U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject:	GUIDELINES ON THE MARKING OF AIRCRAFT POWERPLANT INSTRUMENTS (DISPLAYS)	**Date:** 9/30/85 **Initiated by:** ANM-110		**AC No:** **Change:**	20-88A

1. PURPOSE. This advisory circular provides revised guidelines on the marking of aircraft powerplant instruments and electronic displays (cathode ray tubes, etc.). These guidelines offer acceptable, but not exclusive, methods of compliance with the powerplant instrument color marking requirements.

2. CANCELLATION. Advisory Circular 20-88, Guidelines on the Marking of Powerplant Instruments, dated December 11, 1973, is cancelled.

3. RELATED Federal Aviation Regulation (FAR) SECTIONS.

a. Sections 23.1541, 23.1543, and 23.1549 of Part 23 of the FAR.
b. Sections 25.1541, 25.1543, and 25.1549 of Part 25 of the FAR.
c. Sections 27.1541, 27.1543, and 27.1549 of Part 27 of the FAR.
d. Sections 29.1541, 29.1543, and 29.1549 of Part 29 of the FAR.

4. BACKGROUND.

a. Powerplant instrument (display) range markings are intended to provide information to the flightcrew which is clearly readable and interpretable. Powerplant instruments (displays) should show whether the current state of powerplant operation is normal, acceptable for a limited time, or unauthorized. These markings are based on the installed engine operating limits which may not exceed (but are not necessarily equal to) those limits shown on the engine type certificate data sheet. The powerplant instrument color marking scheme generally consists of three colors: red, green, and yellow, in addition to white which is generally used for numerals and graduation marks. The regulations specify only the basic markings required for safety. Additional markings may be desired to denote additional information that might be unique to a specific model. The simplest, adequate markings should be the goal. All markings should be explained in the Airplane/Rotorcraft Flight Manual.

b. Powerplant instruments (displays) may be electromechanical, mechanical, or electronic indicators.

(1) Electromechanical and mechanical indicators comprise round-dial, rotating-pointer instruments; vertical and horizontal scale instruments; translating pointer instruments; fixed-index, moving scale instruments; rotating-wheel counters; and combined analog-digital indicators.

(2) Electronic displays include cathode-ray tube (CRT), liquid-crystal (LCD), light-emitting diode (LED), and electroluminescent (EL) or light-emitting film (LEF) displays. Electronic displays usually depict scale readouts similar in appearance to electromechanical instruments.

c. Digital indicators are most valuable when integrated with an analog display, by providing a precise quantitative indication to compliment the analog display's qualitative indication. Generally, it is not appropriate to use digital powerplant instruments alone in place of analog instruments to indicate values of engine parameters where trend or rate of change information is important because it is difficult to quickly assess trend information from a digital display. Digital indicators are also limited in their ability to provide a comparison of parameters from two or more engines, or to check the general proximity of differing parameters against their individual limits. Digital displays present design difficulties in the presentation of usable and effective limitations and operating range information. While these shortcomings can be compensated for with additional implementation provisions, the application of digital-only indicators to powerplant displays should be made with care and subject to evaluation on a case-by-case basis. Examples of powerplant parameters that should be displayed on an instrument as analog values are exhaust gas temperature (EGT) and the primary power setting parameter such as engine pressure ratio (EPR) or fan speed (N_1).

d. Due to differences inherent in the various display media, methods of effectively applying scale markings can differ considerably. Furthermore, since aircraft powerplant installations vary in design and purpose, the final approval of any instrument (display) marking scheme (even those recommended herein) is subject to validation by the FAA flight test crew.

5. MARKING GUIDELINES FOR CONVENTIONAL DIAL/ROTATING NEEDLE INDICATORS.

a. Since most powerplant instruments in current use are electromechanical, graduated scale instruments of the round-dial, rotating needle indicator type, this section describes the markings in terms of round-dial instruments. The limitation markings discussed below are those required to be established and demonstrated under the type certification standard applicable to the particular aircraft.

b. When marking the instruments, the colored markings are usually placed directly over the instrument graduations in a manner that does not obscure the graduations themselves. When in this position, if the markings interfere with the instrument's readability from the normal crew position(s), adjustment of the colored markings above or below the graduations should be considered. The colored markings may be placed on the coverglass of the instrument provided the readability of the instrument is not compromised and there is a means to maintain the correct alignment of the coverglass with the dial face. The colors of Federal Standard 595a (specified below) are recommended, but reasonable variations from these shades are acceptable:

Colors	Federal Standard 595a Numbers
Red	11105
Yellow	13655
Green	14260

c. Colors generated by electronic displays may unavoidably differ significantly from the above standards. The two primary reasons for this difference are:

(1) The variety of colors available from an electronic display is usually constrained by factors which involve other display characteristics such as brightness and frequency response.

(2) Emissive colors will inevitably appear different than reflective colors under different intensities and color temperatures of ambient illumination.

