Flight Planning to Avoid High Ozone

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1.0 THE PROBLEM

How to most cost-effectively prevent cabin ozone from exceeding a given standard, for more than a permitted duration or frequency.

Some combination of hardware and flight planning seems a reasonable approach to avoid overdesign.

2.0 QUICK REVIEW OF CABIN OZONE CLIMATOLOGY (See Figures 1-7, Table 1)

2.1 Statistical summaries of the vertical distribution of ozone are available in:

Ref 1: Ozonesonde Data for North America, 1962-1975, at standard atmosphere altitudes, Aug 1977.

Ref 2: FAA Guidelines for Flight Planning, Jan 1978. As an improvement over climatological average ozone, guidelines are presented for estimating ozone in terms of forecast temperature, for each flight level, in the stratosphere, by season and latitude. This was prepared in two months as a stop-gap measure. Careful study is still needed. Only 22 months of GASP data were available (Mar 1975 - Dec 1976).

Ref 3: Contract report to NASA-Lewis on GASP data near the tropopause, Apr 1978. This summarizes GASP data from 11 to 12 km true altitudes.

3.0 CONSIDERATIONS

3.1 Many Factors: Cost, logistics, simplicity, maintenance, ability to forecast high ozone quantitatively and to determine its location, ease and cost of avoiding high ozone if ozone forecasts to be observed, frequency of excess ozone.

4.0 POSSIBLE APPROACHES

4.1 Super Filter: Used on all aircraft to remove all ozone always, will be needlessly expensive if there are many routes, times, and altitudes when ozone is below limits.

4.2 Medium Filter: Removes ozone up to some percentage of ambient, so that cabin concentration will usually be below established limit. Use flight planning to avoid higher concentrations.

4.3 Flexible Filter: Use only as strong a filter as required by climatology for each particular route, season, and altitude, but use no filter in low latitudes, altitudes, or seasons where climatology shows seldom needed. Use flight planning to avoid occasional regions of forecast high concentrations. Filter must be easily installed or turned on.

4.4 No Filter: Circulate air in cabin less often when high outside ozone is present. Add odorless, harmless oxidants to decompose ozone. Avoid regions of maximum ozone by flight planning.

5.0 REQUIREMENTS

To help make p[illegible] decision, the following information is needed:

5.1 How well can ozone be forecast operationally by either Flight Planners or NMC? Development of a good forecast system would require a one year study.

5.2 Frequency distribution of GASP ozone data is needed by latitude belt, season, flight level. Update each year as more GASP data become available.

5.3 Consider trade-offs between hardware and operational forecast avoidance of highest ozone.

5.4 From 5.2, determine maximum ozone concentration for which filters should be designed as in Figure 8, for example. For a reliable frequency distribution, where should the limit for filters be set? Is it necessary to have filters to take care of the 3% (or 20%) occurrence of extreme ozone?

REFERENCES

1. Wilcox, R. W. and A. D. Belmont, 1977: Ozone concentration by latitude, altitude, and month, near 80^{o}W. Contract DOT-FA77WA-3999 for Federal Aviation Administration; Report No. FAA-AEQ-77-13, by Research Division, Control Data Corporation, Minneapolis, 41pp.

2. Belmont, A. D., R. W. Wilcox, G. D. Nastrom, D. N. Hovland, and D. G. Dartt, 1978: Guidelines for flight planning during periods of high ozone occurrence. Contract DOT-FA77WA-4074 for Federal Aviation Administration; Report No. FAA-EQ-78-03, by Research Division, Control Data Corporation, Minneapolis, 156pp.

3. Nastrom, G. D., 1978: Variability of ozone near the tropopause from GASP data. Contract NAS3-20618 for NASA-Lewis Research Center; Research Report No. 1, by Research Division, Control Data Corporation, Minneapolis, 45pp; CR-135405, April 1978.

TABLE I. - GASP OZONE DATA (PPBV) FROM 11 TO 12 KM TRUE ALTITUDE AS A FUNCTION OF LATITUTDE AND LONGITUDE

[The plotting code is in the upper left box. The right hand column is the zonal mean, and the max is the largest value at that latitude. The standard deviation (σ) is not given for fewer than ten observations.]

LAT	120E–170E	170E–140W	140W–90W	90W–40W	40W–10E	10E–60E	60E–120E	M
N 66	Mean N Max σ	315 13 656 124	299 11 541 144					307 24 565 133
66–60		345 22 561 155	161 14 296 89		60 4 121			252 40 561 166
60–54				96 37 497 139	195 24 429 152			135 61 497 152
54–48			216 90 1028 195	266 54 1074 266	261 23 497 142			238 167 1074 216
48–42	190 9 282		145 445 604 111	182 51 690 133				149 505 690 113
42–36		41 30 209 37	88 394 519 76					85 424 519 75
36–30		55 282 373 41	81 87 235 46					61 369 373 44
30–24		48 132 129 29	52 26 108 24				93 4 264	50 162 264 33
24–18	3 40 26 5	31 57 84 18	32 3 35				21 3 24	20 103 84 19
18–12		31 31 54 11						31 31 54 11
12–6		27 48 45 8						27 46 45 8
6–0		31 62 57 10						31 62 57 10
0–S 6		29 59 54 11						29 59 54 11
S 6–12		38 65 99 21						38 65 99 21
12–18		55 30 145 31						55 30 145 31
18–24	109 3 116	100 25 175 48						101 28 175 46
24–30	211 27 345 93	148 17 283 61						187 44 345 88
30–36	213 6 279	174 13 318 70						186 19 318 68
36–42								

