STATE OF CALIFORNIA—BUSINESS, TRANSPORTATION AND HOUSING AGENCY

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
5900 Folsom Blvd.
Sacramento, California 95819-4612

METHOD OF TEST FOR DURABILITY INDEX

A. SCOPE

This test method describes the procedure for measuring the relative resistance of an aggregate to producing clay-sized fines when subjected to prescribed methods of inter-particle abrasion in the presence of water. Four procedures are provided for use with materials with various nominal sizes and specific gravities.

Procedure	Designation	Type of Method	Section
A	D_c	Retained No. 4 sieve	G-1
B	D_c modified	Light weight or porous, retained No. 4 sieve	G-2
C	D_f	Passing No. 4 sieve	G-3
D	D_f modified	No. 4 × No. 8 sieve (pea gravel, chips)	G-4

B. REFERENCES

California Test 125 – Sampling Highway Materials and Products Used in the Roadway Structural Sections
California Test 201 – Soil and Aggregate Sample Preparation
California Test 202 – Sieve Analysis of Fine and Coarse Aggregates
California Test 206 – Specific Gravity and Absorption of Coarse Aggregate
California Test 217 – Sand Equivalent
California Test 226 – Moisture Content of Soils and Aggregates by Oven Drying

C. APPARATUS

Detailed descriptions and specifications are included as necessary to assure standardization. Detailed plans are available for those items bearing a Transportation Laboratory (TL) drawing number.

1. Agitator: a mechanical device designed to hold the wash vessel in an upright position while subjecting it to a lateral reciprocating motion at a rate of 285 cycles per minute (cpm) ± 10 cpm. The reciprocating motion to be produced by means of an eccentric located in the base of the carrier and the length of the stroke to be 1.75 in. ± 0.025 in. The clearance between the cam and follower of the eccentric must be between 0.001 and 0.004 in. (Figure 1).

   The Tyler portable sieve shaker meets these requirements when modified according to TL drawing number D-536.

2. Mechanical Sand Equivalent Shaker and Test Apparatus: apparatus in accordance with California Test 217.

3. Measuring Tin: a tin measuring approximately 2 in. in diameter with a capacity of 85 mL ± 5 mL.

4. Wash Vessel: a flat bottomed, straight-sided cylindrical vessel equipped with a watertight removable lid conforming to the dimensions and tolerances shown (Figure 5).

5. Collection Pot: a round pan or container having vertical or nearly vertical sides and equipped as necessary to hold the wire mesh of an 8 in. diameter sieve at least 3 in. above the bottom. An adapter which will not allow loss of fines or wash water may be used to nest the sieve with the container, or the sieve may nest with a blank sieve frame resting in the bottom of the pan.

6. Graduated Cylinder: a graduated cylinder having a capacity of 1000 mL.

7. Rubber Stopper: a stopper to fit the plastic cylinder.

8. Funnels:

   a. A wide mouth funnel suitable for directing water or aggregate into the plastic cylinder.

   b. A wide mouth funnel large enough to hold an 8 in. diameter sieve while directing water into the plastic cylinder.

9. Balance: a balance or scale accurate to 0.2 % of the weight of the sample to be tested.

10. Oven: an oven or other suitable thermostatically controlled heating device capable of maintaining a temperature of 230˚F ± 9˚F.

11. Timer: a clock or watch reading in minutes and seconds.

12. Sieves: U. S. standard sieves conforming to AASHTO M 92. The standard sieve series includes the following sizes: ¾ in., ½ in., ⅜ in., No. 4, No. 8, and No. 200. The No. 8 and No. 200 sieves must be in standard 8 in. diameter frames.

13. Flexible Hose.

D. MATERIALS

1. Stock Calcium Chloride Solution.

   a. "Sand Equivalent Stock Solution" may be purchased and used in accordance with manufacturer's guidelines, or

   b. "Sand Equivalent Stock Solution" may be prepared from the following:

      - 120 g tech. grade anhydrous calcium chloride
      - 542 g (434 mL) USP glycerin (95 %)

      Dissolve the calcium chloride in 1 pint of distilled or deionized water. Cool the solution to room temperature, then filter it through Whatman No. 2V or equivalent filter paper. Add the glycerin to the filtered solution, mix well, and dilute to ¼ gal with distilled or deionized water.

