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WIND SHEAR PROCEDURES AND INSTRUMENTATION

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A recent study by Dr. Angelo Miele and the Aero-Astronautics Group of Rice University entitled "Effect of Pitch Rate on Abort Landing Windshear Encounters" shows that high pitch rates (greater than 3/4 degrees per second) will adversely affect flight path performance in strong wind shears close to the ground (Figures 1 through 5). This study of a typical jet transport aircraft for the landing case is an offshoot of the Optimal Trajectory Studies by the Rice University group which is funded in part by NASA Langley under the direction of Dr. Roland Bowles.

This should call to question the advice in the FAA Wind Shear Training Aid (WSTA) for pilots to rotate "at a normal rate" to a prescribed pitch, a procedure known as the constant pitch technique which was also used for the Rice University study. "Normal rate" is defined and understood by pilots to be 2 to 3 degrees per second which is much too fast for the landing case in a severe shear. In modest wind shears, pitch rate has little effect upon flight path performance. A higher pitch rate may be required for initial rotation at takeoff, but for encounters after takeoff an initial pitch reduction followed by a gradual pitch increase more closely approximates an optimal trajectory.

Borrowing a figure from Dr. Rene Barrios' presentation (Figure 6) which is in close agreement with the optimal trajectory studies at Rice University, it is evident that his altitude profile for deliberate flight at the stick shaker angle of attack (curve no. 2) is a very poor strategy. One must question then the advice from the WSTA to remain at the stick shaker angle of attack after it is initially encountered.

A new study by the Rice University group, yet to be published, should reveal the optimal trajectory after reaching the stick shaker angle of attack. This study is also an offshoot of the optimal trajectory studies and is funded by the Aviation Research and Education Foundation.

Examination of Barrios' curve no. 4 (constant pitch technique) shows that in this very strong wind shear there comes a time when the pitch can no longer be maintained at the prescribed value of 15 degrees and the flight path becomes negative. This effect is also shown in Dick Bray's paper. However, the WSTA tells a pilot that if at the target pitch and if the flight path is not satisfactory then the pitch should be increased. This can be an impossible task which holds out a false hope to pilots.

A correlation is shown in Figure 7 between aircraft performance and the F factor where aircraft performance is described by a constant airspeed. Also shown (Figure 8) are some limiting conditions of aircraft performance which reveal some values far

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below the planned alert level of some aircraft warning systems. As pointed out by Dr. Bowles, in a wind shear an aircraft can in fact escape a condition exceeding the limiting value by trading airspeed. Nevertheless, some consideration to these limiting conditions should be given when designing alert levels and in prescribing escape procedures, especially recommendations to not change the high drag landing flap configurations in some cases.

What pilots want in wind shear instrumentation is a device which assists us. We will know about meteorological and operational conditions which the machine is not going to know. We do not need a decision maker, but rather an information device. Some devices, designed to not have false alarms, in fact do not have false alarms, but they do not protect against wind shear encounters. Others which do protect may have nuisance alerts. We accept this as long as we evaluate the alerts and use our judgement. We also want alerts on positive performance encounters and when on the ground.

