

## Title 14—AERONAUTICS AND SPACE

### Chapter I—Federal Aviation Administration, Department of Transportation

[Docket No. 10204, Amdt. 121-89]

#### PART 121—CERTIFICATION AND OPERATIONS: DOMESTIC, FLAG, AND SUPPLEMENTAL AIR CARRIERS AND COMMERCIAL OPERATORS OF LARGE AIRCRAFT

##### Doppler Radar and Inertial Navigation Systems

This amendment to Part 121 of the Federal Aviation Regulations prescribes requirements for the approval and use of Doppler Radar and Inertial Navigation Systems, and updates the requirements of §§ 121.355 and 121.389.

This amendment is based on a notice of proposed rule making Notice 70-32, published in the FEDERAL REGISTER on August 5, 1970 (35 F.R. 12479). Nine public comments were received in response to the notice, and the recommendations contained therein are discussed below, insofar as they relate to matters within the scope of the notice.

One commentator objected to the proposed amendment to § 121.355 requiring approval of Doppler Radar and Inertial Navigation Systems (INS), because as worded it would have required currently approved systems to be reappraised under proposed Appendix G to Part 121. The FAA agrees with this commentator's recommendation that currently approved systems be excepted from compliance with the approval requirements of Appendix G, as required by § 121.355, and this amendment adopts this change to the notice accordingly.

In addition to this change, proposed § 121.355 is also changed by adding language indicating that the requirements apply to these navigation systems when used in operations outside the 48 contiguous States and the District of Columbia, thus making § 121.355 consistent with § 121.389 in this respect and indicating that the amendment is concerned solely with long-range navigation situations. This change is partially in response to a commentator who objected to the provision in proposed Appendix G which would require that both systems in the required dual system be operational at takeoff. The commentator contended that such a requirement would be too

stringent when such systems were used in conjunction with the area navigation concept. Because the area navigation concept does not involve long-range navigation, the FAA believes that the commentator's suggestion is not a basis for changing the requirement that both systems be operational at takeoff.

Finally with regard to § 121.355, paragraph (a) (2) has been changed for clarity to require that a certificate holder who elects to use Doppler Radar or an Inertial Navigation System on operations within the 48 contiguous States and the District of Columbia, or other specialized means of navigation (regardless of the geographic area of use), show that an adequate airborne system is provided for the specialized navigation authorized for the particular operation. Consequently, no approval in accordance with Appendix G would be required in such cases.

With regard to the proposals concerning § 121.389, minor editorial changes to paragraphs (b) and (c) have been made to cover those situations where both a flight navigator and specialized navigation equipment may be required.

The majority of comments received dealt with proposed Appendix G, and generally speaking, the points raised by the commentators indicate an objection to both the general scheme of the appendix with regard to standards, and to particular standards concerning the accuracy and reliability of Doppler Radar and INS. With regard to the former objection, some commentators expressed the view that Appendix G fails to establish realistic minimum standards with regard to the actual operation of such systems, as well as the collateral problems of proper maintenance thereof, and training of crewmembers in the use of such equipment. In response to this general objection, it should be reiterated that the basic format and substance of Appendix G is based on FAA Advisory Circulars AC 25-4 and AC 121-13, and the operating experience gained thereunder has demonstrated to the satisfaction of the FAA that these specialized navigation systems can be approved and operated effectively and safely within that framework as incorporated in the regulations. For example, the FAA believes that the provisions of paragraph 1(b) (2) and (3) of Appendix G provide the agency with adequate information regarding a certificate holder's training and maintenance program in this area. Unless these elements are shown to the satisfaction of the Administrator to contribute to the effective use of these specialized navigation systems, an application for their approval will receive unfavorable action. In the same regard, the FAA believes that the requirements of paragraph

1(b) (5), concerning normal and emergency procedures, will help to insure that all probable contingencies concerning these systems in flight will be properly dealt with by the certificate holder. In this connection, a new paragraph (c) has been added to paragraph 5 of Appendix G requiring that the initial training programs required thereunder include abnormal and emergency procedures.

One commentator stated that the proposals contained in the notice are inadequate because there are no proposed minimum standards, pursuant to Part 37, concerning the equipment used in INS. In this regard, it should be noted that the FAA is currently developing a Technical Standard Order (TSO) to cover this equipment. In the meantime, the FAA considers the general requirements adopted by Amendment 25-23 (effective May 8, 1970, 35 F.R. 5665) to be adequate in insuring the reliability of the subject equipment.

