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AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
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Standard Test Method for Asbestos Strength Units[1]

This standard is issued under the fixed designation D 3880; 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 test method gives a procedure for the evaluation of the strength-giving properties of asbestos fibers used to reinforce asbestos-cement products.

1.2 The purpose of this test method is to determine the number of strength units that may be assigned to the sample tested.

1.3 Asbestos fiber possesses the ability to impart strength to an asbestos-cement product. Every fiber grade may be regarded as possessing a certain quantity of strength-giving units. The quantity of fiber required in an asbestos-cement composition varies inversely with the number of strength units it possesses. For example, if an amount, designated by *X*, of a fiber possessing 100 strength units produces a product of a given strength, 2*X* would be required to produce a product of equivalent strength from fiber possessing only 50 strength units.

1.4 The following definition is the basis for the strength unit test: An asbestos fiber that gives the standard strength at the standard density when used as 10 % of the furnish is defined as having 100 strength units. Therefore, by knowing the percent fiber required in the mix to give standard strength at the standard density, it is possible to calculate the strength units of a sample of asbestos.

1.5 This procedure is intended primarily for chrysotile asbestos; it has not been verified whether or not it is applicable to other types.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements see 8.1.1, 9.2.2 and Note 6.

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]
C 184 Test Method for Fineness of Hydraulic Cement by the 150-µm (No. 100) and 75-µm (No. 200) Sieves[2]
C 204 Test Method for Fineness of Portland Cement by Air Permeability Apparatus[2]
C 430 Test Method for Fineness of Hydraulic Cement by the 45-µm (No. 325) Sieve[2]
C 1120 Test Method for Wash Test of Asbestos[3]
C 1121 Test Method for Turner and Newall (T and N) Wet-Length Classification of Asbestos[3]
C 1162 Test Method for Loose Density of Asbestos[3]
D 1193 Specification for Reagent Water[4]
D 1655 Specification for Aviation Turbine Fuels[5]
D 2590 Test Method for Sampling Chrysotile Asbestos[3]
D 2946 Terminology Relating to Asbestos and Asbestos-Cement Products[3]
D 2589 Test Method for McNett Wet Classification of Asbestos Fiber[3]
D 3639 Test Method for Classification of Asbestos Fibers by Quebec Standard Test[3]
D 3752 Test Method for Strength Imparted by Asbestos to a Cementitious Matrix[3]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[6]

2.2 *Other Standards:*

Quebec Asbestos Mining Association (QAMA) Standard, Designation for Chrysotile Asbestos Grades[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *point value, n— in asbestos,* an index of commercial value of asbestos fiber used in asbestos-cement products. Point value = (SU-10)/1.39 where SU stands for strength units.

3.1.2 *strength unit, n— in asbestos,* unit of reinforcing potential of asbestos fiber in asbestos-cement products. An asbestos fiber that yields a flexural modulus of rupture of 27 MPa at a product density of 1.6 g/cm^3 when used as 10 % of the furnish (dry ingredients) is defined as having 100 strength units. Therefore, the number of strength units of a given

[1] This test method is under the jurisdiction of ASTM Committee C-17 on Fiber-Reinforced Cement Products and is the direct responsibility of C17.03 on Asbestos-Cement Sheet Products and Accessories.

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[2] *Annual Book of ASTM Standards,* Vol 04.01.
[3] *Annual Book of ASTM Standards,* Vol 04.05.
[4] *Annual Book of ASTM Standards,* Vol 11.01.
[5] *Annual Book of ASTM Standards,* Vol 05.01.
[6] *Annual Book of ASTM Standards,* Vol 14.02.
[7] Available from Asbestos Institute, 1130 Sherbrooke St. West, Montreal, Q.C., H3A2 M8.

asbestos is equal to 1000/(% fiber required in the dry mix to yield 27 MPa at 1.6 g/cm^3).

3.1.3 Refer to Terminology D 2946 for other terms relating to asbestos.

4. Summary of Test Method

4.1 This test method covers the fabrication and flexural testing of asbestos-cement test specimens that contain asbestos fiber from the sample being evaluated. The calculation of strength units of the asbestos, based upon the flexural strength, density and composition of the test specimens, is also described.

