



Designation: **D5154–10 D5154/D5154M – 18**

## Standard Test Method for Determining Activity and Selectivity of Fluid Catalytic Cracking (FCC) Catalysts by Microactivity Test<sup>1</sup>

This standard is issued under the fixed designation **D5154/D5154M**; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This test method covers determining the activity and selectivity of either equilibrium or laboratory deactivated fluid catalytic cracking (FCC) catalysts. The activity is evaluated on the basis of mass percent conversion of gas oil feed in a microactivity unit. The selectivities are evaluated on the basis of mass percent yields of specifically defined products resulting from the catalytic cracking of gas oil feed.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.2.1 *Exception*—SI units have been retained in some of the figures.

1.3 *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.*

1.4 *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:*<sup>2</sup>

[D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography](#)

[D3907 Test Method for Testing Fluid Catalytic Cracking \(FCC\) Catalysts by Microactivity Test](#)

[D4463 Guide for Metals Free Steam Deactivation of Fresh Fluid Cracking Catalysts](#)

[D7964 Test Method for Determining Activity of Fluid Catalytic Cracking \(FCC\) Catalysts in a Fluidized Bed](#)

[E105 Practice for Probability Sampling of Materials](#)

[E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)

[E456 Terminology Relating to Quality and Statistics](#)

[E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

### 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *activity*—calculated as conversion divided by the difference of 100 minus conversion.

3.1.2 *ASTM reference catalysts*—a set of equilibrium FCC catalysts within the useful range of this test method is used to improve the reproducibility of test results between different laboratories. Each catalyst has a consensus mean conversion value assigned to it by Committee D32. Samples of the ASTM reference catalysts can be obtained through NIST.

3.1.3 *ASTM standard feed*—a specific batch of gas oil that is used as feedstock in the described test method.<sup>3</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee [D32](#) on Catalysts and is the direct responsibility of Subcommittee [D32.04](#) on Catalytic Properties. Current edition approved ~~April 1, 2010~~ ~~May 1, 2018~~ ~~May 1, 2018~~ ~~May 2010~~ ~~May 2018~~. Originally approved in 1991. Last previous edition approved in 2005 ~~2010~~ as [D5154–05–10](#). DOI: [10.1520/D5154-10.10.1520/D5154\\_D5154M-18](#).

<sup>2</sup> 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.

<sup>3</sup> ~~Available~~ ~~Formerly available~~ from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, [http://www.nist.gov](#).

3.1.4 *catalyst/oil (C/O) ratio*—the mass of catalyst used in the test divided by the mass of feed fed to the reactor. In practice, the mass of catalyst is usually maintained at a constant value and the total mass of feed is varied.

3.1.5 *contact time*—calculated as  $3600/(WHSV \cdot C/O)$ . This is the delivery time, in seconds, during which feed is introduced to the reactor.

3.1.6 *HCO*—the heavy cycle oil product defined to have a minimum boiling point of 650°F (343°C).

3.1.7 *LCO*—the light cycle oil product defined to have a boiling point range of 421 to 650°F (216 to 343°C).

3.1.6 *measured-conversion*—calculated as the difference between the mass of feed used and the mass of unconverted material divided by the mass of feed used times 100 %. The unconverted material is defined as all liquid product with a boiling point above 42°F (216°C); 216 °C [421 °F].

3.1.7 *gasoline*—C<sub>5</sub> compounds through compounds boiling at 216 °C [421 °F].

3.1.8 *HCO*—the heavy cycle oil product defined to have a minimum boiling point of 343 °C [650 °F].

3.1.9 *LCO*—the light cycle oil product defined to have a boiling point range of 216 °C to 343 °C [421°F to 650 °F].

3.1.10 *liquid product*—all products formed in the catalytic reaction that can be condensed in the chiller bath afterward, usually a combination of gasoline, LCO, and HCO, but can contain a trace of C<sub>4</sub> and C<sub>4</sub> minus compounds.

3.1.11 *normalized product yield*—the result obtained when each product yield has been corrected for non-perfect mass balances. For a run to be judged acceptable, the total recovery, ~~wt-%mass %~~ of feed, should be in the range of 96 to 101 % prior to normalization. If the recovery is outside this range the test data should be discarded.

3.1.12 *product yield*—one hundred times the mass of a specific product divided by the mass of feed used in the test.

3.1.13 *reaction severity*—an indication of the severity of the cracking reaction which allows a range of conversions to be obtained from any particular catalyst without changing reactor temperature. Changing reaction severity is achieved by changing WHSV or C/O ratio or both.

