AC NO: AC 120-33

DATE: 6/24/77

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

SUBJECT: OPERATIONAL APPROVAL OF AIRBORNE LONG-RANGE NAVIGATION SYSTEMS FOR FLIGHT WITHIN THE NORTH ATLANTIC MINIMUM NAVIGATION PERFORMANCE SPECIFICATIONS AIRSPACE

1. PURPOSE. This Advisory Circular sets forth acceptable means, but not the only means, for operators certificated under Parts 121 or 123 of the Federal Aviation Regulations (FAR) and operators utilizing large aircraft under FAR 135.2, to obtain approval to operate within a specific airspace over the North Atlantic designated as the North Atlantic (NAT) Minimum Navigation Performance Specifications (MNPS) airspace after 0001 Greenwich Mean Time (GMT), December 29, 1977.

2. REFERENCES. Federal Aviation Regulations 91.1, 121.79, 121.355, 121.389, 121.405, 121.411, 121.413, 121.415, 121.427, 121.433, 121.443, 121.445, 123.27, 135.2, AC 121-13, AC 25-4, AC 120-31A and ICAO Annex 2.

3. INFORMATION.

a. The concept of the MNPS was proposed on a worldwide basis at the International Civil Aviation Organization (ICAO) 9th Air Navigation Conference. The objective of MNPS is to ensure safe separation of aircraft and enable operators to derive maximum economic benefit from the improvement in navigation performance demonstrated in recent years.

b The MNPS concept is scheduled to be implemented on a regional basis; taking into account particular regional operating conditions. At the September 1976 Limited North Atlantic Regional Air Navigation Meeting, criteria for MNPS, and the introduction of these criteria within parts of the NAT Region, effective at 0001 GMT, December 29, 1977, were agreed upon. (This date corresponds to the initial decommissioning of Loran-A in the NAT Region.) The area concerned is designated as the "NAT-MNPS airspace?

Initiated by: AFS-223

c. NAT-MNPS airspace is defined as follows:

(1) Between latitudes 27°N and 67°N.

(2) The Eastern boundaries of Santa Maria Oceanic, Shanwick Oceanic, and Reykjavik Flight Information Regions (FIR).

(3) The Western boundaries of Reykjavik and Gander Oceanic FIR's and New York Oceanic FIR East of longitude 60° W.

(4) Between FL 275 and FL 400.

d. Contingent upon supportive statistical data, the lateral separation of aircraft in the NAT-MNPS airspace is scheduled to be reduced in October 1978, from 120 nm to 60 nm, and the 2000-foot vertical separation retained. For users of the NAT Organized Track Structure (OTS), this should provide additional tracks nearer the optimum track.

e. When establishing the MNPS concept, it was decided by ICAO that all operators desiring to use the MNPS airspace must show that navigation equipment and procedures to be used are capable of continuously complying with the specifications. In the case of operators certificated under Parts 121 or 123 of the FAR's and operators utilizing large aircraft under FAR 135.2, it is the responsibility of the Federal Aviation Administration (FAA) to make this determination. Acceptable means of showing original compliance with the MNPS requirements are contained herein. Continued compliance is the responsibility of the operator.

f. As established by ICAO, the minimum navigation performance specifications required to operate in the airspace listed in paragraph 3c are listed below. [An operational interpretation of the requirement is in brackets after the specification.]

(1) The standard deviation (one sigma) of lateral track errors should be less than 6.3 nm.

(2) The proportion of the total flight time spent by aircraft 30 nm or more off track should be less than 5.3×10^{-4}. [The proportion of the total flight time spent by aircraft 30 nm or more off the cleared track should be less than 1 hour in 1900 hours. (Note that 30 nm is half of the lateral separation; thus, an aircraft with such an error is closer to the adjacent track than the cleared track.)]