WDC01

Effect of Pitch Rate on Abort Landing Windshear Encounters

by

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WDC1

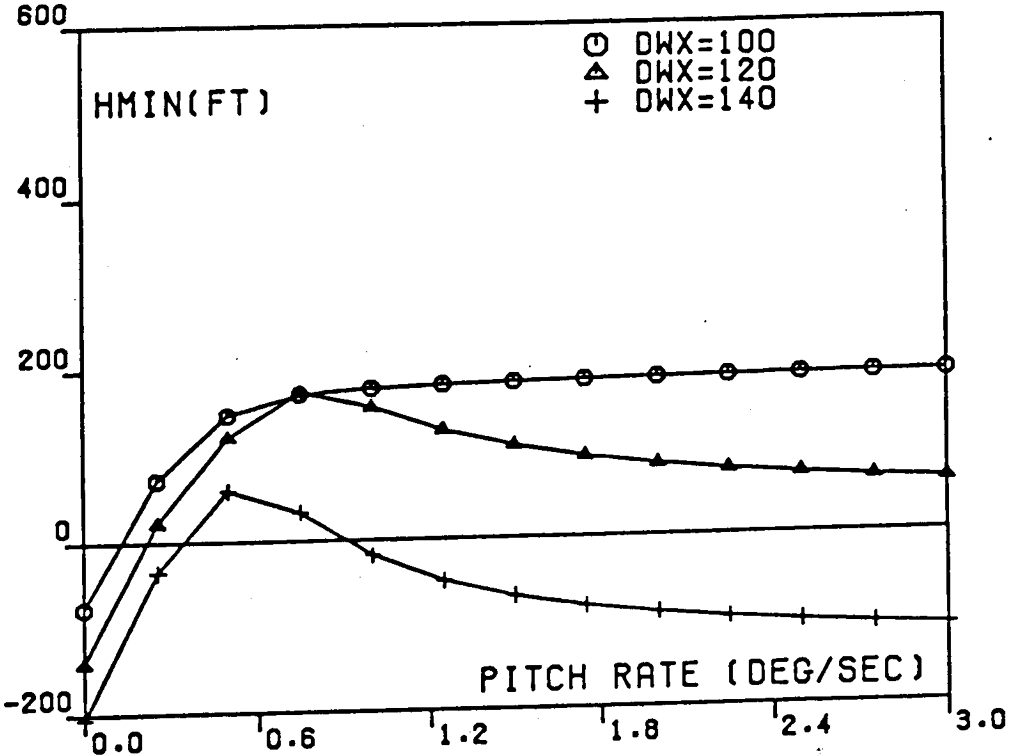


FIG. 3A. HMIN FOR DT = 0 SEC
AND HO = 200 FT.

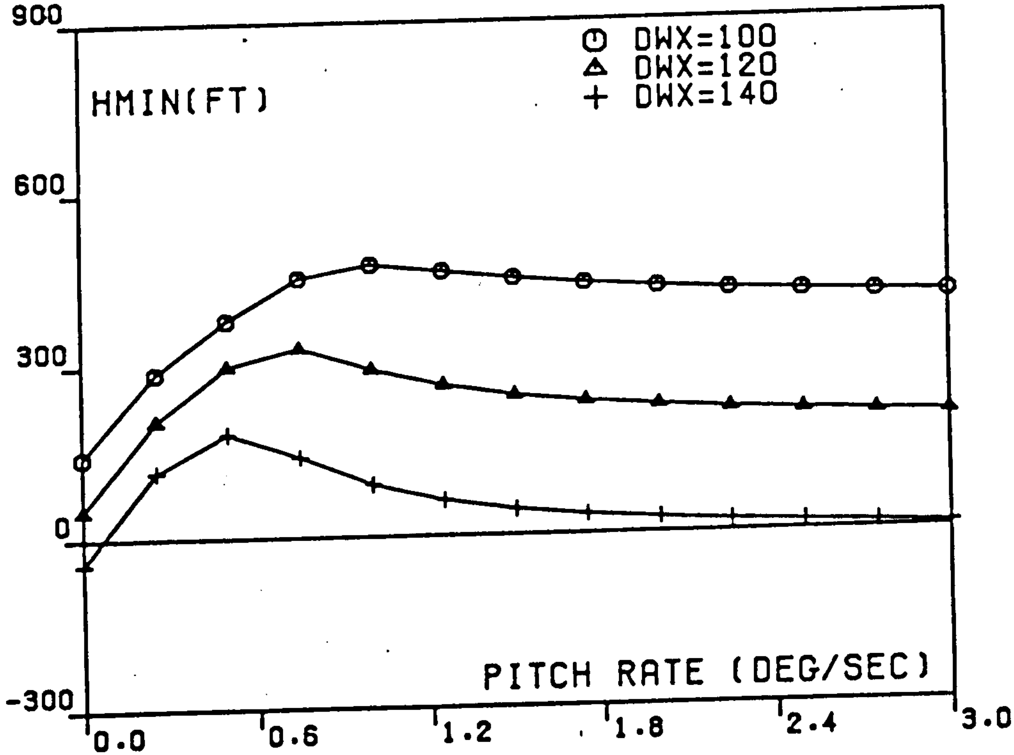


FIG. 3B. HMIN FOR DT = 0 SEC
AND HO = 600 FT.