At present, electronic display colors are not standardized and cannot be stated as general specifications. However, colors for electronic powerplant displays must be readily identifiable under all intensity settings and ambient light conditions. In particular, yellow (amber) must be easily distinguishable from both red and white, and green must be easily distinguishable from blue. Other colors used on electronic powerplant displays, if any, must be as distinctive as possible from the basic display marking colors.

d. To satisfy the requirement for clearly visible markings, the following minimum dimensions are recommended. These dimensions are adequate for reflective markings in low light level conditions at a nominal 28-inch viewing distance.

(1) Red Radial - 0.05 inches wide, 0.30 inches long.

(2) Red, Yellow, or Green Arc - 0.10 inches wide, length as required.

(3) Striped Green Arc - Same length and width as above with alternate green and white stripes 0.05 inches wide.

e. The color red indicates an operating condition beyond authorized limits and requires a specific action on the part of the flightcrew. The specific action to be taken should be described in detail in the Airplane/Rotorcraft Flight Manual.

(1) Red radial lines should be used to identify only the established maximum and minimum (if applicable) safe operating limits. Where appropriate, the maximum should be the limit for takeoff operation. Red radials should be located so that the edge nearest the normal operating range is placed on the limit value. In use, when the needle point touches the edge of the red radial nearest the green arc, the limit is met. To minimize confusion the use of multiple red radials should be avoided, except for certain "conditional limits." Multiple red radials can be displayed one at a time on electronic displays with the switching accomplished automatically. If possible, multiple red radials should have distinguishing features, such as one solid line and one dashed line, or lines of different lengths.

(2) A red arc requirement(s) may be satisfied by marking the applicable instruments for all speed ranges which are restricted because of the excessive vibration and other stresses induced by large rotating or reciprocating masses such as the engine, propeller, turbine, fan, rotor, drive shaft, transmission, or any combination of these components. This requirement obviously applies to tachometers; however, the red arc may also be used on other powerplant instruments. The dial need not be marked to indicate restricted operating range when the restriction applies only under certain conditions (e.g., a propeller vibratory stress restriction that applies only when the landing gear is extended). Instead of a red arc, it may be satisfactory to provide an adjacent placard covering such restricted ranges.

f. The color green is used to indicate a normal condition for operation, both ground and flight. Where applicable, the high value end of the green arc should indicate the maximum limit for normal operation, and the low value end of the green arc should indicate the minimum limit for normal operation. Where appropriate, there may be blank gaps, or other colors, inserted into the green arc. Either the upper or lower end of the green arc may extend to the red radial or stop short of it as appropriate to the measurement being marked. A wide green arc and a narrow green arc may be used to denote a normal all-engine range and a normal engine-out range, if appropriate.

g. The color yellow is used to indicate either a takeoff or cautionary range where limited operation is permissible as directed by the applicable Airplane/Rotorcraft Flight Manual. An example of compliance with the precautionary range requirement is the yellow arc marking on the carburetor air temperature gauge to indicate the range of temperature where carburetor icing may occur. Note that the color amber is used in Part 25 of the FAR for cautionary lights.

h. Other informational markings (such as "warranty ratings" may be included on the instrument face provided they are not red, yellow, or green marks; they do not compromise the other powerplant instrument markings; and they are explained satisfactorily in the Airplane/Rotorcraft Flight Manual or the Pilot's Operating Handbook.

6. MARKING GUIDELINES FOR OTHER TYPES OF INDICATORS AND DISPLAYS.

a. Vertical or horizontal scale instruments may utilize a servo-driven indicator moving along a flat, fixed scale; an indicator bar sweeping through an arc over a curved, convex scale (drum type); a servo-driven tape moving past a fixed pointer; or a series of sequentially lighted colored segments. The same basic color markings apply; however, their positioning obviously differs.

b. On a vertical or horizontal scale instrument, a red line or stripe applied across the scale to mark the maximum (and minimum, when applicable) authorized operating limit is comparable to the red radial line applied to round-dial instruments. Green, yellow, or red lines, or stripes parallel to the scale with the ends of the lines at the specified range limit graduations are practical methods of conveying the same type of information as provided by the colored arcs on round-dial instruments. On a moving tape instrument, the operating range markings should either be placed on the face of the tape or affixed adjacent to the tape.

c. When utilized by itself, a direct-reading digital instrument display does not lend itself to conventional markings; however, some comparable limitations and operating range information are required. The combination of a digital display with an analog presentation is a nearly ideal way of providing this information. An alternate method would be to utilize ancillary displays (caution and warning lights, etc.), activated by threshold sensors or logic systems, along with digital-only instruments, to direct the flightcrew's attention to a display. If light displays are used, the lights should be appropriately colored to indicate the corresponding operating range. In general, such lights should not flash or blink. Placards containing the operating range and limitations information when used alone near digital-only displays generally are not suitable or desirable for instruments required by the airworthiness standards. When placards are utilized with ancillary devices or with optional instrument displays, the markings printed in the corresponding color (i.e., maximum and minimum limits in red print, time limited operating range in yellow print, etc.) are recommended.

