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ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Washington, D.C.

FAR GUIDANCE MATERIAL

Subject: TRANSPORT CATEGORY AIRPLANES CABIN OZONE CONCENTRATIONS

1. PURPOSE. This advisory circular provides guidance concerning acceptable means, but not the only means, for an air carrier to demonstrate compliance with the maximum permissible cabin ozone (O_3) concentrations established by Section 121.578 of the Federal Aviation Regulations (FAR).

2. RELATED FAR SECTIONS. This advisory circular is also related to Section 25.832.

3. RELATED READING MATERIAL. Additional information on ozone concentrations may be found in the following documents:

a. Federal Aviation Administration (FAA) documents:

(1) Simultaneous Cabin and Ambient Ozone Measurements on Two Boeing 747 Airplanes, Volume I - Report Number FAA-EE-79-05 (NTIS Accession Number ADA 079 114).

(2) Guidelines For Flight Planning During Periods of High Ozone Occurrence - Report Number FAA-EQ-78-03 (NTIS Accession Number ADA 050 988).

(3) Effects of Ozone on Exercising and Sedentary Adult Men and Women Representative of the Flight Attendant Population - Report Number FAA-AM-79-20 (NTIS Accession Number ADA 080 045).

(4) Ozone Concentration By Latitude, Altitude, and Month, Near 80° West - Report Number FAA-AEQ-77-13 (NTIS Accession Number ADA 046 956).

Copies of these reports may be purchased from the National Technical Information Service; Springfield, Virginia 22161.

b. Federal Aviation Administration Advisory Circular 00-52, Ozone Irritation During High Altitude Flight. Copies of this advisory circular may be obtained free of charge from the U.S. Department of Transportation; Publications Section M-443.1, Washington, D.C. 20590.

Initiated by: AFO-260

c. National Aeronautics and Space Administration Documents:

(1) Ozone Contamination in Aircraft Cabins - Report Number NASA CP-2066 (NTIS Accession Number N 79-21021).

(2) Procedures for Estimating the Frequency of Commercial Airline Flights Encountering High Cabin Ozone Fields - Report Number NASA TP-1560 (NTIS Accession Number N 79-33171).

Copies of these reports may be obtained from the National Technical Information Service; Springfield, Virginia 22161.

d. National Primary and Secondary Ambient Air Quality Standards, Title 40, Chapter I, Subchapter C, Part 50 - Environmental Protection Agency final rulemaking, Federal Register, Volume 44, Number 28, Page 8202 - Thursday, February 8, 1979.

4. BACKGROUND.

a. Natural ozone is formed primarily above the tropopause in the upper atmosphere as a result of the action of ultraviolet light on oxygen molecules. The amount and distribution of natural ozone in the atmosphere varies with latitude, altitude, season, and weather conditions. [See paragraph 3a(2).] The highest concentrations in the northern hemisphere are generally found at high altitude over high latitude locations during the winter and spring.

b. In late 1976, complaints were received from crewmembers on high altitude, high latitude, long range flights which described discomforts such as eye irritations, coughing, nose irritations and chest pains. Subsequent research determined that some of these symptoms could be attributed to ozone in the aircraft cabin. Significant ozone concentrations were occasionally measured in the cabin of aircraft on high latitude, high altitude flights and research studies conducted in an altitude chamber demonstrated that significant ozone concentrations may produce similar symptoms in some persons.

c. Part 121 of the FAR has been amended so that a certificate holder may not operate a transport category airplane above flight level 180 unless it has successfully demonstrated to the Administrator that the concentration of ozone inside the cabin will not exceed .25 parts per million by volume, sea level equivalent, at any time; and time-weighted value of .1 part per million by volume, sea level equivalent, for scheduled flight segments of more than 4 hours. Compliance with these requirements should be shown by analysis and/or tests based either on airplane operational procedures and performance limitations or the certificate holder's operations. The analysis or tests must show either (1) that atmospheric ozone statistics indicate, with a statistical confidence of at least 84 percent, that at the altitudes and locations at which the airplane will be operated that the permissible levels of cabin ozone concentrations will not be exceeded; or (2) that the airplane ventilation systems, including any ozone control equipment, will maintain the cabin ozone concentrations at or below the permissible levels. Acceptable means of conducting the required analysis or tests are discussed in paragraph 5 of this advisory circular.

d. It is expected that research into the physiological effects of ozone and effective methods for its control will continue to provide a greater understanding of its effects on persons and will increasingly provide more effective methods to eliminate excessive ozone quantities. Nevertheless, current technology is adequate to eliminate excessive levels of ozone in aircraft cabins. Filters and catalytic converters for reducing cabin ozone concentrations are available which can be installed on affected aircraft types. However, several additional methods exist which may, in certain cases, maintain cabin ozone concentrations at or below the maximum permissible levels. An air carrier may use any of the methods contained in this advisory circular if the analysis or tests conducted show that the method(s) chosen are effective.

e. Since each of the various methods has certain beneficial aspects, one method is not favored over any other. However, the FAA intends to conduct inflight spot checks to ensure compliance with the standards.

5. MEANS OF COMPLIANCE.

a. Acceptable means of demonstrating compliance includes any one or a combination of the following:

(1) A statistical analysis which is based on acceptable atmospheric ozone statistics, the types of aircraft flown, and the route structure used in the air carrier's operation.

(2) A statistical analysis which is based on actual measurements of cabin ozone concentrations for the types of aircraft operated and obtained over routes or areas representative of the air carrier's route structure.

(3) Modifications to the aircraft by an air carrier, under a Supplemental Type Certificate (STC), FAA Form 337 approval, or an engineering order/authorization to comply with a manufacturers approved service bulletin, which reduces the ozone concentrations to acceptable levels in the aircraft cabins.

(4) Modifications to the aircraft by the manufacturer or design changes which reduce cabin ozone levels to acceptable levels.

(5) Modifications to operational procedures, such as the use of a higher stage bleed air or the use of recirculation controls, to reduce ozone to acceptable levels.

(6) Flight planning procedures to adjust the flight altitude and/or route of flight to reduce cabin ozone to acceptable levels.

b. Examples of the specific means or combination of means which may be used by an air carrier to demonstrate compliance are discussed in detail in paragraphs 6, 7, and 8 of this advisory circular.

6. STATISTICAL ANALYSIS.

a. If the carrier elects to use statistical analysis to demonstrate compliance, the method used should demonstrate with a statistical confidence level of 84 percent that the cabin ozone levels will be within acceptable limits.

b. The ozone data base used in the analysis should include sufficient data to demonstrate compliance within the area of operation on a month-to-month basis. Any statistical analysis should be based on acceptable atmospheric ozone statistics, actual inflight measurements, or a combination of both.

c. Acceptable atmospheric ozone statistics are contained in the publications listed in paragraph 3a(2) and 3a(4). If actual inflight measurements are used, they should provide a sufficient data base to establish the required statistical confidence level and contain monthly altitude, latitude and longitude resolution elements equivalent to those in Appendix A of the publication listed in paragraph 3a(2) for the type(s) of airplanes flown and the operations conducted. Additionally, actual inflight cabin ozone measurements should be obtained with equipment which has been periodically calibrated and maintained in accordance with approved Environmental Protection Agency (EPA) procedures.

d. One of the elements which should be considered in a statistical analysis based on acceptable ambient ozone statistics is the ozone dissociation (destruction) rate for the environmental control system installed in a particular type of airplane. This factor determines the percentage of the ambient ozone which is ultimately introduced into the cabin environment. The ozone dissociation rate is applied to the ambient ozone statistics to determine the cabin ozone statistics for that flight altitude, time and location.

e. Normally, the dissociation rate has been determined by simultaneous inflight measurements of ambient and cabin ozone levels. However, other methods, such as laboratory measurements or an engineering analysis, may be used to establish the dissociation rate for a particular environmental control system if these methods are shown to be accurate and reliable.

f. In cases where the dissociation rate is unknown, a statistical analysis may still be used to show compliance. In this case, it may be necessary to assume that the rate is zero and the cabin levels are equal to the ambient levels.

g. Statistical analysis required by this advisory circular may be obtained from pools of data formed by cooperation between operators and manufacturers. Data to determine the cabin ambient ozone dissociation (destruction) rate for the statistical analysis approach of Appendix 1 of this advisory circular may be accepted if it comes from other operators of the same type of aircraft with the same cabin air handling systems, or is otherwise shown to be appropriate. Cabin ozone data from these aircraft may also be accepted for demonstrating compliance with the permissible ozone level if the data are taken in the same geographic area.

h. Acceptable means of conducting this statistical analysis are contained in Appendix 1 of this advisory circular and the publication listed in paragraph 3c(2). However, either of these methods should use acceptable ozone statistics (see Appendix 2).

7. AIRCRAFT DESIGN CHANGES/MODIFICATIONS AND EQUIPMENT INSTALLATION.

a. Design changes/modifications may be used to demonstrate compliance if analysis and/or tests show that these methods reduce the cabin ozone concentrations to acceptable levels for each type of aircraft flown and each operation conducted. The tests, if required, may be conducted in a laboratory, inflight, or a combination of both. A statistical analysis based on acceptable ozone statistics may also be used to demonstrate that the ozone dissociation rate for the device(s) installed will reduce the cabin ozone to acceptable levels.

b. Once the ozone dissociation rate has been established for a particular device, the potential maximum cabin ozone concentration and the time-weighted averages, if appropriate, are determined by applying the dissociation rate to the ambient ozone concentrations contained in the statistical analysis. The dissociation rate should be high enough to demonstrate compliance on a month-by-month basis within the area of operation.

c. In any case, the air carrier should demonstrate to the Administrator that the design changes/modifications and/or the equipment installed will reduce the cabin ozone concentrations to acceptable levels in each type of aircraft used and for each route flown by its aircraft. The ozone dissociation equipment, if installed, should be included in the air carrier's approved maintenance program and should be inspected, repaired and/or replaced in accordance with approved procedures. The initial service life of the ozone dissociation equipment should be established through analysis and tests.

d. Examples of a procedure for demonstrating compliance after installation of equipment with a known ozone dissociation rate are contained in Appendix 1 of this advisory circular.

