9. CORRECTIONS

Corrections were applied to the installation to reduce the interference levels from each source to meet specification requirements. The following were the corrections installed:

....

....

....

....

10. EFFECTIVENESS OF CORRECTIONS

Similar tests to those conducted under paragraph 8 were made to prove the effectiveness of each correction.

11. FINAL FLIGHT TEST

After completing all the above tests, a final flight was made to judge the overall effectiveness of all corrections. Readings were ...... were not ...... taken during the flight.

12. RESULTS*

a. DATA.

1. Original interference condition of airplane is given on data sheet(s) No(s). ....

2. List of interference sources is given on data sheet(s) No(s). ....

3. Effectiveness of corrections are shown on data sheet(s) No(s). ....

4. Final interference condition of airplane with all corrections applied is given on data sheet(s) No(s). ....

b. CURVES.

The above information is presented graphically for each interpretation on curve sheets Nos. ....

13. CONCLUSIONS

14. RECOMMENDATIONS

Submitted by: .... Approved ....
Crew Chief — Project Engineer

Date: .... Date:...............

Approved: ....
Head of Department

*NOTE

The Bureau of Aeronautics has requested that on all interference tests conducted, the measurements of interference be reported in decibels. (0-db. being equal to 1 milliwatt or 0.775 volts across 600 ohms pure resistance load.)

If an RCA, type 302B audio frequency output meter is not used to make the actual measurements, a calibration curve should be attached to the report, giving the details of the instruments which were actually used and the technique of their use, as well as the data correlating their readings with those of the RCA type 302B meter. Fleet units may usually dispense with this provided the same meter type is always used.

**CHECK FOR MALFUNCTIONING OF IFF EQUIPMENT

Whenever the necessary radar interrogating devices are available, checks should be made to see if any electrical, radio or electronic equipments cause malfunctioning of the IFF.

Tests of this nature may be made with the aircraft on the ground, or in flight, with an observer at the ground station interrogating device in constant communication with the plane and in control of the tests. This observer can then instruct the pilot and crew to turn on and off the various equipments and check to see if they cause the IFF to transmit spurious signals.

b. Effective Date: 5 March 1943

SR-125

NAVY AERONAUTICAL SPECIFICATION COVERING RADIO INTERFERENCE MEASUREMENT AND LIMITS FOR NAVAL AIRCRAFT

PART I

Radio and interphone equipment shall operate satisfactorily when all specified equipment is installed in the airplane. Satisfactory performance shall be determined by the Bureau through the trial board, employing the measuring technique and maximum noise levels as hereinafter set forth.

PART II

1. The method to be employed for measuring radio interference influence voltages shall be the "calibrated receiver" method.

2. PROTOTYPE AIRPLANE

2*a*. Three receivers of each type which are to be installed in the airplanes shall be checked throughout their frequency range, at several frequencies in each band, to determine general receiver performance at 28 volts input. One of the three receivers of each type shall then be selected which has the most uniform over-all performance conforming with the equipment specifications. These selected receivers shall be fully calibrated as later described, and shall be used as the measuring instruments for the respective radio installations in the prototype airplane.

2*b*. Calibration shall be made in a screened room or other location where interference from atmospherics, man-made interference and radio signals are negligible. A high grade approved type of signal generator such as the general radio types 605B or 805A, or Ferris type 16C, modulated 30 percent at 400 or 1,000 cycles shall be used as the input source.

2*c*. An RCA type 302B, or equivalent, audio frequency noise meter shall be used for measuring the receiver output, both when calibrating in the laboratory and when making noise measurements in the airplane.

2*d*. The d-c input voltage to the receiver shall be maintained at approximately 28 volts during calibration and when making all measurements.

2*e*. Specific instructions for calibrating each type of "calibrated receiver" will be furnished by the Government, along with information concerning the maximum altitude at which the receiver may be operated for the purpose of this specification. The calibration data shall be plotted as a family of curves for each frequency, with microvolt-input plotted as abscissae and audio frequency noise meter readings as ordinates.

2*f*. To measure radio interference levels in the prototype airplane the calibrated receivers shall be installed in the same locations and in the same manner as in production models; then the airplane shall be flown at normal rated cruising speed, engine r. p. m., and manifold pressure over areas free of man-made radio interference and on a day which is relatively free of atmospheric interference. The receiver shall be tuned to a frequency nearest each of the calibration frequencies where regular radio signals cannot be heard. With the previously selected amount of gain (normally maximum), the antenna trimmed, and with the audio frequency noise meter and one set of AN standard flat-response headphones, meter readings shall be recorded. Care must be taken to aurally monitor each frequency setting at which readings are taken to assure that the receiver is not tuned to a regular signal and, accordingly, giving an erroneous indication of noise output.

