1. Document No.:	2. Project Manager:	3. Reviewing Office:	4. Date of Review:	5. Date of Disposition:
AC 33-Burner Rig - Oxidation, Hot Corrosion, Thermal Fatigue, and Erosion Characteristics Testing to Support 14 CFR, Part 33, 33.15, Compliance for Turbine Engines	Marc Bouthillier 781-238-7120 Daniel Tibuni 781-238-7181 ANE-111	**Reviewer's Name & phone #:** **HEICO**		5-28-14

Instructions for Completing the Document Review Log

Blocks 1 & 2: To be completed by project manager prior to sending out for comments.
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Item No:	Page and Paragraph No:	Comment:	Reason:	Recommendation:	Disposition:
HEICO [MP1] (Note: [MP#] in these comments match with the [MP# in the attached marked up AC draft.)	Page 1 Paragraph 1	Change the ”Purpose” to broaden the scope of the AC to be consistent with the body of the AC.	This draft advisory circular has been developed to provide guidance on the use of Burner Rigs to develop data to show compliance to § 33.15. Burner Rigs can be used to develop data to support: 1) New TC applicants 2) TC holder design changes 3) STC applicants 4) PMA applicants 5) Repair Development Burner rig data can be used to develop new specifications, verify the suitability and durability of a current specification, and development/improvement of coating application processes.	Change the middle two sentences to read “Assessment of key functional and durability properties is necessary for certain engine combustor and turbine section part designs and manufacturing process. These properties may include oxidation resistance, hot corrosion resistance, and thermal fatigue capability and erosion resistance. The selection of properties for assessment should be based on the function and environment of the parts. Comparative assessment could be applicable for a design and/or production change, e.g., base material change, coating change, or application method change.”	Do not agree. The AC is only intended to address comparative testing needs, and is therefore limited in scope. There is no plan to expand the scope of the AC to address other possibilities. This AC does not limit the use of burner rig testing for other purposes. Portions of the recommended statements/thoughts in this comment are addressed in other sections of the AC. Several of these HEICO comments are repeated in later entries.

HEICO [MP2]	Page 2 Paragraph 4.c.	The body of the AC provides guidance "how to" and "what to look for" as opposed to "when to."	The body of the AC provides guidance on how to perform a burner rig test and how to use the data to show compliance to § 33.15. The "when to" question more appropriately sits with the development of the compliance matrix and any project specific compliance plans. Note: This is more of the purpose of the AC than background information.	Change paragraph 4.c from "This AC provides guidance on when such testing is required for compliance under § 33.15 and describes an acceptable test method and criteria." To "This AC provides guidance <u>for how burner rig testing may be used to show</u> compliance to § 33.15 and describes an acceptable test method and criteria." Move this paragraph to the end to Paragraph 1 (Purpose)	Agree. Sentence revised as suggested.
HEICO [MP3]	Page 2 Paragraph 4.a.	Additional background on the reasons for development of replacement parts may be helpful for future readers	Replacement parts can be developed for many different reasons. Understanding the reason for the proposed replacement part will help drive appropriate test selection.	At the end of paragraph 4.a add "Development of replacement parts may arise from different factors including; product improvement, manufacturing process improvements, environmental concerns, or commercial reasons."	Agree in part. A new sentence similar to that proposed has been added.

HEICO [MP4]	Page 2 Paragraph 4.b.	Durability testing can range from independent static tests to full engine tests, with Burner Rigs being something between. For some applications, static testing can be sufficient to show compliance to § 33.15. Other applications may require combinations of the Burner Rig testing and static testing. Still other design changes may require, independent testing AND Burner Rig and even potentially engine testing.	Durability testing can range from independent static tests to full engine tests. For each project the type of testing and analysis should be selected based on an understanding of the part, any proposed changes to the design or manufacture, and the environment that the part is expected to experience. The paragraph of the background should allow for all possible combinations of tests on a part/application specific basis.	Change "The testing normally needed is of a dynamic nature, because traditional static tests do not adequately replicate an engine environment. For example, the effects noted above can occur simultaneously in an engine environment and, therefore, cannot be evaluated by independent static tests." To "Tests and analyses should be developed based on the function and environment of the part. Tests can range from independent static testing to full engine testing. Between these two extremes is burner rig testing."	Agree. New text has been added to the end of this paragraph reflecting the concerns expressed in this comment. However the intent of the AC is to address comparative testing via burner rig. That focus is unchanged.

