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CIVIL AERONAUTICS ADMINISTRATION

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CIVIL AERONAUTICS

MANUAL 16

AIRCRAFT RADIO EQUIPMENT AIRWORTHINESS

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DEPARTMENT OF COMMERCE
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CIVIL AERONAUTICS ADMINISTRATION
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AIRCRAFT RADIO EQUIPMENT AIRWORTHINESS

INTRODUCTORY NOTE

This manual contains material intended to interpret and explain the airworthiness requirements pertaining to the type certification of aircraft radio equipment. It sets forth acceptable procedures for the presentation of technical data required, acceptable practices, standards of construction and test procedures for establishing compliance with the airworthiness requirements of Part 16 of the Civil Air Regulations.

Requirements which, in the opinion of the Administrator, are equivalent to those herein set forth will be equally acceptable as a method of establishing the airworthiness of aircraft radio equipment. Likewise, any requirement shown to be inapplicable may be modified as required by the design of certain equipment. This manual will be revised from time to time as the progress of the radio art, the requirements of aircraft flight technique, or the development of more satisfactory test procedures warrant. Such revisions will become effective as of the date of their approval by the Administrator, rather than the date of their incorporation in this manual.

The material in this manual is arranged in sections numbered to correspond with pertinent sections of Part 16 of the Civil Air Regulations. To provide a convenient reference, applicable sections of the regulations are quoted as a heading to each section of this manual.

The primary requirement of the Civil Air Regulations in regard to the type certification of aircraft radio equipment is reliability, both in the equipment itself and in its functional operation. All inspections and tests, recommended nechanical and electrical design practices, and other material set forth in this manual have been established either for the purpose of achieving reliability of design, or to ascertain the degree of reliability that has been attained by a particular design.

The Civil Aeronautics Administration Inspectors assigned to supervise type certification inspections of radio equipment perform additional duties in connection with the inspection of the operation and maintenance of radio communication and navigation facilities of scheduled air carriers. These duties permit the Inspectors to observe the operation of radio equipment from the pilot's viewpoint, and the maintenance of this equipment from the viewpoint of the carrier's maintenance organization. Records are frequently examined, and analyses are made of equipment failures, their cause and contributory causes. This information, together with the experience gained in conducting certification inspections on approximately 400 units of equipment, has provided an opportunity to observe those methods of construction and electrical design which are satisfactory, and those which are unsatisfactory. The knowledge thus gained has been applied in drafting the regulations pertaining to airworthiness, and the interpretative material associated therewith.

It is one of the purposes of this manual to acquaint the design engineer responsible for the development of radio equipment with the knowledge thus gained. Therefore, there has been included with each regulatory item a resume of faults in design which have been found to militate against the reliability of the equipment. In the preparation of this manual, an effort has been made to present the material in such form that the manual may provide a ready reference for the design engineer to enable him to avoid known unsound design and construction practices, and thereby produce reliable, airworthy aircraft radio equipment.

The term "Aircraft Radio Equipment" as used in this manual is understood to mean complete units of aircraft radio equipment which are assigned a model or type number, and identified by the name-plate of the manufacturer affixed to the unit. Such complete units of radio equipment comprise transmitters, receivers, radio direction finders, power units, et cetera, and their associated control equipment, such as azimuth controls, tuning controls, output selector and sensitivity control devices and such accessories as head-sets, microphones, jack-boxes, and the like.

Requests are frequently made for type certification of such component parts as resistors, fixed and variable condensers, tubes, tube sockets, power cable connectors, head-set and microphone jacks, and similar components. Since the airworthiness of such components is a function of their application in a particular unit of radio equipment, it is obvious that blanket type certification cannot be issued to such component parts. For example, a tube socket may not be considered airworthy until it has been determined that the current and voltage to which the socket will be subjected in a unit of radio equipment are within safe operating limits. Similarly, a variable condenser which is entirely satisfactory for use in an aircraft radio receiver may have insufficient spacing of the condenser plates to permit its use in an aircraft radio transmitter, where higher voltages are developed in the resonant circuit. For this reason, applications for the type certification of component parts will not be considered.

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APPLICATION

Reference: Footnote Page 1, Part 16.

The application for a type certificate should be presented in the following order and detail:

(a) Name and address of applicant.
(b) Name of equipment for which certificate is applied.
(c) Type designation of equipment.
(d) Purpose for which equipment is intended.
(e) Date on which equipment will be ready for inspection.

The above information should be submitted in a letter of application for a type certificate to the Administrator of Civil Aeronautics. This letter should be addressed to the Regional Manager, Attention: Air Carrier Inspection Section of the region in which the applicant is located. The map included in the back of this manual shows the regional divisions of the continental United States and the location of each region headquarters. Letters of application should be addressed as follows:

Region 1 - LaGuardia Field, New York City.
Region 2 - P. O. Box 4327, Atlanta, Ga.
Region 3 - 1204 New Post Office Bldg., Chicago, Ill.
Region 4 - Box 1689, Fort Worth, Texas.
Region 5 - City Hall Bldg., Kansas City, Mo.
Region 6 - 1508 Fourth Street, Santa Monica, Calif.
Region 7 - King County Airport, Seattle, Wash.

16.10 SCOPE: AIRCRAFT RADIO EQUIPMENT REQUIRED BY THE CIVIL AIR REGULATIONS TO BE TYPE CERTIFICATED AND INSTALLED IN CERTIFICATED AIRCRAFT IS ELIGIBLE FOR A TYPE CERTIFICATE UPON MEETING THE REQUIREMENTS HEREINAFTER PRESCRIBED.

.100 Part 40 of the Civil Air Regulations sets forth certain type certificated radio facilities which are required to be installed in certificated air carrier aircraft for the following types of operation; viz; (a) visual contact day, (b) visual contact night; and (c) instrument or over-the-top operation.

An interpretation of Part 40 regarding radio equipment required for each of the three types of flight operation is given below:

(a) Visual-Contact Day Operation.
1. Radio transmitter) comprising two-way
2. Radio receiver) radio telephone system
3. Radio range receiver system.
4. Simultaneous audio filter system
   (not required if the route traversed is not equipped with simultaneous radio range stations)

(b) Visual-Contact Night Operation.
Same as Visual-Contact Day Operation under (a) above.

(c) Instrument or Over-The-Top Operation.
1. Radio transmitter) comprising two-way
2. Radio receiver) radio telephone system
3. Radio range receiver system, and
4. Auxiliary range receiver system, and
5. Radio direction finder system (may be incorporated with 3 or 4), and
6. Anti-precipitation static antenna system (may be incorporated with 5 for use on 3 and/or 4), and
7. Auxiliary power supply (to be used with 3 and/or 4)
8. Simultaneous audio filter system
9. 75 megacycle marker beacon receiver system
10. Two headsets
11. Two microphones

A properly designed automatic radio direction finder is considered satisfactory in meeting requirements of (3), (5), and (6), or (4), (5), and (6).

Compliance with the requirement in regard to an independent power source set forth under (7) Instrument or Over-The-Top Operation, may be achieved by either of the two following methods:

a. The provision of a power source entirely independent of the aircraft electrical system, which may, at the option of the pilot, be connected to the input power terminals of the receiver in lieu of the aircraft electrical system, or

b. The provision of two generator-battery systems or equivalent, aboard the aircraft, either one of which is capable of carrying the electrical emergency load of the aircraft, and either one of which may be independently connected to such emergency running load.

The "emergency running load" is defined as that electrical load which is necessary for the safe operation of the aircraft, as distinguished from that load normally used for the comfort and convenience of passengers.
The word "system" as used in the above interpretation of Part 40 of the Civil Air Regulations is understood to include, in addition to the basic unit of radio equipment, all accessories which are necessary for the proper functional operation of the basic unit.

For example, a radio range receiver "system" comprises not only a radio range receiver, but also the power supply, tuning controls (remote or local), jack boxes, volume controls, headphones, and such other accessories as are required for the satisfactory functional operation of the receiver. Each such accessory comprising a part of the radio range receiver "system" is required to be type certificated. However at the option of the applicant the equipment may be certificated as a "system" (in which case the certificate will list by make and model number all units comprising the system), or each unit of the system may be individually certificated.

In the interests of convenience or necessity in certain aircraft installations, it may be desirable to group certain functional controls of a number of aircraft radio units on a single panel. Such grouping of controls is satisfactory, provided that the "control panel" is certificated in accordance with Part 16 of the Civil Air Regulations.

In general, any unit of an aircraft radio installation associated with the functional operation of the equipment is required to be type certificated.

Fixed antennae, junction boxes, wiring conduits, et cetera, which are fabricated as a part of the aircraft structures and such items as batteries, tachometer shafts, and equipment racks are not required to be certificated. These items are inspected as to their suitability for their intended purpose in connection with the original and periodic airworthiness inspection of the aircraft.

101 Type certification of aircraft radio equipment is applicable only to such aircraft radio equipment required by the Civil Air Regulations to be installed in certificated aircraft. In this respect it is to be noted that _at present the Civil Air Regulations only require type certificated radio equipment to be installed in air carrier aircraft_. Therefore, aircraft radio equipment designed for installation in private, commercial, military, and other non-air carrier aircraft _is not eligible_ for a type certificate under the present provisions of the Civil Air Regulations. Accordingly, the applicant for a type certificate may be required to show that the aircraft radio equipment for which a certificate is desired is required by the Civil Air Regulations to be type certificated and installed in air carrier aircraft.

If subsequent amendments to the Civil Air Regulations require the installation of type certificated radio equipment in other than air carrier aircraft, the provisions of Part 16 of the Civil Air Regulations will make such aircraft radio equipment eligible for type certification.

102 Nothing in the present regulations prohibits the installation and use of type certificated radio equipment in other than air carrier aircraft.

16.11 DEVIATION: NEW TYPES, OR NEW TYPES OF CONSTRUCTION OF AIRCRAFT RADIO EQUIPMENT WHICH MAKE THE TESTS PRESCRIBED BY THESE REGULATIONS INAPPLICABLE MAY BE SUBJECTED TO SUCH OTHER TESTS AS THE ADMINISTRATOR MAY DEEM NECESSARY TO INSURE SAFE OPERATION.

.110 The tests prescribed by Part 16 of the Civil Air Regulations for the determination of the airworthiness of aircraft radio equipment are necessarily based upon the present development of radio equipment design, and upon the requirements of present aircraft flight technique.

Experience indicates that when these tests are applied to conventional types of design, the airworthiness of aircraft radio equipment may be determined with a reasonable degree of accuracy.

.111 When functional considerations preclude the use of conventional design, any of the prescribed tests may be waived, at the discretion of the Administrator, if:

a. It can be shown that the requirement is not applicable because the equipment is unconventional with respect thereto, and

b. The objective on which the requirement is based has been met by actual flight operation in air carrier aircraft, or may be met by the application of tests other than those specified in Part 16 of the Civil Air Regulations.

.112 The prescribed tests are intended to simulate conditions which may be expected to be encountered under the most severe flight conditions. Certain tests which may be considered to exceed severe flight conditions are prescribed for the purpose of providing an accelerated life-test to compensate for the gradual deterioration of the equipment.

.113 It is emphasized that section 16.11 provides only for the waiver of non-applicable test procedures, and is not to be interpreted as providing for the waiver of airworthiness requirements. For example, the design of certain radio equipment may preclude the application of the specified vibration test without shock mounts; it is still necessary to demonstrate that the radio equipment is airworthy and can withstand the vibration encountered in the operation of air carrier aircraft. This may be accomplished by waiving the specified vibration test, and applying a modified vibration test in which a suitable shockmount is incorporated as an integral part of the radio equipment, or by an equivalent test.

.114 In the example cited above, a type certificate issued to such radio equipment would contain a restriction limiting the use of the equipment in a certificated aircraft to those installations incorporating the special shock mount or its equivalent as an <u>integral</u> part of the equipment.

.115 Generally speaking, a type certificate is applicable to all units of radio equipment which are identical in design and construction to the particular unit of equipment which was subjected to the type certification tests, and the application of the tests to each such identical unit of equipment is not required. However, in certain specific cases, it is necessary that a type certificate contain a restrictive clause which makes it necessary that certain tests be conducted on each unit of radio equipment covered by the type certificate before the validity of the type certificate is recognized. For example, quartz crystal frequency controls, due to the nature of their production and to certain physical limitations of their component parts, may not be considered to be identical without the application of certain tests to each quartz crystal unit. Therefore, a type certificate issued to a particular type of quartz crystal control would contain the following restrictions in order to insure that each crystal produced under the type certificate is identical to that which was originally type certificated.

"By the terms of the certificate granted the manufacturer it is required that each _____ crystal unit be separately tested, and that only those units meeting the specifications given below shall be type certificated:

1. The crystal unit shall operate at all temperatures in the ambient temperature range of minus 40 to plus 55 degrees centigrade.

2. Over the ambient temperature range specified in paragraph 1 above, the temperature coefficient of the unit shall be such that the unit will not depart from a specified frequency by more than plus or minus 0.015 percent.

3. The output of the crystal unit at any ambient temperature in the range of minus 40 degrees to plus 55 degrees centigrade shall not be less than 70 percent of the output obtained at any other temperature in this temperature range.

4. The crystal unit shall show no evidence of any parasitic condition within the frequency range of from 50 percent to 150 percent of the specified frequency when tested in a laboratory oscillator.

5. The crystal unit shall be single frequency and shall show no evidence of multiple response over the frequency range of from 50 percent to 150 percent of the specified frequency when tested in a laboratory oscillator.

6. The frequency of the quartz plate used in the ________ crystal unit shall be in the frequency range of _________ to _______________kcs.

Definitions:
"Multiple response" refers to the condition wherein one or more frequencies different than and not harmonically related to the main frequency can be generated by varying the tuning elements of the oscillator circuit.

"Parasitic condition" is that condition wherein one or more spurious frequencies are generated simultaneously with the main frequency.

"Specified frequency" is the frequency given as the frequency of the unit on its name plate."

16.12 WAIVER: THE TESTS PRESCRIBED HEREIN MAY BE WAIVED WHENEVER, IN THE OPINION OF THE ADMINISTRATOR, A PARTICULAR PART OF AIRCRAFT RADIO EQUIPMENT IS SO DESIGNED OR CONSTRUCTED THAT SUCH TESTS ARE NOT NECESSARY TO INSURE AIRWORTHINESS.

.120 When aircraft radio equipment falls within the three general classifications, listed below, certain tests may be waived:

1. Equipment which, because of its simplicity of mechanical design, method of construction, and intended functional use, may be determined by visual inspection to be airworthy, without the application of any of the specified tests.

2. Equipment which is purely mechanical in design and functional use, and which may be determined to be airworthy without the application of certain specified tests intended only to show electrical characteristics.

3. Equipment which, because its design is identical with, or similar to, previously certificated equipment, may be considered to be airworthy without the application of certain specified tests.

.121 Examples of aircraft radio equipment falling within the three classifications listed above are as follows:

1. A jack box, fabricated from acceptable components and materials, and consisting only of a housing enclosing the jacks and a terminal strip, which is so constructed and assembled that it may upon visual inspection, be determined to be airworthy without the application of the specified test.

2. A "coffee grinder" tuning control, which is purely mechanical in design and operation, the airworthiness of which may be demonstrated without the application of the "pressure" and other tests intended to determine electrical characteristics.

3. A receiver which is identical in design and construction to a certificated receiver with the exception of minor modifications which may be considered to produce no degradation in the reliability of the receiver.

.122 In all cases involving the waiving of specified tests, the power to waive rests with the Inspector, as a representative of the Administrator, and tests may be waived only with his permission. An entry should be made in the test report submitted by the applicant whenever any specified test is waived, setting forth the reasons for such waiver.

