# Discussion and Status of the Proposed Revision (1978) to MIL-F-8785B

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ABSTRACT

This paper discusses the the proposed revisions to MIL-F-8785B contained in the February 1978 Working Paper distributed for industry review (Reference 1). Comments and questions received from various reviewers are used with second thoughts by the authors to indicate the status of the revision effort. The intent is to clarify the proposed changes and/or their rationale.

# I. INTRODUCTION

The current revision is the result of work done in the Control Dynamics Branch from 1973 through 1975. Various working papers were collected for internal review in early 1976, contributed by the following people:

J. Callahan, Maj USAF (currently assigned Columbus AFB, Miss.)

J. Lockenour (currently with Northrop Corp.)

D. Mayhew (currently with Draper Labs.)

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R. Quaglieri (currently with AFFDL/FGD)

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During the summer of 1977 the three authors of this paper reviewed the collection of working papers, revising and correlating the proposals into a single document. Following preliminary coordination meetings with the Navy (Dec 77) and ASD (Jan 78) the current working paper (Ref. 1) was issued for industry review. A primary object of the symposium in general and this paper in particular is to facilitate the review process. It is planned to draft an Amendment 3 to MIL-F-8785B, based on Reference 1 and the results of this symposium before the end of 1978.

# II. DISCUSSION

## II.1 General

A summary of the proposed revisions is given in Figure 1. It is acknowledged that other requirements also need revision, but those will not be discussed here. The second object of the symposium is to identify these remaining deficiencies and to discuss future requirements. Some of the revisions are general in nature and apply to various paragraphs. The terms "elevator," "aileron" and "rudder" have been changed to the more general notation of "pitch," "roll" and "yaw control". Also, requirements on control surface deflection have been deleted in favor of requirements relating aircraft response to pilot control input. Both of these changes admit the possibilities of advanced flight control systems - additional control surfaces and non-classical control responses. Each of the specific proposed revisions will now be discussed in order.

II.2 Scope and Classifications

1.1 Scope: The proposed definition mentions more explicit factors: inflight and on the ground, manned airplanes, speed at or above $V_{con}$ Also, in response to some industry suggestions, material which 8785B places in 6.1 has been incorporated here to give it more prominence.
1.2 Application: The changes are an attempt at clarification, not considered to involve any change in intent of the specification.
1.5 Levels of Flying Qualities: MIL-F-8785B contained a detailed turbulence model, the most common use of which has been in piloted simulation. However, there are few specific requirements on the use of the model, or on the effects on flying qualities of atmospheric disturbances in general. The revisions proposed here do not redress that deficiency. We have attempted, however, to recognize explicitly that atmospheric disturbances do affect flying qualities. It will be seen that a number of considerations bear on the form this change should take.

Chalk, et. al., discuss ways of correcting this deficiency (Reference 2), specifically in piloted simulation. They recommend that a pilot "fly" the aircraft in smooth air, light-to-moderate (i.e. most probable) turbulence and severe turbulence. The pilot would be informed of the expected frequency of encounter of the different turbulence values and would then give a composite or overall rating. This is felt to be still an indirect way of evaluating the effects of disturbances, requiring subjective pilot judgment; such judgments should be minimized (Reference 3).

In the proposed revision of this section, repeated here as Figure 2, the intent was to account for the effects of atmospheric disturbances in an explicit manner. If the pilot is instructed not to compensate mentally for the effects of the disturbances in his rating, then we have the basic use of the Cooper-Harper rating scale (Reference 3): the pilot is rating a given aircraft configuration to do a particular task in a certain atmospheric environment. In that respect, then, we would expect increasing disturbance magnitudes to worsen task performance and/or increase pilot workload to accomplish the task. These are the same as the qualitative effects of degrading basic airplane characteristics, heuristically leading to the form of the proposed revision given in Figure 2. This figure also shows the relation of this definition to Cooper-Harper ratings. The amount of allowable degradation at a given Level has an essentially subjective basis; for certain aircraft the procuring activity may desire to change that aspect of the Level definitions. It seems better for such judgments to be made by the Project Office than by individual evaluation pilots.

