Designation: D7155 – 18

Standard Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils[1]

This standard is issued under the fixed designation D7155; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the compatibility of mixtures of turbine lubricating oils as defined by Specification D4304. The methods compare properties of specific mixtures with those of the neat oils after storage at specified conditions.

1.2 The methods are grouped into four tiers of testing types:

1.2.1 *Tier 1*—Visual appearance

1.2.2 *Tier 2*—Interfacial properties

1.2.3 *Tier 3*—Physical and chemical properties

1.2.4 *Tier 4*—Specific performance properties

1.3 The methods can be used to evaluate new (unused) lubricant compatibility or the effects of adding new (unused) lubricant to in-service lubricant in the system.

1.4 This practice does not evaluate the wear prevention characteristics, load carrying capacity, or the mechanical shear stability of lubricants mixtures while in service. If anti-wear (AW), extreme pressure (EP), or shear stability are to be evaluated, further testing of these parameters may be required.

1.5 Mixtures of the two constituent oils are evaluated using the Tier 1 and Tier 2 testing protocol. Sequential or concurrent testing is continued by applying tests from Tier 3 or Tier 4 until the test requestor or user is satisfied that the intent of this practice has been met. If any mixture fails the methods, the oils are considered incompatible by that method. If all mixtures pass the methods, the oils are considered compatible by those methods. It is recommended that passing only Tier 1 does not adequately test for fluid compatibility.

1.6 If the mixture passes Tier 1, it shows two oils are visually compatible only. If the mixture passes Tier 1 and 2, it shows two oils are visually and interfacially compatible. If the mixture passes Tier 1, 2 and 3, it shows two oils are visually, interfacially, physically, and chemically compatible. If the mixture passes Tier 1, 2, 3, 4, it shows two oils are compatible with the highest confidence level. Testing each tier level is giving the user more confidence that the two fluids are compatible.

1.7 This practice applies only to lubricating oils having characteristics suitable for evaluation by the suggested test methods. If the scope of a specific test method limits testing to those oils within a specified range of properties, oils outside that range cannot be tested for compatibility by that test method.

1.8 This practice may be used to evaluate the compatibility of different types and grades of oil. However, it is not intended to evaluate such mixtures for lubrication performance. The user is advised to consult with suppliers in these situations.

1.9 This practice does not purport to cover all test methods that could be employed.

1.10 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.11 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.C0.01 on Turbine Oil Monitoring, Problems and Systems.

Current edition approved June 1, 2018. Published August 2018. Originally approved in 2006. Last previous edition approved in 2011 as D7155 – 11. DOI: 10.1520/D7155-18.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D665 Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
D892 Test Method for Foaming Characteristics of Lubricating Oils
D893 Test Method for Insolubles in Used Lubricating Oils
D974 Test Method for Acid and Base Number by Color-Indicator Titration
D1401 Test Method for Water Separability of Petroleum Oils and Synthetic Fluids
D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 °C and 100 °C
D2272 Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel
D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
D3427 Test Method for Air Release Properties of Hydrocarbon Based Oils
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4304 Specification for Mineral and Synthetic Lubricating Oil Used in Steam or Gas Turbines
D4310 Test Method for Determination of Sludging and Corrosion Tendencies of Inhibited Mineral Oils
D4629 Test Method for Trace Nitrogen in Liquid Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5762 Test Method for Nitrogen in Liquid Hydrocarbons, Petroleum and Petroleum Products by Boat-Inlet Chemiluminescence
D5846 Test Method for Universal Oxidation Test for Hydraulic and Turbine Oils Using the Universal Oxidation Test Apparatus
D6186 Test Method for Oxidation Induction Time of Lubricating Oils by Pressure Differential Scanning Calorimetry (PDSC)
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6514 Test Method for High Temperature Universal Oxidation Test for Turbine Oils
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D7843 Test Method for Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry
D7873 Test Method for Determination of Oxidation Stability and Insolubles Formation of Inhibited Turbine Oils at 120 °C Without the Inclusion of Water (Dry TOST Method)

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology D4175.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *compatibility, n—of lubricating oils*, the ability of lubricating oils to mix together without significant degradation of properties or performance.

