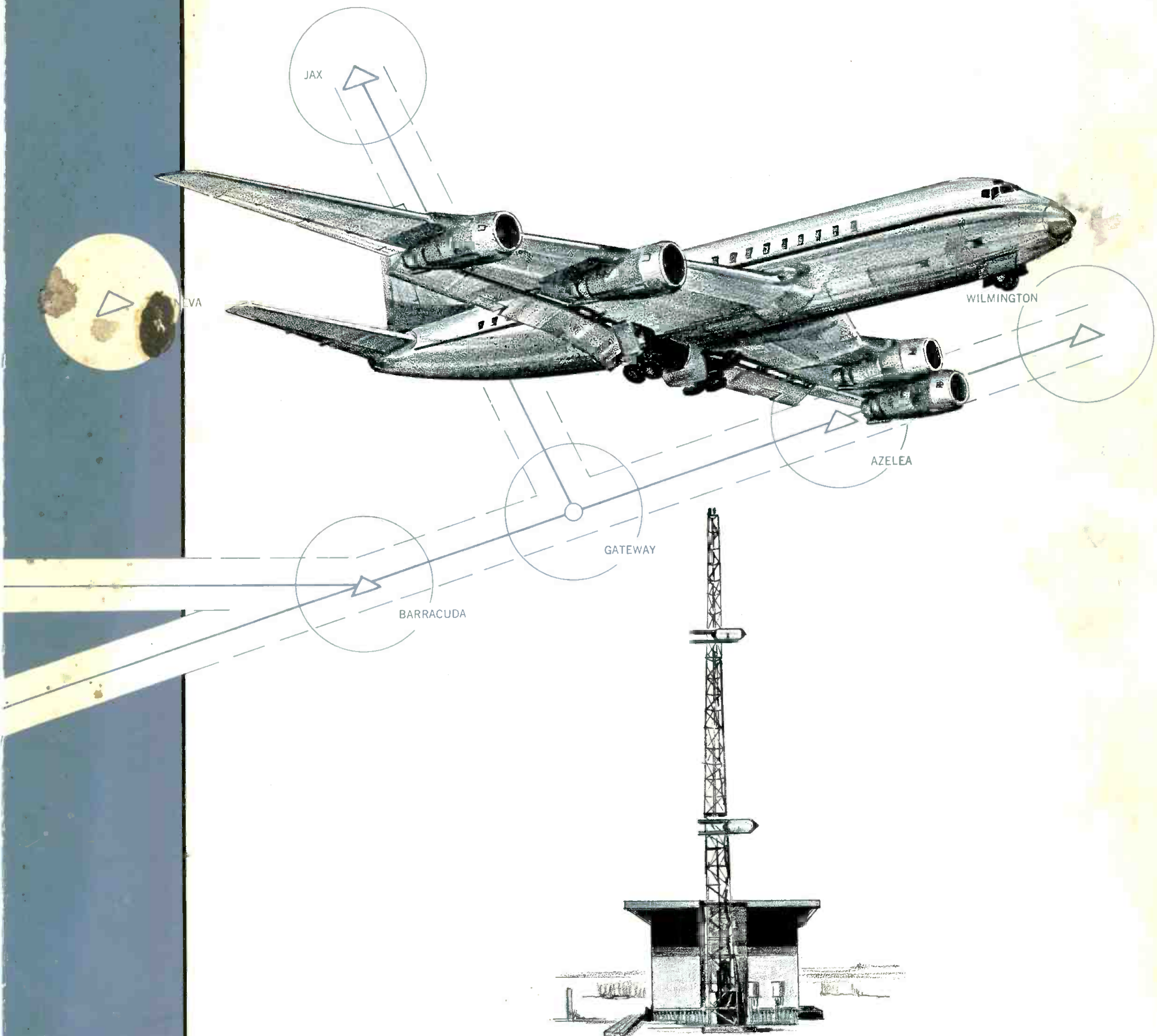
MACHLETT

CATHODE PRESS



VOL. 21 • NO. 3 • 1964

CATHODE PRESS

Vol. 21, No. 3, 1964

Published by:
The Machlett Laboratories, Inc.
An affiliate of Raytheon Co.
Springdale, Connecticut

Editor, *Richard N. Rose*

Art Director, *Edward J. Bulger*

IN THIS ISSUE

Cover:

Machlett planar triodes serve the nation's commercial airlines for air traffic control in DME and Transponder equipment.

Product Lines represented in this issue:

Small Power Tubes

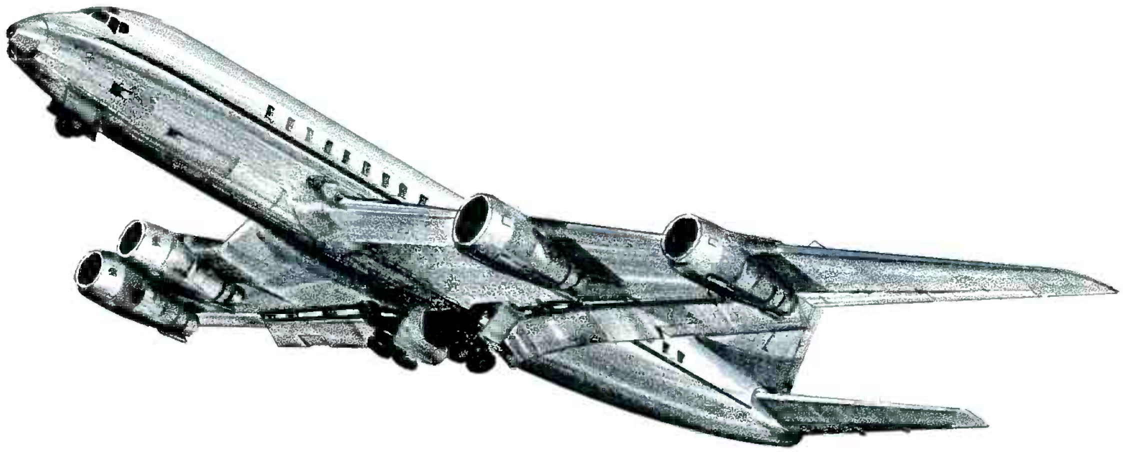
Large Power Tubes

NOVEMBER 1964

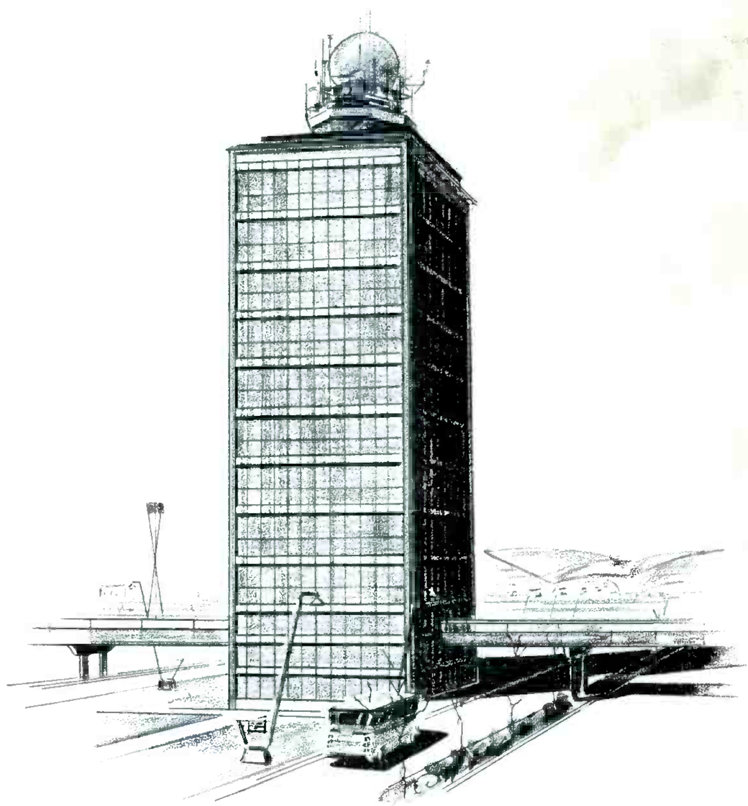
PRINTED IN U.S.A.

MACHLETT

ELECTRON TUBE SPECIALIST



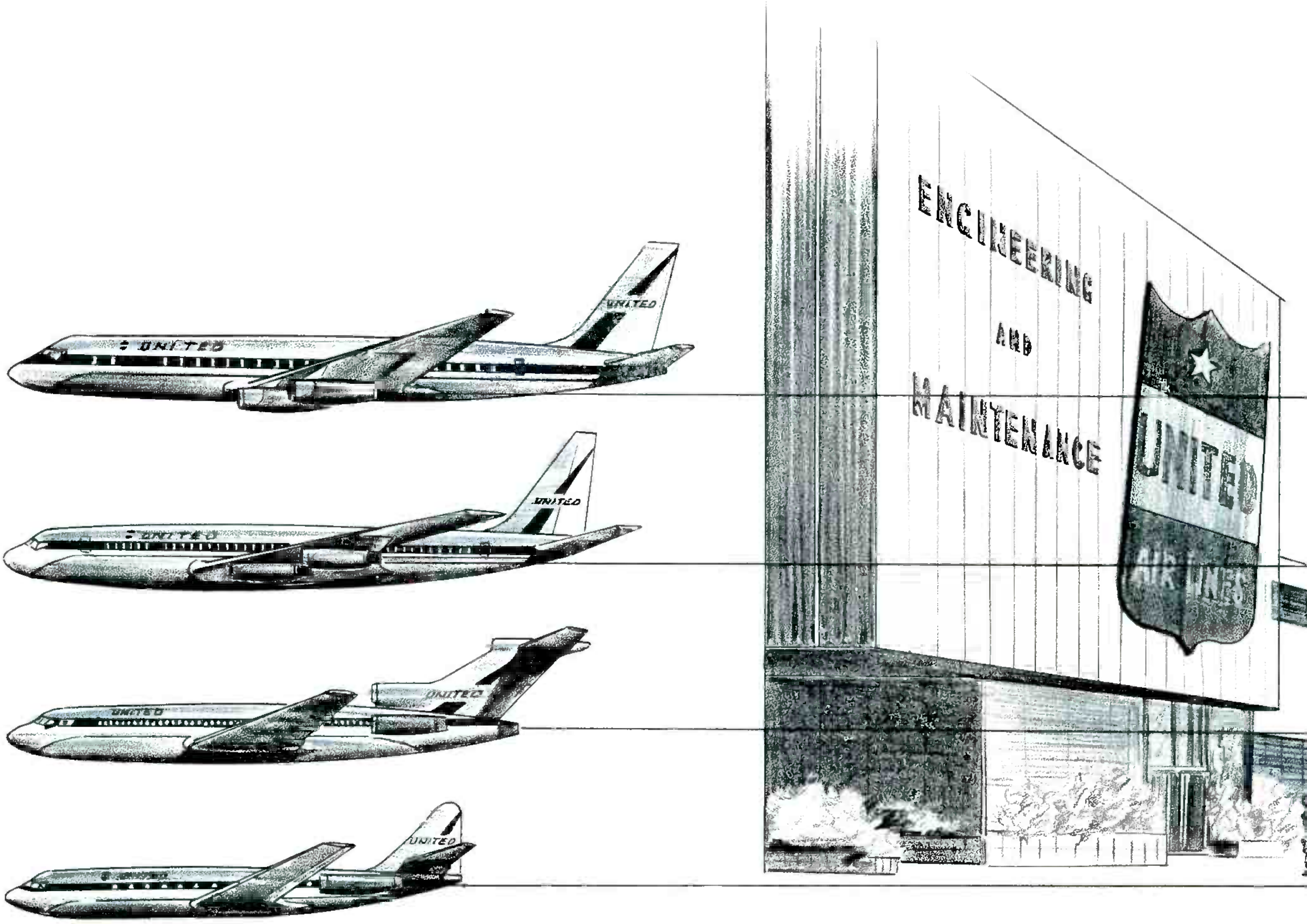
Introduction



It is quite possible that the term "maintenance" with its implications of repair, malfunction and after-hours drudgery should be re-coined so as to acknowledge the new scope of function included within the concept. "Maintenance", today, in the aviation industry is a unique, specialized and continuing production line — one generating its own statistics and response on a continuous input-output basis. It is a field calling for the best productive imagination to be found. The following pages of CATHODE PRESS indicate the discipline, the complexity and the range of this large, relatively unknown (to the public), but intensely active and important group.

All phases of electronic maintenance relating to the DME and Transponder — the general view, the base depot, the line or field shop, as well as indications of the future — are examined in this issue, Volume 21, Number 3. In addition, CATHODE PRESS takes a short and rather special flight to indicate one reason why the maintained equipment (which, incidentally, uses Machlett planar triodes) is around in the first place.

CATHODE PRESS, Volume 21, Number 2, was privileged to discuss the manufacturers' view of the DME and Transponder.



Historical Background
ATC Transponder

United Air Lines' contacts with the ATC Transponder system began prior to 1955 with participation in industry meetings to define the performance, size and interwiring characteristics of the forthcoming equipment. As equipment built to meet these requirements became available in 1957, United's Engineering personnel carried out a bench test program with several manufacturers' transponder units, in connection with plans to install transponder systems in piston aircraft. The transponder system at that time, was considerably simpler in concept than is presently the case, providing only one interrogation mode instead of 4, 64 reply codes instead of 4096, and with no requirements for sidelobe suppression or automatic selective reply features. During 1957, however, the system requirements were broadened to include four interrogation modes, two-pulse sidelobe suppression, and expansion capabilities from 64 to 4096 reply codes. Consequently, plans for fleet implementation were postponed pending development of equipment with these features. To acquire operational and maintenance experience, however, four RCA AVQ-60A and 4 Collins 621A-1 Transponders were purchased and operated in DC-7 aircraft through late 1957, 1958 and early 1959.

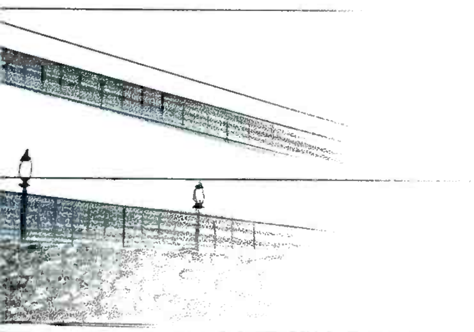
The operation and maintenance of these units prior to availability of special test equipment for the transponder system, required us to develop our own techniques and facilities for maintenance. The system knowledge acquired proved very valuable in subsequent operations.

In 1959, United began fleet operation of Collins 621A-2 Transponders. A total of 95 of these units were procured for use in DC-8 and B-720 jets. In 1960 and 1961, United ordered 118 RCA AVQ-60B Transponders to cover needs for Caravelle aircraft and additional B-720 aircraft ordered, and for Viscount aircraft acquired through merger with Capital Airlines. Between procurement of the Collins and RCA Transponders, another system concept changed — 2-pulse sidelobe suppression requirements were replaced for United States operations with a new system using three interrogation pulses. RCA units were procured with the 3-pulse system, and modification of the Collins units was planned for a later time. In 1962 still another change in system requirements occurred; automatic selective reply requirements were added for Modes C and D to provide for automatic altitude reporting and for another unspecified automatic data link. In 1963, after reviewing our needs, orders were placed for 369 Collins 621A-3 units to provide for dual transponder systems in our B-727 and DC-8F aircraft; retrofit of a second system in DC-8, B-720 and Caravelle aircraft; for retirement of our 621A-2 units because of the system changes since their procurement; and, installa-

A General View of an Airline's Use of DME Transponder Equipment

Editor's Note:
United Air Lines operates the world's largest jet fleet and is the nation's largest domestic carrier. It now operates 139 jet aircraft, with 27 more Boeing 727s on order. United also operates 94 piston aircraft. This fleet serves 116 cities. In 1963 United carried 13,717,000 passengers and 133,459,000 ton-miles of freight.

CATHODE PRESS acknowledges with thanks the assistance given it by the Aircraft Engineering Department of United Airlines and, in particular, Mr. T. A. Ellison, Staff Engineer.



tion of a single transponder system in all piston aircraft (delayed since 1957 by the successive system changes). This order is now being received, and when complete, will make United Air Lines operator of more transponder equipment than any other civilian user. A modification program to add automatic altitude reporting to our AVQ-60 units is also in progress.

DME: Distance Measuring Equipment

As in the transponder system, United participated in industry activities to develop defining specifications prior to the existence of any civil DME equipment. During 1959 and 1960, DME system developments were closely monitored through bench and flight tests and demonstrations. All jet aircraft were ordered with complete aircraft wiring provisions for DME, and in 1960, modification projects to install DME wiring provisions in all piston aircraft began. In the Spring of 1961, it was decided that system developments justified activation of a single DME system in all jet aircraft, and orders were placed for Collins 860E-1 DME units for this purpose. These were delivered in the Fall of 1961, and the installation was completed in November 1961. Additional 860E-1 DME equipment was procured for a single system in Viscount aircraft early in 1962, for a total procurement of 235 860E-1 units. Further DME unit procurement was deferred, pending developments of solid state equipment. In 1963, orders were placed for 275 Collins 860E-2 units to be used for installation of single DME systems in all piston aircraft, for provision of dual systems in B-727 and DC-8F aircraft, and for addition of a dual system in all DC-8, B-720 and Caravelle aircraft. These installations are in progress at present, and will be complete in mid-1964, giving United Air Lines the largest DME equipped civil aircraft fleet in the world.

Maintenance Practices
Equipment Removal

Let's consider first the typical failure which begins the maintenance process. In the case of the ATC Transponder, the flight crew will probably be notified by radio from the ground Air Traffic Control Center that the transponder reply is missing or intermittent. In the case of the DME, the flight crew will probably observe that the flag on the DME indicator has dropped and the indicator is searching rather than displaying a mileage in an area where DME coverage should exist. Checks of the system and of the ground station will be made by the crew to verify that a failure has actually occurred. Although equipment failure is a daily business for the maintenance shop supporting a large fleet of DME or Transponder equipment, the failure is a rather infrequent occurrence for the individual flight crew member. Nine or ten months will have elapsed since the last Transponder

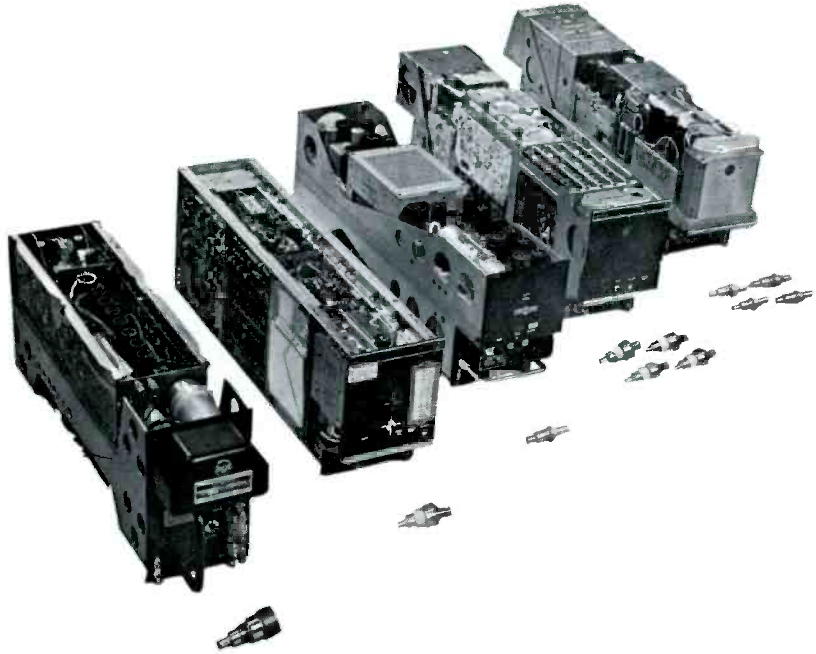
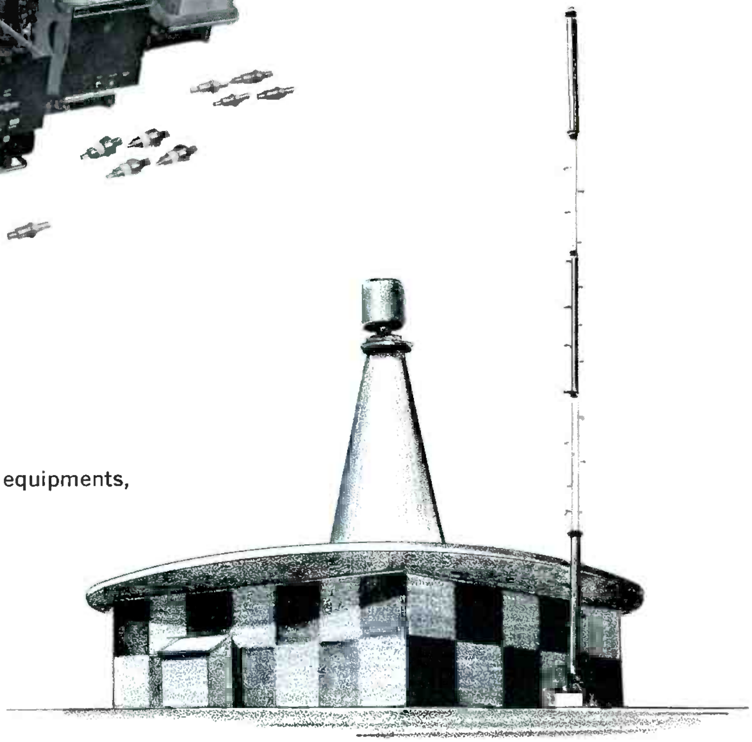


Figure 1 — United Airlines DME and Transponder equipments, shown with Machlett planar triodes used.



failure he experienced; five or six months since the last DME system failure on the average. Because of the protection of back-up systems or procedures, little or no alteration of the flight plan results. However, by radio, United's Line Maintenance coordinators and the FAA's Air Traffic Control Center are advised that the failure has occurred. In addition, a description of the failure is entered in the aircraft's flight log.

On arrival at the next Line Maintenance facility, a radio and electric system specialist will isolate the trouble and correct it, if appropriate, by replacing removable system components and routing them to the Overhaul Shop for repair. To assist him, he has available special ground test equipment and manuals covering the aircraft systems and their maintenance in detail.*

Radio Maintenance Shops

United operates five shops for the maintenance of radio and electronic equipment. The largest of these is located at our San Francisco Overhaul and Maintenance Base. Here a staff of 120 people in the Radio and Electronic Shops overhaul more than 400 different types of electronic assemblies or components, ranging from very simple devices to extremely complex radar or autopilot equipment. All types of electronic equipment operated by UAL can be overhauled at our San Francisco shops with the exception of equipment operated only in Viscount aircraft. The San Francisco Radio Shop occupies an area of approximately 10,000 square feet and has an investment of approximately $400,000 in specialized test equipment for check-out and operation of the components overhauled. Electrical and instrument components are not overhauled by the Radio Shop. These are handled in other shop areas, each roughly comparable in size to the Radio Shop.

Electroplating shops, sheet metal shops and machine shops are also available at United's San Francisco Base to support the radio shop (and others) in major repairs or modifications.

Viscount radio and electronic equipment is handled by a shop at United's Viscount Overhaul Base at the Washington National Airport. This shop employs approximately 35 people and deals in the same scope with Viscount equipment as does the San Francisco Shop with our other aircraft equipment.

United also maintains shops for maintenance of radio

*See page 18 for a detailed review of maintenance shop procedure.

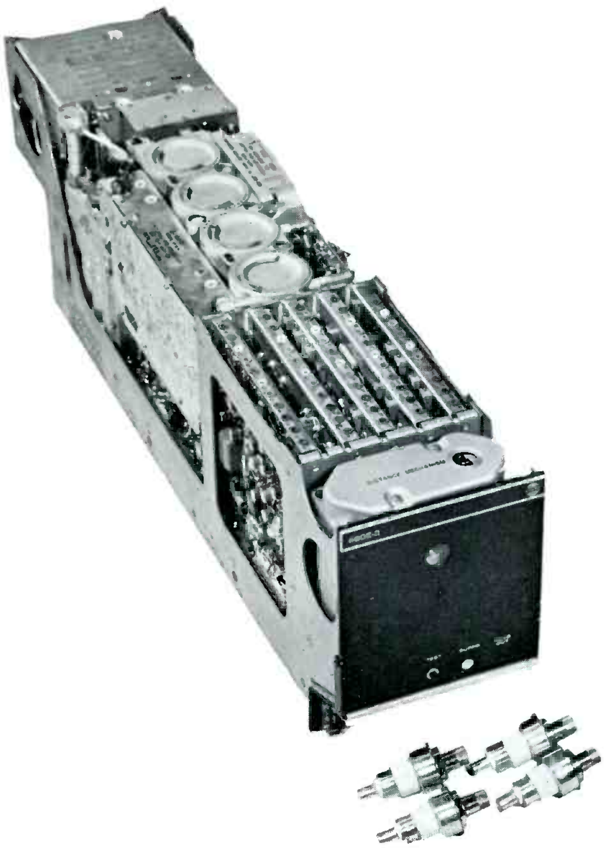


Figure 2 — Collins 860E—2 DME shown with ML-7815 planar triodes.

