U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: ATMOSPHERIC TURBULENCE AVOIDANCE
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Change:

1. PURPOSE. This Advisory Circular (AC) describes to pilots, aircrew members, dispatchers, and other operations personnel the various types of clear air turbulence (CAT) and some of the weather patterns associated with it. ***Also included are "Rules of Thumb" for avoiding or minimizing CAT encounters. Appendix 1 provides a sample Atmospheric Hazards Advisory and Avoidance System that air carriers can tailor to their specific needs.***

2. CANCELLATION. AC 00-30A, Rules of Thumb for Avoiding or Minimizing Encounters With Clear Air Turbulence, dated November 21, 1988, is cancelled.

3. RELATED READING MATERIAL.

a. AC 00-6A, Aviation Weather.

b. AC 00-45, Aviation Weather Services (current edition).

c. AC 61-23, Pilot's Handbook of Aeronautical Knowledge (current edition).

4. BACKGROUND.

a. In 1966, a National Committee for Clear Air Turbulence officially defined CAT as "all turbulence in the free atmosphere of interest in aerospace operations that is not in or adjacent to visible convective activity (this includes turbulence found in cirrus clouds not in or adjacent to visible convective activity)." Over time, less formal definitions of CAT have evolved. The Aeronautical Information Manual expands the basic CAT definition as "turbulence encountered in air where no clouds are present." This term is commonly applied to higher altitude turbulence associated with windshear. Thus, clear air turbulence or CAT has been defined in several ways, but the most comprehensive definition is:

"turbulence encountered outside of convective clouds." This includes turbulence in cirrus clouds, within and in the vicinity of standing lenticular clouds and, in some cases, in clear air in the vicinity of thunderstorms. Generally, though, CAT definitions exclude turbulence caused by thunderstorms, low-altitude temperature inversions, thermals, or local terrain features.

b. CAT was recognized as a problem with the advent of high altitude jet operations in the 1950's. CAT is especially troublesome because it is often encountered unexpectedly and frequently without visual clues to warn pilots of the hazard.

5. DISCUSSION.

a. One of the principal areas where CAT is found is in the vicinity of the jetstreams. A jetstream is a river-like flow of high-altitude wind following the planetary atmospheric wave pattern, with speeds of 50 knots or greater. There are, in fact, three jetstreams: the polar front jetstream, the subtropical jetstream, and the polar night jetstream.

(1) The polar front jetstream, as it's name implies, is associated with the polar front or the division between the cold polar and warm tropical air masses. The mean latitude of the jetstream core varies from 25° north latitude during the winter months to 42° north latitude during the summer months. It is the center of the planetary wave pattern and as such meanders over a large portion of the hemisphere throughout the year, particularly during the winter months when it is most intense. Although the polar jetstream varies in altitude, the core is most commonly found around 30,000 feet and it is generally best depicted on the 300 millibar constant pressure map.

(2) The subtropical jetstream is a very persistent circumpolar jetstream found on the northern periphery of the tropical latitudes between 20° and 30° north latitude. It normally forms three waves around the globe with crests over the eastern coasts of Asia, North America and the Near East. Like the polar front jetstream, the subtropical jetstream is most active during the winter months and often intrudes well into the southeastern United States. It is generally higher than the polar front jetstream with the core between 35,000 and 45,000 feet.

(3) The polar night jetstream is found in the stratosphere in the vicinity of the Arctic Circle during the winter months and does not have a significant affect on air travel over the United States and southern Canada.

b. CAT associated with a jetstream is most commonly found in the vicinity of the tropopause (a very thin layer marking the boundary between the troposphere and the

stratosphere) and upper air fronts. Analyses of the tropopause are issued by the National Weather Service on a scheduled basis. In the absence of other information, the tropopause will generally have a temperature of between -55°C. and -65°C. In some cases, it will be at the top of a cirrus cloud layer. Clouds are very seldom found above the tropopause in the dry stratosphere (a layer typified by relatively small changes in temperature with height except for a warming trend near the top), except in the summertime when occasionally large thunderstorms will poke through the tropopause and spread anvil clouds in the stratosphere. CAT is most frequently found on the poleward side of the jetstream (the left side facing downwind). It is additionally common in the vicinity of a jetstream maxima (an area of stronger winds that moves along the jetstream).