FIG. 2

WDC19

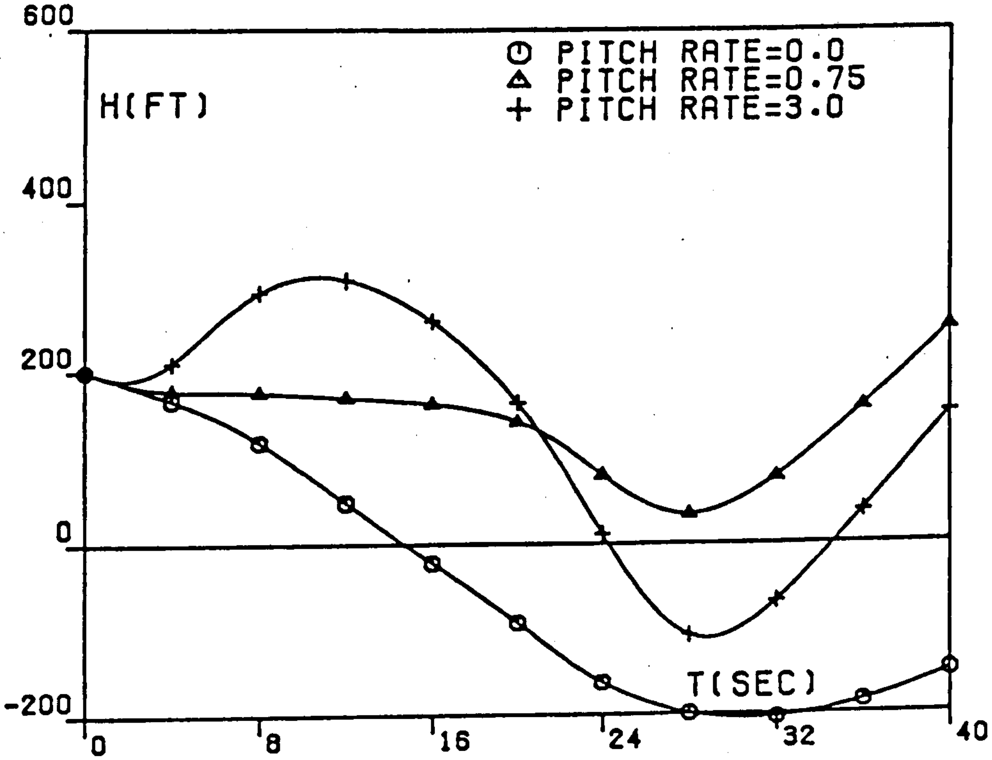


FIG. 7A. TRAJECTORY COMPARISON, DT=0 SEC, H= 200 FT, DWX=140 FPS.