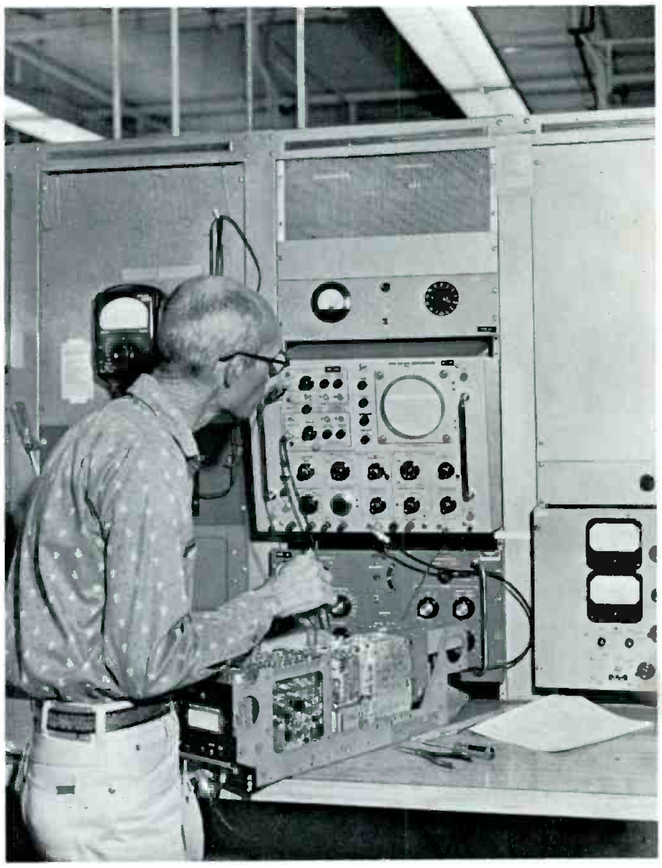


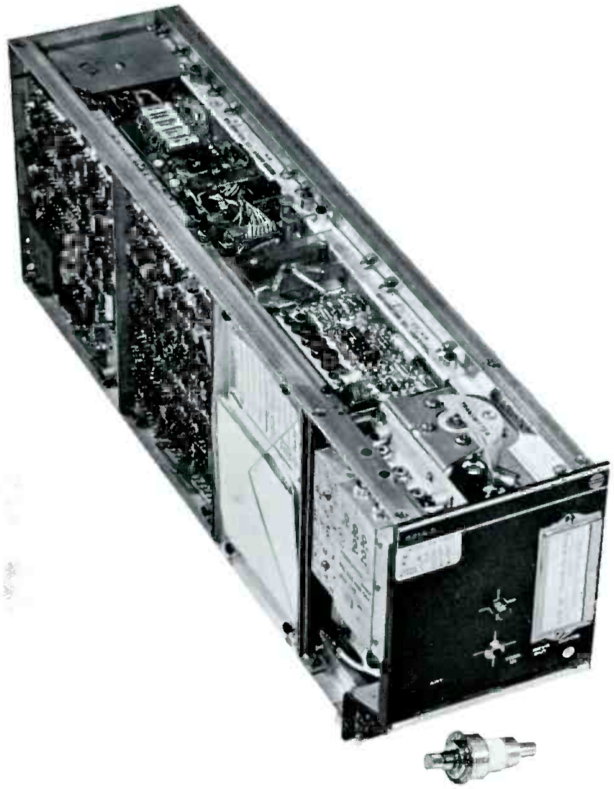
Figure 3 — DME Maintenance Test Position.

equipment at Seattle-Tacoma Airport, Chicago's O'Hare Airport, and Kennedy Field in New York. These shops have a combined employment of 30 to 40 people, and a combined output of radio equipment, of the types of equipment handled, comparable to that of the San Francisco Base. These shops handle only the heavily used types of radio equipment, however, and do no overhaul of autopilot equipment.

Transponder/DME Maintenance Practices

DME and ATC Transponder equipment specifically, is overhauled at our San Francisco, Chicago and New York shops. The same overhaul practices, test equipment and specifications are used at each location. The choice of shop is governed by the station at which the unit is removed from service. The incoming unit when received carries a tag with complete information on the circumstances surrounding the removal, including the pilot's description of the failure symptoms. The unit is turned over to an electronic mechanic specializing in maintenance of this type of equipment, and worked at a test station designed for and devoted exclusively to DME or to Transponder maintenance. The mechanic first attempts to verify, localize and correct the actual failure, using the data provided, and operating the unit with the signal environment and the balance of the aircraft system simulated by shop test equipment. This phase of the overhaul may vary considerably in difficulty and time required, but in general, with the test equipment, test data and check points in the unit circuitry, faults can be localized quite readily. For various reasons, the Line Mechanic may remove units from the aircraft on a precautionary basis if their performance is questioned. Consequently, a certain proportion of the "failed" units tested will be found to have no need of repair. In the DME and Transponder systems, this amounts to about 20% to 30% typically. All units carry a maintenance record covering one or more years of previous service to insure that actual faults, perhaps intermittent in nature, are not overlooked.

After fault location and correction, the modification record of the unit is checked to see if all known modifications or performance improvement changes have been accomplished. If not, such modifications are accomplished at this point. This type of modification for performance up-grading is a continual process throughout the years that the unit is used. At times, units may be called in specifically for such modifications. Modifications may originate from the equipment manufacturer, the airline shops, or engineering department,



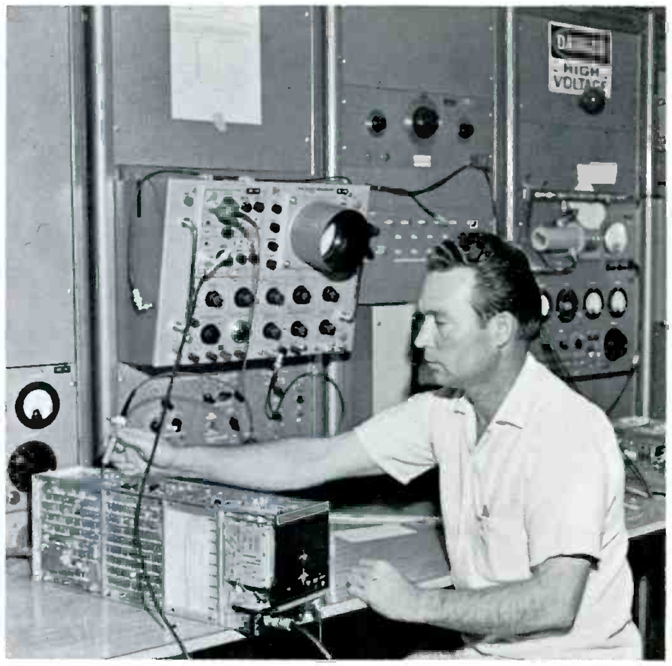


Figure 4 — (Left) Collins 621A-3 Transponder shown with ML-7815.

Figure 5 — (Right) Transponder Maintenance Test Position.

but are accomplished only if approved by United's Engineering Department, where control of the unit configuration and performance specifications resides.

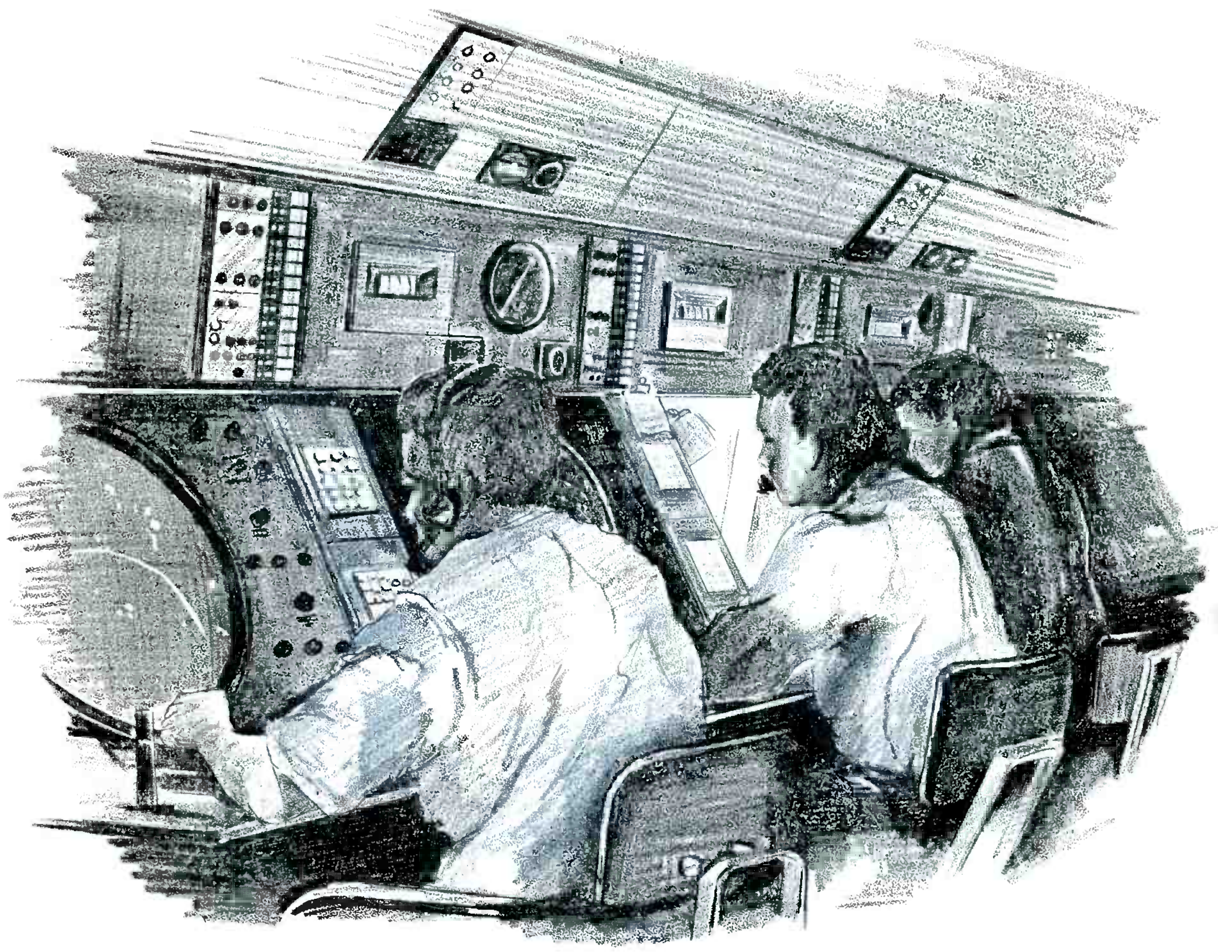
After completion of any necessary modifications, the unit is subjected to a comprehensive performance analysis. The tests conducted in this analysis and the specifications to be met are governed by specifications issued to the shops by United's Engineering Department. These tests and specifications are summarized for the mechanic in a highly condensed symbolic form on overhaul check sheets, which are filled-in with the test results for each unit overhauled. These tests in general insure that performance equal to or better than that of a "new" unit is obtained prior to release from overhaul. The check sheets are maintained in shop files as an overhaul record and may be consulted if questions arise about unit performance trends. The check sheet for the 860E-1 is a 6 page document calling out 44 separate performance specification areas, including such things as transmitter frequency, power and pulse shape, IF sensitivity and bandwidth, AGC action, decoder sensitivity and aperture, phantastron circuit operation, range gate tracking, distance accuracy, and so on. The ATC Transponder check sheet is a 3 page document and includes checks of receiver bandwidth, sensitivity and output, sidelobe suppression, decoder aperture, spike rejection and cross mode rejection, transmitter power, pulse shape, encoding, and other items for a total of 19 specification areas.

If the unit fails to meet any of specified requirements, the cause must be determined and corrected before release to service.

Units may be returned to the shop for reasons other than suspected failure. Units might be returned for example — for modification as mentioned, for analysis to collect performance data, or in some cases, because of expiration of a fixed calendar time or flight time. Regardless of the reason for removal or the time since last overhaul, the complete overhaul procedure and specifications apply.

Airline Electronic Engineering

In the previous sections, some of the functions of the airline engineer have been mentioned. The typical airline engineer of today holds a degree in Engineering or related sciences. Usually, in addition, he has had some previous experience or interest in the aviation industry. In addition to his electronic technical background, he must have acquired



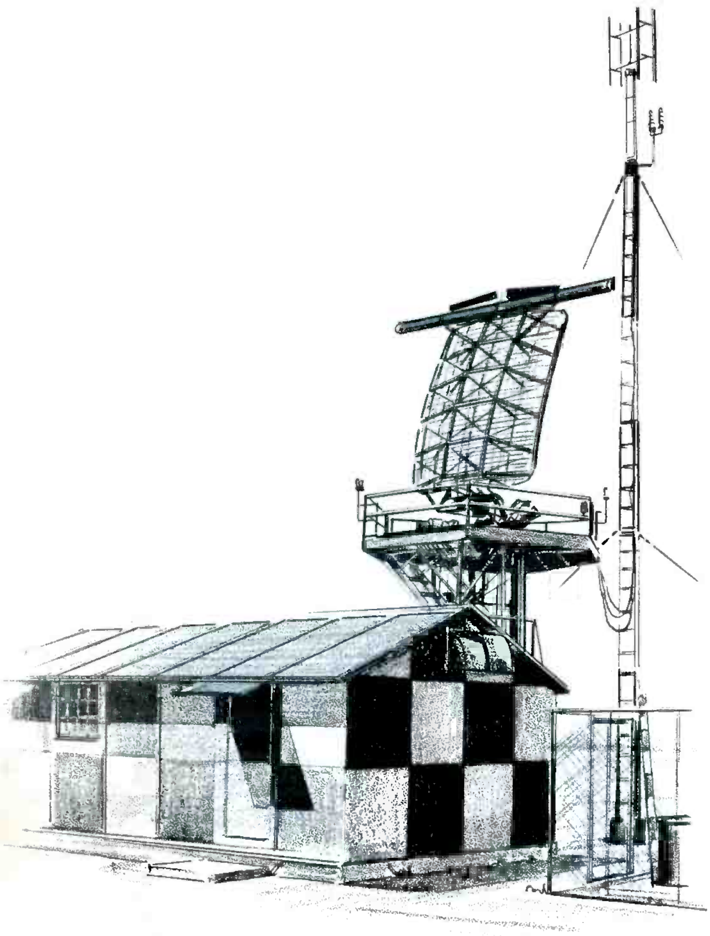
a thorough knowledge of the problems of operation of the aircraft in scheduled service and a good background in the practices and the references of the various aircraft manufacturers with respect to system, and to some extent, airframe design.

United Air Lines, as might be expected to support operation of the largest civil jet fleet, has one of the largest, if not the largest, Engineering staff in the airline industry. The function of the airline engineer includes a wide variety of responsibilities, falling somewhere between those of a field engineer and electronic system design engineer. He has much the same field performance monitoring responsibilities as the former, but more direct responsibility to correct the problems uncovered. He has responsibility for determining the extent and the specifications for equipment overhaul to insure that operation and reliability of the system is satisfactory and that legal requirements are met. If reliability or operational problems are encountered he may work with the equipment or component manufacturer to investigate the problems and determine the corrective action necessary, or he may investigate and develop corrections himself; depending upon circumstances. Corrective actions may include design of equipment modifications or changes to overhaul or operational practices.

Through the Airlines Electronic Engineering Committee of Aeronautical Radio, Incorporated, airlines coordinate development of descriptive "Characteristics" for new equipment. These provide design guidance to manufacturers by defining the system functions and performance, equipment, size, and interwiring.

The airline engineer, in cooperation with manufacturer's design engineers, may work in AEEC subcommittee activities to prepare new system "Characteristics" and revise and up-date old ones. The result is to broaden the market for the manufacturer by consolidating and defining airline equipment needs. The airline benefits from this equipment standardization by achieving interchangeability between manufacturer's equipments and from aircraft to aircraft, by reduction of equipment costs in comparison to "custom tailored" designs, and, of great importance in new aircraft procurement, through the ability to specify aircraft system wiring and mounting provisions in advance of actual procurement of the system hardware.

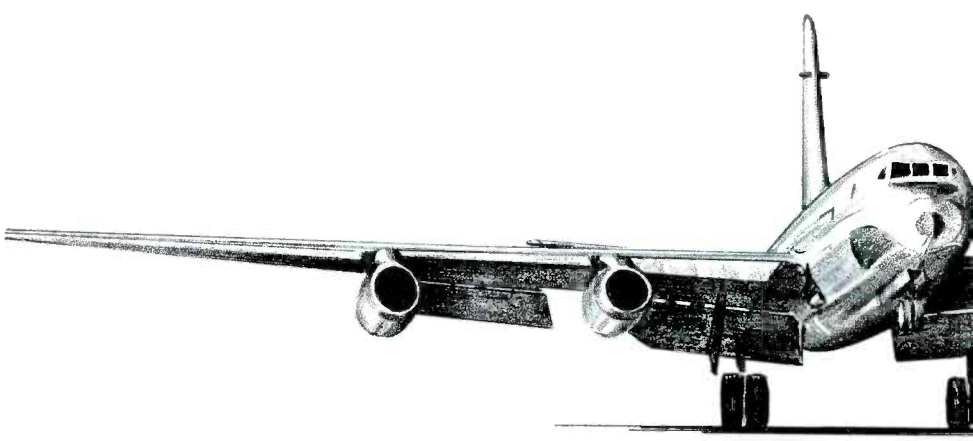
During periods of new aircraft or equipment procurement, United's Engineering Department assists in review and selection of the equipment best suited to United Air Lines needs,



in cooperation with Flight Operations or Ground Services Departments affected. These reviews often involve prolonged and sophisticated function test programs conducted by the Engineering Department. Prior to selection of new aircraft, a detailed specification of the configuration and performance of the aircraft and its systems is prepared by the Engineering Department for each aircraft under consideration. Forecasts of operating capabilities and costs of the aircraft on United's routes are also prepared to assist in the selection.

In the airline radio and electronic industry, there exists an unusually high degree of cooperative effort between the airline user, the equipment manufacturer, and the electronic component manufacturer. At its best, this relationship permits each to operate as a specialist in his own area, cooperating to achieve mutual goals of improved system, unit and component reliability. The airline staff works primarily to locate and diagnose problem areas and to provide data to the equipment and component manufacturers. They, in turn, assist in the problem diagnosis, and develop suitable corrective action or product modifications. These are incorporated into the equipment by the airline and the effectiveness of the correction evaluated by the airline staff.

As an example of the effectiveness of this type of cooperation, the attached figure shows the performance improvement obtained over a two year period of operation of a unit using UHF planar triodes in the transmitter section. Quite frequently, new equipment being introduced into service will



experience a "shake down" period of higher than normal removal rate. Operation in real time and the real environment often exposes problems not predicted during the equipment development. Among the problems in this particular case was a condition causing short life of the transmitter tubes. As this problem became apparent, both the equipment manufacturer and tube manufacturers responded with corrective action. Incorporation of these corrections and improved tubes began in February and was essentially complete in April of the first year with very gratifying results. As can be seen, the equipment irregular removal rate showed a rapid short term improvement and continuing long term decrease. Corresponding benefits in transmitter tube mean-time between failures are shown by the horizontally marked bar graphs. Since there tends to be a gratuitous increase in component life by any reduction of unit irregular removal rate, through decreased frequency of overhaul, the diagonally marked bar graphs are shown as confirmation of the improvement in tube life. They indicate a reduction in the ratio of tube removals and removal opportunities.

Examples of this type of manufacturer-airline cooperative product follow-up program could be found in many other cases. While product follow-up relationships exist in many industries, those of the airline industry are particularly successful. This is due in large part to the effort made in the airline industry to obtain meaningful performance information for the manufacturer and to the cooperative response obtained from the manufacturers.

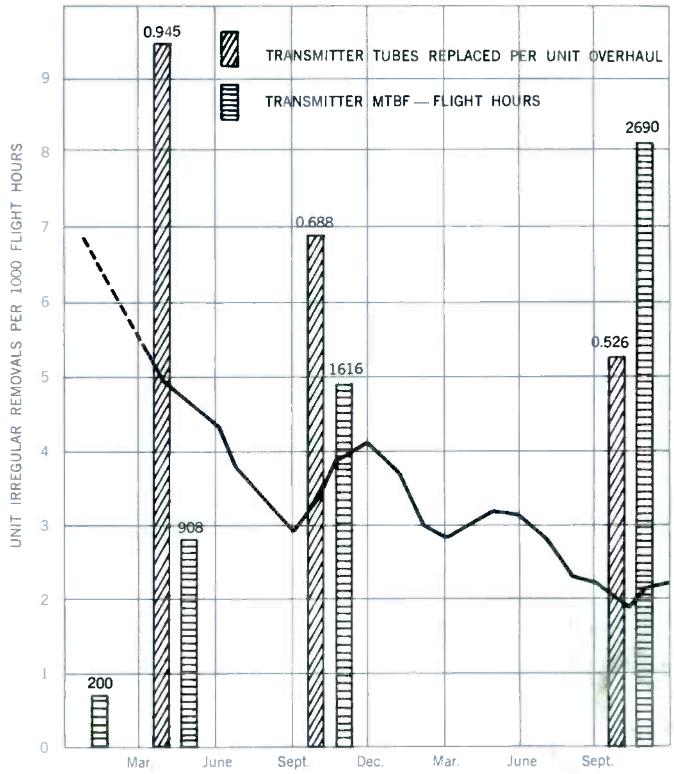
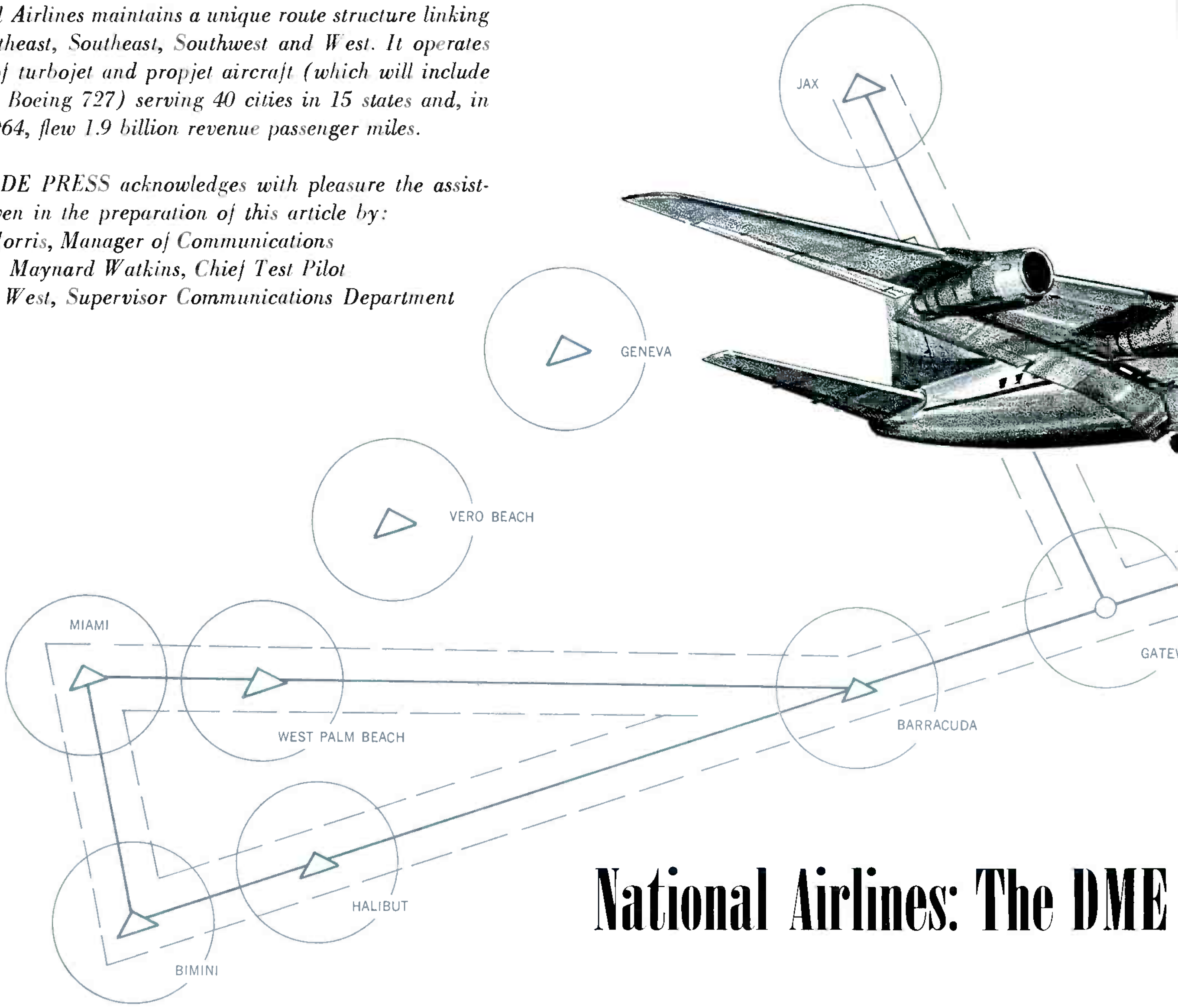


Figure 6 — Improved Tube Life—Longer Transmitter MTBF periods.