(3) The proportion of total flight time spent by aircraft between 50 and 70 nm off track should be less than 1.3×10^{-4}. [The proportion of the total flight time spent by aircraft between 50 and 70 nm off the cleared track should be less than 1 hour in 8000 hours. (Note that between 50 and 70 nm off track is equivalent to flying on the adjacent track.)]

g. If in-flight equipment unserviceability reduces the navigation capability below the MNPS as established by ICAO, Air Traffic Control (ATC) should be immediately advised so that any necessary adjustments of aircraft separation may be accomplished.

h. In evaluating a navigation system for compliance with ICAO MNPS, consideration should be given to maintaining the high level of navigation performance listed in paragraphs 3f(2) and 3f(3). It should be noted that flight time spent between 50 and 70 nm off track [3f(3)] is also flight time spent more than 30 nm off track [3f(2)]. Applicants should consider equipment reliability and a human errors analysis when evaluating a navigation system for use in the NAT-MNPS airspace.

i. To ensure that safety is not compromised through failure of operators to meet the conditions set forth in paragraphs 3f(2) and 3f(3) above, ICAO is establishing procedures for monitoring of aircraft navigation performance using ATC radars near the boundaries of NAT-MNPS airspace. Lateral errors in excess of 25 nm will be reported for investigation as appropriate. Application of the ICAO MNPS requires contracting States to take appropriate action concerning operators who frequently fail to meet the navigation specifications, including restricting flights or withdrawing approval of those operators to fly in the NAT-MNPS airspace. If there is an excessive number of large errors, it may become necessary for ICAO to increase separation standards until improvement has been achieved.

4. OPERATIONAL APPROVAL.

a. General.

(1) Operators certificated in accordance with FAR 121, 123 or 135.2 desiring approval to operate in NAT-MNPS airspace should contact the FAA office that administers their operating certificate a minimum of 30 days prior to the start of the required evaluation.

(2) Navigation equipment utilized and the associated operating procedures are the choice of the certificate holder. The essential provision is that the combination of equipment and method of operation meet the navigation accuracy established by ICAO for operations within the NAT-MNPS airspace.

(3) Data gathered from operational experience with certain equipment now in service, such as Inertial Navigation Systems (INS), have demonstrated the capability of meeting the NAT-MNPS. It is anticipated that dual INS systems can be approved for operation in the NAT-MNPS airspace without

further evaluation if the equipment has been installed, operated and maintained in accordance with Appendix G of FAR 121.

(4) Until more operational experience is obtained, OMEGA, or a combination of OMEGA/VLF, should not be authorized as a sole means of navigation within NAT-MNPS. Either OMEGA or OMEGA/VLF may be used as an update method for another navigation system previously approved by the FAA. If a combination of OMEGA/VLF is proposed as a means of updating another previously approved navigation system, it should be demonstrated that the system is capable of operating with OMEGA only for update information. The combined navigation system performance, not just the updating means, should be evaluated for operation in NAT-MNPS airspace.

(5) Since VLF communication stations are not dedicated to navigation, the use of VLF alone as a means of long-range navigation, or as a sole update means to other methods of navigation, should not be authorized within NAT-MNPS airspace.

(6) Approval to use a navigation system for flight in NAT-MNPS airspace does not constitute approval for that system in accordance with Appendix G to FAR 121. However, credit may be given for flights and evaluations conducted during MNPS certification towards gaining FAR 121 approval.

b. Procedures.

(1) Approval to operate within the NAT-MNPS airspace by use of navigation systems other than that listed in paragraph 4a(3) should be based upon in-flight data acquisitions and in-flight evaluations that demonstrate NAT-MNPS compliance.

(2) Data acquired during in-flight evaluations should be tested for overall navigation system compliance with the NAT-MNPS by use of the statistical methods detailed in Appendix 1.

(3) Data gathering and evaluation flights should be conducted in the NAT-MNPS airspace over typical routes for which approval is requested. However, after sufficient operating experience has been gained, a portion of the flight testing may be conducted as outlined below in paragraph 4b(7).

(4) The flights should be conducted over a period of not less than 30 days to allow for exposure to varying environmental and atmospheric conditions.

(5) The proposed system should be utilized for navigation purposes. However, the currently approvedsystem should be monitored and used as necessary to keep the aircraft within present lateral offset limitations.