d. The advent of the CRT display allows greater flexibility in the design of instrument marking schemes. A concept has been developed where normal engine operating conditions are not identified and only abnormal conditions are designated by colored markings. If all abnormal conditions are adequately indicated by specific design features, green markings are unnecessary based on a finding of equivalency. Yellow and red markings are used but may be subdued until the parameter being monitored reaches the caution or warning value. At that time the respective color is highlighted in some manner to alert the flightcrew.

e. As the technology of instrument development progresses, instruments are expected which will combine the basic engine parameter read-out function with other factors which influence the operating limits of the basic read-out. In some cases the range markings may be attached to and driven by a separate mechanism and thus moved to the applicable limits as determined from the influencing conditions. With a single gauge of this type, the flightcrew need not read values from separate gauges to determine if engine operation is within the safe region.

7. SPECIAL APPLICATIONS.

a. Certain engine installations may require powerplant instrument (display) markings to define "conditional" limits that are determined for specific flight conditions. Instrument marking schemes for several common "conditional ratings" are explained in the following paragraphs. These are recommended marking practices, but alternative methods may be acceptable if they do not conflict with established methods, are appropriate to the design, and are easily interpreted.

b. Engines are restricted to given ranges of operation for safety. These ranges are monitored by observing certain measurements. Some of these measurements need to be observed only during dynamic conditions of operation and are of concern for short time durations. These short term restrictions are

called "transient limits" and are distinct from the more familiar long term "steady state limits." If marking an instrument (display) to show these transient limits is determined to be necessary for operational safety, the limit should be marked by a red triangle, diamond, or dot if the limit is above the normal maximum red radial. If below the normal maximum red radial, the limit mark should be a red/white "barber pole" of smaller dimensions than the red radial. Red radials should always be the dominant marking. On electronic displays, transient limit markings may be removed from the display when they are not applicable to the operating condition. Transient limit markings are shown in Figures 1 and 2.

c. Multi-engine helicopters may be certificated for higher powerplant ratings associated with (and limited to) continued operation after the failure of one engine. These ratings are sometimes called "contingency ratings" because their use is contingent upon a need for higher power during abnormal or emergency operations of relatively short duration. The instrument (display) markings which reflect these limits should be separate and distinct from the normal all-engine operating limits and are normally located beyond the takeoff limit red radial. An offset (outside or inside) yellow arc, from the normal red radial to the maximum one-engine inoperative (OEI) power limit, is recommended with a dashed yellow radial at the 30-minute rating limit and a dashed red radial at the maximum (2-1/2 minute) OEI rating limit. The offset yellow arc may have "OEI" inscribed in the center, if it can be accomplished without obscuring the markings. An example of these markings is shown in Figure 3.

d. For certain engine installations (such as a turboprop that is horsepower limited), it is desirable to display a takeoff torque (or manifold pressure) limit that is less than maximum continuous. The takeoff limit should be marked by a wedge-shaped red radial. The maximum limit should be marked, as usual, with a red radial. The arc between the takeoff and maximum limit (maximum continuous) should be a striped green arc to indicate a conditional operating range. An example of these markings is shown in Figure 4.

e. Engine installations that have two sets of takeoff limits, one based on the use of water injection, should normally be marked with the addition of a dashed red radial placed at the wet takeoff power limit. A wedge-shaped red radial may be used instead of a dashed red radial on small faces if the dashed red radial is not easily distinguishable. An example of markings for a water injection system is shown in Figure 5.

f. Aircraft equipped with Automatic Takeoff Thrust Control Systems (ATTCS) will require instrument markings for both the normal and maximum (ATTCS operating) takeoff rating limits. The normal takeoff rating limit should be marked with a red radial. The maximum takeoff rating limit should be marked with a dashed red radial and an offset yellow arc placed between the red radials, provided there is sufficient space. As above, a wedge-shaped red radial may be used instead of a dashed red radial on small dial faces. An example of ATTCS markings is shown in Figure 6.

