NORTHWEST AIRLINES, INC.

November 12, 1963

Flight Standards Bulletin No. 8-63

TO: ALL FLIGHT CREWS

FROM: MANAGER, FLIGHT RESEARCH & DEVELOPMENT

SUBJECT: JET TURBULENCE PENETRATION

This bulletin is about jet turbulence penetration. Numbers used are specifically for the Boeing 720B and 320B, but the basic material and principles involved apply to all jet transport types. While specifically applicable to the jet, the bulletin is also being issued to non-jet crews. We believe it will be interesting to prop crews, too, and important in view of future jet check-out. The bulletin is to be retained until equivalent material has been incorporated in the manuals.

Paul A. Soderlind

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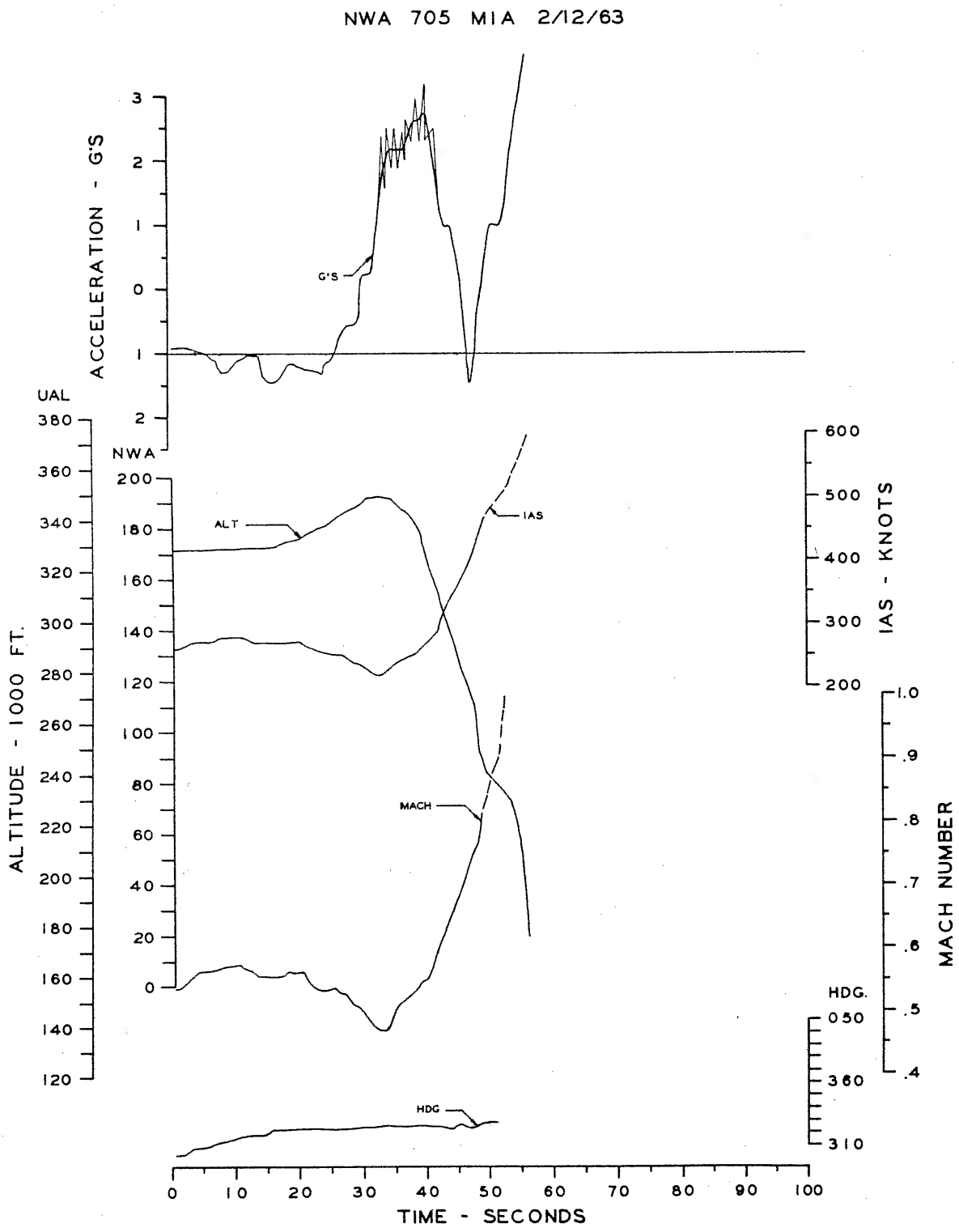

NWA 705 MIA 2/12/63
ACCELERATION - G'S
G'S
UAL
NWA
ALTITUDE - 1000 FT.
ALT
IAS
IAS - KNOTS
MACH
MACH NUMBER
HDG.
HDG
TIME - SECONDS

FIGURE 1

UAL 746 ONL 7/12/63

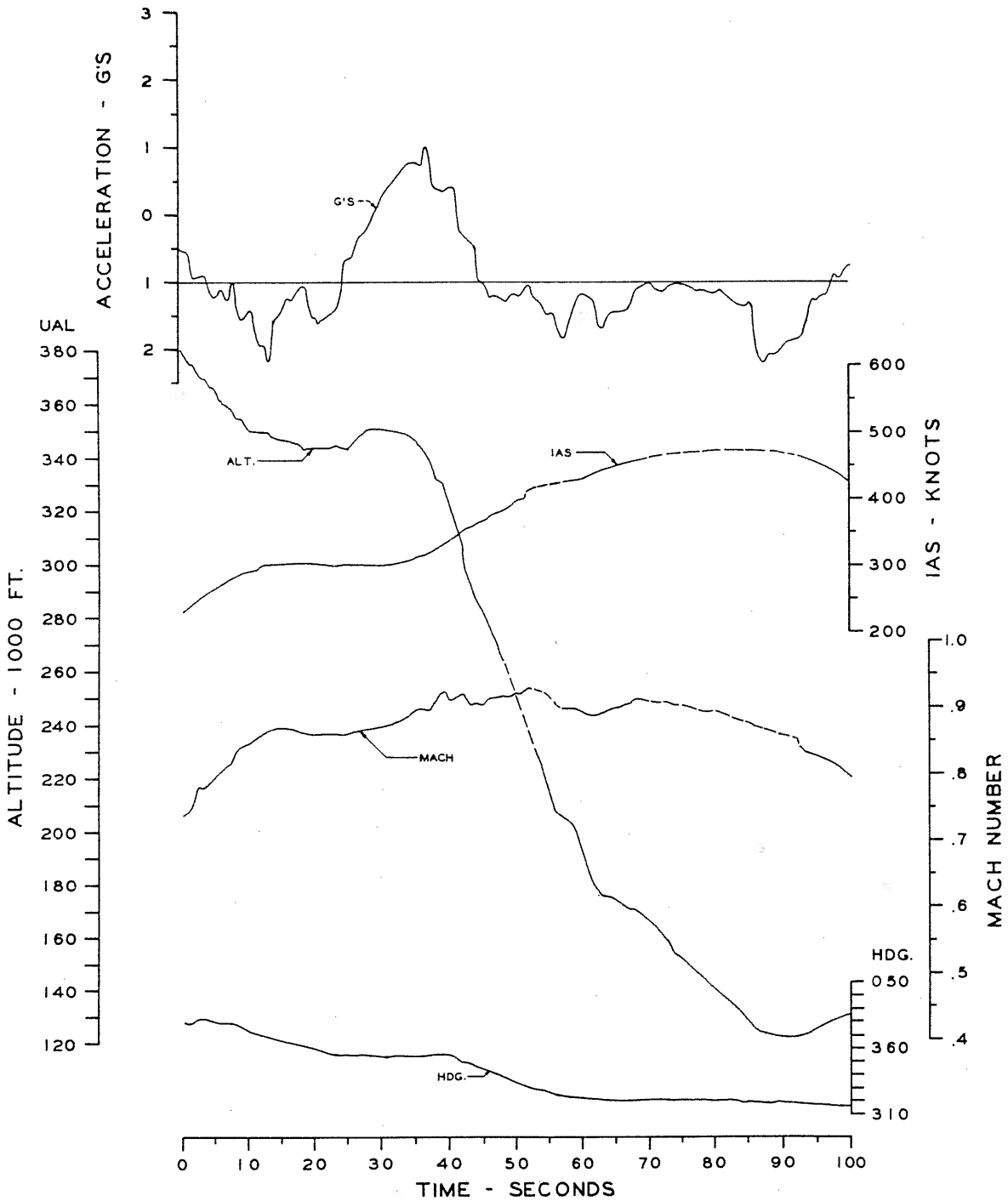
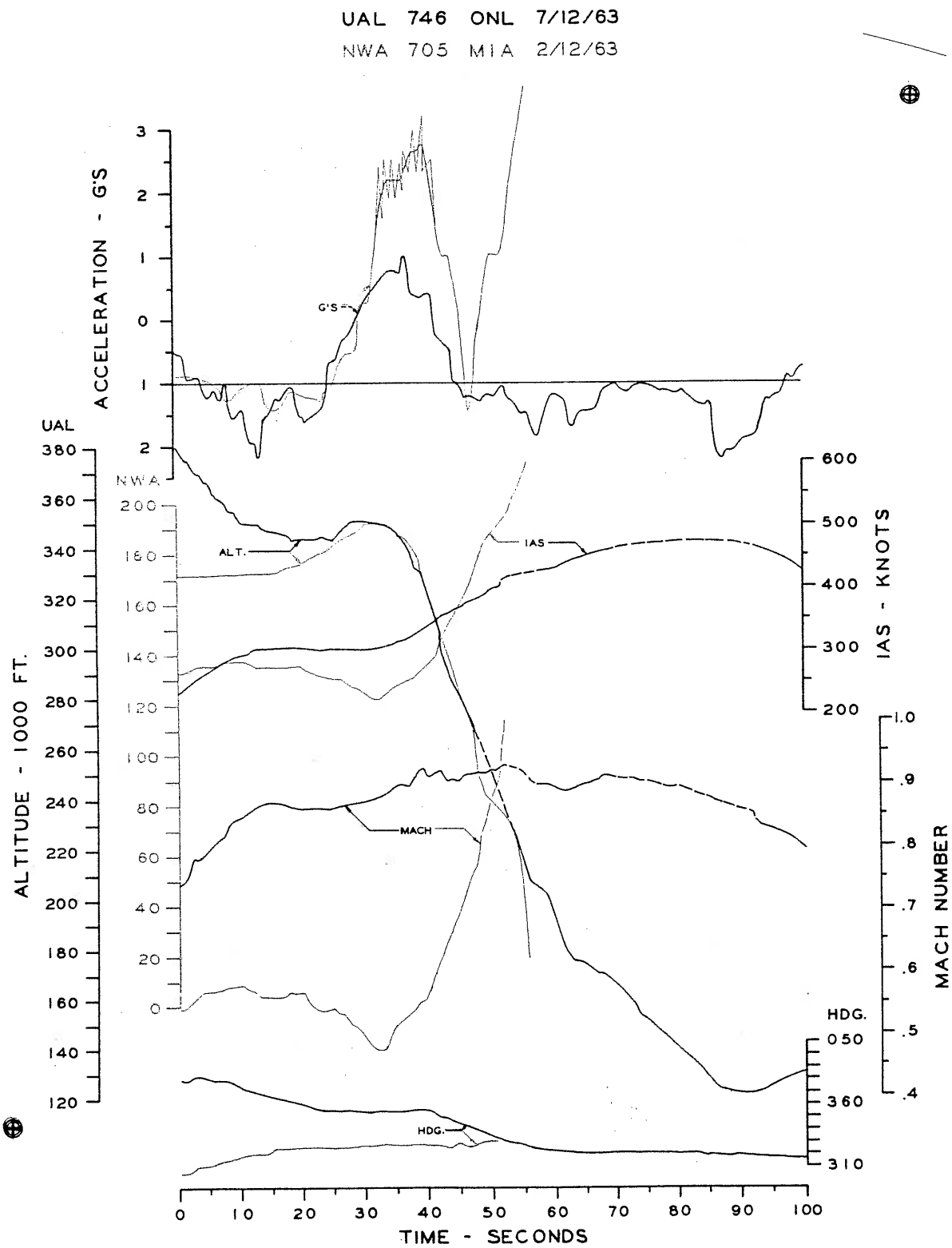