December, January, February

LAT	120E–170E	170E–140W	140W–90W	90W–40W	40W–10E	10E–60E	60E–120E	M
N 66 (above)	Mean N Max σ	484 9 584	483 30 937 154		540 9 598			493 48 937 127
N 66–60		475 2 491	417 23 886 203	625 15 803 151	341 83 700 168			392 123 886 195
60–54	733 7 1169	472 22 1159 237	376 16 697 233	425 93 983 199	292 148 640 173	374 2 428		364 288 1169 213
54–48	288 16 777 209	293 60 669 180	420 199 994 233	347 157 808 192	140 26 517 138	411 31 801 172		361 489 994 218
48–42	184 41 596 153	332 32 635 184	290 641 964 221	222 36 825 217		294 4 464		283 754 964 218
42–36	131 33 324 74	109 76 265 45	127 421 582 100	126 21 580 140		229 29 538 165		130 580 582 102
36–30	84 40 142 26	92 372 378 41	89 84 143 33	61 13 96 19		130 1 130	81 66 159 29	89 576 378 38
30–24	52 48 96 20	77 265 293 46	39 43 255 45	51 7 60			52 66 112 29	66 429 293 43
24–18	40 143 104 18	92 30 138 23	45 40 108 29	36 81 93 22			21 41 59 16	42 335 138 27
18–12				31 103 89 19			38 15 45 5	32 118 89 18
12–6				19 50 46 12				19 50 46 12
6–0				13 30 45 15				13 30 45 15
0–S 6				24 19 45 14				24 19 45 14
S 6–12				19 13 38 9				19 13 38 9
12–18				6 1 6				6 1 6
18–24								
24–30								
30–36								
36–42								

March, April, May

LAT	120E–170E	170E–140W	140W–90W	90W–40W	40W–10E	10E–60E	60E–120E	M
LAT–N 66	Mean N Max σ	314 13 374 37	313 17 359 28					314 30 374 33
N 66–60		280 69 499 104	356 9 405	231 13 343 97	291 63 397 83			285 153 499 95
60–54	341 2 344	219 31 479 133	288 22 463 132	152 60 437 117	179 95 360 106	127 7 179		188 217 479 122
54–48		302 19 393 89	125 65 409 106	99 106 344 67	175 7 195	171 22 336 64		134 219 409 99
48–42	34 7 48		115 239 549 97	86 8 221		80 45 194 38		107 299 549 90
42–36	32 9 59	79 24 189 41	71 281 393 67			53 121 125 17		66 435 393 57
36–30	51 3 83	55 223 174 28	73 99 514 103			40 29 69 8	39 50 98 16	56 404 514 56
30–24		52 136 191 29				41 1 41	33 36 65 9	48 173 191 27
24–18	18 2 24	20 29 36 6		30 3 39			27 56 53 10	25 90 53 9
18–12	16 6 19	18 55 29 5		31 7 44			25 53 65 13	22 121 65 10
12–6	15 5 18	17 52 27 6		23 4 24			24 24 46 10	19 85 46 8
6–0								
0–S 6		20 5 22						20 5 22
S 6–12		19 1 19						19 1 19
12–18								
18–24								
24–30	124 20 178 38						76 5 123	115 25 178 41
30–36								
36–42								

June, July, August

LAT	120E–170E	170E–140W	140W–90W	90W–40W	40W–10E	10E–60E	60E–120E	M
– N 66	Mean N Max σ	340 170 653 106	255 116 542 127					305 286 653 122
N 66–60		324 285 661 107	248 136 537 116	262 25 540 145	188 135 439 111			272 581 661 125
60–54	283 38 562 171	273 138 573 118	143 46 337 74	91 176 389 80	126 195 475 96			161 593 573 127
54–48	91 93 338 72	176 88 401 101	129 85 509 126	92 282 376 72	60 19 106 20			109 567 509 92
48–42	74 152 324 49	147 2 217	80 305 441 73	99 48 321 65		53 17 65 7		80 524 441 65
42–36	45 3 71	41 27 74 23	55 366 284 31	36 19 45 5		43 7 50		53 422 284 30
36–30		43 249 137 24	46 53 116 27	32 19 47 6			42 17 56 7	43 338 137 23
30–24		38 92 102 22	59 9 72	31 15 47 7			44 10 83 14	39 126 102 20
24–18		34 3 51	52 4 58	46 25 93 19			9 1 9	45 33 93 19
18–12		41 6 48		53 26 74 9				51 32 74 10
12–6		35 4 47		65 25 108 23				61 29 108 24
6–0				68 49 109 21				68 49 109 21
0–S 6				60 44 83 15				60 44 83 15
S 6–12		50 10 104 28		55 49 85 13				54 59 104 16
12–18		86 1 86		60 21 100 18				61 22 100 18
18–24								
24–30	130 5 174							130 5 174
30–36	196 6 235							196 6 235
36–42		231 2 255						231 2 255