(6) A maximum of either two or four independent observation points per flight may be utilized to acquire data when conducting flights through MNPS airspace. These points are:

(a) For aircraft not equipped with INS:

1 Overheading the inbound VOR/DME/NDB gateway.

2 A reliable radar fix upon initial acquisition by ground-based radar as the aircraft approaches the inbound gateway.

(b) Aircraft equipped with INS:

1 The observation points listed in (6)(a)1 and 2 above plus two additional comparisons to INS that have a minimum of 1 hour separation, and are at least 1 hour prior to either fix mentioned in (6)(a) above. Any INS comparison should be at least 1 hour past the outbound gateway.

2 The INS equipment used for this comparison should have shown a composite error rate of less than one nautical mile per hour averaged over the entire flight without any update. The comparisons should be post corrected, based upon the INS error rate experienced during flight.

(7) Flight testing should be conducted in the MNPS airspace over representative routes. Alternatively, flight testing may be conducted over other geographical areas provided the following conditions are met:

(a) In the case of radio-based navigation systems, the applicant shows by simulation or analysis that the radio signal environment in the area used is no better than that in the MNPS airspace. The simulation or analysis of the radio signal environment should include such factors as the number of stations, signal to noise ratio, station geometry, and any other pertinent factor(s). The signal environment in a given location may be artificially rendered less desirable so as to meet the above conditions through manual station deselection in the airborne receiver.

(b) In the case of navigation systems which have errors that tend to increase as a function of time, the duration of test flights should be at least as long as a typical flight through MNPS airspace.

(c) Data points should be separated in time by at least 60 minutes, and should be overhead VOR/DME stations.

(8) If an applicant's equipment (including antenna type and location) is installed on an aircraft in a manner that duplicates the installation and operating performance of the same type equipment installed on the same type aircraft under an existing Supplemental Type Certificate (STC), credit may be given for data available from previous flights with the already approved system. The applicant's operating procedures and training should be

equivalent to that of the operator already approved to use that system in the NAT-MNPS airspace. The credit given is for previously demonstrated navigation system equipment performance. This could decrease the number of flights required to obtain data if a satisfactory level of navigation performance is demonstrated. In this instance, the graph in Figure 3 of Appendix 1 would be used.

(9) Upon successful demonstration of the required level of certainty to meet the criteria, the operator's operations specifications will be amended to permit operations within NAT-MNPS airspace with the navigation system(s) demonstrated.

5. EXPANSION OF MNPS TO OTHER OCEANIC AIRSPACES. In time, MNPS may be imposed on other oceanic airspace. The specifications imposed would be determined by the amount of air traffic anticipated, navigation aids available, etc. Specifications for other oceanic airspaces may or may not be as demanding as those imposed over the North Atlantic. Approval to operate within the NAT-MNPS airspace does not constitute approval to operate within any other MNPS airspace that may be imposed in the future.

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APPENDIX 1. COMPLIANCE GRAPHS FOR NAVIGATION SYSTEMS ATTEMPTING MNPS APPROVAL.

1. BACKGROUND.

a. A mathematical analysis was used by ICAO to ascertain that the target level of safety would be achieved in MNPS airspace with 60 nm lateral separation if certain requirements for navigation system performance were met. These requirements were calculated in the mathematical analysis to be those listed in paragraph 3f of this circular. This appendix deals with a means of demonstrating compliance with subparagraph 3f(1) which states that the standard deviation (one sigma) of lateral track errors shall be less than 6.3 nm.

b An extension of the mathematical analysis was used to develop a fairly simple means for the FAA and the operator to determine whether or not the 'performance capability listed in subparagraph 3f(1) has been demonstrated.

c. The mathematics used was that of "sequential sampling.*' This has the advantage of determining when satisfactory performance has been demonstrated as a function of the observed navigational accuracies. Thus, a system which consistently achieves superior accuracies will "pass" sooner than a system which is just marginally acceptable. This is a mathematically sound and more equitable means of compliance than one in which an arbitrary number of flights is set beforehand, and that number is fixed no matter how well or how poorly the system performs.