8. OPERATIONAL AND/OR FLIGHT PLANNING PROCEDURES.

a. If an air carrier chooses to adopt operational or flight planning procedures to demonstrate compliance, these procedures should be shown to reduce cabin ozone concentrations to acceptable levels for each type of aircraft used and for each route or area flown by these aircraft.

b. The required analysis and/or tests should use inflight measurements and/or statistical data from acceptable ozone statistics to show that the operational and/or flight planning procedure to be used will reduce the cabin ozone concentrations to acceptable levels. The ozone dissociation (destruction) rate for the environmental control system installed in the particular type(s) of airplanes used by the air carrier should be considered when conducting a statistical analysis. This factor determines the percentage of the ambient ozone which is ultimately introduced into the cabin environment. If the dissociation rate is unknown, it may be neccesary to assume that the rate is zero and the cabin levels are equal to the ambient levels.

c. In one method, the location of high ozone concentrations would be predicted and flight planning procedures would route the flight to reduce the cabin ozone to acceptable levels. Similar methods may be used to determine when operational procedures, such as using high stage bleed air, or using recirculation controls, are necessary to dissociate sufficient ozone to obtain compliance. However, data from inflight measurements are necessary to demonstrate that these procedures are effective. This is due to the difficulty of reliably predicting ozone concentrations at normal flight altitudes. Furthermore, these data should show that the techniques used to predict ozone concentration levels for a particular flight indicate that there is a statistical confidence level of 84 percent that the flight will not exceed the permissible maximum concentrations at any point along the route of flight.

d. An alternate method would be to restrict the flight altitude on certain flights or segments of flights to achieve compliance. Acceptable ozone statistics should be used to conduct an analysis which shows that the flight altitude(s) authorized for a particular route or area of operation will maintain the cabin ozone concentration within acceptable limits. In some cases, these restrictions may be necessary only during certain months. An example of such a statistical analysis to demonstrate compliance is contained in Appendix 1 of this advisory circular.

e. In any case, sufficient data should be provided to show the Administrator that these procedures are reliable and effective in reducing cabin ozone to acceptable levels for each type of aircraft and each route or area flown by these aircraft.

9. OPERATIONAL APPROVAL.

a. The application for approval of the method(s) proposed by the air carrier to reduce cabin ozone to acceptable levels should be submitted to the FAA certificate holding office for review and approval at least 30 days prior to using the proposed method(s) in air carrier service. This application should contain any pertinent airworthiness approvals, as well as the necessary supporting data, and the proposed amendments to the operations specifications.

b. The supporting data should show that the method(s) to be used by the air carrier will reduce cabin ozone concentrations to acceptable levels for each type of aircraft used and each route or area flown by those aircraft. The operations specifications should reflect any operational restrictions necessary to achieve compliance.

c. If the air carrier demonstrates that the method(s) to be used are effective, approval should be granted by amendment to the operations specifications. Approval in the operations specifications may be granted by area of operation, by individual routes, or a combination of both. The approval should include the restrictions (i.e., maximum flight altitude, operational procedures, aircraft modifications) necessary to achieve compliance. The restrictions should be applicable to the types of aircraft operated or types of operations conducted, or both.

10. REQUESTS FOR DEVIATION FROM THE COMPLIANCE PERIOD.

a. The FAA has determined that the 12-month period provided for air carriers to comply with this rule is reasonable and adequate. However, the new Section 121.578 allows a certificate holder to obtain an authorization to deviate from these requirements by an amendment to its operations specifications, if it shows that due to circumstances beyond its control or to unreasonable economic burden it cannot comply for a specific period of time, and submits a plan acceptable to the

Administrator to effect compliance to the extent possible. A deviation can be authorized in circumstances such as equipment delivery delays or short-term use of aircraft, when the certificate holder shows that, through flight planning or other means, it attempts to avoid areas of cabin ozone concentrations above the limits given in the rule.

b. Any request for deviation should state the reasons why compliance cannot be demonstrated during the time period and why these factors are beyond the control of the air carrier. The request should also contain a compliance schedule and a plan to effect compliance to the extent possible which are acceptable to the Administrator.

c. The request for deviation should be submitted to the FAA certificate-holding office at least 60 days before the compliance date of February 20, 1981, stated in Section 121.578 of the FAR.

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APPENDIX 1. EXAMPLES OF STATISTICAL ANALYSIS

1. PURPOSE. This appendix contains illustrations of a method using statistical analysis to demonstrate compliance with maximum and time-weighted average permissible cabin ozone concentrations established by Section 121.578 of the Federal Aviation Regulations (FAR).

2. EXPLANATION OF TERMS AND SYMBOLS.

a. OZMAX is the permissible maximum ozone concentration inside an airplane cabin as established by FAR Part 121 which may not exceed a value of 0.25 parts per million by volume (ppmv), sea level equivalent (SLE), at any point in time.

b. OZTWA is the permissible time-weighted average (TWA) of the ozone concentration inside an airplane cabin over a flight segment as established by FAR Part 121 which may not exceed a value of 0.1 ppmv, SLE, for each flight segment that exceeds 4 hours.

c. OZSLE is ozone concentration in ppmv referenced to standard conditions of 25° C and 760 millimeters of mercury pressure.

d. (P/P_o) is the ratio of cabin pressure (P) to sea level pressure P_o). This ratio is used to obtain the SLE ozone concentration from the ozone concentration at altitude assuming the cabin temperature is 25° C. OZSLE = $(P/P_o)(O_3)$. Some representative values which can be used in operational calculations are:

For P of:	P/P_o is:
5000 feet	0.83
6000 feet	0.80
7000 feet	0.77
8000 feet	0.74

NOTE: The use of standard P/P_o tables can result in errors of up to 7 percent due to the use of temperatures other than 25° C.

e. R is the retention ratio of the ambient (outside) ozone which enters the airplane cabin after going through the air conditioning system and, in most cases, the engines. Normally, the retention ratio is from 0.75 to 1.00 without cabin air recirculation and can be as low as 0.4 to 0.6 with cabin air recirculation. However, the retention ratio for a particular aircraft may differ from these values depending on the cabin air exchange rate, the interior surface to volume relationship, and the amount of cabin air recirculated.

f. E is the efficiency of a filter or catalytic converter installed to remove a portion of the ambient ozone before it enters the airplane cabin. For the purpose of this appendix, the word "filter" is used to describe either type of device. An airplane without a filter would have E = 0.

g. T_{18} is the flight time above 18,000 feet.

h. T_{FS} is the total flight segment time (block time).

i. OZ16 is the estimated ambient ozone concentration obtained from statistics with a confidence level of 84 percent. As explained in Appendix 2 of this advisory circular, preferable data for this purpose are the ozonesonde statistics given in Appendix A of Report FAA-EQ-78-03. Examples of these data for February are reproduced on pages 12 to 19 of this appendix. In using these data, it should be remembered that they are central values for five degrees latitude and 2000 feet altitude boxes.

j. Although there are many flight routes which are not specifically covered by the data on these pages, the data can be used to interpolate the ozone statistics for any flight route. An example of this is shown in Figure 1 for the month of February where OZ16 values are presented for flight levels 410, 390, and 370. The heavy dashed areas are the regions covered by the ozonesonde data. The Japan and western Europe data used in this example have been linearly interpolated to obtain resolution increments of five degrees similar to those used in the eastern and western North American regions. (For 30N, the Japan ozone data have been set to one-half the value at 32N since a linear interpolation gives negative values). Where data exist at a common latitude, they have been linearly interpolated to determine the values for the Pacific and Atlantic areas and are shown in the lighter dashed regions. For latitudes where there are no Japan or western Europe data, the appropriate North American data should be used. The following examples of this procedure to determine OZ16 values for flight level 410 are given:

Longitude	Latitude	OZ16	Obtained From Extension of the
160 E	65 N	1.2ppmv	western North American data
160 E	70 N	1.3ppmv	eastern North American data
40 W	65 N	1.1ppmv	eastern North American data
40 W	70 N	1.3ppmv	eastern North American data

For the southern hemisphere, the data can be (1) obtained from a mirror image of the northern hemisphere data with a 6-month seasonal shift. For example, ozone data for Janaury at 45 S, 80 W would be obtained from the July ozone data at 45 N, 80 W; or (2) calculated by averaging the northern hemisphere data over all longitudes at a given north latitude and using the resulting value for the same south latitude, again with a 6-month seasonal shift.

3. DISCUSSION. In this appendix, the ozone statistics are used in 3 types of examples.

a. Type 1 - Direct determination if a flight complies with either the maximum or TWA cabin ozone concentrations established by FAR Part 121.

b. Type 2 - Determination of the filter efficiency (E) required for a particular flight to comply with the cabin ozone concentrations established by FAR Part 121.

c. Type 3 - Determination of the maximum flight altitude an airplane could fly given a geographical region, latitude and time of year and still comply with the cabin ozone concentrations established by FAR Part 121.