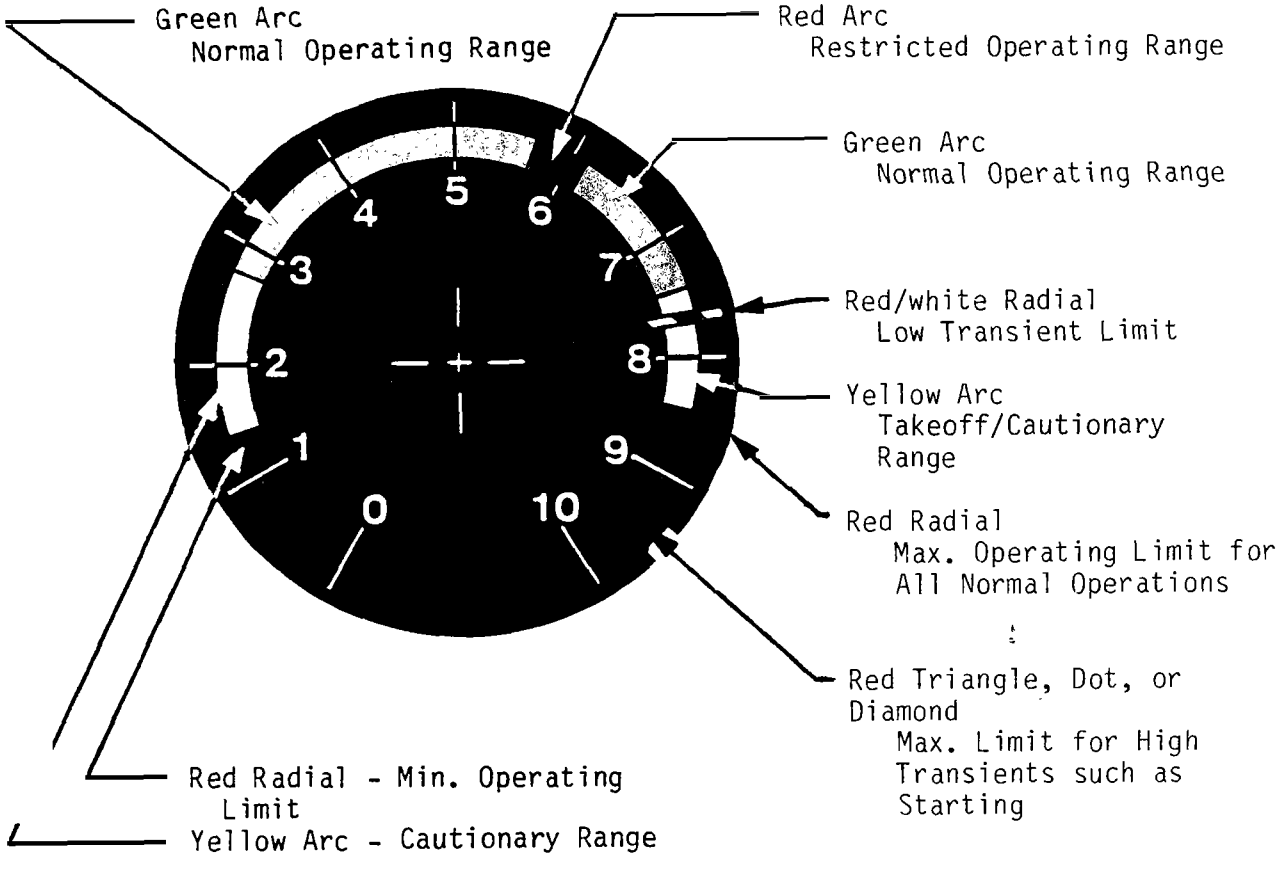
g. The conditional display design philosophy stated in the foregoing paragraphs may be extended to include parameter scales as well as limit markings. The capability of electronic displays can be applied to put

parameters on display only when they are either needed or desired by the flightcrew, thereby reducing both light and visual clutter in the flight deck. Existing applications have shown this to be an effective technique as, for example, in the conditional presentation of secondary engine parameters.