Another commentator recommended that less stringent accuracy requirements be adopted for operations conducted over sparsely flown areas. While the FAA agrees that less stringent accuracy tolerances could be accepted over such areas, we do not believe there should be a "double standard" for accuracy inasmuch as there is no certainty that an aircraft will be operated only over sparsely flown routes.

Finally, it was recommended that the proposals in Notice 70-32 be extended to cover Part 91 operations. While this comment is outside the scope of the notice, it should be noted that the FAA will continue to examine the state-of-the-art and the service record of specialized navigation systems, and if it appears that the requirements adopted herein for Part 121 operations should be applied to Part 91 operations as well, we will take the appropriate rule making action.

With regard to specific standards and requirements, one commentator expressed the view that INS does not require ground-based aids and thus should not be an element of the application as proposed under paragraph 1(b) (7) of Appendix G nor an element of the Administrator's evaluation under paragraph 7(c). However, the commentator stated that if special conditions indicate that requirements for ground-based aids are necessary, they should be clearly prescribed in the regulations. In response to this comment, it should be noted that while ground-based aids are not essential components of INS, terminal gateway aids are valuable in checking the accuracy of the system. Therefore, the availability of these aids must be presented as a part of the application for approval under paragraph 1(b) (7).

(As published in the Federal Register [37 F.R. 6462] on March 30, 1972)

However, the FAA agrees with the comment that under paragraph 7(c) (3), the Administrator's evaluation of ground-based aids should be limited to those required to support the system, and this change has been made accordingly. Because such components are essential to a Doppler Radar System which requires continual updating, the availability of all types of ground-based aids is essential to system approval.

Finally, with regard to this comment, the FAA believes that it is not feasible to place specific requirements for INS ground-based aids in the regulations because, as pointed out by a commentator, the need to require ground-based aids for INS arises only if special conditions dictate their use. The FAA believes that special conditions can best be dealt with through appropriate amendments to the certificate holder's operations specifications.

It was recommended by one commentator that paragraph 3(a) of Appendix G be revised to permit the installation of two or more Inertial Navigation Systems. The FAA agrees with this comment, noting that some B-747 airplanes currently have three systems installed. Accordingly, this paragraph has been revised to permit installation of more than two Inertial Navigation Systems; and, in addition, paragraph 4 has been revised to permit the use of two or more Doppler Radar Systems. In accordance with this change, both paragraph 3 and paragraph 4 have been further revised to permit the duality requirements therein to be satisfied by either two INS units or two Doppler Radar units or by one of each.

One commentator recommended that the proposal in paragraph 3(b) (2) of Appendix G requiring a display of alignment status to the flight crew, be deleted in favor of a "ready to navigate light" set to operate at a certain alignment status. The FAA agrees that a "ready to navigate light" can be used effectively as an alternative to the alignment status display. A "ready to navigate light" is currently used on Mode Selector Units to indicate when alignment is completed and the system is ready to navigate. Therefore, proposed paragraph 3(b) (2) has been revised to permit use of the "ready to navigate light" showing completion of alignment to the flight crew.

One commentator objected to the proposal in paragraph 3(c) of Appendix G concerning the separate electrical power source, because the requirement that it must supply power for at least 5 minutes should apply only to the Inertial Sensor Units and not to the Navigation Computer. The commentator contended that as long as the Inertial Sensor Units keep track of present position, the computer is automatically updated when power is restored.

The FAA believes that this requirement, as proposed, permits the separate power source to be linked to the sensor only, if that procedure is all that is necessary to maintain the operation of the INS to its full capability. However, if other units of the system must likewise be separately supplied, then the 5-minute power supply requirement applies to them as well.

With regard to the proposed requirement in paragraph 3(c) of Appendix G that there be a signal to enable the flight crew to detect reasonably probable failures or malfunctions, one commentator contended that the term "reasonably probable failures or malfunctions" is too vague. The commentator recommended that it be required that a specific percentage of failures must be displayed to the crew.

The FAA does not agree that the term "reasonably probable" is too vague. However, to clarify the concept, the word "reasonably" has been deleted as being redundant.