2. Working Calcium Chloride Solution.

   a. Prepare the working solution by diluting 85 mL ± 5 mL of stock solution with distilled or deionized water to obtain 1 gal of solution. Thoroughly mix the working solution.

b. Working solution that is more than 2 weeks old must be discarded. Working solution mix date and discard date must be posted in the work area where the test is performed.

c. Mixing and storage containers must be thoroughly rinsed prior to mixing a fresh batch of solution.

d. Fresh solution must not be added to old solution regardless of age.

3. Water: use distilled or deionized water for the performance of this test, including the preparation of the working calcium chloride solution.

NOTE: Tap water may be used during the rinse process in accordance with Section G.A2.d., Section G.C3.d., and Section G.D2.d.

E. CONTROL

The temperature of the testing water should be maintained at 72°F ± 5°F. If this is impractical, it is necessary to establish temperature correction factors for each material being tested in accordance with Section E of California Test 217.

Individual test results that meet the minimum cleanness value when the temperature is below the recommended range are acceptable.

F. SAMPLE PROCESSING

1. Obtain a representative sample of the material to be tested in accordance with California Test 125.

2. Process the sample according to the procedures in California Test 201. The material passing the No. 4 sieve is then tested independently from the material retained on the No. 4 sieve. If either of these primary size portions amounts to less than 15 % of the total sample, that portion should not be tested. The durability index of the tested portion will represent the entire sample.

3. Separate the retained No. 4 material on the ¾ in., ½ in. and ⅜ in. sieves.

4. Calculate the size distribution of the ¾ in. by No. 4 portion of the material. Do not include the material retained on the ¾ in. sieve or the material passing the No. 4 sieve in this calculation.

5. Materials with a minimum nominal size larger than ¾ in. must be crushed to pass the ¾ in. sieve and then processed as described above. Do not test the portion of the crushed material which passes the No. 4 sieve.

G. TEST PROCEDURES

PROCEDURE A. Coarse Durability (D_C) For Material Retained on a No. 4 Sieve.

A1. Prepare a test specimen having an air-dry weight of 2550 g ± 25 g by combining the graded fractions as specified below:

a. For materials that have a minimum of 10 % in each of the specified fractions, prepare the test specimen according to the weights listed in Table 1.

TABLE 1

Basic Test Specimen Grading

Sieve Size (Passing × Retained)	**Air-Dry Weight** (g)
¾ in. × ½ in.	1070 ± 10
½ in. × ⅜ in.	570 ± 10
⅜ in. × No. 4	910 ± 5
Total Test Specimen	2550 ± 25

b. For materials with less than 10 % in any of the fractions specified in Table 1, prepare the test specimen using the actual calculated percentage for the deficient fraction and proportionally increase the weights of the remaining fractions to obtain the 2550 g test specimen.

Example 1: Less than 10 % of ¾ in. × ½ in. aggregate

Sieve Size (Passing × Retained)	**Proportion Per Size** (percentage)	**Calculations**	**Air-Dry Wt.** (g)
¾ in. × ½ in.	6	0.06×2550	153 ± 10
½ in. × ⅜ in.	26	$\frac{570\,(2550 - 153)}{570 + 910}$	923 ± 10
⅜ in. × No. 4	68	$\frac{910\,(2550 - 153)}{570 + 910}$	1474 ± 5
Total Test Specimen	100	- -	2550 ± 25

Example 2: Less than 10 % of ¾ in. × ½ in. and ½ in. × ⅜ in. aggregate

Sieve Size (Passing × Retained)	**Proportion Per Size** (percentage)	**Calculations**	**Air-Dry Wt.** (g)
¾ in. × ½ in.	4	0.04×2550	102 ± 10
½ in. × ⅜ in.	7	0.07×2550	179 ± 10
⅜ in. × No. 4	89	2550 - (102 + 179)	2269 ± 25
Total Test Specimen	100	- -	2550 ± 25

A2. Wash the test specimen using the following procedure.

a. Place the test specimen in the wash vessel.

b. Add 1000 mL ± 5 mL water, clamp the lid in place and secure the vessel in the agitator.

c. At 1 min ± 10 s after adding the water to the specimen, start the agitator and shake the vessel for 2 min ± 5 s.

d. Pour the contents of the vessel into a No. 4 sieve and rinse with fresh water until the water passing through the sieve is clear.