2*g*. This same test procedure shall be followed during the operation of various combinations of electrical equipment which are likely to be in continuous or frequent operation during normal use of the radio equipment, and all data recorded. The airplane shall also be flown at its rated service ceiling or receiver ceiling set forth in 2*e*, and the several frequencies checked to determine that there is no increase in noise levels previously measured. Performance shall also be measured using the navigational electrostatic loop.

2*h*. After completion of the radio test flight the noise output, which has been measured in milliwatts or decibels with the audio frequency noise meter in flight, shall be converted to equivalent microvolts input from the receiver calibration curves. This amounts to determining the values of signal generator outputs which produce the equivalent amount of audio frequency noise meter readings which were obtained during flight. These converted data are those referred to in part III.

3. PRODUCTION AIRPLANES

3*a*. For the production acceptance test on radio interference levels in airplanes, each of the various types of receivers prior to final installation shall be checked by the airplane manufacturer to assure normal satisfactory receiver operation in conformity with receiver specification requirements. This checking shall consist of tuning each receiver to five or six frequencies, including the minimum and maximum frequencies of the receiver, where maximum noise levels have been found in the prototype airplane; and, with a given input and gain (see part III) from the signal generator, measuring the audio output with the RCA 302B meter or equivalent. Only one value for each frequency shall be necessary. This work shall be conducted under the same conditions as set forth for the calibration of the receivers for the prototype airplane tests.

3*b*. The receivers shall then be installed, and during the contractor's production flight tests, with an audio frequency noise meter and one set of headphones connected as during the prototype airplane tests, meter readings shall be taken for each of the five or six frequencies at which the receivers were previously checked and at the same receiver gain. Care again shall be taken by monitoring to make sure that the frequencies tuned to do not coincide with regular radio signals, and in event that they do a "free" frequency as near to the preselected one as possible shall be used. Radio transmitting equipment shall be operated in normal standby condition during the production flight, and performance shall be measured using the navigational electrostatic loop.

3*c*. If the data obtained during flight fall within the respective limits set forth in part III, radio reception shall be considered satisfactory for those types of receivers considered.

3*d*. It should be specifically noted that if radio performance in the production airplane meets the one test (and measurement method) above specified, no other tests and measurements shall be normally required, such as measurement of the radio frequency interference influence voltages on the electrical wiring system, at interference sources, etc. However, the Bureau reserves the right to modify or add to test requirements and procedures which may be necessary to obtain satisfactory operation of equipment.

PART III

It is intended in this section to specify maximum interference limits as measured by the audio frequency meter and translated to a standard radio frequency signal input. These will be established for communication receivers, giving due consideration to the allowable levels of electrical background noise for voice receivers, and to the ambient acoustical noise levels in the various types of ships. Thus, the permissible audio-electrical noise ratio for a particular type of communication receiver when installed in a fighter type airplane may be quite different from that permissible when installed in patrol type airplane.

(Sufficient data is not yet at hand properly to determine these levels. In the interim, therefore, a value of 2.5 microvolts shall be used as the maximum noise equivalent; in other words, the allowable noise level permitted by this specification and as measured by the audio frequency meter, shall not exceed the equivalent noise meter reading when an output of 2.5 microvolts from the signal generator is fed into the receiver.)

PART IV

1. It is the intention of the Bureau that the acceptable radio performance required by this specification shall be obtained in all-metal airplanes *without* metallic conduit shielding on the wiring except in the following instances:

(*a*) Ahead of the firewall, and throughout the ignition system and *all* its wiring.

(*b*) Where natural shielding of ship's structure is not adequate or cannot practicably be used.

(*c*) Where needed for mechanical support, protection, or case of replacement of wiring.

2. It is also intended that a minimum amount of source filtering (capacitor or choke type) be resorted to, and instead that progressive engineering design and lay-out be employed to take full advantage of spacing, grouping, and the inherent attenuation and shielding or "shading" within the modern all-metal airplane. Resort to source filtering and the use of coaxial cable must be previously approved by the Bureau, and approval will be granted only after the above requirements are met. (See part VI.)

PART V

1. The contractor shall not be held responsible for the elimination or correction of conditions within the transmitter, receiver, and antenna relay units which might permit coupling of radio interference influence voltages into the antenna; this shall be the responsibility of the Bureau of Aeronautics.

2. The contractor shall consider every other item of electrical equipment as a source or a coupling medium of radio interference. (See part VI.) This includes all G. F. equipment; i. e., generators, inverters, dynamotors, the engine, its ignition system, and propellers.