TECHNICAL DATA

16.20 GENERAL: TO BE ELIGIBLE FOR A TYPE CERTIFICATE FOR AIRCRAFT RADIO EQUIPMENT, AN APPLICANT MUST SUBMIT THE FOLLOWING TECHNICAL DATA:

16.21 DRAWINGS. ONE SET OF DRAWINGS IN BLUE PRINT OR EQUIVALENT FORM FOLDED TO APPROXIMATELY 9 X 12 INCHES CONTAINING THE MANUFACTURER'S DESIGNATION OF THE AIRCRAFT RADIO EQUIPMENT AND ALL DETAILS OF DESIGN, CONSTRUCTION, ASSEMBLY, AND MATERIALS USED WHICH ARE NECESSARY FOR THE REPRODUCTION OF SUCH AIRCRAFT RADIO EQUIPMENT: PROVIDED, THAT ADEQUATE PHOTOGRAPHS MAY BE SUBSTITUTED FOR SUCH DRAWINGS IF SUCH PHOTOGRAPHS ARE SUITABLY MARKED TO INDICATE THE DETAILS REQUIRED HEREIN.

.210 To comply with the above regulation, the applicant should submit drawings in such detail that any one possessing sufficient technical knowledge, mechanical skill and manufacturing facilities would, by reference to the drawings, be able to produce identical radio equipment from materials and component accessories available on the open market.

211 The drawings submitted by the applicant for a type certificate will be retained by the Washington Office of the Administrator as a part of the permanent record of all factual information pertaining to the type certification of the aircraft radio equipment.

212 All technical data submitted by the applicant to the Administrator in regard to the type certification of aircraft radio equipment will be held confidential and normally will be used only in connection with the airworthiness rating of such aircraft radio equipment. However, the Administrator may, at his discretion, make such use of the confidential data as is required in the interest of public safety. Access to confidential data will be provided to the accredited representatives of the holder or applicant for the pertinent type certificate. Confidential data will not be used for reference purposes in connection with the repair, alteration, or modification of certificated aircraft radio equipment by persons other than the holder of the pertinent type certificate without written consent of such holder, unless he is out of business, or has given blanket permission for such use.

213 The requirement in regard to detailed drawings applies only to such component parts, sub-assemblies and complete assemblies as are fabricated by the equipment manufacturer. Component parts which are available in the open market, and which are purchased by the manufacturer for use in the equipment, need not be shown in detailed drawings. Information in regard to such parts should be included in the parts list required by section 16.23 of the Civil Air Regulations.

214 If a manufacturer purchases a standard component part, such as a switch, drawings of the switch are not required. If however, he manufactures the switch, detailed drawings of the switch body, contacts, lever, springs, et cetera, must be submitted, listing the materials of which each part is made, all dimensions, methods of assembly, finish of parts, type number, and other pertinent information. In such cases where purchased component parts are not standard, but are manufactured to particular specifications, or when standard purchased parts are modified by the applicant, detailed drawings of such special component parts must be submitted.

215 For various reasons, manufacturers may desire to submit photographs instead of drawings. Adequate photographs may be submitted in lieu of drawings only to show method of assembly, location of various parts in relation to one another, and for similar purposes where dimensional details are not critical.

16.22 DRAWING LIST: A DRAWING LIST SETTING FORTH IN NUMERICAL ORDER OR BY OTHER SUITABLE CLASSIFICATION, THE TITLE AND NUMBER OR DATE OF EACH DRAWING SUBMITTED UNDER SECTION 16.21

220 The drawing list submitted in compliance with the above regulation should be in the form of an index of the complete set of drawings furnished in support of the application for a type certificate, and so arranged under proper headings and sub-headings that the drawings pertaining to a particular assembly may be easily identified and correlated with the assembly. In general, the main heading should indicate the complete assembly drawing, following by a list of all sub-assembly drawings. Each sub-assembly drawing should then appear as a sub-heading, followed by the list of applicable detail drawings. Where the same part is used in several assemblies, the drawing number of such part should, therefore, appear under each appropriate sub-heading.

.221 The word "drawing" as used herein is understood to include photographs when their use is permitted as provided by paragraph .215. It is permissible to identify such photographs by number only, provided further suitable identification is given in the drawing list.

16.23 PARTS LIST: A LIST SPECIFYING EACH COMPONENT PART OF THE AIRCRAFT RADIO EQUIPMENT SUBMITTED TO THE ADMINISTRATOR FOR CERTIFICATION. THE LIST SHALL INDICATE THE PHYSICAL OR CIRCUIT LOCATION OF EACH ITEM AND THE TYPE OR MODEL DESIGNATION ASSIGNED TO SUCH ITEM BY THE MANUFACTURER.

.230 To comply with the above regulation, the parts list should contain the following information pertaining to each component part of the aircraft radio equipment.

(a) Circuit or physical location, by item numbers, or symbol letters followed by suffix numbers for identification of like parts.

(b) Name of manufacturer of part.

(c) Manufacturer's type or model number.

(d) Rating of part in watts, inductance, capacity, resistance, voltage, current, et cetera (when such rating is applicable to a component part).

.231 The arrangement of the parts list should be such that complete information pertaining to any component part indicated on the complete schematic wiring diagram of the radio equipment, or shown on sub-assembly and complete assembly drawings, may be readily and accurately obtained.

.232 When symbol letters are used to identify parts (i.e., R-1, R-2, R-3, for resistors; C-1, C-2, C-3 for condensers; et cetera) like symbols should be grouped together, and suitably arranged for easy reference. If item numbers are used, they should likewise be arranged with due regard for ease of reference.

.233 It is not considered essential that such standard parts as machine screws and nuts, washers, rivets, soldering terminals, and similar parts be assigned a part number and listed in the parts list. Information pertaining to these parts as well as the wire used for hook-up purposes, may be listed on the assembly drawings and wiring diagrams, and will thereby satisfactorily meet the requirements of the Civil Air Regulations. However, wiring harnesses, power cables, and the like, if assigned part numbers by the manufacturer, should be included in the parts list.

CHARACTERISTICS

16.30 DESIGN AND TESTS: TO BE ELIGIBLE FOR TYPE CERTIFICATION, AIRCRAFT RADIO EQUIPMENT MUST BE SO DESIGNED AND CONSTRUCTED THAT IT WILL SATISFACTORILY PERFORM THE FUNCTION OR FUNCTIONS FOR WHICH IT IS INTENDED TO BE USED IN AIRCRAFT UNDER ALL FLIGHT CONDITIONS WHICH MAY BE MET IN REGULAR SERVICE AND MUST:

(A) BE FREE FROM HAZARD BOTH IN ITSELF AND IN ITS METHOD OF OPERATION;

(B) BE CONSTRUCTED OF SUITABLE AND DEPENDABLE MATERIALS:

(C) SATISFACTORILY PASS A VISUAL INSPECTION OF THE CONSTRUCTION, LAYOUT, AND ELECTRICAL ARRANGEMENT OF ALL COMPONENTS OF THE PARTICULAR AIRCRAFT RADIO EQUIPMENT AND SUCH ELECTRICAL, HUMIDITY, TEMPERATURE, PRESSURE, VIBRATION, DROP, AND OTHER TESTS AS THE ADMINISTRATOR MAY PRESCRIBE.

300 The type certification of aircraft radio equipment involves two considerations, namely, the <u>physical</u> design of the equipment, and its <u>functional</u> operation. The distinction between these two considerations may best be illustrated by the following examples:

Assume that an aircraft transmitter, instead of being provided with an antenna relay which automatically grounds the receiver input circuit, transfers the antenna from the receiver to the transmitter, and applies voltage to the transmitting dynamotor when the microphone button is pressed, is provided instead with three separate toggle switches to accomplish these functions.

Such a transmitter might be designed in accordance with the best engineering practices, and of the best materials obtainable, and would be capable of successfully passing all of the physical tests prescribed for type certification. However, the functional operation of such a transmitter would be hazardous, in that it is readily possible that a pilot using the transmitter in aircraft service might forget either to throw all three of the toggle switches, or to throw them in <u>proper sequence</u>, before he pressed the microphone button, and to properly restore the switches to normal position after each transmission. Such an arrangement might readily result in failure of, or actual damage to, both the transmitter and receiver.

A second example of hazardous operation is taken from an actual case, in which the pilot held down the "press-to-talk" button on the microphone while he operated the frequency change mechanism of a multifrequency channel transmitter. The design of the transmitter circuits in this instance was such that the high voltage was not removed from the circuits during the frequency change cycle. This resulted in an arc flash-over to a radio frequency choke, which was opened circuited by the flash-over, and the transmitter was rendered inoperative. Such hazards may be eliminated by the use of properly sequenced relay systems, or equivalent methods which automatically remove the high voltages from the transmitter circuits during the frequency change cycle, and should be provided unless operating tests under the most adverse simulated service conditions indicate satisfactory operation may be obtained without special considerations of the nature outlined above.

In a multi-channel receiver, it is often desirable to provide AVC on certain frequency bands, and eliminate it on others. The provision of a separate AVC switch to accomplish this constitutes a functional hazard, in that the pilot may not set such a switch to the proper position for the frequency band on which he desires to operate the receiver. This hazard may be eliminated by incorporating the AVC switch in the frequency band selector switch, so that the use of AVC is automatically provided only on the desired bands.

In the design of remote control equipment, special attention should be given to the elimination of separate switches to perform various functions which might be more satisfactorily accomplished by a multi-point multi-section rotary switch.

For example, an automatic direction finder system may be designed to provide the pilot with the following separate functions:

(a) Automatic direction finder; (b) Regular receiver - ICW or MCW reception; (c) Regular receiver - CW reception; (d) Aural-Null direction finder - ICW or MCW reception; and (e) Aural-Null direction finder - CW reception. Good engineering practice with due consideration for the elimination of superfluous controls should immediately suggest the possibility of using a single control multi-section six-point switch of the rotary type to accomplish selection of these operational functions.

An on-off switch may be eleiminated by utilizing the first or "dead" position of the switch. In this position the complete receiver and its power supply is made inoperative. In the second position, complete automatic operation of the direction finder is established by the proper selection of AVC-MVC, antenna system, modulator power supply, loop motor power supply, audio-sensitivity selection, et cetera. In the third position, straight-forward range reception may be provided for by elimination of signal pickup on the loop, selection of MVC, removal of modulator power supply from the receiving circuit, et cetera. In the fourth position the circuit set-up may be identical to the third position except for the addition of the beat frequency oscillator. On the fifth position, aural-null or precipitation static reception may be established by eliminating the sense antenna, removal of modulator power supply, connection of circuits to provide electrical energy for manual control of the loop rotator motor (if provided), elimination of AVC, et cetera. The sixth position may be identical with the fifth position and the beat frequency oscillator can be added for aural-null reception of CW signals.

An examination of the functions grouped on a single control as outlined above shows that to accomplish the same results by use of separate switches would require not less than twelve different switches of various kinds. The use of a great number of switches, as outlines above, constitutes a functional hazard inasmuch as the pilot may forget to throw a switch or operate them in incorrect sequence, thus causing malfunctioning of important radio equipment. To much emphasis cannot be placed on the importance of elimination of unnecessary controls in radio systems of air carrier aircraft.

In a multi-frequency band receiver which is designed to operate on the "range" and other frequency bands, it is necessary to provide a simultaneous range filter in the output circuit of the receiver. However, this introduces the possibility that the pilot might inadvertently leave the filter selector switch in the "range" position when attempting to use the receiver on frequency bands in which voice reception is desired, resulting in an <u>apparent</u> failure of the receiver on these frequency bands. This functional hazard may be eliminated by providing means in the frequency selector switch design for disabling the simultaneous range filters on all but the "range" band. Similarly, when pretuned circuits are provided in the range band for the voice reception of airport traffic control towers on 278 kcs., the "range-airport" switch should automatically disable the range filter when the switch is thrown to the "airport" position.

Another example of a functional hazard was found in a range receiver equipped with a visual "tuning meter". The purpose of the tuning meter was to enable the pilot to accurately adjust the receiver circuits to resonance with the frequency of the desired station by so tuning the receiver that maximum meter deflection was secured. The receiver in this case was more than usually selective, and was, therefore, more difficult to tune properly, for which reason the tuning meter was provided. However, the use of the tuning meter and the high degree of selectivity of the receiver resulted in the following functional irregularity when the receiver was tuned to a simultaneous range station. The tuning meter indicated resonance with the center tower of the simultaneous range station, which condition is satisfactory and desirable if the receiver is used as a radio compass. But when it was desired to use the receiver for the aural reception of range signals, it was found to be necessary due to the selectivity characteristics of the receiver, to detune the receiver approximately one kilocycle (1020 cycles) from the resonant position indicated by the tuning meter in order to receive satisfactory aural signals. In this case, the tuning meter actually defeated the purpose for which it was intended, and instead of being of assistance to the pilot, its use resulted in reduced operation efficiency. This example illustrates how the design engineer, in attempting to correct one phase of an operational difficulty, may inadvertently introduce errors in a second functional application of a unit of aircraft radio equipment.

In the design of multi-function equipment such as automatic direction finders which use motors, relays or other controls operated from the primary power source, consideration should be given to locating the fuses, relays, etc., in the circuits in such manner that failure of a fuse or relay will cause the unit to continue operation in its most simple function. For example, in an automatic direction finder using an AC alternator to supply power for operation of selsyn or autosyn indicating instruments good engineering practice requires that such alternator be separately or "branched" fused in order that a failure of the alternator will not disable the entire receiver, thus precluding reception of range signals.

The design engineer should remember that most controls in an airplane of the air carrier type are operated by the pilot using his sense of "feeling" rather than that of "sight." For this reason, it is undesirable to employ a great number of controls of identical physical size on control units. An example of a practice to avoid is illustrated in the case of a control panel recently submitted for certification. This particular unit was a "master" control for operation of all radio in an air carrier aircraft and contained twelve identical knobs. The design engineer's attempt to achieve symmetry of appearance prompted him to use rotary type switches for simple on-off functions where a single pole single throw toggle switch could have been employed. In order that a pilot could use his sense of feel in the operation of these controls, it became necessary for him to "count off" from the right or left and constantly remember that a certain control was the "fifth" or "sixth" from the left or right. This same panel contained an eight point frequency selector switch using a knob identical to all other knobs on the panel. In order to maintain a symmetrical layout the engineer compromised with efficiency by engraving an arrow on the face of the knob which was approximately five eighths of an inch from the engraved numbers on the panel. In order to obtain proper selection of frequency position it was necessary for the pilot or co-pilot to move his head directly under the control in order to avoid parallax effect. All of the above mentioned faults were brought to the attention of the engineer and became apparent to him after an explanation of the control's functional use was made.

The design engineer must constantly keep in mind that a pilot is not a radio technician. His duties primarily involve the navigation of his aircraft, and the operation of the radio equipment is only one of the many duties involved. Radio controls must, therefore, be kept to an irreducible minimum to avoid functional operational hazards. The design of the equipment must be such that if the pilot fails to operate a certain control, it is immediately apparent to him that he has failed to do so. Thus, if the pilot desires to use a multichannel receiver on the "range" band, and forgets to move the frequency selector switch from the "broadcast" band, the reception of broadcast programs will immediately remind him to properly set the selector switch. It should not be necessary, in addition, for him to turn off an AVC switch and change from a broadcast to a range antenna. These functions should all be performed automatically by the selector switch, in order to avoid improper functioning of the receiver on the range frequency band with a consequent hazard to the safety of the flight.

These functional considerations apply to all units of aircraft radio equipment, both in regard to themselves and in relation to other units of equipment.

.31 Electrical Design and Construction:

Aircraft radio equipment conforming to the electrical construction and design proceures hereinafter set forth will be deemed to have complied with the requirements of CAR 16.30 when:

.310 The electrical characteristics - input, output, frequency range, et cetera - are in accordance with the manufacturer's published ratings.

Measurement of the electrical characteristics in regard to the above should be made as outlined elsewhere in this manual under the heading of "Test Procedures" at normal input voltages, and with output impedances for which the equipment is designed. (Maximum outputs obtainable with abnormal input voltages and into load impedances which are not obtainable in aircraft for the purpose of establishing a high power output rating will not be considered a true output rating)

.311 Component parts, including vacuum tubes, are not subjected to voltages or currents in excess of the ratings recommended by the manufacturer of these component parts.