Another commentator recommended that the proposed requirements of paragraph 3(c) of Appendix G should be changed to permit either analysis or demonstration (rather than both) in establishing what the necessary power is for maintaining INS at its full capability. The FAA agrees, and paragraph 3(c) of Appendix G has been changed accordingly.

One commentator recommended that the list of "other navigational aids" which may be required to update Doppler Radar, be expanded to include the use of airborne weather radar. The FAA agrees that airborne weather radar can be a valuable aid in updating Doppler Radar. Accordingly, paragraph 4(b) of Appendix G has been amended to include this equipment.

One commentator stated that proposed Appendix G was not sufficiently specific with regard to reliability requirements for INS and recommended that 1,000 hours between inflight failures be established as the standard for reliability. Experience with INS indicates that current inflight reliability on an overall basis is in excess of 2,000 hours. Accordingly, the FAA believes that reliability based on compliance with certification, as is now the case, is sufficient.

The recommendation was made that accuracy requirements for INS and Doppler Radar should be the same, regardless of the inherent abilities of the two systems. The FAA does not agree. Based on manufacturer's reports and user experience, the accuracy criteria prescribed in paragraph 6(a) (1) and (2) are effective and realistic for INS, whereas the same is not always true with Doppler Radar. Unlike INS, the accuracy of Doppler Radar is directly related to the

accuracy of the heading information supplied by the compass system, and the frequency of updating from reliable fixes. Thus, due to the inherent difference in the accuracy of the two systems, the FAA believes that INS accuracy should not be reduced to achieve comparability with Doppler Radar.

With regard to specific accuracy criteria, one commentator objected to the "2 nautical miles per hour" accuracy requirement of proposed paragraph 6(a) (1), contending that inasmuch as INS experiences errors which are not only functions of time in flight, accuracy criteria should be based on appropriate probabilities which take into account other INS error functions.

The FAA does not agree that the 2 nautical miles per hour accuracy requirement should be deleted in favor of

the commentator's proposal. Operating history has proven that systems currently in use when properly maintained, can meet or surpass this accuracy requirement. To permit a less restrictive requirement would allow a reduction in the capability of the present state-of-the-art.

In addition to those recommended changes adopted herein, the FAA has, upon further study, made certain clarifying changes in proposed Appendix G. Two definitions have been added to paragraph 1(b) to define a "large divergence" as one that results in a track which falls beyond clearance limits and to define a "gateway" as a specific navigational fix where use of long-range navigation commences or terminates. Paragraphs 6(a) (1) and (2) and 6(c) have been revised to indicate that the 95 percent figure cited therein relates to system flights, thereby making that figure conform with the manner in which all current INS evaluations are conducted. Thus, for an airplane in which three systems are installed, one flight would represent three system flights.

Interested persons have been given an opportunity to participate in the making of these amendments, and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, Part 121 of the Federal Aviation Regulations is amended, effective April 29, 1972, as follows:

1. By amending § 121.355 to read as follows:

§ 121.355 Equipment for operations on which specialized means of navigation are used.

(a) No certificate holder may conduct an operation—

(1) Using Doppler Radar or an Inertial Navigation System outside the 48 contiguous States and the District of Columbia, unless such systems have been

approved in accordance with Appendix G to this part; or

(2) Using Doppler Radar or an Inertial Navigation System within the 48 contiguous States and the District of Columbia, or any other specialized means of navigation, unless it shows that an adequate airborne system is provided for the specialized navigation authorized for the particular operation.

(b) Notwithstanding paragraph (a) of this section, Doppler Radar and Inertial Navigation Systems, and the training programs, maintenance programs, relevant operations manual material, and minimum equipment lists prepared in accordance therewith, approved before April 29, 1972, are not required to be approved in accordance with that paragraph.

2. By amending § 121.389 to read as follows:

**§ 121.389 Flight navigator and specialized navigation equipment.**

(a) No certificate holder may operate an airplane outside the 48 contiguous States and the District of Columbia, when its position cannot be reliably fixed for a period of more than 1 hour, without—

(1) A flight crewmember who holds a current flight navigator certificate; or  
(2) Specialized means of navigation approved in accordance with § 121.355 which enables a reliable determination to be made of the position of the aircraft by each pilot seated at his duty station.