c. There are several patterns of upper-level winds that are associated with CAT. One of these is a deep, upper trough. The CAT is found most frequently at and just upwind of the base of the trough, particularly just downwind of an area of strong temperature advection. Another area of the trough in which to suspect CAT is along the centerline of a trough area where there is a strong horizontal windshear between the northerly and southerly flows. CAT is also found in the back side of a trough in the vicinity of a wind maxima as the maxima passes through.

d. One noteworthy generator of CAT is the confluence of two jetstreams. On occasion, the polar front jetstream will dip south and pass under the subtropical jetstream. The windshear effect of the jetstream between the two jetstreams in the zone of confluence and immediately downstream is often highly turbulent.

e. CAT is very difficult to predict accurately, due in part to the fact that CAT is spotty in both dimensions and time. Common dimensions of a turbulent area associated with a jetstream are on the order of 100 to 300 miles long, elongated in the direction of the wind, 50 to 100 miles wide, and 5,000 feet deep. These areas may persist from 30 minutes to a day. In spite of the difficulty forecasting CAT, there are forecasting rules that have been developed to identify those areas where CAT formation is likely.

f. The threshold windspeed in the jetstream for CAT is generally considered to be 110 knots. Windspeed in jetstreams can be much stronger than 110 knots and the probability of encountering CAT increases proportionally with the windspeed and the windshear it generates. It is not the windspeed itself that causes CAT; it is the windshear or difference in windspeed from one level or point to another that causes the wave motion or overturning in the atmosphere that is turbulence to an aircraft. Windshear occurs in all directions, but for convenience it is measured along vertical and horizontal axes, thus becoming horizontal and vertical windshear. Moderate CAT is considered likely when the vertical windshear is 5 knots per 1,000 feet, or greater, and/or the horizontal windshear is 40 knots per 150 miles or greater.

g. Depictions of the upper air structure, discussed in paragraphs 5c-f, are found in AC 00-6A, chapter 13.

h. The majority of the following guidelines were developed initially by the International Civil Aviation Organization's (ICAO) Sixth Air-Navigation Conference of April/May 1969, but have been expanded based on recommendations from the Department of Defense, the National Transportation Safety Board, and the Federal Aviation Administration.

(1) Jetstreams stronger than 110 knots (at the core) have potential for generating significant turbulence near the sloping tropopause above the core, in the jetstream front below the core, and on the low-pressure side of the core.

(2) Windshear and its accompanying CAT in jetstreams is more intense above and to the lee of mountain wave ranges. CAT should be anticipated whenever the flightpath traverses a strong jetstream in the vicinity of mountainous terrain.

(3) Both vertical and horizontal windshear are, of course, greatly intensified in mountain wave conditions. Therefore, when the flightpath traverses a mountain wave type of flow, it is desirable to fly at turbulence-penetration speed and avoid flight over areas where the terrain drops abruptly, even though there may be no lenticular clouds to identify the condition.

(4) On charts for standard isobaric surfaces, such as 300 millibars, if 20-knot isotachs are spaced closer together than 150 nautical miles (2-1/2° latitude), there is sufficient horizontal shear for CAT. This area is normally on the poleward (low-pressure) side of the jetstream axis.

(5) Turbulence is also related to vertical shear. From the tropopause height/vertical windshear chart, determine the vertical shear in knots-per-thousand feet. If it is greater than 5 knots per 1,000 feet, turbulence is likely.

(6) Curving jetstreams are more apt to have turbulent edges than straight ones, especially jetstreams which curve around a deep pressure trough.

