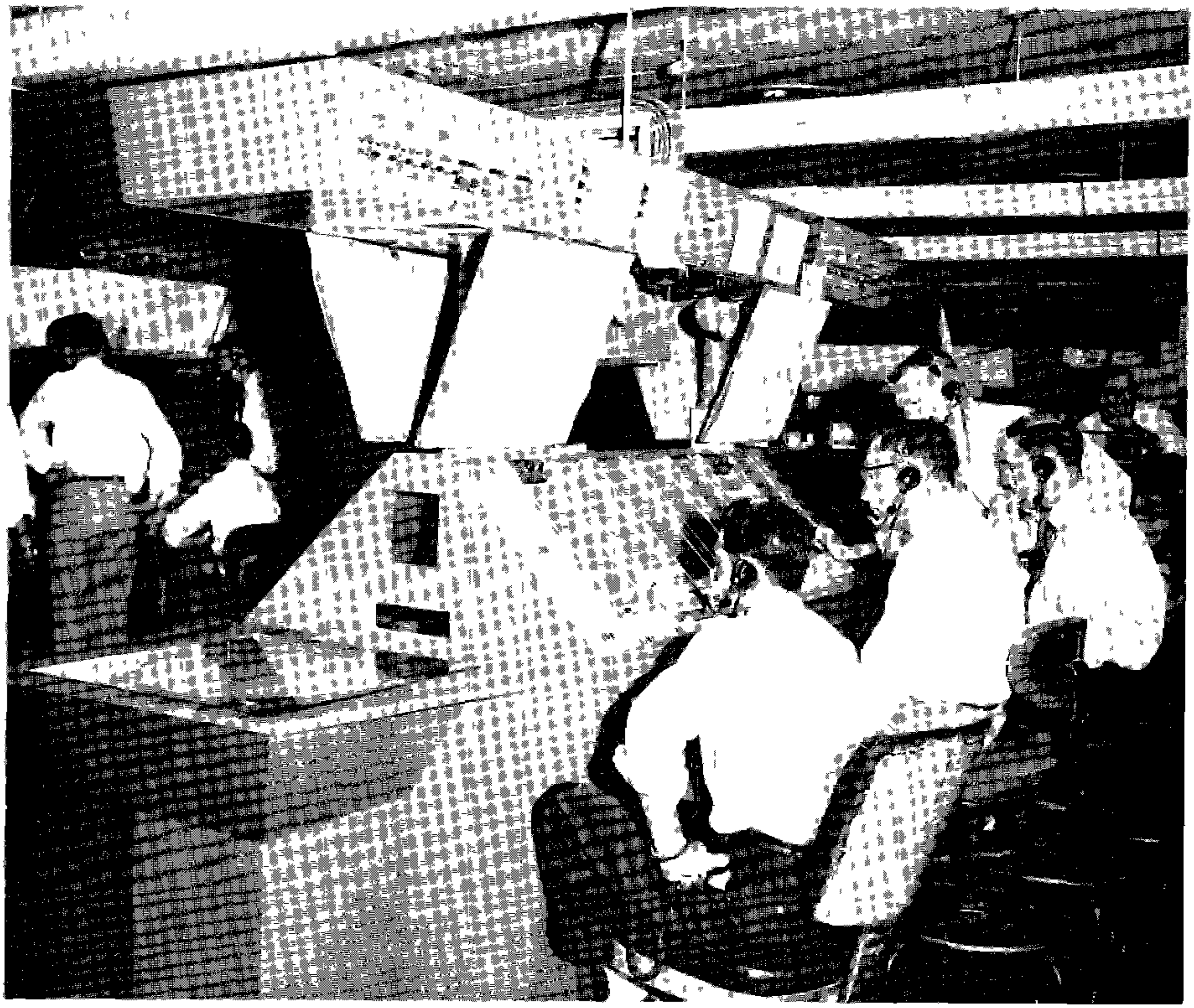
22 INCH FLAT FACE TV MONITOR (DISTANT LEFT)