3.2.1.1 *Discussion*—When a mixture of two oils has properties or performance significantly inferior to either of the constituent oils, then the two oils are incompatible. If the properties are inferior to those of one neat oil but not inferior to those of the other, then such is not necessarily considered an indication of incompatibility. To be considered significantly inferior, the property of the mixture would be worse than the poorer of the two neat oils by an amount exceeding the repeatability (or in the case of third party verification testing, the reproducibility) of the test method used to evaluate the property. (See the definitions for fail and pass.)

3.2.2 *fail, n—in compatibility testing of oil mixtures*, a test result that is inferior to that of the poorer of the two constituent oils by an amount exceeding the repeatability of the test method used for the evaluation.

3.2.3 *insolubles, n*—solids or semi-solid material that accumulate on the bottom of a liquid. As broadened, insolubles include varnishes and "non-sedimentatious materials" resulting from fluid incompatibility that change the appearance of a bright and clear liquid to "hazy" or "cloudy."

3.2.4 *pass, n—in compatibility testing of oil mixtures*, a test result that is equal to or better than that of the poorer of the two constituent oils by an amount exceeding the repeatability of the test method used for the evaluation.

3.2.5 *type and grade, n*—type and grade refer to lubricants of the same general type such as Rust and Oxidation Inhibited turbine oil (R&O) and ISO Viscosity grades.

3.2.6 *10:90 mixture, n*—a uniform blend of 10 % by volume of one oil with 90 % by volume of a second oil.

3.2.7 *50:50 mixture, n*—a uniform blend of 50 % by volume of each of two component oils.

3.2.8 *90:10 mixture, n*—a uniform blend of 90 % by volume of one oil with 10 % by volume of a second oil.

4. Summary of Practice

4.1 *Option 1*—Prepare a 50:50 mixture of two oils to be evaluated for compatibility. This mixture and the two neat, constituent oils are tested using the compatibility tests. Depending on the performance of the mixture, relative to those of the constituent oils, 10:90 and 90:10 mixtures may need to be tested in addition.

4.2 *Option 2*—Instead of testing mixtures in sequential order, 10:90 and 90:10 mixtures are tested at the same time the 50:50 mixture is evaluated. If all mixtures pass Tier 1 and 2

compatibility tests, or if the application requires the evaluation of specific properties, Tier 3 and 4 compatibility tests can be employed for further evaluation. Such tests can be run concurrently, if desired.

5. Significance and Use

5.1 The compatibility of oils can be important for users of oil-lubricated equipment. Mixing of two oils can produce a substance markedly inferior to either of its constituent materials. One or more of the following can occur:

5.1.1 A mixture of incompatible oils most often forms a precipitate. The precipitate will form unwanted deposits in the lubrication system, plug filters, and oil passageways.

5.1.2 A mixture of incompatible oils will sometimes exhibit degradation of certain performance parameters like demulsibility, foam inhibition oxidation stability, rust protection ability, or antiwear protection ability.

5.1.3 A mixture of incompatible oils will sometimes exhibit non-miscibility of the base oils with each other.

5.1.4 Such incompatibilities can lead to catastrophic equipment failures.

5.2 To minimize the chances of these problems occurring, lubricant suppliers recommend evaluating compatibility of lubricating oil of different formulations and sources prior to mixing. Equipment users most often do not have the resources to evaluate oil compatibility and must rely on their suppliers. Mixing of oils without first determining the compatibility is a highly imprudent practice.

5.3 Although new turbine oils may be compatible, in-service oil of the same type may be degraded or contaminated to such an extent that the new oil added may not be compatible with the system oil. In-service oil compatibility with new oil additions should be evaluated on a case-by-case basis.

5.4 The oxidation resistance of different oils of the same type can vary widely, and compatibility does not imply equivalent performance without oxidation performance testing.

6. Apparatus

6.1 The equipment and materials required for this practice shall be those required by the test methods used to evaluate compatibility.

6.1.1 *Laboratory Oven,* static-air or stirred-air type, capable of maintaining the test temperature within ±3 °C and equipped with one or more grill-type wire shelves.