FIGURE 2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ACCELERATION - G'S
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IAS
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MACH NUMBER
HDG.
TIME - SECONDS

FIGURE 3

GENERAL

On July 12, a United Boeing 720 experienced an unusual turbulence encounter. The incident involved a high speed dive in which some 25,000' was lost. The entire encounter lasted about 4 minutes and involved:

1. Pitch attitudes beyond 50° nose up (possibly to near vertical) despite both pilots holding full forward elevator.

2. Extreme up and down drafts during which pitch attitudes were steep enough to cause the horizon bar to disappear behind the mask at the top and bottom of the indicator.

3. Penetration of both the low and high speed buffet boundaries at several points. At at least one point, the airplane was deeply into stall buffet and probably fully stalled.

4. Minimum speeds of 213K and Mach .69.

5. Maximum speeds beyond 470K IAS and Mach .93 (the recorder "pegs" at 460).

6. Reported inability to move either the stabilizer or elevator in the high speed dive despite the efforts of both pilots.

7. Maximum altitude of 39,000' with dive recovery at 12,000'.

8. Peak "G" loads of +3.2 and -1.4 (i.e., variations of +2.2 and -2.4 from the normal +1 "G").

The trouble started during climb from FL 370 to an intended 410 to top a cloud layer--the radar showing one "fuzzy" thunderstorm 30-40 miles away. An aftercast indicated a sharp, broken to solid squall line in the area, that the flight was in an 85K jet stream (no CAT experienced), that overall tops were at least 47,000', and that the layer involved probably was the cirrus shelf of a thunderstorm.

A preliminary study of a photograph of the UAL flight recorder tape revealed factors similar to the NWA MIA case. When a copy of the read-out plot of the UAL case was obtained, and compared to that of the MIA case, certain significant similarities were apparent.

At this point it must be made clear that this bulletin doesn't presume to set down the cause in either case. The cause or causes are unknown and any attempt to state one at this point can be little more than speculation. What can be said is that many facts are known about both cases, and these have led to a better understanding of turbulence penetration problems with the jet airplane. The latter is mainly what this bulletin is about.

THE BUFFET BOUNDARY

General

An airplane can be stalled at any speed. A 270,000# 320B at 35,000' for example will stall regardless of speed if the "G" load is increased much beyond +1.5. And there is nothing peculiar about the 320B in this respect; the numbers will differ for other airplanes but the problem is the same. It may be a low or a high speed stall, or even a mixture of both, the kind being quite academic since either will bring problems. And since these problems usually come before the stall, it is better to talk about the buffet boundary rather than the stall itself.

The buffet boundary for the jet transport is as shown in Figure 4.

The curve to the left of Point A is the low speed buffet boundary. Slow down to this speed and prestall buffet begins. You will note that this speed increases at a faster and faster rate as altitude increases. To the left of this line the airplane will be at or near the

point where all lift is lost. More important, it will be in an area where loss of control is probable--almost certain in turbulence.

The curve to the right of Point A is the high speed buffet boundary. When the airplane moves to the right of this line it also begins to buffet. The buffeting is usually more even and is of a "staccato" or "washboard" character. By itself, high speed buffet presents a far smaller problem than low speed buffet; although some lift is lost, control is adequate. As a matter of interest, Point A is the airplane's aerodynamic ceiling. No amount of thrust will force it higher. And if the airplane was just below Point A, the slightest speed change in either direction would put it into buffet.

The important thing is that the airplane will be in some kind of buffet whenever it is outside the curve. And while high speed buffet is not a serious matter <u>in itself</u>, past incidents show that it usually takes you by surprise and invariably brings on more serious problems.

The Effect Of Altitude

Altitude has a strong influence on the buffet boundary. At 37,000' the buffet-free speed range for a 270,000# 320B is 110K wide (see Figure 5). If the airplane slows to 185K, low speed buffet begins; if it accelerates to 295K, high speed buffet begins. And while the buffet-free range increases to 161K at 31,000', it is cut nearly in half at 41,000'. At 43,000' a small speed change in either direction would put the airplane into buffet. And you will see that the buffet-free range decreases at a faster and faster rate as the aerodynamic ceiling is approached.

The Effect Of Speed

IAS is a convenient measure of the buffet-free range. Figure 5 shows that at 37,000' the airplane will enter low speed buffet at 185K and high speed buffet at 295K, while at 31,000' the boundaries are at 178K and 339K.

Since large speed changes in cruise are unusual, the fact the buffet free range is less at 37,000' than at 31,000' is not particularly important. It is wide enough in either case. It would be hard to think of anything that would slow you up enough in cruise to get you to the low speed boundary. And while normal cruise speed appears to be relatively close to the high speed boundary, it really isn't quite like it looks. The airplane will not have enough thrust to accelerate to the high speed boundary at the weight/altitude combinations concerned.

There is a case where the high speed boundary can be reached at normal cruise thrust in level flight in smooth air. It is possible to have large scale up and down drafts in standing wave conditions with the air perfectly smooth. The same kind of smooth up and down drafts can occur near--especially over the top of--thunderstorms. Holding a constant altitude causes the airspeed to go down in a down draft and up in an up draft, and altitude can be held constant in what for all practical purposes is normal 1 "G" flight. We've had at least one relatively serious high speed buffet encounter where the airplane accelerated to the high speed boundary as a result of the autopilot holding a constant altitude in a large scale up draft. While large speed variations in smooth air are rare, this incident shows they are possible.

The Effect Of Weight And "G" Load

Weight influences the buffet boundary strongly, the buffet-free speed range being widest at low weights. You can see this in Figure 6.

Change in "G" load has an important effect also. The buffet-free speed range 110K wide at 270,000# (see Figure 5) shrinks to 96K at 300,000#. While you're not apt to have a 300,000# 320B at 37,000', you have at your fingertips the ability to increase the apparent weight to this value simply by pulling back on the wheel. A gust, of course, can do the same. An increase in "G" load has exactly the same effect on the buffet boundary as an increase in actual weight. You will see this in Figures 7 and 8.

The curves in both figures are the same. But note that the dashed line is the boundary for 300,000# at +1 "G" (Figure 7) while it is the boundary for 200,000# at +1.5 "G" in Figure 8. The curves, and the aerodynamic phenomenon they are based on, are exactly the same in both cases. It's important that you get this point.

If weight and altitude were the only important factors, Figure 7 would tell much of the story. The cruise altitude shown is fine for 200,000# but not so good for 300,000#. But 200,000# times 1.5 "G" multiplies out to the same buffet problem.

The moral so far is this. The higher the altitude, the narrower the buffet-free range will be. In smooth air this is of little significance, the range will be wide enough for all but unusual circumstances. If the air gets very rough, it becomes a horse of an entirely different collar. A 200,000# airplane is in good shape at the altitude shown only so long as the "G" load stays below +1.5. And what a gust can do, maneuvering can do also. It doesn't matter where the +1.5 "G" comes from. While it takes a 48° banked turn to produce +1.5 "G", 25° will do it if helped by a gust--or too vigorous a pull on the wheel trying to maintain altitude.

SPEEDS FOR TURBULENCE PENETRATION

In general, turbulence penetration speeds are a product of two considerations. The chosen speed must be high enough to protect against a gust-induced stall, yet low enough to protect structure against excessive loads. In the past, these somewhat opposing factors have dictated a range of speeds rather than a single number, and these have been represented by curves similar to Figure 9.

While the curve shown in Figure 9 is no longer in effect, it bears discussing since it influenced the choice of earlier turbulence penetration speeds in a very significant manner. The curve "necks down" at 20,000', implying something especially critical about that altitude. Nothing could be further from the truth.

The left-most line is the speed at which the stall will occur if the design gust is encountered. The line slopes to the right from sea level to 20,000' indicating as it should an increase in stall speed with altitude. At 20,000' it reverses its trend implying that stall speed decreases above 20,000'. Again, nothing could be further from the truth. The seeming inconsistency is related to the term "the design gust".

From sea level to 20,000', the design gust value is considered to be 66 feet per second. If you encounter a 66 fps gust anywhere between sea level and 20,000', you will stall if you are at the speed represented by the left-most line. Above 20,000', the stall speed would continue to increase (as it does from MSL to 20,000') if you encountered a 66 fps gust. For design purposes, however, the design gust is decreased linearly from 66 fps at 20,000' to 38 fps at 50,000', thus the "wrong way" bend in the "STALL SPEED LIMIT" line of Figure 9. Project the zero to 20,000' line, in the same direction, on up to the M_{mo} line and you will have a more realistic picture of the increase of stall speed in gusts with altitude. This is very important. Belief that stall speed in gusts decreases above 20,000' (as implied by this curve) can influence use of a speed that is much too low.