Voltage and current readings should be taken under full load operating conditions. With reference to vacuum tubes, the so-called ICAS (intermittent commercial-amateur service) ratings will be considered only if the tube manufacturer approves the use of such ratings for the particular type of tube, and in the circuit application used in the aircraft radio equipment for which type certification has been requested. In this connection, it must be remembered that aircraft service imposes more severe operating conditions on vacuum tubes than are normally encountered in other types of service. These more severe operating conditions are due to mechanical causes resulting from vibration, and to electrical causes resulting from normal variations in the input voltages.

Applicants desiring to use ICAS ratings will, therefore, be required to show that they have submitted their circuit designs to the tube manufacturer, and have obtained his approval for the use of such ICAS ratings for the particular type of tube used in the circuit design. Blanket approval for the use of ICAS ratings for all types of tubes in all circuit designs will not be considered. Each application of ICAS ratings should be individually approved by the tube manufacturer. In discussions with tube manufacturers regarding the use of ICAS ratings of tubes in aircraft service, we are advised that certain types of tubes are conservatively rated, whereas others are rated at or near their safe maximum capacities. This consideration, as well as the circuit application of a particular type of tube, governs the degree of reliability that may be expected to result in aircraft service when ICAS ratings are used.

In the determination of safe wattage dissipation ratings of component parts, due recognition should be given to the restrictive recommendations made by the manufacturer. For example, a resistor rated at 10 watts in free air cannot be safely used at this rating in a confined space where abnormal temperature rise would result.

.312 Performance of the unit does not vary beyond the established operating limits upon replacement of any or all of the tubes used, by good tubes of the particular type incorporated in the design of the unit. An exception to this requirement may be made, however, where the unit in question is designed for some highly specialized use, in which case selected tubes may be used, provided the manufacturer so states (with due emphasis) on some placard or plate affixed to the unit, and in the instruction bulletins pertaining to the unit.

Mixer, beat frequency oscillator, detector and automatic volume control tubes may be found to be critical as to their operation in certain receiver circuit designs and due care must be taken in selecting the constants for these circuits to prevent malfunctioning of the receiver due to normal variations in tube characteristics. Generally speaking, any circuit which is extremely critical as to its adjustment to secure proper operation of the receiver may be considered as unsatisfactory for aircraft service. Oscillator circuits, in particular, are usually affected by changes in temperature, atmospheric pressure, humidity, and voltage variations, and it is imperative that stability of design be considered of primary importance. The comments above regarding the oscillator of a receiver are equally applicable to transmitter oscillator circuits.

.313 The electrical design of the unit is such that operation is not critical with respect to replacement of plug-in components, i.e., vibrators, crystals, et cetera.

For example, circuits utilizing quartz plates should have their constants so proportioned that the substitution of any certificated crystal manufactured for use in the circuit will not cause the frequency or power output of the generator to vary beyond predetermined limits.

Vibrators constitute a source of radio interference in radio receivers unless adequate filters are provided. Due precautions are required in the design of the vibrator filter in order that variations in vibrators, due either to manufacturing inequalities or to deterioration of the vibrators with use does not result in so-called "hash" interference, either within the equipment with which it is associated or to other radio equipment on the aircraft.

In certain instances special sealed vibrators are required to insure satisfactory operation at high altitudes. Accordingly, it is required that the unit and the instruction bulletins indicate that sealed vibrators must be used to obtain satisfactory operation and avoid abrogation of the type certificate.

.314 In any receiver intended for the reception of radio range signals where the directive properties or the field intensities of these signals are used as an aid to navigation, the receiver functions in such manner that for inputs up to 1 volt the receiver output signal increases with increasing signal input, except that, the output level of the receiver need not be greater than 300 milliwatts per audio output channel with a modulation depth of 30 percent at 400 cycles.

The circuit design of the receiver should be such that radio range quadrant signal reversals will not occur when full sensitivity control is employed or under any condition of signal input encountered in normal service.

Automatic volume control (AVC) should not be used in the design of a radio range receiver; provided that, delayed AVC may be used if the circuit design is such that no AVC action is obtained prior to reaching the 300 milliwatts audio output level. Outputs in excess of 300 milliwatts are entirely acceptable, but a minimum output of 300 milliwatts from a 30 percent modulated signal has been determined to be necessary to prevent "quadrant reversals" of the range signals due to an overload of the receiver circuits. It has been demonstrated that, due to the attenuation of the signal level resulting from the parallel operation of a number of receivers, an output of 300 milliwatts per channel is required to produce an uncomfortable signal in the pilot's headphones, forcing him to reduce the sensitivity of the receiver before the overload point is reached.

Curve A of Plate I shows an ideal audio output curve, which may be obtained by the use of a properly designed delayed AVC circuit. Curve B illustrates a condition where "quadrant reversal" resulting from an overload condition of the receiver circuits may occur. It may be seen that the higher field intensity "A" signal actually produces a lower audio output than the "N" signal. This would indicate to the pilot that he is flying in an "N" zone, whereas he is actually in an "A" zone. As explained above, a minimum audio output of 300 milliwatts is required to prevent the pilot from inadvertently operating the receiver in this overloaded condition.

.315 In the case of automatic radio direction finders the design shall incorporate means for continuous monitoring of the signal to which the receiver is tuned during automatic direction finder operation in order that the presence and effects of interference or atmospherics can be easily and quickly detected by the operator.

.316 The sensitivity control of a receiver used for the reception of radio range signals is so designed as to produce smooth operation through its entire range, such that the minimum perceptible difference in output can be obtained for any signal input up to one volt.

In order to properly utilize radio range signals for air navigation problems, it is necessary that the pilot be able to differentiate between slight variations in intensity of the received signal. It is imperative that the volume control be smooth in its operation in order that the sensitivity of the receiver may be accurately controlled. This is particularly true with high imput signal levels such as are encountered in close proximity to a radio range station.

317 All wire is of sufficient cross section, correct temper, and of proper construction to provide ample current carrying capacity and mechanical strength.

Except in filament and primary power supply circuits, the radio engineer is not ordinarily confronted with any problems in regard to the current carrying capacity of conductors. However, the question of mechanical strength is of vital importance due to the vibration encountered in aircraft service. The use of bare, solid, tinned copper conductors for jumper connections between transformer terminals and similar applications where the lengths of the jumper wire does not exceed 2 inches has been found to be satisfactory, but generally speaking, the use of solid conductors is to be avoided. Solid conductors crystallize under constant vibration, and are subject to breakage from this cause. Further, any slight nick in the surface of a solid conductor, which can easily occur during removal of the insulation, weakens the conductor to an extent that breakage may result when the wire is flexed.

When design considerations indicate the desirability of using solid conductors, the use of such conductors having the so-called "push back" insulation is recommended to avoid the necessity of "stripping" which may nick the conductor.

Stranded wire, in addition to its flexibility, possesses the advantage of being easily cabled to produce a neat and workmanlike wiring assembly, and of facilitating the removal of connections during the overhaul of the equipment and the replacement of component parts. The use of stranded wire wherever possible is strongly recommended.

The processes used for stripping the insulation from stranded wires should be so accomplished that no damage is done to any of the individual strands. Damage frequently results in breakage of one or more strands with consequent reduction in cross-sectional area of the conductor.

For reasons of mechanical strength, individual interconnecting wires smaller than B & S gauge #22 are not recommended.

318 All wires and cables are secured and supported in such a manner as to prevent breakage of the conductor and/or abrasion of the insulation.

Where solid conductors are used, they should be rigidly and adequately supported at frequent intervals along their length in such manner they they are not free to vibrate. Cables should be laced or otherwise bound and adequately clamped or supported to prevent vibration. The clamps utilized to secure either cables or solid conductors, should be of such design as to preclude the possibility of relative movement between the clamp and the wire(s) they are intended to support, and should be so formed that chafing action will be avoided. In instances where the clamp is not depended upon for direct bonding of a shielded cable, protection may be provided by the use of a suitable protective sleeve placed between the wire or cable and the clamp.

The necessity for precluding the possibility of any relative movement between conductors and their supporting clamps may be illustrated by an incident which recently was brought to the attention of the Administrator. A transmission line consisting of a solid conductor supported in a metal tubing by ceramic discs was installed in an airplane. The vibration in flight caused one of the ceramic discs to rotate on the inner conductor, and due to the abrasive action, the conductor was severed after about three hours of flight.

The condition reported above is considered unusual in that the failure of the conductor occurred in such a relatively short period of time, however, it forcefully illustrates the attention that must be given to what might be considered a very minor detail in order to preclude failures of equipment in aircraft service.

Component parts which incorporate a winding or windings, in their design should include a sufficient number of terminals rigidly mounted to the structure of the component part to terminate each winding.

Where conductors are attached to components which are shock mounted such as relays suspended in rubber and detector tube sockets separately shock mounted, provisions should be made to allow an adequate amount of slack to prevent breakage of conductors caused by relative movement of the shock mounted component under conditions encountered by rough landings, etc. Slack should also be allowed in order that the full effectiveness of the shock mount will not be impaired by short stiff conductors.

.319 Conductors which carry sufficient current to heat to incandescence in the event of short circuits, irrespective of whether such circuits are protected by fuses or not, should utilize fireproof insulation.

It is desirable to utilize wire having fireproof insulation in all primary power circuits and in similar applications where the regulation of the source is such that sufficient current could flow to produce extreme temperatures in the conductor. The presence of series resistors between the source and the conductor may not be considered as eliminating the possibility of abnormally high temperatures, since it is possible for such a resistor to become shorted.

The use of fireproof insulation on audio and other low current, low voltage circuits is not mandatory. However, when the superior advantages of such insulation are considered under high humidity and prolonged high temperature conditions, its use in such circuits is recommended in the interests of enhancing the airworthiness of the equipment under such operating conditions.

.320 Insulation used on conductors is of sufficient thickness and quality of material to provide protection to the conductor throughout its length. Where such insulation has been removed to make connections, adequate means are to be taken to prevent misplacement of the insulation.

It is not considered satisfactory if conductors are used whose insulation is of such a flimsy nature that the insulation may creep back from a soldered connection and leave a bare length of wire. The so-called "push-back" type of insulation has been found to be satisfactory, provided that it is woven tightly enough to preclude the possibility of insulation creepage.

The connection between a conductor and a terminal can often be materially improved both mechanically and electrically by installing a short length of "spaghetti" tubing over the insulation and pushing the tubing down over the terminal after soldering. Such an assembly not only keeps the insulation from becoming misplaced, but provides additional mechanical strength tending to prevent wire breakage.

521 The electrical design is such that all wiring used in the aircraft radio equipment is color coded.

Since aircraft radio equipment is subjected to frequent minute inspections, both electrically and mechanically, it is of great advantage to be able to quickly and accurately locate wires associated with various circuits. This may be accomplished through the use of color coding. Experience has shown that many of the color codes used on wires having fabric insulation fade after a relatively short period of service, and it becomes very difficult, and sometimes impossible, to distinguish one color from another. This is particularly true where the colors are not basically different from each other. Wire of the fireproof type has proven to be very satisfactory from the standpoint of color coding, since the contrast between colors is much greater than on fabric covered wires, and the colors remain fixed indefinitely.

522 Metallic shielding used on conductors is terminated at a suitable distance from the exposed conductor and in such a manner as to insure a satisfactory and permanent termination.

The proper termination of braided flexible shielding presents two important problems. First, it is necessary that some method be employed to prevent the braided shielding from unraveling, allowing the strands to come in contact with other electrical connections, and secondly, the strands of the flexible braided shielding must be prevented from digging into the insulation of the conductor and coming in contact with the conductor itself, causing a short circuit or ground. Flexible braided shielding may be suitably terminated in several different ways. In one method, the metallic shielding is trimmed back from the end of the conductor for a sufficient distance to prevent the shielding from coming in contact with the conductor. The shielding is then prevented from unraveling by a serving of lacing cord to securely hold the shielding in place. In a second method, the shielding is trimmed back as described above and the shielding is then prevented from unraveling by soldering the end of the shielding. This method requires that great care be taken in applying the solder to prevent charring the insulation of the conductor. Numerous cases have been found in which the insulation was so damaged by the application of heat to the shielding that the insulation was entirely destroyed, and grounding of the conductor to the shield resulted. A variation of the second method consists in soldering the shielding to a metal clamp which is secured to the structure of the unit.

The same precaution in regard to the application of heat must be observed.

After the shielding has been properly terminated it is necessary that the shielded conductor be secured in such a manner that there is no possibility of the shielding coming in contact with the terminal to which the conductor is attached.

.323 Conductors utilizing metallic shielding which are not protected by means of an insulating sleeve are secured in a manner which will prevent the shielding from coming in contact with exposed terminals or conductors.

Where shielded conductors are used either in a wiring harness or individually, they must be secured throughout their length in such a manner that they may not be displaced from their prescribed routing to an extent that would permit the shielding to come in contact with exposed terminals or conductors. Where shielded conductors are attached to relay arms or other movable contacts, sufficient space must be provided so that the movement of the conductor due to the action of the movable contact does not short or ground other circuits. Where such space is limited, an insulating sleeve should be placed over the shielding to prevent such grounds or shorts.

.324 Any process of soldering, welding, et cetera, using materials which might cause the slightest degree of corrosion includes means for the removal of the corrosive substance.

Thoroughly washing the joint with an appropriate solvent is necessary to adequately remove the corrosive substance. Merely wiping the area with a cloth will not ordinarily prevent the corrosive action.

.325 Mechanical strength of soldered connections do not depend on the solder alone, but are adequately supported mechanically prior to the soldering process.

Soldered connections which are made by merely laying the wire on a flat surface of a terminal and holding the wire in place while the solder cools are not considered satisfactory, since any slight movement of the wire while the solder is cooling crystallizes the solder and results in a "cold" joint. Wires should be so supported mechanically that it is unnecessary to hold them during the soldering process. This may be satisfactorily accomplished by inserting the wire through a hole in the soldering terminal in such manner that the wire will not shift its position when the solder is applied. When eyelets are used to secure soldering terminals to a terminal strip, the hole in the eyelet may be used for this purpose, provided it can be shown there is a good electrical connection between the eyelet and the terminal.

.326 Plugs and receptacles used to connect the circuits of the unit to external circuits or to connect circuits of the various parts of the unit to each other are suitable from the standpoint of: (a) Mechanical ruggedness; (b) Method of locking; (c) Voltage insulation; (d) Current carrying capacity; (e) Method of connecting terminal conductors; (f) Method of terminating shielding (if used); and (g) Method of mechanically supporting terminating conductors.

When selecting plugs and receptacles for use in aircraft radio equipment, the following mechanical and electrical design or installation details should be given careful consideration:

The mechanical means employed to properly polarize plugs and receptacles should be sufficiently rugged to withstand the stresses imposed by the insertion and removal of the plug, and should be sufficiently positive to prevent improper insertion of the plug. When guide pins are provided as a polarization means, it is important that the guide pins engage prior to engagement of the contacts to prevent damage to the contacts. If an unsymmetrical arrangement of the contact is depended upon for proper polarization of the plug, the contacts should be so arranged that it is impossible to incorrectly insert the plug, or to damage the contacts by an attempted improper insertion of the plug.

On drawn shells of thin wall, rolled threads whose pitch and pitch diameter cannot be accurately controlled, have been found to be unsatisfactory for meshing with locking rings due to the insufficient depth of such threads.

Where currents at high voltage are carried through plugs and receptacles adequate spacing must be maintained between the high voltage contact(s) and adjacent contacts, either by special pin spacing or by the non-use of a sufficient number of adjacent contacts to insure adequate insulation.

Cables carrying current to a unit of equipment should, in general, be terminated with the receptacle portion of the assembly in preference to the plug. Where design requires a plug terminal the prong should be adequately protected from short circuit by accidental contact with metal surfaces while disengaged.