3.1.14 *selectivity*—same as yield. Selectivity generally refers to how much of a particular product, such as coke, is formed during a chemical reaction; selectivity is related to, but different from, conversion, which is the total amount of all products formed during the reaction.

3.1.15 *weight hourly space velocity (WHSV)*—the oil feed rate in grams per hour divided by the mass of catalyst in grams. Units are hr<sup>-1</sup>.

#### 4. Summary of Test Method

4.1 At least two samples of FCC catalysts, one of which is chosen as a reference, are separately contacted with gas oil feed (ASTM Standard Feed or other suitable feedstock) in a fixed bed reactor at a specified reaction temperature and at more than one reaction severity. Reaction products (liquid, gas, and coke on catalyst) are analyzed. Conversion, activity, and product yields are calculated for each experiment.

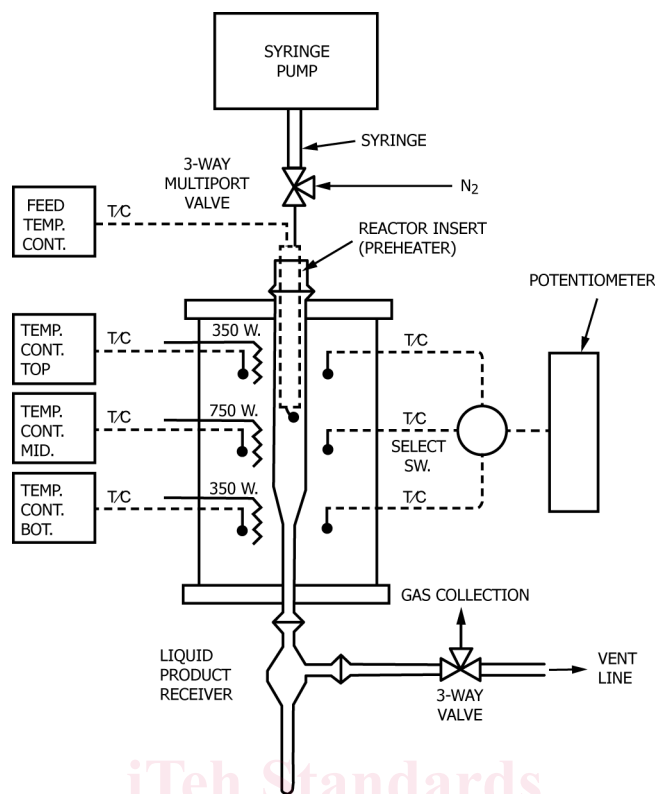
4.2 Following analysis of the products, the total recovery (that is, mass balance) of the feed as converted and unconverted products is determined. If the recovery is less than 96 % or greater than 101 %, the test is rejected as ~~unsatisfactory~~unsatisfactory (an outlier).

4.3 For each catalyst tested, normalized product yields are plotted against conversion or activity to generate a yield curve. The data comprising the yield curve may be used to obtain the parameters of an appropriate mathematical expression for the curve. Comparisons among catalysts can be made by interpolating the yield curves to obtain the product yields at some specified conversion.

#### 5. Significance and Use

5.1 The microactivity test provides data to assess the relative performance of FCC catalysts. Because results are affected by catalyst pretreatment, feedstock characteristics, test equipment, and operating parameters, adherence to this test method is a prerequisite for correct interpretation of results. Apparatus, test conditions, and analytical procedures actually used should closely resemble those described in this test method. Significant variations in apparatus, test conditions and/or analytical procedures may result in activity and selectivity data which do not correlate with data developed by other laboratories on identical catalyst/feedstock samples.

5.2 The standard method reaction temperature is ~~960°F (516°C)~~516 °C [960 °F]. Other reaction temperatures can be used; however, catalyst selectivity data developed at temperatures other than ~~960°F (516°C)~~516 °C [960 °F] may not correlate with selectivity data developed at ~~960°F (516°C)~~516 °C [960 °F]. Also, precision at other reaction temperatures may change compared to data obtained at ~~960°F (516°C)~~516 °C [960 °F].



NOTE 1—This drawing is not to scale. For engineering details, see other drawings.