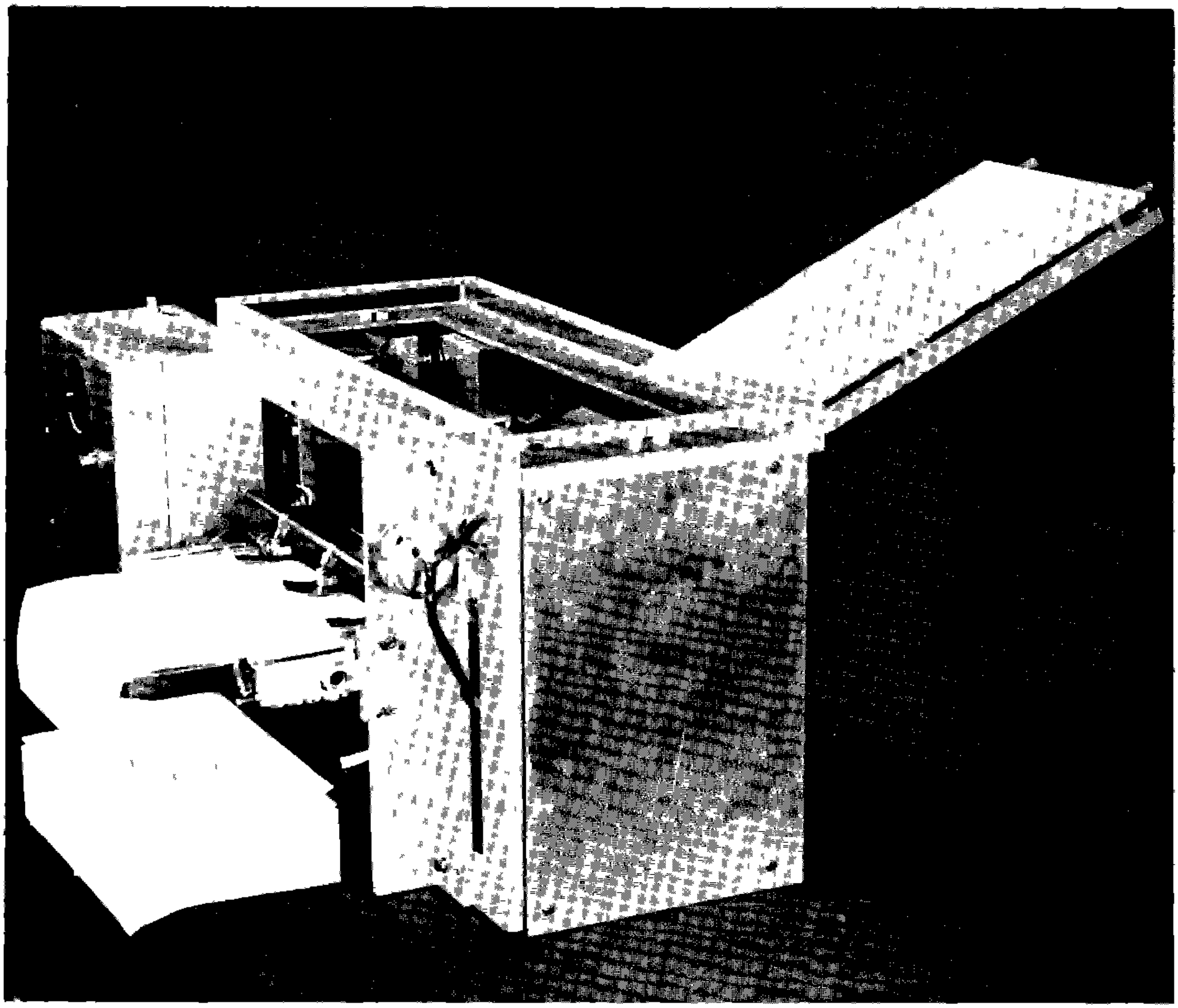
'ISLAND–TYPE' ATC DISPLAY

NOTES

'ISLAND' ARRANGEMENT FROM WASHINGTON SKETCH 24 WITH 22 INCH FLAT FACE TV DISPLAYS AT EACH END

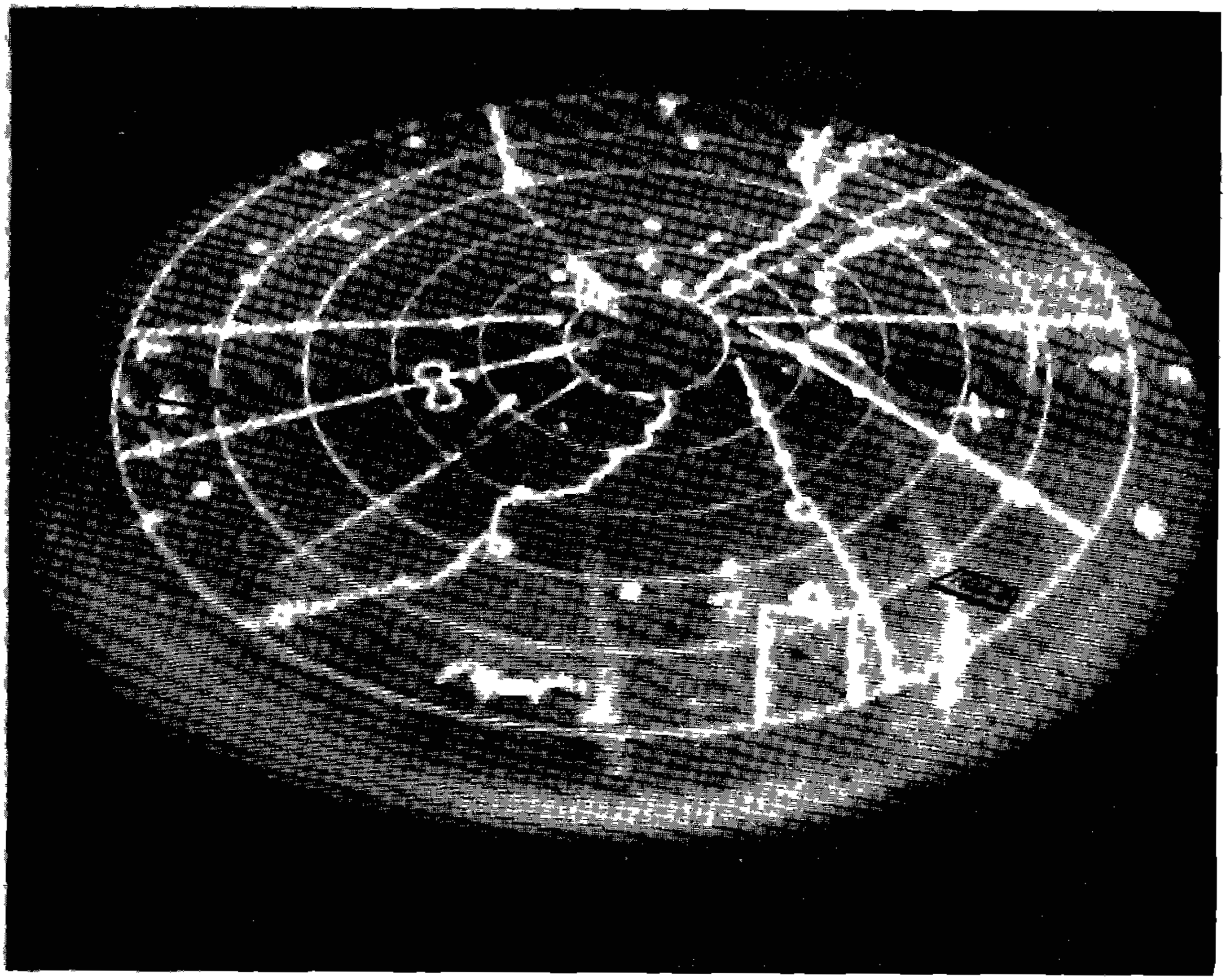