The manufacturer's current rating on plug contacts should not be exceeded. Where currents in excess of the contact rating are encountered, they should be accommodated by a combination of two or more pins. Contact pins which carry high currents should be of one-piece construction, and should not consist of a two-piece assembly secured together by machine-screw threads in such manner that the current flows through these threads. Such threads were found to oxidize to an extent where a high resistance connection resulted.

In multi-contact plugs where the pin spacing is small, it is desirable to use short lengths of "spaghetti" tubing over each terminal conductor with the tubing slipped down over the soldered joint to the base of the plug contacts.

Where shielding is employed around a cable, the use of ferrules, coupling nuts and other fittings necessary to adequately attach the shielding to the threaded shoulder of the plug or receptacle is considered necessary to insure good electrical contact between the shielding and the plug.

Shielded conductors may be satisfactorily terminated within the cable by bringing the conductor out through a hole in the wall of the shielding, terminating the conductors at their contacts, and insulating them by means of a length of spaghetti tubing. The shielding should then be terminated at a grounded contact.

Means should be incorporated in the design of the plug to adequately support the conductors at the end of the shell by means of a suitable cable clamp, to prevent any tensile strains from being applied to the soldered joints between the conductors and the plug contacts.

The use of external shielding adequately attached to a threaded shoulder on the plug in the manner outlined above has been found to provide adequate mechanical support for the conductors.

.327 Material which will ignite or explode from electrical spark or from any degree of heat encountered under service conditions are not used and, in general, the use of materials which will sustain combustion are held to a minimum.

In any process requiring the application of dope, acetate type should be used in preference to nitrate, due to the slower burning characteristics of acetate dope.

The use of conductors coated with lacquer should be confined to those using the so-called "slow-burning" type which may give off smoke under extreme temperature conditions but will not continue to burn or smoulder after the temperature has been reduced.

.328 The characteristics of insulating materials are such that no appreciable changes in dielectric properties, or mechanical deformations result from temperature changes or other climatic conditions.

In general, the following considerations are pertinent in regard to insulating materials:

All cut edges of bakelite should be treated with insulating varnish, or its equivalent, to permanently seal the edges against the absorption of moisture under high humidity conditions.

Insulating materials should be equal to, or better than Grade XXX bakelite.

For mechanical reasons, terminal strips less than 1/16th of an inch in thickness are generally considered unsatisfactory. Unless such strips are adequately supported at frequent intervals to prevent flexure of the strip due to vibration, terminal strips of greater thickness should be employed.

The use of well designed ceramic shapes is desirable where the effects of cold flow and gradual reduction of the specific resistance and power factor may adversely affect the operation of the equipment.

.34 <u>Mechanical Design and Construction</u>:

Aircraft radio equipment complying with the following specifications pertaining to mechanical design and construction may be deemed to have met the requirements of CAR 16.30 when:

.340 The general design of the radio equipment is such that it can be satisfactorily installed in certificated aircraft. Attention should be given to the following design considerations in relation to radio equipment intended for installation in aircraft:

The method of mounting the equipment in the aircraft must be adequate to withstand the shocks encountered on landings and take-offs and to withstand vibration encountered in flight. It is further necessary that the mounting and equipment be so designed that the equipment may be quickly and easily removed and reinstalled to permit rapid replacement.

Due to the limited space in the cockpit of an aircraft, large units of radio equipment such as transmitters, receivers, automatic direction finders and similar equipment, should be so designed that they may be installed in parts of the airplane other than the cockpit and remotely controlled from the cockpit.

The limited space available on instrument panels makes it desirable that units of equipment intended for instrument panel mounting be restricted to a size not larger than a standard flight instrument.

In the design and manufacture of control units for a specific type of aircraft due consideration should be given to the final location of the control unit so that control designations will not be obscured by control knobs. In one instance, the design of a control panel for the windshield "V" ceiling position in n airline aircraft resulted in complete obscurity of the photo-etched control designations by the control knobs themselves. The design considerations should have included the functional operation of these units and these control functions should have been indicated in a position that would have been readily visible after installation.

Due consideration should always be given to the ultimate location of equipment in the airplane as this factor frequently determines the correctness of design practice. An example of unsatisfactory design practice developed during the certification inspection of a sensitivity control box (intended for throttle control column-mounting) of such large dimensions that after mounting, access to the pilot and co-pilot's seats was severely restricted. The unit was subsequently redesigned and reduced in size as to easily fit in its intended location.

All remote controls should be clearly marked as to their functions and provision for the illumination of such controls should be made.

Dial lamps of the positive locking type, such as the so-called "bayonet base" lamps are recommended in preference to the "screw base" type because of the tendency of the latter type to work loose when subjected to vibration.

Provisions are also necessary for controlling the intensity of the illumination of remote control units in order that such illumination may not be objectionable to the pilot under night flying conditions.

Adjustable controls within units of aircraft radio equipment which must be manipulated to secure proper operation of the equipment after it has been installed, should be so located as to be accessible after installation.

It is desirable that such controls as are adjustable from the front panel be equipped with a positive means of sealing the adjustment to prevent tampering by unqualified personnel. A sliding plate which allows holes to match up over the end of adjustment mechanisms in one position only, and which can be sealed in the position in which the holes are closed, is one satisfactory method of accomplishing the desired results.

Adequate safeguards should be provided to protect flight and maintenance personnel from being exposed to high voltages during operation or adjustment.

.341 The dimensions of component parts are held to a tolerance that will:
(a) Preclude the possibility of failure due to misalignment of parts;
(b) Assure the adequate and true alignment of parts in regard to their replacement with like parts.

Examples of unsatisfactory practices under this heading are: Inaccurate alignment of power plugs incorporated in the equipment mount or rack. It is not generally considered good practice to rely on a multi-contact power plug installed in the rear of a unit of equipment to hold the equipment securely to the mount.

The use of bearings which are not self-aligning.

Inaccurate ganging of frequency shift switches, causing binding and poor contact.

Less than positive indexing of frequency and functional selector switches.

The misplacement of mounting holes in the chassis requiring deformation and stretching of component parts to secure initial fit. It is obvious that exact duplicates of the part will require similar deformation, often under conditions where proper tools or processes are not available.

.342 Component parts are so located and disposed with respect to each other and to structural members that they can be inspected, removed and replaced without unduly disturbing or damaging other parts.

It is not considered satisfactory to stack parts one upon the other, nor to secure two or more parts to the assembly by means of common mounting screws, unless electrical considerations of circuit design may be considered to justify the maintenance difficulties introduced thereby.

The use of "anchor nuts" or similar devices where the nut is permanently attached to the chassis, to facilitate quick and easy removal or installation of parts, is desirable. Parts which are periodically removed for cleaning and inspection should not utilize fixed nuts of the type employing a fiber insert for anti-vibration locking purposes, since such devices do not serve the purpose for which they are intended after repeated insertion and removal of the associated machine screws. Such frequently removed parts should be located in a manner which will permit their removal without removing or disturbing other component parts.

343 Magnetically operated switches, or mechanically operated switches having adjustable contacts or contacts requiring periodic servicing, are located in such manner that the contacts can be inspected and cleaned and the tension of contact springs adjusted without removal of the switch or adjacent parts.

Explosion-proof and similar types of sealed relays need not comply with this requirement. However, they should be so installed in the equipment that they may be easily replaced in the event of failure of the relay.

344 The method of securing parts or structures to the assembly is such that any loosening which occurs can be immediately and effectively corrected.

An example of unsatisfactory design may be found in the case of a component part mounted on an assemply by means of a machine screw and a nut, where the nut is not accessible. In this case looseness cannot be corrected without removing other parts in order to gain access to the nut. Machine screws and nuts used inside sub-assemblies where they are not readily accessible for inspection or tightening, should include positive means for preventing the nut from coming loose. The use of adequate lock-washers, or soldering nuts to screws are examples of satisfactory procedures.

345 The use of self-threading screws is restricted to those places where the design features are consistent with such use.

In general, the use of self-threading screws is not considered satisfactory. They should be used only after a thorough inspection has proved them to be satisfactory for the intended application. Under no circumstances should they be used with parts which must be periodically replaced or removed.

.346 The mounting of fragile parts is such as to preclude the existence of destructive strains.

The mounting "ears" on ceramic or phenolic resin parts should be of such design as to insure against their breakage when the mounting screws are tightened, or washers having a slight degree of "compressibility" should be incorporated in the assembly to prevent breakage.

When tapped holes are used in ceramic materials, they should be of such depth and the associated machine screws should be of such length that a sufficient number of threads are engaged to insure adequate mechanical strength. Because ceramic materials are extremely hard and brittle, it is usually not possible to completely tighten machine screws in threaded ceramic materials without danger of breakage, and due consideration should be given to methods of preventing the screws from becoming loose. In applications where the screws are not required to be removed, it is an acceptable practice to cement the machine screws in the ceramic material to insure mechanical permanence. Where such machine screws must be removable, adequate compression washers should be employed under the head of the machine screws to provide a cushioning effect to prevent fracture of the ceramic material by the abrupt tightening of the machine screw.

.347 Wherever machine screws engage threads tapped in sheet material, the tapped material is of ample thickness to assure the permanence and strength of the threads, particularly in those cases where it is necessary to frequently remove or replace such machine screws for routine servicing and inspection purposes.

In general, tapped holes should not be employed in sheet material of a thickness less than the thickness of standard nuts for the size machine screw in question where the sheet material is brass or steel, and 50% greater thickness where the material is aluminum alloy.

.348 Design details are not incorporated which experience has shown to be unreliable or otherwise unsatisfactory.

Among others, there are included under this category highly stressed areas of structural members resulting from abrupt changes in cross-sectional area without appropriate fillets; sharp corners; rough or tool marked area; parts so located in the assembly as to be inaccessible for inspection and maintenance; inadequate provisions for the locking and/or safetying of bolts, nuts, lock rings and similar devices; rotatable shafts and their bearings constructed of similar materials; plated bearing surfaces; removable parts mounted by means of rivets, et cetera. It is satisfactory to use rivets for mounting parts or assemblies which will not be removed or replaced, however, under no circumstances should rivets be used for electrical connection between two parts unless the rivet is adequately soldered to each part.

.349 Suitable provisions are made to avoid possible fire hazard.

In addition to the non-burning materials and fireproof wire previously mentioned, adequate protective devices such as fuses, circuit breakers, et cetera should be incorporated in the primary circuits of the equipment to eliminate the possible development of extreme temperatures resulting from excessive currents, due to defects in equipment or overloads.

In general, it is desirable that provisions for fusing circuits be made outside of the equipment. Most equipment certificated under the Civil Air Regulations will be part of a "system". Experience indicates the desirability of providing a centralized fuse panel in the main radio junction box. The various circuits requiring independent or "branch" fusing should be brought out of the equipment through a connector plug for fusing in the radio junction box. The instruction book furnished with the equipment should indicate the circuits to be fused and the value to be employed.

.350 The structural parts are made of materials which experience or conclusive tests have proved to be uniform in quality and strength or otherwise suitable for aircraft radio equipment construction.

The structural design of aircraft radio equipment requires that consideration be given to mechanical strength. It has been the experience of the Administrator that mechanical strength is frequently sacrificed in order to affect a small decrease in the weight of the complete unit. Such economies are seldom justified and usually result in unsatisfactory service of the unit under flight conditions. It is recommended that the design engineer give careful consideration to various methods of construction and make frequent use of vibration, drop and similar tests designed to show mechanical strength during the initial design of the aircraft radio equipment.

Where lightening holes are provided in chassis or panels of considerable open area, additional strength may be provided by turning the edge of the lightening hole with a slow radius to an angle of approximately 45° from the plane of the panel.

The use of aluminum angle structures reinforced with adequate gusset plates has proven very satisfactory. Where structural parts are formed from sheet stock, reinforcing ribs and formed angles on the edges of the sheet stock are desirable in order to give the structure the desired rigidity. Experience indicates that structural parts fabricated from aluminum alloys should rarely if ever utilize sheet material thinner than .032 inches. Where the harder alloys of aluminum are used, care should be taken that bends are made with proper regard for grain direction and bend radius to produce a uniformly strong structure free from potential cracks or breaks.

Structural parts which are subjected to hard usage should not employ aluminum alloy. This is particularly applicable to bases and sub-panels required to carry heavy components as well as the runners under the base of aircraft radio equipment which are used as guides in inserting the equipment in its mounting. It is also applicable to such components as carrying handles, locking mechanisms, and similar parts which are frequently subjected to either tensile or tortional strains. For such applications, stainless steel, plated brass, or properly rust-proofed ferrous alloys should be used.

The use of phenolic strips as runners under the base of aircraft radio equipment is considered satisfactory, provided that means for adequately grounding the radio unit are incorporated in the design.

351 Ferrous metal parts subject to corrosion are protected by a suitable plating, lacquering or equivalent process applied to the surface of such ferrous parts.

352 Metal parts incorporated in the equipment, designed primarily to provide electrical shielding, are of sufficient structural strength to insure rigidity and permanence of mounting.

Such shields, when not used to support parts and when material thinner than .032" will provide the desired degree of shielding, may be formed of thinner material and considered satisfactory provided they include any necessary lips, ribs, et cetera properly located to produce a rigid self-supporting shield.

When spade bolts are employed to secure shield cans to an assembly, consideration should be given to the length of the spade, the number and location of the rivets used, and the thickness and material of which the shield can is made, to prevent elongation of the rivet holes when the nuts are tightened on the spade bolts.

.353 Control knobs, frictional couplings, and similar fittings are adequately secured to the shafts of control mechanisms.

Experience has indicated that it is desirable to secure such fittings by means of two set screws located 75 to 180 degrees from other other, since fittings of this type equipped with only one set screw have frequently come loose in service with the resultant inability to rotate the desired control.

In general, plastic or bakelite knobs should not be used. In applications not involving hard usage they may be used subject to the condition that they are provided with metal inserts which may be drilled and tapped to engage the threads of the set screws. Metal inserts are necessarybecause threads tapped in plastic molded materials are easily stripped and do not provide an adequate method of securing the knob to the control shaft.

If the design of the control knob precludes the use of two set screws located 75 to 180 degrees from each other as set forth above, it is desirable that one side of the control shaft be flattened in order to provide a sufficient area of contact between the shaft and the set screw, which should be of the "cup-pointed" type.

Due consideration should be given to the type of set screw used. The point of the set screw should not be of a type that digs into the control shaft to an extent that a burr is produced which prevents the easy removal of the control knob.

Due to the ease with which headless set screws having a screw driver slot can be broken, consideration should be given to the use of set screws of the Bristol or Allen type.

.354 All bolts, studs, screws and nuts wherever practicable conform to the National Screw Thread Commission, fine or coarse series threads.

.355 All controls, switches and levers are clearly marked as to their functional purpose.

Wherever practicable it is desirable that such markings be in the nature of etched name plates or the equivalent. The use of ink applied with rubber stamps is considered satisfactory only in those applications where the markings are not subjected to handling or abuse, and where adequate precautions are taken to prevent defacement of the markings by a coating of clear lacquer or other suitable protective material.

.356 All movable controls are so designed that displacement does not result under service conditions.

Continually adjustable controls which might shift from their adjusted position due to vibration or similar causes should be provided with friction loading devices. Undesirable shifting may also be eliminated by the use of gear-reduction devices where such devices are applicable to the nature of the continually adjustable control.

In the arrangement of a number of continually adjustable controls on a control panel, consideration should be given to providing sufficient room around each individual control to permit its easy adjustment without disturbing the adjustment of adjacent controls. It should not be necessary for a pilot to remove his gloves to adjust or manipulate any control.

In following this recommendation, the design engineer should realize that air carrier aircraft cockpits are protected and heated to an extent which makes it unnecessary to wear the old heavy flying mitten. The reference to gloves as used above should be interpreted to mean the ordinary pigskin glove commonly worn.