2. THE "PASS-FAIL" GRAPHS.

a. The **Pass-Fail** Graphs are shown in Figures 1, 2 and 3. On these graphs are plotted successive points of the sum of the absolute value of lateral navigation errors (y-axis) versus the number of independent observations taken (x-axis). Figure 1 is a graph which depicts the entire evaluation process for mathematically determining the acceptability of a navigation system for MNPS operation. Figures 2 and 3 are enlargements of the applicable testing method concerned. Figure 2 applies to navigation systems which have never received prior approval for use in MNPS airspace. Figure 3 can be. used to assist in determining satisfaction of MNPS criteria for applicants requesting credit for data gathered during a previously successful evaluation - see paragraph 4b(8).

b. As an example for a system that has never received prior approval, assume that three independent observations were taken on the first evaluation flight. The three lateral navigation errors were 4 nm left of track, 1 nm left of track, and 3 nm right of track, respectively. The first point, is plotted at 1 on the x-axis and 4 nm on the y-axis; the second at 2 on the x-axis and 5 nm of the y-axis; the third at 3 on the x-axis and 8 nm on

the y-axis. (Note that the errors always add whether right or left; they do not cancel.) Data points from other flights continue to add sequentially - see Figure 2.

c. As in the sample, the first data points will fall in the "Continue Testing" band. As more data points are added to the graph, a trend will normally develop toward the "pass" or "fail" region, depending on the observed navigational accuracy.

d. Once the series of data points reaches the "pass" line and/or extends into the "pass" region, satisfactory performance has been successfully demonstrated. (Mathematically, the "pass" line was calculated so as to provide 95% certainty that the navigation system meets the MNPS.)

e. If the series of data points reaches the "fail" line and/or extends into the "fail" region, unsatisfactory performance has been demonstrated with 95% certainty. The operator should then either withdraw the application or rectify the problem(s) and start the evaluation flights over from the zero-zero point on the graph. (It is not permitted to restart at a position on the graph which takes into account previous data points where the navigation system was accurate, but ignores previous data points which showed inaccuracies.)

f. It should be noted that the x-axis is labeled "number of INDEPENDENT observations," In this case, "independent" means that navigation errors for two or more successive data points must not be correlated. In order to insure that this procedure has been met, guidance has been given in the body of this circular regarding an acceptable means of taking observations which can be considered independent.

g. Should the sequential sampling procedure not yield a conclusion (pass or fail) after 200 independent observations, the testing should be terminated. The adequacy of the proposed navigation system should be determined by the following Chi-square test procedures

$$D_1 = \sum d_1^2 + d_2^2 + d_3^2 + \cdots\cdots\cdots + d_{200}^2$$

$$D_2 = \sum d_1 + d_2 + d_3 + \cdots\cdots\cdots + d_{200}$$

where d is the value of the individual lateral errors. Positive or negative errors must be consistently applied throughout-the sampling procedure. If a deviation to the right is considered positive on one flight, it must be a positive error on all subsequent flights. D_1 is the sum of the square of

each lateral error observed; $d_1^2 + d_2^2 + d_3^2$ etc. out to d_{200}^2. D_2 is the algebraic sum of all of the 200 lateral errors observed. As an illustration, assume that the data in the sample shown on Figure 2 had not yielded a pass result after 200 independent observations. Then, $d_1 = -4$ nm; $d_2 = -1$ nm; and, $d_3 = +3$ nm.

$$D_1 = \sum (-4)^2 + (-1)^2 + (+3)^2 + \ldots + \text{etc.}$$

$$D_1 = 16 + 1 + 9 + \ldots$$

$$D_2 = \sum (-4) + (-1) + (+3) + \ldots + \text{etc.}$$

$$D_2 = -5 + 3 + \ldots + \text{etc.}$$

$$\text{Variance } f_2^2 = \left(D_1 - \frac{D_2^2}{200} \right) \div 199$$

If f_2^2 is equal to or less than 46.36, the system is acceptable.