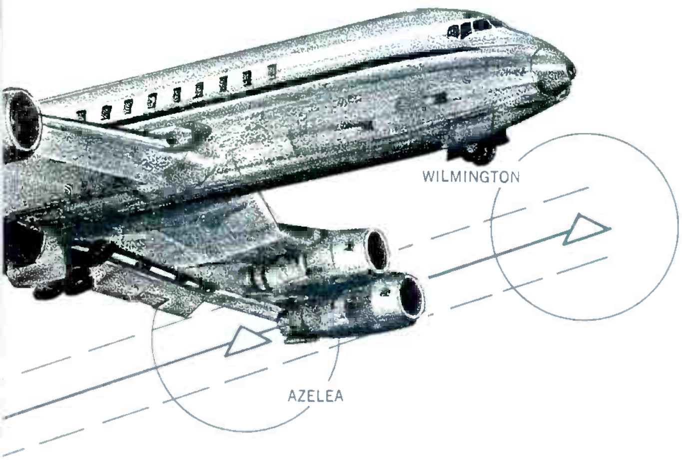
Editor's Note:
National Airlines maintains a unique route structure linking the Northeast, Southeast, Southwest and West. It operates a fleet of turbojet and propjet aircraft (which will include the new Boeing 727) serving 40 cities in 15 states and, in fiscal 1964, flew 1.9 billion revenue passenger miles.

CATHODE PRESS acknowledges with pleasure the assistance given in the preparation of this article by:
W. E. Morris, Manager of Communications
Capt. G. Maynard Watkins, Chief Test Pilot
Merwin West, Supervisor Communications Department



National Airlines: The DME

Although not a few of us can remember when low level flight might have meant tree leaves (or worse) in the air intake, "low level" for sometime now has referred to any flight altitude below 14,000 feet. It is in this busy lower pool of air (of all flights today 93% are made below 18,000′) that the shorter distance flights, 50 to 500 miles, are made. Here a captain and co-pilot flying direct from one city to another may even be concerned with his en route navigation for a shorter period of time than his terminal approach and landing procedures. A somewhat more normal low level flight situation might require flight plan calling for 3, 4 or more airway changes prior to nearing the destination terminal. During the relatively brief, and certainly concentrated time the pilots have much to do beside navigate. While one man devotes full attention to the control and flight of the aircraft the other "works" the



and Transponder in Action

VHF communications radio (the Captain monitors the radio through his headset) making position reports to the Air Traffic Control, writing down instructions received by them; providing company dispatchers with position reports, weather data, fuel supply and so on. Therefore any device which frees a pilot to concentrate on his many other duties, as well as one which provides him with great accuracy — and the confident feeling which accompanies this — is to be highly desired. Such, of course, is the DME, a device which is to the pilot as the Transponder is to the traffic controller. Each instrument in its sphere immensely relieves the operating individual of the burden of detail and provides him with exact and instantaneous units of information.

A DME in Action

NAL Flight 383, its flight plan (IFR) filed to Norfolk,

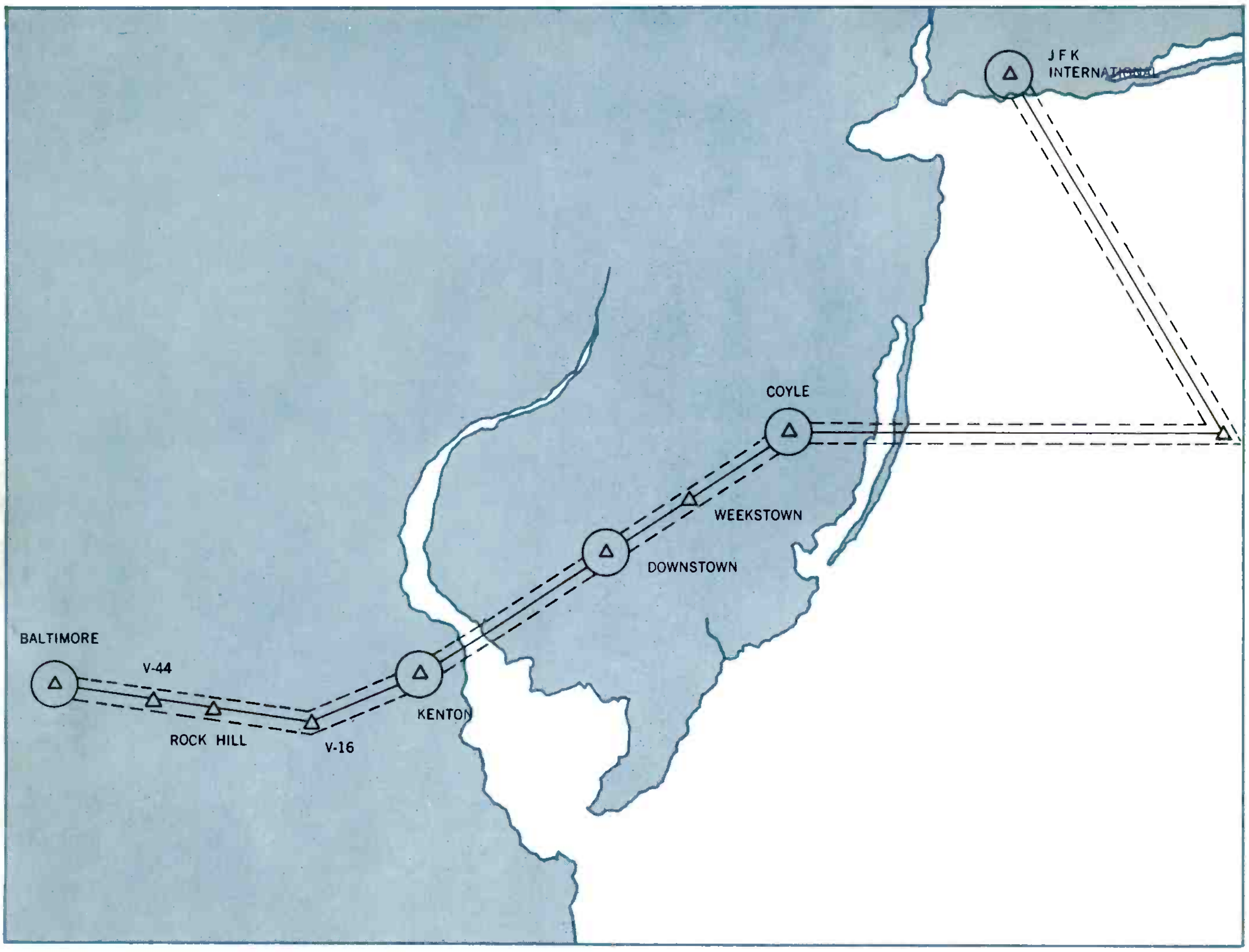


Figure 1 — DME equipment in use on the New York-Baltimore leg of a New York-Norfolk "low-level" flight. "Low level" includes all flights to 14,000 feet.

is now airborne after clearance for takeoff on Runway "31". Departure Control picks up the plane and identifies it as it begins the initial climb out of JFK. The transponder is set to Mode A, Code 10 indicating a climbing attitude. A heading of 290° (established as soon as possible to minimize noise) is maintained to 1000 feet followed by a left turn (in this case) to 160° holding this heading until cleared to turn on course. Still climbing, NAL "383" crosses the JFK VORTAC 224 radial at an altitude of about 2500 feet. Cleared for a turn on course, the transponder, still on Mode A, is set to Code 1 (0 to 14,500 feet). Figure 1, above.

Shortly following this the pilot is asked for his ETA to Coyle, a VORTAC station approximately halfway between Lakehurst and Atlantic City, N. J. Within one-half minute or less the answer is relayed over the VHF communications radio to JFK. For close-in ETA's a quick figure of TAS (True Airspeed) divided by 60 (to get miles per minute) times DME miles to go to Coyle provides a rapid and useful figure. (For longer distances and times ground speed is, of course, used.) Protractor, compass, even radio fixes, have been eliminated; a useful rate of speed has been found in a tenth or a twentieth of conventional navigation time. But this has been a clear day. Had the flight been over the clouds the only ETA for Coyle would be given when the plane was over Coyle. Now both the National dispatcher and the FAA controller know at once — and under any condition. Once at Coyle, Victor Airway 16 is picked up and Flight 383 is off and away on a heading of 246° with a total distance (as given by the chart) of 62 miles to the next VORTAC/DME station (which is the second VOR station along the route and almost exactly on course).

Along a Victor (or VOR airway) are plotted a number of compulsory/option checkpoints. Pre-DME in concept these points represent intersection of the VOR radials and provide a reasonably rapid means of establishing air-to-ground position reports. Such an intersection is located at

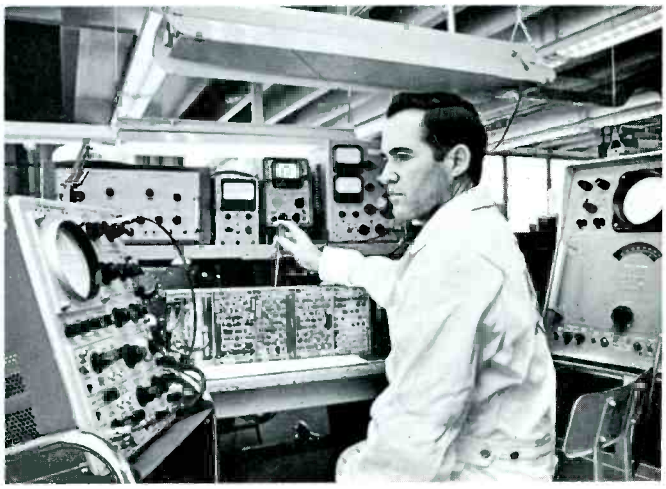
Weekstown, 13 miles southwest of Coyle and is the crossing of the Yardley (116.2 mc; ARD) 171° radial and the Coyle (113.4 mc; CYN) 246° radial. If necessary this point could be used to cross-check DME miles or, of course, as a back-up or substitute. Much more direct, however, is to follow along on the Coyle radial and pay out the line, so to speak, with the DME indicator showing the miles from Coyle. Now the pilot has an infinite — or nearly so — number of checkpoints and can report his position with reference to one reading only; for his own information he may maintain a continual running reference.

At Millville he reports position as required and concentrates next on Kenton 32 miles distant along the Victor-16 airway. At Kenton he prepares for a course change from Victor 16 to Victor Airway 44, to bring him into Friendship International. Since there will be no DME signal at the airway junction to Victor 44, NAL 383 tunes to Kenton and waits for an 18 mile DME indication (showing position away from the station); he uses this reading, together with this VOR radial, to establish position for the turn. But he can quickly get a fix at this junction by reading ahead to Friendship and establishing (with a half minute or less) that his DME reading to Friendship is 38 miles. Prior to DME he would have had to plot two or more radio bearings, determine his position by the interception of the beams and turn accordingly. Useful — but much slower, much less accurate.

Assume though that he is advised of turbulence on or near Victor 44 as he approaches the turn off from Victor 16. He is requested to hold at Rock Hall, for example. Because of his continuous distance reference he locates Rock Hall at once and proceeds to hold as directed. Permitted to proceed he nears Friendship, Code 14 is placed on the Transponder; Code 4 is set in after landing. The first of the four stops of the Norfolk run has been completed — accurately, and on time.

Figure 2 — The aircraft radio truck delivers a DME to a waiting DC-8. Dual DME and Transponder installations are used on these and other National aircraft.

Figure 3 — A Federal ITT DME is checked out in the Radio Shop. Machlett ML-7815 tubes are used in this equipment.



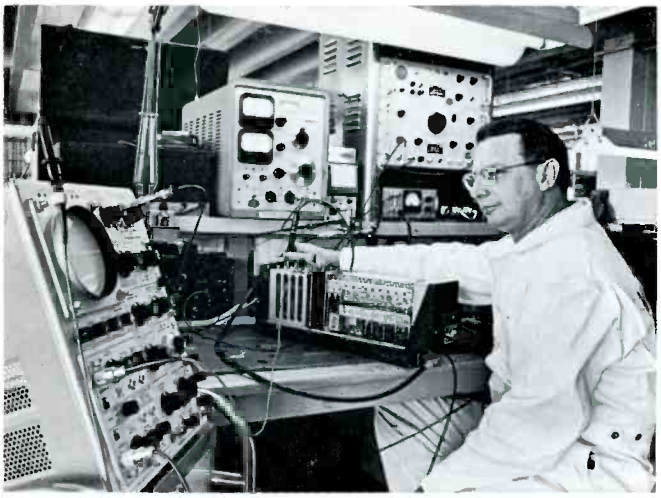


Figure 4 — The Collins 621-A transponder is adjusted in for peak performance. Cavity for the Machlett ML-7815 is visible at the left of the transponder unit.

"Hi-Level"

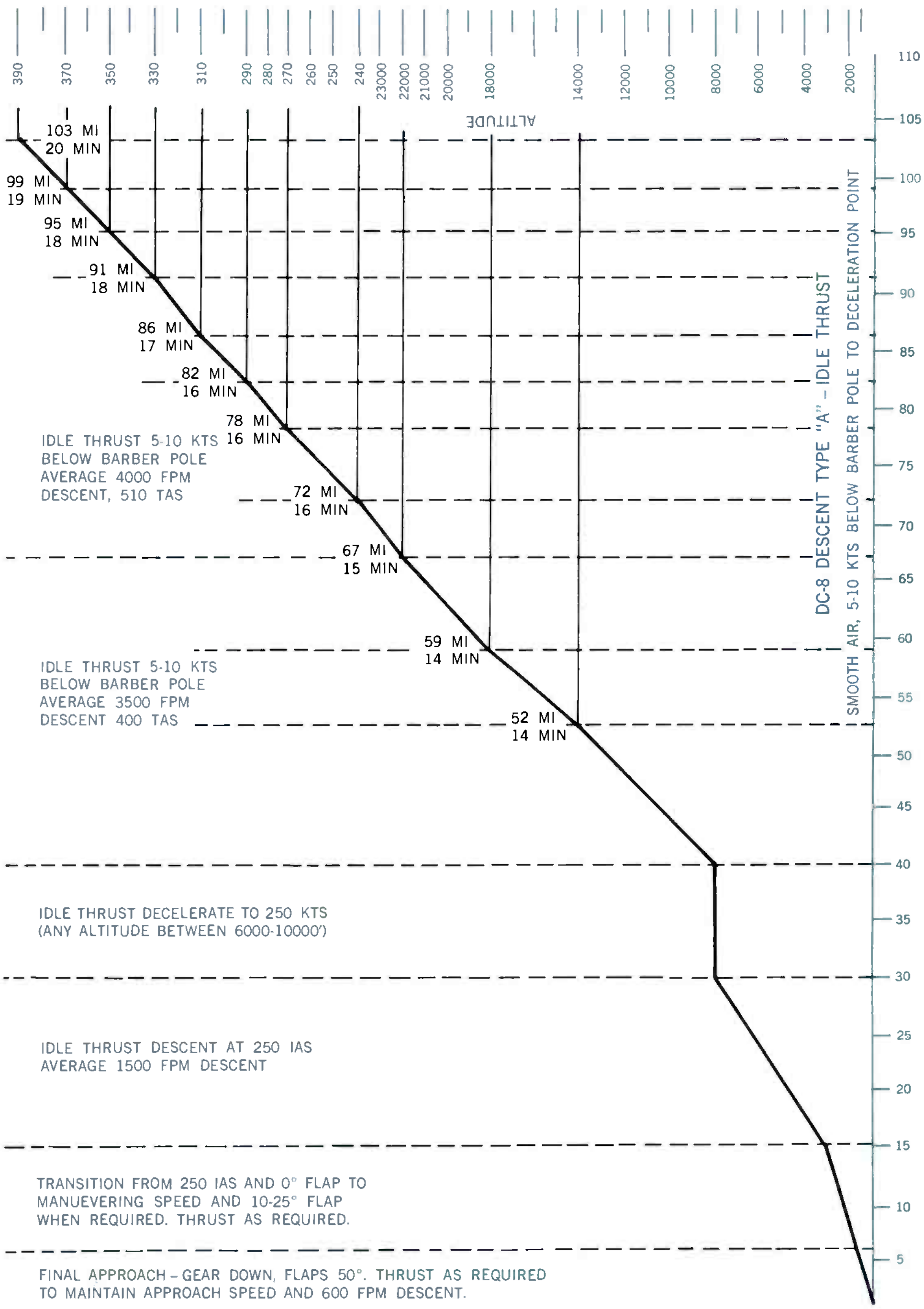
With a muted nod to Biscayne Boulevard and Collins Avenue, NAL Jet Flight 80 proceeds outward bound from Miami to New York. Gaining altitude imperceptibly but rapidly as it reaches its on-course heading (008°) it rushes northward up the airways slot at 31,000′ past Cape Kennedy toward its first landfall at Carolina Beach. A DME reading off Jacksonville confirms the plane's position as 157 miles due east (as indicated on the chart). This is important because north south slot (from Bimini Island, south, to Wilmington, South Carolina, north) is only five miles wide. It is also about one-half minute wide at the ground speed of NAL 80. Radio bearings from Daytona, Jacksonville or Savannah could be used to maintain airspace position in this channel but these are slow (and, at this distance reception may not always be good); waiting for needle deflection to average out takes a considerable time at 600 mph.

Figure 5 — John F. Kennedy International Airport.
Courtesy of The Port of New York Authority

The DME, like an unusual flashlight which, instead of illuminating a target, obligingly tells you how far away it is, supersedes the Radio compass in both speed and accuracy. (As a matter of fact, National's DME's and those of the other airlines have been used not only to confirm but to correct mileages listed on the navigation charts). Using DME mileage references, similar to those described for the low-level flight, NAL 80 proceeds on course toward its destination.

Code 21 (above 24,000 feet) had been set in on flight 80's transponder, but this changes now to Code 14 as it begins its descent into JFK. Suppose now that incoming traffic at the terminal area has built up somewhat and the plane is requested to hold. In pre-DME days he would have "held" in relation to the intersection of radio range courses or the intersection of VOR radials. In each instance the holding pattern would have been determined by a time run (inbound or outbound) on a leg, a standard turn and an-

Figure 6 — Accurate mileage determination made possible by DME allows use of fuel saving schedules such as shown below.



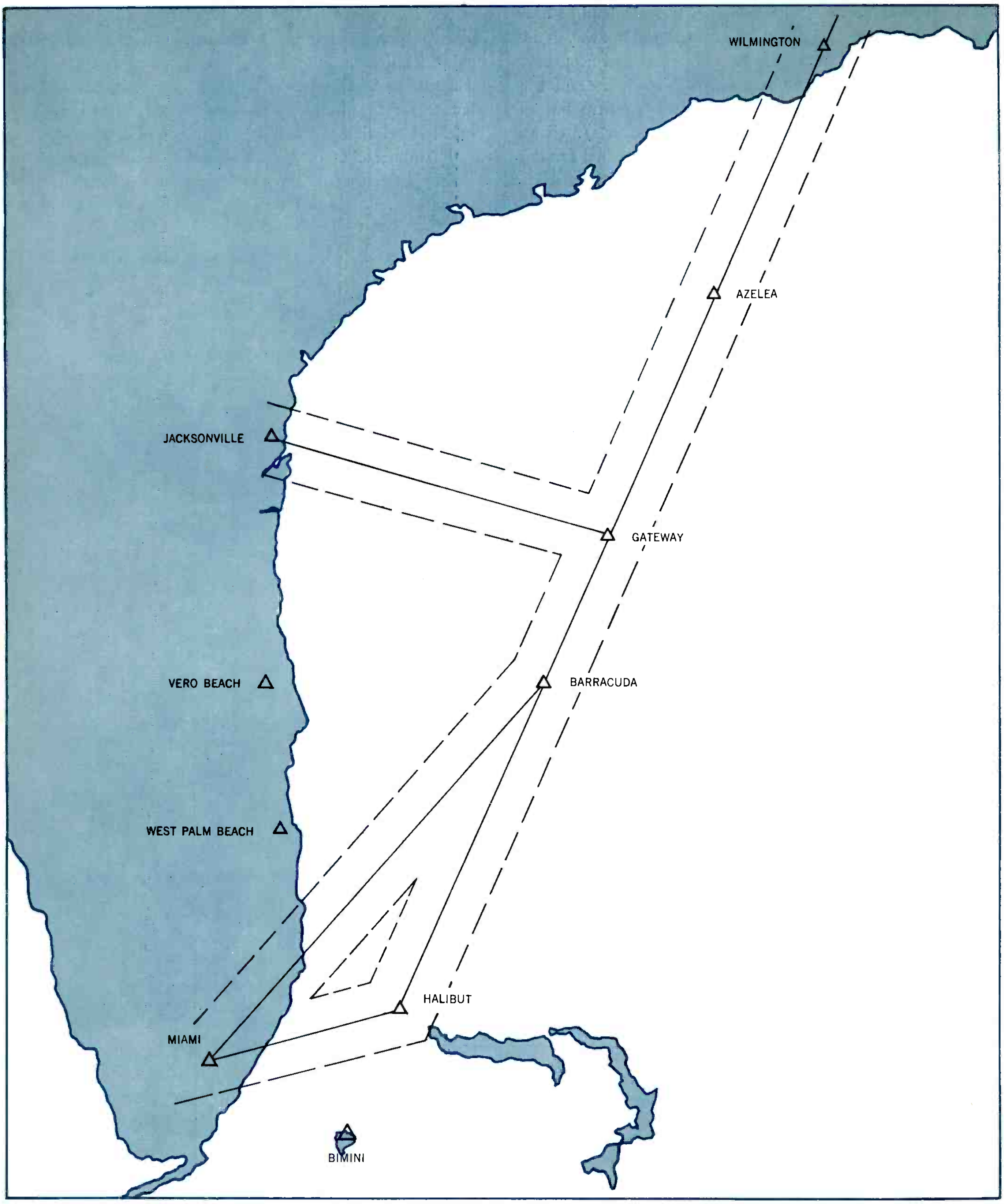
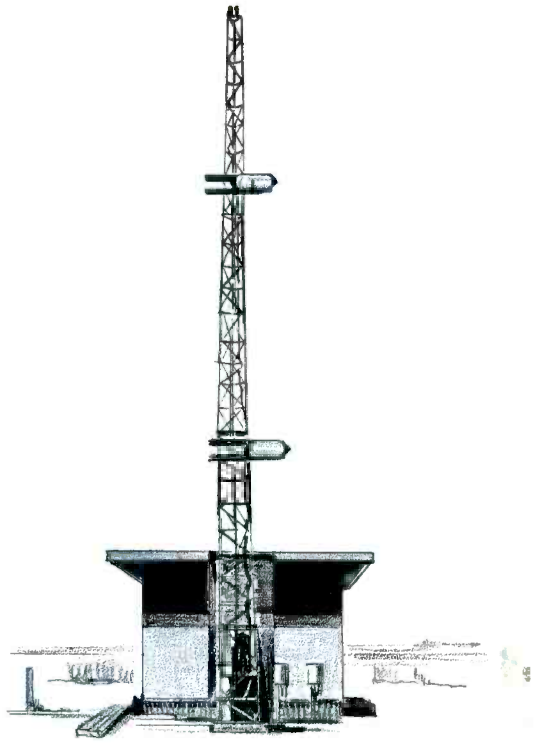


Figure 7 — DME equipment in use on the Miami-Wilmington (S.C.) leg of a Miami-New York "high-level" flight. "High-level" includes all flights above 24,000 feet.

other timed run. Timing would have to account for wind velocity — no simple matter when winds aloft may be upwards of 100 knots. Reading a second hand and compensating for wind drift and for ground speed variation take pilot time and additional concentration. Using the DME odometer for holding pattern information has a clear advantage. Once again, the pre-DME reference point for establishing the holding pattern had been the intersection of VOR radials — (and it had been necessary to re-establish this point after each circuit of the pattern). Now, the instructions, "Hold at a point 15 miles from the navaid in a standard pattern," require minimum navigational attention for accurate compliance.