The controls for adjusting trimmer condensers and similar components parts, which are required to retain a fixed setting after adjustment, should be provided with suitable and positive locking device. In the case of timmer condensers, and similar components where the rotating element is comparatively light in weight, friction locking devices have been found to be satisfactory. Suitable means should be employed to indicate the relative position or setting of the tuning condenser or other component part.

It is desirable that the locking device be so designed that no special tools are required to lock or unlock it. The operation of the locking mechanism should not affect the adjusted setting of the variable component part.

The use of trimmer or padder condensers of the compression type should be avoided wherever possible as under normal service conditions their capacity changes beyond permissible tolerances. This change is frequently due to corrosion and vibration which are extremely difficult to guard against.

357 All controls which are manipulated during operation of the equipment are of rugged design and construction to permit their operation without damage by non-technical personnel under the most adverse service conditions.

An example of unsatisfactory design is an extension shaft on a tuning control to place the crank handle in a more accessible position with the resultant possibility of a bent shaft and consequent inability to rotate the control. Another example of unsatisfactory design is a manual frequency shift mechanism with inadequate detent mechanism such that operating personnel are unable to determine definitely the point at which end of travel has been reached.

Mechanical rotating controls, such as tuning, band switching or loop rotating controls, should be located so that the rotating crank will not obscure portions of dials, meters, or other types of visual indicators. Where mechanical controls of the rotating or push-pull type are used, it is required that an indexing method for proper alignment of the control be provided at the unit. This requires that the tuning element of radio receivers or remotely-tuned units be provided with an indexing dial scales calibrated in kilocycles, to agree with the position of the tuning controls which may be located in the cockpit of the aircraft. Similarly, push-pull controls should possess adequate detent action to permit alignment of mechanical controls.

.37 Tests:

Aircraft radio equipment which has been satisfactorily subjected to the following tests may be deemed to comply with Section 16.30 (c) of the regulations.

370 The equipment may be subjected to any or all of the following tests, as the Administrator may prescribe. During all of these tests the performance of the equipment is to be satisfactory for the purpose for which the equipment is designed. If, during the tests, failures occur, or other unsatisfactory conditions develop, the applicant should take such corrective action as may be necessary to remedy the defects. This remedial action shall be outlined in the test data and the corrective action included in the drawings and specifications furnished the Administrator.

.371 Humidity Test:

The equipment will be placed in an atmosphere of clear vapor maintained at 95% humidity and 50 degrees centigrade temperature for a period of 48 hours. The humidity is to be maintained within plus or minus 5% of 95% and the temperature within plus or minus 5 degrees of 50 degrees centigrade. The percentage of humidity and the time during which the equipment is in the chamber may be less than the maximum indicated above, if, in the opinion of the Administrator's representative, the design of the unit is such that any inherent defects will be disclosed at a lower temperature or percentage of humidity, or within a shorter period of time.

The equipment is to be operated at intervals specified by the Administrator's representative during the humidity test to determine the effects of such tests. When measurements are not being made the equipment is to be rendered inoperative. When testing equipment whose operating frequency is adjustable manually over a band of frequencies, it is satisfactory to operate the equipment on one frequency only, when it is not practical to tune such equipment from a remote point. Upon completion of exposure to humidity the equipment is to be tested to obtain such pertinent comparison data as the Administrator's representative may require. An inspection of the equipment should not show any evidence of corrosion or other condition, the presence or the continuance of which will lower the performance of the unit below the minimum necessary for the service intended. After exposure to humidity the sensitivity performance of receiving equipment and the power output of transmitting equipment is not to be below the following values at the time intervals stated. After a warm up period of 30 minutes the sensitivity of receiving equipment should be such that not more than four times that input required prior to exposure to produce reference output, is subsequently necessary to obtain the same reference output, and at the end of 4 hours of operation substantially complete recovery should be obtained.

After a warm up period of 15 minutes the power output of transmitting equipment should not be less than 75% of the power output prior to exposure, and at the end of 4 hours of operation substantially complete recovery should be obtained.

The tolerance of 5% in humidity and 5 degrees in temperature is permitted for the sole purpose of allowing for variations in the accuracy of measuring and recording equipment, and is not to be interpreted to permit the applicant to arbitrarily choose a value of conditions lower than that specified as standard.

The loss in sensitivity in receiving equipment has been determined to result in part to surface leakage due to moisture condensation on the surface of insulating materials used in high impedance circuits. To decrease such surface leakage between resistors, condensers and other component parts of various circuits, it is desirable to mold metal grounding separators between each individual resistor or condenser. The effects of surface leakage may also be reduced by separating screen, plate and other high voltage resistors from grid and grid control resistors and condensers.

Receivers employing self-excited oscillator circuits may fail to recover due to a shift in oscillator frequency as a result of the humidity exposure. Such frequency snift has been known to result from a permanent change in the values of circuit components during the humidity test. Care should be taken in the selection of component parts, impregnation processes and physical arrangement of parts to prevent such effects.

Since portions of the prescribed tests are in the nature of accelerated life tests, no unit of equipment which has been subjected to them will necessarily be considered suitable for use in air carrier service after completion of the tests.

372 Temperature Test:

The equipment will be placed in an ambient temperature of plus 55° centigrade for a sufficient period of time to permit all component parts to reach that temperature. The equipment will be operated at a supply voltage 20% above normal in the case of 12-14 and 24-28 volt DC equipment, and 10% above normal in the case of 105-120 volt AC equipment, for a period of one hour. The equipment will then be operated at a supply voltage 10% below normal for such time period as the Administrator's representative may deem necessary to determine the effects of such test. The equipment will then be rendered inoperative and placed in a temperature of minus 35 degrees centigrade for a period of time sufficient to allow the component parts to reach that temperature. It will then be operated at supply voltages 10% above and below that specified as normal for a sufficient period of time to determine the effects of such tests. All mechanical controls are to be operated while the equipment is at the reduced temperature, to ascertain that such controls perform the function for which they are intended.

The time element "a period of one hour" as used above will be interpreted to mean continuous operation in the case of receiving equipment or other equipment designed for continuous operation. In the case of transmitting equipment or equipment designed for intermittent operation "a period of one hour" will be interpreted as duty cycles of 5 minutes on and 5 minutes off, for a period involving six complete cycles.

The development of subnormal and abnormal input voltage in the temperature test as outlined above will be determined on the basis of the applicant's selection of "normal" terminal voltage. For example, if a receiver is designed for "normal" input of 12 volts the subnormal input shall be 10.8 volts and the abnormal input will be 14.4. If the "normal" rating is given as 14 volts the subnormal input will be 12.6 volts and the abnormal input will be 16.8 volts, as measured at the input terminals (plug) of the unit.

.373 Vibration Test:

The equipment will be vibrated for a period of four hours at a frequency between 30 and 60 cycles per second, as may be selected by the applicant, with an amplitude and waveform sufficient to produce a vertical acceleration of 10G. During this period of vibration the equipment is to be in operating condition under the supervision of the Administrator's representative in order to detect variations in output, frequency, et cetera, and any other detrimental effects caused by the vibration. At the termination of this portion of the test a visual inspection will be made, and should disclose no conditions produced by the vibration, the presence of, or continuation of which would be detrimental to the satisfactory performance of the equipment.

The equipment will then be operated over a continuously variable frequency range from 25 to 60 cycles with sufficient amplitude to permit the vibration to be easily felt by placing the hand on the vibration table. This test is to be of sufficient duration to permit the Administrator's representative to observe the behavior of all component parts throughout the specified frequency range for evidence of resonant vibration. Parts which show such tendencies should be redesigned or remounted to eliminate the resonant condition. Where redesigning or remounting is not practical, the applicant shall satisfactorily demonstrate that the resonant vibration of the part will in no manner be detrimental to the airworthiness of the unit. The use of shock mounts will not be permitted during the vibration tests unless such shock mounts form an integral part of the design of the unit, or the equipment is placarded to indicate that it should not be used unless mounted on a shock mount equivalent to that used in the test.

In some instances air carriers desire to mount equipment on specially designed shock mounted racks which form a part of the aircraft structure. Provisions are not made in this part of the Civil Air Regulations for certification of such special racks. The method of showing "equivalency" will be determined upon individual application of the carrier and will be considered a part of installation inspection rather than certification inspection.

The applicant shall furnish a strobotac or other satisfactory stroboscopic device for use in ovserving the equipment under vibration.

While conducting the variable frequency portion of the vibration tests it may be desirable to mount the equipment in an inverted position during a portion of the test in order to observe the behavior of component parts located beneath the chassis.

Equipment incorporating meters as an integral part of the design will be subjected to the full 10G acceleration during the test, although an individual meter need only be subjected to acceleration of 5G, provided that current meters subjected to an acceleration test of only 5G are equipped with a shunt having sufficient current carrying capacity to carry the full load current of the circuit in which the meter is intended to be used. This provision will prevent equipment failures resulting from failures of the meter movement itself. The failure of a volt meter will not normally render inoperative the equipment with which it is used. Since the spring loaded moving coil of meter movements is inherently a mechanically resonant circuit, such resonance will not be considered unsatisfactory and no redesign of such a system will be required nor will the equipment be necessarily operated for the 4 hour period at the resonant frequency of the meter movement.

It has been the experience of the Administrator that aircraft radio equipment frequently fails to satisfactorily pass the vibration test because of the following faults in design:

Heavy component parts such as power transformers, audio transformers, and components of similar nature which are mounted in the center of a chassis without adequate support may vibrate excessively and cause structural failures.

Certain component parts may vibrate excessively due to the lack of sufficient mounting base area and insufficient spacing between the machine screws in such mounting bases. This is particularly true of relays which are frequently supported to the chassis structure by two machine screws very closely spaced. The great lentth of the relay in relation to the mounting base area causes the relay to vibrate excessively at certain frequencies.

In all cases, leads should not be stretched taut, as any relative movement between the various component parts on the chassis may result in breakage of the leads, usually at the soldered connection. When flexible leads pass through holes drilled in a metal chassis or metal shielding partitions, the insulation of the wire should be protected from abrasion by grommets or other suitable means.

Vibration transmitted by power cables and wiring harness frequently cause single-hole mounted terminals to rotate from their normal position to an extent that they short circuit or ground against adjacent terminals. Adequate precautions should be taken to prevent any rotation of the terminals from their normal position.

Certain types of vacuum tubes, particularly those of the multi-element type, sometimes fail in vibration tests. When it can be demonstrated that such tube failures are not due to any inherent fault in the structural or electrical design of the particular tube type, the failure may not prohibit the type certification of the aircraft radio eqiupment. Wherever possible, vacuum tubes of a type which experience has shown to be airworthy should be employed.

Vacuum tubes of a type which experience has shown to be unsatisfactory in aircraft service may not be acceptable for use in certificated aircraft radio equipment.

.374 Drop Test:

The equipment will be subjected to at least 100 free drops from 6 to 18 inches as follows: 34 drops from 6 inches, 33 drops from 12 inches, and 33 drops from 18 inches. During this test no shock absorbers will be attached to the unit, and if shock absorbers are incorporated in the design as an integral part of the equipment, they will be removed. Commercial sponge rubber of a thickness not to exceed one inch may be interposed as a damping medium between the equipment and the substantially solid platform upon which the equipment will come to rest. During this test the equipment will be released in the free drop in such a manner that it will come to rest in the attitude in which it was designed to operate, and in such manner as to provide equally distributed stress to the equipment structure. During this test the Administrator's representative may require that connecting plugs, cables and external plug-in devices be connected to the equipment to determine the suitability of the locking devices employed in the design. The platform on which the equipment is mounted during the drop tests is to be of such design as to be as free from friction as possible during the drop.

.375 Pressure Test:

The equipment will be operated in a pressure chamber under variable pressures from 29.92 to 8.52 inches of mercury (sea level to 31,000 feet altitude). The period of observation at the reduced pressures will be of sufficient duration to disclose any defects which may be aggravated by the reduced pressure. The equipment should operate satisfactorily throughout the pressure range specified. Transmitters subjected to this test will be tuned to their lowest operating frequency and operated into the smallest antenna and at the highest percentage of modulation for which the transmitter is designed. It is within the jurisdiction of the Administrator's representative to require a radio transmitter to be operated under various pressure conditions with the tuning circuits of the transmitter misaligned, or with the antenna disconnected, to determine if flash-overs or other hazardous conditions result from such operation.

.376 The Administrator will assume no responsibility for damage to equipment resulting directly or indirectly from type certificate tests.

INSPECTION AND TESTS

16.40 GENERAL: THE PRESCRIBED INSPECTIONS AND TESTS SHALL BE CONDUCTED BY THE APPLICANT UNDER THE SUPERVISION OF REPRESENTATIVES OF THE ADMINISTRATOR AT A DESIGNATED TIME AND PLACE AND IN SUCH MANNER AND UNDER SUCH CONDITIONS AS THEY MAY DEEM NECESSARY.

.400 Applicants will be deemed to have complied with the requirements of CAR 16.40 when they have:

.401 Made application for a type certificate in the manner outlined in Part 02 of Civil Air Regulations as explained under "Application".

.402 Appointed a definite date upon which to begin type certification inspection, and notified the Administrator in regard to this date as far in advance as possible.

This information may be included in the application for a type certificate.

It is desirable that the Administrator be notified at least one week in advance of the date on which it is desired to begin the type certification tests to avoid confusion and conflicting dates whenever possible.

.403 Advised the Administrator of the place at which the inspection is to be conducted and the name of the applicant's representative assigned to the inspection.

.404 Made the necessary preparations to conduct the inspection in accordance with the requirements of CAR 16.41.

16.41 FACILITIES: ALL ENGINEERING, TECHNICAL AND PHYSICAL FACILITIES WHICH MAY BE NECESSARY FOR THE CONDUCT OF ALL OF THE PRESCRIBED INSPECTIONS AND TESTS SHALL BE PROVIDED BY THE APPLICANT.

410 An applicant will be deemed to have complied with the requirements of CAR 16.41 when:

411 There is made available all necessary laboratory equipment required for the engineering design of aircraft radio equipment. This shall include meters of all necessary types, signal generators, test benches, storage batteries, screen rooms, et cetera.

Every effort will be made by the representatives of the Administrator to cooperate with the applicant by using necessary test equipment to its fullest advantage, giving due consideration to other development projects which require the use of the test equipment by the applicant. Due to the relatively high cost of conducting type certificate tests, arrangements should be made to have the necessary test equipment readily available at all times during the tests in order that the tests may be conducted as economically as possible.

412 The applicant is equipped with special apparatus of the type outlined in the specifications established by Sub-Committee No. 14 of the Radio Technical Committee for Aeronautics, August 2, 1939, except that high and low operating limits of such apparatus need only meet the requirements of CAR 16.30 as interpreted by section .37 of this manual.

The following is a copy of these specifications:

"Humidity Chambers

"Humidity chambers shall be capable of being varied or maintained throughout a range of 35 to 95% relative humidity at a temperature of plus 50 degrees centigrade. Permissible tolerance with respect to humidity shall be plus or minus 5% relative humidity, and with respect to temperature, shall be plus or minus 5 degrees centigrade. It shall be possible to operate equipment normally while undergoing humidity test.

"Temperature Chambers

"Temperature chambers shall be capable of being varied or maintained from minus 35 degrees centigrade to plus 80 degrees centigrade with an accuracy of plus or minus 5 degrees. It shall be possible to maintain the aforementioned temperature requirement while the equipment undergoing test is in an operative condition.

"Vibration Table

"Vibration testing equipment shall be designed to permit continuously variable amplitude.

"Vibration testing equipment shall be designed to give vertical acceleration.

"Vibration testing equipment shall be designed to operate from 10 to 60 cycles inclusive.

"Vibration testing equipment shall be capable of being set to give maximum acceleration of 2G at 10 cycles, 3½G at 15 cycles 5G at 20 cycles and 10G at 25 to 60 cycles.

"Drop Testing Equipment

"Drop testing equipment shall be designed to permit a free drop from a maximum height 18 inches.

