Federal Aviation Agency

ADVISORY CIRCULAR

AC NO: AC 20-20

AIRCRAFT

EFFECTIVE: 2/11/64

SUBJECT: FLAMMABILITY OF JET FUELS see AC 20-20A

1. PURPOSE: This circular presents information on the factors which determine the possibility of combustion in aircraft fuel tanks in the event an ignition source should occur. Interest has focused on this subject due to the possibility that a lightning strike was responsible for a recent aircraft accident.

2. FLAMMABILITY LIMITS: The attached chart shows the flammability limits of several aircraft type fuels contained in a tank under quiescent conditions. Under these conditions, the fuel-air ratio of the mixture in the vapor space immediately above the fuel is about .035 for the lower limit and .288 for the upper limit. These fuel-air ratios are valid flammability limits, but the actual fuel-air ratios in an aircraft fuel tank may be different for the altitudes and fuel temperatures shown because of numerous influencing factors, among which are the following:

   a. The fuel-air ratio in the vapor space varies with volume, size, and shape of the vapor space.

   b. Agitation of the fuel due to vibration of the tank or turbulence from atmospheric disturbances will cause atomization and evaporation.

   c. Local heating of wetted surfaces may increase the degree of evaporation in local areas.

   d. The penetration of a foreign object into the tank may cause heat and pressure waves that will result in evaporation.

   e. Air entering the tank during a letdown will lower the mixture ratio.

   f. The mixture will enrichen during a climb due to air and fuel vapors flowing from the tank.

g. The light ends of the more volatile fuels, particularly if warm, may be lost during a climb to high altitudes, thus leaning the mixture during cruise and letdown.

3. IGNITION IN A JET ENGINE: Ignition can be obtained in a jet engine with aviation kerosene to temperatures as low as -20° F. This condition is somewhat analogous to ignition in a fuel tank under turbulent conditions. The vapor liquid ratio is far below the lower flammability limit, but with sufficient ignition energy the fuel droplets in the vapor can be vaporized to provide sufficient vapor to propagate combustion.

4. GUN FIRE TESTS: Tests conducted by firing incendiary bullets through the vapor space of tanks containing low vapor pressure fuel under quiescent conditions showed that combustion could be obtained far below the lower limits shown on the attached chart. In this condition, vaporization and ignition probably resulted from the heat and pressure waves produced.

5. IGNITION ENERGY: The energy required for ignition of a fuel mixture and explosive forces that result from the combustion vary with temperature and fuel-air ratio. At stoichiometric fuel-air ratio, which is about .067 for all aircraft fuels, the ignition energy is a very small percent of that required at the upper and lower limits and the explosive forces are infinitely greater. With high ignition energies, fuel droplets in the vapor mixture and liquid fuel on wetted surfaces may be vaporized to bring a normally lean mixture into the flammable range. Under such condition, the lower limit shown on the attached chart will not be valid.

6. FUEL TANK TEMPERATURES: The fuel temperatures in an aircraft at takeoff are not likely to be above 80° F. During a long flight at high altitudes the fuel may be cooled to about -40° F.

7. ALTITUDES AND TEMPERATURE WHERE LIGHTNING OCCURS: Lightning strikes rarely occur at altitudes above 20,000 feet and 92 percent of the strikes recorded occurred in the range from 4,000 to 17,000 feet. The atmospheric temperature at which these strikes occurred ranged from 14° F. to 50° F. with the most critical temperature being 32° F.

8. LIGHTNING ENVELOPE: The probable maximum altitude at which lightning may occur has been plotted on the attached chart and the probable maximum and minimum fuel temperatures are indicated to give a possible lightning strike envelope. It will be noted that the lightning envelope

cuts into the flammability limit envelopes of all fuels shown on this chart, which, as previously noted, is for quiescent conditions. Under the varying conditions of aircraft operation, particularly in turbulent flight, the actual flammability limits will be wider than those shown on the chart for each type of fuel represented. This widening of the flammability limits involves primarily an extension of the lower limits (solid lines) toward lower temperatures by an undetermined amount.

9. <u>CURRENT FUELS</u>:

a. Fuels being produced for jet aircraft use as reported by the Department of Interior, Mineral Industry Surveys, Petroleum Survey No. 29, are as follows:

| Fuel | Specification |
|---|---|
| JP-4 | MIL-J-5624E |
| JP-5 | " " " |
| Type A | ASTM D 1655 |
| Type A-1 | " " " |

b. Fuels type A and A-1 are often erroneously referred to as JP-1. Military JP-1 fuel is essentially a commercial kerosene with a relatively high freezing and low flash point with a vapor pressure of about 1.0 lbs/sq in.