Cleared to leave the holding pattern NAL 80 now cleared to go direct to the airport on a DME radius keeping a constant rate of turn and constant mileage indication on the odometer. Constant reference equals constant control — and, once again, on time arrival.



Many of the uses of DME have not been referred to in these brief sketches of the low and high level flights. One additional mention, though, is of interest. Since it costs about $20.00 a minute to keep a large jet flying it is apparent that any thing which saves time will, in short order, save a significant sum of money. In this connection descent from altitude gains significance. A turbojet flying with a favorable wind at high altitude wishes to maintain that altitude as long as possible and to descend, consistent with safety, as fast as possible so as to remain in the denser air for the shortest time. In the western terminal areas — nearing the completion, for example of a Miami-Los Angeles flight — a straight in descent, made at rates determined by the pilot, is frequently authorized. Since the pilot knows his distance from the destination airport to within a tenth of a mile, he can initiate his minute-saving, money saving descent with the knowledge that he will complete his descent at just the right place. The accompanying table, Figure 6, for "idle thrust" indicates his options. At 39,000′, for instance, he could begin Descent Type "A" with idle thrust (engines idling) 103 miles and 20 minutes from the airport. (For the meaning of "below the barber pole" see p. 31, KIFIS reference). On the basis of only 20 flights a day and saving a total of only 20 minutes a carrier would realize a total saving of approximately $12,000 over a month's period. DME, then, not only pays in safety, but pays for itself in profit.

Editor's Note:

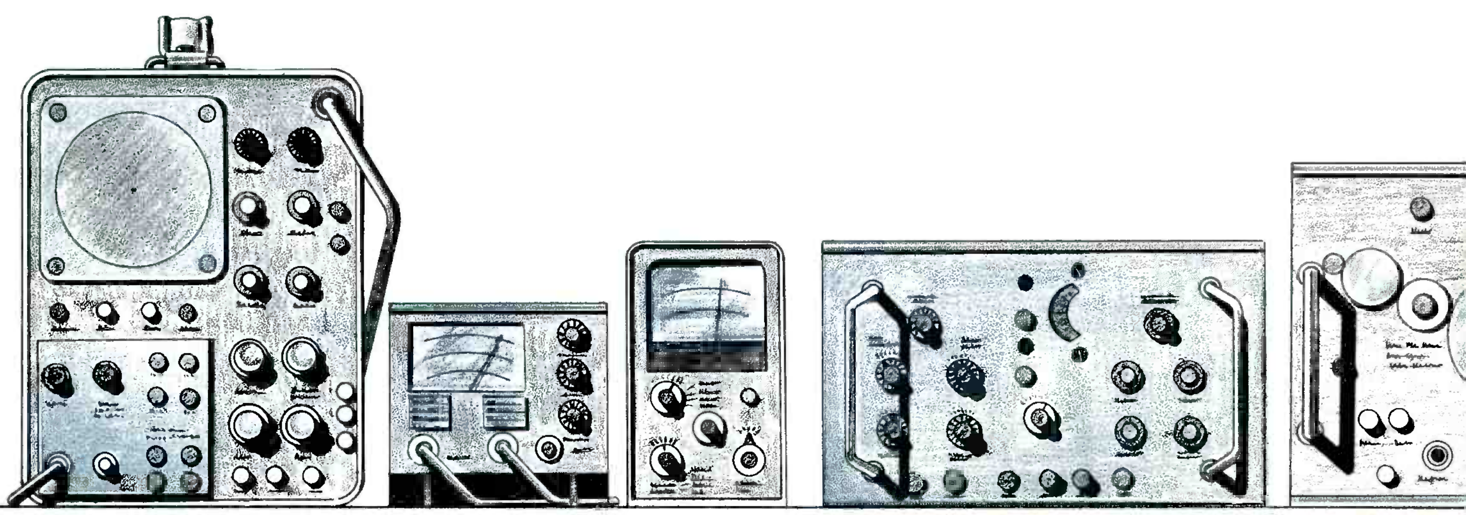
Pan American Airways is the world's largest carrier of international air passengers and air cargo. It operates a fleet of 67 jet aircraft to over 100 cities in 86 lands around the globe. Pan American, in 1963, carried 4,833,000 passengers and 200,000,000 ton-miles of air freight. Pan American has ordered 15 U.S.-built supersonic transport aircraft and six Anglo-French "Concorde" supersonic aircraft.

Pan American — Overseas Division —

One of the Divisions of Pan American World Airways, the Overseas Division, is headquartered at the John F. Kennedy International Airport. Comprised of over *15,000* employees, this Division schedules and operates as many as 80 departures daily. The blue and white Jet Clippers leaving for points from London to Calcutta maintain an especially busy traffic on the high density North Atlantic routes. Of the several groups included in the Overseas Division (Operations, Maintenance, and Flight) one of the busiest is the two-shift a day electronic maintenance overhaul group. Not only are they responsible for the electronic gear on a large number of aircraft, but typical of the standards that they and similar groups throughout the industry maintain, each individual equipment overhaul involves a minutely detailed examination taking on an average of 4 to 7 hours. Add together all the electronic units maintained and the answer becomes, in this case, a two-shift operation.

Whereas high density units (electronics, jet engines) are maintained at JFK, air frames are serviced at Miami where the "barn" doors can stay open all the year. Although JFK has prime responsibility for all "jet electronics", there is a Radio Engineering group at Miami which handles electronics for piston aircraft. A large radio shop, similar to the one at JFK, handles repairs for all types of aircraft, including jets flying the South American routes. And at San Francisco, electronics for the Pacific air fleet is kept in trim; while the planes flying the middle and far eastern routes are serviced at London.

A typical electronic overhaul procedure is scarcely what could be called a "check". It is a thoroughly organized,

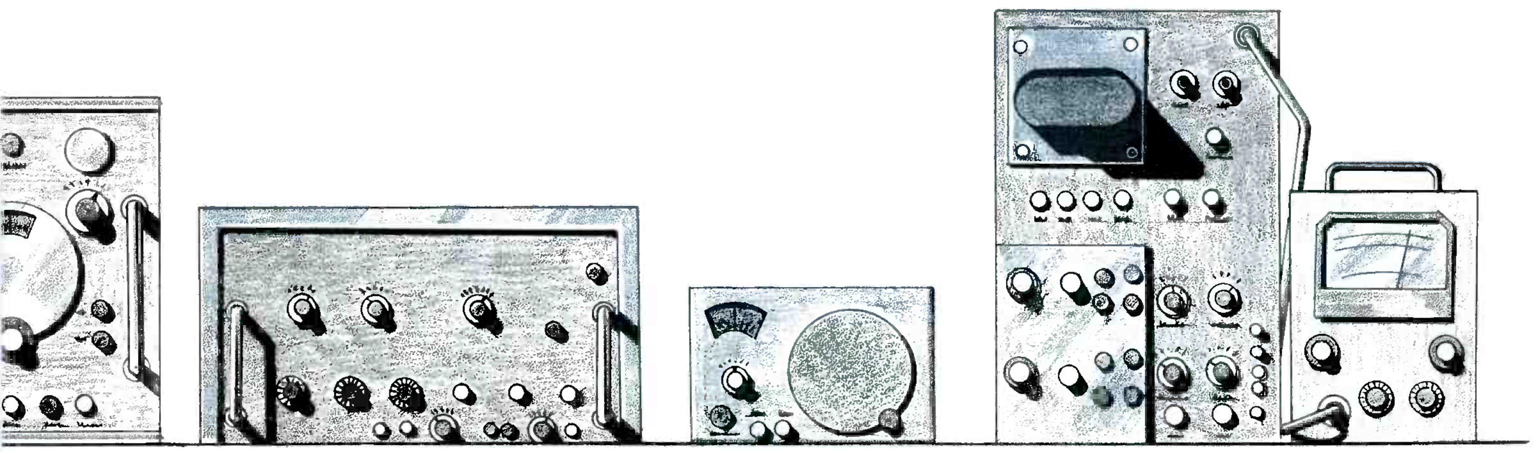


A detailed view of the Maintenance Bench

detailed, positively monitored and supervised examination. It is executed by a trained and licensed radio mechanic schooled as well, on the particular equipments for which he is responsible, in the classrooms of the electronics manufacturer. (No longer does a finger on an input lead serve suitably as a 60 cycle signal generator; and a fluorescent lamp has become a dubious device as an rf null indicator. But such is to be expected in a day when a DME, for example, can say more during a single dot of the Morse code than Mr. Morse could have said in five minutes, had his sending key remained intact.)

To provide some insight into the detailed thoroughness with which a modern electronics shop performs its duty the procedures followed in the overhaul of the Transponder and the DME are reviewed below. A complete set of test equipment is provided for each overhaul procedure. As many as eighteen units are associated with the Transponder tests; and, although this number represents alternate test gear configurations, the radio mechanic must know all the equipment. Typically, for a Transponder examination, the following would be employed:

A. Tektronix Scope, Model 535.
B. Hewlett-Packard 614 Signal Generator (2 required).
C. Beckman Berkeley Double Pulse Generator (2 required).
D. Narda Echo Box.
E. Dual Directional Coupler, H-P, Model 766D.
F. Termaline Coaxial Resistor, Bird Electronics Corp., Model 81.
G. Thermistor Mount, H-P, Model 477B.



H. Rada Sweep, Kay Electric.

I. Microlab XP-6 L-Band Detector.

J. General Radio Co., 50 ohm load, Type 874.

K. Weston Analyzer Multitester.

L. Pan American Design Test Panel with AC and DC Voltmeters and Variac.

M. Mixer Pad.

N. Isolation Resistors.

O. Beckman Frequency Counter.

Transponder Examination

It should be noted that although what follows is not the actual plan used by the electronics shop, it is a close approximation to it and includes all major steps.

Preliminary

1. General inspection of unit to reveal loose connections, corrosion, dirt, etc.; examination of fuses and holders, wiring and insulation, capacitors (for leaks and bulges); and tubes, for microphonics.

2. Set up test equipment.

Test 1 Receiver Pulse Output

With the Transponder interconnected to the proper test equipment it is initially checked for proper output pulse amplitude against an input signal of —74 dbm. The receiver output pulse is further monitored in 9 dbm steps throughout a —74 dbm to —20 dbm range to make sure that the lin/log detector does not distort or overload causing amplitude distortion (which would vary the original relation between the two input pulses).

Test 2 Receiver Sensitivity

Tested at an interrogation rate of 1000 pps the receiver should produce 50% replies at a —74 dbm input. Gain is then reduced by 12 dbm and sensitivity rechecked on a higher input level. This is done to make sure that the receiver will not overload in the presence of strong signals (i.e., when it is close to a station).

Test 3 The Decoder

Test equipment is set up for a two-pulse check with attention being given to pulse spacing and pulse width while pulse amplitude is varied. A three-step procedure (specified input; proper pulse-to-pulse relation; specified replies at specified pulse relation) is repeated through 6 steps from high to low input. This test assures that the two-pulse sidelobe suppression circuitry is operating properly. A similar three-pulse check follows.

Test 4 Identification Time Delay Test

This test is performed to ascertain the proper functioning of the IDENT Switch (the switch used by the pilot to acknowledge the radar ground controller's request for aircraft identification). The identification pulse must appear in the reply code for 15 seconds and must be removed (automatically) at the end of this period.

Test 5 Suppression Pulse

Suppression pulses are generated within the transponder and are used to suppress other pulsed radar systems or units within the transponder's frequency range, while the transponder is transmitting; pulses are used to suppress the transponder's own receiver during transponder transmissions.

Test 6 Automatic Output & Countdown

This test is made to insure that the transponder will provide fewer than 90% replies at signal levels down to a specified point; the test is made at an interrogation rate of 2400 pulses per second. A "countdown" circuit (similar to an AGC) is used in the transponder to prevent overloading of the modulator and transmitting tubes (i.e., to prevent exceeding their duty cycle). The countdown circuit acts to reduce transponder replies as inquiries increase beyond a certain limit. The countdown test monitors this circuitry.

Test 7 Reply Frequency Test

This test is made to ascertain that the transponder is replying on the correct frequency. Transmitter output frequency, monitored by an echo box, must be accurate to within ± 2 tenths of one percent at 1090 mc.

Test 8 Transmitter Power Output Test

In this test the unit is monitored with an incoming signal set just below the minimum triggering level. A minimum output of .5 kw must be obtained; if not, the unit is shut down and adjustments are made to achieve proper power. Sustained, reliable life is sought from the power or transmitting tubes. Machlett planar triodes fulfill these requirements.

Test 9 Transmitter Pulse Characteristics Test

After it has been established that the proper pulses are displayed for the proper code setting of the Transponder Reply Code Selector the pulse width, pulse rise time, and pulse decay time of the first and last reply pulses (framing pulses) are recorded. Adjustments are made as required to obtain proper pulse characteristics, not only for the framing pulses, but for all other pulses as well.

Test 10 Ringing Oscillator Frequency Adjustment

First the spacing between framing pulses is established. Next the spacing of the pulses between the framing pulses is established. In-between spacing time is 2.9 usec; overall time, between the first framing pulse and the Identification pulse which follows *must* be a tight 24.65, ± .1 usec. The unit has now been readied for flight. It is given a new rotation schedule date and is fed into the "pipe line" to await installation. Scheduled time to overhaul the Transponder is approximately six and one-half hours.

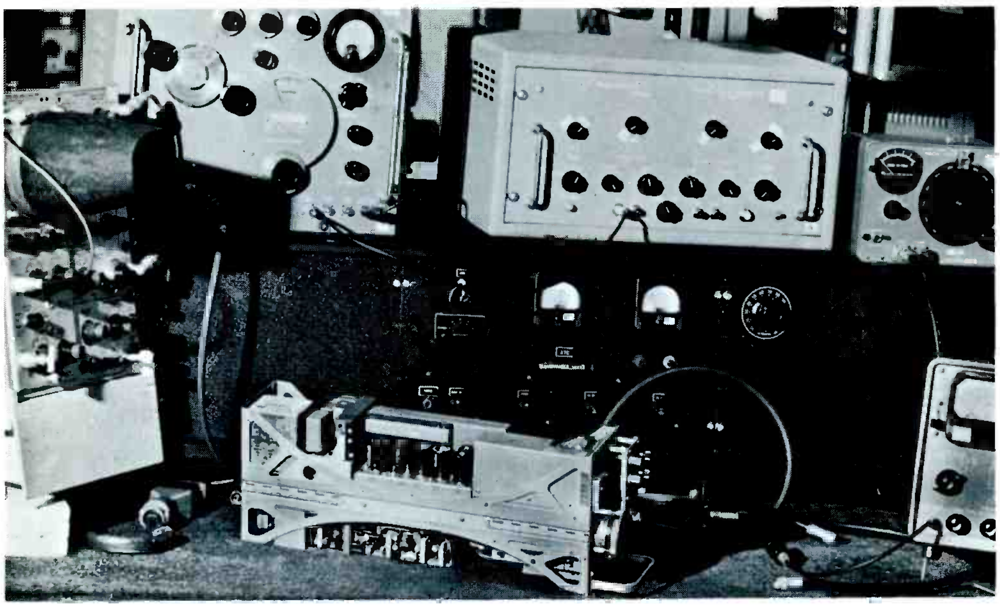


Figure 1 — A Federal ITT DME 100A, is shown with modulator card removed. The final output tube position (see just above the right hand of the Master Mechanic) is readied for a check of the ML-7815. Machlett planar triodes at Pan American have shown a very low removal rate.

The DME

Somewhat more complex than the Transponder the DME requires more extensive test gear for its evaluation. Whereas ten basic units were required for the Transponder, twenty-four are required for the DME, including such possibly unexpected items as a stop watch, swamping tool and a torque wrench. More usual are: Frequency Counter, Audio Oscillator, audio output meter, DC and AC VTVM's, UHF Signal Generator, dual trace oscilloscope, slotted line and two special units, the 578D-1 DME Test Set and the 235A Navigation Aids Test Set. The remainder of the items include such pieces as signal injection probe, test cables and special adjusting tools.

After preliminaries, as indicated in the Transponder tests, (but including more complicated mechanical inspection; e.g., checking of auto positioner clutch torques), the DME is tested for its ability to track, to measure elapsed time between its interrogation and ground return reply pulses and to convert the latter information into a digital readout (i.e., miles from a station).

Test 1 Time Delay

A time delay is employed to permit output tubes to warm up prior to operation.

Test 2 AGC Adjustment

Automatic Gain Control is set at a high squitter* rate using the AGC voltage at the decoder module.

*Squitter or fill-in pulses are used by the ground station to maintain a constant duty cycle during periods of varying interrogations. Squitter pulses are random spaced pulse pairs.

Test 3 Transmitter Frequency

The DME is operated on 126 different channels; these are tested throughout the entire range. The output frequency must be maintained within .007% of the assigned frequency.

Test 4 Power Output

Measured across the DME spectrum on 126 channels, the peak power output of the first and second transmitted pulses is measured. Output should not be less than 28 dbw (630 watts) and must not vary more than 1 db between pulses.

Test 5 Transmitter Pulse Characteristics

Rise and fall times of the first and second transmitted pulses is measured to be within 3 usec; pulse width characteristics are measured and pulse shapes observed. This test is repeated at the mid and at the high end of the band. To establish the pulse width, the 50% voltage point of the leading edge of the first transmitted pulse is measured with reference to the trailing edge of the same pulse.

Test 6 Receiver Sensitivity

The DME is adjusted so that it operates properly at a sensitivity of —90 dbm. Twelve channels across the band are then checked for sensitivity.

Test 7 Receiver Decoder Selectivity

With the antenna jack connected to the rf jack of the Navigation Aids Test Set (which, although it has not been so mentioned, has been used extensively in previous tests), a signal at an extremely low level is fed to the DME Receiver. The receiver is then checked for its ability to search, lock on and track.

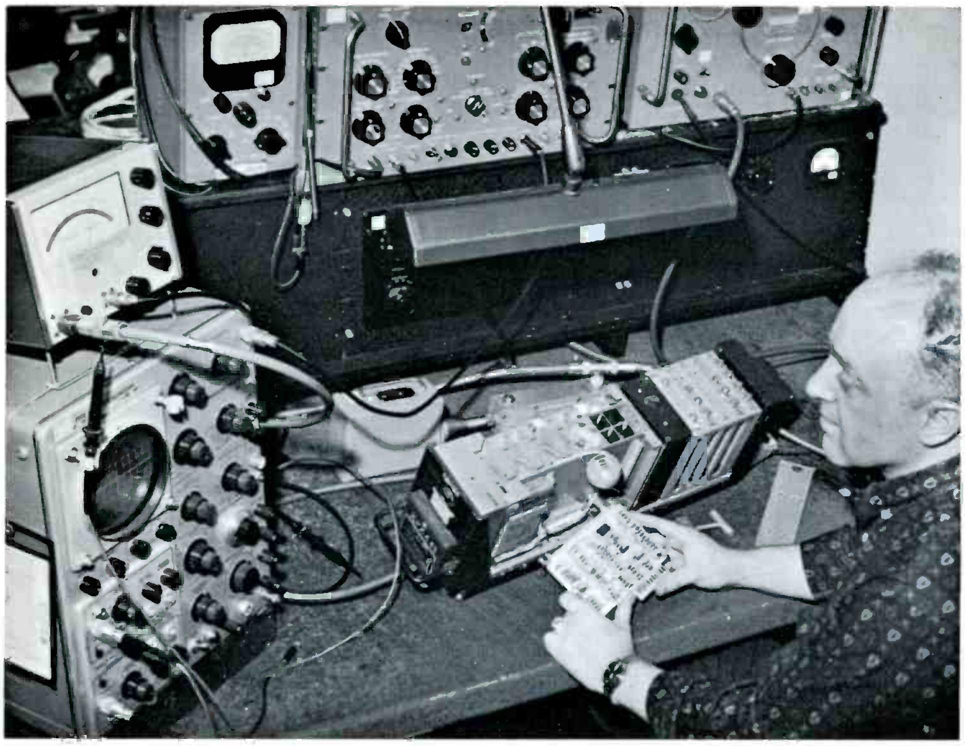


Figure 2 — Video output, taken from the video amplifier, and shown on the scope, left, provides a two pulse waveform with a 12 usec spacing for a given rf. The detected video pulses must attain a specified amplitude — thus indicating proper receiver sensitivity.

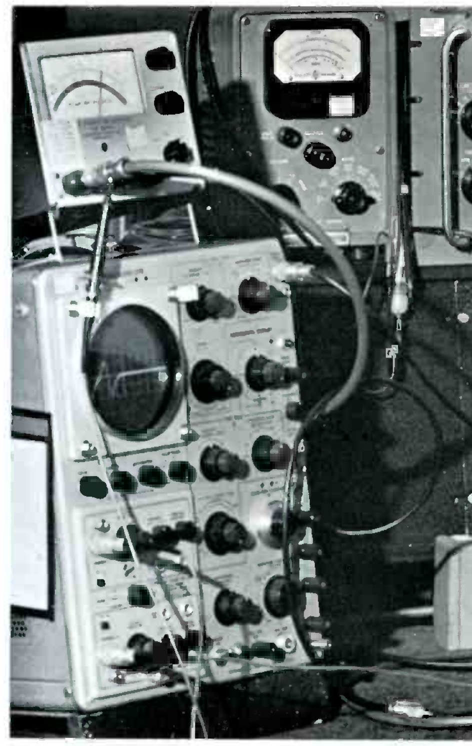


Figure 3 — A Wilcox 714B Transponder undergoes a bench check. These units were recently modified to provide two and three pulse sidelobe suppression.

Test 8 Interrogation Pulse Repetition Rate

Connected to a frequency counter, and with the Distance switch set nearly to the maximum range, the pulse repetition frequency is measured while the DME is searching. The search rate of 145 ± 2 pulse pairs, as averaged over 10 seconds, should be recorded. With the unit set to close range similar measurements are made, with the prf being reduced to approximately 30 pulses per second (or the prf used during track). Pulses are also checked for irregularity of spacing, this being a necessary condition.

Test 9 Search Limit

A short-range search mode is used when the aircraft is within 50 miles of an airport VORTAC station. Channels 17 to 56 are associated with this mode and are usually paired with the VOR which provides the proper bearing for approach to the airport.

An over-ride switch permits the pilot to search beyond the 50 mile range when he is operating on Channels 17 through 56.

With the DME test set adjusted to a low-number channel and suitably connected to the DME, observation is made to determine that the DME transmits only between zero range and middle-close range (50 miles). This procedure is checked on four channel positions.

Test 10 Distance Accuracy

The DME unit is compared to the DME test set and adjusted as required to be certain that the distance module reading is accurate; i.e., that the read-out number corresponds to the proper distance.

Test 11 Distance Module Adjustments

The distance module is basic to the DME; it provides the primary frequency on which all mileage measurements are based.

The distance module test involves three separate sections:

a) check to determine that the suppression pulses are satisfactory.

b) check to determine that the prf has the necessary random characteristic or "jitter". Jitter is needed to provide a unique signature for each DME and to assure that a DME will read back only its own transmitted pulses. If this provision were not made one aircraft could read another and achieve unreliable data—to say the least.

c) check to determine that the DME will provide mileage readings accurate to within ± .2 miles. This is done by adjusting the distance module to a prf of

Figure 4 — Two day's incoming equipments line the first four bins; outgoing, plastic bagged, serviceable, units are on the right. The apparent discrepancy in in-versus-out is accounted for by the fact that serviced units are picked up four times a day.

145 ± 2 pulse pairs (as averaged over 10 seconds) then adjusting the Phantastron gate width so that as the search out to maximum occurs the square wave pulse width (controlled by the Phantastron) increases and maintains a proper relation to distance sine wave. The trailing edge of the Phantastron pulse must always occur midway between the positive peak and negative going zero crossing of the sine wave.

Test 12 Tracking Characteristics and Tracking Error
The DME must track properly at its maximum distance or conversely at minimum signal input. Tests are made to determine that the DME will search, lock on and track from a signal level starting at —90 dbm.

Test 13 Prememory and Memory Test
A DME must "remember" a signal input for a brief time period to accommodate occasions when, for example, the aircraft attitude might not permit reception of a station. During the memory interval, the red flag appears on the distance indicator partially obscuring the reading shown and indicating that it is not to be used. Prior to this, however, or during the prememory period the indicator will stop turning for a period of 4 to 8 seconds; if the signal is found during that time the unit will then continue. If the signal is not found the flag appears and remains for 7 to 11 seconds. Once again, if the signal is found the flag will drop, the unit will "catch-up" and continue to track. Or, if the signal has been lost the unit will begin to search.