September, October, November

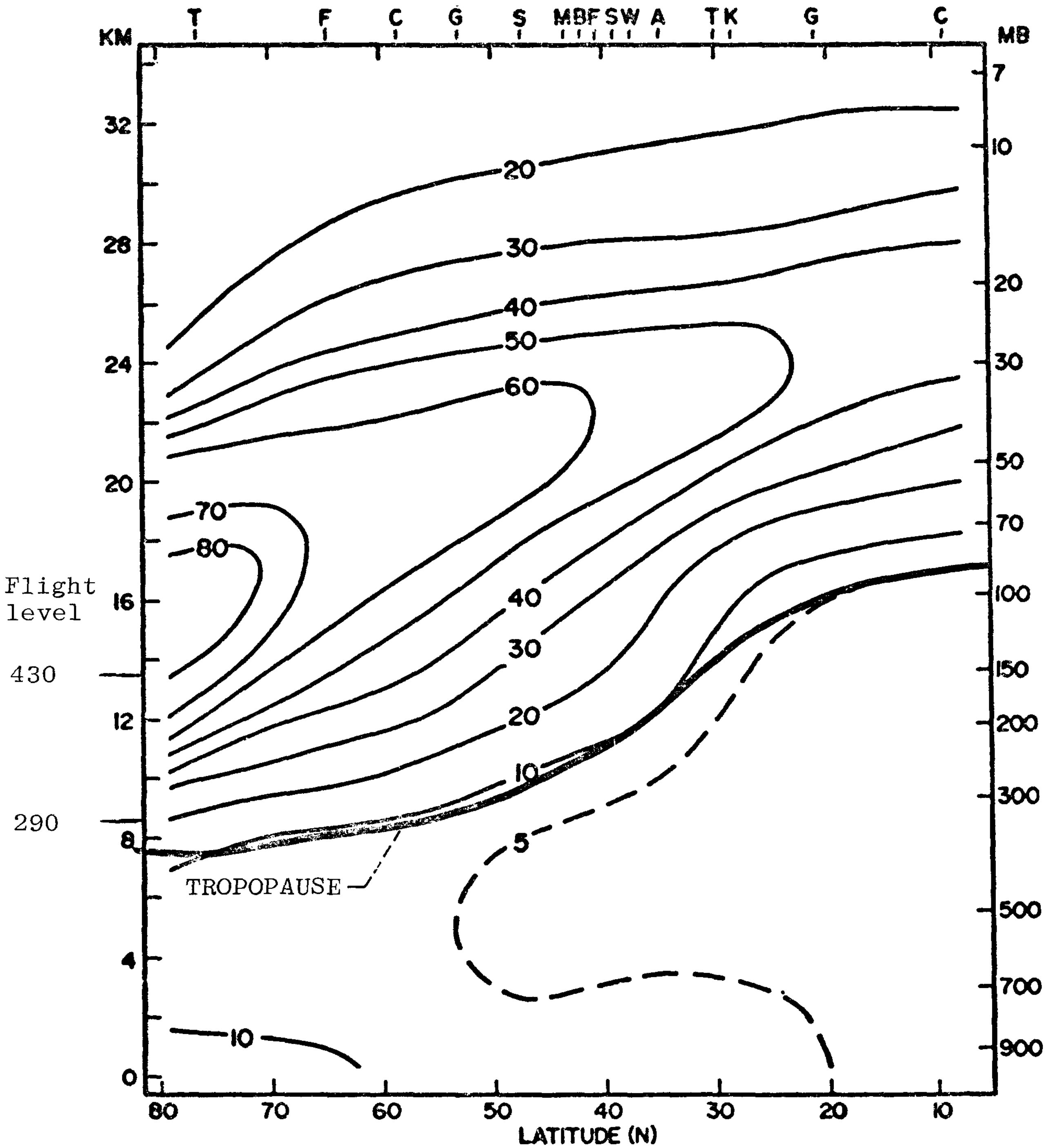

Figure 1. - Vertical distribution of ozone concentration for January over North America. Units are 10^{11} molecules cm^{-3}. Ozonesonde stations used are indicated at top of figure; see Table 2 for periods of record at each. (From J. of Appl. Meteor., vol. 16, p. 293.)