4. EXAMPLES - MAXIMUM CABIN OZONE CONCENTRATION (0.25 ppmv, SLE). The maximum cabin concentration using ozone statistics should be determined at each point along the route of flight and is given by:

$$OZMAX = (1-E)(OZ16)(R)(P/P_O) \qquad \text{(Equation 1)}$$

In all examples, the value for R is 0.8 and the value for (P/P_O) is 0.77 (a cabin altitude of 7,000 feet). Equation 1 then becomes:

$$OZMAX = (0.8)(0.77)(1-E)(OZ16)$$
$$= (0.62)(1-E)(OZ16) \qquad \text{(Equation 2)}$$

a. Type 1 - Example to determine if any point along a flight route is in compliance with the maximum cabin ozone concentration (0.25 ppmv, SLE). From the ozonesonde statistics on Page 16 of this appendix (Page A-15 of the ozonesonde statistics) look up OZ16 using the following example information:

Region: eastern North America
Month: February
Flight level: 370

(1) Case 1. Latitude: 50° North

Page 16 of this appendix (Page A-15 of the ozonesonde statistics) gives OZ16 = 0.50 ppmv.

Therefore (assuming E = 0, or no filter):

$$OZMAX = (0.62)(0.50) = 0.31 \text{ ppmv}$$

THIS POINT ALONG THE FLIGHT ROUTE WOULD NOT HAVE DEMONSTRATED COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 40° North

Page 17 of this appendix (Page A-16 of the ozonesonde statistics) gives OZ16 = 0.40 ppmv.

Therefore (assuming E = 0, or no filter):

$$OZMAX = (0.62)(0.40) = 0.25 \text{ ppmv.}$$

THIS POINT ALONG THE FLIGHT ROUTE WOULD HAVE DEMONSTRATED COMPLIANCE WITH THE MAXIMUM OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

b. Type 2 - Example to determine the filter efficiency required to show compliance at a point along the flight route with the maximum cabin ozone concentration. Equation 2 can be rewritten to determine E, the filter efficiency:

$$E = 1 - \left[\frac{OZMAX}{(0.62)(OZ16)}\right] \qquad \text{(Equation 3)}$$

For OZMAX = 0.25 ppmv, Equation 3 becomes:

$$E = 1 - \left[\frac{(0.25)}{(0.62)(OZ16)}\right]$$

$$E = 1 - \left[\frac{(0.40)}{(OZ16)}\right] \qquad \text{(Equation 4)}$$

(1) Case 1. Latitude: 50° North
OZ16 0.50 ppmv

$$E = 1 - \left[\frac{(0.40)}{(0.50)}\right]$$

$$= 1 - (0.80) = 0.20 = 20\%$$

INSTALLATION OF A FILTER WHICH REMOVED 20 PERCENT OF THE OZONE ENTERING THE CABIN WOULD ENABLE THIS POINT ALONG THE FLIGHT ROUTE TO SHOW COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 45° North

NO FILTER REQUIRED FOR THIS POINT ALONG THE FLIGHT ROUTE AS COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121 WAS SHOWN DURING EXAMPLE TYPE 1, CASE 2.

(3) Variation of Type 2. The filter efficiency required for an airplane to show compliance with the maximum cabin ozone concentration for a point along any flight route can be determined using the method of the Type 2 example. For a worst case analysis, the following assumptions are made:

P/P_O = 0.74 (Cabin Altitude of 8,000 feet - maximum pressure differential of 8.9 pounds per square inch at 45,000 feet)

R = 1.0 (All ambient ozone enters the airplane cabin)

At flight level 450 the maximum ozone concentration at an 84 percent confidence level the ozone statistics [paragraph 3(a)2, Appendix A] is found to be 1.8 ppmv during February at 80° north latitude in the eastern North American region. This is shown on page 15 of this appendix.

Equation 1 can be written as:

$$E = 1 - \left[\frac{OZMAX}{(OZ16)(R)(P/P_O)}\right]$$

$$= 1 - \left[\frac{0.25}{(1.8)(1.0)(0.74)}\right]$$

$$= 1 - 0.19 = 0.81 = 81\%$$

INSTALLATION OF A FILTER WHICH REMOVED 81 PERCENT OF THE OZONE ENTERING THE CABIN WOULD ENABLE AN AIRPLANE TO SHOW COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121 UNDER THE WORST CASE CONDITIONS (ANY POINT ALONG ANY FLIGHT ROUTE).

c. Type 3 - Example to determine the maximum flight altitude allowed to show compliance at a point along a flight route with the maximum cabin ozone concentration. Equation 2 can be rewritten to determine OZ16, the ambient ozone concentration derived from statistics with a confidence of 84 percent.

$$OZ16 = \left[\frac{OZMAX}{(0.62)(1-E)}\right] \qquad \text{(Equation 5)}$$

For OZMAX = 0.25 ppmv and no filter E = 0, Equation 5 becomes:

$$OZ16 = \left[\frac{(0.25)}{(0.62)}\right]$$

$$= 0.40 \text{ ppmv}$$

(1) Case 1. Latitude: 50° North

For this case, page 16 of this appendix (Page A-15 of the ozonesonde statistics) shows the OZ16 value of 0.40 ppmv occurs for flight level 340. (This value is determined by straight line interpolation between the OZ16 values of 0.35 ppmv and 0.45 ppmv occurring at flight levels 330 and 350, respectively. The use of straight line interpolation is permissible where appropriate.)

THIS POINT ALONG THE FLIGHT WOULD HAVE TO BE FLOWN AT OR BELOW 34,000 FEET TO SHOW COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 40° North

For this case, page 17 of this appendix (page A-16 of the ozonesonde statistics) shows the OZ16 value of 0.40 ppmv occurs for flight level 370.

THIS POINT ALONG THE FLIGHT WOULD HAVE TO BE FLOWN AT OR BELOW 37,00 FEET TO SHOW COMPLIANCE WITH THE MAXIMUM CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

d. Variation of Type 3. The example shown for Type 3 can be extended to show compliance with the maximum cabin ozone concentration established by FAR Part 121 at any latitude for any month of the year. One example of such a determination is shown in Figure 2 for an airplane flying in eastern North America with R = 0.8, E = 0, and a cabin altitude of 7,000 feet (which, like the Type 3 example, gives a required OZ16 of 0.40 ppmv).

5. Examples - Time-Weighted Average (TWA) Cabin Ozone Concentration (.1 ppmv, SLE). To determine the TWA cabin ozone concentration, the OZ16 values are used to ensure that the ozone statistics are known with an 84 percent confidence value for any one flight (the 50 percent value would only give a confidence value of 50 percent that a flight would meet the required ozone concentration standard).

a. The TWA cabin ozone concentration using ozone statistics is given by Equation 6 which is similar to Equation 1 with time-weighted OZ16 values for flight segments at constant latitude and altitude in the same geographic area.

$$OZ16 = (1-E)(R)(P/P_O) \left[\sum_{i=1}^{N} (OZ16)_i \; T_i/T_{FS} \right] \text{(Equation 6)}$$

WHERE: N is the number of individual flight segments at a constant latitude and altitude in the same geographical area; T_i is the flight segment, above flight level 180, at a constant latitude and altitude in the same geographic area.

NOTE: $\sum_{i=1}^{N} T_i = T_{18}$

$(OZ16)_i$ is the ambient ozone concentration obtained from the ozone statistics with a confidence level of 84 percent which is estimated to be encountered during the time period, T_i.

In all the example types shown, the following values are assumed: R = 0.8 and P/P_O = 0.77. Equation 6 then can be written as:

$$OZTWA = (0.8)(0.77)(1-E) \left[\sum_{i=1}^{N} (OZ16) \; (T_i/T_{FS}) \right]$$

$$OZTWA = (0.62)(1-E) \left[\sum_{i=1}^{N} (OZ16)_i (T_i/T_{FS}) \right] \quad \text{(Equation 7)}$$

b. Type 1 - Example to determine if a flight is in compliance with the TWA cabin ozone concentration. For all Type 1 examples, assume the following: the month is February, the flight level is 370, no filter (or E=0), and the flight segment (T_{FS}) is 5 hours. Two hours are flown in the eastern North American region (ENAR) and two hours are flown in the western North American region (WNAR) above flight level 180.

(1) Case 1. Latitude: 50° North

Pages A-15 and A-12 of the ozonesonde statistics (Figure 1 of this advisory circular) give OZ16 = 0.50 ppmv for the ENAR and OZ16 = 0.25 ppmv for the WNAR. Therefore, from Equation 7:

$$OZTWA = \left[\frac{(0.62)(0.50 \times 2 + 0.25 \times 2)}{5} \right] = 0.19 \text{ ppmv}$$

THIS FLIGHT WOULD NOT HAVE DEMONSTRATED COMPLIANCE WITH THE MAXIMUM TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 40° North

Pages A-16 and A-13 of the ozonesonde statistics (Figure 1 of this advisory circular) give OZ16 = 0.40 ppmv for the ENAR and OZ16 = 0.50 ppmv for the WNAR. Therefore:

$$OZTWA = \left[\frac{(0.62)(0.40 \times 2 + 0.50 \times 2)}{5}\right] = 0.22 \text{ ppmv}$$

THIS FLIGHT WOULD NOT HAVE DEMONSTRATED COMPLIANCE WITH THE MAXIMUM TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(3) Case 3. Latitude: 30° North

Figure 1 of this advisory circular (page A-16 and interpolation between pages A-16 and A-11 of the ozonesonde statistics) gives OZ16 = 0.12 ppmv for the ENAR and OZ16 = 0.10 ppmv for the WNAR. Therefore:

$$OZTWA = \left[\frac{(0.62)(0.12 \times 2 + 0.10 \times 2)}{5}\right] = 0.05 \text{ ppmv}$$

THIS FLIGHT WOULD HAVE DEMONSTRATED COMPLIANCE WITH THE MAXIMUM TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

c. Type 2 - Example to determine the filter efficiency required to show compliance with the TWA cabin ozone concentration. Equation 7 can be rewritten to determine E, the filter efficiency:

$$E = 1 - \left[\frac{(OZTWA)(T_{FS})}{(0.62)\left[\sum_{i=1}^{N} (OZ16)_i (T_i)\right]}\right] \qquad \text{(Equation 8)}$$