The impression given by the line in the middle of Figure 9 (the right half of the "hourglass" figure) can be equally erroneous. It is somehow thought of as the speed at which the airplane would be in structural trouble if it encountered the design gust. And again, nothing could be further from the truth. The right side of the hourglass is based on structural considerations but the airplane is by no means going to come apart if you hit the design gust at this speed. Significant strength margins exist beyond V_{mo} for stresses developed by the design gust.

Down through the years most of us tended to favor the lower speeds, probably because we were more afraid of the airplane coming apart than we were of an inadvertent stall. The consequences of structural failure

seemed obviously more likely to lead to grief. But while the consequences of structural failure could well be catastrophic, the probability of structural failure in turbulence is far lower than it may seem. The design ultimate load factor is +3.75 yet early in the jet transport history a Boeing 707 went beyond +5 "G" at an IAS of 460K and did not come apart. And of course there are other actual cases where the design load factors were far exceeded. There are many things that indicate strongly you are more likely to get into serious trouble as the result of an inadvertent stall than you are to experience structural failure.

For simplicity's sake a single turbulence penetration speed would be nice. A first look at Figure 10 indicates 270K would be a good choice--and it might but for one complication. At the higher altitudes compressibility gets into the act and the buffet boundary becomes the limiting factor. Figure 10 is a plot of the original 720B turbulence penetration speed envelope superimposed on the buffet boundary curve.

At 39,000', 270K would put the airplane at Point A where the margin to high speed buffet is small. While this wouldn't be serious in smooth air, a +1.5 "G" gust would put the airplane deeply into high speed buffet. 270K would be too fast. But now look at the guy who still thinks it best to favor the low speed end of the range. The low end lies at 214K (Point B) and +1.5 "G" would put the airplane deeply into low speed buffet--probably out of control.

The Mach .80 line lies through the peak of the buffet boundary curves for different weights or "G" loads. As weight or "G" load increases, the buffet boundary curves pull down along the Mach .80 line (.78 for the DC8C), and this speed will thus be the only one that gives the greatest margin to buffet onset at the higher altitudes. Figure 10 shows this clearly.

THE STABILIZER AND ELEVATOR

Stabilizer Drive Stall

If the load on the stabilizer is too high (as when the airplane is mistrimmed and stabilizer is being opposed by elevator), it will be difficult or impossible to trim manually. You will remember this from training in runaway stabilizer procedures. The same thing happens with the electric drive; it takes a greater load but it can be stalled nevertheless.

The point at which the drive stalls depends primarily on the aerodynamic load. In general, it will not stall unless significant amounts of mistrim are involved.

The amount of mistrim possible before the drive stalls depends primarily on speed. While upwards of 4 units of mistrim may stall the drive in the 250K range (720B) it may be stalled by as little as 1 unit of mistrim at high speeds. No firm numbers can be tied to these areas since there can be a relatively wide variation between airplanes. It can be generalized, however, that the problem is less on the 320B than on the 720B.

Trimming in severe turbulence can lead to stabilizer drive stall problems, and these in turn can lead to serious control problems. Trimming to resist a pitch change on entering a large draft will put the airplane out of trim when the draft reverses itself. This reversal of pitching motion is usually first opposed by elevator which in turn loads the stabilizer, possibly enough to stall the drive. While it takes an unusual set of circumstances to produce the drive stall problem, all the necessary ingredients are there in severe turbulence cases.

The main point is this. Keep the stabilizer in trim or you can get into serious control difficulties. And since trimming in turbulence is difficult, it is best to establish the trim setting required for turbulence penetration airspeed <u>and then leave it alone while in the turbulence</u>.

Elevator Capability

The elevator is not big enough to fight both the gust and the stabilizer. Four units of stabilizer trim are roughly equivalent to full elevator. Get four units out of trim and all the elevator goes just to fight the stabilizer--none is left to recover from a dive or other unwanted maneuver. Even one unit of mistrim can be a problem. If you are one unit out of trim in the nose up direction and a gust pitches the airplane to a high attitude, one-fourth of the elevator will be used up just opposing the stabilizer. Only three-fourths will be left to counter the gust.

Elevator Forces

Elevator forces "heavy up" at high speed. Where a light pull produces a certain "G" load at low speed, it takes a surprisingly heavy pull to produce the same "G" at high speed. The elevator may even seem to be immovable at speeds out beyond the barber pole. It is so by design. The designer gives you stick forces pleasantly light at normal maneuvering speeds yet heavy enough to prevent overstressing the airplane at high speeds. To recover from a dive you must apply a certain amount of positive "G". The amount depends on the dive angle, the speed, and the amount of altitude you have left. The higher the speed or dive angle, the higher the positive "G" necessary to recover in a given altitude. It takes about 60# pull to produce 2 "G" at 200K in the 720B, but it would take upwards of 200# at the 470K + attained in the cases mentioned above. And if the stabilizer was out of trim in the nose down direction, the forces would be higher yet.

What is the practical meaning of all this? Just this. If you find yourself in a high speed dive, it will take a much bigger pull to make the airplane respond than you probably think. And precisely because the pull is heavy, the likelihood of overstressing the airplane in such a case is remote.

THE AUTOPILOT IN TURBULENCE

Should the autopilot be used in turbulence penetrations? There can be no pat yes or no answer to this question. It depends. Some things favor turning it OFF, some favor leaving it ON. It is best to acquaint you with the pros and cons, then let you make the decision yourself based on the circumstances in a particular case.

The arguments go something like this:

1. "It's better to leave the autopilot OFF because it will try to control pitch attitude quite rigidly and thus add to the structural loads imposed by the gusts."

   As an autopilot elevator input can couple with a gust and increase the overall load factor, so can an input from the pilot. While the human pilot may be gentle with elevator inputs, the forces the autopilot can apply are also limited. The fact is, either the autopilot or human pilot can add to the gust load factor but it doesn't necessarily follow that the autopilot is more apt to do so. The autopilot is "force limited" but the human pilot is not.

2. "The autopilot should be OFF in turbulence because it can put the airplane in an out of trim condition."

   If an up draft, for example, causes the pitch attitude to change, the autopilot will resist the change first with elevator, then with stabilizer trim. If the requirement for elevator input persists, the autopilot will call for stabilizer trim. Sooner or later the draft will reverse in direction and at this point the airplane will be out of trim. For this to be significant, the up or down draft must be sustained in a given direction for a relatively long period. The rate of autopilot trim is very low and it is easy to monitor to prevent large amounts of mistrim. While the trim problem may well be the most valid argument against autopilot use in turbulence, it should not call for a hard and fast autopilot OFF rule.

3. "Do not use the autopilot in severe turbulence since an inadvertent disengagement at an inopportune time might put the airplane in an attitude from which it would be difficult to recover."

   Maloperation of the radar at an inopportune time could result in difficulties for the pilot but we would not leave it OFF in thunderstorm areas because of this. Maloperation of any important unit at an inopportune time can result in difficulties for the pilot if he does not monitor the operation. There are many devices we could not use if the rule said: "Do not use because it may fail at an inopportune time." The pilot himself can "malfunction" at an inopportune time. He may get the airplane in an attitude from which it would be difficult to recover because he can't read the shaking instruments. He may get the airplane in an unusual attitude because of "floating" cockpit papers obscuring instruments (a factor in the UAL case). He may allow the airplane to get in unusual attitudes because of distractions from the primary job of flying the airplane (and who is entirely free of distractions at times like these?). He may not know whether to push or pull because the horizon is unreadable in extreme attitudes. The autopilot isn't going to have instrument readability problems and it isn't going to be distracted.

What all this seems to suggest is this. Autopilot ON or OFF, there are problems both ways. If the turbulence is moderate or less, there seems little doubt but what it is best to use the autopilot. If turbulence is greater than moderate, the autopilot may be used <u>as long as its operation is monitored</u> and its practical limitations known. Until more is known about the problem, it probably is best to leave altitude hold OFF although this too is by no means susceptible of a neat yes or no answer. If the autopilot is not used, the yaw damper should be ON in all cases.

It is neither necessary nor desirable to require that the autopilot be OFF in turbulence. Loss of control that might occur without the autopilot might well be prevented if the autopilot were used. And use of the autopilot leaves the pilot free to monitor--in itself an important safety factor.

THE PROBLEMS OF NEGATIVE "G"

The final maneuver in the MIA accident involved load factors beyond -3 "G". Some believed that the average human would become unconscious at -2 "G", and suffer permanent brain damage or death beyond -3 "G". Such is not the case. Comprehensive tests on animals have shown no permanent physical effects at load factors as high as -40 "G", and human subjects have gone at least to -5 "G" without lasting adverse effect. Rodney Jocelyn, now a PAA pilot and for years the international aerobatic champion, has repeatedly experienced load factors up to -5 "G" in his performance. Neither is there a problem of applying any necessary control forces so long as the pilot is properly restrained.

As far as flight in turbulence is concerned, these are the practical problems of negative "G":

1. Cockpit vision will be obscured by dust and other debris dislodged by the negative "G" forces. In flight tests on a new 720B, even repeated preflight cockpit vacuuming did not eliminate this problem. With older airplanes, the problem would be greater.

2. If you reach for something without looking, you will probably miss it (your "aim memory" is accustomed to the normal +1 "G" condition).

3. You will have difficulty applying necessary control forces <u>unless you are properly restrained</u>. Injury is also possible without proper restraint (it is possible, among other things, to slide out from under the seat belt if it is not reasonably tight).

4. Values at or beyond zero "G" will be disconcerting especially if they are prolonged.

THE THUNDERSTORM CIRRO-STRATUS OVERHANG

The UAL severe turbulence encounter (and at least one fairly recent one of our own) occurred in what appeared to be the cirro-stratus overhang of a thunderstorm. There is reason to believe this type of cloud contains more turbulence than was previously supposed. There is also reason to believe that radar may not be effective in seeing turbulent areas in such cases.

PROCEDURES FOR OPERATION IN TURBULENT AREAS

It is probable no two pilots would agree on just what constitutes "moderate" or "severe" turbulence. No practicable way has been found to tie specific numbers to definitions of turbulence intensity. It is purely a matter of opinion. The following procedures are intended to apply when the turbulence is greater than moderate. Your own judgment and experience are all that can be used to decide on the intensity of the turbulence.