(b) Notwithstanding paragraph (a) of this section, the Administrator may also require a flight navigator or special navigation equipment, or both, when specialized means of navigation are necessary for 1 hour or less. In making this determination, the Administrator considers—

- (1) The speed of the airplane;
- (2) Normal weather conditions en route;
- (3) Extent of air traffic control;
- (4) Traffic congestion;
- (5) Area of navigational radio coverage at destination;
- (6) Fuel requirements;
- (7) Fuel available for return to point of departure or alternates;
- (8) Predication of flight upon operation beyond the point of no return; and
- (9) Any other factors he determines are relevant in the interest of safety.

(c) Operations where a flight navigator or special navigation equipment, or both, are required are specified in the operations specifications of the air carrier or commercial operator.

3. By adding a new appendix immediately after Appendix F to read as follows:

**APPENDIX G**

**DOPPLER RADAR AND INERTIAL NAVIGATION SYSTEM (INS): REQUEST FOR EVALUATION; EQUIPMENT AND EQUIPMENT INSTALLATION; TRAINING PROGRAM; EQUIPMENT ACCURACY AND RELIABILITY; EVALUATION PROGRAM**

1. *Application authority.* (a) An applicant for authority to use a Doppler Radar or Inertial Navigation System must submit a request for evaluation of the system to the Air Carrier District Office or International Field Office charged with the overall inspection of its operations 30 days prior to the start of evaluation flights.

(b) The application must contain:

(1) A summary of experience with the system showing to the satisfaction of the Administrator a history of the accuracy and reliability of the system proposed to be used.

(2) A training program curriculum for initial approval under § 121.405.

(3) A maintenance program for compliance with Subpart L of this part.

(4) A description of equipment installation.

(5) Proposed revisions to the Operations Manual outlining all normal and emergency procedures relative to use of the proposed system, including detailed methods for continuing the navigational function with partial or complete equipment failure, and methods for determining the most accurate system when an unusually large divergence between systems occurs. For the purpose of this appendix, a large divergence is a divergence that results in a track that falls beyond clearance limits.

(6) Any proposed revisions to the minimum equipment list with adequate justification therefor.

(7) A list of operations to be conducted using the system, containing an analysis of each with respect to length, magnetic compass reliability, availability of en route aids, and adequacy of gateway and terminal radio facilities to support the system. For the purpose of this appendix, a gateway is a specific navigational fix where use of long range navigation commences or terminates.

2. *Equipment and equipment installation—Inertial Navigation Systems (INS) or Doppler Radar System.* (a) Inertial Navigation and Doppler Radar Systems must be installed in accordance with applicable airworthiness requirements.

(b) Cockpit arrangement must be visible and useable by either pilot seated at his duty station.

(c) The equipment must provide, by visual, mechanical, or electrical output signals, indications of the invalidity of output data upon the occurrence of probable failures or malfunctions within the system.

(d) A probable failure or malfunction within the system must not result in loss of the aircraft's required navigation capability.

(e) The alignment, updating, and navigation computer functions of the system must not be invalidated by normal aircraft power interruptions and transients.

(f) The system must not be the source or cause of objectionable radio frequency interference, and must not be adversely affected by radio frequency interference from other aircraft systems.

(g) The FAA-approved airplane flight manual, or supplement thereto, must include pertinent material as required to define the normal and emergency operating procedures and applicable operating limitations associated with INS and Doppler performance (such as maximum latitude at which ground alignment capability is provided, or deviations between systems).

3. *Equipment and equipment installation—Inertial Navigation Systems (INS).*

(a) If an applicant elects to use an Inertial Navigation System it must be at

least a dual system (including navigational computers and reference units). At least two systems must be operational at takeoff. The dual system may consist of either two INS units, or one INS unit and one Doppler Radar unit.

(b) Each Inertial Navigation System must incorporate the following:

(1) Valid ground alignment capability at all latitudes appropriate for intended use of the installation.

(2) A display of alignment status or a ready to navigate light showing completed alignment to the flight crew.

(3) The present position of the airplane in suitable coordinates.

(4) Information relative to destinations or waypoint positions:

(i) The information needed to gain and maintain a desired track and to determine deviations from the desired track.

(ii) The information needed to determine distance and time to go to the next waypoint or destination.