6.1.2 *Laboratory Cooler,* capable of maintaining the test temperature within ±3 °C.

6.1.3 *Reflector Flood Lamp,* 150 W.

7. Procedure

7.1 Testing is conducted (see Section 7.3 – 7.6) for mixture proportions as agreed upon with the test requestor or user and dependent on the available sample volumes supplied. Either the sequential testing protocol described in Option 1 or the concurrent testing protocol described in Option 2 can be used. Using Option 1, a 50:50 mixture and the two constituent oils are tested. If this mixture is found compatible, 10:90 and 90:10 mixtures which reflect drain-and fill conversion or make up proportions may be tested. Using Option 2, all mixtures (10:90, 50:50, and 90:10) and the two constituent oils are tested concurrently. At the discretion of the interested parties, the testing may be continued even after an incompatible test result is observed.

7.2 *Preparation of Mixtures*—Prepare mixtures similarly, regardless of whether one or three mixtures of differing ratios will be tested sequentially or concurrently.

7.2.1 Blend a fresh mixture of the two oils to be evaluated for compatibility (neat, constituent oils are designated A and B). Determine the amounts to be mixed from the amount of oil required by the tests. Blend at least 10 % more mixture than is actually needed for the tests. Do not blend more than can be used immediately. No more than 7 days should elapse between mixture preparation and the start of any test.

7.2.1.1 For example, one can prepare a 50:50 mixture by adding equal amounts ±1 % of oils, neat oils A and B, into a separate clean, dry, glass beaker, and mixing thoroughly.

7.2.2 Heat the beaker and mixtures in the oven, or appropriate heating assembly, at 65 °C ± 3 °C for a minimum of 23 h to 25 h with occasional mixing before completing the mixing procedure.

NOTE 1—Test Method D7843 has taught us the sample shall be heated for 23 h to 25 h for proper incorporation of the insoluble components.

7.2.3 After the blending procedure is complete, the user may continue heating the sample in an oven for the incubation time or instead, not heat and store at room temperature for the incubation time.

NOTE 2—The storage temperature needs to be agreed between the parties involved.

7.2.4 However, before testing, a room temperature incubation is suggested as described in Test Method D7843, subsection 8.2, stored between 15 °C to 25 °C, away from UV light for an incubation period of 68 h to 76 h.

NOTE 3—Test Method D7843 testing has taught that the proper formation of varnish particles requires this incubation period condition. Many examples have reported no insoluble material formed directly after the heating cycle.

7.3 *Tier 1 Testing*—This is the first series of evaluation for the oils. The properly blended oils (Section 7.2) may be tested using the recommended Tier 1 tests.

7.3.1 Observe the oil in accordance with Appendix X1. If the oils display an incompatible result, conclude the test and report in accordance with Section 8.

7.4 *Tier 2 Testing*—This is the second series of evaluation for the oils. The properly blended oils (Section 7.2) may be tested using the recommended Tier 2 tests.

7.4.1 Compatibility issues of oils can have their root cause through the variation of interfacial forces of the fluid: liquid-liquid (Test Method D1401), liquid-gas (Test Method D892) and liquid-solid (Test Method D7843). For that reason, interfacial tests are recommended to be included as a part of required testing. When oils are blended the lack of compatibility is accentuated at the fluid surfaces. Measuring these interfacial properties provides a closer look at the fluid interactions and demonstrate the oil compatibility or lack of

compatibility. Many times, the changes in these interface properties are the cause of changes in other properties.

NOTE 4—Use great care when preparing the contents of the beaker for some tests. Semi-solid material not visible to the unaided eye may have settled to the bottom of the vessel. This material needs to be thoroughly mixed back into the sample prior to testing for insolubles.