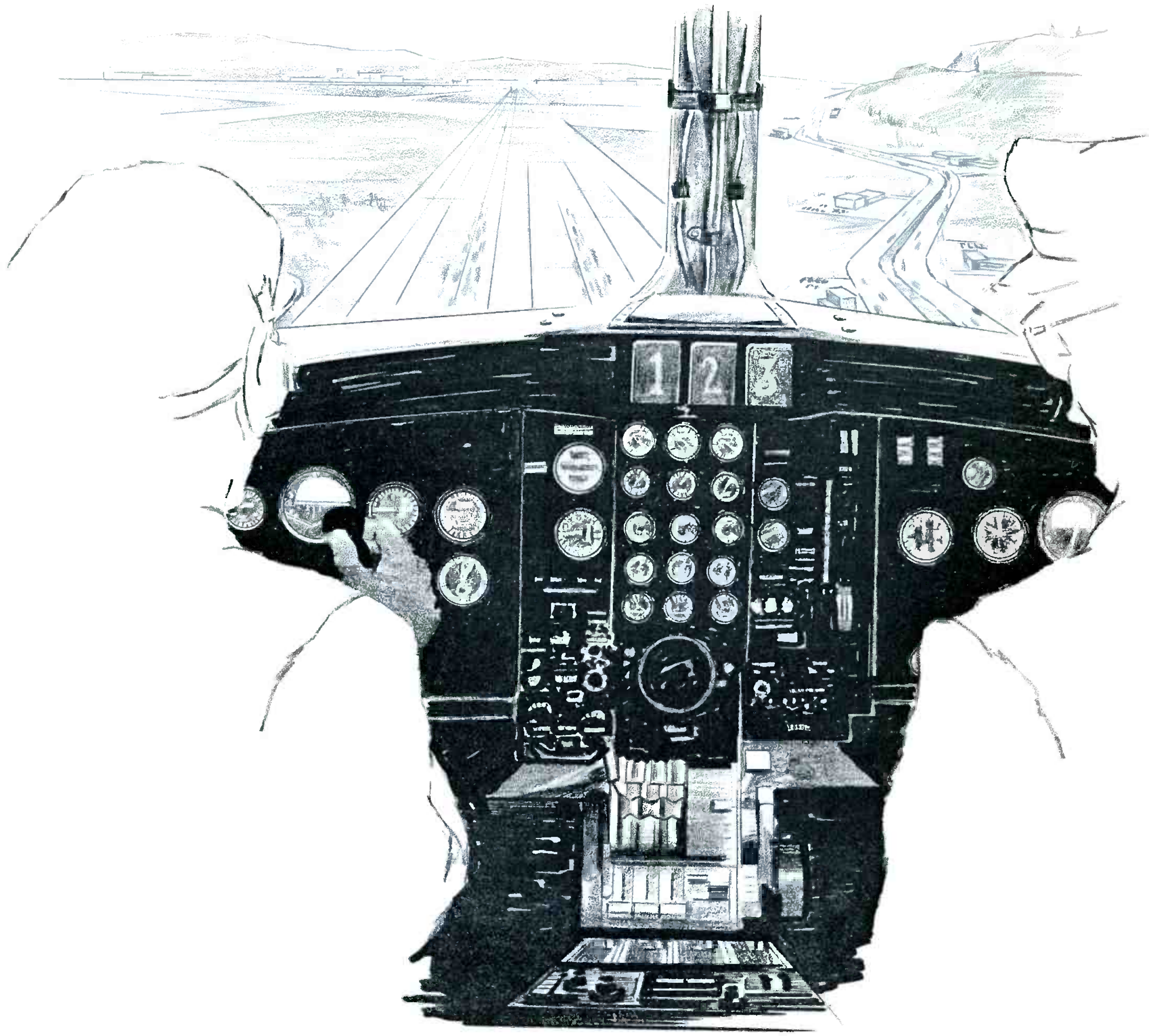
Test 14 Search Time
In this test the unit is adjusted so that it will search throughout its entire range, 0 to 200 miles in no more than 20 seconds.

Test 15 Identification Tone Output
Adjustment for the proper tone output signal to the headsets. The signal referred to comes from the ground station which identifies itself by Morse Code and by tone every 35 seconds.

Test 16 Suppression Pulse Input Test
Pulse suppression is required during transmission from the transponder or DME to prevent receiver overload. Suppression of the incoming video pulse requires adjustment of the suppression pulse and video pulse; the suppression pulse amplitude must be of a specified size. These factors are determined by this test.

Wrapped neatly in its polyethylene sack, properly tagged and with a new date card, the DME awaits flight use. Time for overhaul, approximately eight hours.

American Airlines: A review of a major



Editor's Note:

American Airlines is a major domestic carrier of air passengers and air cargo. It operates a fleet of 171 airplanes (76 fanjets, 24 turboprop Electras, 71 piston planes) to 50 cities in 21 states in the U. S., Canada and Mexico. In 1963 American carried 9,124,000 passengers and flew 7,205,474,757 revenue passenger miles and 210,791,670 ton miles of air cargo. American has on order for delivery in the 1964-65-66 period, 34 more subsonic jets (19 three-engine and 15 two-engine types). American has also reserved delivery positions for 12 supersonic transports, 6 of the U. S. version and 6 of the British-French type.

CATHODE PRESS acknowledges with pleasure the assistance given in the following article by:
E. H. Brown, Manager, Electronics Maintenance
L. F. Reilly, Senior Radio Eng., Communications Section
H. Heyer, General Foreman, Field Electronics Repair Shop

network of Field Electronic Repair Shops

A major airline system must provide a major network of maintenance bases. To take advantage of climate and the unusual mobility of their "product" many such bases are located in warmer areas away from traffic centers. Here the "barn" doors may be open most of the time and here the large scale work — airframe overhaul — is performed. However, a combination of traffic density, inventory maintenance level, and item availability sometimes dictate the need for maintenance base stations located near major terminal areas. Such is the case, for example, with the Field Electronic Repair Shops operated by American Airlines.

This system of Base stations comprises — in conjunction with line maintenance — the first line of defense in the maintenance program. Five such units are operated by American (See Figure 1) at New York (LaGuardia); New York (J. F. K. International); Chicago (O'Hare); Dallas (Love Field); and Los Angeles (Los Angeles Municipal). These shops, in turn, act as a center for area maintenance as shown in the figure just noted. An inventory of spares is provided at each of these five stations as well as at the "feeder stations" shown in Figure 1.

It must be apparent that in any endeavor so thoroughly organized and so thoroughly committed to operate in a specific, legally sanctioned way — as are the airlines — that an electronic shop must be more than a group of electronic technicians or line shop mechanics, as they are known in the industry. Such is, of course, the case.

Beginning, first, with what might be termed the "charter" of the Field Electronic Repair Shop, it is, in accordance with this document, authorized to perform certain specific repairs. These repairs are to be done only by FAA certificated mechanics operating in an FAA certificated shop. In the Shop station repairs are restricted to tube replacement, fixing broken wires, replacing resistors, and to the determination of whether or not a given unit does or does not meet satisfactory operating criteria. These criteria are determined by reference to the Field Electronic Repair Manual which closely defines the checks which may be made. The checks themselves are performed in accordance with individual repair manuals describing a given equipment. A repair manual is prepared by the airline using the vendor's material and is submitted to the FAA for approval of procedure and accuracy. Not until this legal sanction has been given may the manual be used. It may be assumed that changes of its contents are not lightly made since each change would, again, require approval. In this manner a continuity of discipline and high standard of performance is established.

To place the American Airlines' line shop maintenance operation in perspective, it will be well to outline the general program of which it is a part, a maintenance practice known as "Progressive Maintenance." Although the final goal of this program for all aircraft items is "On Condition Status" (in which a piece of equipment, in theory, could never receive a major overhaul, being kept in proper trim by the repeated shop maintenance reviews) this ultimate ideal has not been reached. Progressive Maintenance, is, however, a major step in this direction and relies on the performance of as many maintenance services as possible—short of overhaul—on the aircraft, and the performance of these services primarily in terms of the operating conditions of the item. This is in sharp contrast to "calendar maintenance" in which, regardless of how well it was working, an item was removed and overhauled on a certain time schedule.

In the present system the aircraft is:

a) given a "walk-around" check on layover (every 4 to 6 hours approximately), at which time a visual of equipment security is made.
b) given a service check every 30 hours by line mechanics. (Electronic components, for example, are reviewed to see if their calendar "due dates" for overhaul have matured. Units are monitored for proper output, etc.)
c) given a systems check every 300 to 500 hours in which a mobile "test bench" is wheeled to the aircraft and all systems — electrical, hydraulic, electronic, and so forth — are examined. If everything is all right nothing is changed.

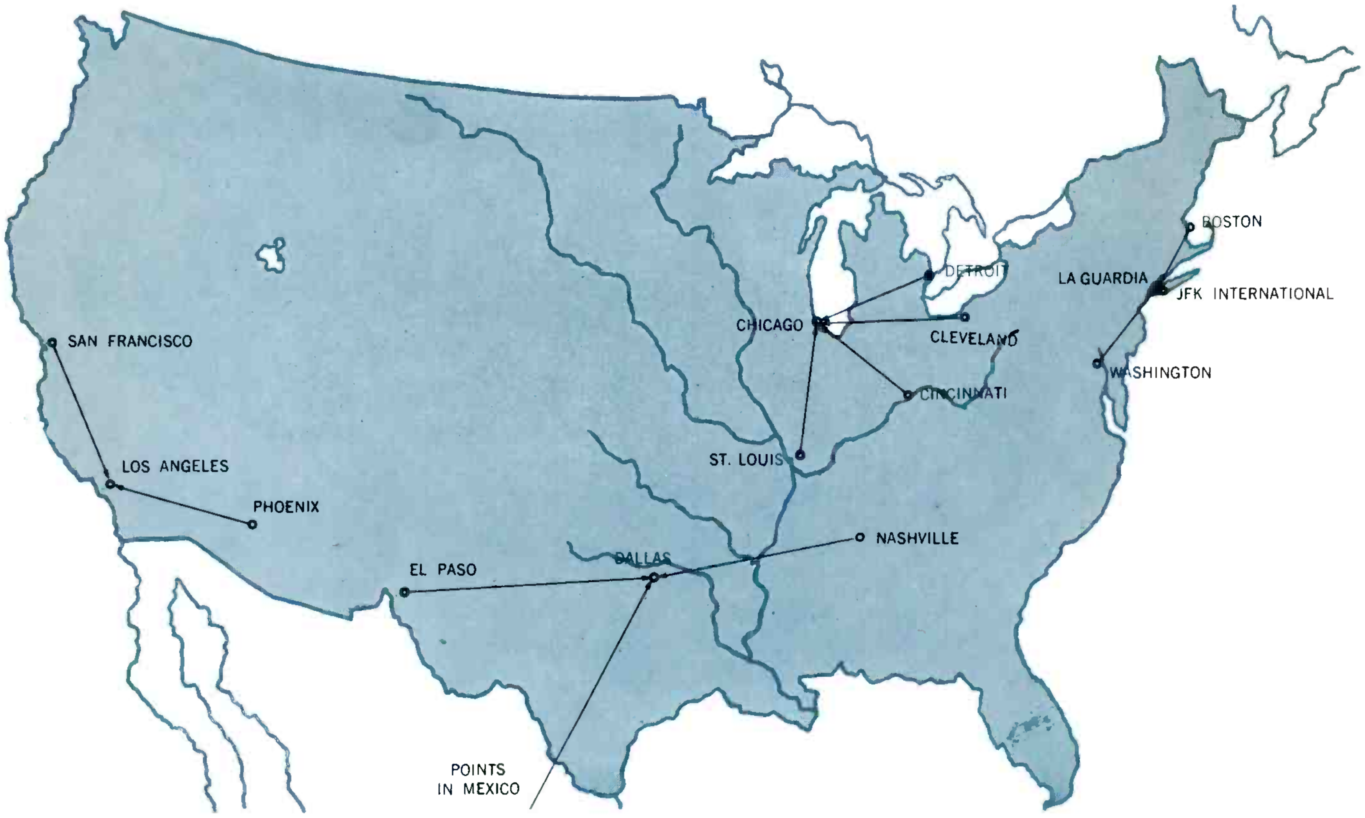


Figure 1 — American Airlines' Field Shop network: Los Angeles; Dallas; Chicago; and New York (two shops). Other points, such as Boston, are feeder shops sending equipment to the Field Shop. Electronic equipment not serviceable by the Field Shop goes to the Electronic Overhaul Shop at LaGuardia (New York).

d) given a base overhaul. (Primarily engines, airframe and cabin furnishings.)

The degree to which longer "on condition" periods in electronic equipment participates continues to grow. The primary change, reflected now in present practice, is found in less frequent removal for interim checks and on the greater reliance on localized or "on-the-aircraft" checks.

Returning now to the specific details of the line shop maintenance situation the usual sequence is as follows:

1. A line mechanic removes a unit on a Pilot complaint or as a result of finding a unit out of specification on the periodic 300 hour check.

2. The unit is reviewed by a line shop mechanic to determine if the complaint or "squawk" can be verified. If it can't be verified (as is frequently the case) and the unit meets operating specifications as defined by the Manual the unit is certified as Serviceable, and returned to inventory. (Note here that its "Service Date" or "zero time" is not thereby altered. The Service Date, found on small card mounted in front of a unit, is changed only after a main base overhaul.) Should the unit be found unserviceable it is, at the discretion of the Foreman of the Electronics Line Shop, repaired and verified as serviceable by the line shop mechanic responsible. His verification is, in turn, reviewed by a lead mechanic known as a Quality Control Designee. Finally, the unit is routed to stores.

An Instrument Panel 60′ x 60′

In a manner of speaking this is what a field shop might be called, for each of the electronic units associated with the instrument panel and pedestal are "mounted" on benches carrying specifically designed test equipment for a given unit (see Figure 2). Nearly all test panels are designed and built at American's main Electronics Overhaul Base at LaGuardia. (Some units, such as KIFIS, are purchased as are, of course, commercial test meters and specialized testers.)

A test panel is designed to accommodate only one type of unit — such as a DME or a VOR/ILS receiver — and provides, operating voltages, input signals and a suitable readout and calibrating device. Each test bench which is electrically isolated, carries power sources, paralleling those found on the aircraft. Power available is: 28 Vdc; 115v,

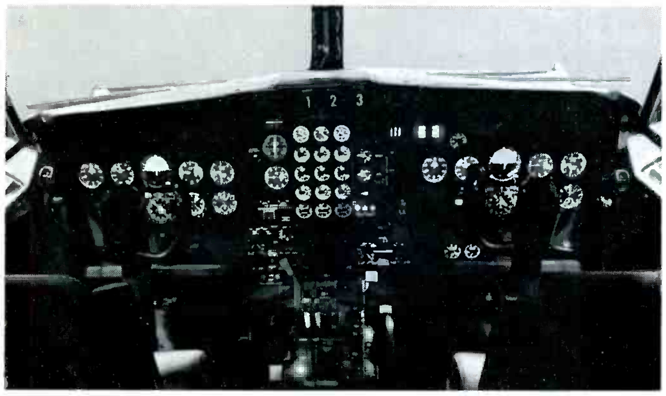
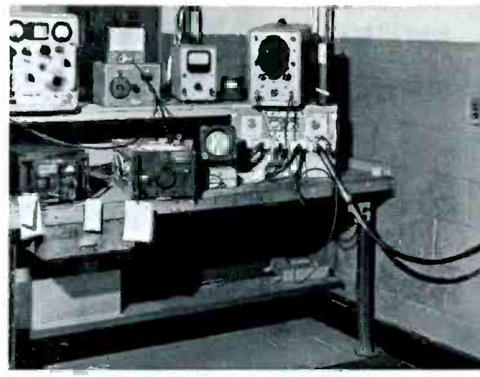


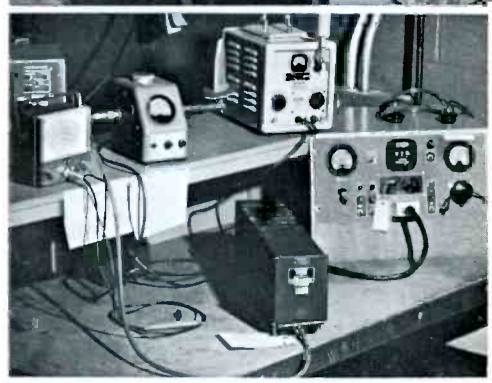
Figure 2 — Above the instrument panel of American Airlines' new 727 jet. To the right, sections of the "60'x 60' instrument panel" — which is, in actuality, a series of specialized test benches on which are laid out the various electronic instruments used by American's aircraft. . . . 2a AVQ 10 Weather Radar; 2b VOR/ILS Receiver; 2c DME; 2d Transponder; 2e KIFIS.

2A



2B

2C



2D

2E

400c, 3 Ø; and 115v, 60c, 1 Ø. Dry compressed air is available at each bench.

To assure the uniform performance of each of its five Line Shops all standards used for calibration, output or other measurements are maintained by a specialist from the LaGuardia overhaul base. Line Shop instruments are calibrated every 30 days against the base standards from LaGuardia.

Twelve Black Boxes and a Tape Recorder

Someday, perhaps, the equipment manufacturers may relent and furnish their units in colors more stimulating than black. Until that time, the term "black box" is necessarily appropriate — (even the Tape Recorder comes in a black box). This seemingly out of place unit, which serves to welcome aboard the passenger prior to his flight, is not on hand to entertain the busy line shop mechanics whose job it is, every so often, to change the tape. In the course of tape changing and the more serious business of calibration and repair, the Field Maintenance Shop at JFK handles approximately 300 units a month, achieving, typically, a 92% effectivity (or, in other words, forwarding to base overhaul only 8% of the incoming units).

Weather Radar

Search unit for safe flight, airborne weather radar provides a display of precipitation areas which may lie in the flight path. The radar return indicates the storm cells and thus allows the pilot to avoid them and fly through the calm areas of the cloud system.

Shown here (Figure 2a) is the C-Band AVQ-10 radar ready for a bench check. AVQ-10 with a peak power of 75kw sweeps out ranges of 20, 50, and 150 miles.

The JFK line shop replaces sub-assemblies as required, services all tubes (except the magnetron), and makes general repairs. Conditions diagnosed as outside the province of the line shop are referred to Tulsa.

A Bench test unit for the smaller AVQ-50 radar is also provided.

VOR/ILS Receiver

Since 1946 when the first VOR systems were installed the VOR-VHF Omnidirectional Radio range has been a major element in the FAA "navaid" or navigational aid program. VOR was coupled with TACAN (as described elsewhere in this issue) in 1958 to produce VORTAC, now the primary navigational system for commercial airlines — and a growing system general aviation.

A VOR station, operating on frequencies between 108 and 118 mc, provides a 360° "spoked" wheel giving an azimuth information to the pilot. Each spoke or radial, separated by 1°, is indicated on bearing selector on the aircraft's instrument panel; other indicators provide on-bearing or off-bearing information and to-or-from the station data.

Using a VOR* bearing a pilot may fly an accurate course heading, may establish ground speed by noting time between radials (as he flies on a course perpendicular to the radial), may establish a fix or series of fixes using two or more of the 700 plus VOR stations now in use.

With the equipment here, as with the similar units used by commercial airlines, the VOR receiver has associated with it an ILS — Instrument Landing System — section used after the plane has approached the terminal area and is established in the traffic pattern.

Shown here (Figure 2b) is the test equipment associated with the VOR/ILS receiver. At the left, signal generator (power supply not shown), next an ac voltmeter; top right a commercial unit providing omnirange and localizer simulated signals: middle, right, power supply; bottom, right, a panel designed and built by American Airlines at LaGuardia. This panel displays: receiver signal output; glide path deviation and localizer, or range deviation, output (readout unit, top row of instruments, second from left); omnirange course information — given in ua; bearing indicator; and a to-from indicator. On the bench is the unit under test.

Marker Receiver

Closely related to the ILS equipment, just noted, is a highly selective receiver tuned only to the 75 mc marker beacon signal. As the aircraft descends on the glide slope toward the runway it passes over an outer and then a middle marker beacon. These are narrow, highly directional beams (in the vertical), which cause signal lights (first purple, then amber) to appear on the instrument panel as the aircraft passes over the beacons. Beacon position is specifically charted for every landing field runway and the pilot knows, for example, that as he passes over the outer marker beacon he is 5 miles from the end of the runway, and next, when the amber beacon signal appears, that he is 3500 feet from the end of the runway. The runway approach lights lead in from this point. (The marker receiver bench is not illustrated.)

Glide Slope Receivers

Glide slope information, transmitted in the 328.6 to 335.4 frequency range, is originated from an antenna located on the center line of the runway and is normally under the 50 to 1 clearance plane. Glide slope angle is established between 2½ and 3 degrees depending on the terrain. Glide slope reference is maintained in cockpit by means of the glide slope needle on an indicator (as shown on the test panel, Figure 2b).

Communications

VHF Receiver — VHF Transmitter

Air to ground voice communications is an essential part of the operation of the commercial aircraft. Because of the basic importance of voice communications the commercial aircraft maintain a VHF transmitter and receiver* for use at all times to talk with the en route FAA controller or with the air line's own communications network.

Similar to the transition from 200-400 mc airways "beams" to the VOR radials has been the change from HF to VHF in communications equipment. VHF has eliminated the effects of variable propagation characteristics (the right frequency had to be "matched" to existing atmospheric conditions for best reception; but this was not always possible and added complications in any event). VHF provides positive communications but limits propagation to line-of-sight, hence requiring more ground stations than HF for adequate coverage.

Designed to tune in 50 kc increments over the band from 118.0 mc to 135.95 mc the VHF transmitter is checked for accuracy of carrier frequency (.01%) and power output (25 watts). The VHF receiver is checked for sensitivity and alignment as well as proper frequency selection. Transmitters are checked for proper modulation and sidetone. (The Communications Bench is not illustrated.)

*VOR has superseded the LF/MF or A/N four quadrant range system which supplied the "beam" for navigators and pilots up through WW II and which is now in the process of being largely phased out. Relying on aural indications for to-from (station) and on-off (course), subject to static and fading, severely limited in numbers of channels and accuracy of "beams," the old low frequency system is entirely inadequate for modern high speed, high density navigation.

*There are two VHF communication systems on each aircraft. And two VOR systems that could be used as auxiliary receivers on the communications band.

ADF — Automatic Direction Finder

Originally associated with the LF/MF "beam" airways the ADF was used to provide radio fixes or, if necessary, to "home" on known radio stations. Covering a band from 100 to 1700 kcs this permitted, and still permits, the pilot to use, for example, commercial AM transmitters as powerful homing devices. However, ADF is relatively slow, and somewhat less accurate than VOR and also requires that the pilot generate his own To/From reference. ADF is now a back-up system (except for those areas outside United States and Europe where VOR systems do not exist).

The active element for the ADF is a rotatable loop antenna automatically tuned or positioned with to face to the desired station. It provides a "radio compass" readout on the instrument panel. Unlike the VOR reading magnetic variation is not accounted for and must be included as a correction. (The ADF test bench is not illustrated.) The Automatic Direction Finder is checked for sensitivity; antenna and loop position; dial accuracy (e.g., that the dial reads 200 kc on 200 kc); and azimuth accuracy.

DME

A DME is set up as shown (Figure 2c and Figure 3), connected to the 28 Vdc and 115 V 400 Cac supplies. Output pulse power (1 kw to 3 kw) is verified. Set to a frequency at the low end of the band (117.1 mc) a unit is checked for search at 5 and at 100 miles; this step is repeated at the high end of the band, 134.6 mcs. For the final check the unit is connected to an outside antenna and operated, proper mileage readout on the indicator being the final criteria.