For OZMAX = 0.1 ppmv and the flight conditions of the example Type 1, Equation 8 becomes:

$$E = 1 - \left[\frac{(0.1)(5)/(0.62)}{2 \times (OZ16)_1 + 2 \times (OZ16)_2}\right]$$

$$= 1 - \left[\frac{(0.40)}{(OZ16)_1 + (OZ16)_2}\right] \qquad \text{(Equation 9)}$$

(1) Case 1. Latitude: 50° North

OZ16 is 0.50 ppmv for ENAR and 0.25 ppmv for WNAR. (see Type 1, Case 1)

$$E = 1 - \left[\frac{(0.40)}{(0.50 + 0.25)}\right]$$

$$= 1 - 0.53 = 0.47 = 47\%$$

INSTALLATION OF A FILTER WHICH REMOVES 47 PERCENT OF THE OZONE ENTERING THE CABIN WOULD ENABLE THIS FLIGHT TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 40° North

OZ16 = 0.40 ppmv for ENAR and 0.50 ppmv for WNAR. (see Type 1, Case 2)

$$E = 1 - \left[\frac{(0.40)}{(0.40 + 0.50)}\right]$$

$$= 1 - 0.44 = 0.56 = 56\%$$

INSTALLATION OF A FILTER WHICH REMOVES 56 PERCENT OF THE OZONE ENTERING THE CABIN WOULD ENABLE THIS FLIGHT TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(3) Case 3. Latitude: 30° North

NO FILTER REQUIRED AS COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121 WAS SHOWN DURING EXAMPLE TYPE 1, CASE 3.

d. Variation of Type 2. The filter efficiency required for an airplane to show compliance with the TWA cabin ozone concentration for the worst case can be determined using the method of the Type 2 example. For a worst case analysis, the assumptions are the same as were used for the worst case analysis for the maximum ozone concentration example.

P/P_O = 0.74 ppmv

R = 1.0

Flight Level is 450

OZ16 = 1.8 ppmv

In addition, the total flight segment time (T_{FS}) is 14 hours, Equation 6 can be rewritten as:

$$E = 1 - \left[\frac{(OZTWA)(T_{FS})}{(OZ16)(R)(P/P_O)(T_{FS} - 1)}\right]$$

$$= 1 - \left[\frac{(0.1)(14)}{(1.8)(1.0)(0.74)(13)}\right]$$

$$= 1 - 0.08 = 0.92 = 92\%$$

INSTALLATION OF A FILTER WHICH REMOVES 92 PERCENT OF THE OZONE ENTERING THE CABIN WOULD ENABLE AN AIRPLANE TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121 UNDER THE WORST CASE CONDITIONS.

e. Type 3 - Example to determine the maximum flight altitude allowed to show compliance with the TWA cabin ozone concentration. Equation 7 can be rewritten to determine OZ16, the ambient ozone concentration derived from statistics with a confidence of 84 percent.

$$(OZ16)_1(T_1) + (OZ16)_2(T_2) = \left[\frac{(OZTWA)(T_{FS})}{(0.62)(1-E)}\right]$$

For OZTWA = 0.10 ppmv, no filter (E=0), and a total flight segment of 5 hours, with 2 hours above 18,000 feet in both the ENAR and WNAR, Equation 10 becomes:

$$(OZ16)_1 + (OZ16)_2 = \left[\frac{(0.10)(5)}{(0.62)(2)}\right] = 0.40 \text{ ppmv}$$

(1) Case 1. Latitude: 50° North

For this case, pages A-12 and A-15 of the ozonesonde statistics show that $(OZ16)_1 + (OZ16)_2$ equals 0.51 ppmv at flight level 330 and 0.34 ppmv at flight level 310. Linear interpolation shows a value of 0.40 ppmv occurs for a flight level of 316.

THIS EXAMPLE FLIGHT WOULD HAVE TO FLY AT OR BELOW 31,600 FEET TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(2) Case 2. Latitude: 40° North

For this case, pages A-13 and A-16 of the ozonesonde statistics show that $(OZ16)_1 + (OZ16)_2$ equals 0.55 ppmv at a flight level of 330 and 0.38 ppmv at a flight level of 310. Linear interpolation shows a value of 0.40 ppmv occurs for a flight level of 312.

THIS EXAMPLE FLIGHT WOULD HAVE TO FLY AT OR BELOW 31,200 FEET TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

(3) Case 3. Latitude: 30° North

For this case, use of data on pages A-11 and A-16 of the ozonesonde statistics, interpolated as described in paragraph 2i of this appendix, shows $(OZ16)_1 + (OZ16)_2$ equals 0.63 ppmv at a flight level of 470 and 0.37 ppmv at a flight level of 450. Linear interpolation shows a value of 0.40 ppmv occurs for a flight level of 452.

THIS EXAMPLE FLIGHT WOULD HAVE TO FLY AT OR BELOW 45,200 FEET TO SHOW COMPLIANCE WITH THE TWA CABIN OZONE CONCENTRATION ESTABLISHED BY FAR PART 121.

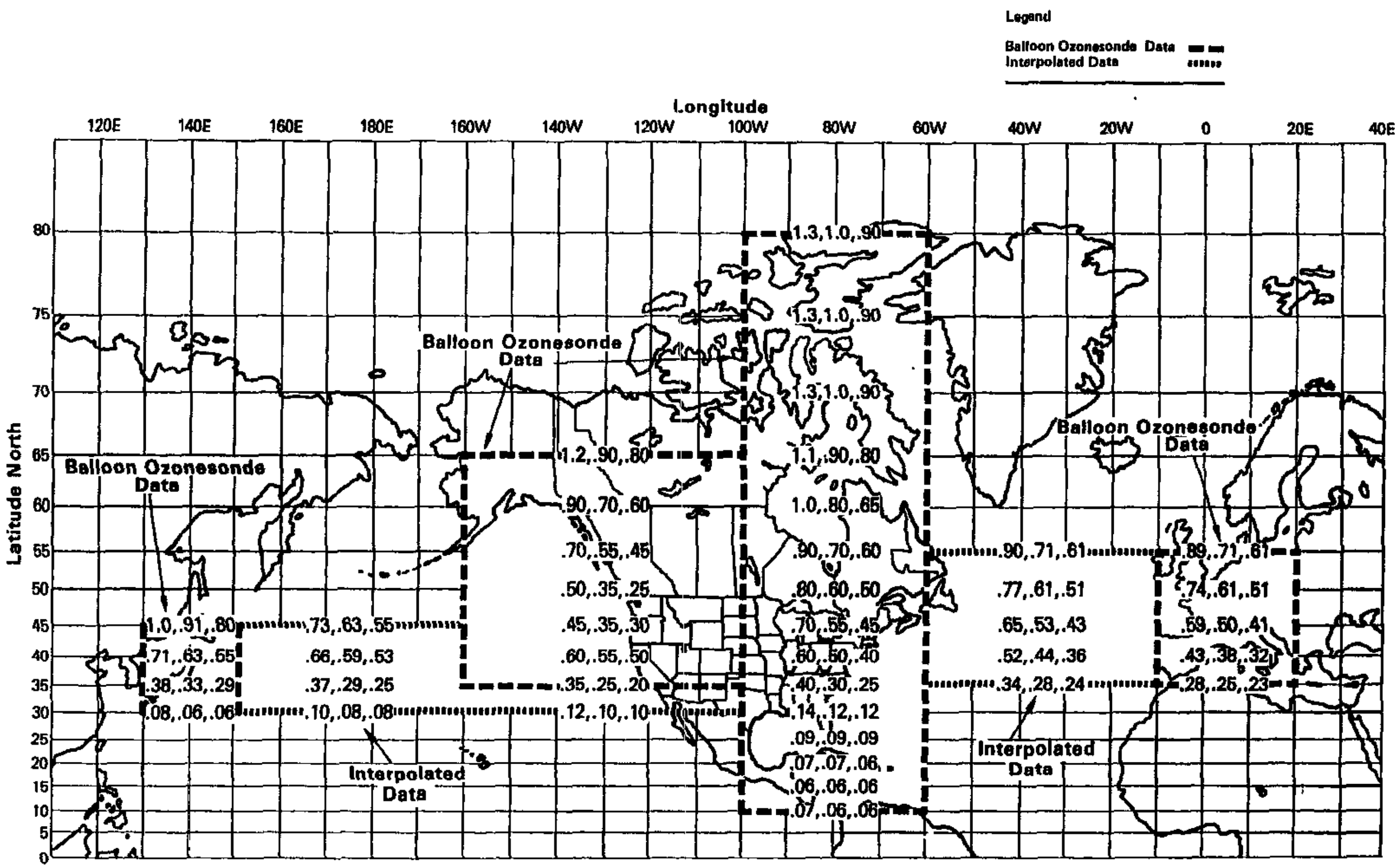
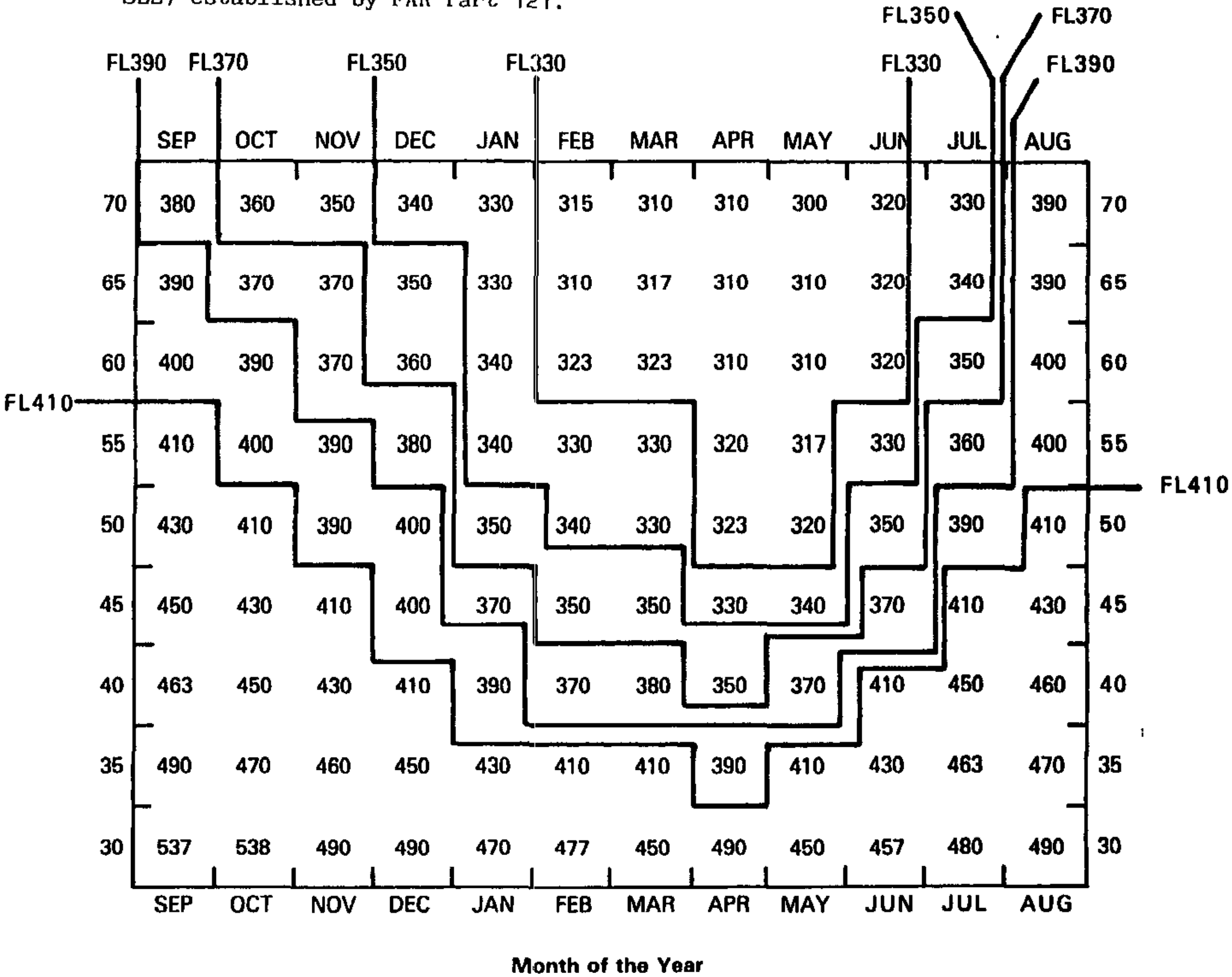