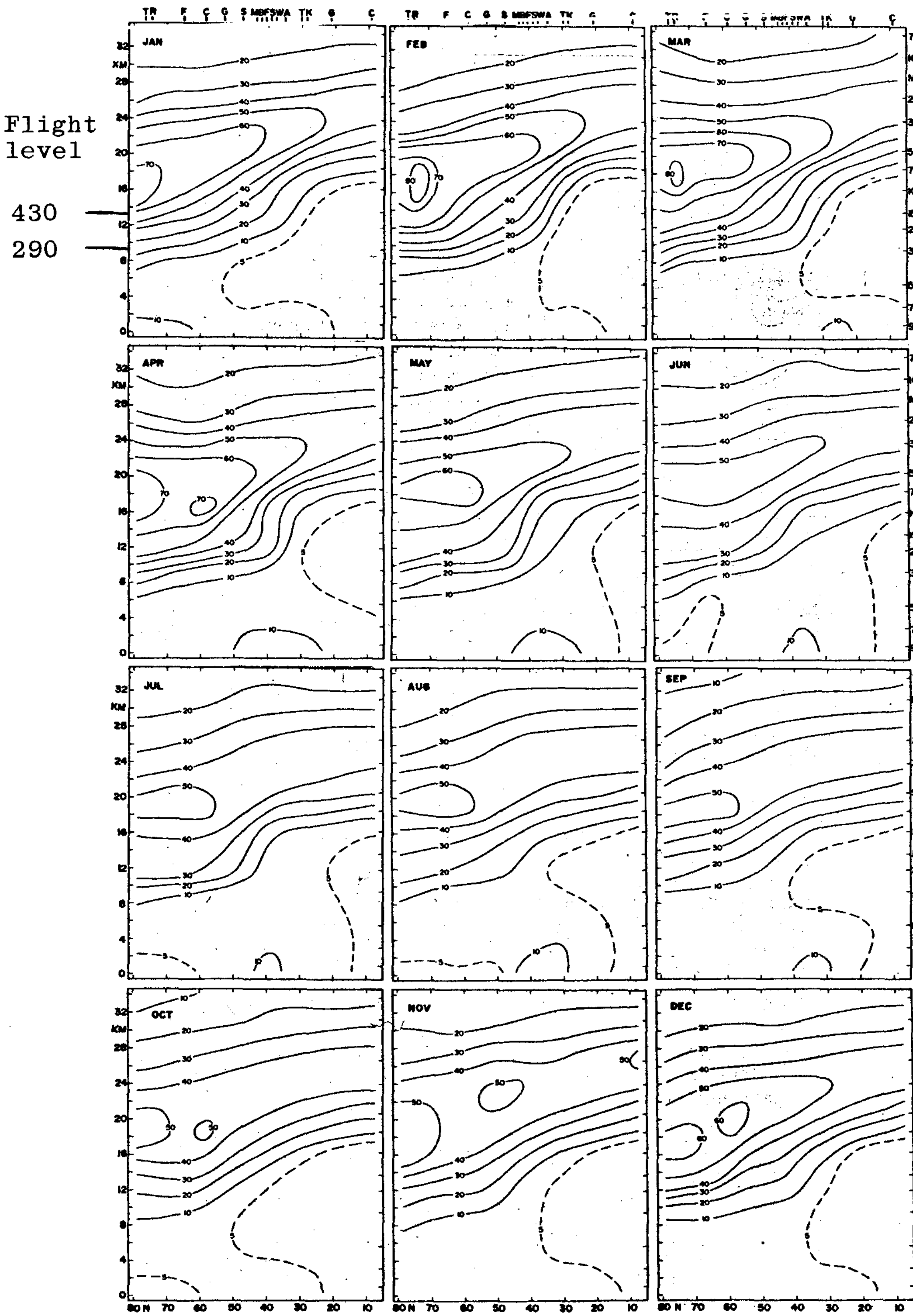

Figure 2. - Vertical distribution of ozone over North America by month. Units are 10^{11} molecules cm^{-3}. Ozonesonde stations are indicated at the top of the figure. (From J. of Appl. Meteor., vol. 16, p. 293.)

DECEMBER - FEBRUARY

PPMV

MEAN

KM	80N	70	60	50	40	30	20	10
32.5	6.3	6.5	6.3	5.8	6.2	7.3	8.0	8.3
30.0	6.0	6.3	6.2	5.7	6.2	7.0	8.0	8.3
27.5	5.7	6.2	6.1	5.7	6.2	6.7	7.0	7.6
25.0	5.5	6.0	5.9	5.5	5.8	5.8	5.7	5.7
22.5	5.0	5.2	5.2	5.0	4.9	4.3	3.5	3.1
20.0	4.3	4.1	3.8	3.5	3.0	2.1	1.3	.9
17.5	3.4	3.1	2.4	1.8	1.3	.6	.3	.2
15.0	2.4	1.9	1.4	1.0	.5	.2	.08	.06
12.5	1.2	.9	.6	.4	.3	.1	.04	.03
10.0	.5	.4	.2	.2	.1	.06	.03	.03
7.5	.1	.1	.08	.07	.06	.04	.03	.03
5.0	.04	.04	.04	.03	.04	.03	.03	.02
2.5	.04	.04	.03	.03	.04	.03	.03	.02

STANDARD DEVIATION

KM	80N	70	60	50	40	30	20	10
32.5	2.3	2.0	1.4	1.1	1.2	1.0	1.2	1.0
30.0	2.2	1.8	1.3	1.1	1.0	.9	.9	.9
27.5	1.9	1.5	1.2	.9	.8	.8	.7	.7
25.0	1.4	1.2	1.1	.8	.7	.6	.6	.6
22.5	1.1	1.0	.9	.7	.7	.5	.5	.5
20.0	.8	.9	.7	.7	.6	.5	.4	.3
17.5	.7	.6	.6	.6	.5	.3	.15	.08
15.0	.6	.5	.5	.4	.4	.10	.03	.02
12.5	.4	.4	.3	.3	.2	.07	.02	.01
10.0	.15	.15	.15	.10	.09	.03	.01	.01
7.5	.05	.05	.05	.04	.03	.02	.01	.01
5.0	.01	.01	.02	.01	.02	.01	.01	.01
2.5	.01	.01	.02	.01	.01	.01	.01	.01