NOTE: The following recommendations supersede those contained in Flight Standards Bulletin No. 5-63 in their entirety.

1. Do not normally operate above the normal cruise ceiling for the weight.

   a. The highest altitude for which EPR values are given in the cruise charts is the normal cruise ceiling for the weight in question. Flight at this altitude will normally give adequate margin to buffet onset for turbulence up to moderate intensity.

b. Moderate turbulence will usually require operation one cruise level (4000') below the normal cruise ceiling. Protection against greater than moderate turbulence will usually require operation two levels (8000') below this ceiling.

c. Consider the "booby trap" aspects of trying to top a turbulence condition by climbing to altitudes near or above the normal cruise ceiling.

d. Figures 11 through 16 are buffet boundary curves for the complete operating weight range of the 720B, 320B and DC8C. These may be used in choosing cruise or holding altitudes whenever there is any question as to buffet margin adequacy. The curves cover both the +1 and +1.5 "G" cases. In general, the +1 "G" curves may be considered applicable for operations in up to moderate turbulence, the +1.5 "G" curves for operations in turbulence greater than moderate intensity. You should also note the relationship of holding IAS to the buffet boundary and keep this narrowed margin in mind when holding at the higher altitudes and/or in turbulence.

2. Maintain 280K or M .80 whichever is lower (it will be 280K below 34,000', .80 above 34,000').* These are target speeds, <u>not</u> limit speeds. Maintain the speed by maintaining a constant <u>attitude</u>.

* Turbulence penetration speeds were established on a slightly different basis in the certification of the DC8C. The speeds shown in Table VI on page 1 of reference 5:5:08 are the maximum speeds to be used in severe turbulence. For turbulence penetration, the speed used should be near but not above these values. And since the peak of the buffet boundary curves for various weights and/or "G" loads lies at Mach .78, the latter will be the optimum speed at the higher altitudes to insure the greatest margin to buffet onset.

a. The attitude required will usually be between 1 and 4° nose up on the horizon indicator. It will be highest at the high weights and altitudes, and lowest at low weights and altitudes.

b. Set thrust as required and then do not change it unless required by large and/or persistent airspeed or altitude variations. The airplane's real airspeed will remain within reasonable limits so long as thrust is set properly and a reasonably constant attitude and thrust maintained. Do not let Mach or airspeed indicator fluctuations tempt you into large thrust or attitude changes.

c. If no elevator inputs were made, the pitch attitude and airspeed would vary quite widely but "G" loads would be at a minimum and the altitude would remain fairly constant. If pitch attitude were held absolutely constant, the "G" loads would be increased, the altitude would vary to a greater extent, but the airspeed would remain surprisingly constant (the airplane's real speed, not what the indicators might show). The best method is a happy compromise between the two. Maintain a reasonably constant pitch attitude but do it "loosely". Use small to moderate elevator movements to oppose attitude changes but do not try to hold the attitude rigidly.

3. Trim the stabilizer for turbulence penetration speed and then DO NOT MOVE IT WHILE IN THE SEVERE TURBULENCE.

a. If able to do so before entering the turbulence, trim for zero elevator force at 280/.80, then leave the trim alone for the turbulence penetration.

b. If turbulence is encountered before proper trim can be set, and is such that no good trim reference is present due to rapidly changing elevator forces, the following may be helpful:

(1) In the 720B, the stabilizer trim indicator will usually be between 0° and 2° nose down at 280/.80.

(2) In the 320B, the stabilizer trim indicator will usually be between 1° nose up and 1° nose down at 280/.80.

(3) In both cases the setting will more often favor the forward rather than the aft end of this 2° range.

4. Set thrust and then do not change it unless required by large and/or persistent speed or altitude changes. If the thrust required for level flight at 280/.80 cannot be established before entering the turbulence, the following may be helpful in establishing the initial setting:

a. In the 720B, "average" weights will require an N_1 of approximately 93% above 30,000' and 79% at 10,000'.

b. In the 320B, "average" weights will require an N_1 of approximately 95% above 30,000' and 78% at 10,000'.

NOTE: These are rule-of-thumb values only. Actual N_1 required will vary with altitude, weight and temperature. The above values are useful primarily for the initial setting when unable to establish the actual thrust required before entering the turbulence.

c. For severe turbulence cases, the ignition should be ON in the FLIGHT START position.

5. Set the Flight Director heading bug to the desired heading and zero the horizontal bar at the desired pitch attitude (use HEADING ONLY and PITCH ONLY modes). This will give you an excellent reference for control about all axes. The bars cannot disappear from view as can the horizon bar, and bar deflections will always call for control inputs in the proper direction.

6. If you do not use the autopilot, use the yaw damper in all cases.

7. If you choose to use the autopilot, the following factors are important:

   a. Monitor the stabilizer trim indicator to see that it does not move far from the 280/.80 trim position. Exposure to autopilot stabilizer mistrim will be greatest in <u>sustained</u> up or down drafts.

   b. Monitor attitude, airspeed and altitude (and this is also the order of relative importance of these variable) and be alert for an inadvertent autopilot disconnect.