3. Since engine ignition systems and propellers may be extremely intense sources and propagators of interference, the manufacturers of this equipment shall be required to meet a maximum radio interference influence voltage level specified by the Bureau. However, the airplane manufacturer shall be responsible for the correct installation of this equipment and the production of an over-all satisfactory radio installation as defined and specified herein.

PART VI

The Bureau has compiled a compendium (appendix A) of suggested construction practices which have evolved from research and experience, and are conducive to radio interference-free airplanes. These suggestions are not to be construed as specification requirements, but it is recommended that they be considered by the contractor. Suggestions based upon experience of contractors and Inspectors of Naval Aircraft concerning amendments or additions to this compendium will be appreciated.

APPENDIX A OF SR–125

AIRCRAFT RADIO NOISE ELIMINATION AND SUGGESTED CONSTRUCTION PRACTICES

PART I

PURPOSE:

1. The Bureau of Aeronautics requires that the use of electrical bonding, shielding and filtering in all-metal airplanes be reduced to an absolute adequate minimum in the interest of:

(*a*) reducing weight
(*b*) conserving critical materials
(*c*) saving man-hours
(*d*) reducing the vulnerability of wiring during combat.

2. Experience and research demonstrates that this departure from former construction practices need not result in sacrificing radio performance in any way, provided sound engineering is employed. A clear understanding of the factors involved in this process is essential and in order to assist contractors in their design of naval aircraft incorporating these features, there is set forth hereafter a rational development of the problem along with general and specific principles which must be observed to obtain the necessary results.

3. It must be kept in mind that the first essential is satisfactory radio performance as specified in SR–125, and that the purpose set forth in paragraph 1 above is always subject to this requirement.

PART II

BASIC PROBLEM AND PRINCIPLES:—

1. A radio interference influence source is of itself no concern until by means of conduction or coupling into a radio receiver it results in an unsatisfactory output. (This definition is expanded to include all radio influences which result in malperformance of radio indicating or triggering receivers.)

2. In the modern, well shielded aircraft receiver employing all-metal construction, there are only two important means of electrical entrance therein, namely, by means of the antenna and the power supply. There are secondary entrances via headphones and cords, remote control circuits, and through the case itself in ultra high frequency fields of great intensity, but these are shielding problems which do not need to be considered here.

3. The problem may thus be reduced to providing every means possible to minimize the coupling of magnetic and electrical radio interference-influence voltages to the antenna system, and to prevent conduction via the power supply into the receiver. This latter factor is common with every type of radio installation whether conduit is used or not, and the conducted interference appearing at this entrance to the receiver is readily blocked by properly designed power supply filters. This is an essential part of all receiver equipment. (See also appendix A, part III.)

4. In all-metal airplanes the antenna system, for the purpose of this analysis, is made up of two parts: that external to the fuselage, and that internal, or the "lead-in", which connects to the receiver. Within the fuselage, the "lead-in" is the only other entrance into the receiver of radio interference. Obviously the first step, and the most important single step possible, is to keep the "lead-in" physically short so as to keep down the coupling factor. This means locating the radio receiver against the skin of the ariplane and placing the "lead-in" insulator adjacent thereto. The minimum length of "lead-in" which has to be used must then be shielded or "shaded" by the ship's structure, and to reduce the area of coupling loop it forms with the ground-plane, it must be kept as close to the basic structure as electrically possible.

5. If this length of the antenna circuit, that is, the "lead-in," is completely shielded, then no matter what sources of radio interference-influence may exist within the airplane they cannot be coupled thereby into the receiver and become "noise." If after judicious use of all available inherent shielding possibilities mentioned above, the shielding of the "lead-in" is not sufficiently complete, then coaxial cable of proper design may be resorted to.

6. The remaining means of interference entrance to the receiver is external to the fuselage and consists of coupling to the antenna proper. In this instance the method of approach is reversed since the function of the antenna is to couple with desired radio signals, so shielding *it* cannot *be* resorted to as a means of eliminating interference-influence voltages. Therefore, the *source* of the "interference" must be shielded.

7. Primarily, the all-metal fuselage may be considered as a large section of conduit which shields radio interference sources within the airplane from coupling to antenna. If this shielding were unbroken, further practical consideration of radio interference-influence voltage coupling in airplanes might stop at this point since the remaining means of coupling would be accounted for.