"Pressure Chambers

"Pressure chambers shall be capable of pressure ranges from normal atmospheric to equivalent pressure represented by 35,000 feet altitude, and such chambers shall be designed to permit visual inspection of equipment undergoing test at reduced pressures"

During the formative stages of design it is of great assistance to the engineer to be able to adequately test component parts and sub-assemblies prior to type certificate tests. This may eliminate many lengthy delays during the type certification tests caused by the failure of inadequately pre-tested components.

16.42 REPORT: THE APPLICANT SHALL SUBMIT IN DUPLICATE A WRITTEN REPORT OF THE RESULTS OF THE PRESCRIBED INSPECTIONS AND TESTS WHICH SHALL BE IN SUCH DETAIL AS THE ADMINISTRATOR MAY REQUIRE.

.420 Satisfacrory compliance with 16.42 may be accomplished by the presentation of information and data in the detail and form outlined below. The test report should be suitably bound, with all pages consecutively numbered, and separated from such drawings and blue prints as are otherwise required.

.421 Section 1

a. Name and address of applicant.

b. Name of equipment for which application for Type Certificate has been made (listing all associated units which form a part of this equipment).

.422 Section 2

Index of test report - This index should be as complete as possible, indexing to page number and not to section number.

.423 Section 3

a. Applicant's exact designation of equipment (to be exactly that designation which will be given on the name plate and which the applicant desires to have incorporated in the wording of the type certificate). It is desirable to submit a typed facsimile of the actual name plate.

b. Applicant's designation of associated units which form a part of the type certificated equipment.

.424 Section 4

a. Purpose for which equipment is intended.

b. General description of equipment giving size, weights, electrical characteristics, i.e., input, output, frequency range et cetera; description of circuit (brief); description of controls; other equipment with which this equipment is designed to be used, et cetera.

.425 Section 5

Test - Test data should be submitted in order of -
a. Mechanical construction and design
b. Electrical design
c. Material and workmanship
d. Instruction book and specifications
e. General performance at normal battery voltage
f. Temperature test
g. Pressure test
h. Humidity test
i. Vibration test
j. Drop test
k. Interchangeability of tubes and component parts test
l. Any other tests required by the Administrator's representative.

For each test prescribed to determine the airworthiness or operating characteristics of the equipment, a separate entry should be made in the test report to indicate that the test outlined has been made, and that the unit is either satisfactory or unsatisfactory in regard to the test applied. Where possible, give condition before and after test to facilitate quick comparison. Record at the heading of each specific test the following information:

a. Date
b. Name of company engineer(s) conducting test.
c. Name of Administrator's representative witnessing tests.
d. Name of unit under test.
e. Ambient temperature and relative humidity of room in which testing is done.

Head each list of data with a record of the condition under which the test was made, such as input voltage, signal to noise ratio, input from signal generator, output load impedance, et cetera, and whatever description is applicable to the particular test. Conclude each list of data with a record of any defects or functional irregularities that are disclosed as a result of the test, together with the corrective action taken to eliminate such defect or irregularity.

.426 Section 6
Plotted Data - Inasmuch as curves are easier to interpret and provide quick means for interpolation between reference points, it is desirable that all data taken in the various tests be plotted, whenever the nature of the test permits this method of

recording the data. Curves outlining the normal conditions and the conditions existing after a specific test should be plotted on the same graph to facilitate quick comparison. For example, plot the sensitivity versus frequency curve under normal conditions and again under conditions of high temperature, after vibration, after humidity, et cetera. The value of complete and numerous plotted data cannot be over-emphasized.

.427 Section 7

Photographs - Photographs showing the equipment from various angles with detail sufficient to show every single part comprising the equipment should be submitted wherever necessary to clarify methods of assembly, and the relation of various parts to one another.

.428 Section 8

Administrator's representative's recommendation - Include in the report, on a separate page, a letter bearing the signature of the Administrator's representative setting forth his comments as to whether or not the unit satisfactorily fulfills the requirements of "CAR - 16 - Aircraft Radio Equipment Airworthiness" and his recommendations in regard to the issuance of a Type Certificate, together with any restrictions under which such type certificate should be issued.

.429 Section 9

Two copies of the final service and installation manual shall be submitted. Inasmuch as final copies of this manual are very seldom ready when the test report is submitted it is desirable that a tentative manual marked "TENTATIVE" be submitted to aid in reviewing the test report.

It is desirable that the final installation and service manual be submitted to the Administrator prior to the time any of the equipment to which the type certificate applies is delivered to customers.

REGULATIONS

16.50 IDENTIFICATION: TYPE CERTIFICATED AIRCRAFT RADIO EQUIPMENT SHALL BE PLAINLY AND SUITABLY MARKED WITH AT LEAST THE FOLLOWING INFORMATION:

(a) NAME AND ADDRESS OF MANUFACTURER;

(b) MANUFACTURER'S TYPE OR MODEL DESIGNATION;

(c) WEIGHT TO THE NEAREST POUND AND FRACTION THEREOF;

(d) SERIAL NUMBER OR DATE OF MANUFACTURE;

(e) TYPE CERTIFICATE NUMBER.

.500 Equipment whose nameplate contains information as outlined hereinafter will be deemed to have complied with CAR 16.50 when:

501 The nameplate includes the name by which the manufacturer is legally known and the address of his principal place of business, including city and state.

In cases where the equipment is designed to the specifications of an intermediate or ultimate purchaser, who desires that his name appear on the nameplate, such purchaser's name may appear on the nameplate provided the actual manufacturer's name also appears for identification purposes. The manufacturer's name should be preceded by the words "Manufactured by", or otherwise differentiated from the name of the purchaser.

The Administrator has no specific interest in the patent notices which are frequently included on nameplates. The inclusion of this information, if desired, is considered satisfactory. However, since this information is often quite lengthy, it is suggested that such patent notices be set forth in letters and numbers smaller than the designation data, and suitably segregated on the nameplate.

502 The manufacturer's type or model designation appears legibly on the nameplate.

To be type certificated, aircraft radio equipment should be identified by a type or model number, appearing on the nameplate of the radio equipment. Such type certificate will be applicable only to units of equipment bearing the assigned type or model number. Should it be desired, for any reason, to change the type or model designation of the equipment, a new type certificate will be required.

503 The weight of the unit to the nearest pound and fraction thereof is included on the nameplate. The indicated weight shall include the weights of crystals, tubes and other component parts necessary for the operation of the equipment as a unit, but should not include the weights of shock mounts, power cables, frequency selector devices, and similar accessories unless such accessories are considered to be an integral part of the unit. Units of equipment designed for multi-channel operation whose weight may be variable, dependent upon the number of channels with which the unit may be equipped, should have weights designated in the following manner:

(1) Basic weight ___________lbs.________oz./(or tenth lbs.________).
(2) Weight per channel _____lbs.________oz./(or tenth lbs.________).

The basic weight shall include the weights of such tubes, transformers and other components normally required for the operation of the unit, but <u>less</u> the weights of all crystals, coils, transformers, et cetera, which are associated with channel operation. The weight per channel shall include the weights of <u>one set</u> of crystals, coils, transformers, et cetera, normally required to be installed in the transmitter to place a particular frequency in operation. (Where there is a variation in weight per channel, occasioned for example by heavier coils for use on the lower frequencies, the <u>average</u> weight of the various channel weights should be listed as the weight per channel.)

To comply with this requirement, the applicant may at his option, indicate the weight either in pounds and ounces, or pounds and tenths of a pound to the nearest tenth.

.504 The serial number of the unit and/or its date of manufacture appears on the nameplate.

When the date of manufacture is given, it should indicate the month and year during which the equipment was completed. Since the date of completion is not always definitely known at the time etched panels and/or nameplates must be prepared, it is considered satisfactory to use the estimated date on which the first unit of an order will be completed.

When a unit is placed in production several different times under the same type certificate but with a considerable lapse of time between orders, each new stock of such equipment should bear a separate date of manufacture (if used), to indicate as accurately as possible the actual date on which each unit was fabricated

.505 The unit is plainly marked with the type certificate number.

The actual number should be preceded by the letters "CAATC" so that the designation would appear CAATC #000 or CAATC No. 000.

As a convenience to applicants in the preparation of photo-etched nameplates where the type certificate number must be shown, the administrator may upon application reserve a block of 10 to 20 numbers for the applicant. The applicant may feel free to use these numbers with the distinct understanding that they are tentatively assigned pending the issuance of a type certificate. The type certificate number when issued will be adjusted to correspond with the number selected by the applicant from the reserved numbers. Should any units of equipment be shipped from the applicant plant prior to final issuance of the certificate the certificate number selected from the reserve pool will be removed or obscured in an unmistakable manner.

16.51 MODIFICATION: NO CHANGE SHALL BE MADE IN THE APPROVED SPECIFICATIONS UNDER WHICH TYPE CERTIFICATED AIRCRAFT RADIO EQUIPMENT IS MANUFACUTRED PRIOR TO THE APPROVAL OF SUCH CHANGE BY THE ADMINISTRATOR.

.510 In order to permit desirable changes to type certificated aircraft radio equipment, the Administrator may consider applications for approval of modifications to equipment which has been type certificated.

.511 Modifications which have been made in accordance with the following procedure will be deemed to have complied with the requirements of CAR 16.51.

.512 Application for approval of modifications to type certificated units of aircraft radio equipment may be initiated by the following classifications of applicants:

a. Manufacturers engaged in the fabrication, assembly and sale of units of type certificated aircraft radio equipment.

b. Manufacturers' subsidiaries, representatives, or agents engaged in the fabrication, manufacture, sale or installation of units of type certificated aircraft radio equipment and then only wnen specifically authorized by the type certificate holder to make application for modification.

c. Aircarrier operators, engaged in the design, manufacture, installation and/or use of units of type certificated aircraft radio equipment.

513 An application for authority to modify a type certificated unit of aircraft radio equipment should be made by a letter to the Administrator in the same manner outlined for original certification under "Application" and should contain the following information:

a. Name and address of applicant.

b. Type or model designation of the unit affected and type certificate number assigned to such unit.

c. Purpose and extent of proposed modification.

d. Date and place where the equipment may be inspected.

The date and place of inspection should be determined as far in advance as possible so that the Administrator's representative may arrange his itinerary to avoid delays.

.514 The modified equipment will, at the discretion of the Administrator's representative, be submitted to any or all of the tests outlined in CAR 16.30.

The purpose of the inspection of the modified equipment is to determine that the modifications are desirable in the interest of increased performance or efficiency, and that no degradation of reliability will result therefrom.

CAR 16.12 applies to all applications for authority to modify type certificated equipment, and equipment will not be subjected to irrelevant or superfluous tests.

.515 The applicant should prepare, and submit to the Administrator's representative, two copies of all drawings, test data, and other factual data necessary to fully describe the changes affected. This information should include two copies of revised drawings which clearly indicate in detail the proposed changes. These drawings should be so prepared that they may be easily correlated with the drawings originally submitted with the type certificate test data.

There should also be included two copies of a test report containing the data, applicable curves, et cetera, obtained from the tests conducted on the modified equipment. This test report should be prepared in a manner similar to that previously outlined for the preparation of type certificate reports and contain any comments applicable to the preparation of the modification test report. The use of photographs is recommended as an excellent method of indicating how the modified equipment differs mechanically from the original.

The Administrator's representative will forward this information together with his recommendations to the Washington office of the Administrator, and if the data indicates that the changes are desirable, the Administrator may authorize the type certificate holder, at his option, to incorporate the modifications set forth in the data submitted by the applicant. When the applicant is not the type certificate holder, one copy of all data submitted will be forwarded to the type certificate holder.

The importance of complete and adequate drawings showing all details of the proposed changes cannot be over-estimated, since the final decision by the Washington Office of the Administrator regarding the desirability of the proposed modifications is based on an examination of these drawings, qualified by the recommendations of the Administrator's representative. Minor changes may often be approved without conducting tests, providing the drawings, photographs et cetera show the changes in sufficient detail.

16.52 LIST CHANGES: THE HOLDER OF A TYPE CERTIFICATE FOR AIRCRAFT RADIO EQUIPMENT SHALL KEEP ALL LISTS FURNISHED THE ADMINISTRATOR CURRENT BY SUBMITTING REVISED LISTS CONTAINING ALL CHANGES MADE SUBSEQUENT TO ORIGINAL CERTIFICATION.

.520 Type certificate holders who follow the procedure set forth hereinafter, will be deemed to have complied with the requirements of CAR 16.52.

.521 Arrangements should be made either in the drafting or engineering departments or both, to be sure that any and all changes, however minor, to the approved drawings or specifications of type certificate aircraft radio equipment are qpproved by the Administrator prior to the inclusion of such details in type certificated equipment in use.

A suggested method is to mark each drawing pertaining to the equipment with a prominent identification mark such as a bold face "CAA", so that whenever revisions are made to any such drawings, it will be a routine matter to supply a copy of each revised print to the Administrator, through the Administrator's representative.

There should be included a list of parts necessary to affect the modification. This parts list should include a complete list of those parts it is necessary to add and those necessary to delete from the type certification parts list required by CAR 16.23.

TEST PROCEDURES
Receiving Equipment

The following definition of terms and conditions of test are applicable to the receiving equipment specified hereinafter.

STANDARD TEST ANTENNA:

A standard test antenna shall consist of a capacitance of 100 micro-microfarads, plus or minus 10%, and a series resistance of 10 ohms. The output resistance of the signal generator shall be included in the 10 ohms specified.

Note: In cases where the input circuit of the receiver is designed for a specific input impedance as, for example, a 72 ohm transmission line, the tests hereinafter prescribed shall be conducted at the input impedance for which the receiver is designed in lieu of the "Standard Test Antenna" defined above. A notation shall be made in the test data setting forth the value of the specific input impedance used.

SIGNAL-TO-NOISE RATIO:

(a) MCW - The MCW signal-to-noise ratio specified in these tests shall be determined with the carrier "ON", and the modulation "ON" and "OFF" for "SIGNAL" and "NOISE" respectively.

(b) CW - The CW signal-to-noise ratio specified in these tests shall be determined with the modulation "OFF", and with the carrier "ON" and "OFF" for "SIGNAL" and "NOISE" respectively.

Note: In cases where the specified signal-to-noise ratio cannot be obtained because of the performance characteristcs and/or circuit design of the receiver, the specified tests shall be conducted with the receiver sensitivity/volume control set at the "maximum" position, and a notation to this effect, together with the actual signal-to-noise ratio obtained, included in the test data.

GENERAL REQUIREMENTS:

(a) All receiver tests shall be conducted with input power voltage adjusted to 14 volts plus or minus .25 volts for 12-14 volt equipment, or to 28 volts plus or minus .5 volts for 24-28 volt equipment. The input voltage shall be measured at the power source end of the power cables normally supplied or recommended for use with the receiving equipment.

(b) Unless otherwise specified, the "AVC" switch shall be in the "OFF" position.

(c) Unless otherwise specified, the beat frequency oscillator switch shall be in the "OFF" position.

(d) The circuits of the receiving equipment shall be properly aligned and otherwise adjusted in accordance with the manufacturers recommended practices prior to the application of the specified tests.

(e) The resonant circuits of the receiving equipment normally varied to accomplish tuning of the receiver shall be accurately adjusted to the frequency of the source of radio frequency input (signal generator), unless otherwise specified.

(f) Audio frequency inputs shall be held constant over the frequency range specified at that level established at the reference input frequency, unless otherwise specifically required by the test procedure.

(g) Due precautions shall be taken to prevent the introduction of errors resulting from the employment of headphones, voltmeters, oscilloscopes and other test instruments across the input and/or output impedances used in connection with the specified tests.

(h) All tests shall be conducted under conditions of normal room temperature and humidity, unless otherwise specified.