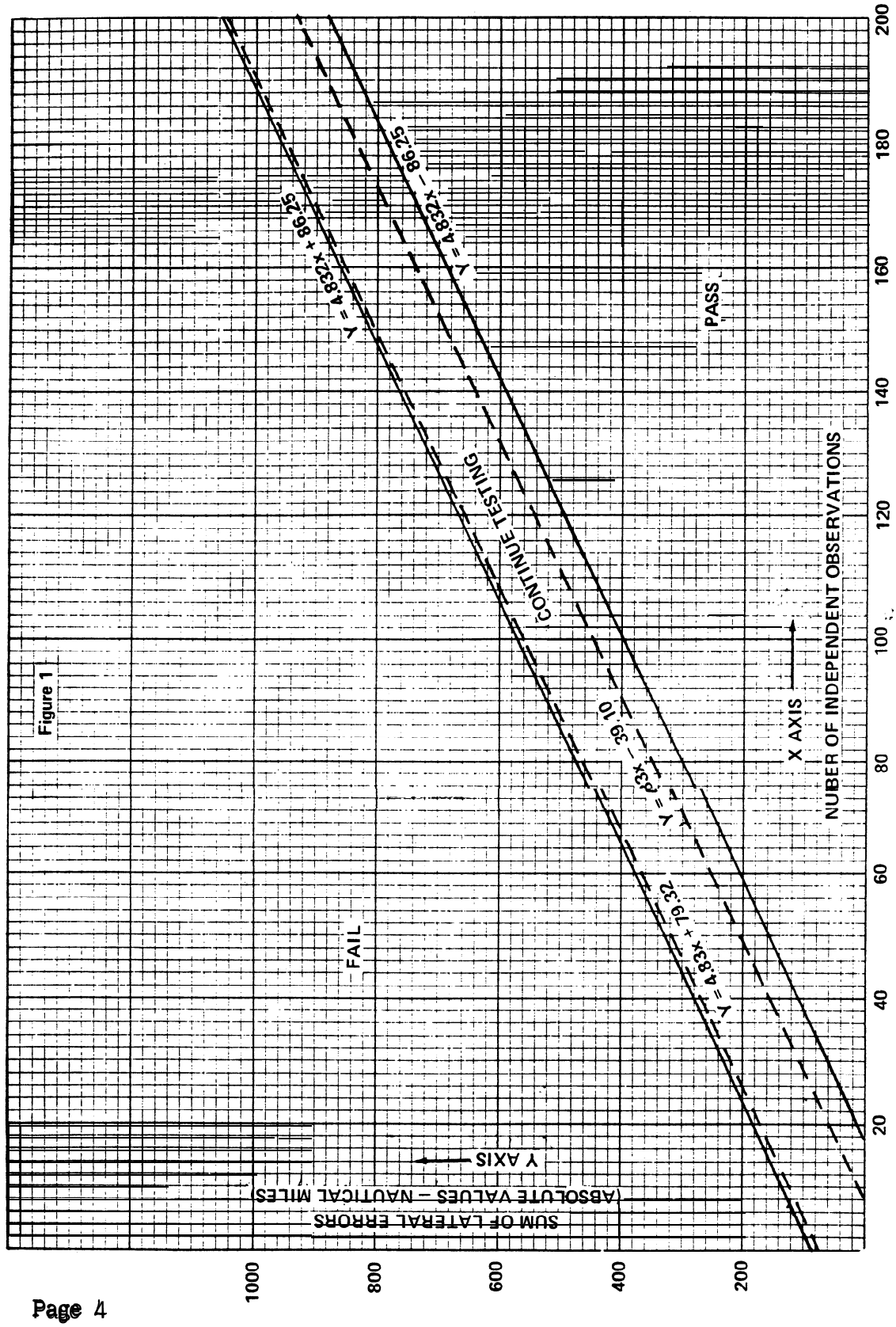
Y = 4.832X + 86.25
Y = 4.832X - 86.25
CONTINUE TESTING
Y = 4.83X - 79.32
Y = 4.83X - 39.10
PASS
FAIL
X AXIS
NUBER OF INDEPENDENT OBSERVATIONS
Y AXIS
SUM OF LATERAL ERRORS
(ABSOLUTE VALUES - NAUTICAL MILES)
20
40
60
80
100
120
140
160
180
200
1000
800
600
400
200