Now, let us consider an airplane design which is clearly adequate for its intended mission, i.e. "Level 1", and let us also consider the landing Flight Phase in the Operational Flight Envelope. In smooth air the task of landing this hypothetical aircraft should yield a Cooper-Harper rating better than 3.5. The rating should also remain better than 3.5 in disturbances up to LIGHT.* With greater, MODERATE* disturbances, glideslope tracking might degrade or pilot workload increase and the pilot rating for Level 1 would be allowed to degrade commensurately, but no worse than 6.5. Similarly, in SEVERE* disturbances the rating for Level 1 could degrade to worse than 6.5 but not beyond 9. This last statement is equivalent to requiring that a "good" or Level 1 airplane can be landed in something like a thunderstorm with reasonable confidence that the pilot will not lose control. To the authors this progression is logical and consistent with basic

*The terms LIGHT, MODERATE and SEVERE are intended to correspond to specific probabilities; $10^{-1}$, $10^{-3}$, and $10^{-5}$ are suggested, as defined in detail in Section 3.7. Such a footnote should be added to the proposed revision of 1.5.

flying qualities definitions. For an Aircraft Normal State, in the Operational Flight Envelope, the usual connotation of Level 2 and 3 numerical pilot ratings as requiring improvements would not necessarily apply to such effects of disturbances. A similar progression of the effects of disturbances is shown for airplanes which have less than Level 1 flying qualities in smooth air. In this case we have combinations of probabilities where the requirement is that, e.g. although a landing may be aborted, control must be maintained to make a go-around, "fly out of the disturbance."

In acknowledging the degradation in flying qualities due to atmospheric disturbances, we do not need to require that the airplane characteristics remain unchanged. Changes can occur due to basic non-linearities, augmentation saturation, etc. The point is that the proposal limits this degradation - it does not require degradation. This is consistent with the whole philosophy of MIL-F-8785B in presenting minimum acceptable requirements. The revision should not dissuade the use of gust alleviation or ride-smoothing systems - as now, the advantages and disadvantages of such systems must be weighed for each particular application. The procuring activity always has the option of increasing these minimum requirements, such as requesting all-weather capability. This could be achieved by a modified requirement, as illustrated in Figure 3. This example puts the design objective as maintaining basic flying qualities in disturbances up to values corresponding to a probability of $10^{-3}$.

A few last comments on the proposed changes to 1.5 - they are intended to be more a clarification than an amplification of requirements, they address recognized questions of interpretation. For piloted simulations, the problems of simulating turbulence, especially the higher intensities, are acknowledged. The acceptability of pilot ratings is a function of the intensity of turbulence, wind shear, etc, and the proposed revisions define this trend. Analytical evaluation of flying qualities is unchanged pending the development of quantitative criteria for aircraft response to disturbances. It is suggested that the proposed revisions form a framework for the development of such quantitative criteria. These could take the form of correlating pilot rating either with aircraft responses at the different levels of disturbance or with calculated pilot compensation to keep the responses within acceptable levels. Lastly, it is believed that evaluation of flying qualities in flight test will be aided, not hampered, by the proposed revisions. The proposal could be used to assess correctly a flight that "finds" turbulence (using weather information for the location). There is no requirement to fly in thunderstorm turbulence to demonstrate compliance with MIL-F-8785B, nor will there be a requirement to demonstrate compliance with all of the proposed 1.5 in-flight test. Flight test requirements will be determined by the procuring activity, as they are now.

This extended discussion of the proposed 1.5 was prompted by comments that ranged from unequivocal disagreement, through questions, to agreement.

II.3 General Requirements

3.1.1 Operational Missions: The proposed changes are an attempt to clarify the intent of the paragraph.

3.1.3 Moments and products of inertia: A semantic change to include products of inertia (if the paragraph is necessary).

3.1.9 Permissible flight envelopes: This proposed change will require the contractor to define the permissible flight envelope, in order to avoid any undue restrictions. It is recognized that this change is primarily oriented to advanced fighter configurations, whereas transports are likely to use the same limiting factors as presently in MIL-F-8785B. The present requirements could, therefore, be included in a back-up document (an updated version of Reference 4).

3.1.10 Application of Levels: The changes proposed for this paragraph are to make it consistent with changes in 1.5 and 3.4.11. Acceptance of the changes will therefore depend on acceptance of the other paragraphs.

## II.4 Longitudinal Requirements

3.2.1.1 Longitudinal static stability: This proposal explicitly allows zero control gradients with artificial speed stability and, more significantly, also static instability for Level 3. For Levels 1 and 2 the basic requirement remains that "there shall be no tendency for airspeed to diverge aperiodically...". As stated in Reference 1, zero control gradients were not intended to be excluded by MIL-F-8785B. The second item is just to catch up with the facts represented by the success of the F-16 and many simulation results ground-based and flight. The proposals have so far received qualified approval.

One reason cited for the conservatism of the present requirement is to allow margin for design error and for operational growth. The proposed relaxation thus places more stringent responsibilities on both designers and users.