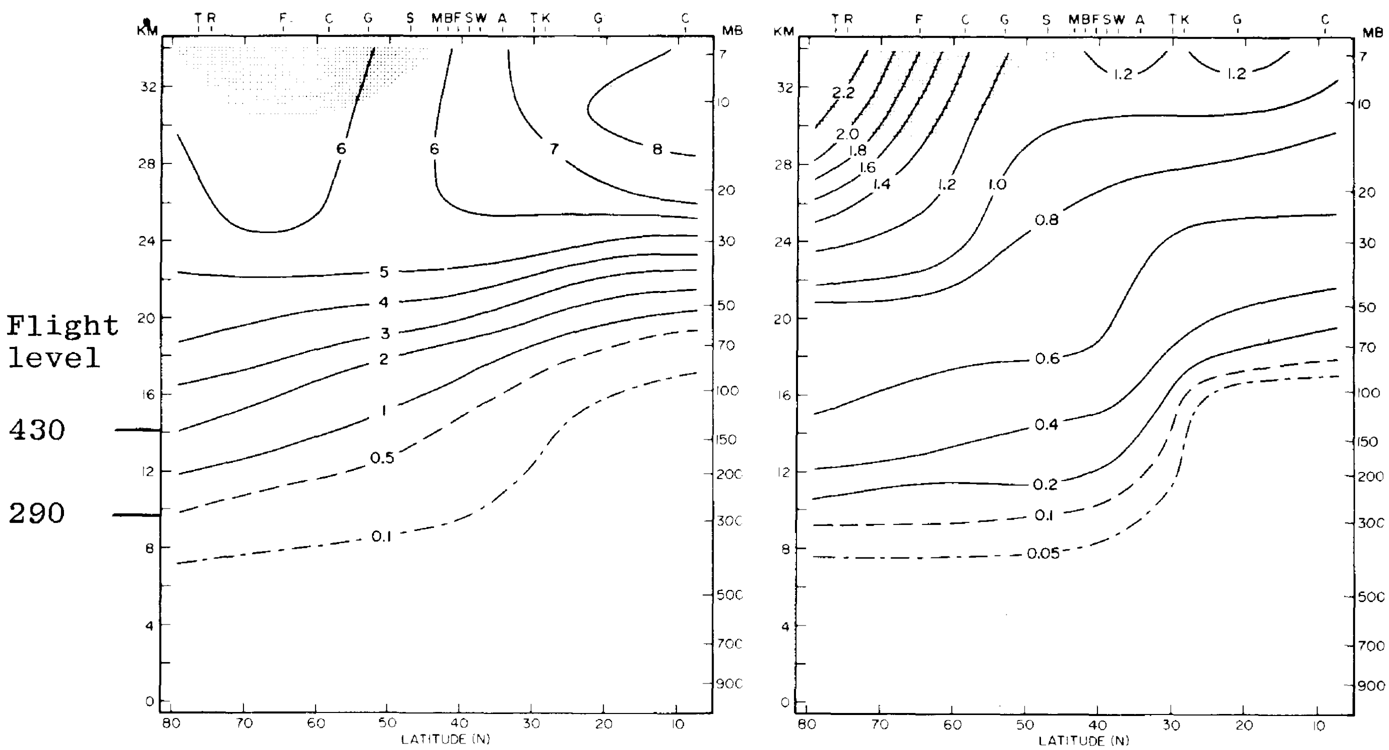

Figure 3. - Seasonal height-latitude cross-sections of ozone means and standard deviations near 80°W in units parts per million by volume. Shaded areas have no data. The pressure scale is approximate, based on the annual mid-latitude average (Ref. 1).

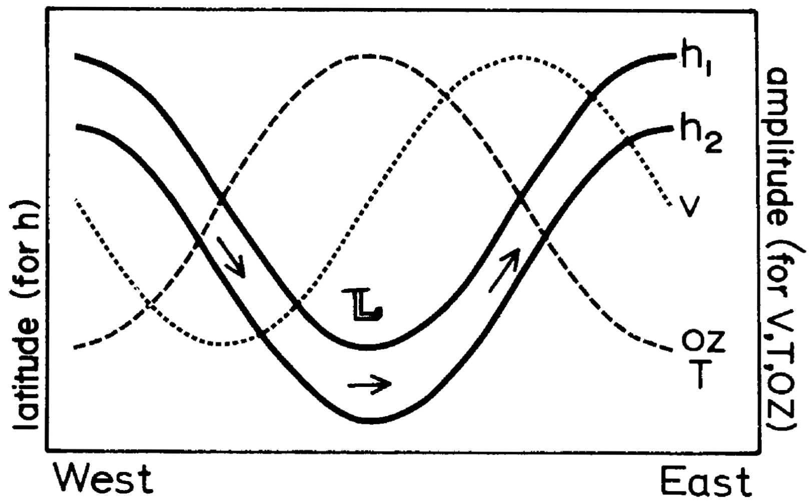

Figure 4. - Schematic picture showing the phase relations between pressure-height, geostrophic meridional wind, and ozone and temperature. At a given pressure near the tropopause, largest ozone is found with lowest height (Ref. 3).