7.4.2 *Membrane Patch Colorimetry Test (MPC)*—Determine and record the membrane patch test results as described in Test Method D7843. Varnish production or insoluble formation is a measurement of oil compatibility. The Tier 1 visual testing is a crude visual measurement of this property. In many cases the amount of the insoluble is too small to be observed visually. For this reason, it is recommended to test the oil by Test Method D7843 (MPC testing). The formation of solids (insoluble or varnish) is a physical measure of the liquid to solid interface. Oil incompatibility shows changes in the liquid-solid interface more frequently than many other properties. A blend of the oils that shows an increase in the MPC values is considered failing this test. Record as *compatible* or *pass* if the insoluble content of the mixture is the same or lower than both of the constituent oils by an amount greater than repeatability of the test method. Record as *incompatible* or *fail* if the insoluble content of the mixture is greater than the larger of the two constituent oils by an amount greater than repeatability of the test.

7.4.2.1 *Pentane Insolubles*—Determine the pentane insoluble content using Test Method D893. Similar to the D7843, the pentane insoluble test is a measure of the liquid-solid interface and could be considered a basic Tier 2 test as well. The mixture is considered to be compatible if the pentane insoluble content of the mixture is equal to or less than either constituent oil. Record as *compatible* or *pass* if the insoluble content of the mixture is the same or lower than both of the constituent oils by an amount greater than repeatability of the test method. Record as *incompatible* or *fail* if the insoluble content of the mixture is greater than the larger of the two constituent oils by an amount greater than repeatability of the test.

7.4.2.2 Test Method D7843 is more sensitive to low levels of varnish formation than Test Method D893. There needs to be an agreement between the parties involved as to the measurement test method of the insoluble content.

7.4.3 *Foaming Characteristics*—Determine and record the foaming characteristic as described in Test Method D892. Sequence I foam testing is the recommended procedure. Foam is an example of the measurement of the liquid-air interface property. Like insoluble material formation and the liquid-solid property, the air-liquid property is one of those properties very sensitive to oil incompatibility. Degradation of this property is one of the first observed between incompatible oils. The mixture is considered to be compatible if the foaming characteristic of the mixture is equal to or less than either constituent oil. Record as *compatible* or *pass* if the foaming characteristic of the mixture is better (less) than the constituent oils by an amount greater than repeatability of the test method. Record as *incompatible* or *fail* if the foaming characteristic is worse (more) than the constituent oils by an amount greater than repeatability of the test.

7.4.3.1 *Air Release Properties*—Determine and record the air release property as described in Test Methods D3427.

7.4.3.2 Air release is another example of the measurement of the liquid-air interface property. Due to its measurement complexity, it is not typically considered a Tier 2 test but it could augment foam as an air-liquid test if desired. The mixture is considered to be compatible if the air release properties of the mixture are equal to or better (lower air release time) than either constituent oil. Record as *compatible* or *pass* if the air release property of the mixture is equal to or better than the constituent oils by an amount greater than repeatability of the test method. Record as *incompatible* or *fail* if the air release property of the mixture is worse (higher air release time) than the constituent oils by an amount greater than repeatability of the test.

7.4.3.3 There needs to be an agreement between the parties involved as to the measurement test method of the air-liquid property test.

7.4.4 *Water Separability*—Determine and record the water separability results as described in Test Method D1401. Water separation (demulsibility) is a measurement of the liquid-liquid interface property. The liquid-liquid interface property is the third interface property that shows a high degree of sensitivity to oils compatibility. The mixture is considered to be compatible if the water separability of the mixture is equal to or better (lower demulsibility time) than either constituent oil. Record as *compatible* or *pass* if the water separability of the mixture is better than the constituent oils by an amount greater than repeatability of the test method, Record as *incompatible* or *fail* if the water separability of the mixture is worse (higher demulsibility time) than the constituent oils by an amount greater than the repeatability of the test method.

NOTE 5—If one of the oils is an in-service oil the test results on the initial oils being blended may not be passing for a new oil specification; however, the compatibility of the blend is judged based on a degradation the initial oil test values.

NOTE 6—Some oils do not demulsify. In these cases, this test may not be relevant.

7.4.5 Obtain results for Test Methods D1401, D892 and D7843 in accordance with these test procedures. If the results show a derating for the blended oil compared to the initial oils, these oils can be considered as incompatible; conclude the test and report in accordance with Section 8. If the results are satisfactory and Tier 3 or Tier 4 level testing is to be conducted, proceed to 7.5 or 7.6. If only Tier 1 and Tier 2 testing were requested the testing can be concluded and reported in accordance with Section 8.