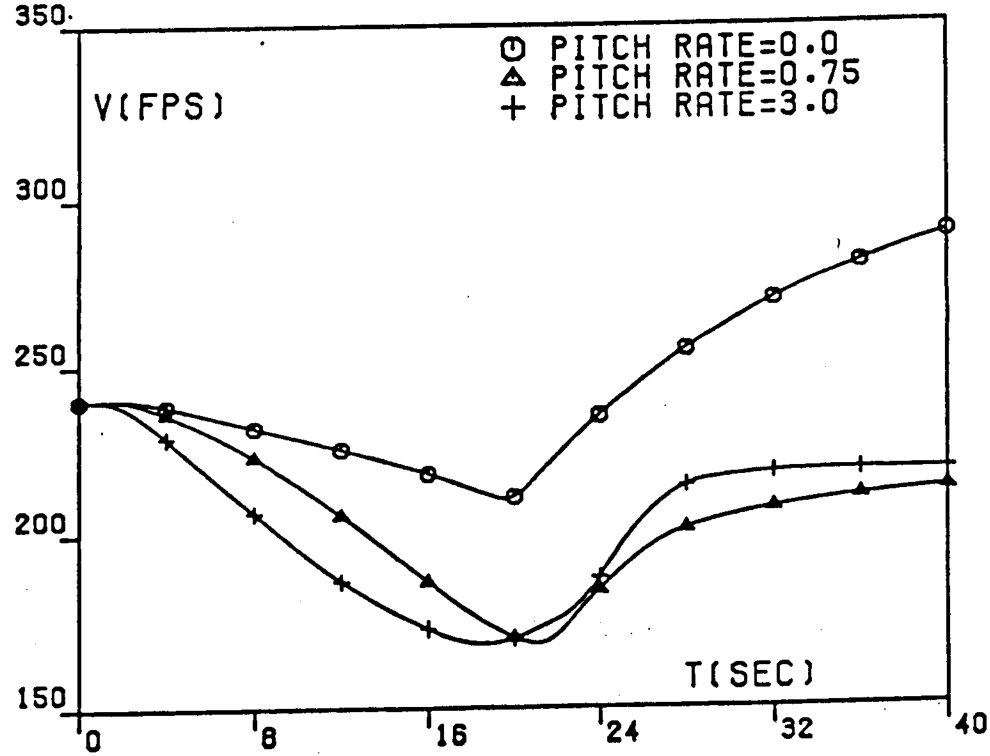


FIG. 7B. TRAJECTORY COMPARISON, DT=0 SEC, H= 200 FT, DWX=140 FPS.

FIG. 3

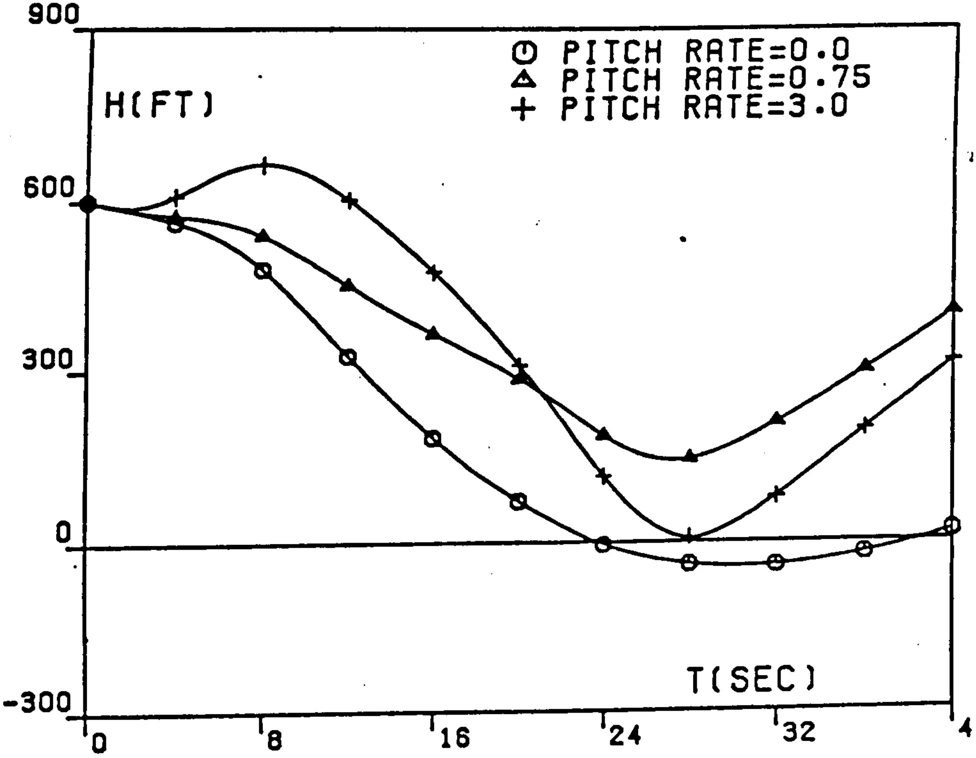


FIG. 8A. TRAJECTORY COMPARISON, DT=0 SEC,
H= 600 FT, DWX=140 FPS.