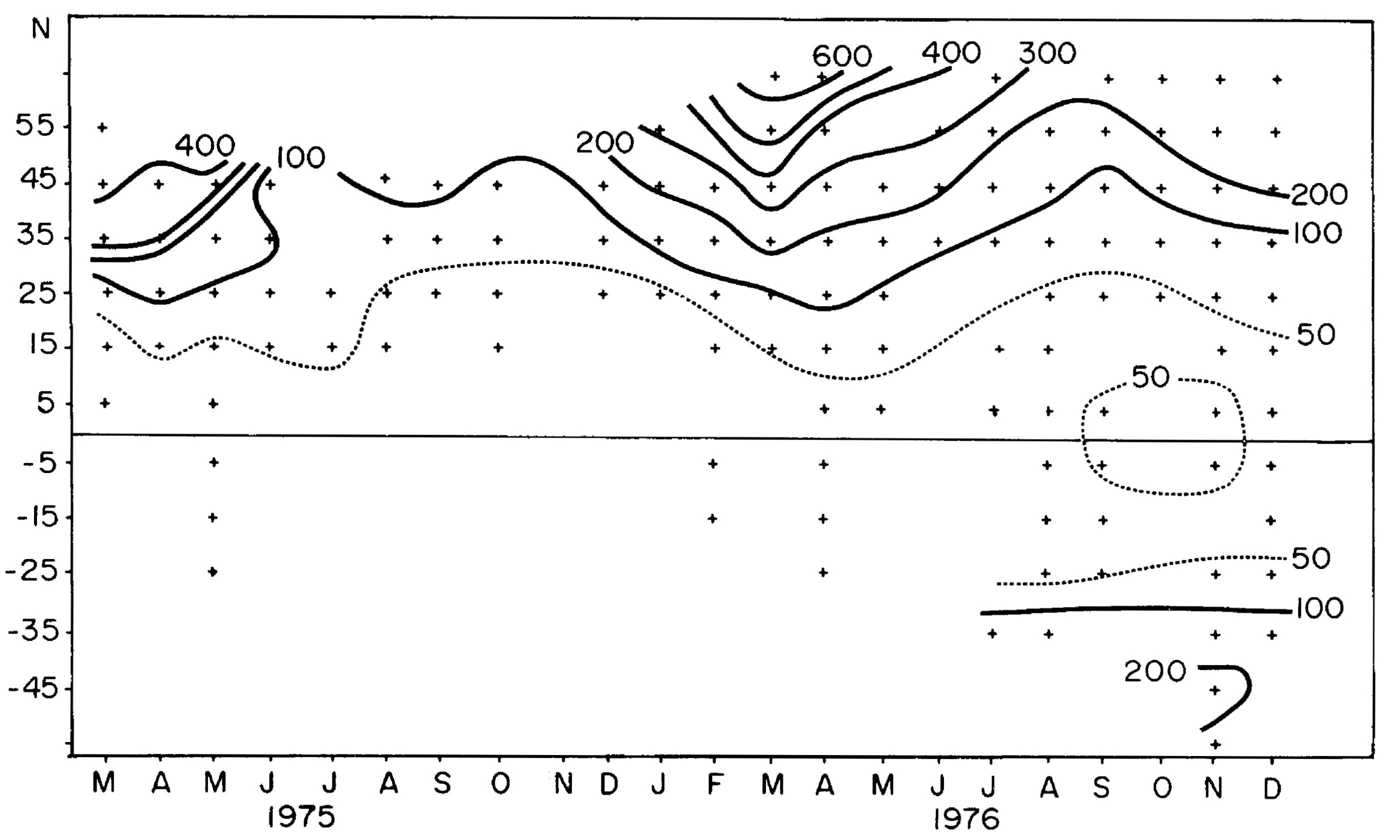

Figure 5. - Zonal-monthly mean ozone amount (ppbv) for data taken at 217 hPa (37000 $\pm$ 1000 feet in the standard atmosphere, or about 11.3 km). Those grid points with data are depicted by small crosses (Ref. 3).