FIG. 1 Microactivity Flow Chart

## 6. Apparatus

6.1 The apparatus of this test method is essentially that described in Test Method D3907, as shown in Figs. 1-4, with the addition of a gas collection system on the effluent gas vent line. In a typical gas collection system, a fluid-water is displaced by the collected gas and the volume of displaced liquid-water provides a quantitative measurement of the amount of gas collected. To minimize the solubility of gases like H<sub>2</sub> and H<sub>2</sub>S in the fluid, a saturated brine (NaCl) solution is recommended. Other gas collection systems can be used, such as the water-free gasometer (consisting of two gas chambers in series, each with a piston inside) which is more ideal for H<sub>2</sub>S quantification.<sup>4</sup> Some publications have appeared which give example flow schematics and more detailed descriptions of typical apparatus.<sup>5</sup> Alternatively, there are several vendors as listed in Research Report RR:D32-1030<sup>6</sup> who can provide specific equipment for performing this test. However, Committee D32 can only suggest and will not recommend nor certify any specific vendor. Significant variations from the test apparatus of this method most likely will result in significantly different activity and selectivity data from identical catalyst samples.

### 6.2 Chromatographic Equipment:

6.2.1 Liquid product analyses should be performed using Test Method D2887 on a gas chromatograph (G.C.)(GC) equipped with a flame ionization detector.

6.2.2 Gas product analyses may be accomplished in two parts. First, an analysis using a G.C. GC equipped with a thermal conductivity detector, employing N<sub>2</sub> as a carrier gas, and for quantitative identification of H<sub>2</sub> using an N<sub>2</sub> G.C. H<sub>2</sub> column that permits the separation and quantitative identification of H<sub>2</sub> can optionally be detected, but will not be quantitative in, and units that, S. collect gas by water displacement. Second, an analysis using a G.C. GC equipped with a FID or TCD, employing He as a carrier gas and using a column that permits the separation and quantitative identification of methane, ethane, ethylene, propane, propylene, n-butane, iso-butane, 1-butene and iso-butene, cis-2-butene, and trans-2-butene, C<sub>5</sub>'s (C<sub>5</sub> and saturates, i.e., i-pentane and n-pentane) and a C<sub>5</sub><sup>+</sup> lump (including C<sub>5</sub> olefins, i.e., i-pentenes and n-pentenes, and C<sub>6</sub><sup>+</sup>, i.e., C<sub>6</sub> to C<sub>9</sub>) that is not resolved. The C<sub>5</sub>'s and the C<sub>5</sub><sup>+</sup> group are included as part of the gasoline fraction.

<sup>4</sup> Ng, S.H., Shi, Y., Heshka, N.E., Zhang, Y., Little, E. "Laboratory Production of Biofuels and Biochemicals from a Rapeseed Oil through Catalytic Cracking Conversion", J. Vis. Exp. e54390, doi:10.3791/54390.

<sup>5</sup> Campagna, R. J., Wick, J. P., Brady, M. F., and Fort, D. L., "Fresh FCC Catalyst Tests Predict Performance," OGI, March 24, 1986, p. 85.

<sup>6</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D32-1030.