c. The average physical properties of these fuels that may affect flammability are as follows:

| | MIL-J-5624E | | ASTM D1655 | |
|---|---|---|---|---|
| | JP-4 | JP-5 | Type A | Type A-1 |
| Gravity API | 53.3 | 43.0 | 43.9 | 43.6 |
| Init. Boil Point °F. | 141 | 356 | 342 | 330 |
| 10% Fuel Evap. °F. | 214 | 382 | 370 | 359 |
| 20% " " " | 242 | 391 | 381 | 371 |
| 50% " " " | 303 | 411 | 408 | 399 |
| 90% " " " | 406 | 455 | 465 | 458 |
| End Point °F. | 468 | 491 | 503 | 500 |
| Freezing Point °F. | -76 | -58 | -55 | -62 |
| Reid Vapor Pres. lbs/sq in. @ 100° F. | 2.6 | Nil | Nil | Nil |
| Flash Point °F. | Below Zero | 140 | 122 | 128 |
| Viscosity, Cent. @ -30° F. | 2.61 | 9.44 | 8.85 | 8.01 |

10. CONCLUSION: Because of the various factors discussed previously, there is no clear-cut basis for believing that any one type of fuel offers superior overall safety. The flammability limits given on the attached chart, representing laboratory data, are of limited validity when considering overall safety.

George S. Moore
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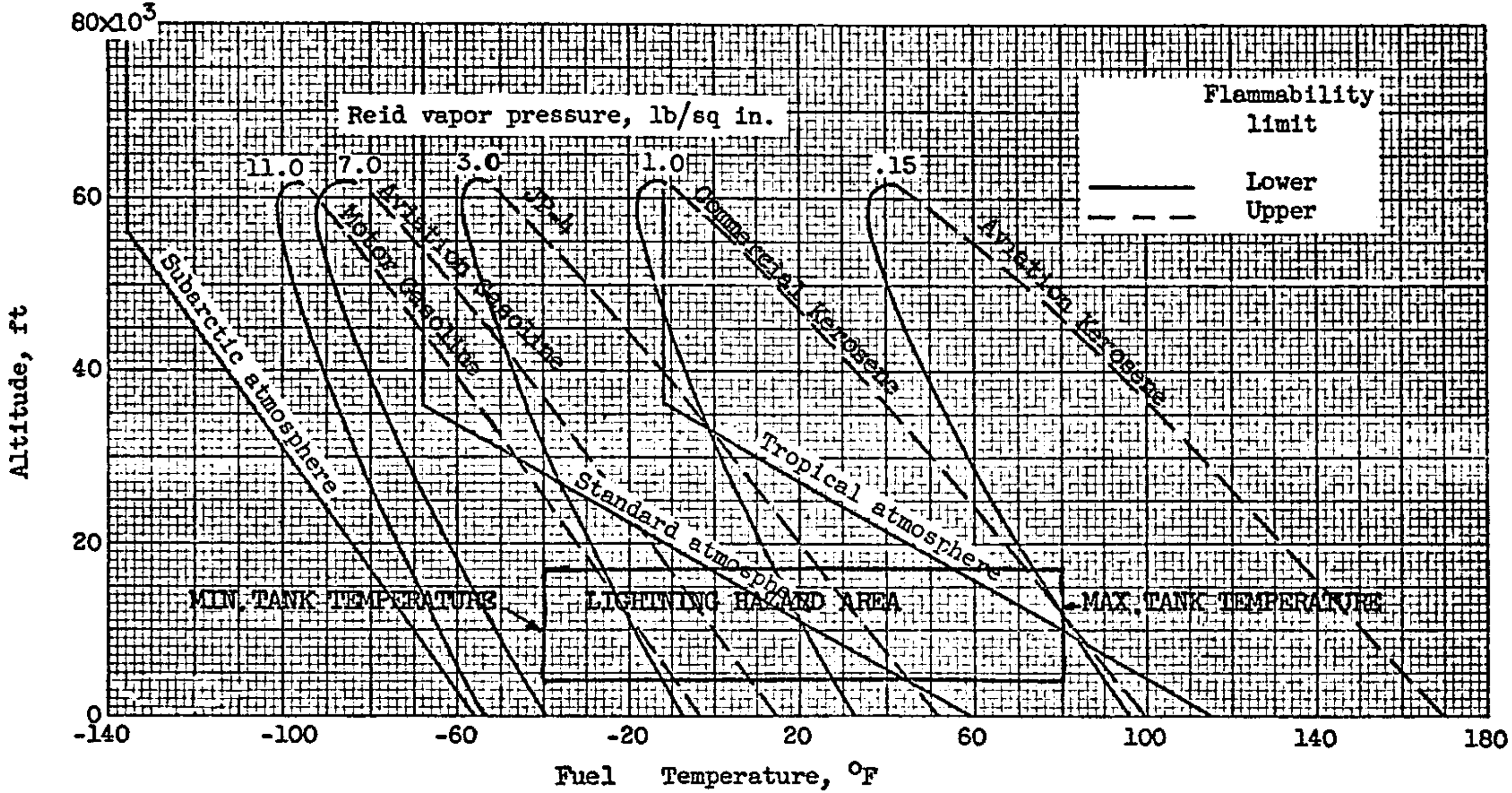


Figure 23. - Altitude-temperature flammability limits for fuels of varying vapor pressure