8. EXAMPLES OF TYPICAL MARKING SCHEMES.

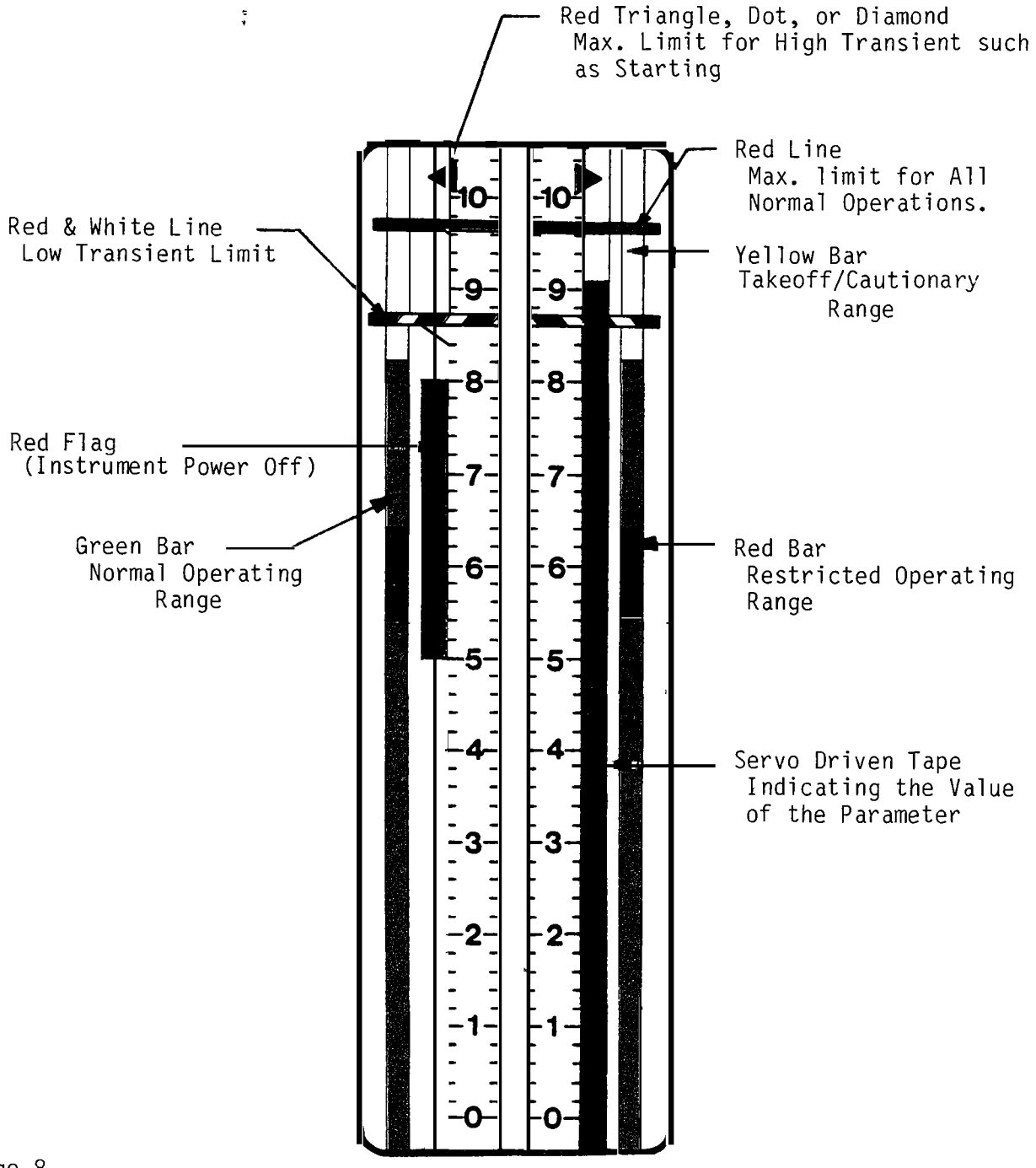
a. A hypothetical instrument dial with illustrative range markings is shown in Figure 1. This dial face is intended only as a guide. Most instruments will need only a few of these markings.

FIGURE 1. INSTRUMENT DIAL ILLUSTRATING RANGE MARKINGS.
(Not to Scale)



b. The markings on a typical Vertical Tape Instrument are illustrated in Figure 2. This instrument face is intended only as a guide. Most instruments will need only a few of these markings.

FIGURE 2. DUAL VERTICAL TAPE INSTRUMENT
(Not to Scale)



c. Markings for several types of "conditional rating limits" are illustrated in Figures 3, 4 and 5.

FIGURE 3. TWIN ENGINE HELICOPTER
(Not to Scale)

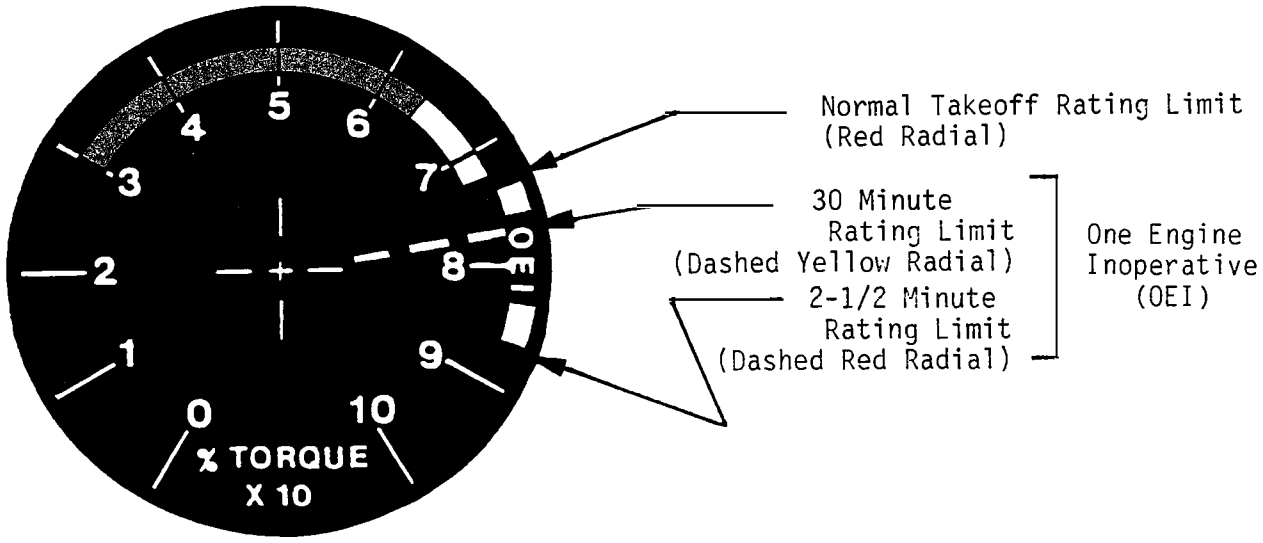


FIGURE 4. TURBOPROP INSTALLATION (HORSEPOWER LIMITED)
(Not to Scale)