(c) For INS installations that do not have memory or other inflight alignment means, a separate electrical power source (independent of the main propulsion system) must be provided which can supply, for at least 5 minutes, enough power (as shown by analysis or as demonstrated in the airplane) to maintain the INS in such condition that its full capability is restored upon the reactivation of the normal electrical supply.

(d) The equipment must provide such visual, mechanical, or electrical output signals as may be required to permit the flight crew to detect probable failures or malfunctions in the system.

4. *Equipment and equipment installation—Doppler Radar Systems.* (a) If an applicant elects to use a Doppler Radar System

it must be at least a dual system (including dual antennas or a combined antenna designed for multiple operation), except that:

(1) A single operating transmitter with a standby capable of operation may be used in lieu of two operating transmitters.

(2) Single heading source information to all installations may be utilized, provided a compass comparator system is installed and operational procedures call for frequent cross-checks of all compass heading indicators by crewmembers.

The dual system may consist of either two Doppler Radar units or one Doppler Radar unit and one INS unit.

(b) At least two systems must be operational at takeoff.

(c) As determined by the Administrator and specified in the certificate holder's operations specifications, other navigational aids may be required to update the Doppler Radar for a particular operation. These may include Loran, Consol, DME, VOR, ADF, ground-based radar, and airborne weather radar. When these aids are required, the cockpit arrangement must be such that all controls are accessible to each pilot seated at his duty station.

5. *Training programs.* The initial training program for Doppler Radar and Inertial Navigation Systems must include the following:

(a) Duties and responsibilities of flight crewmembers, dispatchers, and maintenance personnel.

(b) For pilots, instruction in the following:

(1) Theory and procedures, limitations, detection of malfunctions, preflight and inflight testing, and cross-checking methods.

(2) The use of computers, an explanation of all systems, compass limitations at high latitudes, a review of navigation, flight planning, and applicable meteorology.

(3) The methods for updating by means of reliable fixes.

(4) The actual plotting of fixes.

(c) Abnormal and emergency procedures.

6. *Equipment accuracy and reliability.* (a) Each Inertial Navigation System must meet the following accuracy requirements, as appropriate:

(1) For flights up to 10 hours' duration, no greater than 2 nautical miles per hour of circular error on 95 percent of system flights completed is permitted.

(2) For flights over 10 hours' duration, a tolerance of  $\pm 20$  miles cross-track and  $\pm 25$  miles along-track on 95 percent of system flights completed is permitted.

(b) Compass heading information to the Doppler Radar must be maintained to an accuracy of  $\pm 1^\circ$  and total system deviations must not exceed  $2^\circ$ . When free gyro techniques are used, procedures shall be utilized to insure that an equivalent level of heading

accuracy and total system deviation is attained.

(c) Each Doppler Radar System must meet accuracy requirements of  $\pm 20$  miles cross-track and  $\pm 25$  miles along-track for 95 percent of the system flights completed. Updating is permitted.

A system that does not meet the requirements of this section will be considered a failed system.

7. *Evaluation program.* (a) Approval by evaluation must be requested as a part of the application for operational approval of a Doppler Radar or Inertial Navigation System.

(b) The applicant must provide sufficient flights which show to the satisfaction of the Administrator the applicant's ability to use cockpit navigation in his operation.

(c) The Administrator bases his evaluation on the following:

(1) Adequacy of operational procedures.

(2) Operational accuracy and reliability of equipment and feasibility of the system with regard to proposed operations.

(3) Availability of terminal, gateway, area, and en route ground-based aids, if required, to support the self-contained system.

(4) Acceptability of cockpit workload.

(5) Adequacy of flight crew qualifications.

(6) Adequacy of maintenance training and availability of spare parts.

After successful completion of evaluation demonstrations, FAA approval is indicated by issuance of amended operations specifications and en route flight procedures defining the new operation. Approval is limited to those operations for which the adequacy of the equipment and the feasibility of cockpit navigation has been satisfactorily demonstrated.

(Secs. 313(a), 601, 604, 605, Federal Aviation Act of 1958, 49 U.S.C. 1354(a), 1421, 1424, 1425; sec. 6(c), Department of Transportation Act, 49 U.S.C. 1855(c))

Issued in Washington, D.C., on March 23, 1972.

K. M. SMITH,  
Acting Administrator.