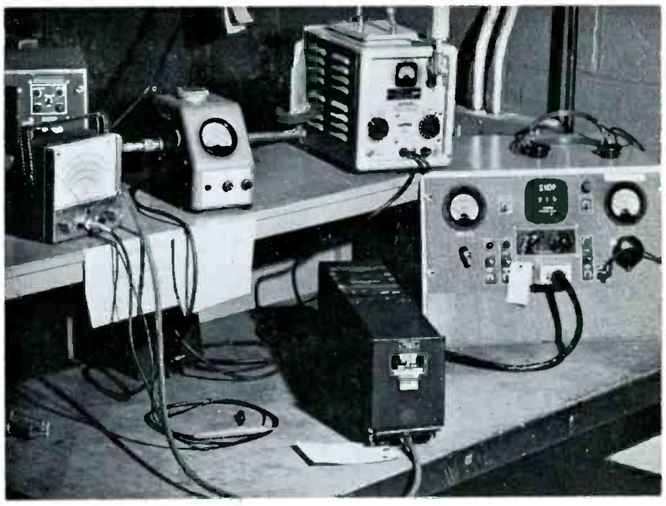
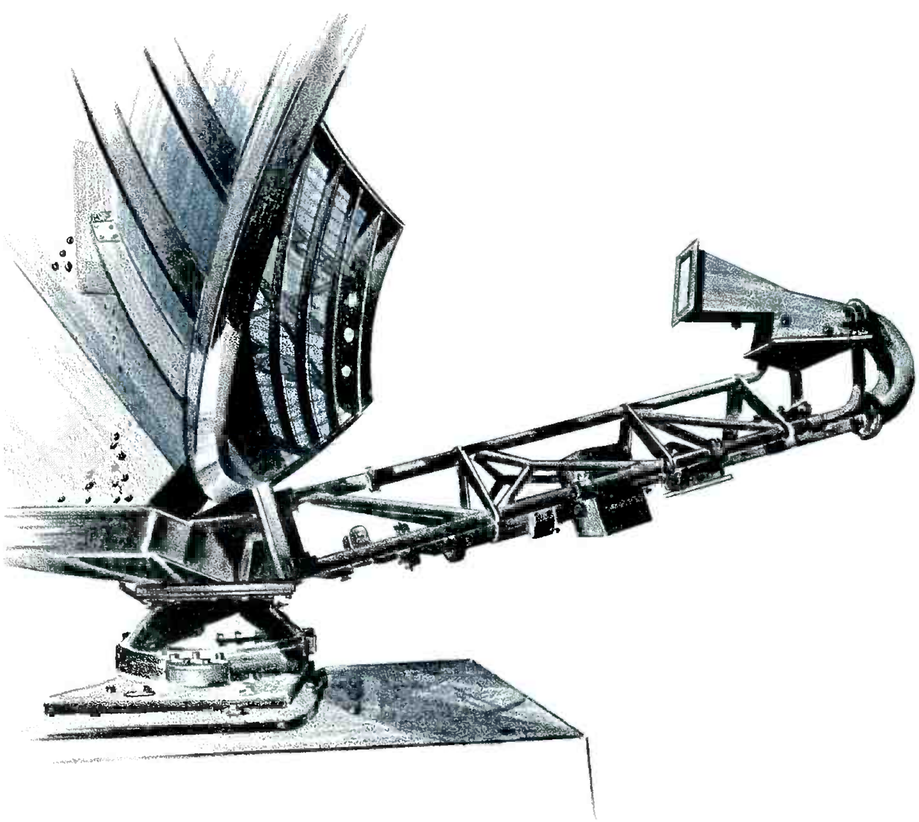


Figure 3 — DME Test Bench. The DME 100A and B (similar in external appearance to the unit shown) is now used extensively. The DME 100A or B is manufactured by Federal ITT.

The line station installs Machlett ML-7815 tubes as required. These output tubes are replaced one at a time until



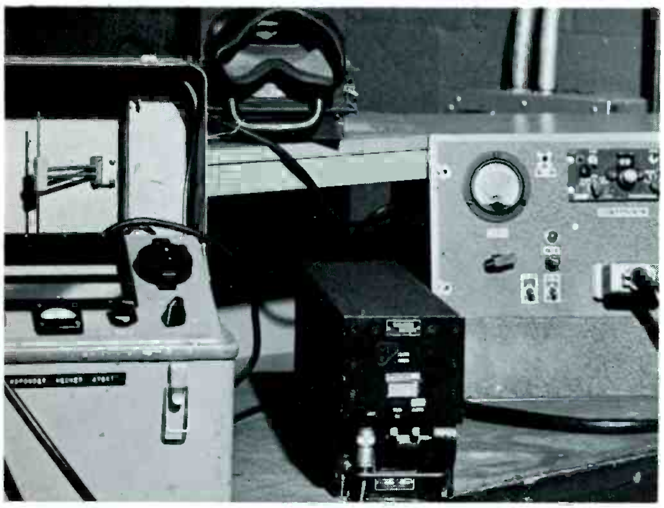


Figure 4 — Transponder Test Bench shown is the Collins transponder (Model No. 621A-2), bench and line check instrument and readout equipment.

required power is obtained.

For the purposes of the photograph the test units have been grouped in a manner which is not normal. For an actual test, the TACAN test set (manufactured by Federal ITT) is placed approximately 15 feet from the DME transmit-receive antenna (the blade seen in the upper center of the picture). The TACAN test unit is adjusted to transmit a certain mileage range and its output is fed to the DME 100A as shown. The TACAN test set provides both distance and bearing signals; the distance being read out on the range module of the test unit on the bench. Bearing signals are not used in the DMET system.

Transponder

The Transponder bench shows, from the left (Figure 4) a Transponder checker, Collins 576X-1, (used on the line, also), an oscilloscope, a Transponder and a test panel providing for mode and code selection. Briefly, the Transponder (Collins 621A-2) is examined for: power output (a minimum of 500 watts); receiver sensitivity (—72db); and mode selection.

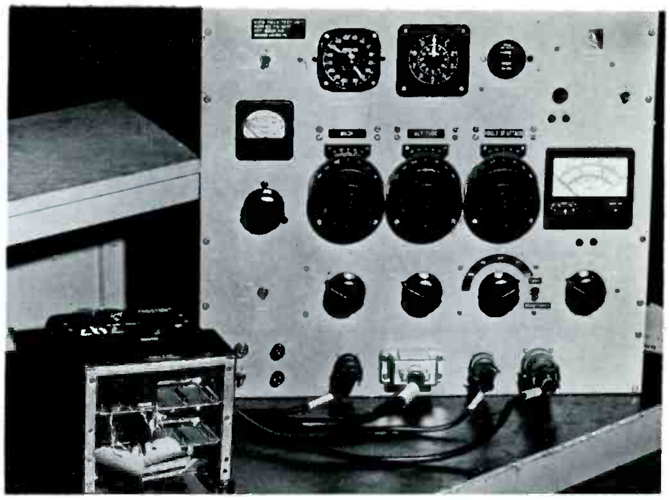


Figure 5 — KIFIS test unit, KIFIS at left, readout equipment at right. The KIFIS system provides accurate instrumentation data for the pilot.

KIFIS

KIFIS (Figure 5) is the name of an integrated flight system (manufactured by Kollsman Instrument Corporation) which presents to the cockpit flight readings which are continuously calibrated, corrected and/or inter-related as the case may be. A control chassis, shown, left in Figure 5, contains the matchbox size computers which perform the integrating operations.

Basically the KIFIS presents:

a) a reading for Airspeed/Angle of Attack*

b) a Machmeter

c) an Altimeter

d) True Air Speed (Airspeed vs. altitude vs. temperature)

e) Static Air Temperature.

*This instrument dial (not shown in the photograph) uses two pointers (one checkered, one plain) and an "angle of attack" segment indicator. The checkered pointer indicates maximum allowable airspeed (a modern version of the "red line" speed beyond which the aircraft may not go) corresponding for variations of altitude and temperature. As the aircraft climbs beyond 23,000 feet the maximum IAS (indicated airspeed) must decrease to keep the plane within proper Mach limits. The second pointer shows IAS. The angle-of-attack segment receives information from the angle of attack sensor; this data is integrated with pitot pressure (or airspeed data). The angle of attack segment then follows the IAS pointer to show the optimum IAS range for a given angle of attack — or in other words, to show the optimum IAS during cruise, approach, climb-out and rotation (nose up on take-off).

Editor's Note:

Trans World Airlines is a major carrier flying 50,000 miles of domestic and international routes. It operates a fleet of 83 jet aircraft and 86 piston aircraft serving 87 cities in 13 countries. In 1963 TWA carried 6,836,000 passengers and 152,267,000 ton-miles of airfreight. TWA has ordered 10 of U.S. manufactured and 6 Concorde supersonic transport aircraft.

CATHODE PRESS acknowledges with pleasure the assistance given in the preparation of the following article by:

John J. Kennyhertz, Director, Electronic & Communications Engineering

G. R. Hoffman, Manager, Electronic Modification Engineering

L. S. Gallemore, Master Engineer

J. F. Nemecek, Master Engineer

New Directions

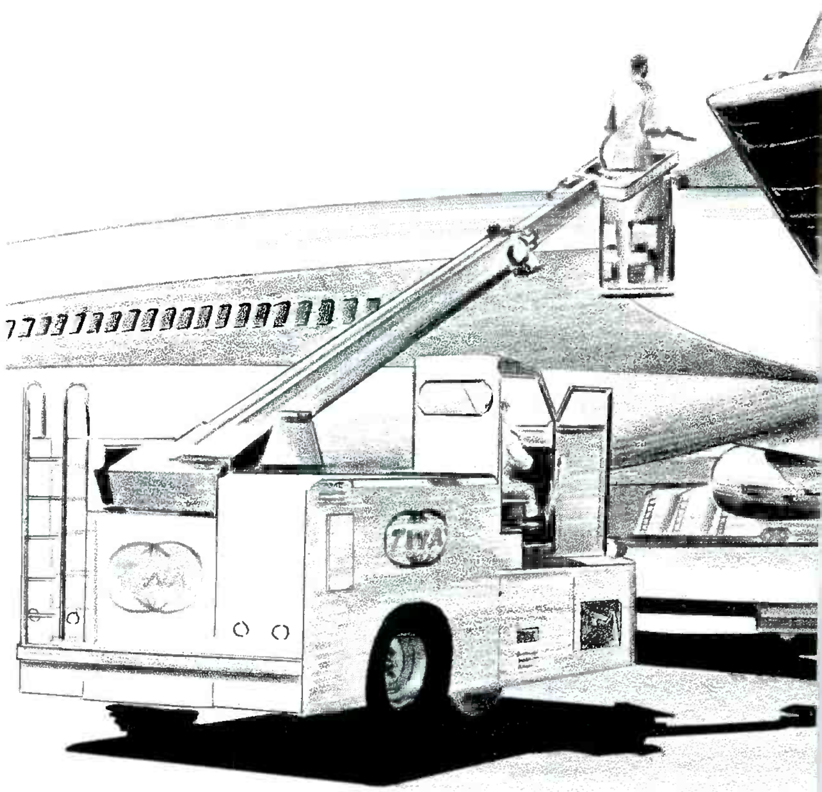
Trans World Airlines

Thirty years ago the railroad track was a useful part of a visual "coordinate system" used by the pilot-navigator. Today it is doubtful if he could even see the main line much of the time. Coupled with the virtual disappearance of visual reference, (even the clouds are watched with radar), the loss of physical reference (the stall warning computer has done much to replace the "seat of the pants") and the tremendously increased complexity of the aircraft — to say nothing of the need to make firm decisions well in advance of trouble (too late comes much sooner these days) — has been the explosive development and use of electronics. It may be fairly said that no other form of transportation (if we exclude space capsules*) would be so quickly crippled without its use.

Data prepared by the TWA engineering staff documents the foregoing in a striking way and shows a range of 440 to 7300% for increases relating to Number of Tubes and Semi-Conductor Devices to electronic equipment dollar value. (See Figures 1 to 4).

An obvious corollary to this situation is a heightened requirement for precise equipment maintenance. But, as in-

*It is apparent, too, that the space capsule does not even have a pre-electronic past; it was born full into the golden age and would be inconceivable without electronics.



in Maintenance Program — Trans World Airlines

dicated elsewhere in this issue, as well as here, large-scale equipment maintenance is not simply a matter of precise work on the bench. It is, indeed a matter of affecting the very structure of the airline operation, and is designed to keep equipments at work for periods of as long as can be established as statistically valid, and requires a very nearly superhuman sense of self-awareness.

Although a jet engine itself is four to eight times as reliable as the best piston engine, the overall "mechanical delay" rate of the jet aircraft is perceptibly higher. To keep this factor as close to the piston rate as possible (4% vs 2%) TWA, in keeping with other airlines, has engaged in programs which go directly into the actual design of the aircraft and its associated equipment. For a major trunk airline the cost and complexity of such a program is great. TWA, for one, has had to:

"1) Make organizational changes to arrange our 5400 "manyears" of technical talent into a staff which in some respects resemble the specialization of the medical field. Specialty Foremen in power plant, electrical and instruments, electronics, mechanical systems and structures handle the front line day-to-day problems. The second echelon, Maintenance Engineers in the same specialties coordinate the activities of the Specialty Foreman and disseminate the distilled knowledge gained from front line experience. Their concern includes development of quick fixes, frequently on a fleet basis. Backing up both of these echelons are specialized Systems Engineers concerned with the development and application of long term modifications to improve performance of systems, to facilitate maintenance or to extend service life of components.

2) Establish a central Maintenance Coordinator office (see figure 5) at our base (see figure 6) near Kansas City provided with a nationwide network of leased intercom-type telephone circuits for rapid communication with the various stations on our routes.

3) Accomplish over 20,000 manhours per airplane of modification effort. This is nearly two hours of modification effort for each hour of flight.

4) Make a spare parts investment exceeding $71,000,000 representing 20 per cent of our aircraft original cost. This, incidentally, has been held nearly 5 per cent below what would have been otherwise necessary through aggressive and judicious pursuit of parts pooling with other carriers.

5) Make a tooling and test equipment investment of $8,000,000. (See figures 7 and 8).

6) Provide initial and recurrent training in excess of 1,250,000 manhours, the equivalent of 400 man-

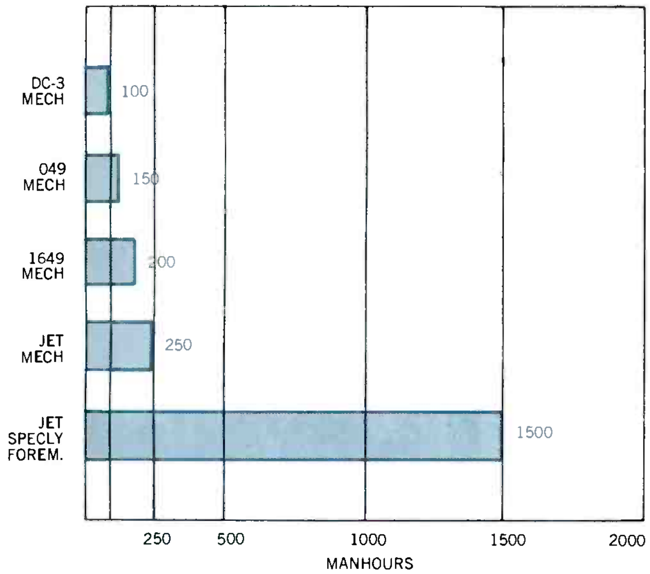


Figure 1 — Electronic Training Requirements.

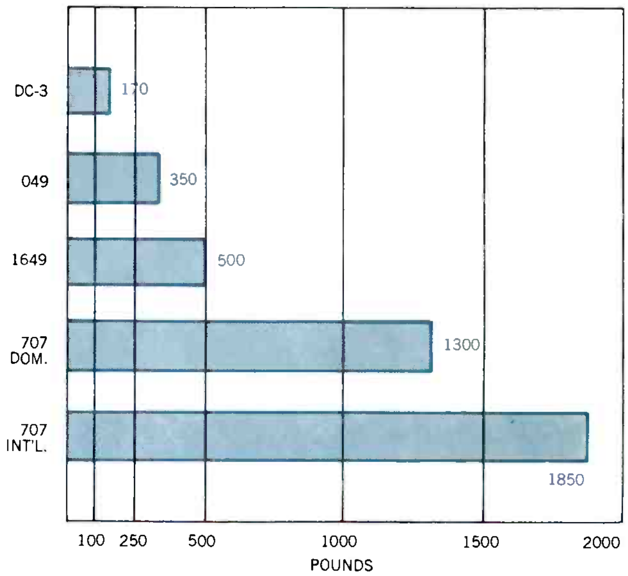


Figure 2 — Weight of Electronic Equipment.

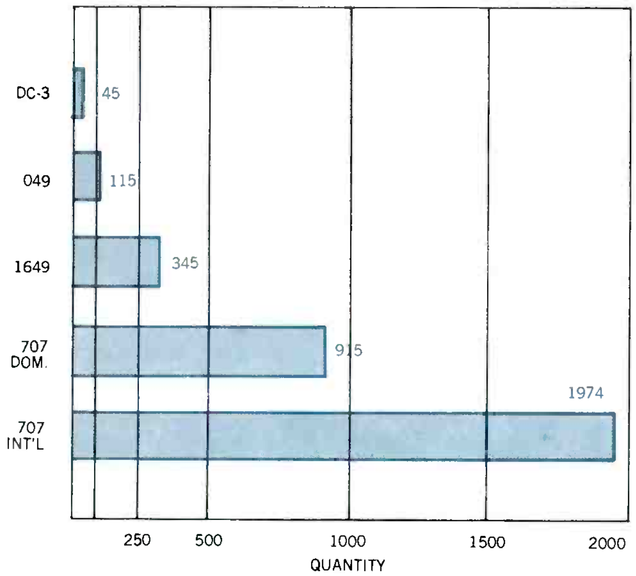


Figure 3 — Number of Tubes and Semi-Conductors Devices.

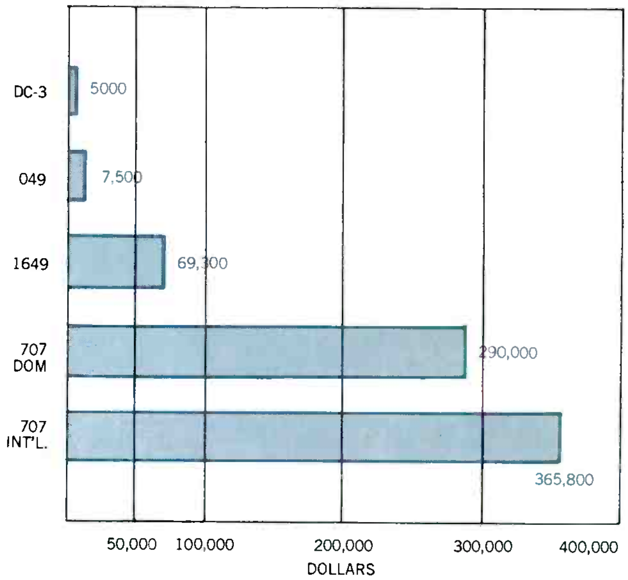


Figure 4 — Electronic Equipment Dollar Value.

hours per mechanic.

7) And most importantly, properly utilized the dedicated efforts of an experienced, well organized group of sensitive responsive people who can set winning strategy and quickly marshall the forces to achieve it."*

At 11:00 each morning

At precisely eleven o'clock each morning a group of ten to fifteen persons — each having specific responsibility for some section of TWA technical operations (as distinguished from marketing, finance, etc.) — meets to discuss and evaluate, in the manner of a post-graduate engineering seminar, the principal factors involved in delays of the day preceding. In a special room, (see figure 8) lit in a low key, with a podium for the speaker, microphones hanging from the ceiling, a large conference table — as well as chairs by the wall — the agenda is presented to the group. Surrounding them are ten sizeable bulletin boards, each with updated information on subjects such as Operational Performance, On Time Performance, Engine Time, Major Modification Status, aircraft comparisons, and Departure Delays Due to Maintenance.

Before each participant is a document (two, three or more pages) entitled

"Trans World Airlines, Inc.
Operational Planning
Operational Planning Briefing and
Performance Resume
Issued . . .
Covering the period 0001-2400 local
time . . . (date prior to issue date)"

Listed on Planning sheet is weather, both domestic and international.

For example:

International

February 25 F-585-25 was setup over MIL due to rain and snow. Fog at LON resulted in the over weather operation of F702-25.

February 26 Slack gradient over the United Kingdom France Germany with widespread low ceilings and fog causing LON and PAR to be marginal to below limits until 1000Z. A new Atlantic wave approaching the Iberian Peninsula will cause gusty surface winds at LIS.

"Activity Factors", Domestic is the next major listing. This includes "Mileage Performance" (scheduled miles, e.g., 302,171 miles flown and performance factor, e.g. 99.8); "Total Cancelled Miles" (cancelled departures and a breakdown of miles and flight sectors); "Origination Performance" (flight departure delays as grouped by number of minutes delayed); and "Termination Performance"

*From "Daily Sensitivity to Reliability", a paper prepared by B. M. Meador for presentation at the American Management Association Air Transport Conference.

Figure 5 — Open for business 24 hours a day, seven days a week, the Maintenance Coordinator's office is in constant contact with the entire maintenance system, acting to correct immediate aircraft problems and coordinating action with the appropriate Engineering, Flight Operations or Administrative group as required to keep TWA flights on schedule.

Figure 6 — TWA's $25,000,000 overhaul and maintenance facility at Mid-Continent International airport at Kansas City, Mo., is pictured in this bird's eye view. Building at left foreground is the engine overhaul center, with its adjoining noise proof test cells. In upper center is the airframe overhaul building which has a center section for shops on the ground floor and offices on upper two floors.

Figure 7 — Ground time must be kept to a minimum to keep pace with the fast flight schedules of jet aircraft. Whether it be a routine de-icing job or repair of an antenna up at the top of the vertical fin, aircraft maintenance must be exacting and backed up by specialized equipment.

(arrival time vs scheduled time). A similar group of data is prepared for International Flights. The report also includes information on "Equipment" (engine changes; cylinder changes; fuel leaks; damage) and a section "Unusual Incidents — Preliminary Report". Here, for example, one finds such problems as loading delays, fuel pump malfunction, windshield crack, and so on.

Each participant having read his report, the briefing chairman, (using a telephone tie-in), then proceeds with a roll-call around the United States: Chicago, St. Louis, Kansas City, San Francisco, New York. Each person, Maintenance Director or Supervisor, is asked what his previous day's problems, if any, might have been. He reports and is questioned (via the ceiling mikes) by the expert member (or members) of the panel whose responsibility lies in the area of the difficulty. The discussion may be brief: "San Francisco reports no malfunctions or difficulties today"; or, for example, "New York reports a wing flap warning horn failed to turn off on Convair 880 — P8810 . . ." This, in turn, may start a discussion between New York, Kansas City and Chicago on the warning horn. The briefing system would, at that moment, be serving a major function by unifying otherwise isolated units of information, sensing and then defining a trend before it reaches a "noticeable" size. In other words, it is the function of this group to "notice" before anyone else — and they are equipped for this apparent clairvoyance by their individual expertise and by the immediate review of the entire operations system that their briefing provides. (We are pleased to note that, on the day that CATHODE PRESS was privileged to attend a session, no electronics equipment malfunction was listed by any reporting station. See figure 9).

The briefing session, proper, may last one half hour or more, but the ideas generated and the trends established and to be acted on, go far beyond this period. In fact, a form of centralized technical coordination is active 24 hours a day. The Maintenance Coordinator staffs a central office manned by specialized personnel; he accepts incoming teletype and telephone messages from the entire system and even, as required, from the flight captain or flight engineer during a flight. In addition, this office acts to correct immediate problems and perceives trends and coordinates action with the appropriate Engineering, Flight Operations, Technical Services or Administrative Group.

On Condition Maintenance

The Wonderful One Hoss Shay, with its extraordinary record for maintenance-free performance, has perhaps influenced too many of us. It is unfortunately apparent, for example, that many motorists continue to operate their vehicles long after even the most optimistic overhaul period

Figure 8 — At precisely eleven o'clock every morning this group from Technical Services Management at the Kansas City Overhaul Base review with the Maintenance Manager at all major maintenance stations the flight activities of the previous day to evaluate factors that have caused flight delays. This type of nation-wide conference is made possible by special telephone circuits connected to the microphones hanging from the ceiling.

has passed. But it is still a fact that "least maintenance" is the ideal goal. "On Condition" maintenance is the modern approach to this and is the answer in dynamic terms (as apposed to "static" or scheduled, periodic maintenance) to the question: How long may this equipment be safely operated before it needs repair or overhaul? TWA has inaugurated a program for providing an answer to this difficult question. Although the program now relates primarily to engine performance, aircraft structure, and electrical systems, it is planned in the future to apply it to the electronics equipment also. For this reason, but more because of the significant implications of this development, the "Airborne Performance Recorder" Program is reviewed below in some detail. (See figure 10).

TWA uses a recorder capable of monitoring 315 individual parameters; 207 are used in the present system, data being presented in analog form available for conversion to digital data for computer use.

In the present installation the recorder uses inputs from various existing sensors or transducers (used in conjunction with cockpit instrumentation) to obtain electrical signals for such factors as speed, positions, levels, temperatures, and pressures. As described* by B. M. Meador, Vice President, Engineering, Flight Test & Inspection, the current program "is directed toward establishing and developing:

1. Reliability of the recorder and sensing equipment.
2. Selecting and revising parameters as necessary to detect faults and equipment deterioration.
3. Development of the data processing programming which is necessary to handle the volume of recorded data.
4. Print out of data at line stations to be used as an aid for trouble correction.
5. Transmission of data from a line station to a central computer control point.
6. Transmission of data from the aircraft to ground for processing prior to flight termination.