4.2 The specimen fabrication process includes the following steps:

4.2.1 *Asbestos fiber preparation*, including ball milling, fiberizing, and blending.

4.2.2 *Compounding*, including dry mixing, the preparation of saturated water, and wet mixing.

4.2.3 *Test specimen formation*, including the pressing of asbestos-cement cakes in a semi-automatic press.

4.2.4 *Specimen curing*, including a stage in a humidity cabinet, autoclaving, air cooling, and saturating in a water bath.

4.3 *Specimen testing*, including the determination of immersed mass, saturated mass, flexural strength, specimen thickness and width, and dry mass.

4.4 *Calculations*, involving the determination of specimen volume, modulus of rupture, density, modulus of rupture adjusted for density, asbestos fiber content required to attain standard strength, fiber ratio required, point value, and strength units.

5. Significance and Use

5.1 This test method facilitates the comparison of different types and grades of chrysotile asbestos by the property most pertinent to its use in asbestos-cement, namely, the strength or reinforcing value it imparts to the product.

5.2 While similar comparative results could be obtained on any given production equipment, this method allows the testing of small samples, avoids costly interruptions in production for numerous trial runs, and allows test values to be obtained by a single standard method so that results can be compared among different locations.

5.3 Strength Unit (SU) value of a fiber blend used in asbestos-cement products may be estimated by taking the proportionate SU value of each component of the fiber blend.

5.4 If the fiber blend is formulated with the aim to optimize another fiber property such as filterability, the SU calculation will assure that the blend will not fall below an acceptable strength level.

5.5 This test method is restricted to grades of asbestos used in asbestos-cement products. Very long (Group 3) fibers are difficult to evaluate by this method because the test specimens produced may not be sufficiently homogeneous. Similarly, very short (Group 7) grades may not be retained satisfactorily in the mold during the pressing of test specimens or may not provide sufficient strength to meet the test requirements.

NOTE 1—The term Group 3 or 7 refers to the standard designation for chrysotile asbestos grades established by the Quebec Asbestos Mining Association, See 2.2.

5.6 Because of certain differences between this method and the many variations in plant production procedure commonly used in asbestos-cement manufacture, it is emphasized that the strength values obtained by this standardized procedure will not necessarily give exactly the same strength values as obtained at any one specific manufacturing plant.

6. Apparatus

6.1 *Ball Milling*:

6.1.1 *Porcelain Ball Mill Jars*, [8] meeting the following specifications:

Capacity	11 000 cm^3(671 in.^{3})
External diameter	280 mm (11.02 in.)
Internal diameter	230 mm (9.06 in.)
Internal height	210 mm (8.27 in.)

6.1.2 *Porcelain Balls*, [9] machine made, meeting the following specifications:

Diameter	40 mm (1.575 in.)
Mass (each)	74 to 75 g (0.163 to 0.165 lb)
Specific activity	2.3 ± 0.1 (The manufacturer specifies a nominal specific gravity of 2.22.)

Alternatively, handmade balls approaching these specifications may be used.

6.1.2.1 Discard balls when their diameter is 35 mm (1.38 in.) or less.

6.1.3 *Roll Table*, to rotate the ball mill jars at 6.81 ± 0.21 rad/s (65 ± 2 r/min). See Note 2.

6.2 *Fiberizing*:

6.2.1 *Disintegrator*, [10] B.O.P. (Ball, Opener, Penmen) Type O, driven at 565 ± 21 rad/s (5400 ± 200 r/min) by a squirrel-cage induction motor rated at no less than 1.492 kW (2 hp).

6.2.2 *Perforated Steel Discharge Plates*, for the fiberizer. One each of the following opening diameters: 3, 5, 7 and 10 mm, ± 3 %. Holes must be on an equilateral triangular pitch with wire edges pointing outward.

6.2.3 *Cardboard Drum*, approximately 410 mm (16 in.) in diameter by 400 mm (15 in.) in height with removable ring clamp on top, and canvas dust cover (transition piece) to serve as a receiver for the fiberizer discharge. Other arrangements for receiving the fiberizer discharge that are satisfactory with respect to relief of static pressure generated by the fiberizer rotor and with respect to the prevention of sample losses and contamination are acceptable. The free area of cloth while in operating position must be within the limits from 1300 to 4500 cm ^{2}, and the cloth must be square weave, unbleached cotton duck weighing 0.41 ± 0.02 kg/m^2(12 oz/yd^2), or a cloth of equivalent permeability.