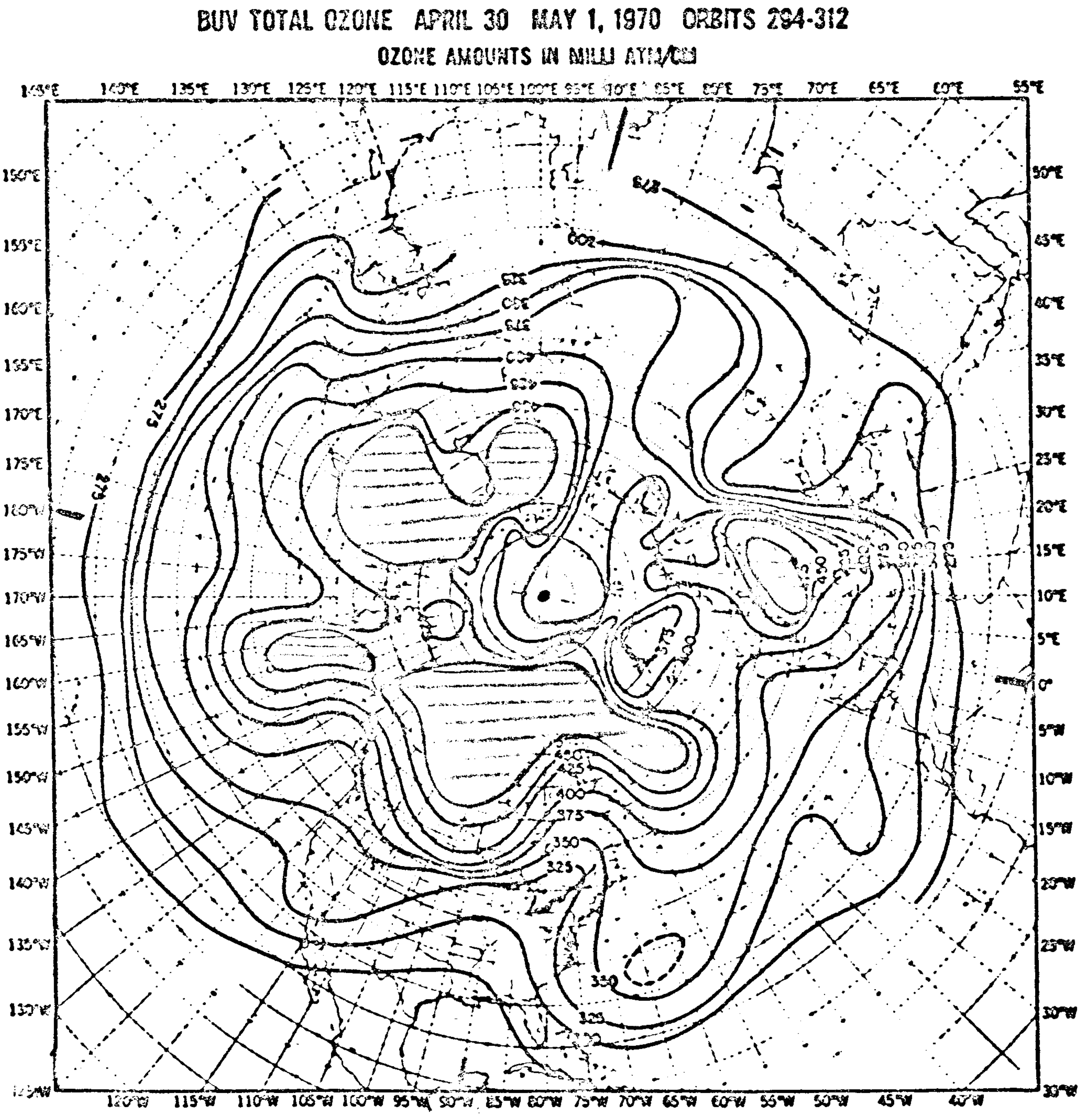

Figure 6. - Total ozone contours (in milliatm/cm) for Northern Hemisphere, Derived from BUV measurements on April 30 and May 1, 1970. Areas of maximum ozone are hatched. (Taken from Heath, et al., 1973.)