HIGH ALTITUDE CONTROL SECTOR–INDIANAPOLIS



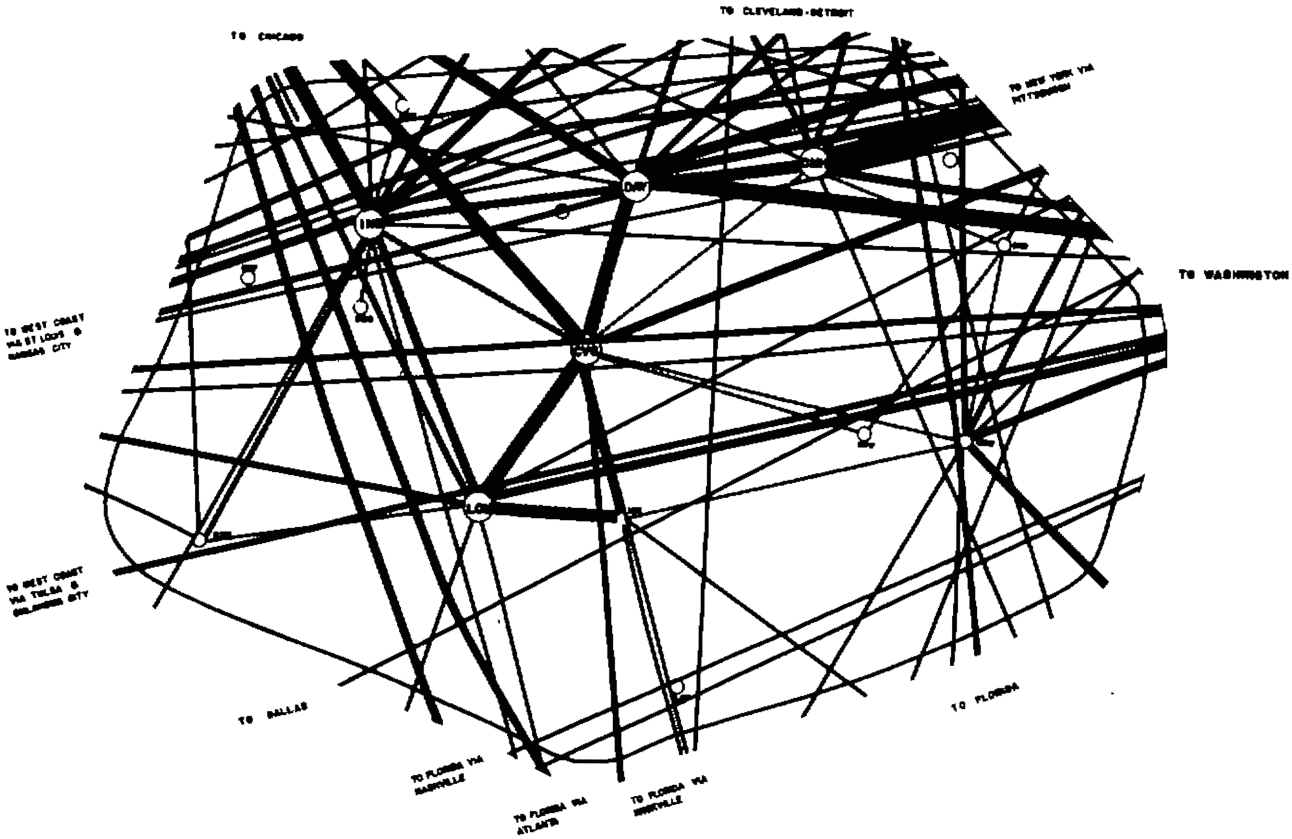
AUTOMATIC FLIGHT PROGRESS STRIP LOADER

NOTES
PAPER FEED SHOWN



PLASTIC FLIGHT MARKERS ON RADAR DISPLAY