FIDELITY (AUDIO)

Apply to the input of the first audio stage an audio signal of sufficient amplitude to produce an output of 50 milliwatts into the load impedance for which the receiver is designed, at a reference frequency of 400 cycles. Vary the audio frequency input through the audio frequency band of 100 to 4000 cycles per second. Plot the output ratio in DB above and below the reference output of 50 milliwatts at the following frequencies:

100, 200, 300, 400, 600, 800, 1000, 1250, 1500, 2000 , 2500, 3000 and 4000 cycles per second.

FIDELITY (OVERALL)

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal, 30% modulated at 400 cycles, of sufficient amplitude to produce an audio output of 50 milliwatts into the load impedance for which the receiver is designed. For this test, so adjust the sensitivity control of the receiver that a signal-to-noise ratio of 20 DB is obtained, in order that the stability of the output voltage will not be seriously affected by the presence of noise. Vary the audio modulating frequency through the range of 100 to 4000 cycles and plot the output in DB above and below the reference output of 50 milliwatts at the following frequencies:

100, 200, 300, 400, 600, 800, 1000, 1250, 1500, 2000, 2500, 3000, and 4000 cycles per second.

This test shall be made at the end points of each frequency band.

FIDELITY (SIDE-TONE)

This test is applicable when provisions are made in the design of the receiver to use the audio stage or stages, as a side-tone amplifier. Apply to the side-tone connection, a 400 cycle audio signal of sufficient amplitude to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Vary the audio frequency input through the audio frequency band of 100 to 4000 cycles per second. Plot the output ratio in DB above and below the reference output of 50 milliwatts at the following frequencies:

100, 200, 300, 400, 600, 800, 1000, 1250, 1500, 2000, 2500, 3000, and 4000 cycles per second.

RESONANT OVERLOAD AND DISTORTION (OVERALL)

This test is applicable to those receivers, or to such frequency bands of multi-frequency channel receivers, which do not employ an automatic volume control as an inherent function of their circuit design.

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal 30% modulated at 400 cycles. Vary the radio frequency input from zero to 1 volt, and record the output into the impedance for which the receiver is designed. Take output readings with inputs of 1, 3, 5, 7, 10, 30, 100, 300, 1000, 3000, 10,000, 30,000, 100,000, and 300,000 microvolts and 1 volt. This test shall be made at the center point of each frequency band with the sensitivity control set at the full, and at two reduced sensitivity positions. The two reduced sensitivity positions are determined by the settings which will result in a 50 milliwatt output at inputs of 100 and 1000 microvolts respectively. Plot curves from the observed data.

Concurrently determine, by means of a properly designed distortion and noise meter, and record the percentage of combined distortion and noise present in the receiver output with the 3, 10, 100, 1000, 10,000, and 100,000 microvolt and 1 volt input measurements in the low and high frequency bands.

AUTOMATIC VOLUME CONTROL CHARACTERISTICS AND DISTORTION

This test is applicable only to those receivers, or to such frequency bands of multi-frequency channel receivers, which employ an automatic volume control as an inherent function of their circuit design.

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal modulated 30% at 400 cycles. Vary the radio frequency input from 1 microvolt to 1 volt, and record the output into the impedance for which the receiver is designed.

Take output readings with inputs of 1, 3, 5, 7, 10, 30, 100, 300, 1000, 3000, 10,000, 30,000, 100,000, and 300,000 microvolts, and 1 volt. Make this test at the center point of each frequency band with the audio level control set at the full, and at two reduced audio level positions. The two reduced audio level positions are determined by the settings which will result in a 50 milliwatt output at inputs of 100 and 1000 microvolts respectively. Plot curves from the observed data.

Concurrently determine, by means of a properly designed distortion and noise meter, and record the percentage of combined distortion and noise present in the receiver output with the 3, 10, 100, 1000, 10,000, and 100,000 microvolt and 1 volt input measurements in the low and high frequency bands.

SENSITIVITY CONTROL

Apply to the antenna connection of the receiver through a standard test antenna, a radio frequency signal, 30% modulated at 400 cycles, of an amplitude sufficient to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. The receiver sensitivity shall be adjusted to maximum. Decrease the sensitivity by rotation of the sensitivity control knob until 1 volt (or more) of radio frequency input is required to produce 50 milliwatts of output power. Record the input required at each 10 degree rotation of the sensitivity control knob to maintain the 50 milliwatts output. Conduct this test at the center of each radio frequency band, and plot a curve for that frequency band showing the poorest sensitivity control characteristics.

DUAL CHANNEL POWER OUTPUT

Terminate both audio output channels into the load impedance for which the receiver is designed and apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal 30% modulated at 400 cycles, of sufficient amplitude to produce an output of 50 milliwatts into one dual output channel. So adjust the sensitivity control of the receiver that a signal-to-noise ratio of 6 DB is obtained. Record and plot the output of each dual output channel with inputs of 1, 3, 5, 7, 10, 30, 100, 300, 1000, 3000, 10,000, 30,000, 100,000, and 300,000 microvolts and 1 volt. The purpose of this test is to determine if the outputs of the two channels are reasonably equal in power.

DUAL OUTPUT CHANNEL COUPLING

Connect each dual output channel to the load impedance for which the receiver is designed. Apply a 500 milliwatt audio signal across the output impedance of one channel and record the value of the signal present across the other channel impedance. Now change the load impedance of the second channel to 50% above and below the design value and record the output. Conduct the above tests over a frequency range of 100 to 3000 cycles at the following audio frequencies:

100, 500, 1000, 1500, 2000, and 3000 cycles per second.

Test with input to first one channel and then to the other, and record the output obtained under each test condition in DB below the 500 milliwatt input level. The purpose of this test is to determine the extent of inductive or other coupling between channels, and the extent to which coupling is affected with variation in output impedance loads.

SENSITIVITY (MCW) - (REGULAR ANTENNA)

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal modulated 30% at 400 cycles, of sufficient amplitude to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Make this test with the receiver sensitivity control so adjusted that a signal-to-noise ratio of 6 DB is obtained, and at six approximately equally spaced points in each frequency band. Plot signal input in microvolts versus frequency.

SENSITIVITY (CW) - (REGULAR ANTENNA)

With the CW oscillator switch turned "on", apply to the antenna connection of the receiver, through a standard test antenna, an unmodulated radio frequency carrier of an amplitude sufficient to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Make this test with the receiver sensitivity control so adjusted that a signal-to-noise ratio of 10 DB is obtained, and with the receiver tuning so adjusted that an audio output frequency of approximately 1000 cycles (800-1200 cycles) is obtained. Conduct this measurement at six approximately equally spaced points in each frequency band. Plot signal input in microvolts versus frequency.

SENSITIVITY (MCW) - (LOOP ANTENNA)

Orient the loop for maximum signal response and adjust the field strength of a radio frequency carrier, modulated 30% at 400 cycles, to an amplitude necessary to produce an audio output of 50 milliwatts into the load impedance for which the receiver is designed. Make this test with the sensitivity control so adjusted that a signal-to-noise ratio of 6 DB is obtained and at six approximately equally spaced points in each frequency band. Plot field strength in microvolts per meter versus frequency.

SENSITIVITY (CW) - (LOOP ANTENNA)

With the "CW" oscillator switch turned "on" orient the loop for maximum signal response, and adjust the field strength of an unmodulated radio frequency carrier to an amplitude sufficient to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Make this test with the receiver sensitivity control so adjusted that a signal-to-noise ratio of 10 DB is obtained, and with the receiver tuning so adjusted that an audio output frequency of approximately 1000 cycles (800-1200 cycles) is obtained. Conduct this measurement at six approximately equally spaced points in each frequency band. Plot field strength in microvolts per meter versus frequency.

SELECTIVITY (INTERMEDIATE FREQUENCY)

Apply to the input of the intermediate frequency amplifier a radio frequency signal, 30% modulated at 400 cycles, of sufficient amplitude to produce an output of 50 milliwatts into the impedance for whch the receiver is designed. Make this test with the receiver sensitivity so adjusted that a signal-to-noise ratio of 6 DB is obtained. Plot the frequencies to which the signal generator must be tuned, above and below resonant frequency, to produce a 50 milliwatt output at 2 times, 10 times, 100 times, and 1000 times the input at resonant frequency for an output of 50 milliwatts.

SELECTIVITY - OVERALL (REGULAR ANTENNA)

Apply to the antenna connection of the receiver a radio frequency signal, 30% modulated at 400 cycles, of sufficient amplitude to produce an output of 50 milliwatts into the impedance for which the receiver is designed. Make this test with the receiver sensitivity so adjusted that a signal-to-noise ratio of 6 DB is obtained. The automatic volume control shall be rendered inoperative. Plot the frequencies to which the signal generator must be tuned to produce an output of 50 milliwatts at 2 times, 10 times, 100 times, 1000 times, and 10,00C times the input at resonant frequency for an output of 50 milliwatts. Conduct this test at the high and low points of each frequency band.

Note: This test may be eliminated on the high frequency bands of multifrequency channel receivers provided that the receiver manufacturer is agreeable to accepting the intermediate frequency selectivity curce as being representative of the over-all receiver selectivity obtainable on these high frequency bands.

SELECTIVITY - LOOP ANTENNA (OVERALL)

Orient the loop antenna for maximum signal response. Adjust the field strength of a radio frequency carrier, modulated 30% at 400 cycles, to an amplitude necessary to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. So adjust the sensitivity of the receiver that a signal-to-noise ratio of 6 DB is obtained. The automatic volume control shall be rendered inoperative. Plot the frequencies to which the signal generator must be tuned, above and below resonant frequency, to produce a 50 milliwatt output at 2 times, 10 times, 100 times, 1000 times, and 10,000 times the input at resonant frequency. Conduct this test at the high and low ends of each frequency band.

INTERMEDIATE FREQUENCY REJECTION

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal, 30% modulated at 400 cycles, of an amplitude sufficient to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. So adjust the receiver senstitivity that a signal-to-noise ratio of 6 DB is obtained. Record and express in DB the reciprocal of the ratio of the input at the frequency to which the receiver is tuned (signal generator frequency) to the input at the intermediate frequency required to produce a 50 milliwatt output. Conduct this test at the high, center and low points in each frequency band.

IMAGE FREQUENCY REJECTION

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal, 30% modulated at 400 cycles, of an amplitude sufficient to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. So adjust the sensitivity of the receiver that a signal-to-noise ratio of 6 DB is obtained. Record and express in DB the reciprocal of the ratio of the input at the frequency to which the receiver is tuned (signal generator frequency), to the input at a frequency equal to the carrier frequency plus or minus twice the intermediate frequency (dependent upon whether the frequency of the heterodyne oscillator is equal to the carrier frequency plus or minus the intermediate frequency) required to produce an output of 50 milliwatts. Conduct this test at the high, center, and low points in each frequency band.

INTERMEDIATE FREQUENCY HARMONIC BEATS

Apply to the antenna connection of the receiver, through a standard test antenna, a signal modulated 30% at 400 cycles, at a frequency equal to the second harmonic of the intermediate frequency amplifier. Set the radio frequency input at 50 microvolts, tune the receiver to the applied frequency, and adjust the sensitivity control so that maximum undistorted output is obtained into the output impedance for which the receiver is designed. (Undistorted output is considered to contain 10% or less of harmonic distortion). Observe this output. Remove the modulation from the carrier, and with the sensitivity control unchanged, make slight adjustments of the tuning of the receiver and of the carrier frequency until the maximum beat note output (if any) is obtained, and again observe the output. The ratio between these two outputs shall be recorded in DB. Repeat the above test using inputs of 5000 and 10,000 microvolts.

Repeat the above procedure at each harmonic of the intermediate frequency amplifier which falls within the tunable range of the receiver.

REJECTION OF OTHER UNDESIRABLE RESPONSES

Apply to the antenna connection of the receiver, through a standard test antenna, a radio frequency signal 30% modulated at 400 cycles, of sufficient amplitude to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Make this test with the receiver sensitivity control so adjusted that a signal-to-noise ratio of 6 DB is obtained.

Without changing the receiver controls, increase the output of the signal generator to 2 volts and vary the frequency of the signal from the lowest frequency to which the receiver can be tuned on the band being tested to twice the highest frequency on this band. At frequencies where response is shown, decrease the signal generator output to the value required for an output of 50 milliwatts and record the ratio of input at the undesired frequency to the signal input at resonance for 50 milliwatts audio output. Calculate the ratio between 2 volts and the signal voltage required at resonance to produce 50 milliwatts audio output. This is the maximum ratio that need be measured. Where responses are found that will not give 50 milliwatts audio output with 2 volts signal input, record them as greater than the maximum calculated. This test shall be made at the low, center, and high points in each frequency band.

NOISE LEVEL

Adjust the sensitivity control for maximum output. Connect a standard test antenna between the antenna and ground binding posts. Record the actual level of the internal receiver noise in milliwatts into the load impedance for which the receiver is designed as indicated by an output meter. Conduct this test at the high, center, and low points in each frequency band.

SELECTIVITY (LOOP ANTENNA-WIDTH OF INTERFERRING AREA-AUTOMATIC AND VISUAL INDICATING DEVICES)

Orient the loop for maximum signal response. Set the field of a radio frequency carrier, modulated 30% at 400 cycles, for a field strength of 100 microvolts per meter, and tune the radio direction finder to the frequency of the carrier. The loop shall then be oriented to the null position as indicated by the visual indicating device. Set up an interferring field the frequency of which may be adjusted, at 90 degrees (physically) from the desired signal. Record the frequencies, above and below resonant frequency to which the interferring signal must be tuned to produce errors of 1, 3, 5, 10, and 25 degrees in the bearing indicated by the visual indicating device. This test shall be made with interferring signal field strengths of 100 times and 1000 times the amplitude of the desired signal field strength. Conduct this test at the high and low ends of each frequency band and plot the results.

The purpose of this test is to determine how near to the frequency of the desired signal an interferring signal may come, with different field strengths relative to the desired signal field strength, without causing deviation of the indicating device from that point which is controlled by the desired signal. The interferring signal is placed 90 degrees, physically, to the desired field in order to simulate the worst condition.

WIDTH OF NULL - LOOP ANTENNA

Orient the loop for maximum signal response. Set the field of a radio frequency carrier, modulated 30% at 400 cycles, to an amplitude necessary to produce a field strength of 1000 microvolts per meter, and tune the radio direction finder to the frequency of the carrier. Then orient the loop to the null position as indicated by the visual indicating device. Adjust the gain of the receiver so that an output of one-half milliwatt is obtained, as indicated on an output meter connected to the output terminals of the receiver. Rotate the loop and record the number of degrees of rotation to the right and left of the null position to which the loop must be turned in order to obtain an output of 50 milliwatts into the load impedance for which the receiver is designed. Repeat the above test with field strengths of 500, 250, 100, and 50 microvolts per meter, readjusting the sensitivity of the receiver, if necessary, for each field strength specified to obtain an output of one-half milliwatt in the null position. Conduct these tests at the center point of each frequency band. Plot loop setting in degrees right and left for 50 milliwatts output versus field strength in microvolts per meter.

ACCURACY OF BEARING (VISUAL INDICATING DEVICES - TEST SET-UP)

The test set-up as outlined below is applicable to the three test procedures outlined immediately hereafter.

For the purpose of these tests, mount the loop assembly (loop, loop mount, rotating mechanism, et cetera), on a rotatable support in such manner that the loop assembly may be rotated about the loop axis through 360 degrees in a horizontal plane. Provide the rotatable support with a scale graduated in degrees so that the angular position of the loop assembly with reference to a lubber line may be determined by reference to this scale. It is further required that the relation between the angular rotation of the loop and the scale readings of the loop azimuth control and/or bearing indicator be linear (i.e., no "quadrantal" correction provided).

Conduct tests using the maximum length of tach shaft and loop transmission line recommmended by the manufacturer between the various component units of the radio direction finder.