7.5 *Tier 3 Testing*—If resources permit, the specified tests can be performed concurrently. Otherwise, any sequence of these tests can be used. The properly blended oils (7.2) may be tested using the recommended Tier 3 tests.

7.5.1 Tier 3 testing is focused on compatibility with respect to physical and chemical properties.

7.5.2 When two oils are blended having different physical properties the resultant blended oil can exhibit a change in these properties. Some of these changes might be expected – for example if one oil has a lower viscosity, the viscosity of the mixture will be between the values of the two individual oils.

However, there can also be unexpected changes. There needs to be an agreement between the parties involved regarding the acceptable limits of any Tier 3 testing values.

7.5.2.1 Tier 3 compatibility tests are suggested, but not required, by this practice.

7.5.3 *Viscosity*—Determine and record the viscosity as described in Test Method D445 or D7042.

7.5.3.1 Viscosity is considered one of the most basic and important properties of an oil. Changes in this physical property can affect the oil's performance properties and should be considered if studying performance properties (Tier 4). The viscosity of a turbine oil determines its ability to flow in a lubrication system and to support bearing loads, transfer heat, and operate hydraulic controls. The mixture is considered to be compatible, and its results shall be recorded as *compatible* or *pass* if the viscosity is that of either constituent oil or if the mixture viscosity lies between the viscosity of either constituent oil. If the viscosity of the mixture is less than that of the lower viscosity oil or greater than that of the higher viscosity oil by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.4 *Viscosity Index*—Determine and record the viscosity index as described in Practice D2270.

7.5.4.1 The temperature at which the viscosity is performed to determine the ISO Viscosity Grade is 40 °C. To obtain the viscosity index an additional viscosity measurement must be performed at 100 °C. There needs to be an agreement between the parties involved as to the limits of change. If the change in viscosity index is outside the agreed upon range by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.5 *ASTM Color*—Determine and record the color as described in Test Method D1500.

7.5.5.1 The color of the resultant blended oil can change during blending. There are cases in which this color change could be important for assessing compatibility. There needs to be an agreement between the parties involved as to the acceptable limits of change. If the change in color is outside the agreed range by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.6 It is known that additive reactions can occur when the oils are blended. Some of these reactions can affect the compatibility of the blended oils.

7.5.7 *Acid Number*—Determine and record the acid number as described in Test Methods D664 or D974.

7.5.7.1 The initial acid number is influenced by base oil and additives. The acid number of the blended oil can change from those of the initial oils due to chemical reactions of oil components. The acid number could also change due to dilution effects. Knowing the difference is important in evaluating the results of the test measurement.

7.5.7.2 As oils age acid number can increase, especially near the end-of-life. A dilution or lowering of this value may not be a sign of incompatibility. Knowing the difference is important in evaluating the results of the test measurement. In some cases, the treated oil may start with high acid number. The high acid number is due to carboxylic acid rust inhibitor or antiwear. As these additives degrade or are consumed the acid number will go down. In the latter stages of oil cycles, the acid number can go up through oxidation mechanisms. The mixture is considered to be compatible if the acid number of the mixture is between or equal to the acid number of either constituent oil. Record as *compatible* or *pass*. If the acid number of the mixture is less than or greater than the constituent oils by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.8 *Additive Elements*—Determine and record the additive elements concentration as described in Test Method D5185. Like all chemical properties, dilution of the oils by the blending with another oil can lower these values. If there is an expected change, the calculation of this change needs to be determined before evaluating the results of this test as a compatibility test.

7.5.8.1 The mixture is considered to be compatible if the additive elements concentration of the mixture is the sum of the weighted element concentrations in the individual oils within repeatability of the method. Record as *compatible* or *pass*. If the additive elements concentration of the mixture is less than or greater than this weighted value by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.9 *Sulfur Content*—Determine and record the sulfur concentration as described in Test Method D3120.