All these steps must be evaluated prior to further consideration of equipment and methods for complete fleet installation.

Through proper system recording and data analysis we expect to be able to achieve "on-condition" maintenance. Our interpretation of "on-condition" maintenance is: To avoid the regular replacement of operating units so long as their performance is definitely above minimum established performance levels. This is quite different than the existing "time" control methods employed today. Time between overhauls is a very cautious and conservative limit placed on units and systems by statistical methods estab-

*From "Airborne Maintenance Recorder. A New Airline Tool" by B. M. Meador, a paper presented at the Aerospace and Navigational Electronics Conference, Baltimore, Maryland, October 21-23, 1963.

lished to avoid the consequences of a large number of failures. The penalty for this method of control is that many systems are removed with actually many more hours of good serviceable life remaining.

A more practical approach would be to know the actual state of health of a system at a frequent interval throughout its entire service life. This can be achieved through the use of an airborne recorder and proper utilization and analysis of the data acquired. Essentially this is the same principle as an electrocardiograph that a doctor performs when checking a person's state of well being.

Let us now consider the capability of recording each aircraft and its systems performance during each entire flight and retaining this information on a magnetic tape. By the use of high speed ground playback and computer processing we will have the ability to recognize out of limit conditions and establish trend information which will enable the prediction of impending out of limit conditions. From this we expect to schedule unit removals at a convenient time ahead of a malfunction. This will permit us to take advantage of the system's potential reliability — extending utilization and thereby reducing overall operating cost and at the same time reducing further the percentage of flight delays.

Thought has also been given to the sudden or abrupt type failure. As we know from experience a unit may operate satisfactorily within limits for months and yet suddenly fail. We believe that previous to the malfunction there may have been slight indications which are warnings of impending malfunctions. We intend using the recording system as a tool to determine if there are significant warnings in advance of an actual failure.

Others in industry, like ourselves, are reaching for the benefits of the "on-condition" maintenance philosophy in lieu of time removals by statistical control. Through the use of recording programs similar in nature to ours data is gathered and trend and performance charts are plotted for analysis. This is particularly evident in the field of aircraft jet engines through log analysis studies. The readings and recording of data has been manual in nature for the most part, however it is significant that recording is being conducted.

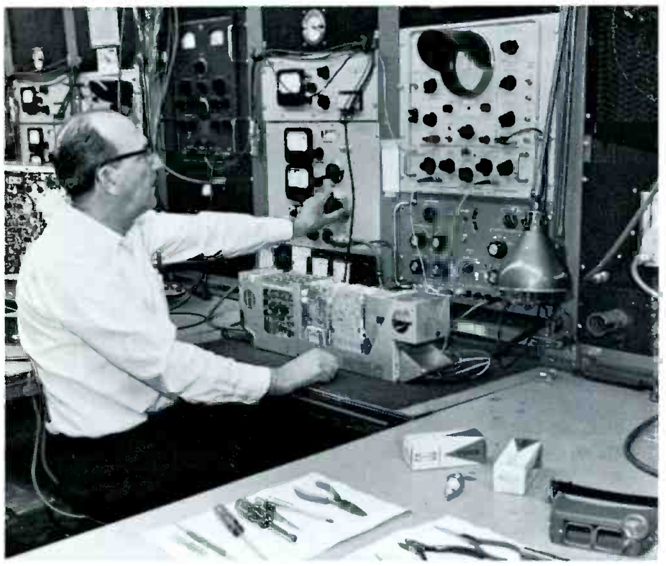


Figure 9 — When electronic units such as this DME Interrogator are removed from an aircraft, they are sent to the Kansas City Overhaul Base Shops where a large force of approximately seventy-five men keep TWA's electronic equipment in peak condition. The superior stability and long life of Machlett 7815 planar triode tubes used in the transmitter section help maintain optimum performance over long periods of time in service.

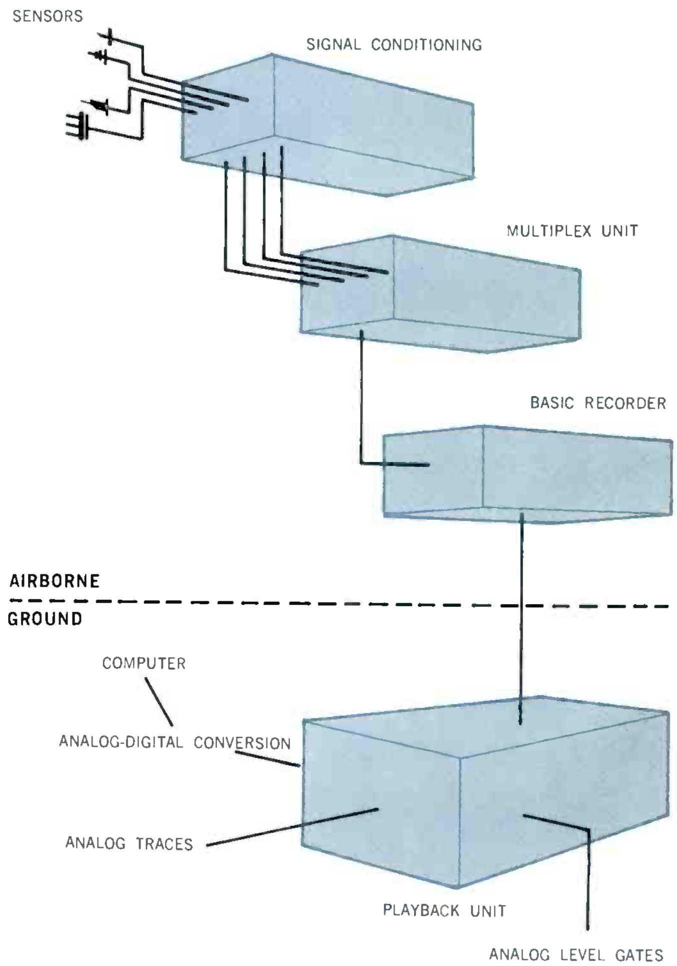


Figure 10 — The Airborne Performance Recorder monitors up to 315 individual parameters which can be analyzed and compared at high speed in the Ground Playback Unit and Computers. Much as an electrocardiograph is used to check a person's state of well being the Performance Recorder continuously checks the condition of an airplane. This analysis of recorded data makes it possible to predict impending out of limit conditions and schedule unit removals at a convenient time ahead of malfunction.

Our automatic recording program provides the advantages of:

1. Automatic recording
2. Higher sampling rate
3. More parameters
4. Increased accuracy
5. Faster processing for analysis
6. Correlation and computation of related parameters
7. Library of data for evaluation of aircraft and systems performance

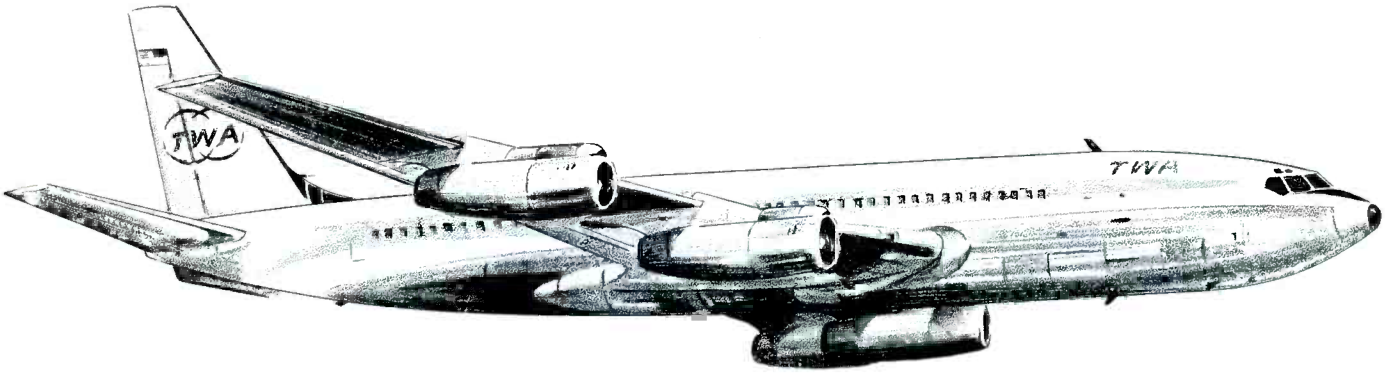
Through these advantages we anticipate that we will not only be able to detect impending malfunction but will be able to run an audit and analysis of the fleets on a full time, 100%, aircraft basis. This, when applied to fleets of aircraft, would also enable the pinpointing of individually "sick" aircraft which may be responsible for fleets being off performance average. To our knowledge a continuous 100% fleet audit of individual aircraft performance has not previously been accomplished. Through the use of an airborne recorder we will be able to handle the performance analysis of individual aircraft on a daily basis and fleet on a bi-weekly schedule. This type of audit increases the sensitivity from which early signs of gradual performance deterioration can be detected and corrected. The result is expected to be a substantial monetary savings.

For example in 1962 TWA's fuel bill was over fifty million dollars. With only a two per cent improvement in our actual versus chart performance operation of our jet aircraft we can obtain savings in the order of one million dollars. We believe that such a saving is both realistic and obtainable."

It is not, we suspect, too large a flight of fancy to conceive of a time when, coupled with a telemetry system, and a suitable computer network that some SST* of the future may be maintained in flight and, to a large degree, automatically by virtue of the output of its own multiparameter performance recorder. Surely reliability must keep pace with performance — for, utltimately, there cannot be one without the other.

---

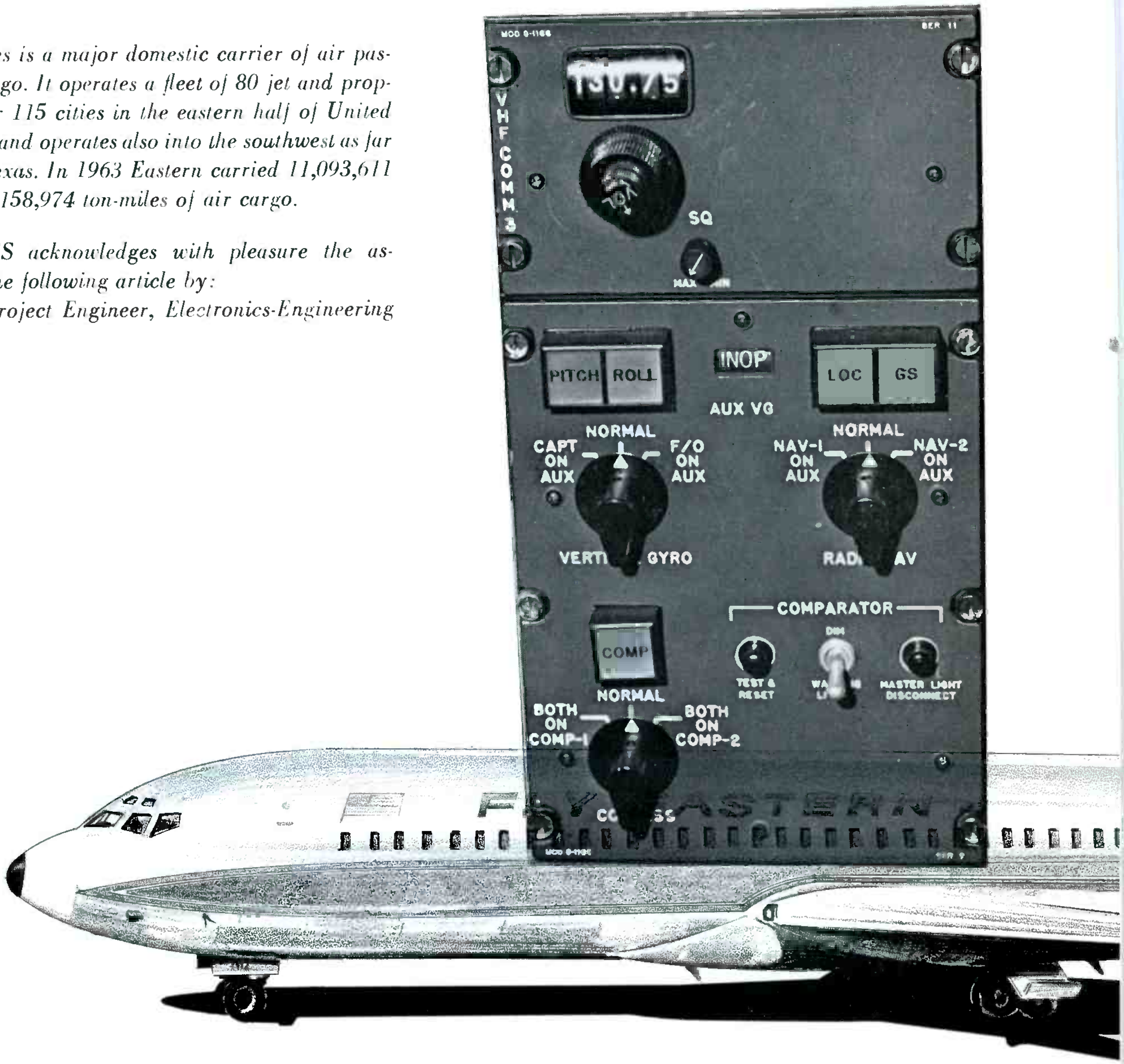
*Super Sonic Transport, operating at Mach 2 or Mach 3.



Editor's Note:

Eastern Air Lines is a major domestic carrier of air passengers and air cargo. It operates a fleet of 80 jet and prop-jet aircraft, to over 115 cities in the eastern half of United States and Canada and operates also into the southwest as far as San Antonio, Texas. In 1963 Eastern carried 11,093,611 passengers and 71,158,974 ton-miles of air cargo.

CATHODE PRESS acknowledges with pleasure the assistance given in the following article by:
H. F. Harrison, Project Engineer, Electronics-Engineering



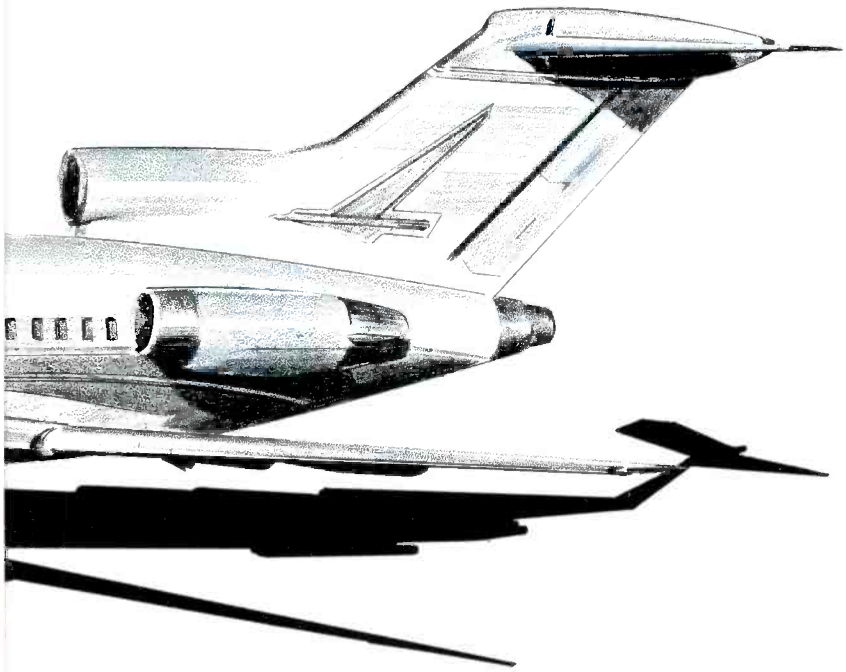
The Boeing 727, a 3 engine medium range jet, has been received with enthusiasm by the air transport industry. Nearly all carriers have plans to use the aircraft. Eastern Air Lines is one of an advanced group already using it. Although the EAL 727 has been in service for less than a year, plans concerning it — especially those relating to its electronics systems — have been undergoing development and definition since the plane was first conceived in 1959.

The primary interest behind these electronics plans was the ultimate desire to eliminate "the practice of scheduled removals" while, at the same time, operating the equipment "on a continuous service basis." As new as the aircraft itself, these plans — named Controlled Maintenance — proposed to 1) utilize the most reliable and advanced electronic equipment (so as to eliminate random failure problems); and 2) as far as possible, to make the aircraft its own test bench (by including self-test provisions for all major devices utilized by the B-727). To this end a set of general specifications were prepared.

General Specifications for Controlled Maintenance

1. Use of solid state devices:
   a) in place of vacuum tubes, where feasible. (In this connection the Machlett planar triode has found itself as much a part of the old order as the new.

Eastern Air Lines — Controlled Maintenance: A New Concept.



Machlett planar triodes have served as the most highly stressed device — the transmitting element — in some of the nation's most important space vehicles; Mercury, Mariner II, as well as others. In this respect, equipment design aboard Eastern's 727 is one with the space craft.)

b) in place of mechanical relays (with some exceptions).
c) for frequency selector switching.

2. Elimination of rotating electro-mechanical devices (e.g., dynamotors). Solid state switching is used to develop high voltage when needed.
3. Elimination of heat producing devices to achieve low ambient operating temperatures.
4. Use of self-test circuitry so that the line mechanic may confirm correctness of equipment operation.
5. Optimization of ramp tests of inter-related devices and provision of test points for this.
6. Improvement of controls and warning devices for the flight crew with considerations for improvement of devices which will permit more accurate analysis of equipment performance.

As a result of these design concepts Eastern has been able to introduce its new service concept.

"The Eastern B-727 electronics installation will incorporate self-test features which will enable the line mechanic to periodically confirm correct performance without the

Figure 1 — EAL's new B-727 at the Miami overhaul base is checked-out and readied for the next flight.

necessity of removing the equipment from the airplane. Eastern intends to schedule such periodic sampling at reasonable periods to assure correct performance tolerances. This procedure will be identified as a Controlled Maintenance program to differentiate from the old maintenance concept."

Included in this program, of course, are the DME and Transponder equipments.

Equipment Redundancy

Although equipment redundancy is associated with most commercial aircraft, the integration of redundancy with Controlled Maintenance on the B-727 provides an important new departure.

Equipment redundancy on the most used aircraft systems is normally limited to duplication. Here, for the first time, triplication is used (VOR, ILS, Vertical Gyro, VHF Communications), with the third unit being, in each case, carried as a "hot spare". Each equipment serves not only as back-up for in-flight use, but provides an extended reference base for "self-test" and comparator monitoring of equipment on the aircraft. Further to this, a continuing goal of the Controlled Maintenance program will be the development of new schedules within which equipment removal will be unnecessary.

System Comparison

An Instrumentation Comparator system is utilized to monitor dual systems in the aircraft. If a disparity develops the pilot is alerted by a Master Comparator Warning Light plus a sub-system light which indicates the system in which the disparity exists. With the ability to select a third system, the malfunctioning equipment may be "ferreted out" and disconnected from the system.

The following are compared and the pilot is warned when the indicated tolerance between the dual systems is exceeded:

Roll	4 degrees
Pitch	4 degrees
Heading	6 degrees
Localizer	30 microamps
Glide Slope	50 microamps.

Controlled Maintenance Checks

A "Bench Service Interval" has been established for certain B-727 electronics equipment, including the DME (Interrogator) and Transponder (Control Panel) whereas the DME Indicator and Antenna and the Transponder itself are maintained on an "On Condition" basis. These represent an important departure from the "Hours Scheduled" basis. An equipment will be maintained on board the aircraft by "Periodic Checks" and "Inspections" (as described by EAL Specifications). When indicated by either failure or other indication "On Conditions" equipment is removed for a "Bench Service" performed in accordance with established Shop Test Procedures. In this manner, Eastern plans to avoid needless removal of equipments and permit them, so to speak, to establish their own removal rates.

The units listed below are maintained on the Code I program procedure (the Phase Check Code I of the Periodic Service Period has been designated as the ultimate acceptable time interval for a thorough Operational Check of the Electronic Systems and Equipment).

A. VHF Communications System (VHF-1, VHF-2 & VHF-3).
B. Interphone Systems (Flight & Service).
C. Passenger Address System.
D. Radio Navigation Systems, Localizer, VOR & Glide Slope (NAV-1 & NAV-2).
E. Compass Systems (No. 1 & No. 2 Remote and Magnetic).
F. Integrated Flight Systems (Capt. & Pilot).
G. Instrumentation Comparator System.
H. Automatic Direction Finder System (ADF-1 & ADF-2).
I. Marker Beacon System.
J. Distance Measuring Equipment Systems (DME-1 & DME-2).
K. ATC Transponder Systems (TRANSP-1, NORM & TRANSP-2, AUX).
L. Radar System.
M. Automatic Flight Control Systems.

Self-Test: DME & Transponder

DME Self-Test

Self-Test for the DME begins with equipment in operation, flag up (blocking view of mileage reading on indi-

Figure 2 — Eastern Airlines' B-727 cockpit showing new instrument comparator system.

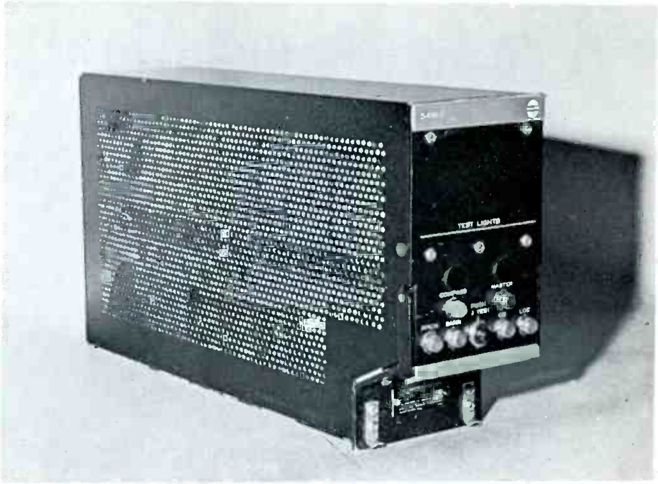


Figure 2A — Basic to the Controlled Maintenance plan is the instrument comparator which integrates instrument readings and provides a continuous comparison between the dual systems in use.

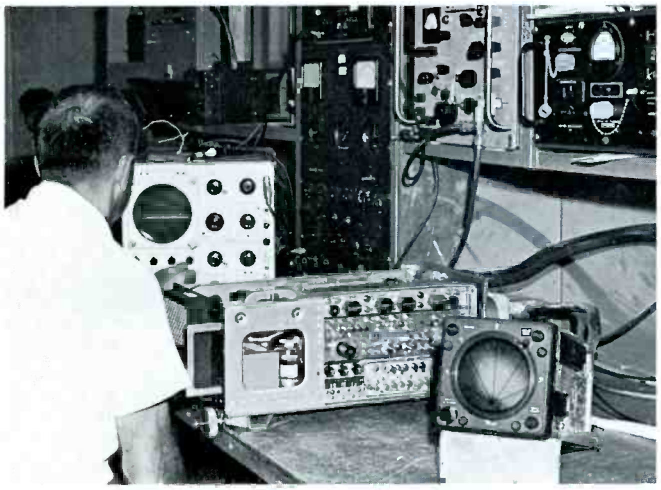


Figure 3 — Test Bench for Transponder Overhaul. Shown is the Wilcox 714B transponder. Use of Machlett tubes (ML-6442) in this equipment has significantly reduced replacement rate.

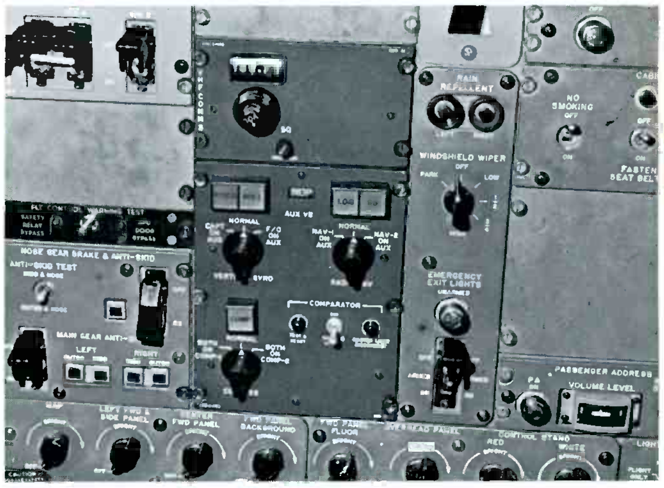


Figure 4 — View of Electronics Overhaul section for maintenance of radio-navigation equipment. Work is done here on these units: Radar, DME, Transponder, Glide Slope Equipment, Omnidirectional Receiver, Course Indicator, LORAN and also the Engine Analyzer. Other sections maintain Communications gear and instruments.

cator), with system in search mode. When the Self-Test Switch is pressed; the flag should retract, the counter rotate to zero ± 0.2 mi., and the DME should lock on. Upon release of the Self-Test Switch the DME should resume the search mode. A return of the DME/STBY switch to Standby should cause the flag to show and stop rotation of the mileage indicator.