ACCURACY OF BEARING (LEFT-RIGHT INDICATOR)

Set the field of a radio frequency carrier, modulated 30% at 400 cycles, for a field strength of 1000 microvolts per meter. With the loop azimuth control set at the "zero" reading, orient the loop to the "on-course" position, as shown by the visual indicator, by turning the loop assembly on the rotatable mount. (For convenience in making readings of the loop assembly position, the zero degree reading of the rotatable mount scale should coincide with the lubber line in this position). Rotate the loop assembly by turning the rotatable mount through 360 degrees in 15 degree steps, and orient the loop to the "on-course" position as shown by the visual indicator at each setting of the loop assembly by adjustment of the azimuth control. Make adjustment of the azimuth control in both a clockwise and counter-clockwise direction in order to determine the amount of "back-lash" in the azimuth control tach shaft. Conduct this test at the center position in the low frequency band, and record the azimuth control readings (clockwise and counter-clockwise) for each setting of the loop assembly.

Secondly, orient the loop to the "on-course" position as shown by the visual indicator, and vary the output of the signal generator to produce field strengths of 50, 100, 1000, and 10,000 microvolts per meter. Note any deviation of the visual indicator from the "on-course" position resulting from the variation in field strength, and record the number of degrees to the right or left through which the loop must be rotated to return the visual indicator to the "on-course" position. Conduct this test at five approximately equally spaced points in each frequency band.

ACCURACY OF BEARING (AUTOMATIC RADIO COMPASS-REGULAR SENSE ANTENNA)

Set the field of a radio frequency carrier, modulated 30% at 400 cycles, for a field strength of 1000 microvolts per meter. Orient the loop by turning the rotatable loop mount to the "on-course" position of the loop as shown by the bearing indicator. Rotate the loop assembly in a clockwise direction through 360 degrees, in 15 degree steps, and record the bearing indicated at each step by the azimuth indicator. Repeat the above procedure, rotating the loop assembly in a counter-clockwise direction. Conduct this test in the center (300 kilocycle) position of the "range" band.

With the radio frequency carrier set for a field strength of 1000 microvolts per meter as specified above, allow the loop to "home", and note the reading of the bearing indicator. (The bearing indicator should read "zero" degrees when the loop is in this position). Turn off the carrier and turn the loop in a clockwise direction 175 degrees from the "home" position. Then turn on the carrier, record the time required for the loop to "home", and the final reading of the bearing indicator. Repeat this procedure, turning the loop 2 degrees from the "home" position, except that the time required need not be determined if less than one second. Duplicate the above test turning the loop in a counter-clockwise direction. Conduct this test with field strengths of 50, 100, 1000, and 10,000 microvolts per meter, and at five equally spaced points in each frequency band.

ACCURACY OF BEARING (AUTOMATIC RADIO COMPASS-LOOP SENSE ANTENNA)

Duplicate the tests specified immediately above, using the "loop" sense antenna instead of the "regular" sense antenna, and setting the loop at 85 degrees instead of 175 degrees from the "home" position, because of the 180 degree ambiguity of bearing obtained when a "loop"

RECIPROCAL BEARINGS (LOOP ANTENNAS)

Orient the loop for maximum signal response. Set the field of a radio frequency carrier, modulated 30% at 400 cycles, to an amplitude necessary to produce a field strength of 1000 microvolts per meter, and accurately tune the radio direction finder receiver to the frequency of the carrier. Orient the loop to the null position as indicated by the visual indicating device or by an output meter in the audio output circuit of the receiver. Adjust the gain of the receiver so that an output of one-half milliwatt is obtained.

Record the reading of the azimuth control indicator, and rotate the loop to obtain a reciprocal null as indicated by the visual indicating device or output meter. Record the azimuth control bearing and audio output reading.

Repeat the above tests with field strengths of 500, 250, 100, and 50 microvolts per meter, readjusting the sensitivity of the receiver, if necessary, for each field strength specified to obtain an output of one-half milliwatt in the null position.

Conduct these tests at the center point of each frequency band and record the results.

PHASE SHIFT-RADIO COMPASSES

This test is applicable to radio compass receivers of either the "automatic" or visual "left-right" type. Check for any malfunction resulting from phase shift between the "loop" and "sense antenna" input voltages, in the following manner:

With all the circuits of the radio compass properly resonated and adjusted, set the output of a signal generator 30% modulated at 400 cycles to that value which will produce a field strength of 1000 microvolts per meter. Orient the loop so that an "on-course" bearing is indicated on the visual bearing indicator.

Adjust the receiver sensitivity control to the "maximum" position, and the audio level control for an output of 50 milliwatts into the load impedance for which the receiver is designed. Successively detune the "sense antenna" and "loop" input circuits above and below resonance sufficiently to cause a 3 DB decrease in the resonant output indicated by the output meter. To determine a 3 DB decrease in the resonant output for detuning of the "loop", connect (or switch) the equipment to function as a receiver operating without AVC, and using only the loop as a source of signal pickup, set the audio level control for 50 milliwatts output, and detune the "loop" circuit the amount necessary to reduce the output to 25 milliwatts. Follow the same procedure for detuning of the "sense antenna" circuit, except use only the "sense antenna" as a source of signal input.

Secondly, simultaneously detune the "loop" and "sense antenna" input circuits in various combinations above and below resonance to cause a 3 DB decrease in the resonant output, following the same procedure for detuning.

Conduct this test at the high and low frequency end of each frequency band. Repeat the test using field strengths of 100 and 100,000 microvolts per meter. Note any deviation of the indicated "on-course" bearing resulting from the application of this test, and record the test conditions under which such deviations occur.

OPERATION OF DIRECTION FINDERS AT HARMONICS OF THE BEAT FREQUENCY OSCILLATOR

When a receiver is intended for use in connection with aural null, and particularly with visual indicating or fully automatic direction finders, and is equipped with a beat frequency oscillator, check to determine if the operation of the beat frequency oscillator adversely affects the operation of the receiver direction finder function. If investigation discloses evidence of malfunction due to the operation of the beat frequency oscillator, with particular attention being given to such of its harmonics as fall within the tunable range of the receiver, record the frequencies, degree of bearing error, and other conditions under which the malfunction is observed.

LOOP ANTENNA AND LOOP CIRCUIT COUPLING

Orient the loop for maximum signal response. Set the field of a radio frequency carrier, modulated 30% at 400 cycles, to an amplitude necessary to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. So adjust the receiver sensitivity control that a signal-to-noise ratio of 6 DB is obtained.
Secondly, without changing the adjustment of the receiver loop selector switch, connect the signal generator to the antenna connection of the receiver through a standard test antenna and apply a signal 30% modulated at 400 cycles of sufficient amplitude to produce an output of 50 milliwatts into the load impedance for which the receiver is designed. Record the ratio of the signal generator output in DB. (The signal generator output for the loop signal must be divided by the correction factor used to convert signal generator microvolts to microvolts per meter field strength for a particular test set-up used). Conduct this test at the center of the "range" frequency band. In making this test, take due precautions to isolate the external connections between the signal generator and the loop antenna to prevent stray pick-up of the signal generator voltage by the loop antenna.

CRYSTAL OPERATION

Where a crystal is provided to "lock-in" the oscillator at a certain frequency, check for smoothness of operation. Determine and record the frequency in kilocycles (indicated by the receiver dial) above and below resonance at which the crystal "takes control". Record the sensitivity of the receiver with crystal oscillator versus self-excited oscillator.

INTERCHANGEABILITY OF TUBES AND PLUG-IN COMPONENT PARTS

Check and record any change in sensitivity resulting from a complete change of tubes. Check and record frequency change resulting from change of oscillator tube. Check hum or radio frequency interference changes resulting from change of plug-in power vibrators. Check and record sensitivity changes resulting from inter-change of crystals in crystal controlled receivers.

CALIBRATION

Using a signal generator having a calibration accuracy of at least .05%, record the indicated frequency (shown by the receiver dial or control unit dial, or both if both are used) and the actual frequency (as shown by the signal generator calibration). Record the deviation above and below the signal generator frequency in cycles at a minimum of 10 points in each frequency band, covering the full range of each band in approximately equal frequency separations.

FREQUENCY RANGE

Using a signal generator having a calibration accuracy of at least .05%, record the maximum and minimum frequency, in each band to which the receiver can satisfactorily be tuned.

WARM UP DRIFT

Record at 10 minute intervals the frequency drift which occurs between the time the unit is turned on (cold start) until stable operation (frequency) is reached. The unit must be carefully aligned and otherwise checked while in a stable condition after continuous full load operation for at least two hours. Measure the frequency drift change in resonant frequency occurring during this test and record it as the percentage of the carrier frequency. Conduct this measurement at the center of each radio frequency band. Concurrently check the stability of the beat frequency oscillator (if provided) with the above measurements.

TEST PROCEDURES
Transmitting Equipment

FIDELITY (AUDIO)

Apply to the input (microphone) terminals of the modulator, a sine wave audio frequency signal through a phantom microphone circuit which introduces the internal impedance and direct current flow characteristics of the recommended type microphone for which the transmitter is designed. (A typical phantom microphone circuit having the desired characteristics is shown in Figure 1). Terminate the output terminals of the modulator in a dummy load impedance equal in value to the input impedance of the load into which the modulator output is designed to work. Measure the audio frequency input for which minimum level will produce rated output level and hold it constant over the range of audio frequencies as follows: 100, 200, 300, 400, 600, 800, 1000, 1250, 1500, 2000, 2500, 3000, 4000, 6000, 8000, and 10,000 cycles per second. Measurements of response in the 3000 to 10,000 cycles per second range need not be recorded if more than 30 DB below the reference audio frequency input level but this fact shall be stated in the test data. All frequencies in the 3000 to 10,000 cycles per second range shall be investigated for undesirable response peaks. The specified input level shall be maintained constant by means of the indications of Meter M-1. Plot variation of output in DB below reference output versus frequency.

INPUT IMPEDANCE (SPEECH AMPLIFIER)

When provision is made in the design of the speech amplifier of a transmitter for the use of various types of microphones (i. e., carbon single and double button, dynamic, crystal, capacitor, et cetera), having different values of input impedance and output level record the range of such microphone impedance values. Conduct tests of the fidelity (audio) of each such input system in accordance with the procedures outlined under "FIDELITY (AUDIO)", and plot the results recorded on a single graph for purposes of rapid comparison.

FIDELITY (OVERALL)

Adjust the transmitter circuits for optimum radio frequency output into an optimum load, and apply to the input terminals of the modulator, through the phantom microphone circuit, an audio frequency signal of sufficient amplitude to establish 100% modulation, or maximum modulation capabilities if less than 100%. Measure that audio frequency input for which minimum level input will produce the specified percentage of modulation and maintain it constant over the range of audio frequencies as follows: 100, 200, 300, 400, 600, 800, 1000, 1250, 1500, 2000, 2500, 3000, 4000, 6000, 8000, and 10,000 cycles per second. The percentage of modulation obtained at each audio input frequency shall be determined by means of a suitable modulation meter. Measurements of response in the 3000 to 10,000 cycles range need not be recorded if more than 30 DB below zero reference, but this fact shall be stated in the test data. All frequencies in the 3000 to 10,000 cycle range shall be investigated for the presence of undesirable response peaks. This test shall be made at a high, intermediate, and low frequency within the frequency range of the transmitter, and curves plotted showing the percentage of modulation obtained for each audio input frequency.

DISTORTION AND NOISE

Operate the transmitter as described under "FIDELITY (OVERALL)", and determine the percentage of combined distortion and noise appearing - (a) in the output of the audio modulator and (b) at the radio frequency output terminals of the transmitter as follows:

Apply to the input of the phantom microphone circuit audio signals of 100, 200, 400, 1000, 2000, and 3000 cycles per second of sufficient amplitude to produce percentages of modulation of 25%, 50%, 75%, and 100% (or maximum modulation capabilities if less than 100) successively. The percentage of combined distortion and noise at the modulator and radio frequency output terminals shall be determined by means of a suitable distortion meter, and curves plotted showing percentage of distortion versus input audio frequency for each percentage of modulation level specified. This test shall be made at the high and low points in the frequency band of the transmitter. Secondly, remove the audio input signal and close switch SW-1 of the phantom microphone circuit. Determine the noise level appearing at the modulator and radio frequency output terminals in DB below the 1000 cycle input level required for, and previously determined for 100% modulation, or maximum modulation if less than 100%. If a variable audio gain control is incorporated in the design of the modulator, take and record measurements of noise at 25%, 50%, 75% and the full on positions of this control.

MODULATOR LOADING

Operate the transmitter at rated radio frequency power output into a resistive load. Apply a 1000 cycle audio signal, the amplitude of which may be varied from zero to a value sufficient to over-modulate the transmitter, to the input terminals of the phantom microphone circuit. Vary the audio input signal from zero, in steps sufficient to produce approximately 10% changes in the modulation percentage of the carrier, to such value that further increases in the audio input signal fail to produce corresponding changes in the percentage of modulation of the carrier.

Determine the percentage of modulation by means of a suitable modulation meter, used in conjunction with a simultaneously operated cathode ray oscilloscope for the rapid visual evaluation of modulation percentage.

This test shall be made at the mid-point in the frequency band of the transmitter. Plot audio input level in millivolts versus percentage of modulation of the full rated radio frequency power output. This curve shall be shown in comparison with the ideal straight line response curve characteristic.

POWER OUTPUT (CARRIER UNMODULATED)

Determine the macimum radio frequency power output of the transmitter by measurement of the radio frequency current through a resistive load. The value of the resistor employed in this measurement shall conform to that value used in determining the manufacturer's published power rating. Either of the following methods may be employed in making the radio frequency power output measurements:

(a) Current Resistance Method - Calibrate a non-inductive resistor at the frequency and temperature at which it will be operated during the power measurement. Measure the current through this resistor by a suitable radio frequency ammeter, connected in the ground side of the resistor load. Power output may then be computed from the formula: Watts = $I^2 R$

(b) Photometric Method - Set up an incandescent lamp, of proper power and resistance rating, and having negligible inductive and capacitive reactance, together with a photronic cell and meter, as shown in Figure 2. Plot the power, indicated by a suitable wattmeter or other approved method, required to produce varying degrees of incandescence of the lamp, against the readings of the photronic cell currents indicated by the meter M-1.

Note: The following precautions shall be observed in calibration of the lamp: The metal base of the lamp should be removed; for ease of adjustment during calibration, the photronic cell should be readily adjustable on the base; the input leads should be kept as short as possible. The lamp may then be used as a resistive load for the transmitter, and the power ouput obtained by noting the reading of the meter M-1 with reference to the plotted curve obtained above.

Power output measurements shall be made at the high and low points in the frequency band for which the transmitter is designed. At least one power output measurement shall be made in each frequency band of a multi-channel transmitter.

POWER OUTPUT (CARRIER MODULATED)

Determine the radio frequency power output of the transmitter as described under "POWER OUTPUT (CARRIER UNMODULATED)", with the carrier modulated 100%, or to the highest percentage of modulation of which the transmitter is capable with not more than 10% total distortion.

POWER OUTPUT (IMPEDANCE CHARACTERISTICS)

Determine the value of inductive and capacitive reactance of an antenna system which will permit tuning of the final and/or antenna circuit of the transmitter to proper resonance with delivery of the rated power output as follows:

(a) Capacitive Reactance - Set up the transmitter as described in "POWER OUTPUT (CARRIER UNMODULATED)" and adjust for operation on the lowest frequency for which the transmitter is designed with maximum positive (inductive) reactance in the antenna output circuit. Connect a variable condenser in series with the output load resistor. Operate the transmitter and tune the variable antenna capacity to the point of antenna circuit resonance. Load the final amplifier stage to that value determined to be normal input and record the radio frequency power output. Remove the dummy antenna from the transmitter output and measure its reactance with a "Q" meter or equivalent instrument. Record the measured reactance and corresponding radio frequency power output. Repeat the above test at six approximately equally spaced reduced reactance values including the zero reactance value.

(b) Inductive Reactance - Repeat the procedure set forth under (a) above, operating the transmitter at the highest frequency for which it is designed and set up to present the maximum negative (capacitive) reactance in the antenna circuit, and with a variable inductance substituted for the variable capacity in the dummy antenna circuit.