NOTE: Tap water may be used during this rinse process.

A3. Dry to a constant weight at 230˚F ± 9˚F in accordance with California Test 226, and cool to room temperature.

NOTE: When testing aggregate samples containing reclaimed asphalt pavement (RAP), the oven drying temperature must not exceed 100°F.

A4. Abrade the test specimen using the following procedure.

a. Place the washed and dried test specimen in the wash vessel.

b. Add 1000 mL ± 5 mL water, clamp the lid in place and secure the vessel in the agitator.

c. At 1 min ± 10 s after adding the water to the specimen, start the agitator and shake the vessel for 10 min ± 15 s.

A5. Separate the aggregate and water on the No. 200 sieve.

a. Remove the lid from the wash vessel and bring the fines into suspension by holding the vessel in an upright position while moving it vigorously in a horizontal circular motion 5 or 6 times, causing the contents to swirl inside.

b. Immediately pour the contents of the vessel into No. 8 and No. 200 sieves nested over the collection pot.

c. Tilt the No. 8 sieve to promote drainage, then discard the material retained on the No. 8 sieve.

d. Collect all of the wash water and minus No. 200 sieve material in the collection pot. To assure that all material finer than the No. 200 sieve is washed through the procedure:

(1) As the wash water is draining through the No. 200 sieve, apply a jarring action to the sieve by lightly bumping the side of the sieve frame with the heel of the hand.

(2) When a concentration of material is retained on the No. 200 sieve, re-rinse the fine material by pouring the wash water through the sieve again, using the following procedure.

(a) Allow the wash water to stand undisturbed in the collection pot for a few moments to permit the heavier particles to settle to the bottom.

(b) Set the No. 200 sieve aside and pour the upper portion of the wash water into a separate container.

(c) Place the No. 200 sieve back on the collection pot and pour the water back through the material on the No. 200 sieve.

If two collection pots are available, the specimen may be rinsed by alternately placing the sieve on one and then the other while pouring the wash water through the material on the sieve. Before each rinsing allow the heavier particles to settle to the bottom and pour only the upper portion of the water through the material.

(d) Repeat this procedure as necessary until all of the minus No. 200 sieve material has been washed through the sieve. When the

material has been rinsed sufficiently, the material on the sieve will be free of visible streaks of clay and the wash water will flow freely through the sieve and accumulated material.

A6. Pour all of the wash water and passing No. 200 sieve material into a graduated cylinder. Use additional water as necessary to flush all the fines from the collection pot and adjust the volume to 1000 mL ± 5 mL.

A7. Return the wash water to the collection pot taking care to include all water and fines.

A8. Fill the graduated plastic cylinder to the 3 unit mark with stock calcium chloride solution and place the funnel on the cylinder.

A9. Stir the wash water vigorously with one hand to bring all fines into suspension. Use a circular motion allowing the fingers to rub the sides and bottom of the collection pot.

A10. Immediately fill the graduated plastic cylinder to the 150 unit mark with the turbulent water.

A11. Stopper the cylinder and thoroughly mix the wash water and calcium chloride solution by inverting the cylinder 20 times in approximately 35 s. Allow the air bubble to completely transverse the length of the cylinder each time.

A12. Place the cylinder on a workbench or table free of vibrations, remove the stopper, and allow the cylinder to stand undisturbed for 20 min ± 15 s.

A13. Immediately read the top of the sediment column to the nearest 1 unit.

A14. Determine the coarse durability index (D_c) from Table 2.

PROCEDURE B. Course Durability (D_c) "Modified" (For Light Weight or Porous Aggregates).