6.3 *Blending*:

[8] Type KU5a ball mill jars, and machine-made balls, manufactured by Staatliche Porzellan Manufaktur, Berlin Werk Seld, Selb/afr. Hartmannstrasse 1–3, German Federal Republic (West Germany), have been found suitable. These are distributed by Fish-Schurman, 70 Portman Road, New Rochelle, NY.

[9] Manufactured by Ateliers de Lessines S.A., Division BOP, 55 rue de Wauthier 1020, Bruxelles, Belgium.

[10] Those supplied by Canadian Laboratory Supplied Limited, Box 2090 Stn. St. Laurent, Montreal 307, P. Q., Canada, are suitable. Specify dimensions required, request a design similar to Catalog No. J3028, and refer to Canlab Quotation No. 2713 (1969).

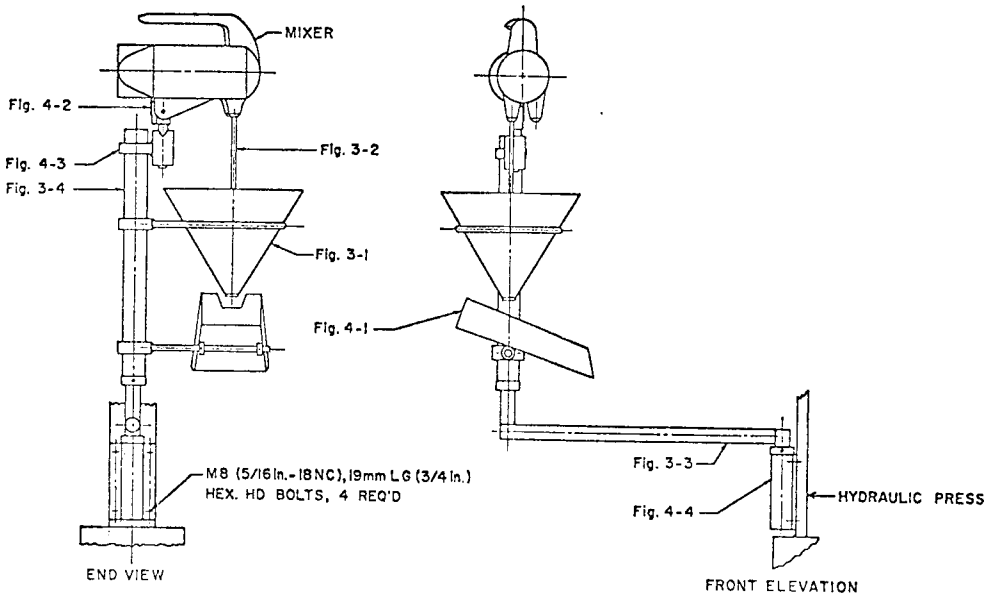


FIG. 1 Wet-Mixer Assembly

6.3.1 *Polyethylene Jar with Cover*, [11] meeting the following specifications:

Inside diameter	311 mm (12.25 in.)
Outside diameter	327 mm (12.875 in.) (wall thickness 8 mm (0.3 in.)
Inside height	311 mm (12.25 in.)

Other containers, such as stainless steel blenders, with similar internal dimensions may be used.

6.3.1.1 The jar may be fitted with a circumferential rubber tension band 100 mm (3.94 in.) wide by 3 mm (0.125 in.) thick to retain the cover. This band may be rolled down, turtleneck fashion, when the cover must be opened. Alternatively, the cover may be retained by mechanical clamps. In that case, the use of a gasket to seal the cover may be necessary.

6.3.1.2 The jar must be fitted with tires around the outer diameter to allow it to roll on a roll table in a horizontal attitude and to allow any clamps or projections to clear the rolls.

6.3.2 *Roll-Table*, to rotate the blending jar at a speed of 5.87 ± 0.21 rad/s (56 ± 2 r/min). See Note 2.