3.2.2.1.3 Higher order dynamic systems: This new paragraph was proposed for certain configurations as an alternative to the short-period requirements currently in MIL-F-8785B. Although the exact numerical boundaries have been challenged (see e.g. Reference 5), the current requirements are reasonably well supported for classical configurations, in which the short-term response is governed by a single pair of complex poles. A frequent product of advanced control systems is a higher-order dynamics system such that there is no unique "short-period" mode. The proposed revision uses a second-order transfer function to define an equivalent short-period mode and a corresponding first-order numerator with an added pure time delay for pitch response. The proposed boundaries were derived from the Neal-Smith criterion of Reference 6. Reference 1 suggested another form of the Neal-Smith criterion for consideration. As-yet-unpublished correlation work in AFFDL/FGC indicates problems with this alternate criterion. A better alternative may be stated in terms of the required bandwidth and allowable peak overshoot and droop - the closed-loop parameters which Neal and Smith suggested that pilots use to adjust their dynamic response (Reference 6). Additional data for other Flight Phases and other airplane Classes, and for Level 3 generally is needed.

3.2.2.2 Control feel and stability in maneuvering flight at constant speed: This proposal would remove the requirements on control surface deflection, provided that the pilot control force and deflection are stable. This allows an unstable airframe, with stability provided through an augmentation system, although the consideration of a Special Failure State (3.1.6.2.1) still applies. Control margin then becomes a safety consideration; see the proposed paragraph 3.4.11.

3.2.2.2.1 Control forces in maneuvering flight: The proposed change defines a range over which linearity is expected. As pointed out in a comment, a limit of 3 g would be inappropriate at lower speeds. We recommend, therefore, that the upper limit for Class IV be made the same as the other Classes. We feel that in arriving at this suggested change we have given consideration to opposing points of view regarding control-force linearity.

For Level 3, the present 3 lb per g limit would seem to serve the B-1 better than the proposed 2 lb per g.

3.2.2.2.1.1 Sidestick controller forces: This proposed paragraph does little more than recognize the existence of sidestick controllers, because there is insufficient data to support definitive requirements. AFFDL/FGC is currently assembling such a data base; results to date are presented elsewhere in this report. (Interestingly one comment supports having only qualitative requirements.)

3.2.2.2.2. Control Motions in maneuvering flight: A minimum force per deflection gradient is added for sidestick controllers.

3.2.2.3 Compatibility of steady maneuvering forces and pitch sensitivity: This proposed new paragraph repeats the Control Anticipation Parameter (CAP) or $\omega^2 n_{sp}/n_\alpha$ values of the current short-period requirements (3.2.2.1.1). The application here is to aircraft response to control input (independent of the short period requirements). As stated in Reference 1, this requirement is added here so as to apply where the proposed 3.2.2.1.3 is used in place of the current short-period requirements.

3.2.2.4 Longitudinal pilot-induced oscillations through 3.2.2.4.3 Control system phase lag: These expanded PIO requirements are from work by Ralph Smith (Reference 7). Comments received to date indicate acceptance qualified by lack of both prior knowledge of, and experience with, the requirements.

An effort is currently underway in AFFDL/FGC to verify both the theory and its use for design requirements. If certain pre-conditions are satisfied, the final criterion of Smith's theory requires that the phase margin of the normal acceleration at the pilot station to stick force transfer function (with pilot delay of 0.25 secs) should be positive to preclude PIO. Figure 4 shows the mimimum phase of the above transfer function versus PIO pilot rating for the LAHOS data (presented elsewhere in this report). The trend is obviously correct, however a first impression is that the criterion may be overly conservative. This validation work is continuing, and the results will be published as soon as appropriate.

3.2.3.5 Longitudinal control forces in dives - Service Flight Envelope: A minor change to make control forces for one-handed wheel operation the same as for center-stick operation.

## II.5 Lateral-directional requirements

We still do not know enough to write a good Dutch roll requirement. It is generally a nuisance mode; perhaps delineating what is not satisfactory, acceptable, or safe is more difficult than stating what is needed. Further, the typical roll and Dutch roll modes both have significant short-term responses - thus a larger number of parameters must be considered together than for longitudinal motion. The present requirements on lateral-directional dynamic response characteristics, though overly complex, provide only fair boundaries even for classical types of response. Suggestions for improvement have tended to increase complexity rather than to simplify. So for now we do what we feel we can do to upgrade the existing requirements.

For all the dynamic requirements, the data base consists almost entirely of configurations which have characteristics which do not change drastically from controls-free to controls-fixed. With modern flight control systems this is no longer the only viable design alternative, and one might ask what consequences such changes in dynamics hold for flying qualities requirements (both longitudinal and lateral-directional).