The intended inter-particle abrasion can not be achieved due to the low specific gravity and/or high absorption rate of some aggregates making the proportions of aggregate to wash water too great. Testing of these materials requires adjustment of the test specimen weight and volume of test water. All materials which are not completely inundated when 1000 mL water are added to the 2550 g test specimen must be tested according to Method A with the following modifications.

B1. Determine the bulk specific gravity (oven-dry) and the absorption of the aggregate in accordance with California Test 206.

B2. Adjust the total weight of the test specimen specified in Section G.A1 using the formula:

$$\text{Adjusted Specimen Weight (g)} = \frac{\text{Specific Gravity of Aggregate}}{2.65} \times 2550$$

B3. Adjust the weight of material in each size fraction proportionally to the weight specified in Section G.A1.a and Section G.A1.b.

B4. Adjust the volume of test water specified in Section G.A1.c. and Section G.A1.e. using the formula shown below except that the volume of water must always be at least 1000 mL.

$$\text{Adjust Water} = 1000 + (A \times W) - 50$$

Where: A = Absorption of Aggregate % × 0.01
W = Weight of Test Specimen

PROCEDURE C. Fine Durability (D_f) For Material Passing a No. 4 Sieve.

C1. Process the material to be tested as described in Section F. Split or quarter 500 g ± 25 g of material from the passing No. 4 portion of the sample.

C2. Dry to a constant weight at 230˚F ± 9˚F in accordance with California Test 226 and cool to room temperature.

NOTE: When testing aggregate samples containing RAP, the oven drying temperature must not exceed 100°F.

C3. Wash the dried material by the following procedure:

a. Place the material in the wash vessel.

b. Add 1000 mL ± 5 mL of water, clamp the lid in place, and secure the vessel in the agitator.

c. At 10 min ± 30 s after adding water to the material, start the agitator and shake the vessel for 2 min ± 5 s.

d. Pour the contents of the vessel into a No. 200 sieve and rinse with fresh water until the water passing through the sieve is clear. Use a flexible hose attached to a faucet to direct water onto the material.

NOTE: Tap water may be used during this rinse process.

C4. Dry to a constant weight at 230˚F ± 9˚F in accordance with California Test 226 and cool to room temperature.

NOTE: When testing aggregate samples containing RAP, the oven drying temperature must not exceed 100°F.

a. Use water from the flexible hose as necessary to rinse the material from the sieve into the pan.

b. Free water can be removed by tilting the pan and then, after the fines have settled, carefully pouring off the clear water.

C5. A 500 g fine sieve analysis test specimen which has been tested in accordance with California Test 202 may be utilized in lieu of the material prepared according to Section G.C1. through Section G.C4. If the fine sieve analysis test specimen is used, all of the material separated during sieving, including that portion retained in the sieve pan must be thoroughly recombined before proceeding to Section G.C6.

C6. Split or quarter the washed and dried material to provide a test specimen of sufficient size to fill the measuring tin to level full. Predetermine the exact amount of material to be split using the following procedure:

a. Fill the measuring tin to overflowing with the prepared material.

b. Consolidate the material in the tin by tapping the bottom edge with a hard object.

c. Strike off to level full using a straight edge and determine the weight of the material.

C7. Fill the graduated plastic cylinder to 40 units ± 1 unit with working calcium chloride solution.

C8. Pour the prepared test specimen into the plastic cylinder.

a. Use the funnel to avoid spillage.

b. Release air bubbles and promote thorough wetting by bumping the base of the cylinder against a firm object while the test specimen is being poured into the cylinder or by tapping the cylinder sharply on the heel of the hand several times after the test specimen has been poured in.

C9. Allow the wetted material to stand undisturbed for 10 min ± 1 min.

C10. Abrade the test specimen by the following procedure:

a. At the end of the 10 min soaking period, stopper the cylinder, then loosen the material from the bottom by shaking the cylinder while holding it in a partially inverted position.

b. Secure the cylinder in the mechanical sand equivalent shaker.

c. Start the shaker and allow it to operate for 10 min ± 15 s.