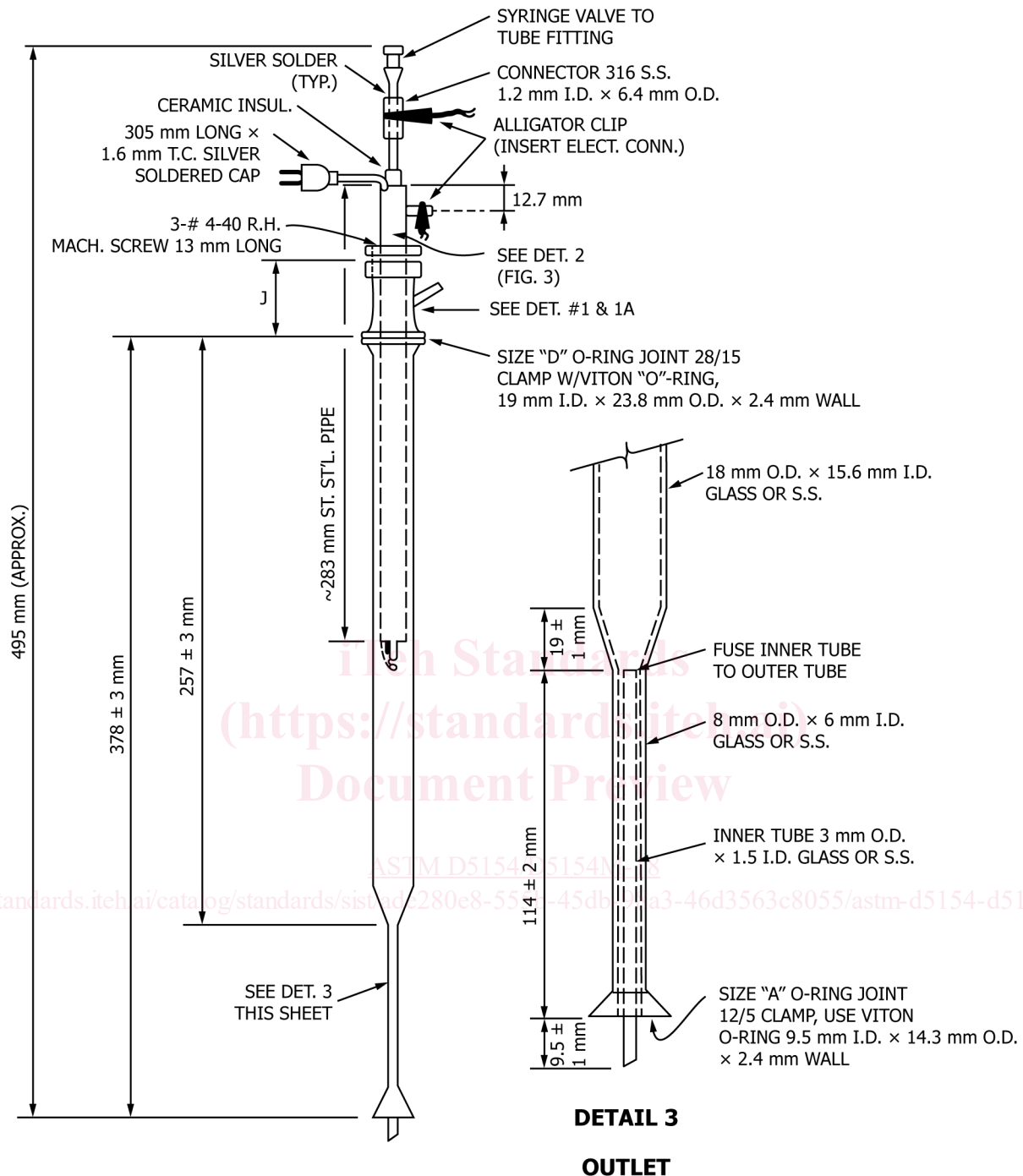


FIG. 2 Microactivity Reactor

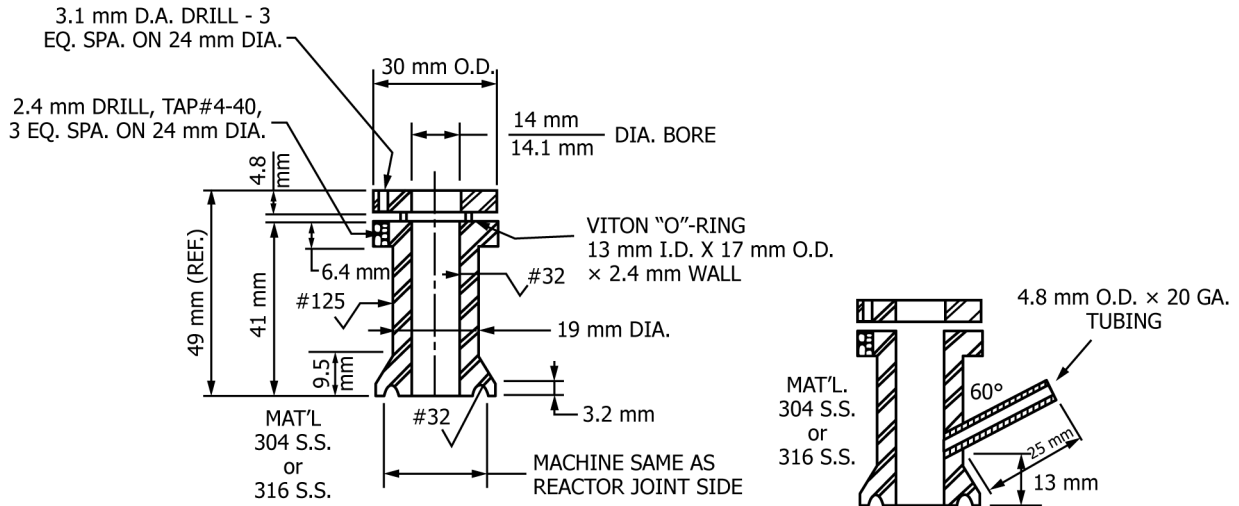
6.3 Carbon analysis of a representative sample of the spent catalyst (that is, the catalyst after the cracking reaction has been completed) may be accomplished using a commercially available carbon analyzer if the microactivity unit being used does not have catalyst regeneration capability. If the microactivity unit is a model that does have regeneration capability, then the carbon on catalyst is back calculated from the CO<sub>2</sub> evolved in the flue gas during the regeneration cycle.