3.3.1.1 Dutch roll: The numerical Dutch roll changes are those recommended by Calspan (Reference 2). Also, by deleting the requirement for control-surface-fixed Dutch roll stability we eliminate a roadblock to relaxed static stability. The possibility of increased stability augmentation reliability, we feel, warrants at least allowing such measures to be considered in design trade-offs. The same caveats apply as in the longitudinal case.

3.3.1.3 Spiral stability: The changes to spiral stability requirements also are the Calspan recommendations (Reference 2).

3.3.1.4 Coupled Roll-spiral oscillations: The coupled roll-spiral oscillation boundaries are based on the data presented in Reference 2, but it was felt that lines of constant better fit that data. As pointed out in the proposed change material, some autopilot and low-maneuverability control wheel steering modes inherently produce roll-spiral coupling in order to improve stabilization, control and ease of piloting.

## II.6 Roll Control Requirements

There have been a number of complaints that the roll response requirements of MIL-F-8785B are too stringent at the extremes of the flight envelopes. Furthermore, there has also been a reluctance to accept literally that those roll requirements apply throughout the applicable load factor range. There is also some confusion caused by an apparent conflict with the flight loads specification (MIL-F-8861) which only requires full control 360° rolls at one g load factor. The revisions proposed are in response to the above concerns.

The references to "$V_{o_{min}}$" and "$V_{min}$" in the speed range portions of the proposed revisions should be changed to "V at $n_o(+)$" and "V at n(+)" to agree with the definitions of section 6. That is, the speed ranges are intended to exist at all applicable normal load factors as functions of the speed-load factor boundaries at a given altitude.

3.3.4 Roll control effectiveness: The proposed format modification leaves only Classes I and II in this paragraph. The specification values are unchanged from MIL-F-8785B, primarily because of a lack of data, although one reviewer suggests that the Class II requirements are too stringent.

3.3.4.1 Roll performance for Class IV airplanes through 3.3.4.1.2 Roll performance in Flight Phase GA: The Class IV requirements are the most extensively modified, but the change is not as massive as it would seem from the increase in the size of the section. The requirements are adjusted to relax the requirements at the speed extremes and the bank angle change has been modified to be compatible with the speed at which the roll performance will be demonstrated. Maybe more importantly, the requirements are clearly applied with respect to aircraft load factor. The roll performance for 360 degree rolls are proposed to apply only at one g which, because it agrees with the current requirement in the loads specification, can be tested without special planning in a typical test program. The roll performance requirements at elevated load factor are proposed as bank-to-bank rolls through bank angles of 180 degrees or less. These rolls will be initiated at load factors up to the maximum for the applicable flight envelope. No change has been proposed for the roll-pitch-yaw coupling paragraph (3.4.4) though this is an important interface with the structural laods functional area which will be addressed in future work.

3.3.4.2 Roll performance for Class III airplanes: The Class III requirements also have been adjusted to relax the requirements at the speed extremes and to make the bank angle change compatible with the speed at which the roll performance would be demonstrated.

3.3.4.5 (Old) Rudder-pedal-induced rolls: The proposed revision eliminates the roll-rate-due-to-rudder requirement. This was done as a result of pilot comments which indicated that some tasks were easier if the aircraft had no roll due to sideslip. The elimination led to a comment that perhaps the requirement should be retained to apply only to single-seat aircraft. In any event, little data exists to support any requirement and the subject of whether to limit the amount of roll due to rudder or sideslip has not even been addressed.

## II.7 Control System Requirements

3.4.11 Control margin: This new paragraph is proposed mainly to complement other changes. With an unstable airframe now allowed, we must ensure that control authority and rate are sufficient to provide stability under all reasonable conditions and also to recover from almost any upset and departures from controlled flight. Comments show general acceptance of the proposal.

3.5.3 Dynamic characteristics: The current 3.5.3 and 3.5.3.1 are restated in the proposal, as requirements on the relation between airplane response and controller inputs. One negative comment received was to delete the "guide for airplanes with simple, conventional control systems." The "guide," retained from MIL-F-8785B Table XIII, was added back into the 1977 version of Reference 1 at the suggestion of the Navy based on their experience. In addition, the caveat on "simple conventional control systems" may be unnecessary.

3.5.5 Failures: A restatement of the same requirements, plus explicit mention of configuration change as a way of adapting to a failure situation.

3.5.5.1 Failure transients: This proposal changes the requirements so that, for Level 1 conditions after the failure, the allowable transients are the same as for Level 2. Additional limits are also stated for bank angle and vertical and lateral translations. For the Level 1 condition the requirements are far less severe. Comments on the proposal include a suggestion for limits on angle of attack and sideslip, and a suggestion for less severe requirements for Level 2 conditions.