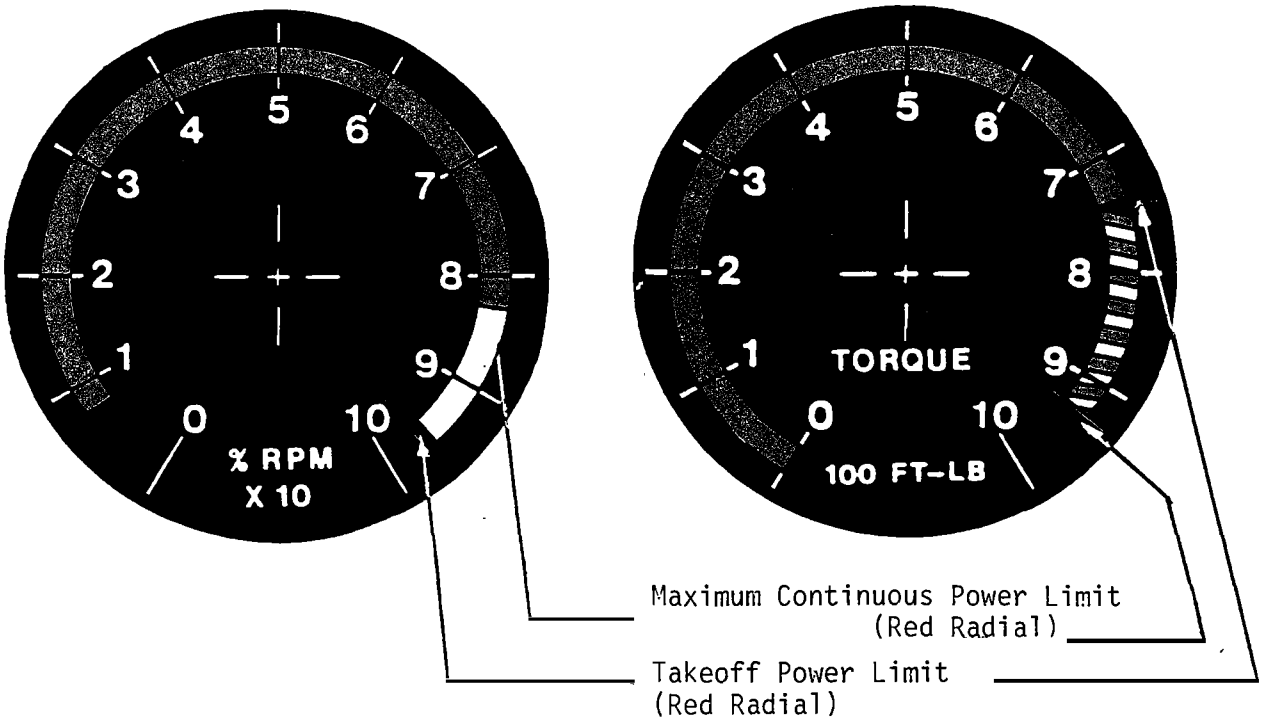


FIGURE 5. LIMIT MARKINGS FOR WET AND DRY TAKEOFF POWER
(Not to Scale)