## 7. Sampling

7.1 A sampling procedure is needed. Practice E105 is appropriate.

## 8. Sample Preparation

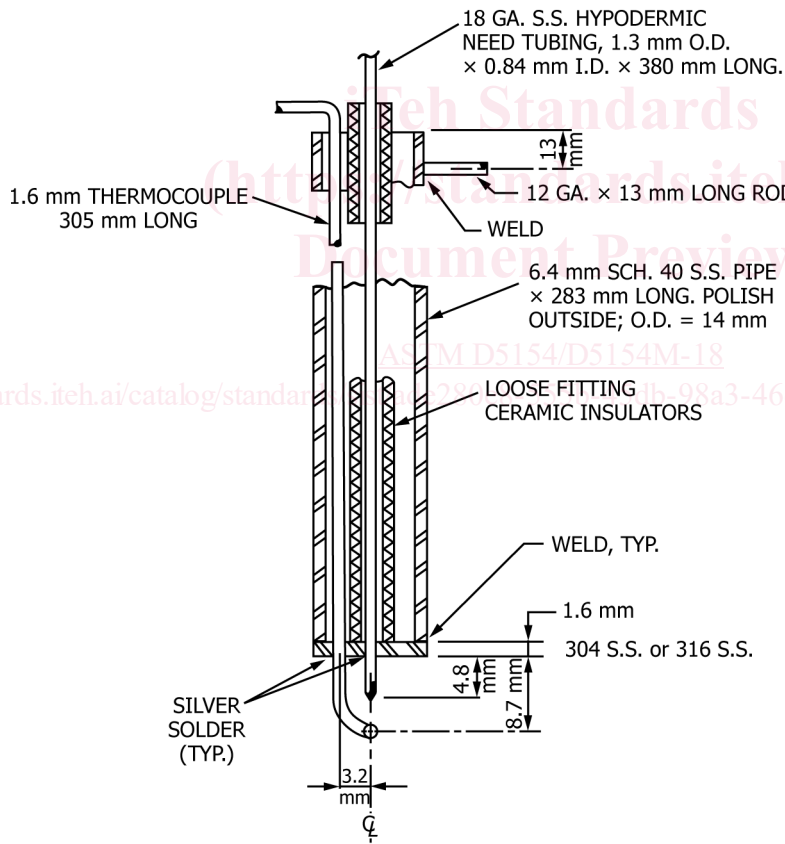
8.1 *Equilibrium Catalysts*—Dry samples or de-coke, or both, and remove coke by heating a shallow (less than 10 mm thick) bed of catalyst in a porcelain crucible at  $1094.590 \pm 36^\circ\text{F}$  ( $590.20^\circ\text{C}$  [ $1094 \pm 20^\circ\text{C}$ ]) for a length of time sufficient to remove



**DETAIL 1**

**DETAIL 1A**

WITH SIDE ARM FOR PRESS, MEASUREMENT DURING RUN



**DETAIL 2**

FIG. 3 Reactor Feed Tube Insert

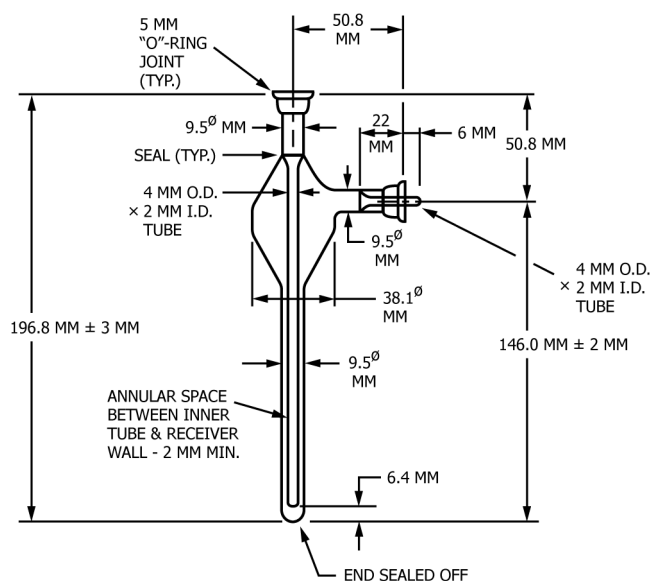


FIG. 4 Liquid Product Receiver

any coke. This typically requires approximately ~~three hours~~ 3 h. Sufficient air should be available in the furnace to burn the sample free of coke. Insufficient ~~decoke~~ coke removal is indicated by a difference in color of the top and bottom layers. The hot crucible is cooled in a desiccator to prevent moisture pickup.