7.5.9.1 The mixture is considered to be compatible if the sulfur concentration of the mixture is the concentrations of sulfur in the blend is the sum of the weighted sulfur concentrations in the individual oils within repeatability of the method. Record as *compatible* or *pass*. If the sulfur concentration of the mixture is less than or greater than this weighted value by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.10 *Nitrogen Content*—Determine and record the nitrogen concentration as described in Test Method D4629 or D5762.

7.5.10.1 The mixture is considered to be compatible if the nitrogen concentration of the mixture is the concentrations of sulfur in the blend is the sum of the weighted nitrogen concentrations in the individual oils within repeatability of the method. Record as *compatible* or *pass*. If the nitrogen concentration of the mixture is less than or greater than this weighted value by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.5.11 *Water*—Determine and record the water content as described in Test Method D6304. Prevention of water content ingress should be considered when handling the blending and testing of the fluids if water content is a concern for the compatibility testing protocol.

7.5.11.1 The mixture is considered to be compatible if the water content of the mixture is between or equal to either constituent oil. Record as *compatible* or *pass*. If the water content of the mixture is less than or greater than the constituent oils by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.6 *Tier 4 Testing*—If resources permit, the specified tests can be performed concurrently. Otherwise, any sequence of these tests can be used. The properly blended oils (7.2) may be tested using the recommended Tier 4 tests.

7.6.1 Tier 4 testing provides information about the compatibility with respect to the performance of the oil in its designed application. Such tests are driven by the critical features of a given application. For example, if the application subjects the oil to extraordinarily high temperature an evaluation of the onset of oxidation at various temperatures to construct an Arrhenius plot may be warranted.

7.6.1.1 Tier 4 compatibility tests are suggested, but not required, by this practice.

7.6.2 When two oils are blended having different performance properties the resultant blended oil can exhibit a change in these properties. Some of these changes might be expected. However, there can also be unexpected changes. There needs to be an agreement between the parties involved as to the limits of any Tier 4 testing values.

7.6.3 *Oxidation Stability*—Select the appropriate oxidation stability test based on the type of lubricant being investigated. Determine and record the oxidation stability as described in the selected test method. The mixture is considered to be compatible if the oxidation stability of the mixture is equal to or higher than either constituent oil. Record as *compatible* or *pass*. If the oxidation stability of the mixture is lower than the constituent oil with the lowest value by an amount greater than repeatability of the test method, record as *incompatible* or *fail*.

7.6.3.1 *Rotating Pressure Vessel Oxidation testing (RPVOT)*—Determine and record the oxidation results as described in Test Method D2272. The blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing like the RPVOT. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.3.2 *High Temperature Universal Oxidation Test*—Determine and record the oxidation results as described in Test Method D6514. Like the RPVOT, blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.3.3 *Universal Oxidation Test for Hydraulic and Turbine Oils*—Determine and record the oxidation results as described in Test Method D5846. Like the RPVOT, blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.3.4 *Oxidation Induction Time of Lubricating Oils by Pressure Differential Scanning Calorimetry (PDSC)*—Determine and record the oxidation results as described in Test Method D6186. Like the RPVOT, blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.3.5 *Dry TOST*—Determine and record the oxidation results as described in Test Method D7873. The Dry TOST is run in the absence of water and may be a more suitable oxidation test for oils formulated with components that are especially susceptible to hydrolysis (e.g., esters). Like the RPVOT, blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.3.6 *Determination of the Sludging and Corrosion Tendencies*—Determine and record the oxidation results as described in Test Method D4310. Like the RPVOT, blending of oils with different antioxidant formulations has been shown to affect how these antioxidants behave in oxidation testing. The user needs to understand the effects of this as part of the evaluation of the results. There needs to be an agreement between the parties involved as to the limits.

7.6.4 *Rust Prevention*—Determine and record the rust prevention results as described in Test Method D665. The mixture is considered to be compatible if the rust prevention characteristics test is a pass. Record as *compatible* or *pass*. If the rust prevention characteristics test of the mixture is a fail, record as *incompatible* or *fail*.