6.3.3 *Rolling Sheet*, 1 m^2(1 yd^2) or larger, made of rubber, plastic, or some other flexible elastomer.

6.4 *Dry Mixing*:

6.4.1 *Polyethylene Jar with Cover*, [11] meeting the following specifications:

Inside diameter	248 mm (9.75 in.)
Outside diameter	257 mm (10.125 in.)
Inside height	273 mm (10.75 in.)
Capacity	13 200 cm^3

Other containers, such as stainless steel mixers, with similar internal dimensions may be used.

6.4.1.1 The jar must be fitted with a rubber band as described in 6.3.1.1.

6.4.1.2 The exterior of the jar must be fitted with tires as described in 6.3.1.2.

6.4.1.3 The interior of the jar must be fitted with three mixing vanes located 2.09 rad (120°) apart, along the full length of the jar and projecting 38.1 mm (1.5 in.) from the inside wall. The vanes may be fastened to the wall by smooth head rivets or an adhesive. The corners of the vanes at the jar opening should be rounded to a radius of 12.7 mm (0.5 in.). The vanes may be fabricated from aluminum or any other corrosion-resistant sheet metal 1 mm (0.04 in.) thick.

6.4.2 *Roll-Table*, to rotate the blending jar at a speed of 8.17 ± 0.21 rad/s (78 ± 2 r/min).

NOTE 2—If a judicious choice of drive roll diameter and speed is chosen for the roll table, together with suitable tire dimensions for containers mentioned in 6.1.1, 6.3.1 and 6.4.1, it is possible to use the same roll table for the three containers. For example, if the drive roll has a diameter of 125 mm (4.93 in.) and a speed of 17.3 rad/s (165 r/min), then the appropriate speed would be obtained for each container if tires were adjusted to bring the effective outer diameters to 311 mm (12.25 in.) for the ball mill jars, 361 mm (14.21 in.) for the blending jars, and 259 mm (10.2 in.) for the dry-mixing jars.

6.5 *Wet Mixing*:

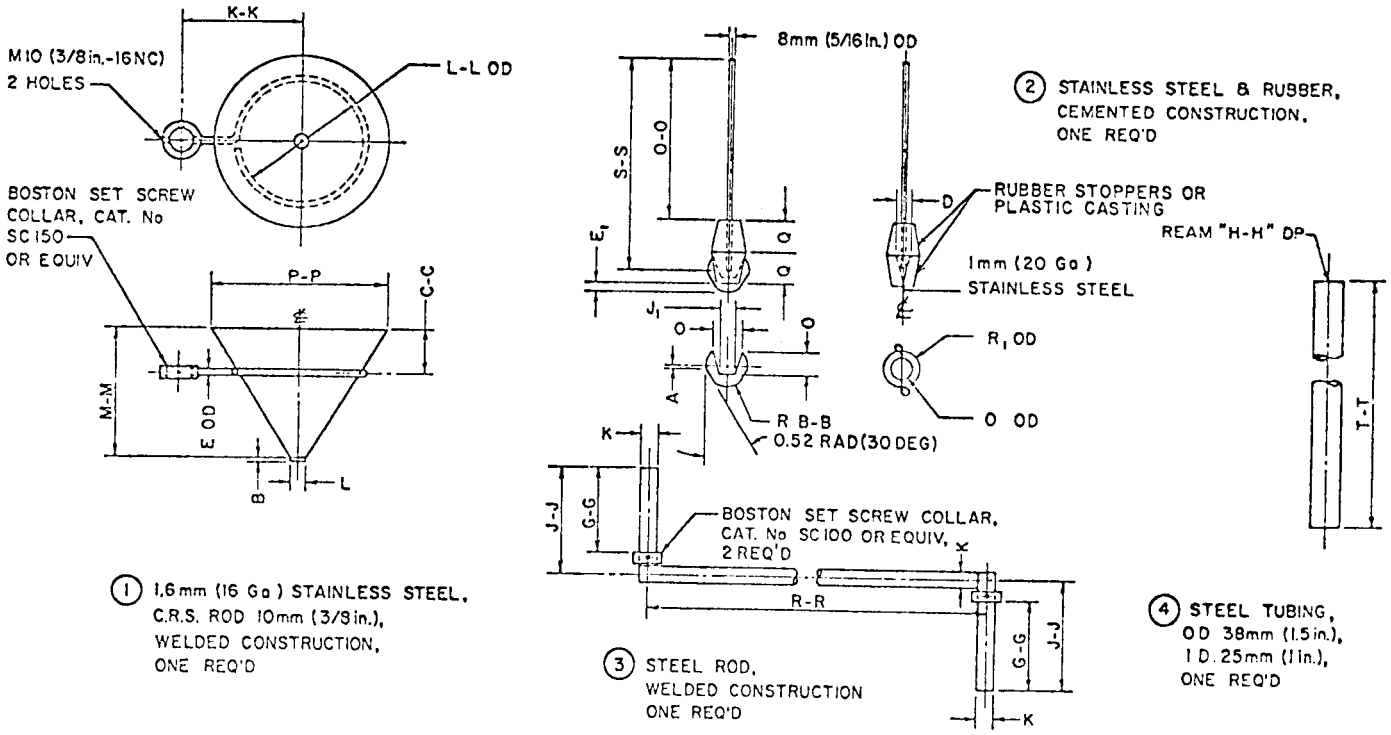
6.5.1 *Wet Mixer*, as described in Fig. 1, Fig. 2, Fig. 3 and Fig. 4 and mounted on the press. The drive motor must be able to maintain a speed of 62.83 ± 2.62 rad/s (600 ± 25 r/min) under load.