3.5.6 Transfer to alternate control modes: A restatement of the objective without specific "how-to" requirements.

3.5.6.1 Transfer transients: The proposal is for less severe requirements, consistent with the changes to 3.5.5.1.

3.6.1 Trim system: A minor clarification - the Level 3 requirement applies to steady-state not transient forces.

3.6.1.2 Rate of trim operation: The proposed change directs center-stick control force limits for one-handed wheel operation.

3.6.3 Transients and trim changes: Minor changes for clarification.

## II.8 Atmospheric Disturbance Model

The initial approach was to use the disturbance model in MIL-F-8785B and revise it only where necessary. A major deficiency of that model is its characteristics at low altitudes. The proposed solution is to provide a model specifically for low altitudes based on the assumption that the terminal Flight Phases are separated from other Flight Phases in simulation, in analyses and also in flight test, to large degree. It is believed that the changes made (with the exception of terminology changes) were necessary to upgrade the existing model while still retaining the philosophy of presenting minimum acceptable requirements. More sophisticated (complex) disturbance models are available, e.g. References 8 and 9, and their use is certainly not discouraged.

A second change is to give three values of the disturbance intensities, LIGHT, MODERATE and SEVERE. These terms correspond to specific probabilities to be used in defining explicitly (together with the proposed 1.5) the effects of disturbances on flying qualities. In general, the proposed changes are consistent with the changes to 1.5 and the previous discussion applies here also. General acceptance of all the proposed disturbance model may depend on acceptance of 1.5.

3.7.1 Use of environmental models: The change to this paragraph introduces the use of a model specifically for low altitudes. It also dictates consideration of changes in altitude for the low altitude Flight Phases. In the following changes the original model in MIL-F-8785B (3.7.2 through 3.7.4.2) is basically the medium/high altitude model of the revision (3.7.2 through 3.7.3.4).

3.7.2.3 Discrete gust model: The "1 - cosine" gust of MIL-F-8785B has been retained, although half a period is specified. This makes the gust model more general. With the right parameters, for instance, the discrete gust can represent a simple wind shear. In a different application, a pair of gusts can be used with the spacing chosen to produce the largest disturbance. This approach is illustrated in Figure 5, and is based on the work of Jones of the RAE. The remaining deficiency appears to be a lack of quantitative requirements for the allowable responses (discussed in Section III.4, Vol. II, Reference 1).

3.7.3.2 Turbulence intensities: The turbulence intensities proposed for the three probabilities are consistent with other models, such as MIL-F-9490D. The proposed variation with altitude, however, is an obvious simplification. With the possibility of wide variation in local conditions, the use of complex curves for global average does not seem justified. According to Reference 10, the probabilities tabulated in MIL-F-9490D were calculated using MIL-A-008861A values of proportions of flight time in nonstorm and storm turbulence at a given altitude, and also the expected values of intensity in nonstorm and storm turbulence at that altitude.

Several questions might be raised. One is nomenclature, equating intensity to probability: for example in Figure 4, Reference 1, LIGHT turbulence does not exist above 30,000 ft. Related is the alternative of stating intensity per se. Reference 2 points out that the expected value of nonstorm turbulence, once it is encountered, is relatively invariant with altitude. It is the probability of finding turbulence at all that varies with altitude. For flying qualities evaluation they recommend this value, around 2.3 ft/sec as "light-to-moderate turbulence which [the pilot] is likely to encounter," plus more severe turbulence. Then the proper values of either intensity or probability must be chosen.

3.7.3.4 Gust magnitudes: A major inclusion in the proposal is severe discrete gust values to be consistent with structural requirements. This change is intended to ensure that control can be maintained even in large disturbances. It would be impractical to show compliance with this requirement in flight test, and probably also in a simulator. It is suggested that compliance be shown analytically.

3.7.4 Low altitude environmental model: This paragraph introduces the requirement to consider the cumulative effects of wind shear, turbulence and gusts - defined in the following paragraphs. Reference is made to the use of non-Gaussian turbulence models. In particular, Jones' Discrete Gust Spectrum model is much better developed now than it was when Reference 1 was first drafted in 1975.

3.7.4.2 Wind shear: A simple logarithmic profile is specified to provide a natural variation of wind speed with altitude. Either a discrete gust or vector shear can be used to evaluate the effects of the more unusual or extreme wind shears, in the absence of more definitive models.

3.7.4.3 Vector shear: This paragraph was added to produce variations representative of the more unusual wind conditions such as may be produced by frontal conditions, temperature inversions, thunderstorm gust fronts, etc.