NOTES
LETTERED WITH CHINA MARKING PENCILS



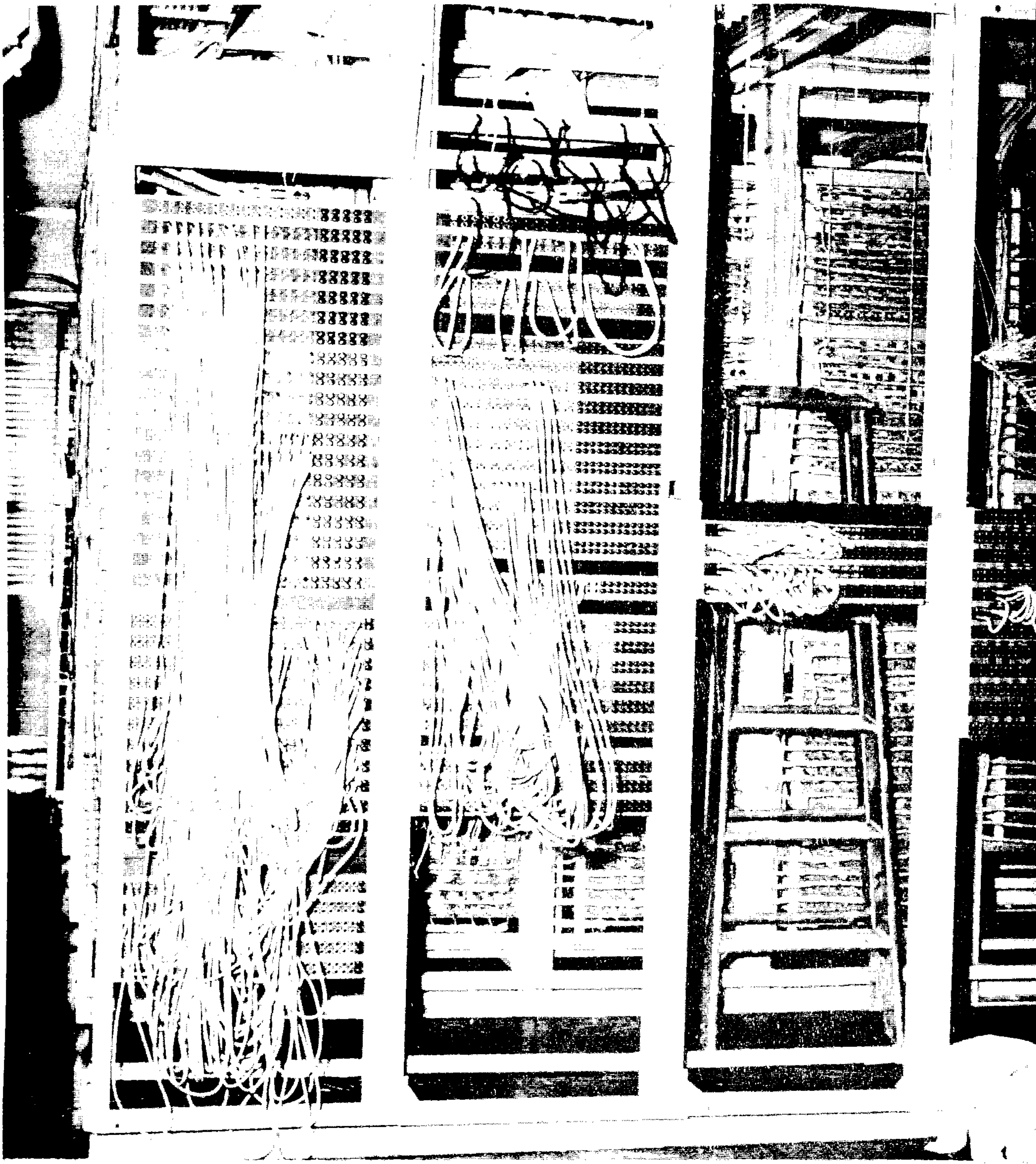
TRAFFIC VOLUME CHART INDIANAPOLIS AREA

IFR TRAFFIC VOLUME BETWEEN TERMINALS AUGUST 6, 1956 (24,000 FEET AND BELOW)