The Self-Test checks the decoder, instrumentation and all circuits not normally checked by the flag circuits. The test is used in conjunction with local DME stations or standard ramp test equipment.

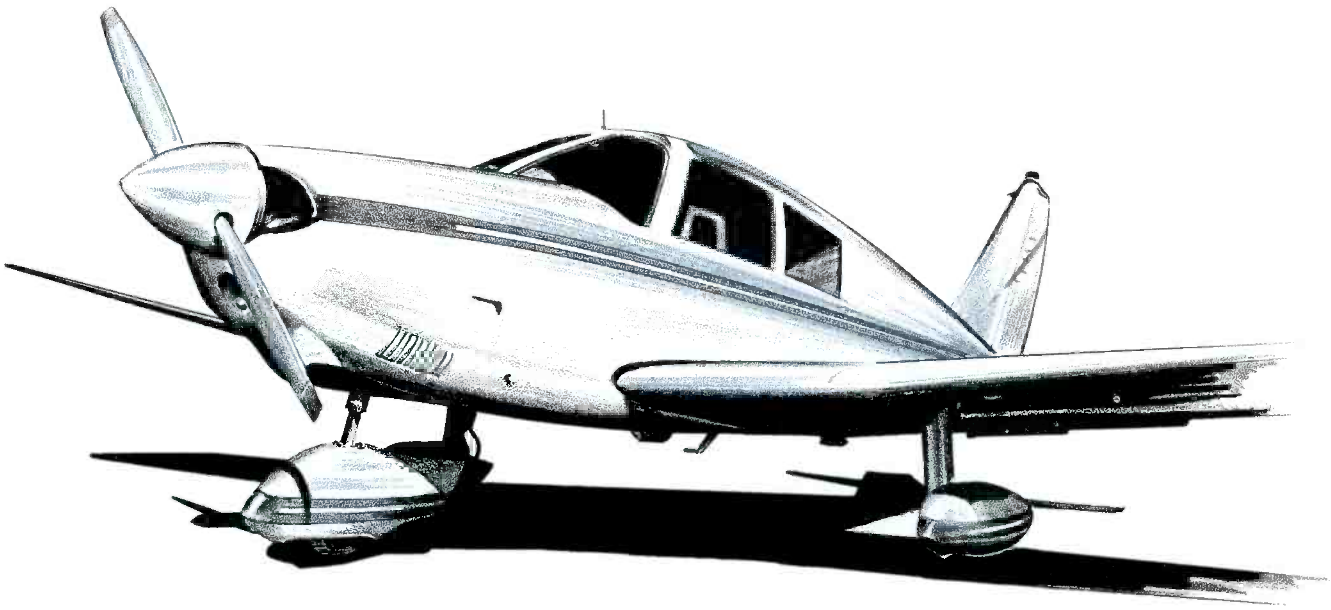
Transponder Self-Test

Self-Test for the Transponder utilizes positive test light indication to check the receiver, transmitter and framing pulses. This test is also augmented by standard ramp test equipment to check the accuracy of the coding.

Self-Test is also provided for: VOR, localizer and glide slope; marker; VHF Communications, radar and automatic flight control systems.

A Wide Range of Utilization is Met by a New Microwave Energy Source

By Ralph Barkes, Trak Microwave Corporation
As told to CATHODE PRESS



Introduction

A transmitter oscillator for transponders built to meet the ARINC No. 532D specification has been developed by Trak Microwave Corporation. This uhf oscillator satisfies the critical requirements for frequency stability as a function of environment and system operating variables. The oscillator provides maximum performance with the ML-8403 frequency-stable, large cathode uhf planar triode but will operate within less critical parameters with the use of other planar triodes.

General

The minimum performance specifications for ATC Transponder Equipment for use in ATC Radar Beacons have, since their publication in 1960, served as a goal as much as a guide. While anticipating the need for increased transponder utilization — yet at the same time recognizing the practicalities of the design process — these specifications have established a system whose ultimate performance is yet to be realized. With the maximum development of this system the Transponder will include not only the present IFF function (which includes climb and descent coding) but will include altitude reporting and either "discrete airframe identity" or flight identity. As in the case of any airborne equipment, complexity and performance must be subordinate to reliability and unit weight. For these latter reasons, among others, systems development has awaited a suitable device which could satisfactorily support all design parameters as envisaged by the 1960 specifications. The Trak 9506-1000 transmitter oscillator provides the basic microwave energy source for such a unit and does so because it takes full advantage of the frequency stable functions and high current provided by the Machlett ML-8403 planar triode.

Performance Specifications

Prior to describing this unit, a review of the specifications is in order.

Those factors primarily effecting the microwave oscillator itself involve: operating frequency and stability, reply code capability, transmitter power output and, to some extent, the reply transmission pulse characteristics.

Operating Frequency:

Typical Performance (Commercial)

1090 mc ± 2.5 mc

Typical Performance (Private and General Aviation)

1090 mc ± 3.0 mc

Frequency Stability:

Maximum (Commercial)

The maximum allowable frequency drift under all service conditions is ± 2.5 mc.

Minimum (Commercial)

State of art establishes minimum.

Maximum (General Aviation and Private)

The maximum allowable frequency drift is ± 3.0 mc under service conditions of 1.5; 1.0 VSWR, any phase or reply rate variation.

Transmitter Power Output:

Commercial	Nominal 500 watts (27 db ± 3 db above 1 watt into 50 ohms)	
Private & General Aviation	Above 15,000 feet	+24 to +30 db above 1 watt*
	Below 15,000 feet	+20 to +28.5 db above 1 watt*

Reply Pulse Shape:

Commercial:

Rise Time: 0.1 usec or less

Duration: 0.45 ± 0.1 us at 50% point

Decay Time: 0.2 usec or less

Pulse amplitude variation in constituent pulses is less than ± 5%

Private and General Aviation:

Rise Time, Duration & Decay Time same as above.

Pulse amplitude variation in train, 1 db relative to any other pulse.

Reply Rate:

Commercial: 2000 groups/sec of 4 pulse reply
4000 groups/sec of 2 pulse reply

Private and General Aviation:
1200 groups/sec of 4 pulse reply-over 15,000 feet
1000 groups/sec of 2 pulse reply-under 15,000 feet

*This assumes that the antenna and transmission line losses are 3 db.

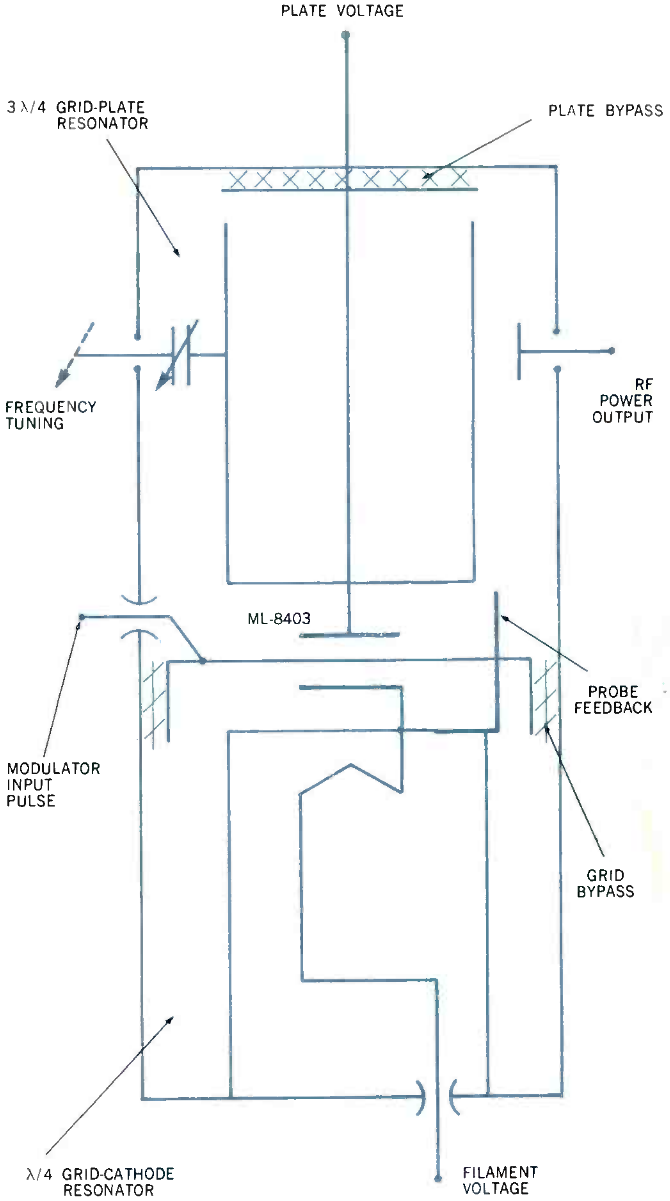


Figure 1 — Transmitter Oscillator Equivalent Circuit.

Design Considerations

General

Almost immediately after having discovered that the designer has a device that will work, he is confronted with the question, How much "work" should be built in and for what cost? The economics of design, in short, achieve a commanding position very nearly from the start. In terms of the Trak 9506-1000 the position was taken that (given a specific unit size, not requiring pressurization) this one unit would meet all ARINC 532D specifications, and by the substitution of different tube types, would meet all needs up to this established maximum. Table 1, below, lists these variations.

TABLE 1

Typical Application	Tube Type	General Operating conditions
Low performance aircraft	ML-7289/ 3CX100A5 or ML-7815	Low duty cycle Variable duty cycle stability not critical Some frequency deviation with loading allowable
Basic unit for low performance aircraft, but operating in crowded area	ML-7855	Low duty cycle Frequency deviation with loading must be tightly controlled
Low performance aircraft operating in uncrowded areas with large distances between landing fields	ML-7698	High duty cycle; high power Some frequency deviation allowable
Hig performance commercial, executive, ilitary aft	ML-8403	High duty cycle; high power Frequency deviation with loading must be tightly controlled

, build one oscillator — or microwave energy source — 'ould span this range required considerable skill in the ba ice of the conflicting parameters of cost and capability.

In general terms these were resolved by the choice of:

1. Unit size. A size was chosen such that pressurization was not needed, but which could still provide altitude capability to 55,000′. Size reduction beyond that of the 9506-1000 would have necessitated pressurization to avoid arcing or corona effects.

2. Frequency deviation vs. power output limits. To compensate for antenna loading, effects of cable length on loading and yet maintain a nominal power output together with a suitable frequency deviation vs. phase shift, the oscillator is designed to operate slightly de-coupled from the load; and feedback design is such as to enhance frequency stability. This means, of course, that for any given installation power may be increased (at the expense of frequency deviation, resulting from VSWR changes) by increasing the coupling or, in the case of undesirable loading effects, the frequency deviation may be improved, somewhat, at the expense of lowered power.

It is important to note, however, that the choice of parameters is such that for most general or commercial installations load isolation is not required. This in itself, effects a cost saving of considerable magnitude.

3. Use of the planar triode. Competitive with other

Figure 2 — Power Versus Plate Voltage

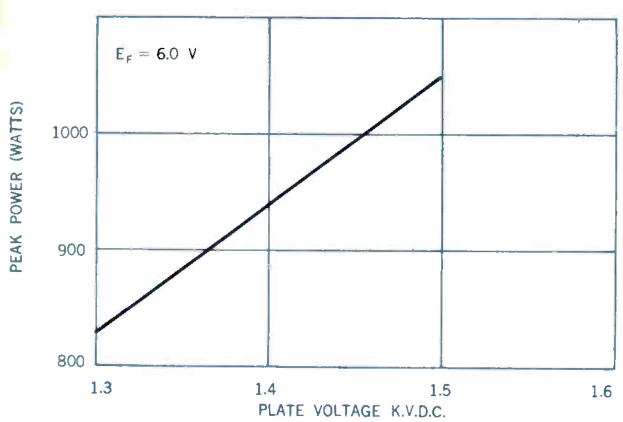


Figure 3 — Frequency Deviation Versus Plate Voltage

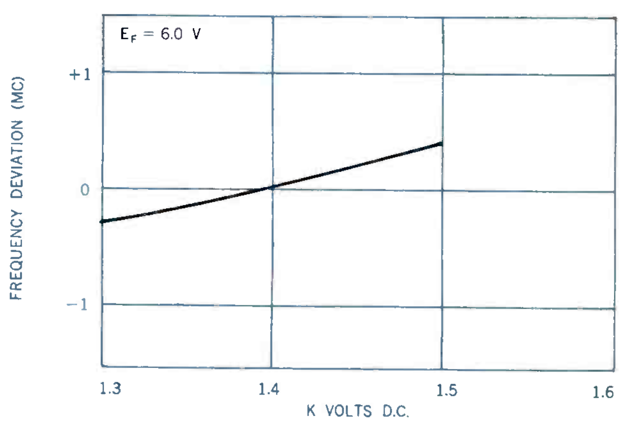


Figure 4 — Frequency Deviation Versus Phase Shift

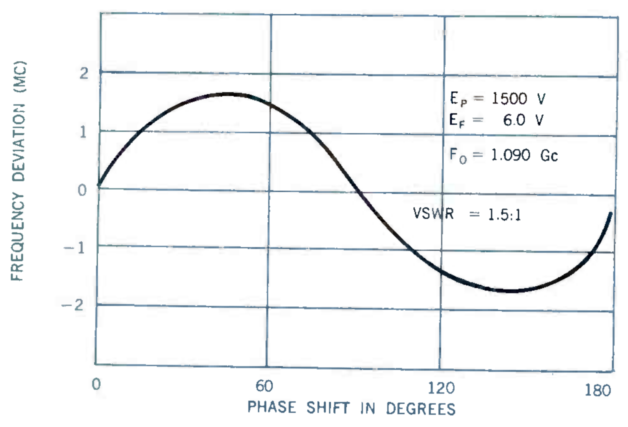
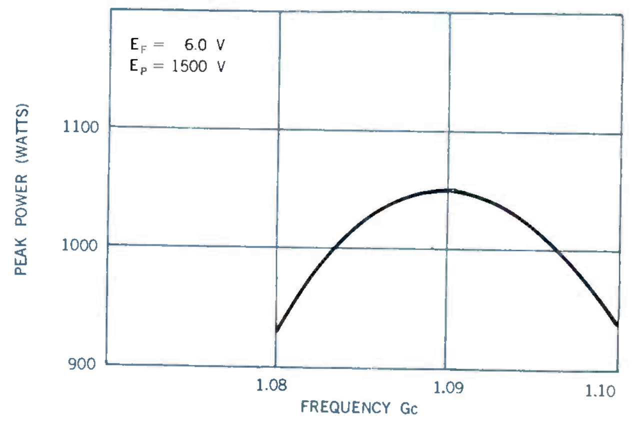


Figure 5 — Power Versus Frequency



devices, such as the klystron and magnetron, the planar triode in this installation offers advantages of considerable magnitude in relation to cost (low, replaceability (simple), life (very good), and reliability (very good); electrical requirements (e.g. drive), plate voltage easily realized); performance (good to outstanding). It is in this latter category that the planar triode makes its mark — and the ML-8403 in particular. Perhaps more than any other factor this tube has allowed a significant simplification in oscillator design with its combined advantages of relatively high power and frequency stable performance.

Where the oscillator designer is forced to compensate for the thermal effects of a variable duty cycle by electrical or electronic means the addition, at the very least, of a new black box would be necessary. Since this tube automatically compensates for the effect on frequency of variable duty cycle the whole problem is disposed of at the start.

4. Grid pulsed circuitry. Grid pulsing of the planar triode permits further design simplification by reducing by a factor of 10 or more the pulsing power required. Here the phormat cathode of the ML-8403, ML-7698, ML-7815 or ML-7855 allows reliable performance. It is apparent that the low pulsing voltages associated with grid pulsing permit use of a considerably smaller and more economical power supply than would otherwise be the case.

TYPICAL SPECIFICATIONS

FREQUENCY: 1090 Mc ±10 Mc.

PART NUMBER: 9506-1000.

POWER OUTPUT: 500 watt minimum.

POWER INPUT REQUIREMENTS: 1500 VDC plate at 2.5 amp. peak plate current max., —50 VDC grid bias with +80 V peak grid pulse max., 6.0 VDC E_{fil} at 1.25 amp. nominal.

ALTITUDE: 55,000 ft.

TYPICAL FREQUENCY STABILITY CHARACTERISTICS ARE:

Frequency vs. E_{fil} ±0.20Mc for 6.0 V@±3% regulation.
Frequency vs. E_p ±0.40Mc for 1500 V@±5% regulation.
Frequency vs. VSWR ±1.50Mc for 1.5: 1 all phase angles.
Frequency vs. duty ±0.15Mc for .001 to .002 duty (.01 duty max.)
Frequency vs. temp. ±0.25Mc for —10°C to +55°C (±0.50Mc for —54°C to +90°C.)

Total frequency stability characteristics are ±2.50Mc max.

Physical: 2 in. diameter by 5 5/16 in. long excluding projections.

Weight: 13 ounces in aluminum, 30 ounces in brass.

As a triode oscillator, advantages over other types include smaller size and lighter weight, plus operating economy. The replaceable triode means that the oscillator, at end of tube life can be brought back to optimum performance at nominal cost by replacement of the triode.

Design considerations — Detail

Suitable structural design required a light metal, easily machinable and with good thermal or heat absorption characteristics. Aluminum was selected as the most desirable metal even though its coefficient of expansion is greater than that of Kovar or invar. However, techniques associated with Trak's manufacturing processes — plus use of the ML-8403 — preclude the possibility of frequency instability.

To further enhance stability the use of a ¾ λ grid-plate resonant line was chosen. This choice was indicated by the greater frequency stability vs. VSWR changes throughout all phase angles. The improvement in VSWR pulling stability being achieved by creating a resonant circuit with greater stored energy. This ¾ λ section was folded back as shown in Figure 1 so as to provide compactness in size.

Once these basic, but highly important, decisions were made, the design dimensions were determined by certain prescribed formulas while taking into consideration that physically long arc paths were required in an unpressurized unit to prevent corona or arcing at high altitude operation.

In brief form, the basic formulas required to determine the final mechanical dimensions are shown below:

(1) $\lambda/4 \text{ (air)} \simeq \dfrac{3000}{f_0(\text{mc})} = 90°$

(2) $Xc = \dfrac{.159}{f_0 C}$

(3) At resonance $Xc = X_L = j\ Zo \tan \Theta$

(4) $Zo = 138 \log D/d$ (for air dielectric)

WHERE

(A) F_0 = desired resonant frequency
(B) C = capacitance (hot) grid to plate or grid to cathode
(C) Zo = characteristic impedance of the resonant lines
(D) Θ = electrical links (degrees) of the transmission line circuit element.
(E) X_L = input inductive reactance of the transmission line which resonates with the given Xc
(F) D/d = ratio of diameters (outer/inner) of conductors of the resonant line.

Conclusion

As demonstrated in the typical performance specifications shown, the Trak 9506-1000 microwave energy source — using the Machlett ML-8403 planar triode — achieves the design objectives provided by, and allows full compliance with, the ARINC specification 532-D.

New Machlett Developments

Tetrodes for Broadcast/Communications Applications

ML-8170/4CX5000A

ML-8281/4CX15000A

The ML-8170/4CX5000A and ML-8281/4CX15000A are general-purpose, high frequency, forced-air-cooled tetrodes designed to provide stable, long-life oscillator, amplifier, or modulator service. The internal structure of these tetrodes is so designed as to permit high rf operating efficiency with low rf losses, at frequencies to 110 Mc. Envelopes are of sturdy, low-loss coaxial ceramic-to-metal construction.

MAXIMUM RATINGS AND TYPICAL OPERATION

RF Power Amplifier & Oscillator — Class C Telegraphy (key down conditions)

	ML-8170/ 4CX5000A	ML-8281/ 4CX15000A	
Maximum Ratings, Absolute Values			
DC Plate Voltage	7.5	10	kV
DC Screen-Grid Voltage	1500	2000	V
DC Plate Current	3	5	A
Control-Grid Dissipation	75	200	W
Screen-Grid Dissipation	250	450	W
Plate Dissipation	5	15	kW
Typical Operation			
DC Plate Voltage	7.5	10	kV
DC Control-Grid Voltage	−350	−550	V
DC Screen-Grid Voltage	500	750	V
Peak RF Grid Voltage	590	790	v
DC Plate Current	2.8	4.6	A
DC Control-Grid Current	.25	.28	A
DC Screen-Grid Current	.50	.55	A
Plate Dissipation	5	9	kW
Driving Power, approx.	150	220	W
Plate Power Output, approx.	16	36	kW

WORLD'S HIGHEST POWER TETRODE

The New Vapor-Cooled ML-8545

Another Machlett innovation. The ML-8545 is a general-purpose tetrode capable of 300 kW continuous output as a Class C amplifier or oscillator at frequencies to 50 Mc. Maximum plate input is 420 kW, and is substantially higher during momentary overloads or intermittent operation.

Applications include:

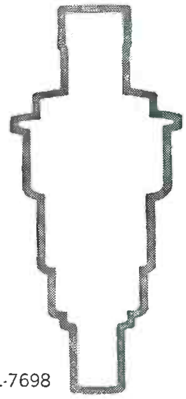
- High-power broadcast and communications
- All-purpose rf generation
- Particle acceleration

For further data on the ML-8545 and the ML-8546, water-cooled version, write: The Machlett Laboratories, Inc., Springdale, Conn. An affiliate of Raytheon Company.

MACHLETT

ELECTRON TUBE SPECIALIST

MACHLETT UHF PLANAR TRIODES



ML-7698

ML-8534
ML-8536

demonstrated reliability in Mariner II, Mercury and Ranger programs.

HERE'S WHY:

Phormat Cathode: High voltage stability for grid or plate pulsed applications. Phormat (matrix) cathodes have been tested to 12,000 volts and more. Used in planar triodes ML-7211, ML-7698, ML-7815, ML-8403, ML-8533 and all Miniature Planar Triodes.

Frequency Stable Anode: Unique anode design allows frequency stable operation within 10-15 seconds after application of high voltage, plus these advantages:

1. Frequency shift during initial tune-up less than 1 Mc.
2. Does not require regulated plate supply, since change of anode dissipation does not affect frequency.
3. Permits variable duty cycle without noticeable shift in frequency.

Used in planar triodes ML-7855, ML-8403, and Miniature Planar Triodes, ML-8534, ML-8535, ML-8536 and ML-8537.

High Cathode Current: 50% more cathode current (190 vs. 125ma) permits power to 110 watts CW. Used in planar triodes ML-7211, ML-8403 and Miniature Planar Triodes, ML-8534 and ML-8535.

Pulsed Operation: High voltage stability—phormat cathode provide reliable pulsed service (see table).

SPECIFICATIONS OF MACHLETT PULSED PLANAR TYPES

Miniature Tube Type	Conventional Tube Type	Plate Pulsed Max f	Plate Pulsed Max Power input	Grid Pulsed Max f	Grid Pulsed Max Power input
—	ML-6442	5Gc	3000 v eb 2.5 a ib	—	—
—	ML-6771	6Gc	2500 v eb 1.5 a ib	—	—
—	ML-7210[1]	3Gc	3500 v eb 2.8 a ib	—	—
ML-8535[2, 3, 4]	ML-7211[2]	3Gc	3500 v eb 5.0 a ib	3Gc	2500 Vdc Eb 5.0 a ib
ML-8534[2, 3, 4]	ML-7698[3]	3Gc	3500 v eb 5.0 a ib	3Gc	2500 Vdc Eb 5.0 a ib
ML-8536[3, 4]	ML-7815[4]	3Gc	3500 v eb 3.0 a ib	3Gc	2500 Vdc Eb 3.0 a ib
ML-8537[3, 4]	ML-7855[3, 4]	3Gc	3500 v eb 3.0 a ib	3Gc	2500 Vdc Eb 3.0 a ib
ML-8535[2, 3, 4]	ML-8403[2, 3, 4]	3Gc	3500 v eb 5.0 a ib	3Gc	2500 Vdc Eb 5.0 a ib
ML-8538[3] ML-8539[3]	ML-8533[3]	DC Pulse Modulator DC Plate Volts 8 kv	Pulse Cathode Current 5.0 a ib	3Gc	8000 Vdc Eb 5.0 a ib

[1] 12 second warm-up. [2] High current cathode. [3] Phormat cathode. [4] Frequency stable anode.

Send for UHF Planar Triode Brochure for data, application notes, cavity information, installation notes—over 100 pages of information.

The Machlett Laboratories, Inc., Springdale, Connecticut, an affiliate of Raytheon Company.

MACHLETT

ELECTRON TUBE SPECIALIST