C11. Irrigate the test specimen to flush the abraded fines from the sand using the following procedure:

a. At the end of the shaking period, remove the cylinder from the shaker and set it upright on the work bench. Insert the irrigator tube in the cylinder, start the flow of working calcium chloride solution, and rinse the material from the sides of the cylinder as the irrigator is lowered.

b. With the cylinder remaining in an upright position and the solution flowing from the tip, apply a twisting action to the irrigator and force it to the bottom of the cylinder. The flow of solution will flush the clay-size particles upward and into suspension. Withdraw the irrigator from the sand as necessary to change position and again force it to the bottom. The most effective technique for penetrating the sample with the irrigator is to hold the irrigator between the palms of both hands and rotate it by rubbing the hands back and forth while applying a downward pressure.

c. Continue twisting and forcing the irrigator to the bottom of the cylinder until the fines have been flushed from all areas of the sample. Rotate the cylinder with each penetration of the irrigator and visually inspect the test specimen for pockets of fine material.

d. When the solution reaches the 150 unit mark in the cylinder, slowly withdraw the irrigator without shutting off the flow. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 150 units.

C12. Immediately place the cylinder on a workbench or table free of vibrations and allow the cylinder and contents to stand undisturbed for 20 min ± 15 s from the time the irrigation is completed.

C13. Determine the "clay reading."

a. At the end of the 20 min period, read and record the level of the top of the sediment column. This is the clay reading.

b. When the clay reading falls between graduations, record the level of the higher graduation.

c. If a clearly defined line of demarcation does not form between the sediment and the liquid above it in the specified 20 min period, allow the cylinder to stand undisturbed until the clear demarcation line does form. Then immediately read and record the time and the height of the column.

d. If the liquid immediately above the line of demarcation is still darkly clouded at the end of 20 min, and the demarcation line, although distinct, appears to be in the sediment column itself, read and record the level of this line at the end of the specified 20-min period.

C14. Determine the "sand reading."

a. After the clay reading has been taken, gently lower the weighted foot assembly into the cylinder until it comes to rest on the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered.

b. As the weighted foot comes to rest on the sand, tip the assembly toward the graduation on the cylinder so that the position of the indicator is visible. Take care not to press down on the assembly.

c. Read the level of the top edge of the indicator.

d. Subtract 100 units from the observed reading. This is the sand reading.

e. When the sand reading falls between graduations, record the level of the higher graduation.

C15. Calculate the fine durability index (D_f) using the formula:

$$D_f = \frac{\text{sand reading}}{\text{clay reading}} \times 100$$

If the calculated durability index is not a whole number, report it as the next higher whole number.

PROCEDURE D. Fine Durability (D_f) "Modified" for Pea Gravel or Chips Having a Nominal Minimum Size No Smaller Than a No. 16 Sieve.

D1. Process the material to be tested as described in accordance with Section F. Split or quarter out 500 g ± 25 g of material from the passing No. 4 portion of the sample.

D2. Wash the test specimen by the following procedure:

a. Place the material in the wash vessel.

b. Add 1000 mL ± 5 mL of water, clamp the lid in place, and secure the vessel in the agitator.

c. At 10 min ± 30 s after adding water to the material, start the agitator and shake the vessel for 2 min ± 5 s.

d. Pour the contents of the vessel into a No. 200 sieve and rinse with fresh water until the water passing through the sieve is clear. Use a flexible hose attached to a faucet to direct water onto the material.

NOTE: Tap water may be used during this rinse process.

D3. Transfer the material to a pan, dry to constant weight at 230˚F ± 9˚F in accordance with California Test 226, and cool to room temperature.

a. Use water from the flexible hose as necessary to rinse the material from the sieve into the pan.

b. Free water can be removed by tilting the pan and then, after the fines have settled, carefully pour off the clear water.

D4. Split or quarter the washed and dried material to provide a test specimen of sufficient size to fill the measuring tin to level full.

a. When filling the measuring tin, consolidate the material in the tin by tapping the bottom edge on a hard object such as the workbench.

b. Fill the measuring tin to slightly round above the brim and then strike off to level full using a straightedge.

D5. Fill the graduated plastic cylinder to 40 units ± 1 unit with water.