8. However, there are windows, doors, turrets, cowl openings, etc., which will permit straight-line coupling to antenna if radio interference sources are not properly installed (or shielded) when located near these openings. It is evidently essential then that wiring, cables, and similar radiators or coupling mediums along with all sources of radio interference such as alternators, dynamotors and inverters, when near openings in the fuselage, be so routed or placed that metallic structure in some of its many forms in the airplane intervenes between these and the antenna. When these means are not practicable in the case of wiring, then conduit must be used along that portion of the run where straight-line coupling may occur.

9. The frequently found "leaks" of radio interference into the receiver have thus been accounted for with the exception of radiation from the propellers to the antenna. This is recognized as a separate problem, the remedy for which is not considered the airplane contractor's responsibility. Interference coupling from this source can be readily determined should question arise.

PART III

INHERENT ATTENUATION, CANCELLATION, SHIELDING AND FILTERING MEANS:

1. In part II, means of radio interference influence coupling and methods of correction were discussed. Mention was made of eliminating noise conduction in the receiver power supply by use of filters. It is possible to place filters either at the sources of radio interference, at the receiver only, or at both locations.

2. It is the Bureau of Aeronautics' intention that basically only *receiver* filtering (supplied with the radio receivers) be used, along with well engineered lay-out and installation of the complete electrical and radio system so as to take full advantage of:

(*a*) The inherent attenuation of wiring, especially at the high frequencies.

(*b*) The airplane's metallic structure for shielding or screening so as to minimize cross-coupling from bad interference sources into interference-free circuits.

(*c*) The equivalent filtering action of batteries, electrical apparatus, system capacitance, etc.

(*d*) The cancellation of magnetic fields by running positive and negative leads together and transposing them.

(*e*) The isolation of electrical and magnetic fields by physical placement of noise sources, etc.

3. When well conceived use is made of these "natural" factors, the strength of the radio interference-influence voltage appearing at the receiver power supply terminals is greatly reduced over that which would result were these principles ignored. By so reducing the interference signal strength and taking into consideration the greatly improved coupling factors in modern receivers, the required decibel attenuation of a satisfactory filter on the receiver power supply is relatively reduced.

4. Should it be found in the prototype airplane that, after taking into account the factors discussed in paragraph 2 above, the interference signal is still too high for satisfactory attentuation by the receiver filter, then through trial and substitution, effective results may be obtained by the addition of capacitor type filters at the major interference sources, at junction panels, etc. The use of several of these small filters so employed must be balanced against the use of properly designed network type filters for the major interference sources. A combination of these remedies occasionally may be necessary. In this regard, an item of G. F. equipment which may be found to be an intense source of radio interference will be equipped with a filter where it is determined from experience that this equipment generally requires filtering.

PART IV

SPECIFIC RECOMMENDATIONS:

The following suggestions, based upon practical experience of the military services and aircraft contractors, are set forth as a guide and aid to obtain satisfactory interference-free operation of aircraft radio equipment which is defined and required by Specification SR--125.

1. ANTENNA "LEAD-IN."

(*a*) The overall length of the antenna "lead-in" connected to the receivers shall be as short as possible, with the exception that a reasonable increase in length may be required in order to route the "lead-in"close to structure of other metallic members to take advantage of their shielding effect; stand-off insulators shall be used for this purpose.

(*b*) Remotely controlled antenna transfer relays should be so located and oriented that the antenna "lead-in" to the receiver is as short as possible, as suggested above, and so that coupling between the relay control leads and the antenna "lead-in" will be the least possible.

(*c*) "Lead-ins" should not be routed close to moving or vibrating parts, such as control cables, or items of electrical equipment or electrical wiring.

(*d*) Transmitters containing the antenna transfer relay should be so located that the overall length of "lead-in" to the receiver may be installed as suggested above.

(*e*) The "lead-in" from the transfer relay to the transmitter should also be installed to follow the rules set forth above, as interference-influence voltages picked up on this "lead-in" may be transferred to the receiver through the transfer or by coupling between the antenna and receiver "lead-in."

(*f*) The use of "L" or "U" sections for the purpose of shielding the "lead-in" is suggested in cases where adequate shielding of the "lead-in" by the structure will result in excessive length.

(*g*) Attention is called to the fact that high radio frequency voltages are present on the "lead-in" connected to the transmitter when the transmitter is in operation. Adequate insulation must be provided under all types of operating conditions of moisture and humidity.

2. ELECTRICAL INSTALLATION.

(*a*) Electrical wiring, including engine instrument circuits, should be located as far away as practicably possible from "lead-ins-" and radio receivers.

(*b*) Whenever possible, all wiring should be installed so as to take advantage of the shielding effect of the aircraft structure, bulkheads, floors, etc.; and must always be so installed as to be readily accessible for inspection and replacement.