7.6.5 *Copper Corrosion*—Determine and record the copper corrosion results as described in Test Method D130. The mixture is considered to be compatible if the copper corrosion result is a pass. Record as *compatible* or *pass*. If the results of the mixture is a fail, record as *incompatible* or *fail*.

7.6.6 *Aniline Point*—Determine and record the aniline point temperature results as described in Test Method D611.

7.6.6.1 Aniline point might be added to evaluate the relative difference in solvency characteristics. Base stocks of the oils or formulated solvent enhancement added to the oils can change the ability of the oil to dissolve components. In the case where insolubles or varnish have been observed in the initial oil, the addition of an oil with improved aniline point might improve the oil's performance in this area. An improvement (lowering of the aniline point temperature) can be considered an improvement and not a failing compatibility issue. The mixture is considered to be compatible if the aniline point temperature is equal to or lower (better) than either of the constituent oils alone. Record as *compatible* or *pass* if the aniline point temperature of the mixture is lower than the constituent oils by an amount greater than the repeatability of the test. Record as *incompatible* or *fail* if the aniline point temperature of the mixture is higher than both constituent oils by an amount greater than the repeatability of the test.

7.6.7 If all of the mixtures pass all Tier 1 and Tier 2 tests and the selected Tier 3 and Tier 4 tests, the oils shall be reported as compatible. If any mixture passes all Tier 1 and Tier 2 tests but fails one or more Tier 3 or Tier 4 tests, the oils shall be reported as generally compatible but incompatible in certain applications. The failed tests shall be reported as well as the applications suggested by these tests.

8. Report

8.1 Report the following information:

8.1.1 Identity of the constituent oils and the mix-ratios of the mixtures tested.

8.1.2 Whether the oils were found compatible or incompatible by Tier 1 or Tier 2 assessment, and if found incompatible, report the mixing ratio(s) found incompatible and in which test(s).

8.2 If supplementary testing procedures were used, report these results in 8.1.1 and 8.1.2. In addition, report the test methods used in supplemental testing and whether the oils were found compatible or incompatible.

9. Precision and Bias

9.1 For complete precision and bias statements, see the pertinent test methods.

10. Keywords

10.1 compatibility; incompatibility; lubricant mixtures; lubricating oil; mixtures

APPENDIXES

(Nonmandatory Information)

X1. APPEARANCE RATING

X1.1 Lubricants opaque in character or in-service lubricants that are not bright, or contain sediment, or both, may not be suitable for Tier 1 evaluation. In such cases, the Tier 2 evaluation, excluding appearance, may be conducted in agreement with the test requester or user. Set up the appearance rating test using a 150 W reflector flood lamp.

X1.2 *Rate the Sediment*—Hold the sample beaker vertically, without disturbing the sample, about 25 cm in front of your eyes and in front of the flood lamp. View the sample bottle from the different directions, angles, and distances from the light source. Assign a sediment rating according the Table X1.1.

X1.3 *Rate for Fluid Appearance*—View the sample beaker from the side, looking directly through the product mixture. Assign a fluid rating according to Table X1.1. When samples are too dark to rate for fluid appearance, they may be rated by tilting sample on side and observing the material adhering to the beaker.

TABLE X1.1 Codes for Rating Compatibility of Turbine Oils

NOTE 1—There may be other characteristics that are an indication of incompatible lubricants. Examples of these characteristics are phase separations, "fish eyes," and gels.

Fluid Clarity	Sediment Rating	Description	Pass/Fail
0	...	Absolutely Bright	Pass
1	...	Bright	Pass
2	...	Very Slight Cloud	Fail
2.5	...	Medium Moderate Cloud	Fail
3	...	Moderate Cloud	Fail
4	...	Heavy Cloud	Fail
5	...	Detectable Floc	Fail
6	...	Heavy Floc	Fail
...	0	No Sediment	Pass
...	1	Very Slight Sediment	Fail
...	2	Slight Sediment	Fail
...	3	Heavy Sediment	Fail
...	4	Appreciably More Sediment than 3	Fail
Other Observations			

X2. SUMMARY CHART

X2.1 A flow chart is shown in Fig. X2.1 to aid in understanding the overall summary of the standard.