Figure 1

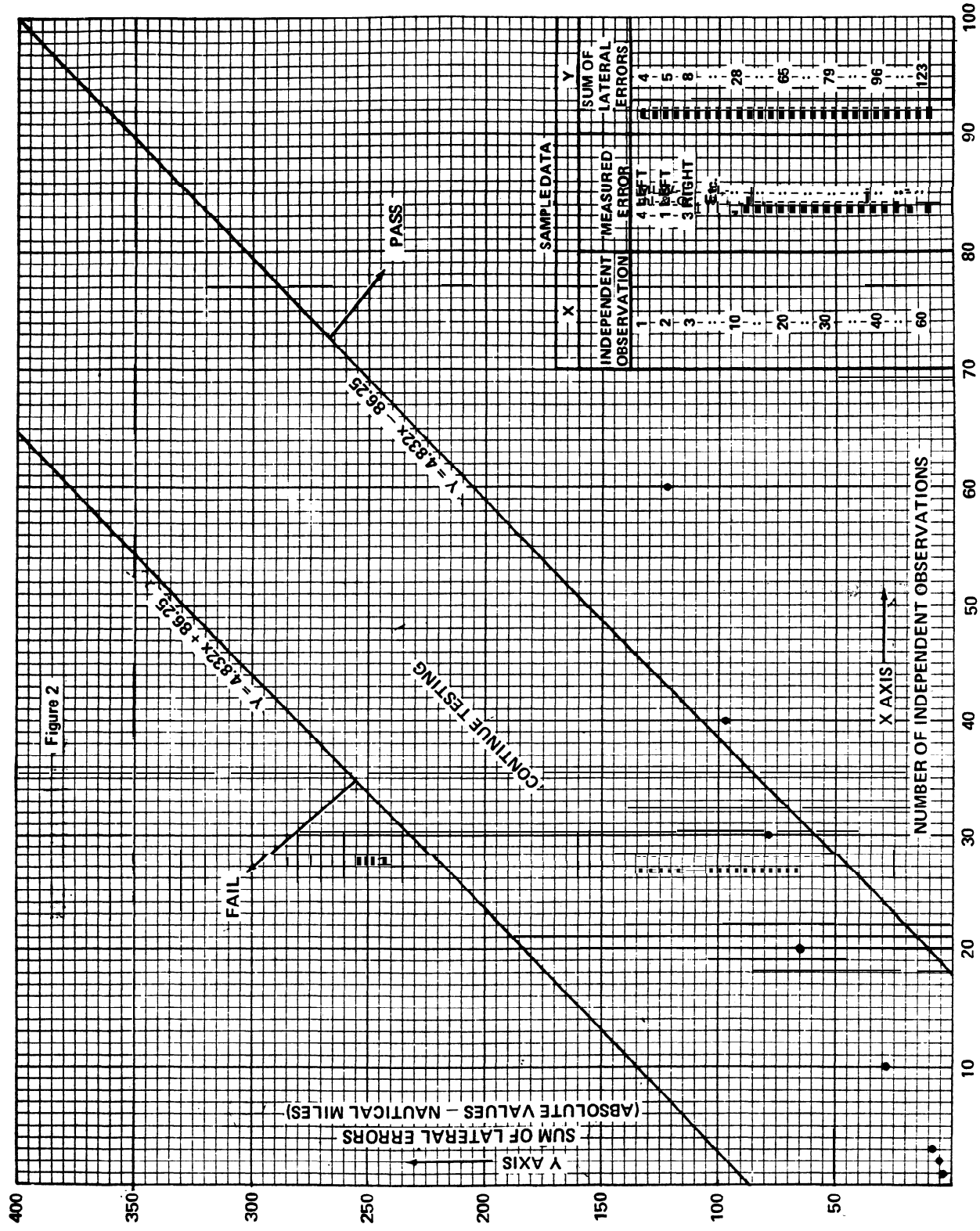
SAMPLE DATA
X
INDEPENDENT OBSERVATION
1
2
3
10
20
30
40
60
Y
SUM OF LATERAL ERRORS
MEASURED ERROR
4 LEFT
1 LEFT
3 RIGHT
4
5
8
28
65
79
96
123
PASS
FAIL
CONTINUE TESTING
Y = 4.832X + 86.25
Y = 4.832X - 86.25
X AXIS
NUMBER OF INDEPENDENT OBSERVATIONS
Y AXIS
SUM OF LATERAL ERRORS
(ABSOLUTE VALUES - NAUTICAL MILES)
400
350
300
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100