(*c*) Wiring should be so located with respect to windows, doors, turrets, cowl openings, etc., that coupling to antennas of interference voltages appearing on these circuits will not occur. If coupling does occur, shielding by means of conduit or structural members may be required.

(*d*) Locate and orient all dynamotors other than those built into the radio equipment, inverters, and similar electrical equipment as far away as possible and behind bulkheads, under decks, etc., from receivers, "lead-ins" and openings in the metal fuselage. Orientation involves physically placing the apparatus so that its magnetic and electrical fields have minimum effect upon the radio equipment.

(*e*) Electrical circuits which carry interference influence and transient voltages usually require separate routing to prevent coupling to other electrical circuits. Examples include ignition, propeller, engine instrument, remote compass, generator field, ordnance and illumination circuits.

(*f*) Storage batteries should be connected directly to the main distribution panel and no other electrical or radio equipment capable of producing interference influence voltages on the power line should be connected to the circuit between the battery and the distribution bus. This is for the purpose of taking advantage of the filtering action of the storage battery. It is desirable that this circuit be separately routed whenever possible.

(*g*) The circuit which furnishes power to the radio receivers should be connected to the main distribution bus at or as close as possible to the point where the storage battery is connected. This circuit should *not* be bundled with other electrical circuits. No other electrical loads should be taken off this circuit with the exception of small radio receiver panel illumination lights which might be located near the antenna "lead-in" terminals of the receiver.

(*h*) Electrical circuits which supply power to the radio receiving equipment or which are necessarily located near radio receiving equipment and "lead-ins" may require shielding, or occasionally may require the use of appropriate capacitor type filters.

(*i*) The electrical control circuits of antenna transfer relays may require shielding to reduce coupling of interference influence voltages to the "lead-in."

(*j*) Shielding of electrical circuits near transmitter circuits may be required to prevent pick-up of radiated transmitter power.

(*k*) Power and indicator or control circuits to remote controlled antenna reels and automatic loop antenna may require shielding in the vicinity of the antenna circuits.

(*l*) Electrical circuits ahead of the firewall require shielding and preferably separate routing.

(*m*) Common ground connections of electrical and radio equipment which might introduce common or series voltage drops should not be used.

3. IGNITION WIRING.

(*a*) Booster coils should be located as close to the magneto as possible to reduce the length of lead carrying ignition noise-influence voltages.

(*b*) Magneto switch circuits as well as all ignition wiring must be separately routed from other electrical circuits and completely shielded by conduit (see SR–125, part IV).

(*c*) Engine starter circuits, even though anticapacity switches are incorporated, may require shielding as well as isolation from other electrical circuits and should not be run in the same conduit or bundles with the magneto switch circuits.

4. PROPELLERS.

(*a*) Electrical control and power circuits for electrical propellers should be routed separately from other electrical circuits and may require installation in conduit.

5. CAPACITOR AND CHOKE TYPE FILTERS.

(*a*) The use of filters must be kept to a minimum, both to reduce weight and the number of electrical items which might, through failure, cause malfunctioning of the aircraft electrical system.

(*b*) Network type filters should be limited to use in low current circuits and used in high current circuits only when absolutely necessary.

(*c*) Mica and paper capacitor type filters of suitable voltage breakdown characteristics should be used whenever possible in lieu of network type filters, and should provide effectively low impedance throughout the frequency range of the receiver.

(*d*) Capacitor type filters should be mounted directly between the power circuit and ground without the use of additional wires or leads, since these materially change the characteristics of the filter.

(*e*) It is pointed out that the attenuation produced by two or more capacitors in parallel is not numerically additive but that entirely new conditions exist which may produce an adverse effect.

(*f*) Capacitor type filters having the same physical dimensions may not have comparable electrical characteristics.

6. MISCELLANEOUS.

(*a*) Microphone and other audio circuits may require shielding to prevent cross-talk or pick-up of interference on electrical circuits or radiated transmitter power. Audio and radio receiver control circuits should be installed separately from electrical circuits.

(*b*) Automatically operated cowl flap circuits (operated by thermostatic control) may require shielding.

(*c*) In the process of designing for the elimination of conduit, care should be exercised to determine that it is not essential for mechanical protection or support, or that it is required for ease of replacement of wiring in inaccessible locations.

C.
Rev WCAB.
28 July 1944.

AN–I–24

ARMY-NAVY AERONAUTICAL SPECIFICATION INTERFERENCE LIMITS; AIRCRAFT RADIO

This specification was approved on the above date by joint action of the War and Navy Departments for use in the procurement of aircraft, and shall become effective immediately upon issue.

A. APPLICATION.

A–1. This specification is drawn to provide interference limits and instructions for testing of radio,