D6. Pour the prepared test specimen into the plastic cylinder.

a. Use the funnel to avoid spillage.

b. Release air bubbles and promote thorough wetting by bumping the base of the cylinder against a firm object while the test specimen is being poured into the cylinder or by tapping the cylinder sharply on the heel of the hand several times after the test specimen has been poured.

D7. Allow the wetted material to stand undisturbed for 10 min ± 1 min.

D8. Abrade the test specimen by the following procedure:

a. At the end of the 10 min soaking period, stopper the cylinder, then loosen the material from the bottom by shaking the cylinder while holding it in a partially inverted position.

b. Secure the cylinder in the mechanical sand equivalent shaker.

c. Start the shaker and allow it to operate for 30 min ± 1 min.

D9. Transfer the water and passing No. 200 sieve size material to a second graduated plastic cylinder.

a. Fill an empty graduated plastic cylinder to the 3 unit mark with stock calcium chloride solution.

b. Place a No. 200 sieve into a funnel that empties into the cylinder containing the calcium chloride solution.

c. Tip the stoppered cylinder containing the test specimen upside down and shake to loosen the material from the bottom.

d. Hold the mouth of the inverted cylinder over the sieve and remove the stopper, allowing the test specimen and water to pour onto the sieve.

e. Collect the water and passing No. 200 sieve material in the second cylinder.

(1) Rinse the remaining fines from the first cylinder onto the sieve with a small amount of additional water.

(2) Rinse the material retained on the sieve with additional water to ensure that the minus No. 200 portion passes through the sieve. Take care not to fill the cylinder above the 150 unit mark.

(3) Adjust the level of the liquid to the 150 unit mark with additional water.

D10. Stopper the cylinder and thoroughly mix the wash water and calcium chloride solution by inverting the cylinder 20 times in approximately 35 s. Allow the air bubble to completely traverse the length of the cylinder each time.

D11. Place the cylinder on a work bench or table free of vibrations, remove the stopper and allow to stand undisturbed for 20 min ± 15 s.

D12. Immediately read the top of the sediment column to the nearest 1 unit.

D13. Determine the Fine Durability Index (D_f) "Modified" from Table 2.

H. REPORTING

When both D_c and D_f are determined for a material, report the lowest of the 2 values. In no case can the D_c and D_f be averaged or otherwise combined.

I. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Caltrans Laboratory Safety Manual is available at:
http://www.dot.ca.gov/hq/esc/ctms/pdf/lab_safety_manual.pdf

End of Text
(California Test 229 contains 15 pages)

TABLE 2

Durability Index of Coarse Aggregate and Chips

Sediment height (units)	Durability index	Sediment height (units)	Durability index	Sediment height (units)	Durability index	Sediment height (units)	Durability index	Sediment height (units)	Durability index
00	100	30	53	60	39	90	29	120	18
01	96	31	52	61	38	91	29	121	18
02	93	32	52	62	38	92	28	122	18
03	90	33	51	63	38	93	28	123	17
04	87	34	51	64	37	94	28	124	17
05	85	35	50	65	37	95	27	125	16
06	82	36	49	66	37	96	27	126	16
07	80	37	49	67	36	97	27	127	15
08	78	38	48	68	36	98	26	128	15
09	76	39	48	69	36	99	26	129	14
10	74	40	47	70	35	100	26	130	14
11	73	41	47	71	35	101	25	131	13
12	71	42	46	72	35	102	25	132	13
13	70	43	46	73	34	103	25	133	12
14	68	44	45	74	34	104	24	134	12
15	67	45	45	75	34	105	24	135	11
16	66	45	44	76	33	106	24	136	11
17	65	47	44	77	33	107	23	137	10
18	63	48	43	78	33	108	23	138	9
19	62	49	43	79	32	109	23	139	9
20	61	50	43	80	32	110	22	140	8
21	60	51	42	81	32	111	22	141	7
22	59	52	42	82	31	112	22	142	7
23	59	53	41	83	31	113	21	143	6
24	58	54	41	84	31	114	21	144	5
25	57	55	40	85	30	115	20	145	4
26	56	56	40	86	30	116	20	146	4
27	55	57	40	87	30	117	20	147	3
28	54	58	39	88	29	118	19	148	2
29	54	59	39	89	29	119	19	149	1
								150	0