Figure 2

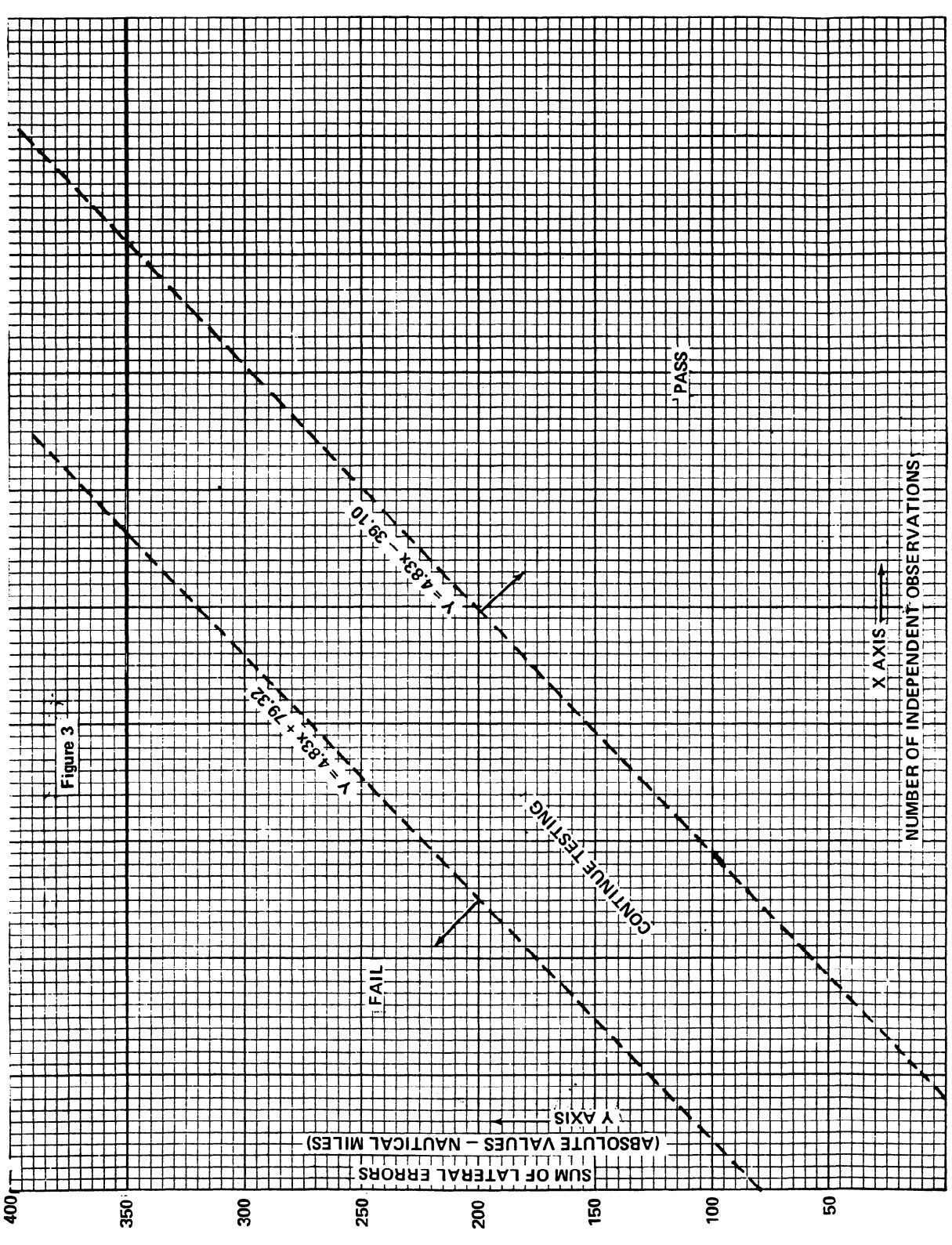
SUM OF LATERAL ERRORS
(ABSOLUTE VALUES – NAUTICAL MILES)
Y AXIS
FAIL
CONTINUE TESTING
PASS
Y = 4.83X – 39.10
Y = 4.83X + 79.32
X AXIS
NUMBER OF INDEPENDENT OBSERVATIONS
400
350
300
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100

Figure 3