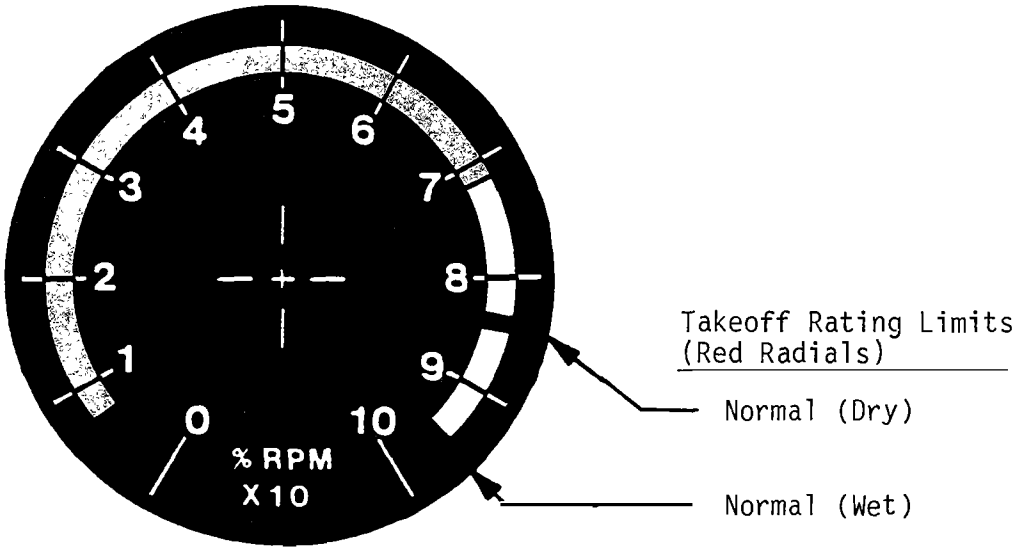
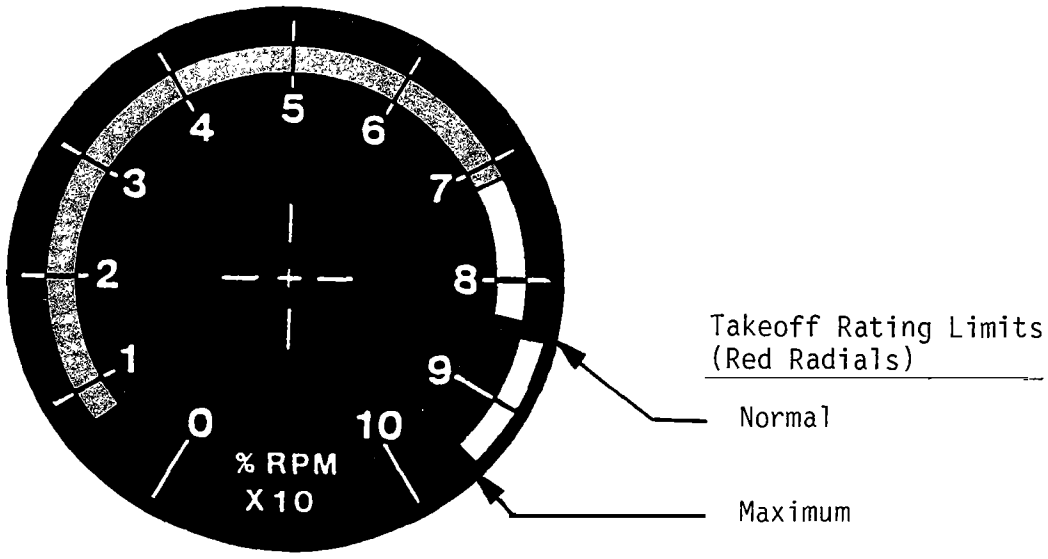


FIGURE 6. LIMIT MARKINGS FOR ATTCS TAKEOFF POWER
(Not to Scale)



9. SUMMARY OF MARKING GUIDELINES BY INSTRUMENT TYPE. The following information summarizes the required basic markings on common powerplant instruments. Additional markings may be required or desired on certain instruments. Other powerplant related instruments not addressed here may also require markings.

a. Carburetor Air Temperature (Reciprocating Engine Aircraft)

Red Radial - At maximum permissible carburetor inlet air temperature recommended by the engine manufacturer.

Green Arc - Normal operating range for trouble-free operation with the upper limit at maximum permissible carburetor inlet air temperature and the lower limit at the point where icing may be anticipated. Additional green arc may be required in the temperature range below the icing range.

Yellow Arc - Range indicating where icing is most likely to be encountered.

b. Cylinder Head Temperature (Reciprocating Engine Aircraft)

Red Radial - At maximum permissible cylinder head temperature.

Green Arc - From maximum permissible temperature for continuous operation to minimum recommended by the engine manufacturer for continuous operation.

Yellow Arc - From maximum temperature for continuous operation to maximum permissible temperature.

c. Manifold Pressure (Reciprocating Engine Aircraft)

Red Radial - At maximum permissible manifold absolute pressure for dry or wet operation, whichever is greater.

Green Arc - From maximum permissible manifold pressure for continuous operation to the minimum manifold pressure selected by the aircraft manufacturer for cruise power.

For propeller driven small airplanes which must meet the requirements for Appendix F to Part 36 of the FAR at maximum normal operating power, from the corrected manifold pressure (horsepower) used to establish the airplane noise level to the minimum manifold pressure selected by the airplane manufacturer for cruise power.

Yellow Arc - From maximum manifold pressure for continuous operation to maximum permissible manifold pressure.

Conditional Limit Markings (if applicable):

Red Wedge Shape - At normal takeoff rating, if less than maximum limit.

Striped Green Arc - From the normal takeoff rating (red wedge shape) to the maximum limit (red radial).

d. Fuel Pressure (Reciprocating and Turbine Engine Aircraft)

Red Radial - At maximum and/or minimum permissible pressure established as engine operating limitations. NOTE: For engines with variable minimum permissible pressure limits, the lower red radial should be placed at the highest minimum absolute pressure allowed.

Green Arc - Normal operating range.