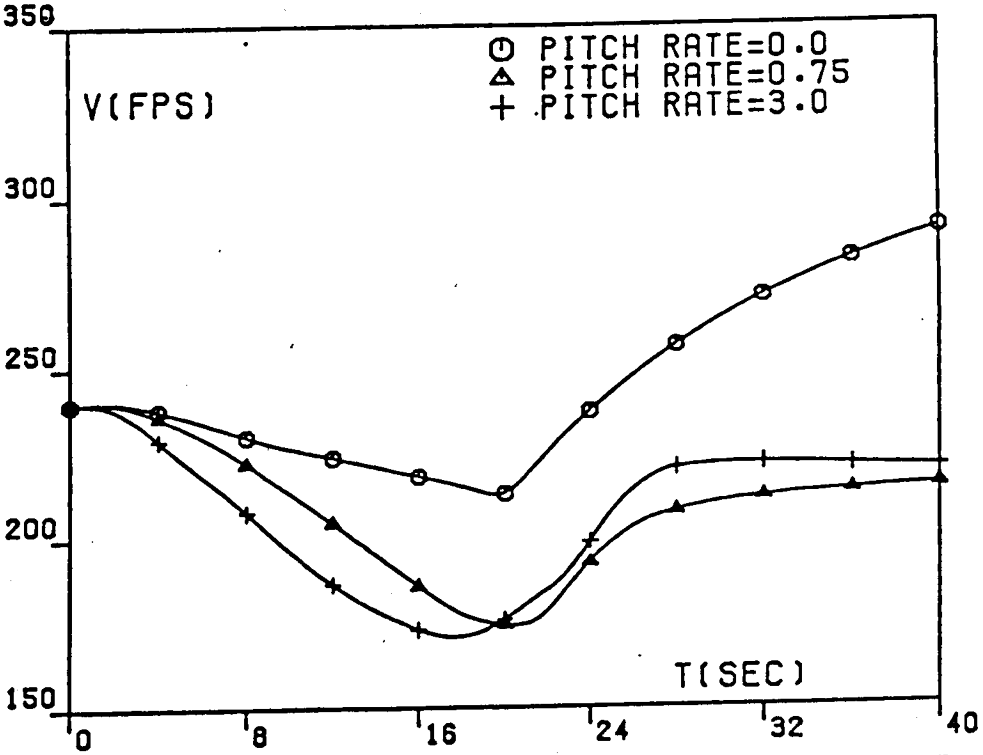


FIG. 8B. TRAJECTORY COMPARISON, DT=0 SEC,
H= 600 FT, DWX=140 FPS.