3.7.5 Application of the environmental models in analyses: For the medium/high altitudes this paragraph is unchanged from MIL-F-8785B. The proposed change is to require the turbulence axes to be referred to the mean wind direction at low altitudes. This is consistent with the definitions of measured turbulence velocity components. The angular velocity perturbations are retained in aircraft body axes, however, because the expressions used are simple approximations.

## III. CONCLUDING REMARKS

This paper summarizes revisions proposed for MIL-F-8785B, "Military Specification, Flying Qualities of Piloted Airplanes." Additional justification has been added to answer comments already received. It is intended to stimulate discussion and hopefully it will help to finalize industry coordination of the proposed revisions. With industry and government agreement, Amendment 3 to MIL-F-8785B will be drafted as soon as possible.

IV. REFERENCES

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| | |
|---|---|
| 1.1 | Scope - clarification |
| 1.2 | Application - guidance on add'l rqmts; mentions 9490 & 18244 |
| 1.5 | Levels - while the Levels must apply to the flight vehicle being procured, there is recognition that atmospheric disturbances themselves degrade flying qualities. |
| 3.1.1 | Operational Missions - clarification |
| 3.1.3 | Moments and Products of inertia - $I_{xz}$ added |
| 3.1.9 | Permissible Flight Envelope - left for contractor to define |
| 3.1.10 | Appl. of Levels - accounts for atm. disturbances in 1.5 |
| 3.2.1.1 | Longitudinal static stability - allows a degree of divergence for Level 3 |
| 3.2.2.1.3 | (New Higher order systems - an equivalent classical systems approach to short-period dynamics when FCS adds roots, or an alternative Calspan formulation of the Neal-Smith criteria |
| 3.2.2.2 | Maneuvering flight - allows basic airframe instability at procuring activity's discretion (3.1.6.2.1, Special Failure States); rqmts refined, side stick recognized. |
| 3.2.2.4 | Longitudinal pilot-induced oscillations - Ralph Smith's criteria |
| 3.2.2.5 | Longitudinal force in dives - refined |
| 3.3.1.1 | Dutch roll - refined; surface-fixed stability rqmt deleted |
| 3.3.1.3 | Spiral stability - refined |
| 3.3.1.4 | Coupled roll - spiral oscillation - allowed, within $\zeta\omega$ limits |
| 3.3.4 | Roll control - reorganized, refined; rqmts lessened near flt envelope boundaries |
| 3.4.11 | (new) Control margin - controllability of "control-configured vehicles" |
| 3.5.3 | Dynamic characteristics - refined; the specified values of lag are not always vlaid |
| 3.5.5 | Failures - recast; ± .5g transient (instead of ± .05g) if Level 1 is retained after the failure |
| 3.5.6 | Transfer to alternate control modes - recast; 0.1g transient (instead of 0.05g) allowed in Operational Flt Envelope |
| 3.6.1 | Trim system - Refined |
| 3.6.2 | Speed and flight-path control devices - clarified |
| 3.6.3 | Transients and trim changes - adds thrust reverser; refined |
| 3.7 | Atmospheric disturbances - refined discrete gust model, using maxim from structural spec; "light,""moderate," "severe" intensities defined; wind logarithmic shear & vector shear added to low altitude model |
| 6.1 | Intended use - refined |

Throughout - change "elevator, aileron, rudder" to "pitch, roll, yaw controls"

Figure 1. Summary of Proposed MIL-F-8785B Revisions

| COOPER-HARPER RATING* | | ATMOSPHERIC DISTURBANCES | | |
|---|---|---|---|---|
| | | LIGHT | MODERATE | SEVERE |
| 1-3.5 | Level 1 | Flying qualities clearly adequate for the mission Flight Phase | Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate, or both. Category A Flight Phase can be terminated safely, and Category B and C Flight Phases can be completed. |
| ≤ 6.5 | Level 2 | Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed | Flying qualities such that control can be maintained long enough to fly out of the disturbance. |
| ≤ 9 | Level 3 | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed. | Flying qualities such that control can be maintained long enough to fly out of the disturbance. | No requirement |
| ≤ 10 | | | | |

* If Pilot does not mentally compensate for effects of turbulence, etc.

Figure 2 Proposed Levels of Flying Qualities with Atmospheric Disturbance Effects

ATMOSPHERIC DISTURBANCES

| LEVEL | LIGHT | MODERATE | SEVERE |
|---|---|---|---|
| 1 | Flying qualities clearly adequate for the mission Flight Phase | Flying qualities clearly adequate for the mission Flight Phase | Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists |
| 2 | Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists | Flying qualities adequate to accomplish the mission Flight Phase, but some increase in pilot workload or degradation in mission effectiveness, or both, exists | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed |
| 3 | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed | Flying qualities such that the airplane can be controlled safely, but pilot workload is excessive or mission effectiveness is inadequate or both. Category A Flight Phases can be terminated safely, and Category B and C Flight Phases can be completed | Flying qualities such that control can be maintained long enough to fly out of the disturbance |

Figure 3. Possible Flying Qualities Levels for 'All-Weather' Aircraft

Solid symbols may be pitch sensitivity not PIO.