HEICO [MP5]	Page 2 Paragraph 5	Durability testing using a burner rig can be used for more than just comparative testing.	Limiting the scope of this AC by placing the whole applicability and test development sub paragraphs under "Comparative Tests" would limit the scope of this valuable test method. Comparative testing and assessment should have its own section after the discussion of burner rig durability testing.	Change the title of Paragraph 5 from "Comparative Tests" to "Durability Testing" and move the content of first 3 sentences to a new paragraph 6 on "Test Results and Equivalence Determinations." See comment [MP14]	Do not agree. The AC is only intended to address comparative testing needs, and is therefore limited in scope. There is no plan to expand the scope of the AC to address other possibilities. This AC does not limit the use of burner rig testing for other purposes.
HEICO [MP6]	Page 2 Paragraph 5.a	For some applications, static testing can be sufficient to show compliance to § 33.15. The specific test requirements should come from the development of the compliance matrix and any project specific compliance plans.	For each project the type of testing and analysis should be selected based on an understanding of the part, any proposed changes to the design or manufacture, and the environment that the part is expected to experience. This paragraph should allow for all possible combinations of tests on a part/application specific basis.	Change "Applicants must…" to "Part specific field experience, failure modes, and design evolution history should be used to determine which types of durability testing should be performed. As appropriate, applicants should evaluate…"	Do not agree. The AC addresses the five characteristics noted. There is no plan to expand the scope of the AC. Aftermarket would not likely have comprehensive data on failure modes and design history of OEM parts. The term "as applicable" was added to 5a to make it clear that only applicable characteristics need to be investigated, as you suggest. The new text in 4b also addresses a portion of this comment.

HEICO [MP7]	Page 4 Paragraph 5.b.	The overall intent of a burner rig is to test durability of samples. Burner rig testing can be used to develop data for anything from new material/coating development to comparative testing. For TC design change and STC projects the proposed replacement part may not need to be at least equal to the current type design part. If the margin are known, then a less capable part may still meet the § 33.15 requirements.	The overall intent of a burner rig test method is to test durability of samples. Burner rig testing can be used to develop durability data for anything from new material/coating development to comparative testing. The comparison back to an existing part would be more part of the test planning or part of the PSCP as opposed to the test method.	Change "The overall intent of this test method is to generate adequate data to show that the proposed part is at least equal to the type design part relative to overall oxidation, hot corrosion, thermal fatigue, and erosion resistance when …" To "The overall intent of this test method is to generate data to show that materials and coatings have adequate durability (overall oxidation resistance, hot corrosion resistance, thermal fatigue capability, and erosion resistance) when …"	Do not agree. The AC is designed to address comparative test needs only. This necessitates a comparison with a set standard which is the existing part. There is no plan to expand the scope of the AC for other purposes, or to establish independent standards for non-comparative type of testing. Such non-comparative testing may necessitate engine testing. That would be beyond the scope of this AC effort and intent.

HEICO [MP8]	Page 5 Paragraph 5.c.	Durability testing using a burner rig can be used for more than just comparative testing.	Burner rig test planning in and of itself does not need to have FAA test plans. The FAA test plans should be as a result of the compliance matrix and part/project specific compliance plan. Comparative testing and assessment should have its own section after the discussion of this type of durability testing. See proposed paragraph 6.a in Comment [MP14].	Move the content of the first 3 sentences to a new paragraph 6 on "Test Results and Equivalence Determinations." See comment [MP14]. Delete "comparison of" in the 4th sentence. In the last two sentences change "severity so that degradation occurs in a way that useful comparisons can be made. Test conditions should address the following:" to "severity so that degradation occurs. Depending on the application/environment of interest, test conditions should address the following, as appropriate:"	Do not agree. See disposition for comment MP5, which is a similar comment. However paragraph 5c was edited to address a couple of the suggested edits in the Recommendation column. The first sentence of Paragraph 5c has been deleted as it was unnecessary. The 2nd sentence of Paragraph 5c now keys in on "project compliance and test plans".
HEICO [MP9]	Page 5 Paragraph 5.c.(1)	Some parts do not see high Mach # exhaust gas velocity.	Some parts do not see high Mach # exhaust gas velocity. Specifically static parts and parts not in the flow path. Note: The NASA burner rig referenced is a Mach 0.3 rig.	Add "may" to the last sentence." Meaningful results may require gas streams of relatively high velocity (refer to Table 1)."	Agree. Added the word "may" to the last sentence.