TRAFFIC FLOW DURING ONE 24 HOUR PERIOD

SOLID LINES INDICATE OVER TRAFFIC

BROKEN LINES INDICATE FLIGHTS LANDING IN THE AREA

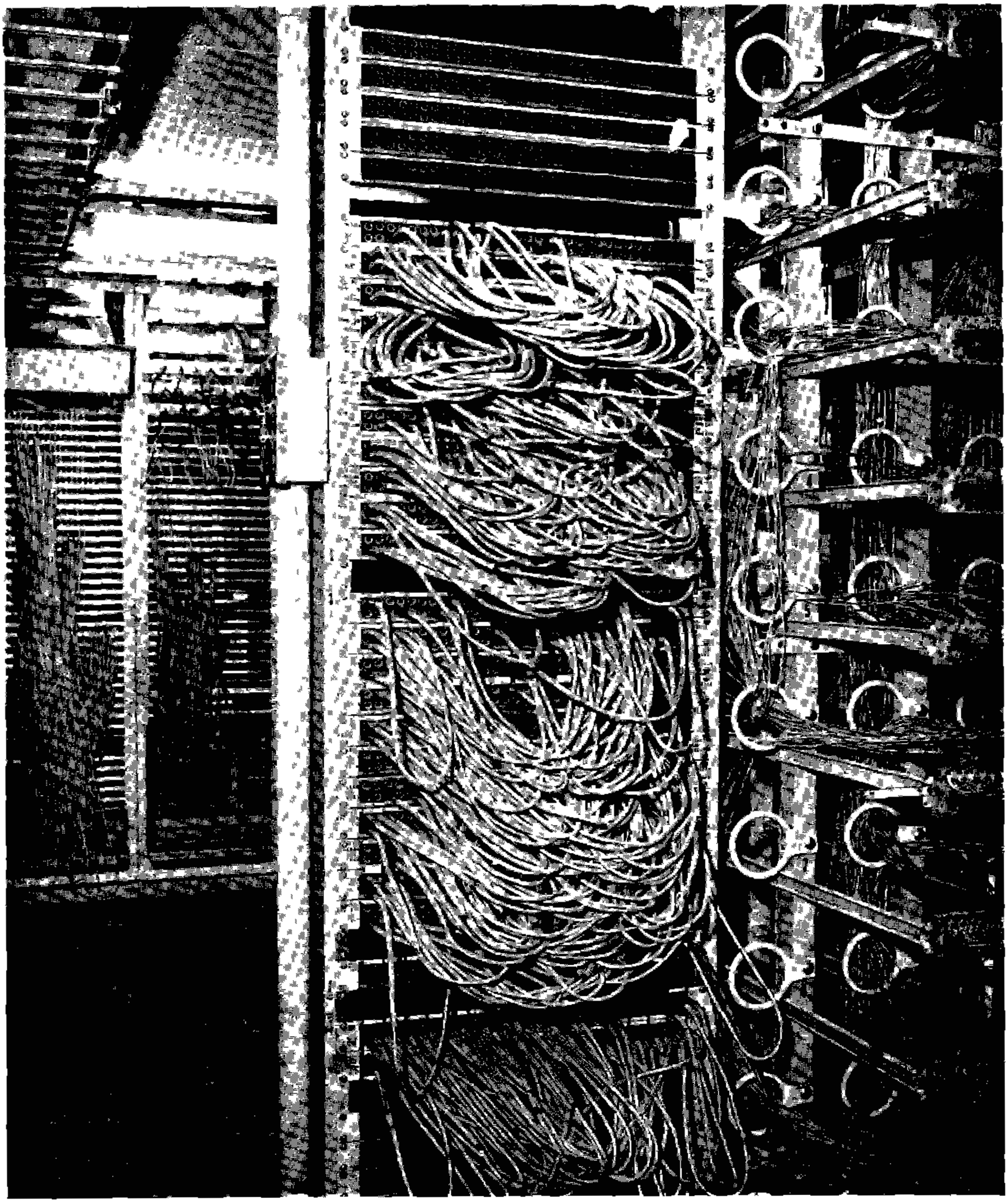


INTERPHONE PATCHING PANEL

NOTES:

LEFT PANEL – LINE TERMINATION PATCH PANEL.