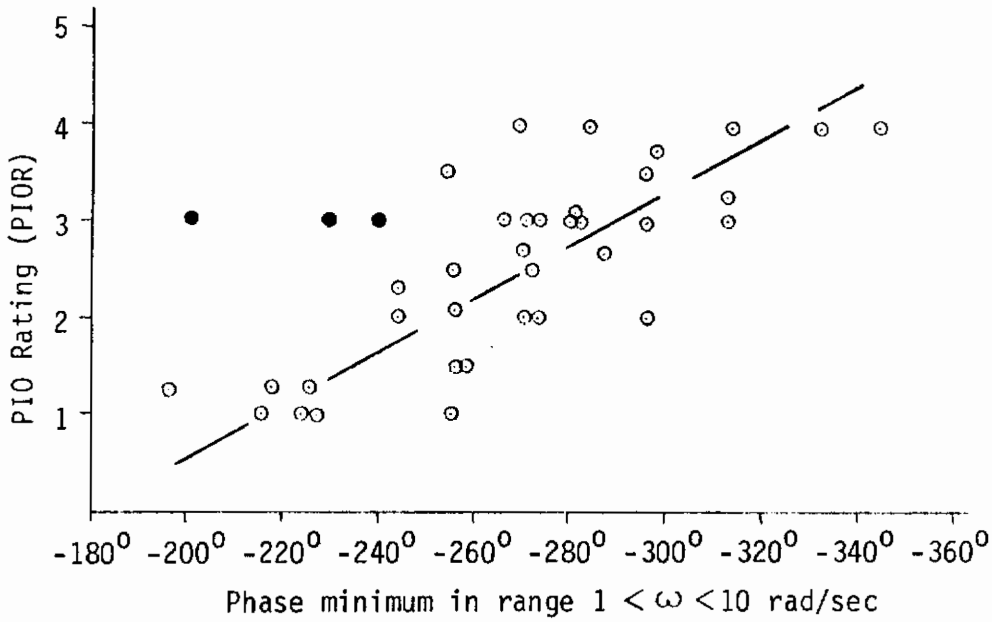
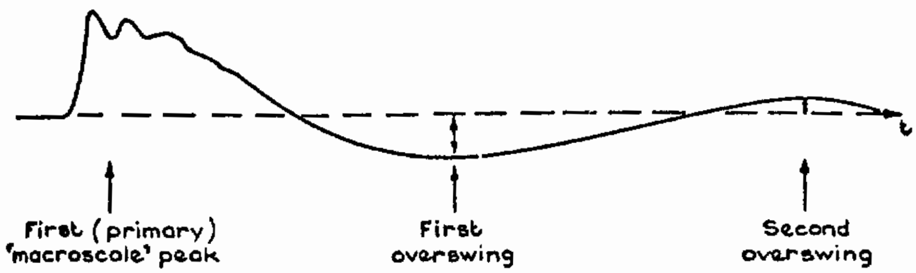
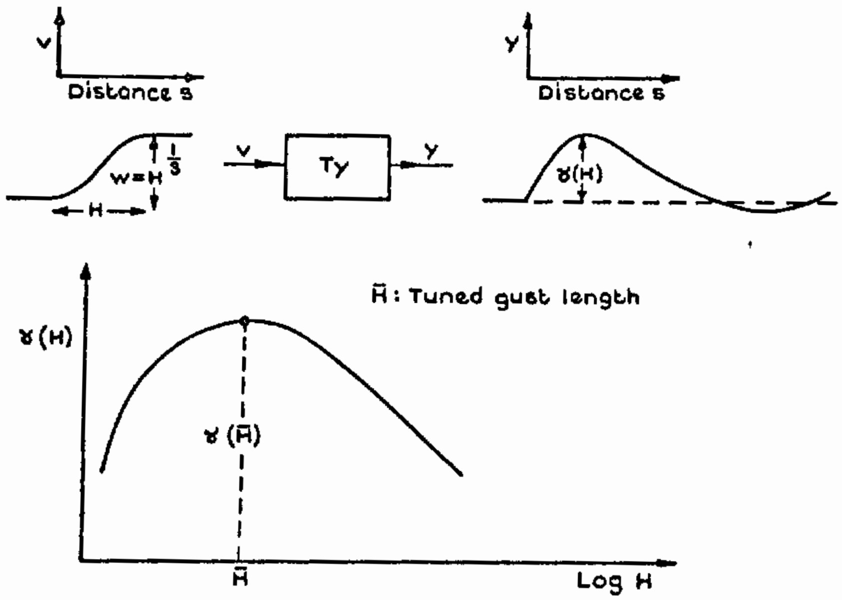