HEICO [MP10]	Page 5 Paragraph 5.c.(2)	Corrosion was included in paragraph 5.a but is not included in 5.c.	Corrosion was included in paragraph 5.a but is not included in 5.c.	Change the title from "Hot Corrosion" to "Corrosion and Hot Corrosion"	Do not agree. The AC focuses on oxidation and hot corrosion, which are the primary "corrosion" concerns addressed by this Galvanic action. Corrosion was defined at a higher level in 5a for perspective and completeness of terminology.
HEICO [MP11]	Page 5 Paragraph 5.c.(2)	Consistency within the paragraphs.	To provide consistency with other paragraphs change part features to engine operating conditions.	Change "… over the range of part features." to "over the range of engine operating conditions."	Agree in part. We added a phrase addressing engine operating conditions as suggested.
HEICO [MP12]	Page 5 Paragraph 5.c.(3)	Moving too quickly in and out of the gas stream may not allow the thermal gradient to fully develop.	Moving too quickly in and out of the gas stream may not allow the thermal gradient and thermal stresses to fully develop.	Delete "rapidly" from ".accomplished by ~~rapidly~~ moving the test specimens in and out of the gas stream.."	Agree. We deleted the word "rapidly".

HEICO [MP13]	Page 5 Paragraph 5.c.(5)	For some applications, static testing can be sufficient to show compliance to § 33.15. The specific test requirements should come from the development of the compliance matrix and any project specific compliance plans.	For each project the type of testing and analysis should be selected based on an understanding of the part, any proposed changes to the design or manufacture, and the environment that the part is expected to experience. This paragraph should allow for all possible combinations of tests on a part/application specific basis.	Add a new paragraph (5) "Tests can be developed to include all of the above conditions in series or parallel, or only some of the conditions. Test design should be appropriate to the application and environment being evaluated."	Agree in part. Paragraph 5a now states conditions "as applicable." Paragraph 4b now includes a discussion about alternative test methods as a function of test objective. However, the AC is focused on burner rig testing when that is appropriate or selected.

HEICO [MP14]	Page 6 Paragraph 5.d.	Comments [MP5] and [MP8] try to improve the flow and utility of the AC by moving the comparative test to its own paragraph. This new paragraph should include references back to other existing AC guidance material on PMA templates and PMA Test and Comp	Comparative testing and assessment (Equivalence Determination) should have its own section after the discussion of this type of durability testing. Guidance material exists for PMA Test and Computations equivalency determinations. Paragraph 26 of AC 21.303-2 provides this guidance. Guidance material also exists for PMA applicants on when they should be looking to make a durability equivalency assessment. Paragraph 6 of AC 33-8 discusses understanding the functional design parameters (including durability as an example.) Appendix 2 of AC 33-8 also provides guidance on when showings of compliance to § 33.15 is recommended.)	Promote paragraph 5.d. to Paragraph 6 and combine prior paragraphs on comparative testing from [MP5] and [MP8]to read: **"6. Test Results and Equivalence Determinations.** In cases where the base material or coating requirements are not identical to the type design part, (as determined by patent evaluation, formal material certification documentation, material reverse engineering, manufacturing processes, etc.), comparative durability tests may be necessary to adequately support a showing of compliance to § 33.15. (See AC 33-8 for examples of when showings of compliance to § 33.15 is recommended.) Such testing most often uses material specimens (coupons), but could use actual parts in certain cases. Durability properties can include both time-to-failure and the actual failure mechanisms. Applicants can perform various tests to collect the data needed for this showing.	Do not agree. See disposition for comment MP5, which has similarities to this comment. Also, the AC is not PMA specific by intent, and does not require special cross references to be effective. Doing so would change the nature of the AC from generic to aftermarket. The AC is limited to describing a MoC for comparative testing for specific parameters when it is determined that such testing is necessary. Also, compliance and test plans are generally needed for tests that generate specific compliance data. However, this is determined on a case-by-case basis by the ACO and applicant. Paragraph 5c has been edited in this regard.