8. Wear your shoulder harness if turbulence greater than moderate is expected or encountered.

9. Avoid the cirro-stratus overhang of thunderstorm activity whenever practicable.

Paul A. Soderlind

PAS/s

Attachments: FIGURES 4 thru 16

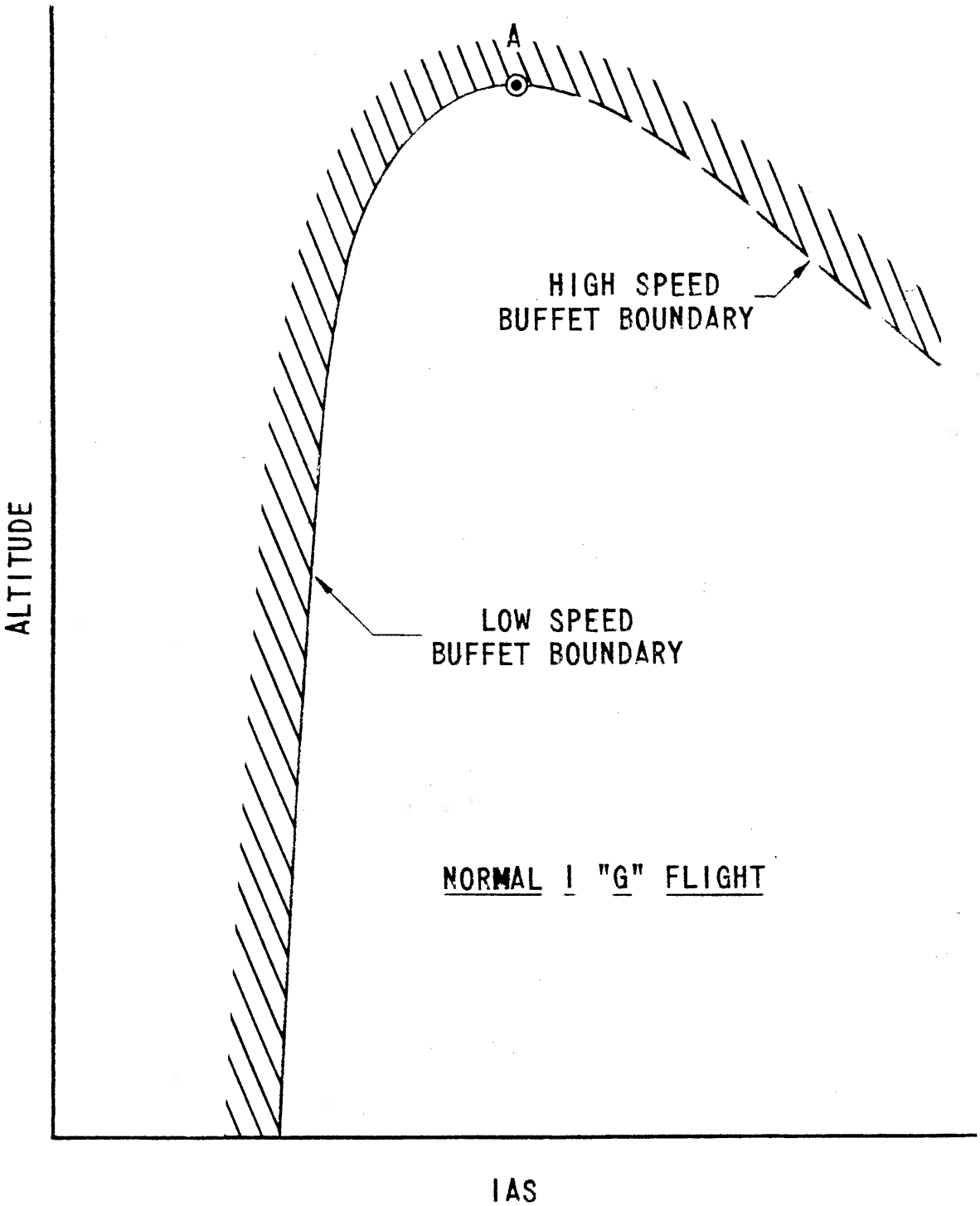

FIGURE 4, BUFFET BOUNDARY AT ONE WEIGHT

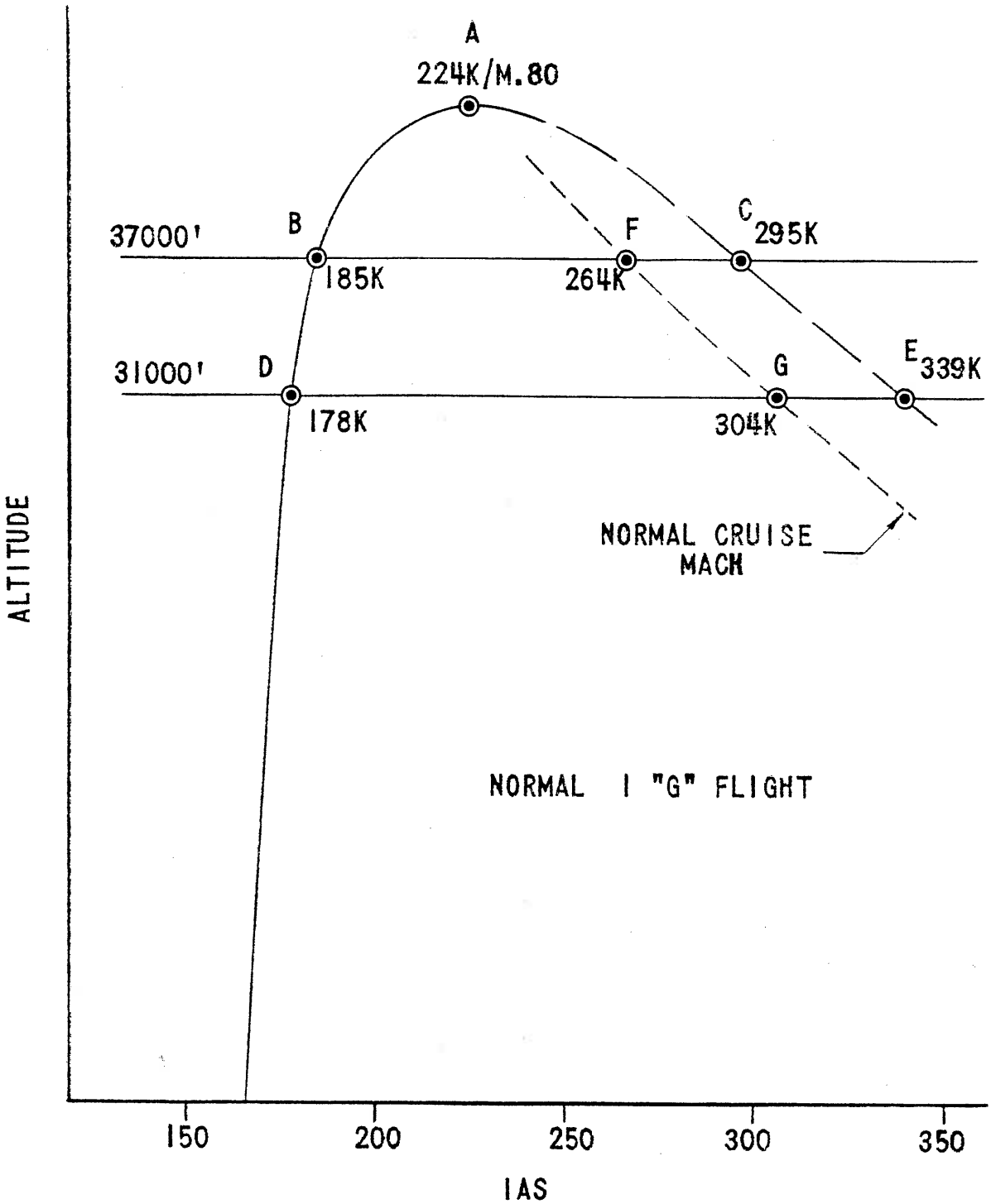

FIGURE 5, 320B AT 270,000#, NORMAL 1 "G" FLIGHT

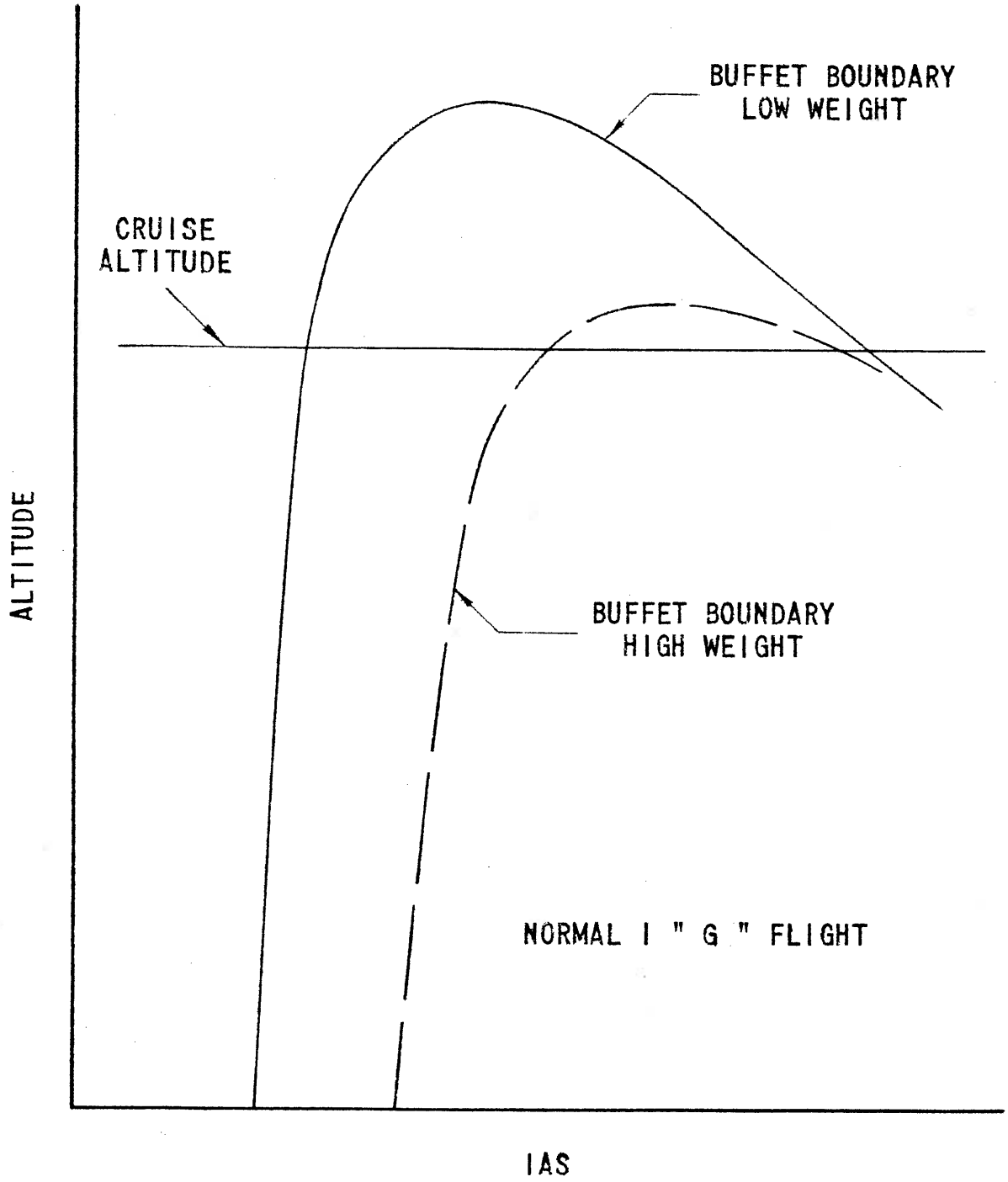

FIGURE 6, BUFFET BOUNDARY AT TWO WEIGHTS

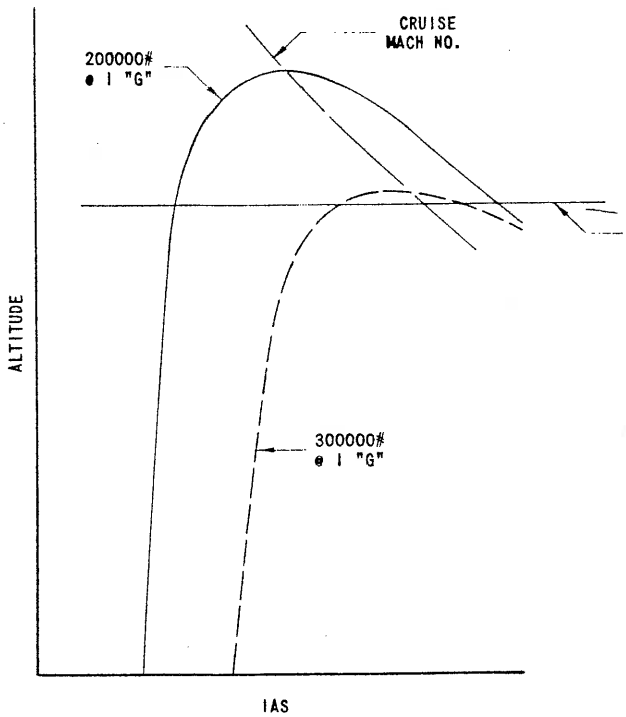