Figure 1. 0Z16 Values for February at flight levels 410, 390 and 370 obtained from FAA Report FAA-EQ-78-03 with linear interpolation between regions.

Figure 2. Maximum flight level for an airplane flying in Eastern North America with R=0.8, E=0 (no filter) and a cabin altitude of 7,000 feet to show compliance with the maximum cabin ozone concentration (0.25 ppmv, SLE) established by FAR Part 121.



Latitude	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
70	380	360	350	340	330	315	310	310	300	320	330	390
65	390	370	370	350	330	310	317	310	310	320	340	390
60	400	390	370	360	340	323	323	310	310	320	350	400
55	410	400	390	380	340	330	330	320	317	330	360	400
50	430	410	390	400	350	340	330	323	320	350	390	410
45	450	430	410	400	370	350	350	330	340	370	410	430
40	463	450	430	410	390	370	380	350	370	410	450	460
35	490	470	460	450	430	410	410	390	410	430	463	470
30	537	538	490	490	470	477	450	490	450	457	480	490

FEBRUARY - JAPAN

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

43°N N=18

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.3	2.9	3.4	4.0	3.4	1.2
570	2.1	2.6	3.2	3.7	3.2	1.0
550	1.8	2.3	2.9	3.5	3.0	.8
530	1.4	2.0	2.6	3.2	2.8	.60
510	1.3	1.9	2.4	2.9	2.5	.60
490	1.2	1.7	2.1	2.6	2.2	.55
470	1.1	1.4	1.8	2.2	1.9	.50
450	.9	1.2	1.5	1.8	1.5	.50
430	.8	1.1	1.3	1.6	1.3	.40
410	.7	.9	1.2	1.4	1.2	.35
390	.60	.8	1.0	1.3	1.1	.25
370	.50	.7	.9	1.1	.9	.20
350	.40	.55	.7	.9	.7	.16
330	.30	.40	.55	.7	.55	.12
310	.18	.25	.35	.45	.35	.06
290	.12	.18	.25	.30	.25	.04
270	.12	.16	.20	.30	.20	.04
250	.10	.14	.20	.25	.18	.04
230	.08	.12	.16	.20	.16	.03
210	.07	.10	.12	.14	.12	.03
190	.05	.07	.08	.10	.09	.03

36°N N=18

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.4	2.0	2.5	3.1	2.7	.8
570	1.3	1.8	2.4	2.9	2.5	.60
550	1.1	1.6	2.2	2.7	2.3	.40
530	.9	1.4	1.9	2.5	2.0	.20
510	.8	1.2	1.7	2.2	1.8	.18
490	.65	1.0	1.4	1.8	1.5	.16
470	.50	.8	1.1	1.4	1.2	.14
450	.35	.55	.7	.9	.8	.10
430	.30	.45	.65	.8	.7	.09
410	.25	.45	.60	.8	.7	.08
390	.25	.40	.60	.8	.7	.07
370	.20	.35	.55	.7	.60	.06
350	.20	.30	.45	.60	.55	.06
330	.16	.25	.35	.45	.45	.05
310	.12	.20	.30	.35	.35	.05
290	.10	.16	.20	.30	.30	.04
270	.09	.14	.20	.25	.25	.04
250	.08	.12	.18	.20	.20	.04
230	.07	.10	.14	.18	.18	.04
210	.06	.09	.12	.14	.14	.04
190	.05	.07	.08	.10	.09	.04

32°N N=14

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	.8	1.1	1.5	1.9	1.6	.35
570	.60	.9	1.3	1.6	1.4	.25
550	.45	.7	1.0	1.3	1.1	.18
530	.25	.50	.7	.9	.8	.09
510	.25	.45	.60	.8	.7	.08
490	.20	.35	.55	.7	.60	.07
470	.18	.30	.45	.55	.50	.06
450	.14	.25	.35	.40	.40	.05
430	.12	.20	.25	.35	.30	.04
410	.10	.16	.20	.25	.25	.03
390	.09	.12	.16	.20	.16	.02
370	.08	.12	.16	.18	.16	.02
350	.08	.12	.16	.20	.18	.03
330	.08	.12	.16	.20	.20	.03
310	.08	.12	.16	.20	.20	.04
290	.07	.12	.16	.20	.20	.04
270	.07	.10	.14	.18	.20	.04
250	.07	.10	.12	.16	.16	.04
230	.06	.09	.12	.14	.14	.04
210	.06	.08	.10	.12	.12	.03
190	.05	.07	.08	.10	.09	.03

FEBRUARY - WESTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

65°N N=3

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.5	2.9	3.3	3.7	2.9	1.9
570	2.3	2.7	3.1	3.5	2.7	1.9
550	2.2	2.5	2.9	3.2	2.6	1.8
530	2.0	2.3	2.6	3.0	2.4	1.7
510	1.8	2.1	2.4	2.8	2.2	1.5
490	1.6	1.9	2.2	2.6	2.0	1.3
470	1.5	1.7	2.0	2.3	1.8	1.1
450	1.3	1.5	1.8	2.1	1.6	.9
430	1.1	1.3	1.6	1.8	1.4	.8
410	1.0	1.2	1.3	1.5	1.2	.8
390	.8	.9	1.0	1.1	.9	.7
370	.7	.8	.9	1.0	.8	.60
350	.55	.65	.7	.8	.65	.45
330	.40	.45	.55	.60	.45	.30
310	.20	.25	.35	.40	.30	.12
290	.10	.18	.25	.30	.20	.05
270	.10	.16	.20	.25	.18	.04
250	.08	.12	.18	.20	.14	.04
230	.07	.10	.14	.16	.12	.04
210	.05	.07	.10	.12	.08	.03
190	.04	.05	.05	.06	.05	.03

60°N N=0

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.3	2.8	3.2	3.6	2.9	1.7
570	2.1	2.6	3.0	3.4	2.7	1.6
550	1.9	2.3	2.7	3.1	2.5	1.5
530	1.7	2.1	2.5	2.9	2.4	1.3
510	1.5	1.9	2.3	2.6	2.1	1.2
490	1.4	1.7	2.1	2.4	1.9	1.0
470	1.2	1.5	1.8	2.1	1.7	.9
450	1.0	1.3	1.6	1.8	1.4	.7
430	.9	1.1	1.3	1.5	1.2	.65
410	.8	.9	1.1	1.3	1.0	.60
390	.65	.7	.8	.9	.8	.50
370	.55	.60	.7	.8	.60	.45
350	.40	.50	.55	.65	.50	.35
330	.30	.35	.40	.50	.35	.20
310	.16	.20	.25	.35	.25	.10
290	.09	.14	.18	.25	.16	.04
270	.08	.12	.16	.20	.14	.03
250	.07	.10	.14	.18	.12	.03
230	.06	.08	.10	.14	.09	.03
210	.05	.06	.08	.10	.07	.03
190	.03	.04	.05	.06	.05	.02