HEICO [MP14] (cont.)	Page 6 Paragraph 5.d. (cont.)		Burner rig test planning in and of itself does not need to have FAA test plans. The FAA test plans should be as a result of the compliance matrix and part/project specific compliance plan. AC 21.303-2 paragraph 27 provides additional guidance on test planning and requirements for FAA Test Plans.	Note: For designs/design changes that warrant testing, an FAA approved test plan may be required. The approved test plan could include test conditions addressing oxidation, hot corrosion, thermal fatigue, and erosion. a. Comparative Testing. Back-to-back or simultaneous testing of samples of both proposed and type design parts, or test specimens, may be necessary to compare part characteristics. See AC 33-8 and AC 21.303-2 for additional details on when and how to use comparative testing. b. Test Result Analysis & Assessment Quantitative vs Qualitative. The following assessment methods may be used to compare parts and coatings:" (then continue with (1) Oxidation and Hot Corrosion…)	

HEICO [MP15]	Page 7 Paragraph 5.d.(6)	The overall intent of a burner rig is to test durability of samples. Burner rig testing can be used to develop data for anything from new material/coating development to comparative testing. For TC design change and STC projects the proposed replacement part may not need to be at least equal to the current type design part. If the margin are known, then a less capable part may still meet the § 33.15 requirements.	Burner Rigs can be used to develop data to support: 1) New TC applicants 2) TC holder design changes 3) STC applicants 4) PMA applicants 5) Repair Development The requirement for "at least equal to the type design" is a PMA requirement and would be covered as part of the PMA application. (AC 21.303-2 paragraph 27) TC holder design changes and STC projects many not need to meet the "at least equal to.." requirement.	Delete Paragraph 5.d.(6)	Do not agree. The AC describes a specific comparative test method. Its scope is limited by intent. There is no plan to expand this guidance to other purposes. This AC does not limit the use of burner rig testing for other purposes. To determine whether a "less capable" replacement part has sufficient margin operating in an engine is <u>well beyond</u> the scope of § 33.15 compliance by itself, and relates to compliance with the entire certification basis for the engine product. The comparative test method described in this AC, within the scope of its limitations, can provide data that allows an equivalent finding to be made without engine testing. For less capable parts, different testing and analysis would likely be required, perhaps including engine testing as a TC holder would be required to conduct at initial product certification. But that could only be determined on a case-by-case basis.

1. Document No. & Title: AC 33-Burner Rig	2. Originating Office and PoC: EPD Staff ANE110 (M. Bouthillier)	3. Reviewing Entity: MARPA	4. Date of Review: May 29, 2014	5. Date of Disposition: May 29, 2014

Item No:	Page and Paragraph No:	Comment	Recommendation:	Disposition:
1.	Para 1	The "Purpose" paragraph explains that the AC describes an acceptable method to support compliance with 14 C.F.R. § 33.15, which is applicable to parts approved under TC, STC, PMA or repair alteration authority. However the paragraph goes on to specifically discuss only comparative testing for purposes of compliance, thus serving to significantly narrow the scope and usefulness of the AC.	Paragraph 1 should be amended to read "Comparative assessment of certain data is *may be* necessary to show the required functional and durability equivalencies . . . ." Such a change would reflect the broad scope of the AC and the various uses of test data made available by resort to the Burner Rig test methods described therein.	Do not agree. The AC, by intent, addresses circumstances that require or select a comparative assessment approach. There is no plan or need to expand the scope of the AC for other circumstances. This AC does not limit the use of burner rig testing for other purposes. We have replaced the word "is" in paragraph 1 with "often", to better reflect varying circumstances, which is part of this comment.

2.	General	Burner Rig testing can be used to develop significant data sets for multiple methods of analysis and testing. The AC appears to limit the use of Burner Rig testing to Comparative tests alone.	Paragraph 5 should be re-labeled to reflect a broader scope of Burner Rig testing possibilities rather than limiting the scope to comparative tests alone.	Do not agree. The AC, by intent, addresses circumstances that require or select a comparative assessment approach. There is no plan or need to expand the scope of the AC for other circumstances. This AC does not limit the use of burner rig testing for other purposes.
3.	Para. 5.a	Paragraph 5.a. states that applicants must evaluate certain characteristics in an "engine operating environment." This implies that a Burner Rig test will always be required. However in certain cases, independent static testing can be sufficient to show compliance to § 33.15.	Revise the sentence "Applicants must evaluate the following part and material characteristics in an engine operating environment:" to permit the applicant discretion to determine the testing methods necessary to obtain part and material characteristics data needed to support the project application.	Do not agree. The AC, by intent, addresses circumstances that require or select a comparative assessment approach. The AC does not state or suggest that a burner rig test is required for all circumstances. Paragraph 4b has been revised to discuss other circumstances or possibilities as discussed in this comment. Also, Paragraph 5 has been revised to include the phrase "as applicable" to put a perspective on varying situations.