FIGURE 7

TWO WEIGHTS AT
NORMAL 1 "G" FLIGHT

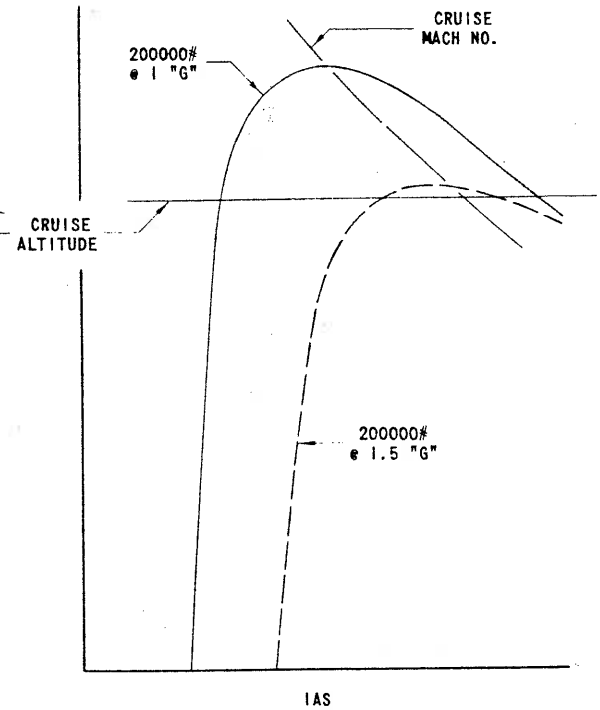

FIGURE 8

ONE WEIGHT AT
TWO DIFFERENT "G" LOADS

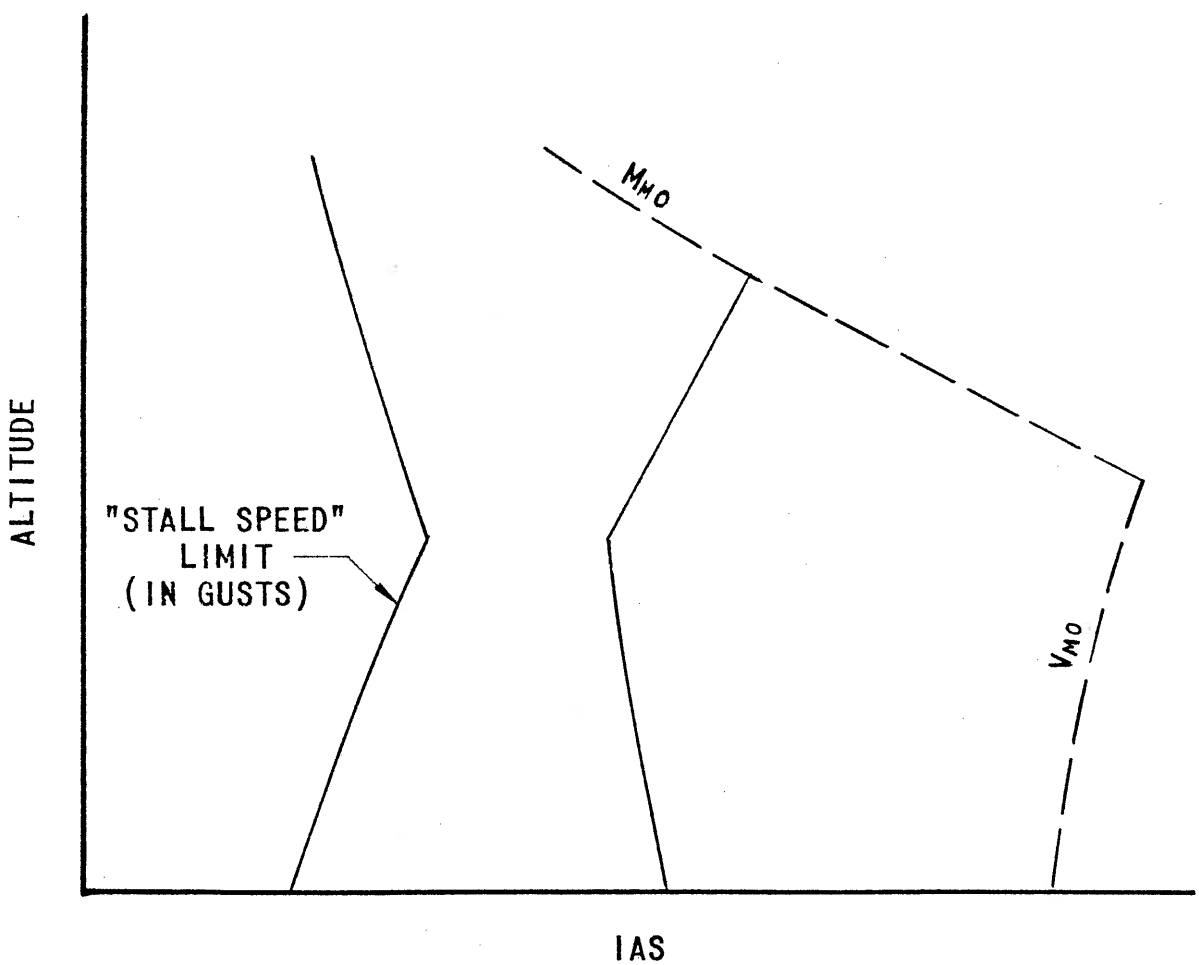

FIGURE 9

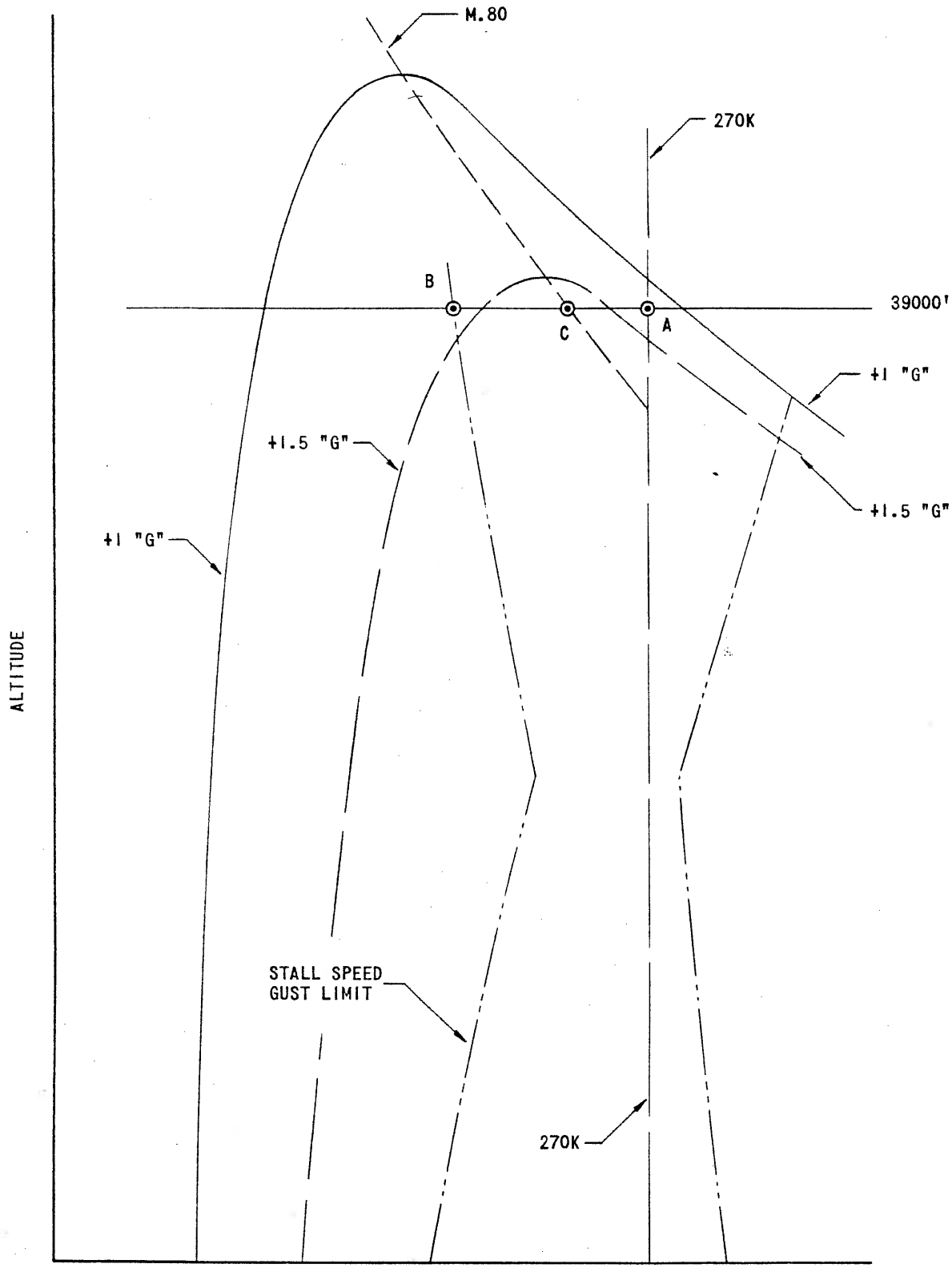

FIGURE 10, 720B AT 170,000#

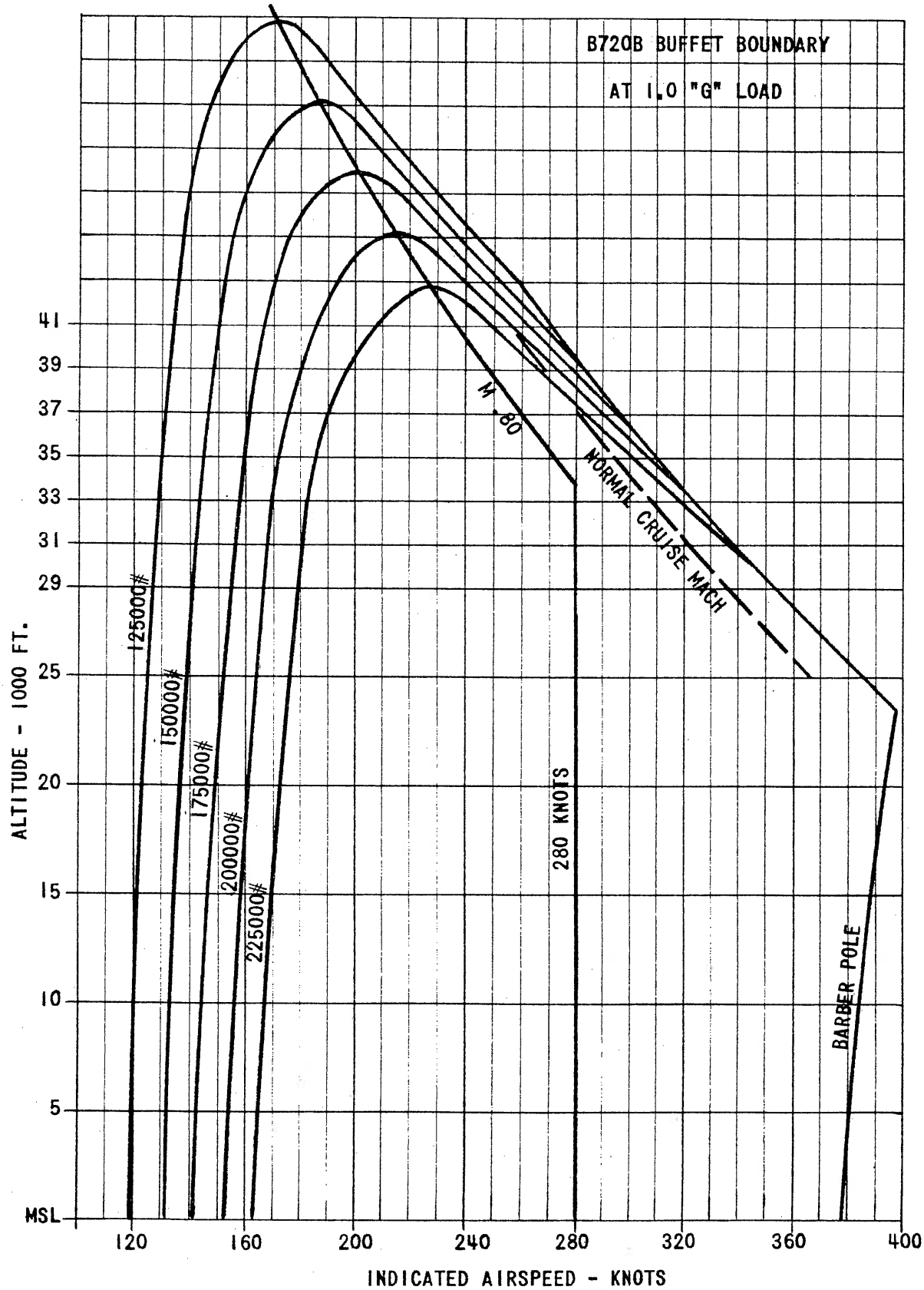
B720B BUFFET BOUNDARY
AT 1.0 "G" LOAD
ALTITUDE - 1000 FT.
41
39
37
35
33
31
29
25
20
15
10
5
MSL
120
160
200
240
280
320
360
400
INDICATED AIRSPEED - KNOTS
125000#
150000#
175000#
200000#
225000#
M .80
NORMAL CRUISE MACH
280 KNOTS
BARBER POLE