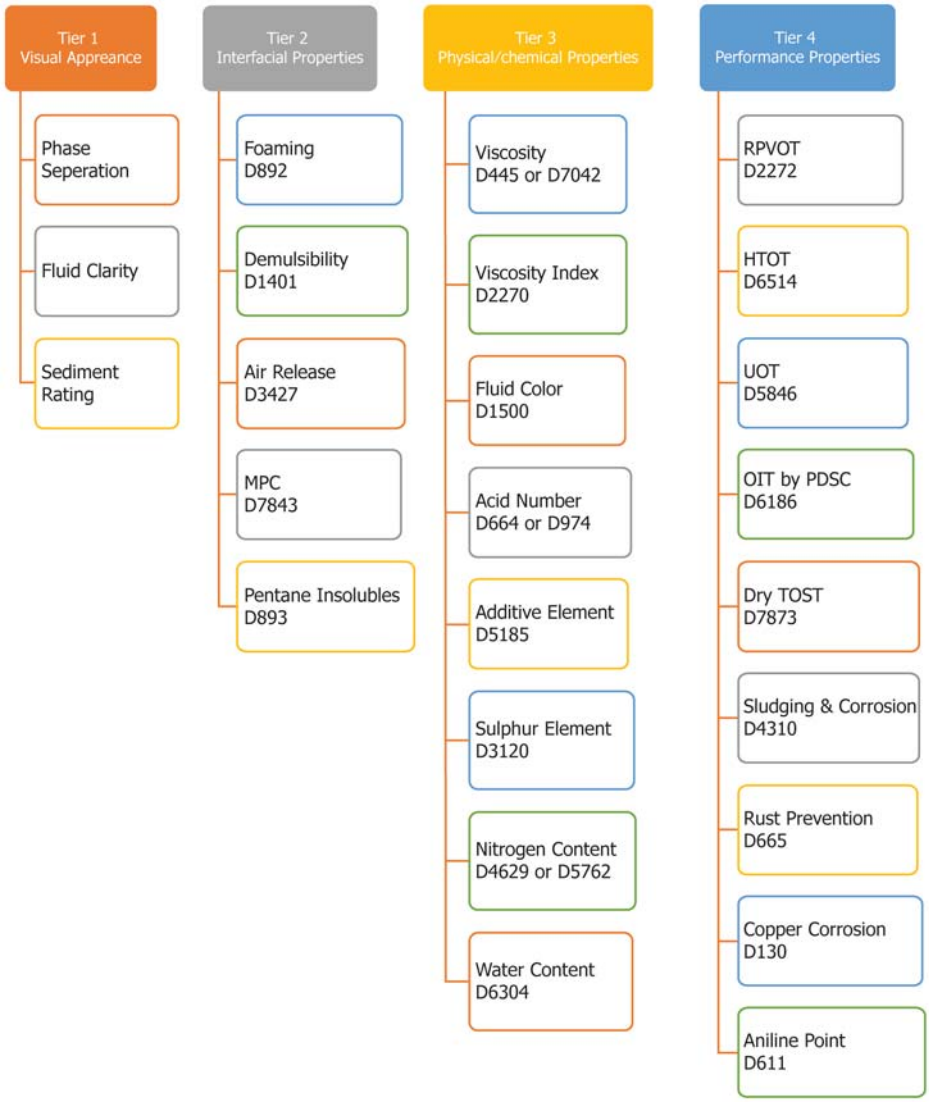

FIG. X2.1 Summary Chart

RELATED MATERIAL

Micetic, J. S. and Beitelman, A. D., *Performance Problems with Group II in Hydropower Facilities*, U.S. Army Corps of Engineers, ERDC/CERL TR-04-2, 2004.

SUMMARY OF CHANGES

Subcommittee D02.C0 has identified the location of selected changes to this standard since the last issue (D7155 – 11) that may impact the use of this standard. (Approved June 1, 2018.)

(1) Entire practice rewritten to reflect better understanding of the testing requirements for oil compatibility.