Yellow Arc - Cautionary ranges indicating any potential hazard in the fuel system such as malfunction, icing, etc.

e. Oil Pressure (Reciprocating and Turbine Engine Aircraft)

Red Radial - At maximum and/or minimum permissible pressure established as engine operating limitations.

Green Arc - Normal operating range.

Yellow Arc - Cautionary ranges indicating any potential hazard due to overpressure during cold start, low pressure during idle, etc.

f. Oil Temperatures (Reciprocating and Turbine Engine Aircraft)

Red Radial - At maximum and/or minimum permissible temperatures established as engine operating limitations.

Green Arc - Normal operating range.

Yellow Arc - Cautionary ranges indicating any potential hazard due to overheating, high viscosity at low temperature, etc.

g. Tachometer (Reciprocating Engine Aircraft)

Red Radial - At maximum permissible rotational speed (r.p.m.).

Green Arc - From maximum rotational speed for continuous operation to minimum recommended for continuous operation (except in the restricted range, if any).

For propeller driven small airplanes which must meet the requirements in Appendix F to Part 36 of the FAR at maximum normal operating power, from the corrected rotational speed used to establish the aircraft noise level to the minimum recommended for continuous operation (except in the restricted ranges, if any).

Yellow Arc - From maximum rotational speed for continuous operation to maximum permissible rotational speed.

Yellow Arc (Offset) - Conditional operating range for one engine inoperative flight that exists above the normal takeoff rating limit (if applicable).

Red Arc - Range(s) in which operation is restricted, except to pass through, for all operating conditions because of excessive stresses, etc.

h. Tachometer (Turbine Engine Aircraft)

Dashed Red Radial - At maximum permissible rotational speed (% r.p.m.) for conditional operation (if applicable).

Red Radial - At the normal maximum permissible rotational speed.

Green Arc - From maximum rotational speed for continuous operation to minimum rotational speed recommended for continuous operation.

Yellow Arc - From maximum rotational speed for continuous operation to maximum permissible rotational speed.

Yellow Arc (Offset) - Conditional operating range that exists above the normal takeoff rating limit (if applicable).

i. Torque Indicator (Reciprocating, Turboprop and Turboshaft Engine Aircraft)

Dashed Red Radial - At maximum permissible torque limit for conditional operation (if applicable).

Red Radial - At the normal maximum permissible torque limit.

Green Arc - From maximum torque limit for continuous operation to the minimum recommended torque value.

For propeller driven small airplanes which must meet the requirements in Appendix F to Part 36 of the FAR at maximum normal operating power, from the corrected torque

value used to establish the aircraft noise level to the minimum torque value recommended for continuous operation.

Yellow Arc - From maximum torque limit for continuous operation to maximum permissible torque limit.

Conditional limit markings (if applicable):

Red Wedge Shape - At normal takeoff limit, if less than maximum torque limit.

Striped Green Arc - From the normal takeoff rating (red wedge shape) to the maximum torque limit (red radial).

Yellow Arc (Offset) - Conditional operating range for one engine inoperative flight that exists above the normal takeoff rating limit.

j. Exhaust Gas Temperature (Turbine Engine Aircraft)

Dashed Red Radial - At maximum permissible gas temperature for wet operation for specific maximum time.

Red Radial - At maximum permissible gas temperature for dry operation.

Green Arc - From maximum permissible temperature for continuous operation to minimum recommended by the engine manufacturer.

Yellow Arc - From maximum temperature for continuous operation to maximum permissible gas temperature.

Yellow Arc (Offset) - Conditional operating range for one engine inoperative flight that exists above the normal takeoff rating limit (if applicable).

k. Dual Tachometer (Helicopter)

Red Radial -

Dual Tachometer (Engine) - At normal maximum and minimum permissible rotational speed (% r.p.m.).

Dual Tachometer (Rotor) - At normal maximum and minimum rotor speed (% r.p.m.) for power "off" operational condition.

Green Arc -

Dual Tachometer (Engine) - From maximum rotational speed for continuous operation to minimum recommended for continuous operating power (except in the restricted ranges, if any).

Dual Tachometer (Rotor) - From maximum to minimum normal operating range (including power off).

Yellow Arc -

Dual Tachometer (Engine) - Cautionary ranges, such as altitude limits.

Conditional Limit Markings for Multiengine Helicopters (if applicable):

Dashed Red Radial - Conditional maximum permissible rotational speed (2-1/2 minute rating) for one engine inoperative flight.

Yellow Radial - Conditional 30-minute rating limit for one engine inoperative flight.

Yellow Arc (Offset) - Conditional operating range for one engine inoperative flight that exists above the normal takeoff rating limit.

l. Thrust Indicator (Turbine Engine Airplanes). No markings because values vary considerably with temperature and altitude operating conditions. Limiting gauge markings cannot be established for all such conditions. It is necessary to refer to thrust setting charts (EPR or N_1, etc.) for the proper values.

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