FIGURE 1. Agitator

FIGURE 2. Mechanical Sand Equivalent Shaker

FIGURE 3. Sand Equivalent Test Apparatus without Shaker

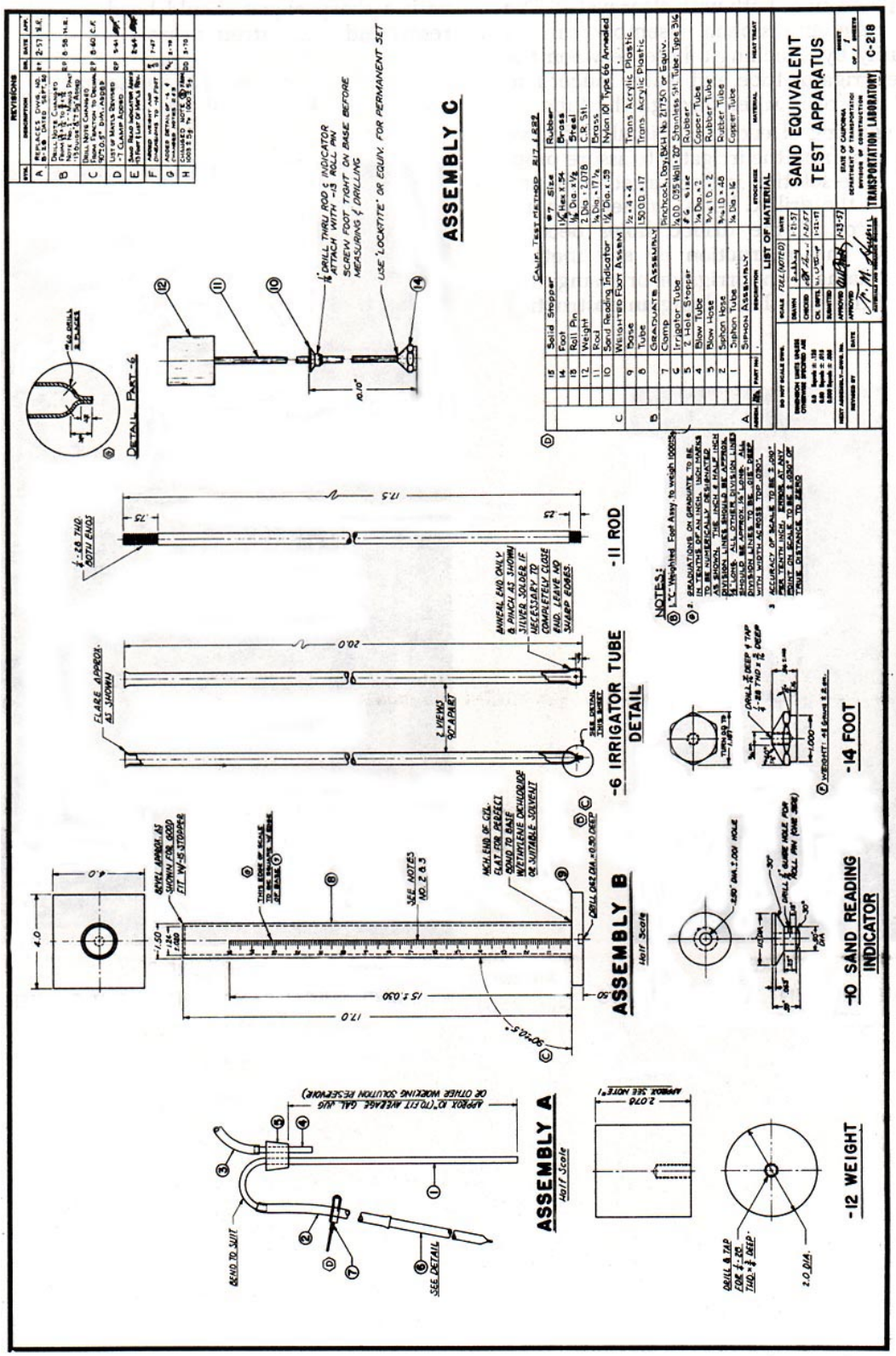