55°N N=0

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.1	2.6	3.1	3.5	2.9	1.5
570	1.9	2.4	2.8	3.3	2.7	1.3
550	1.7	2.1	2.6	3.0	2.5	1.1
530	1.4	1.9	2.3	2.8	2.3	.9
510	1.3	1.7	2.1	2.5	2.0	.8
490	1.1	1.5	1.9	2.2	1.8	.7
470	1.0	1.3	1.6	1.9	1.5	.65
450	.8	1.1	1.3	1.6	1.2	.50
430	.7	.9	1.1	1.3	1.0	.45
410	.55	.7	.9	1.0	.8	.40
390	.45	.55	.65	.7	.55	.35
370	.35	.45	.50	.60	.45	.25
350	.30	.35	.40	.50	.35	.20
330	.20	.25	.30	.35	.25	.14
310	.12	.16	.20	.25	.16	.06
290	.06	.10	.14	.16	.12	.03
270	.06	.09	.12	.14	.10	.03
250	.05	.08	.10	.12	.09	.02
230	.04	.06	.08	.10	.07	.02
210	.04	.05	.07	.08	.06	.02
190	.03	.04	.05	.05	.04	.02

50°N N=10

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.9	2.4	2.9	3.4	2.9	1.3
570	1.7	2.2	2.7	3.2	2.7	1.1
550	1.4	1.9	2.4	2.9	2.4	.8
530	1.1	1.6	2.2	2.7	2.2	.55
510	1.0	1.5	1.9	2.4	2.0	.50
490	.9	1.3	1.7	2.1	1.7	.45
470	.7	1.1	1.4	1.7	1.4	.35
450	.55	.8	1.1	1.3	1.0	.30
430	.45	.65	.9	1.1	.8	.25
410	.35	.50	.65	.8	.60	.20
390	.25	.35	.40	.50	.35	.14
370	.20	.25	.35	.40	.30	.12
350	.16	.20	.25	.30	.20	.09
330	.12	.16	.20	.25	.16	.06
310	.07	.09	.12	.14	.10	.03
290	.04	.06	.08	.10	.07	.02
270	.04	.05	.07	.09	.06	.02
250	.04	.05	.06	.08	.06	.02
230	.03	.05	.06	.07	.05	.02
210	.03	.04	.05	.06	.05	.02
190	.03	.03	.04	.05	.04	.01

FEBRUARY - WESTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

45°N N=31

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.8	2.3	2.9	3.4	3.1	1.0
570	1.6	2.1	2.6	3.1	2.8	.8
550	1.3	1.8	2.3	2.8	2.5	.55
530	1.0	1.5	2.0	2.5	2.2	.25
510	.9	1.3	1.8	2.2	2.0	.25
490	.7	1.1	1.5	1.9	1.7	.20
470	.60	.9	1.3	1.6	1.4	.18
450	.45	.7	1.0	1.2	1.1	.16
430	.35	.60	.8	1.0	.9	.12
410	.30	.45	.65	.8	.7	.08
390	.20	.35	.45	.60	.45	.04
370	.18	.30	.40	.50	.35	.03
350	.14	.25	.30	.40	.30	.03
330	.10	.18	.25	.30	.25	.02
310	.07	.12	.16	.20	.18	.02
290	.05	.08	.12	.14	.14	.01
270	.05	.07	.10	.12	.12	.01
250	.04	.07	.09	.12	.12	.01
230	.04	.06	.08	.10	.09	.01
210	.04	.05	.07	.08	.07	.01
190	.03	.04	.05	.06	.05	.01

40°N N=69

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.8	2.3	2.8	3.4	3.5	.60
570	1.5	2.0	2.5	3.0	3.1	.45
550	1.2	1.7	2.2	2.7	2.7	.30
530	.9	1.4	1.8	2.3	2.2	.10
510	.8	1.2	1.6	2.1	2.1	.09
490	.7	1.1	1.5	1.8	1.9	.09
470	.60	.9	1.3	1.6	1.7	.08
450	.50	.8	1.0	1.3	1.4	.08
430	.45	.7	.9	1.2	1.2	.06
410	.40	.60	.9	1.1	1.0	.05
390	.35	.55	.8	1.0	.8	.03
370	.30	.50	.65	.9	.7	.03
350	.25	.40	.55	.7	.60	.03
330	.18	.30	.45	.55	.50	.02
310	.12	.20	.30	.40	.40	.02
290	.09	.16	.25	.30	.35	.02
270	.08	.14	.20	.25	.30	.02
250	.07	.12	.18	.25	.25	.02
230	.06	.10	.14	.18	.20	.02
210	.05	.08	.12	.14	.14	.01
190	.04	.06	.08	.09	.09	.01

35°N N=14

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.4	1.8	2.3	2.8	2.5	.65
570	1.2	1.6	2.1	2.5	2.3	.50
550	.9	1.4	1.8	2.3	2.1	.35
530	.60	1.1	1.6	2.0	1.9	.14
510	.55	1.0	1.4	1.8	1.7	.12
490	.45	.8	1.2	1.5	1.4	.10
470	.35	.65	.9	1.2	1.1	.08
450	.25	.50	.7	.9	.8	.05
430	.25	.40	.55	.7	.65	.05
410	.20	.35	.45	.60	.55	.04
390	.16	.25	.35	.45	.45	.04
370	.12	.20	.30	.40	.35	.04
350	.10	.18	.25	.35	.30	.03
330	.08	.14	.20	.25	.25	.02
310	.06	.10	.16	.20	.18	.01
290	.04	.08	.12	.16	.14	.01
270	.04	.08	.12	.14	.14	.01
250	.04	.07	.10	.14	.12	.01
230	.03	.06	.09	.12	.12	.01
210	.03	.06	.08	.10	.10	.01
190	.03	.05	.07	.09	.09	.01

FEBRUARY - EASTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

80°N N=17

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	3.4	4.0	4.7	5.4	4.8	1.3
570	3.1	3.7	4.4	5.0	4.5	1.3
550	2.8	3.4	4.0	4.6	4.2	1.2
530	2.5	3.0	3.6	4.1	3.9	1.1
510	2.3	2.8	3.3	3.8	3.5	1.0
490	2.0	2.5	2.9	3.4	3.2	.8
470	1.7	2.1	2.5	2.9	2.7	.7
450	1.4	1.8	2.1	2.5	2.3	.55
430	1.2	1.5	1.8	2.1	1.9	.40
410	1.1	1.3	1.6	1.8	1.6	.30
390	.8	1.0	1.2	1.4	1.2	.18
370	.7	.9	1.0	1.2	1.0	.14
350	.55	.7	.9	1.0	.8	.12
330	.45	.55	.65	.8	.65	.08
310	.30	.35	.45	.55	.45	.05
290	.20	.25	.30	.40	.35	.03
270	.18	.25	.30	.35	.30	.03
250	.16	.20	.25	.30	.25	.02
230	.14	.16	.20	.25	.18	.02
210	.10	.12	.14	.18	.14	.02
190	.06	.08	.09	.12	.09	.02

75°N N=40

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	3.2	3.9	4.6	5.3	4.8	1.3
570	3.0	3.6	4.3	4.9	4.5	1.2
550	2.7	3.3	3.9	4.5	4.2	1.1
530	2.4	2.9	3.5	4.1	3.9	1.0
510	2.2	2.7	3.2	3.7	3.5	.9
490	1.9	2.4	2.9	3.4	3.2	.8
470	1.7	2.1	2.5	2.9	2.7	.65
450	1.4	1.8	2.1	2.5	2.3	.55
430	1.2	1.5	1.8	2.1	1.9	.40
410	1.0	1.3	1.5	1.8	1.6	.30
390	.8	1.0	1.2	1.4	1.2	.18
370	.7	.9	1.0	1.2	1.0	.14
350	.55	.7	.9	1.0	.8	.12
330	.45	.55	.65	.8	.65	.08
310	.30	.35	.45	.50	.45	.05
290	.20	.25	.30	.35	.35	.03
270	.18	.20	.25	.30	.30	.03
250	.16	.20	.25	.25	.25	.02
230	.12	.16	.18	.20	.18	.02
210	.09	.12	.14	.16	.14	.02
190	.06	.07	.09	.10	.09	.02

70°N N=25

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	3.1	3.8	4.4	5.1	4.7	1.5
570	2.8	3.5	4.1	4.8	4.4	1.3
550	2.5	3.2	3.8	4.4	4.1	1.2
530	2.2	2.8	3.4	4.1	3.7	1.0
510	2.0	2.6	3.2	3.7	3.3	.9
490	1.8	2.3	2.8	3.3	3.0	.8
470	1.6	2.0	2.5	2.9	2.5	.65
450	1.4	1.7	2.1	2.5	2.1	.55
430	1.2	1.5	1.8	2.1	1.8	.40
410	1.0	1.3	1.5	1.8	1.4	.30
390	.8	1.0	1.2	1.4	1.1	.18
370	.7	.9	1.0	1.2	.9	.14
350	.55	.7	.9	1.0	.8	.12
330	.45	.55	.65	.8	.60	.08
310	.30	.35	.45	.50	.45	.05
290	.20	.25	.30	.35	.35	.03
270	.18	.20	.25	.30	.30	.03
250	.16	.18	.20	.25	.25	.02
230	.12	.16	.18	.20	.18	.02
210	.09	.12	.14	.16	.14	.02
190	.05	.07	.08	.10	.08	.02