(7) Wind-shift areas associated with pressure troughs and ridges are frequently turbulent. The magnitude of the windshear is the important factor.

i. Although CAT is difficult to predict, there are a number of things to look for and to remember that will help reduce the likelihood encountering CAT. In concert with a good tracking system and pilot reports, knowing the characteristics and signs of CAT can

prevent an incident from occurring. Until practical airborne detectors are developed, pilots are urged to use the "Rules of Thumb to Assist in Avoiding or Minimizing Encounters With Clear Air Turbulence" in the next paragraph.

6. "RULES OF THUMB" FOR TURBULENCE AVOIDANCE The following "Rules of Thumb" apply primarily to the turbulence associated with the westerly jetstreams.

a. If jetstream turbulence is encountered with direct tailwinds or headwinds, the pilot should consider a change of flight level or course since these turbulent areas are elongated with the wind and are shallow and narrow.

b. If jetstream turbulence is encountered in a crosswind, it is not so important to change course or flight level since the rough areas are narrow across the wind.

c. If turbulence is encountered in an abrupt wind shift associated with a sharp pressure trough line, establish a course across the trough rather than parallel to it.

d. If turbulence is expected because of penetration of a sloping tropopause, watch the temperature gauge. The point of coldest temperature along the flightpath will be the tropopause penetration. Turbulence will be most pronounced in the temperature-change zone on the stratospheric (upper) side of the sloping tropopause.

e. If possible, when crossing the jet, climb with a rising temperature and descend with a dropping temperature.

f. Weather satellite pictures are useful in identifying jetstreams associated with cirrus cloud bands. CAT is normally expected in the vicinity of jetstreams. Satellite imagery showing "wave-like" or "herringbone" cloud patterns are often associated with mountain wave turbulence. Pilots should avail themselves of briefings on satellite data whenever possible. (See AC 00-6A, chapter 13.)

g. Last, but not least, monitor your radio - - pilot reports can be invaluable and if you get caught by "the CAT," file a PIREP!

7. INFLIGHT AVIATION WEATHER ADVISORIES. The primary weather products used to disseminate information on atmospheric turbulence, both convective and CAT are the Inflight Aviation Weather Advisories (WST, WS, and WA). All inflight advisories in the conterminous United States are issued by the Aviation Weather Center (AWC) and disseminated as follows:

a. Convective SIGMETS are issued on a scheduled basis at H +55 and are labeled E (eastern third of the continental United States), C (central third of the continental United States) and W (western third of continental United States). They are issued for thunderstorms and related phenomena, when they are present. The Convective SIGMET will state NONE when the required conditions are not present.

b. A SIGMET contains information on specified weather phenomena of an intensity and/or extent that concerns all pilots and operators of all aircraft. The phenomena that require SIGMET issuance are turbulence (including CAT), icing, widespread dust and sand, volcanic eruptions and volcanic ash.

c. AIRMETS are issued to advise of significant weather phenomena at intensities lower than those that trigger SIGMETS.

d. This information is available to pilots through the en route advisory service (flight watch), SIGMET alerts broadcast on air route traffic control center frequencies, and over the hazardous in-flight weather advisory service (HIWAS).

8. RECOMMENDATION. All pilots and other personnel concerned with flight planning should carefully consider the hazards associated with flight through areas where pilot reports or aviation weather forecasts indicate the presence of CAT including mountain wave turbulence.

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APPENDIX 1. A MODEL FOR A CLEAR AIR TURBULENCE AVOIDANCE SYSTEM

1. BACKGROUND.

a. There are three key elements in an effective Clear Air Turbulence (CAT) avoidance system. These three elements are:

(1) an appropriate initial and recurrent training program,

(2) a dedicated planning/dispatch function, and

(3) a fully supported operational implementation of a pilot reporting (PIREP)/communications system (not ATC-based).

b. There is no mystery or magic involved, only the awareness and involvement of three critical functions that are a part of any safe air operation. A truly effective system is based on training, internal communications, and full operational involvement in the process. The rather simplistic model presented is primarily oriented to air carrier operations and represents a "best practice" as developed by industry.