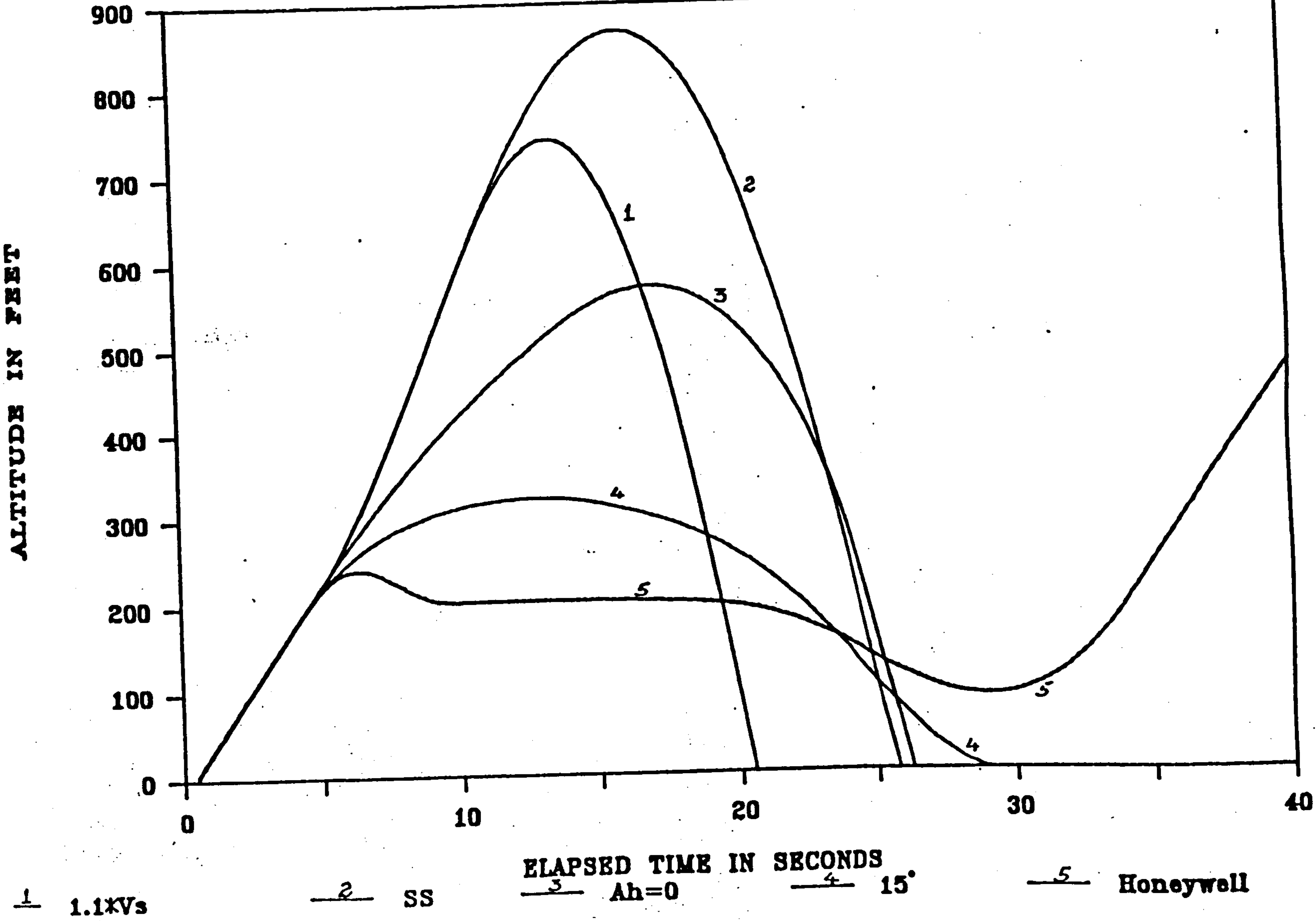
FIG. 4

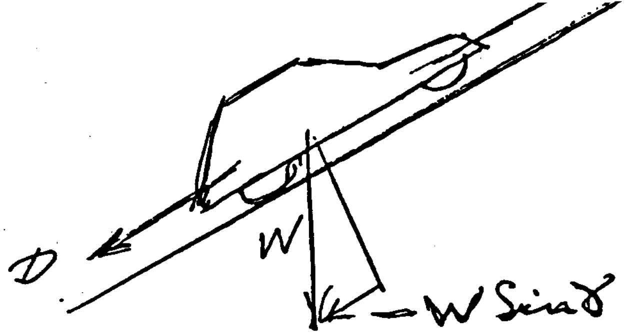
Conclusions for Abort Landing

- * Variable pitch technique is superior to constant pitch technique in terms of minimum altitude and survival capability.
- * Transitions from initial pitch to target pitch is to be performed with gentle pitch rate.
- * Best pitch rates are between 0.50 and 0.75 deg $\sec^{-1}$.
- * Variable pitch technique is closer than constant pitch technique to optimal trajectory behavior.

737 WINDSHEAR GUIDANCE

SHEAR: 20S @ 5KT/S, DNBURST: 18S @ 7KT





$$T - D = W \sin\gamma + \left(\frac{W}{g}\right) a$$

$$\frac{T-D}{W} = \sin\gamma + \cancel{a/g} = F$$

$$\downarrow \qquad\qquad \downarrow$$

$$\frac{T-D}{W} = \frac{Wh}{V} + \frac{W\dot{x}}{g} = F$$

FIG 7

ALL ENGINE CLIMB GRADIENTS
FOR CLIMB LIMITED TAKEOFFS

2 ENG. ~ .15
3 ENG. ~ .11
4 ENG. ~ .075

ALL ENGINE LANDING CLIMB
.032

ENGINE OUT APPROACH CLIMB
2 .021
3 .024
4 .027