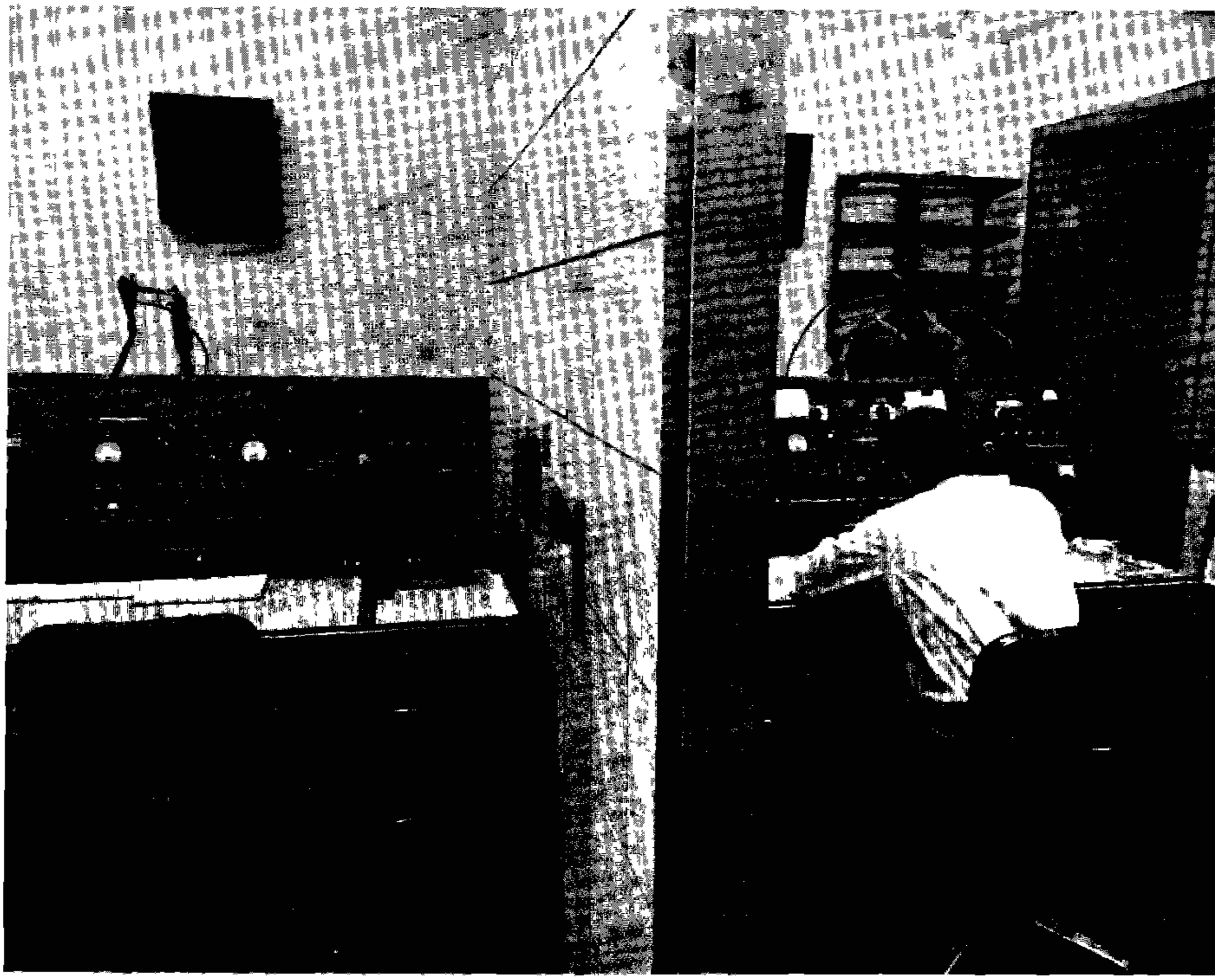
CENTER PANEL – TOP TO BOTTOM POSITION SPLITTING PATCH PANEL OVERRIDE PATCH PANEL PRIME ANSWERING PATCH PANEL



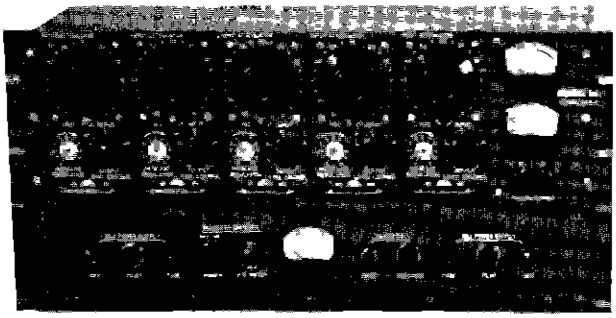
AIR/GROUND PATCHING PANEL

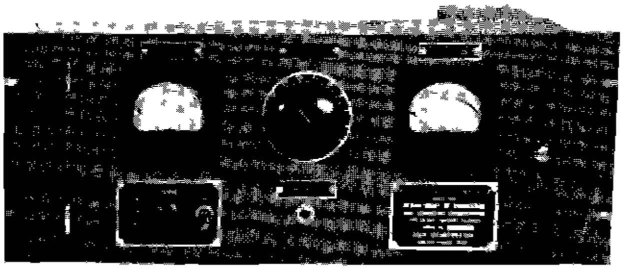
NOTES.

READING TOP TO BOTTOM-TOP PORTION-SPARES SECOND PART-TRANSMITTING PATCH PANEL
THIRD PART-RECEIVING PATCH PANEL FOURTH PART- TAPE RECORDERS PATCH PANEL