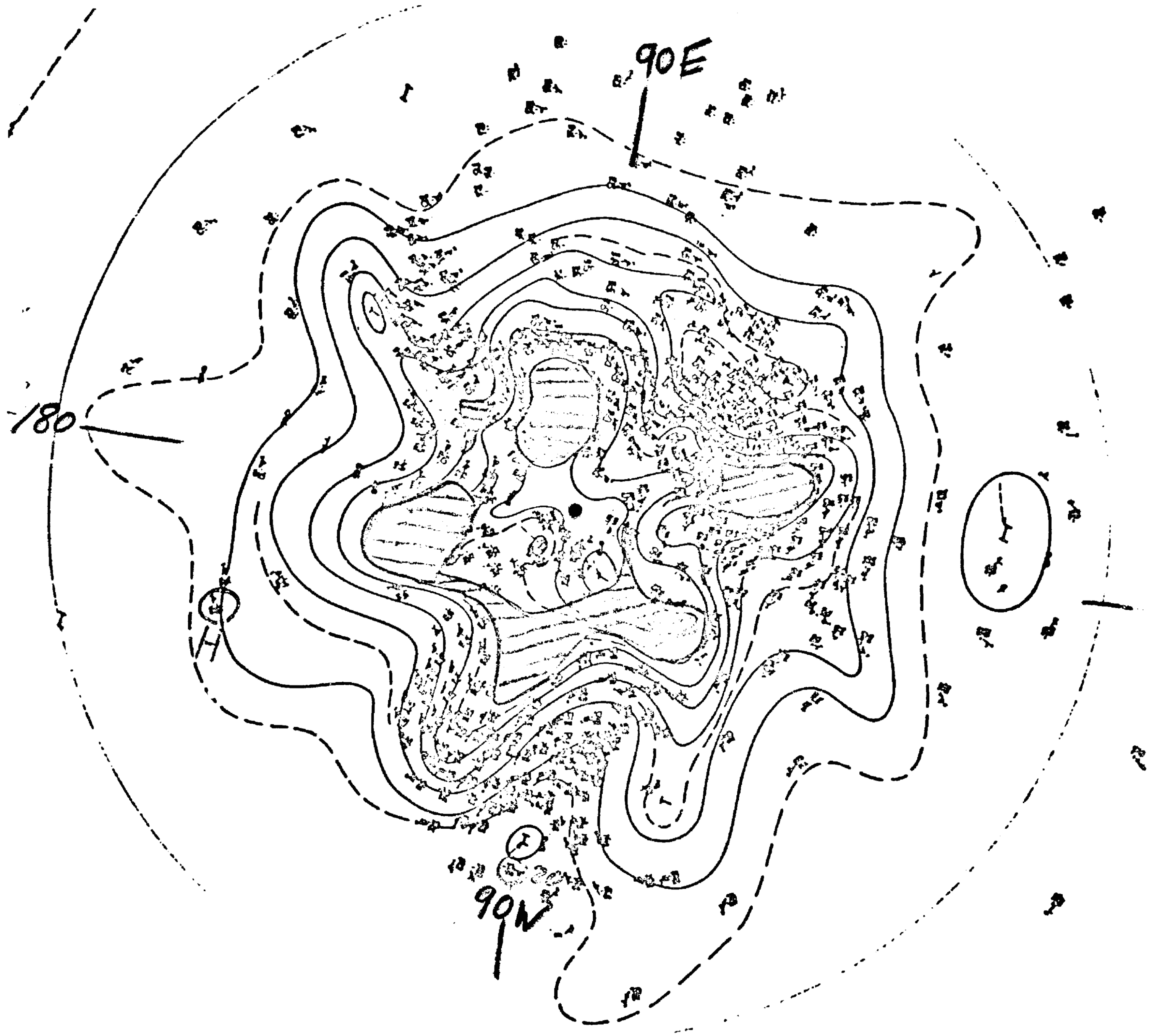

Figure 7. - 300-mb height contours on May 1, 1970. Note that areas of lowest height correspond very closely to areas of maximum ozone in Figure 6. Areas of maximum ozone are hatched.

Ambient	Cabin: No filter (50% natural reduction)	Cabin: 75% filter	Cabin: 90% filter
1.10	.55	.14	.06
1.00	.50	.13	.05
.90	.45	.11	.05
.80	.40	.10	.04
.70	.35	.09	.04
.60	.30	.08	.03
.50	.25	.06	.03
.40	.20	.05	.02
.30	.15	.04	.02
.20	.10	.03	.01
.10	.05	.01	.01
.00	.00	.00	.00

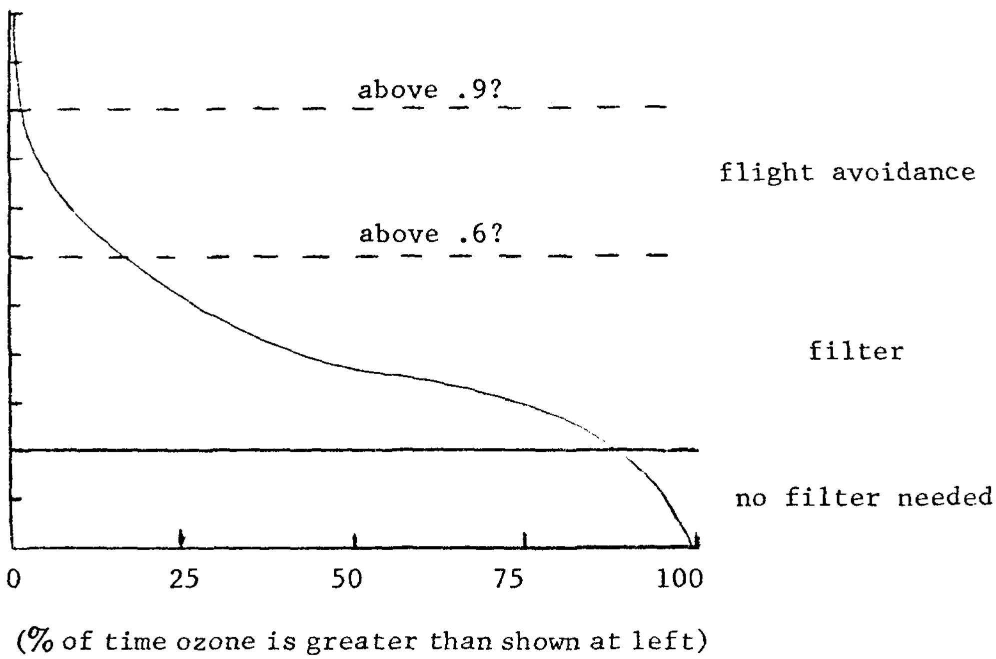

Figure 8. - Hypothetical cumulative frequency distribution of ambient ozone greater than shown in left column. Two possible levels of ozone concentration above which flight planning is advisable are shown as examples. Cabin ozone is assumed to be 50% of ambient. Such distributions will vary greatly depending on altitude, season, latitude.