65°N N=5

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.9	3.6	4.3	4.9	4.6	1.5
570	2.6	3.3	3.9	4.6	4.2	1.3
550	2.4	3.0	3.6	4.2	3.9	1.2
530	2.0	2.6	3.2	3.8	3.5	1.0
510	1.9	2.4	2.9	3.5	3.2	.9
490	1.7	2.1	2.6	3.1	2.8	.8
470	1.4	1.9	2.3	2.7	2.4	.65
450	1.2	1.6	1.9	2.3	2.0	.50
430	1.0	1.3	1.7	2.0	1.7	.35
410	.9	1.1	1.4	1.7	1.3	.25
390	.7	.9	1.1	1.3	1.0	.16
370	.60	.8	1.0	1.1	.8	.12
350	.50	.65	.8	.9	.7	.10
330	.40	.50	.65	.7	.55	.08
310	.30	.40	.45	.55	.40	.05
290	.20	.30	.35	.40	.35	.04
270	.18	.25	.30	.35	.30	.03
250	.14	.18	.20	.25	.25	.03
230	.10	.12	.16	.18	.18	.02
210	.08	.10	.12	.14	.14	.02
190	.05	.06	.08	.09	.08	.02

FEBRUARY - EASTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

60°N N=4

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.7	3.4	4.1	4.7	4.4	1.5
570	2.5	3.1	3.7	4.4	4.0	1.3
550	2.2	2.8	3.4	4.0	3.7	1.0
530	1.9	2.4	3.0	3.5	3.3	.8
510	1.7	2.2	2.7	3.2	3.0	.7
490	1.5	2.0	2.4	2.9	2.7	.65
470	1.3	1.7	2.1	2.5	2.3	.55
450	1.0	1.4	1.7	2.1	1.9	.45
430	.9	1.2	1.5	1.8	1.6	.35
410	.7	1.0	1.3	1.5	1.3	.25
390	.60	.8	1.0	1.2	1.0	.14
370	.50	.65	.8	1.0	.8	.10
350	.40	.55	.7	.9	.7	.09
330	.30	.45	.55	.65	.55	.07
310	.25	.30	.40	.45	.40	.05
290	.16	.25	.30	.35	.35	.04
270	.14	.18	.25	.30	.30	.03
250	.10	.14	.18	.20	.25	.03
230	.07	.10	.14	.16	.18	.02
210	.06	.08	.10	.12	.14	.02
190	.04	.06	.07	.09	.08	.01

55°N N=8

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.5	3.2	3.8	4.5	4.0	1.4
570	2.3	2.9	3.5	4.1	3.7	1.1
550	2.0	2.6	3.2	3.7	3.4	.8
530	1.7	2.2	2.8	3.3	3.1	.50
510	1.5	2.0	2.5	3.0	2.8	.45
490	1.4	1.8	2.2	2.7	2.5	.40
470	1.1	1.5	1.9	2.3	2.1	.35
450	.9	1.3	1.6	1.9	1.7	.30
430	.8	1.1	1.4	1.6	1.4	.25
410	.65	.9	1.1	1.4	1.2	.16
390	.50	.7	.9	1.1	.9	.09
370	.45	.60	.8	.9	.8	.07
350	.35	.50	.65	.8	.65	.07
330	.30	.40	.50	.60	.55	.06
310	.20	.30	.35	.45	.40	.05
290	.14	.20	.25	.30	.30	.04
270	.12	.16	.20	.25	.25	.03
250	.09	.12	.16	.20	.20	.03
230	.06	.09	.12	.14	.16	.02
210	.05	.07	.09	.12	.12	.02
190	.04	.06	.07	.09	.08	.02

50°N N=10

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.4	3.0	3.6	4.2	4.0	1.4
570	2.1	2.7	3.3	3.9	3.8	1.1
550	1.8	2.4	3.0	3.5	3.5	.8
530	1.5	2.1	2.6	3.1	3.3	.40
510	1.4	1.9	2.3	2.8	3.0	.40
490	1.2	1.6	2.1	2.5	2.6	.35
470	1.0	1.4	1.8	2.1	2.2	.35
450	.8	1.1	1.4	1.7	1.8	.30
430	.7	.9	1.2	1.5	1.5	.25
410	.60	.8	1.0	1.2	1.3	.16
390	.45	.60	.8	.9	1.0	.07
370	.40	.50	.65	.8	.9	.05
350	.30	.45	.55	.65	.7	.04
330	.25	.35	.45	.55	.55	.03
310	.16	.25	.30	.40	.40	.02
290	.12	.18	.25	.30	.30	.02
270	.09	.14	.18	.25	.25	.02
250	.07	.10	.14	.18	.20	.02
230	.05	.07	.10	.12	.16	.02
210	.04	.06	.08	.10	.12	.02
190	.04	.05	.07	.08	.09	.01

45°N N=20

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.2	2.8	3.4	4.0	3.8	1.1
570	1.9	2.5	3.1	3.6	3.8	.9
550	1.6	2.2	2.7	3.3	3.7	.65
530	1.3	1.8	2.3	2.8	3.6	.40
510	1.2	1.6	2.1	2.6	3.2	.35
490	1.0	1.4	1.9	2.3	2.8	.30
470	.9	1.2	1.6	1.9	2.3	.25
450	.7	1.0	1.3	1.6	1.8	.20
430	.60	.8	1.1	1.3	1.6	.16
410	.50	.7	.9	1.1	1.4	.10
390	.40	.55	.7	.9	1.2	.03
370	.30	.45	.60	.8	1.1	.02
350	.25	.40	.50	.65	.9	.02
330	.20	.30	.40	.50	.7	.01
310	.14	.20	.30	.35	.50	.01
290	.10	.16	.20	.25	.40	.01
270	.08	.12	.18	.20	.35	.01
250	.06	.10	.14	.16	.30	.01
230	.05	.07	.10	.12	.25	.01
210	.04	.06	.08	.10	.20	.01
190	.04	.06	.07	.09	.16	.01

FEBRUARY - EASTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

40° N N=40

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.9	2.6	3.2	3.8	3.8	.9
570	1.7	2.3	2.8	3.4	3.8	.65
550	1.4	1.9	2.5	3.0	3.7	.45
530	1.1	1.6	2.1	2.6	3.6	.20
510	1.0	1.4	1.9	2.3	3.1	.18
490	.8	1.2	1.6	2.0	2.6	.16
470	.7	1.1	1.4	1.8	2.0	.14
450	.55	.8	1.1	1.4	1.3	.10
430	.45	.7	1.0	1.2	1.2	.08
410	.40	.60	.8	1.0	1.1	.05
390	.30	.50	.65	.8	1.1	.03
370	.25	.40	.55	.7	1.0	.02
350	.20	.35	.45	.60	.8	.02
330	.16	.25	.35	.45	.65	.01
310	.10	.18	.25	.35	.50	.01
290	.08	.12	.18	.25	.40	.01
270	.07	.12	.16	.20	.35	.01
250	.06	.09	.12	.16	.30	.01
230	.05	.07	.10	.12	.25	.01
210	.05	.07	.09	.10	.20	.01
190	.04	.06	.08	.09	.18	.01

35° N N=15

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.6	2.1	2.6	3.1	2.9	.8
570	1.3	1.8	2.3	2.8	2.6	.60
550	1.1	1.5	1.9	2.3	2.3	.40
530	.8	1.2	1.5	1.9	2.0	.16
510	.7	1.0	1.4	1.7	1.7	.14
490	.60	.9	1.2	1.5	1.4	.12
470	.50	.7	1.0	1.2	1.1	.10
450	.35	.55	.7	.9	.8	.08
430	.30	.45	.60	.8	.7	.06
410	.25	.40	.50	.65	.65	.05
390	.20	.30	.40	.50	.60	.03
370	.18	.25	.35	.45	.55	.03
350	.14	.20	.30	.40	.45	.02
330	.12	.18	.25	.30	.35	.02
310	.08	.14	.18	.25	.25	.01
290	.06	.10	.14	.18	.20	.01
270	.06	.09	.12	.16	.20	.01
250	.05	.08	.10	.14	.18	.01
230	.04	.07	.09	.10	.18	.01
210	.04	.06	.08	.10	.14	.01
190	.04	.05	.07	.08	.10	.01

30° N N=10

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.2	1.6	2.1	2.5	2.0	.40
570	1.0	1.4	1.7	2.1	1.7	.30
550	.7	1.1	1.4	1.7	1.2	.18
530	.45	.7	1.0	1.2	.8	.08
510	.40	.60	.8	1.0	.65	.07
490	.30	.50	.65	.8	.55	.06
470	.25	.35	.45	.60	.40	.05
450	.14	.20	.25	.30	.25	.04
430	.12	.16	.20	.25	.20	.04
410	.10	.14	.18	.25	.16	.03
390	.09	.12	.16	.20	.16	.03
370	.08	.12	.16	.18	.16	.03
350	.07	.10	.14	.18	.16	.02
330	.06	.09	.12	.16	.18	.02
310	.05	.08	.10	.14	.18	.01
290	.05	.07	.10	.12	.18	.01
270	.04	.07	.09	.12	.16	.01
250	.04	.06	.08	.10	.16	.01
230	.04	.06	.08	.09	.14	.01
210	.04	.05	.07	.08	.10	.01
190	.03	.05	.06	.08	.08	.01