FIGURE 11

B720B BUFFET BOUNDARY

AT 1.5 "G" LOAD

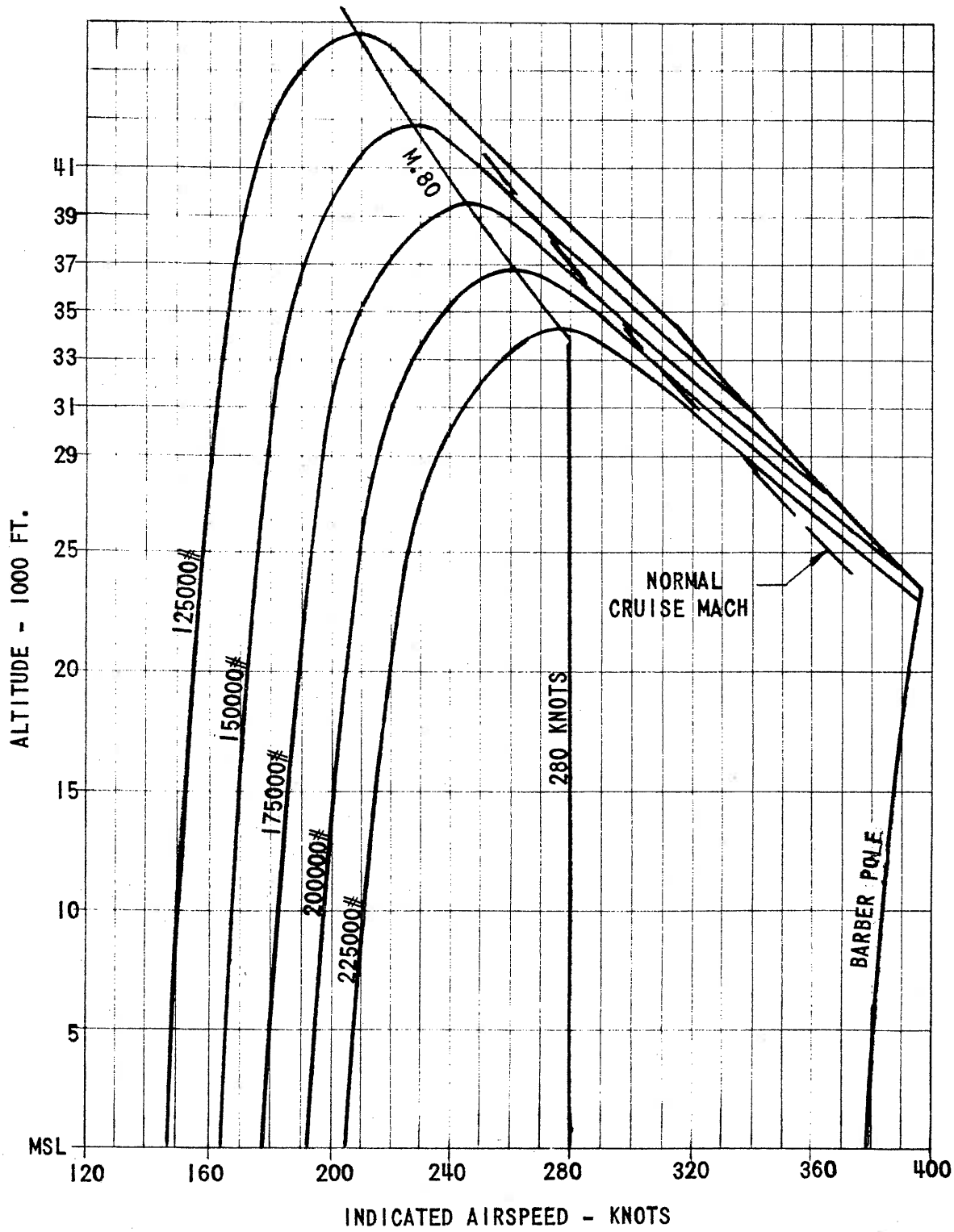

FIGURE 12

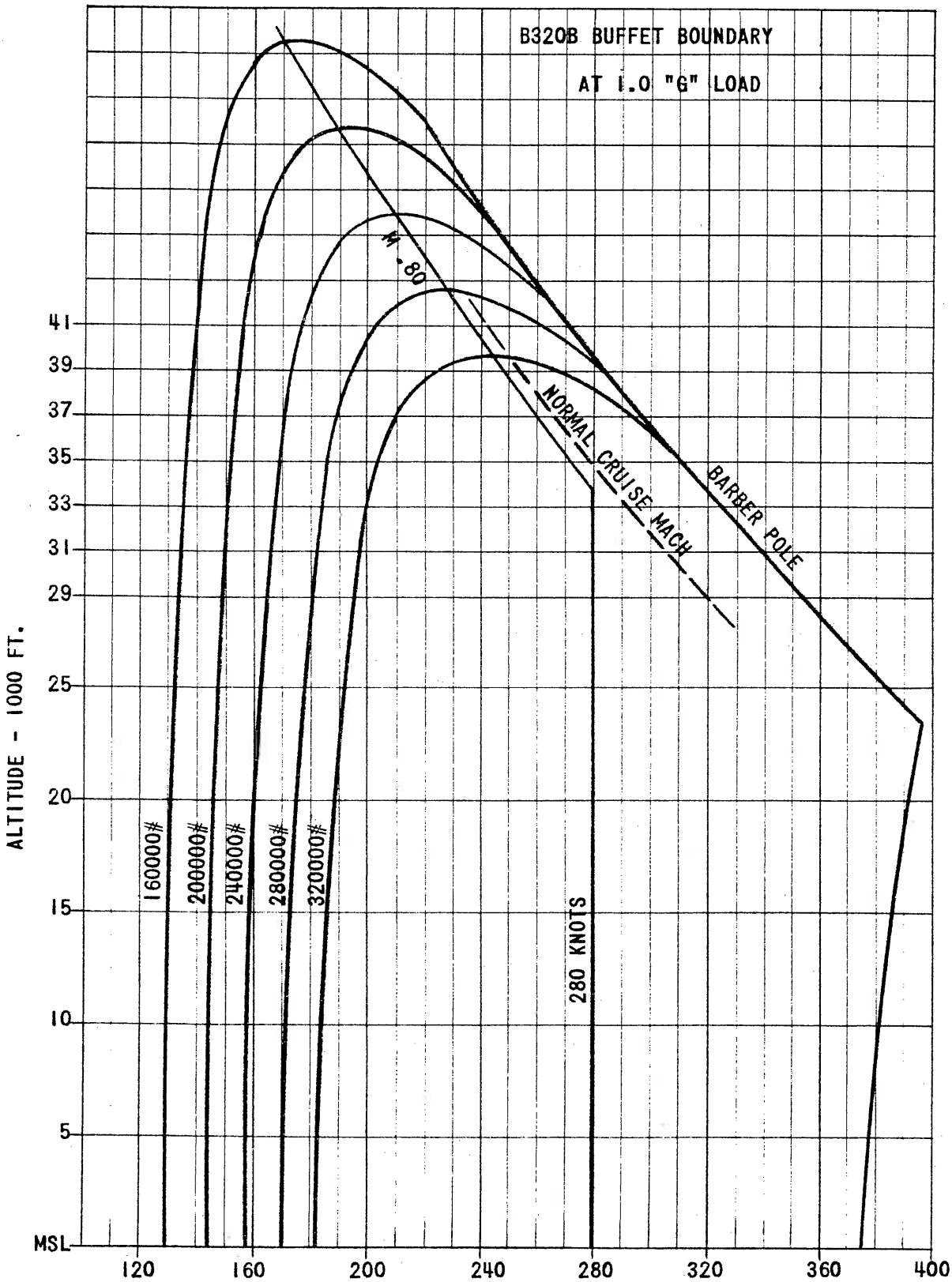
B320B BUFFET BOUNDARY
AT 1.0 "G" LOAD
M .80
NORMAL CRUISE MACH
BARBER POLE
160000#
200000#
240000#
280000#
320000#
280 KNOTS
ALTITUDE - 1000 FT.
41
39
37
35
33
31
29
25
20
15
10
5
MSL
120
160
200
240
280
320
360
400
INDICATED AIRSPEED - KNOTS