BROADCAST BOOTHS AFTER ACOUSTICAL TREATMENT INDIANAPOLIS ATCS

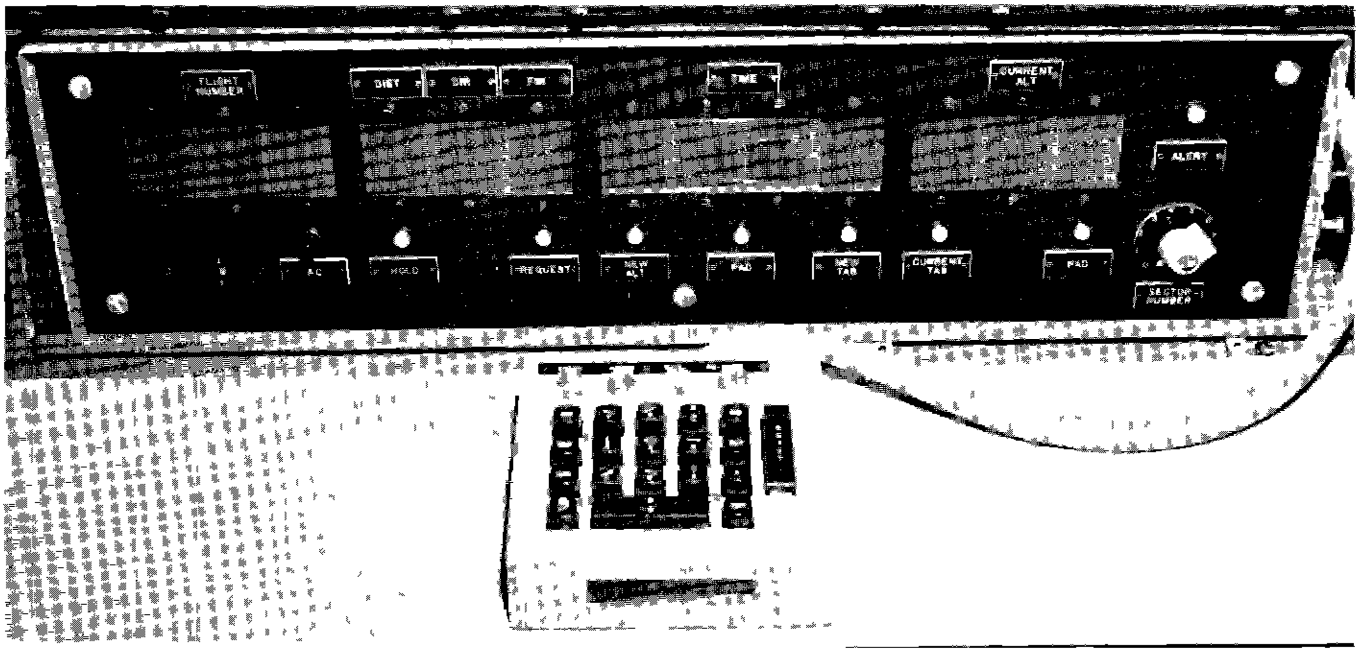




REGULATED OUTPUT AMPLIFIERS

NOTES

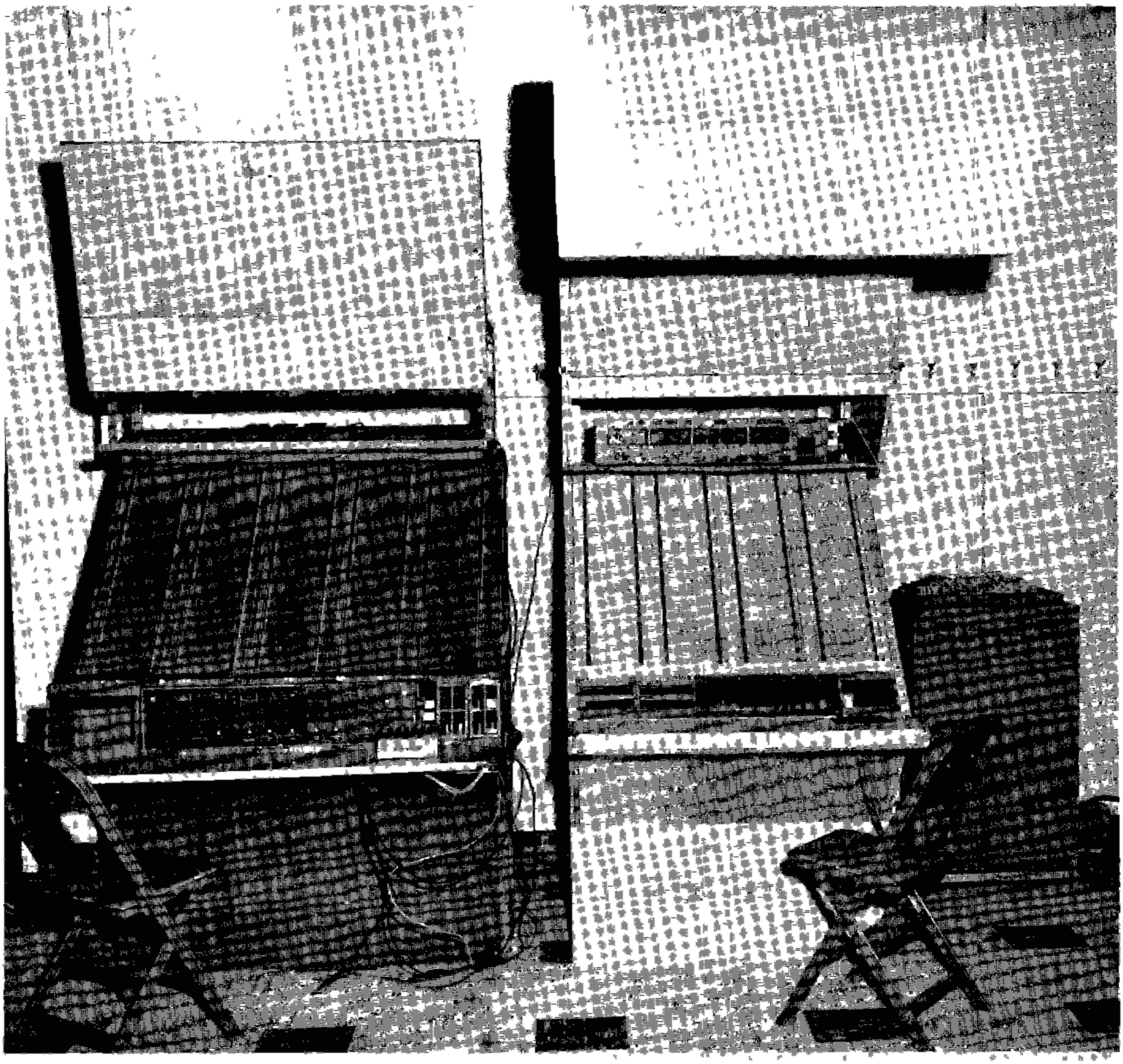
TYPE CA–1503/1529 SHOWN ON THE RIGHT PACKAGE CONTAINING FIVE MODERNIZED AMPLIFIERS ATR–1 WUTG DUAL POWER SUPPLY DIRECTLY BELOW, ON THE LEFT