FIGURE 4. Sand Equivalen Test Apparatus Drawing

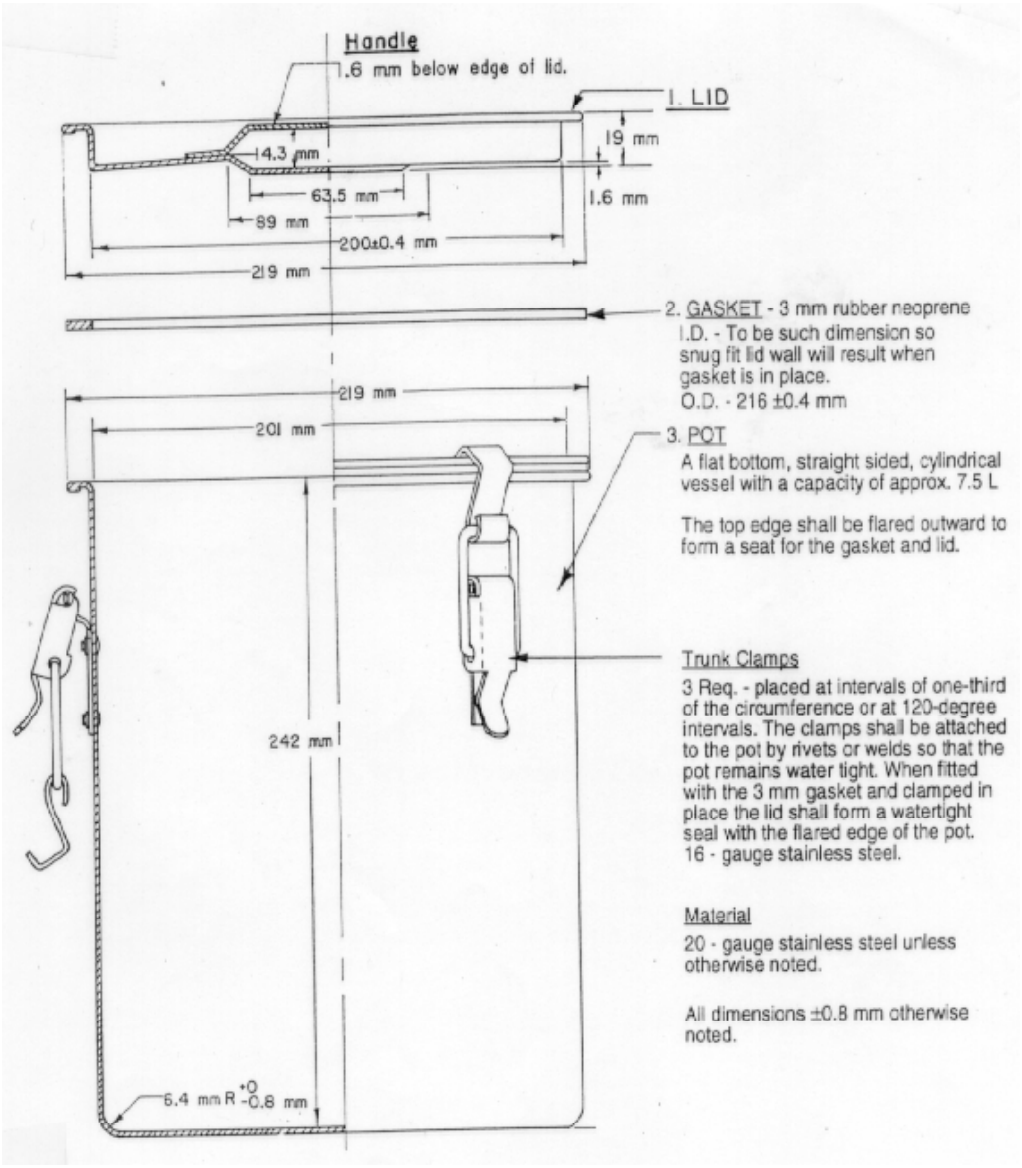

FIGURE 5. Mechanical Washing Vessel