FIGURE 13

B320B BUFFET BOUNDARY
AT 1.5 "G" LOAD

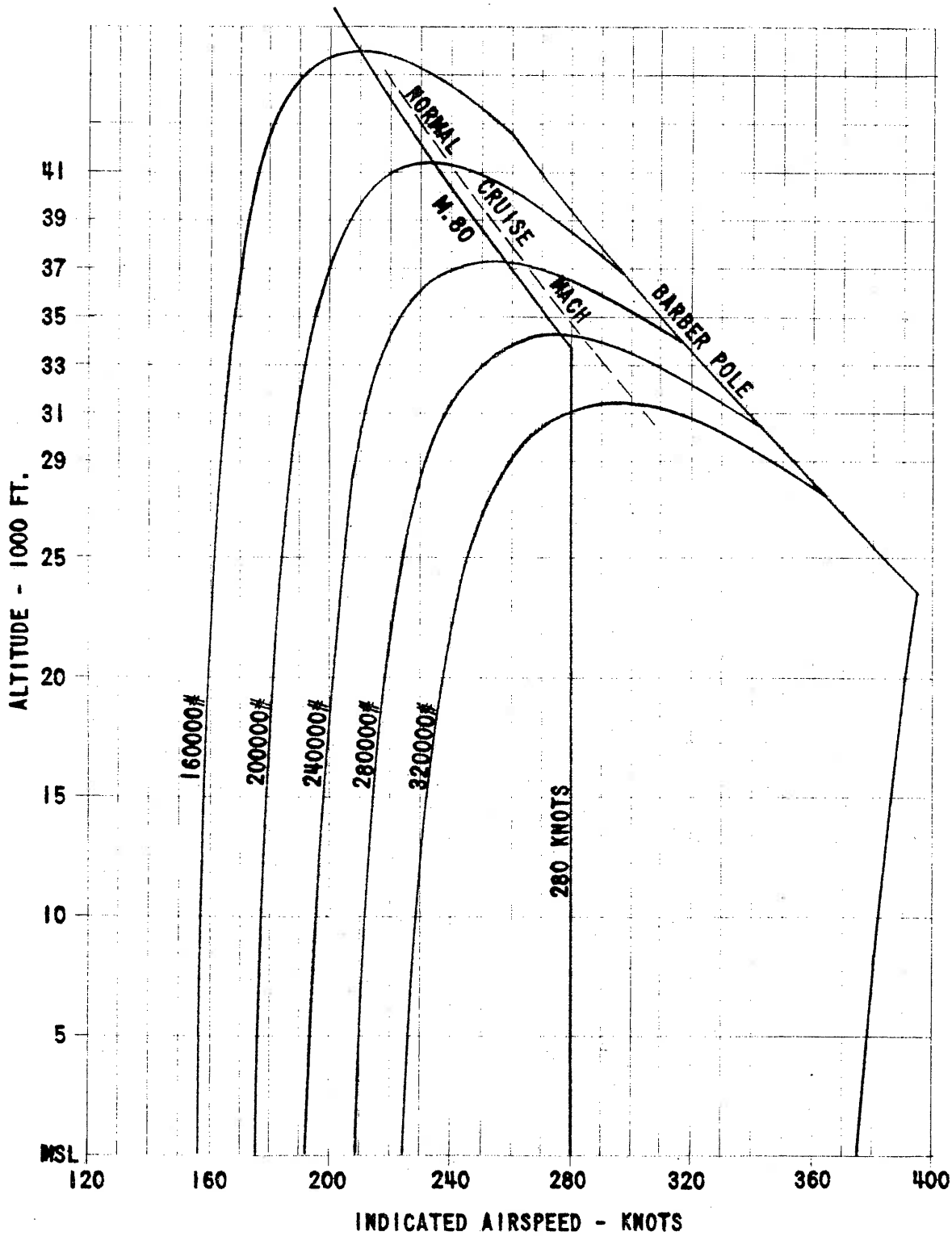

FIGURE 14

DC-8 BUFFET BOUNDARY
AT 1.0 "G" LOAD

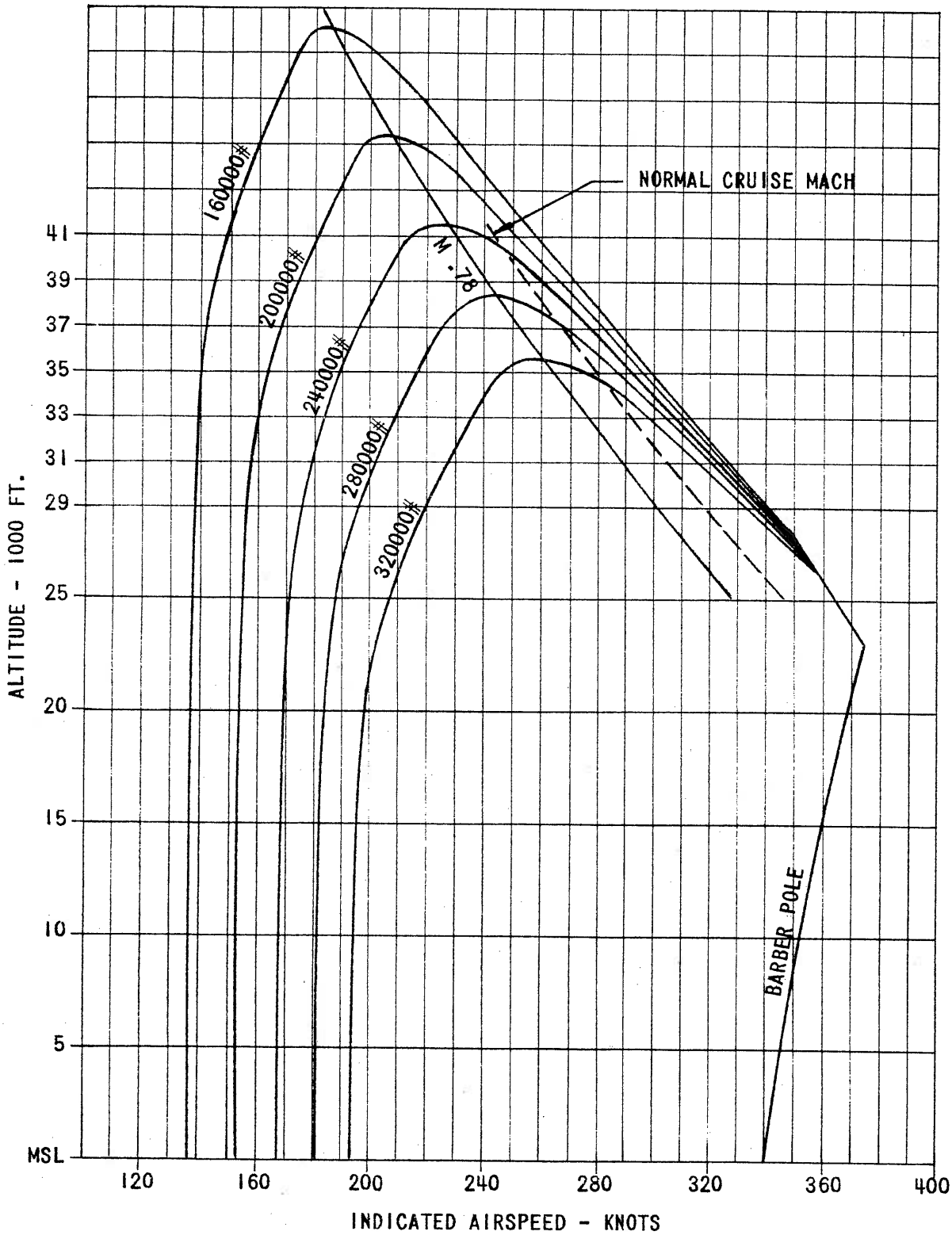

FIGURE 15

DC-8 BUFFET BOUNDARY
AT 1.5 "G" LOAD

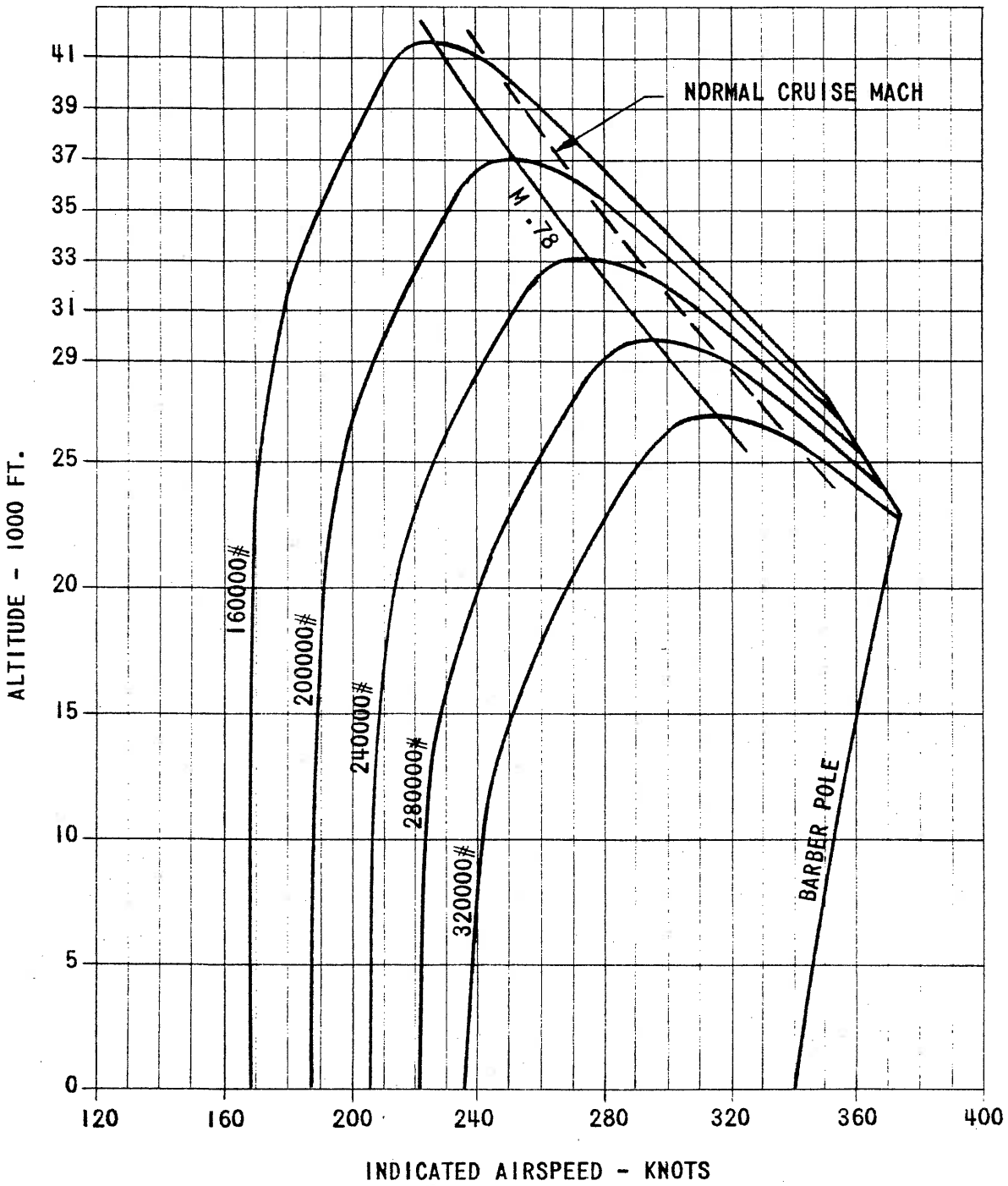

FIGURE 16