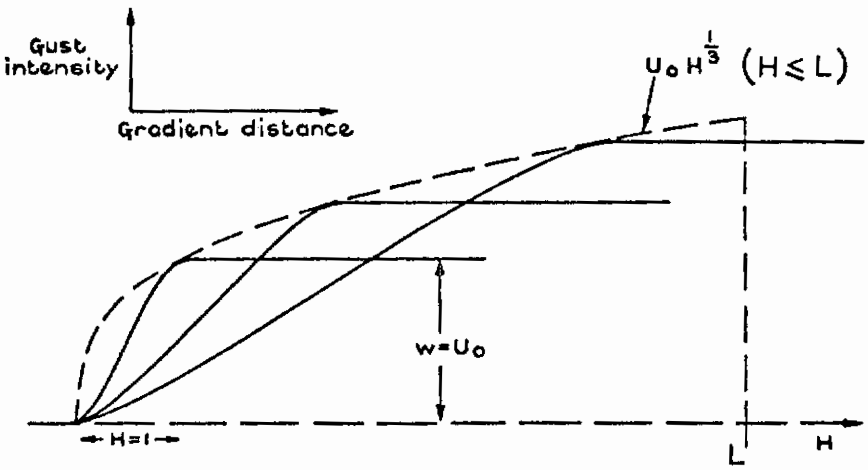

Figure 4. Correlation of $\frac{a_{z_p}}{F_s}$ phase margin with PIO rating.




Typical transient response to discrete-ramp gust illustrating overswings




Discrete-gust response function




Family of equiprobable ramp gusts defined for $H \leq L$ by intensity parameter $U_0$

Figure 5. Discrete gust application of Jones

Don West, Boeing: The flying qualities pilot rating may degrade in moderate or severe turbulence but it is not necessarily so.
Answer: That is correct and the figure may not make that clear. The proposal is to allow some degradation but not require it.

Bud Iles, Grumman: The probability of turbulence varies all over the world. It is possible that a Level 1 aircraft may have to operate in a turbulent area but could handle poorly. I am concerned that it may be a problem just landing.
Answer: What you say is true, but we cannot design an airplane for an individual airport. The turbulence values used in the specification are global averages.

Capt Roy Martin, AF Flight Test Center: After giving the pilot rating, who makes the recording of the turbulence levels?
Answer: I think the engineer should be responsible for correlating the results with the turbulence or the weather for the particular flight.

Jerry Lockenour, Northrop: I do not think a pilot can figure the level of turbulence.
Answer: I agree, the pilot should not try.

Chick Chalk, Calspan: Will the pilot try to compensate for the turbulence or will he rate to the same standards regardless of the environmental conditions?
Answer: I am not really sure of the answer, but I believe the pilot should be required to rate the task performance and not try to mentally compensate for the disturbances.

Dwight Schaeffer, Boeing: I believe there are two errors in the proposed disturbance model. The angular velocity turbulence inputs are wrong, and second, for the low altitude model the axis system should be aligned with the relative wind vector not the actual wind vector.

Answer: I agree that the angular velocity turbulence expressions are crude approximations in lieu of something better; this is mentioned in the revision document. I am not sure I agree with the second point but it will be checked.

Bud Iles, Grumman: I have some questions about the proposed disturbance model. Are gusts in constant directions? Are low altitude gusts in the same direction? What are the gusts for severe turbulence? I think the requirements may be too lenient.
Answer: The turbulence model provides gust inputs in the three axes; the relation between these inputs is a function of altitude close to the ground. Also included at low altitude are winds, wind shear and changes in wind direction as functions of altitude. The severe disturbances are equivalent to typical thunderstorn intensities, so I do not think it is lenient.

John Schuler, Boeing: In severe turbulence aren't we relaxing the requirements so that the designer will always provide the minimum, i.e., a pilot rating of 6.5 in moderate disturbances?
Answer: In a sense the specification provides only minimum requirements. This does not prevent better flying qualities being designed in, for instance a gust alleviation system could still be used if justified for a particular design.

Chick Chalk, Calspan: What if the aircraft must have clearly adequate flying qualities in the moderate or severe disturbances.
Answer: The procuring activity will always have the option of increasing the requirements, either by lowering the probabilities associated with the moderate and severe disturbances or by altering the progression of allowable degradation from light to moderate to severe disturbances.