NOTE 1—Heavily coked samples may be damaged by sintering or deactivation if oxidation is allowed to occur too rapidly, leading to artificially low catalytic activity and surface area.

8.2 *Fresh Catalysts*—Fresh catalyst samples should be steam treated prior to selectivity testing. Steaming procedures such as those specified in Guide D4463 may be used. However, specific conditions (temperature, partial pressure of steam, and time) should be chosen such that the steamed catalyst properties (activity, zeolite and matrix surface areas, and unit cell size) approximate those found in equilibrium FCC catalysts of the same type.

## 9. Procedure

### ASTM D5154/D5154M-18

9.1 *Reactor Preparation:* <https://standards.iteh.ai/catalog/standards/sist/ade280e8-555b-45db-98a3-46d3563c8055/astm-d5154-d5154m-18>

9.1.1 Rinse feed line with acetone or other suitable solvent and dry with air. Periodic cleaning of the insert is recommended by air purge at  $1022^{\circ}\text{F}$  ( $550^{\circ}\text{C}$ ) [ $1022^{\circ}\text{F}$ ] for one hour at least once every 12 tests.

9.1.2 Wash the reactor and product receiver thoroughly with acetone or other suitable solvent and dry. If necessary, burn out any coke deposited in the reactor by heating in air at  $960^{\circ}\text{F}$  ( $516^{\circ}\text{C}$ ) [ $960^{\circ}\text{F}$ ] prior to washing.

9.1.3 Insert a plug of quartz or borosilicate glass wool (about 20 mm length) until it reaches the constricted region of the reactor. Optionally, a reactor with a fritted disc may be used to position the catalyst. Add 4.00 to 4.05 g of catalyst in a free-flowing manner. Tap the reactor lightly to ensure good radial distribution (do not pack). Insert another plug of quartz or glass wool and add approximately 10 cc of 80 to 100 mesh glass microspheres or crushed glass particles. These act as a preheat bed and aid in feed dispersion, especially at higher WHSV's.

9.1.4 Inspect the oil insert needle to ensure it is clear of deposits. Place insert in reactor and adjust if necessary so that the bottom of the oil insert needle is just touching the top of the glass microsphere preheat bed (about 20 mm above the catalyst bed). Inspect the reactor insert before using to be sure the tip of the thermocouple (see Fig. 3, Detail 2) is bent under the tip of the syringe needle. (This is necessary to control the oil preheat temperature accurately.) Place the reactor in the furnace that has been preheated to  $960^{\circ}\text{F}$  ( $516^{\circ}\text{C}$ ) [ $960^{\circ}\text{F}$ ] and connect the nitrogen purge line directly to the reactor feed line. Purge with 30 ~~scm~~ (30 mL/min) mL/min [30 sccm] of nitrogen for at least 30 min.

9.1.5 Make electrical connections on the integral oil feed preheater and connect the thermocouple to the recorder.

9.2 *Preparation of Syringe and Liquid Product Receiver:*

9.2.1 Preheat the gas oil feedstock to  $1044 \pm 9^{\circ}\text{F}$  ( $405 \pm 5^{\circ}\text{C}$ ) [ $104 \pm 5^{\circ}\text{C}$ ] [ $9^{\circ}\text{F}$ ] to allow filling of the syringe. Before testing, calibrate the syringe pump to the correct feed rate by collecting the oil, preheated to  $1044 \pm 9^{\circ}\text{F}$  ( $405 \pm 5^{\circ}\text{C}$ ) [ $104 \pm 5^{\circ}\text{C}$ ] [ $9^{\circ}\text{F}$ ], outside the reactor and weighing the oil or by weighing the syringe before and after delivery to assure the appropriate mass of oil delivered over unit time.

NOTE 2—If heavier feedstocks are used, a syringe temperature of  $1587 \pm 9^{\circ}\text{F}$  ( $705 \pm 5^{\circ}\text{C}$ ) [ $158 \pm 5^{\circ}\text{C}$ ] [ $9^{\circ}\text{F}$ ] should be used for obtaining accurate feed rates.