4.	Para. 5.c	Burner Rig testing can be used to perform tests and obtain data outside the scope of an FAA approved test plan.	Revise the paragraph to clarify that the guidance applies only in the context of an FAA-approved test plan, and not to the use of Burner Rig testing in general.	Agree in part. The AC does not state or suggest that any and all test plans must be FAA approved. That is determined by the project ACO and applicant. However the first sentence of Paragraph 5c is unnecessary and has been deleted. The 2nd sentence of Paragraph 5c has been revised to key in on project compliance and test plans. Overall, tests that are planned to produce approved data for compliance purposes should have FAA approval or concurrence.
5.	Para. 5.c.1	Paragraph 5.c.1 states that "Meaningful results require gas streams of relatively high velocity" and refers to Table 1, which provides for an exhaust gas velocity of up to Mach 0.9.	Revise the final sentence in Paragraph 5.c.1 to read "Meaningful results *may* require . . . ."	Agree in part. The AC does not specifically address non-gas path parts. The problems of corrosion and erosion, as addressed by this AC, are fundamentally gas path concerns. However, we agree to insert the word "may" into the last sentence of Paragraph 5c1 as suggested.

1. Document No. & Title: AC 33-Burner Rig	2. Originating Office and PoC: EPD Staff ANE110 (M. Bouthillier)	3. Reviewing Entity: General Electric	4. Date of Review: May 27, 2014	5. Date of Disposition: May 27, 2014
Item No:	**Paragraph No:**	**Commenter**	**Comment & Recommendation:**	**Disposition:**
1	Sec 5	P. Thompson	Include weld and braze materials in Comparative Test guidance section.	Agree. A reference to braze and weld materials was added to the text of the comparative test paragraph.
2	Sec 5	P. Thompson	Add a statement that test specimens must be manufactured using the same processes as the actual part.	Agree. New text was added to Paragraph 5c this effect.
3	Sec 5.c	P. Thompson	Add reference to new AC 33-XX (10) the Statistics AC for determining test sample size.	Agree. A new reference has been added for this AC. That AC has not been published to date.
4	Sec 5.d(2)	P. Thompson	Add new subparagraph to better address equivalency criteria for TBC systems.	Agree. A new subparagraph has been added to better address TBC/bond coat considerations.

5	Sec 5.a(3)	P. Thompson	Add guidance for corrosive substances other than sodium sulfate.	Agree in part. For applicant awareness we added a cautionary statement about the possibility of other gas path substances being corrosive. However the AC in current form addresses the primary risk for hot corrosion.
6	Figure 1 / Table 1	P. Thompson	Revise Table 1 to reflect more realistic values for temperature and velocity.	Agree. We deleted Table 1 entirely, and included new text in the lead in paragraph to specify temperature and velocity values must be consistent with the actual engine application.
7	Sec 5.c(1)	P. Thompson	Delete sentence specifying cyclic rates.	Agree. Sentence is deleted.
8	General	P. Thompson	General comments about properly identifying operating conditions, part degradation modes and the need for engine testing as burner rig testing is screening in nature.	Agree in principle. No changes to the AC were made in this regard as the limits of burner rig testing are understood.

1. Document No. & Title: AC 33-Burner Rig	2. Originating Office and PoC: EPD Staff ANE110 (M. Bouthillier)	3. Reviewing Entity: Chromalloy	4. Date of Review: May 23, 2014	5. Date of Disposition: May 23, 2014

Item No:	Page and Paragraph No:	Commenter	Comment & Recommendation:	Disposition:
1.	General	M. Fulmer	Expand the overall title, scope and content of the AC to include furnace/oven testing as an alternative when appropriate.	Agree in part. Furnace/oven testing in static air is not a suitable alternative for the majority of the test objectives discussed in the AC. For example, the dynamic nature of engine core flow is significant for oxidation, hot corrosion, and erosion in particular. The example NASA report Chromalloy offered is for a test objective of oxidation in static air up to 1200C, neither of which is representative of a modern engine core environment. However, we concur that the AC needs to be clear that other test methods will be considered when appropriate, so we added a new text to Paragraph 4b in this regard. Note that this AC focuses on burner rig testing when that is determined to be necessary or selected.
2.	Para 3 & 5.b.3	M. Fulmer	Remove reference to NASA report.	Agree in part. The NASA reference is only to provide a real world example of suitable test facility configuration. This reference does not affect the ability of an applicant to propose and have approved a suitable test plan. So using this example is appropriate for the purpose. However, we concur to delete the specific upfront reference in paragraph 3 as we are not driving applicants to that specific facility configuration. We have retained the reference to the NASA report in paragraph 5.b.3, but we added text to make it clear the reference is only for informational purposes and does not imply a required standard.