2. OPERATIONAL CONCEPT. The first step in avoidance of atmospheric hazards, especially turbulence, is to examine available weather information for planning flight operations. Direct access to a meteorological support service (in-house or outside source) by the operator's planning and dispatch function is a major factor in a successful turbulence avoidance system. Forecasting of areas of probable turbulence is essential and the graphic depiction of the impacted airspace on operationally useful plotting charts is highly recommended. Aircrews and dispatch/operational control personnel must be thoroughly trained in the techniques of timely and accurate pilot reports, and the subsequent plotting and relay of those reports throughout the operator's route structure. An efficient communications system must be established and supported to permit quick and easy interchange of flight critical information between the aircraft and the operational control function. However, management philosophy toward the CAT problem is a crucial element in an effective turbulence avoidance system. Management must establish the avoidance of atmospheric hazards as a high organizational priority. Management must be willing to expend resources on the safest operational practices and resist the expedient.

3. A MODEL SYSTEM.

a. The philosophy of avoidance and dedicated training are an integral part of an effective system. There can also be adjuncts to a turbulence avoidance system (one airline company has expanded its system to include other atmospheric hazards, such as thunderstorms, icing, ozone, and volcanic ash).

b. Successful turbulence avoidance and tracking is initiated in the planning and preparation phase of operations through the acquisition of applicable weather data and products. A suggested product list includes:

(1) Alphanumeric weather information such as surface observations.

(2) Area and terminal forecasts.

(3) Wind and temperature forecasts.

(4) National Weather Service (NWS) in-flight advisories (SIGMETS, Convective SIGMETS and AIRMETS).

(5) Upper air charts, graphical radar summaries or composites.

(6) Satellite imagery.

c. Incorporating current data processing and computer plotting techniques will facilitate the analysis and plotting of areas of possible adverse atmospheric turbulence. Software routines are available that will provide the analyst convenient means to track areas of interest. An example of this capability is the automated plotting on map overlays of an adverse weather area by using a "mouse" to "click" on the key features of the computer image.

d. Archiving and distributing turbulence information is the next step in the process. The product(s) should be stored in easily-accessed data bases for use by the operational control/dispatch personnel and should be available for periodic review by the generating office. Aircrew dispatch packages should contain not only the current turbulence advisories, but also the latest applicable PIREPS generated by the system. Accurate and timely pilot reporting is also essential to an effective turbulence and tracking system.

e. A basic component in any tracking/avoidance system is the supporting communications system which facilitates the free and easy flow of turbulence information between aircrew, dispatcher, and meteorological support function. Timely operational control advisories, accurate

CAT forecasts, and feedback through conscientious pilot reporting are the heart of effective avoidance of either convective or clear air turbulence. Without efficient air/ground communications, an air carrier can not ensure the timely delivery of this extremely perishable information to the appropriate operational components. Less than efficient communications will result in an ineffective program for the tracking and avoidance of clear air turbulence or any other atmospheric hazards.

f. Finally, the short- and long-term success of a carrier's turbulence avoidance and tracking system requires a dedicated and continuing training program for aircrews, dispatchers, meteorologists and other operational control personnel. Training should begin with a reasonably detailed exposure to the science of the atmosphere and the meteorological techniques/products involved in turbulence forecasting. This should be followed by continuing recurrency classes for all personnel concerned with flight operations and operational control.

4. RECOMMENDED PRACTICES.

a. Comprehensive training for aircrews, dispatchers, and meteorologists.

b. Establishment of a full meteorological support system (either in-house or outside source).

c. Thorough preflight planning including concentrated examination of upper air wind patterns.

d. Accurate tracking of jet streams.

e. Acquisition of satellite imagery for aircrews and operational control centers and dispatchers.

f. Graphical depictions of forecast areas of turbulence on planned routes of flight.

g. Use of appropriate plotting charts for facilitation of pilot reporting.

h. Establishment of an efficient and effective communications system administered by the operator to support the company's pilot reporting system.

i. Promulgating a corporate philosophy of avoidance as the first line of defense.

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