PROTOTYPE CONTROLLERS INPUT DEVICE TO COMPUTERS

NOTES

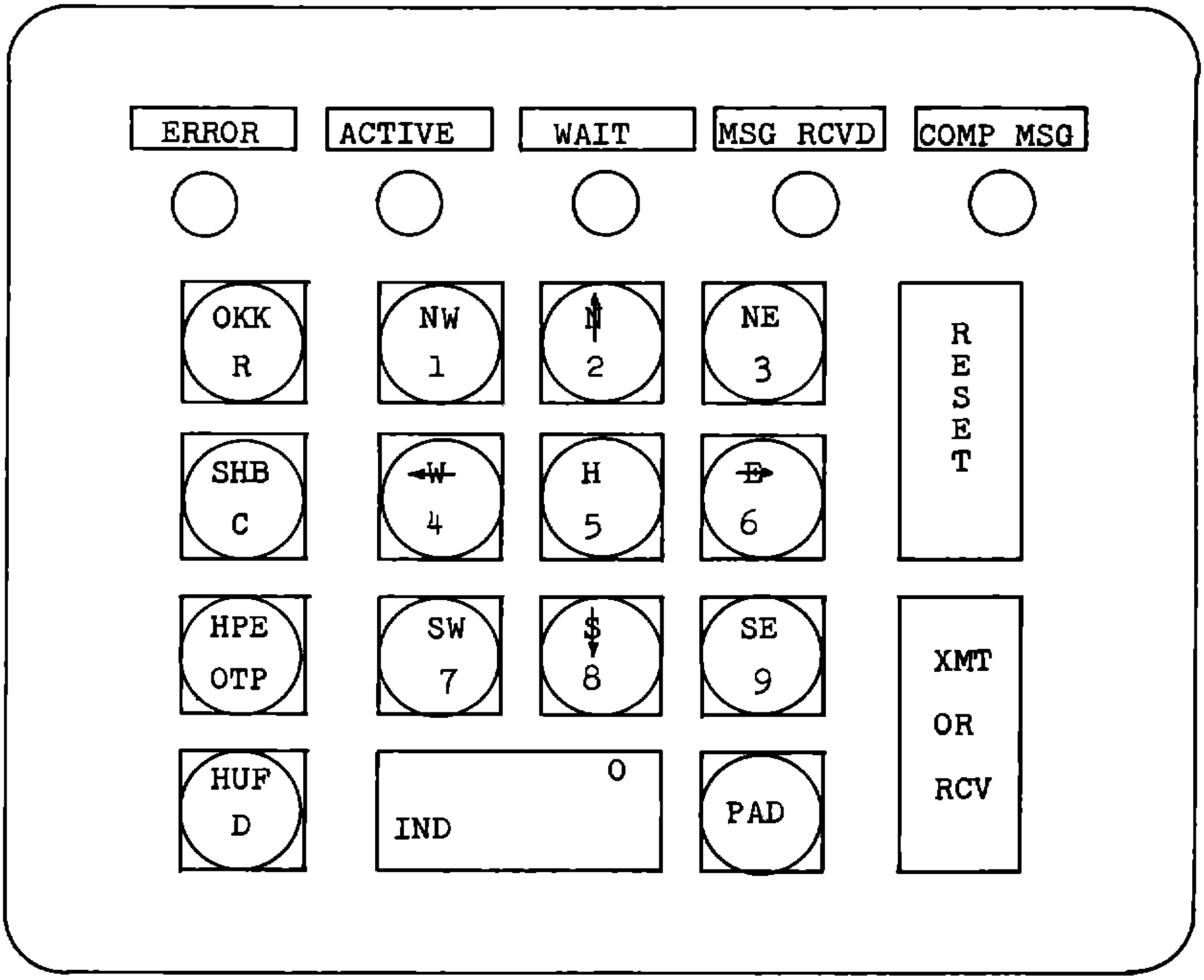
DISPLAY UNIT AND KEY PACK SHOWING THE THIRTEEN ALPHA-NUMERIC CHARACTER WINDOWS AND THE NINETEEN CODED BUTTONS



TWO CONFIGURATIONS OF CONTROLLER UPDATING EQUIPMENTS

NOTES

CONTROLLER–COMPUTER UPDATING EQUIPMENTS MOUNTED IN THE TWO CONFIGURATIONS TESTED THE CABINET ON THE RIGHT CONTAINS STEPPING SWITCHES AND RELAYS



PROPOSED KEYPACK CONFIGURATION