25° N N=8

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	.65	.8	1.0	1.2	1.2	.25
570	.55	.7	.9	1.1	1.0	.20
550	.40	.60	.8	.9	.7	.14
530	.30	.45	.60	.8	.50	.07
510	.25	.40	.50	.65	.40	.06
490	.20	.30	.40	.50	.35	.05
470	.14	.20	.25	.35	.25	.04
450	.08	.10	.14	.16	.16	.03
430	.07	.09	.12	.14	.14	.03
410	.07	.09	.12	.14	.12	.03
390	.07	.09	.12	.16	.12	.03
370	.06	.09	.12	.14	.12	.03
350	.06	.08	.10	.12	.12	.02
330	.05	.07	.09	.12	.12	.02
310	.04	.06	.08	.10	.12	.01
290	.04	.06	.07	.09	.12	.01
270	.04	.05	.07	.09	.10	.01
250	.04	.05	.07	.08	.10	.01
230	.03	.05	.06	.08	.09	.01
210	.03	.05	.06	.07	.08	.01
190	.03	.04	.06	.07	.06	.01

FEBRUARY - EASTERN NORTH AMERICA

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

20°N N=8

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	.35	.45	.60	.7	.55	.18
570	.25	.35	.45	.55	.45	.14
550	.18	.25	.30	.35	.30	.10
530	.09	.12	.16	.18	.14	.06
510	.08	.10	.14	.16	.12	.05
490	.07	.10	.12	.16	.12	.05
470	.06	.09	.10	.14	.09	.04
450	.05	.07	.09	.12	.07	.03
430	.05	.07	.09	.10	.07	.03
410	.05	.07	.09	.10	.08	.04
390	.05	.07	.09	.10	.08	.04
370	.05	.06	.08	.10	.08	.04
350	.04	.06	.07	.09	.07	.03
330	.04	.05	.06	.08	.06	.03
310	.03	.04	.05	.07	.05	.02
290	.03	.04	.05	.06	.05	.02
270	.03	.04	.05	.06	.05	.02
250	.03	.04	.05	.06	.04	.01
230	.03	.04	.05	.06	.04	.01
210	.03	.04	.05	.06	.04	.01
190	.03	.04	.05	.06	.04	.01

15°N N=5

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	.35	.45	.55	.65	.50	.14
570	.25	.35	.45	.55	.40	.12
550	.18	.25	.30	.35	.30	.08
530	.09	.12	.16	.20	.14	.05
510	.08	.12	.16	.18	.12	.04
490	.07	.10	.14	.16	.12	.04
470	.06	.08	.10	.14	.09	.03
450	.04	.06	.09	.10	.07	.02
430	.04	.06	.08	.10	.07	.02
410	.04	.06	.08	.10	.07	.02
390	.04	.06	.08	.10	.07	.02
370	.04	.06	.08	.10	.07	.02
350	.04	.05	.07	.09	.06	.02
330	.04	.05	.06	.08	.05	.01
310	.03	.04	.05	.07	.04	.01
290	.03	.04	.05	.06	.04	.01
270	.03	.04	.05	.06	.04	.01
250	.03	.04	.05	.06	.04	.01
230	.03	.04	.05	.06	.04	.01
210	.03	.04	.05	.06	.04	.01
190	.03	.04	.05	.06	.04	.01

10°N N=8

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	.35	.45	.55	.65	.50	.12
570	.25	.35	.45	.55	.40	.10
550	.18	.25	.30	.35	.25	.07
530	.09	.14	.16	.20	.14	.04
510	.08	.12	.16	.20	.12	.04
490	.07	.10	.14	.18	.12	.03
470	.07	.10	.12	.16	.10	.03
450	.06	.08	.10	.14	.08	.02
430	.05	.07	.10	.12	.08	.02
410	.05	.07	.09	.12	.07	.01
390	.04	.06	.08	.10	.06	.01
370	.04	.06	.07	.09	.06	.01
350	.04	.05	.07	.08	.05	.01
330	.03	.05	.06	.08	.05	.01
310	.03	.04	.05	.07	.04	.01
290	.03	.04	.05	.06	.04	.01
270	.03	.04	.05	.06	.04	.01
250	.03	.04	.05	.06	.04	.01
230	.03	.04	.05	.06	.04	.01
210	.03	.04	.05	.06	.05	.01
190	.03	.04	.05	.06	.05	.01

FEBRUARY - WESTERN EUROPE

UNIT: PPMV

PERCENTAGES INDICATE PROBABILITY OF EXCEEDING AMOUNT SHOWN.

52°N — N=38

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	2.2	2.8	3.5	4.1	3.8	1.1
570	1.9	2.5	3.1	3.7	3.5	.8
550	1.5	2.1	2.6	3.2	3.1	.60
530	1.1	1.7	2.2	2.7	2.8	.30
510	1.1	1.5	2.0	2.5	2.5	.25
490	1.0	1.4	1.8	2.3	2.2	.20
470	.9	1.3	1.7	2.1	1.9	.16
450	.7	1.1	1.4	1.8	1.5	.09
430	.65	.9	1.3	1.6	1.3	.07
410	.55	.8	1.1	1.3	1.0	.05
390	.40	.65	.9	1.1	.8	.04
370	.35	.55	.7	.9	.7	.03
350	.30	.45	.60	.7	.55	.03
330	.20	.30	.45	.55	.45	.02
310	.12	.20	.30	.35	.35	.02
290	.08	.14	.20	.25	.25	.02
270	.07	.12	.18	.25	.25	.02
250	.07	.10	.16	.20	.20	.02
230	.06	.09	.12	.16	.16	.01
210	.05	.08	.10	.14	.12	.01
190	.04	.06	.08	.09	.09	.01

47°N — N=128

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.8	2.4	3.1	3.7	3.8	.20
570	1.6	2.2	2.8	3.4	3.4	.20
550	1.3	1.8	2.4	2.9	3.1	.18
530	1.0	1.5	2.0	2.5	2.7	.16
510	.9	1.4	1.8	2.3	2.5	.14
490	.8	1.2	1.6	2.1	2.2	.10
470	.7	1.1	1.4	1.8	2.0	.07
450	.60	.9	1.2	1.5	1.6	.03
430	.50	.8	1.1	1.3	1.5	.02
410	.45	.65	.9	1.1	1.3	.02
390	.35	.55	.7	.9	1.2	.02
370	.30	.45	.60	.8	1.0	.02
350	.20	.35	.50	.65	.8	.02
330	.16	.25	.35	.45	.60	.02
310	.10	.16	.20	.30	.35	.02
290	.06	.10	.14	.18	.25	.02
270	.05	.08	.12	.14	.18	.02
250	.05	.07	.09	.12	.14	.01
230	.04	.06	.07	.08	.09	.01
210	.04	.05	.07	.08	.09	.01
190	.04	.05	.06	.07	.08	.01

39°N — N=6

FLIGHT LEVEL	MEAN	16%	2%	.1%	MAX	MIN
590	1.6	2.2	2.9	3.5	2.4	.7
570	1.4	2.0	2.5	3.1	2.1	.65
550	1.3	1.7	2.2	2.6	1.9	.55
530	1.1	1.4	1.8	2.1	1.6	.45
510	.9	1.2	1.5	1.8	1.4	.35
490	.8	1.0	1.3	1.5	1.1	.30
470	.55	.8	1.0	1.2	.9	.18
450	.35	.50	.7	.9	.60	.08
430	.30	.45	.55	.7	.50	.07
410	.30	.40	.50	.60	.45	.06
390	.25	.35	.40	.50	.40	.09
370	.25	.30	.35	.40	.35	.08
350	.18	.20	.25	.30	.30	.06
330	.12	.16	.20	.25	.20	.04
310	.06	.09	.12	.14	.12	.02
290	.04	.06	.08	.10	.08	.01
270	.04	.06	.08	.10	.08	.01
250	.04	.06	.08	.10	.08	.01
230	.04	.06	.08	.10	.09	.02
210	.04	.06	.08	.10	.09	.02
190	.04	.06	.08	.09	.08	.02

APPENDIX 2. ALTERNATE OZONE DATA SETS

1. PURPOSE. This appendix discusses the Global Air Sampling Program (GASP) ozone data and the ozonesonde balloon data used in example flights in Appendix 1 of this advisory circular.

2. EXPLANATION. The ozone concentration balloon data of Appendix A of Report FAA-EQ-78-03 listed in paragraph 3a(2) of this advisory circular is acceptable to the FAA for statistical analysis to determine compliance with the cabin ozone concentrations established by Section 121.578 of the FAR. Any other data set would have to have an equivalent vertical (2,000 feet), temporal (monthly), and latitudinal (5 degrees) resolution to be acceptable for purposes of compliance demonstration.

a. For example, in Appendix B of Report FAA-EQ-78-03, data are presented which were collected during the Global Air Sampling Program by the National Aeronautics and Space Administration (NASA). The GASP data have greater geographical coverage; however, as currently tabulated, they do not provide the required vertical, temporal or latitudinal resolution to be used for compliance demonstration. When the resolution of the balloon data is collapsed to that of the GASP data, the results of the two measurement programs agree statistically. This indicates that both data sets are valid; however, the GASP data, in their present tabulation, do not show the necessary resolution elements to be acceptable to the FAA.

b. For example, the balloon data for the eastern North American region at 45° north and of a flight level of 390 give ozone values at the 84 percent confidence level of 0.35, 0.45, and 0.55 ppmv for December, January, and February, respectively. For the western North American region the values are 0.30, 0.35, 0.35 ppmv. At flight level 390, the GASP data show an ozone value at the 84 percent confidence level of 0.37 ppmv for the winter season, between 40° and 90° west longitude at a latitude between 42° and 48° north (page B-6 of Report FAA-EQ-78-03). Between 90° and 140° west longitude, the value is also 0.37 ppmv. This typical example shows that use of the GASP data for showing compliance by statistical methods would not properly account for the expected ambient ozone values which change by as much as 0.25 ppmv during these 3 months. Even though more data points are obtained by GASP at the flight levels between 350 and 390, as presently tabulated, the required resolution elements are not provided.

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