6.5.1.1 The Sunbeam Mix Master® motor suggested in Fig. 1 may be replaced for heavier duty by another motor, such as the Bodine motor[12] with one shaft at motor speed and another shaft driven through a right-angle gear with a speed reduction of 6:1 or 10:1. This motor may be operated with a rheostat speed control, but more satisfactory performance is achieved by means of an autotransformer.

6.5.1.2 The Bodine motor has an additional advantage. If a strobe card is mounted on the higher speed shaft while the impeller is mounted on the other shaft, then the strobe card

[11] Containers supplied by Canadian Laboratory Supplies Limited, Box 2090, Stn. St. Laurent, Montreal 307, P. Q., Canada, (Catalog No. J3028-14), are suitable. These must be fitted with suitable vanes.

[12] Catalog No. 134-1, distributed by Sepor Laboratory Supply, Box 4245, Long Beach, CA 90804, has been found suitable.



Dimension	mm (in.)	Dimension	mm (in.)	Dimension	mm (in.)
A	3.5 (⅛)	O	38 (1½)	K-K	165 (6½)
B	5 (3/16)	Q	46 (1 13/16)	L-L	170 (6 11/16)
D	18 (23/32)	R_1	48 (1 57/64)	M-M	180 (7 3/32)
E	10 (⅜)	B-B	62 (2 7/16)	O-O	230 (9)
E_1	10 (25/64)	C-C	63 (2½)	P-P	240 (9 7/16)
J_1	23 (29/32)	G-G	130 (5)	R-R	290 (11½)
K	25 (1)	H-H	155 (6)	S-S	310 (12)
L	28 (1 1/16)	J-J	160 (6¼)	T-T	420 (16½)

FIG. 2 Wet-Mixer Details

(consisting of two black and two white alternating segments) will rotate at 377 rad/s (3600 r/min) when the impeller is at 62.8 rad/s (600 r/min), and the strobe card will appear stationary when illuminated with standard fluorescent lamps operating on 60 Hz alternating current. For the 10:1 speed reduction motors, mount the strobe card on the impeller shaft (the card will have 12 black and 12 white alternating segments in this case). This provides a simple, accurate speed indicator.

6.5.1.3 A modified motor mount for a Bodine motor (Part No. 7) is shown in Fig. 4.

6.5.2 *Impeller*:

6.5.2.1 A plastic casting may be substituted for the rubber stoppers which are called for in the design of the impeller (Fig. 2).

6.5.2.2 The impeller must rotate clockwise when looking from above, and the vanes must be pitched so as to impel the slurry downward.

6.5.2.3 Maximum clearance between the impeller and the conical wall of the wet mixer must be set at 6.3 mm (0.25 in.).

6.5.3 *Rubber Hoe*, as shown in Fig. 5.

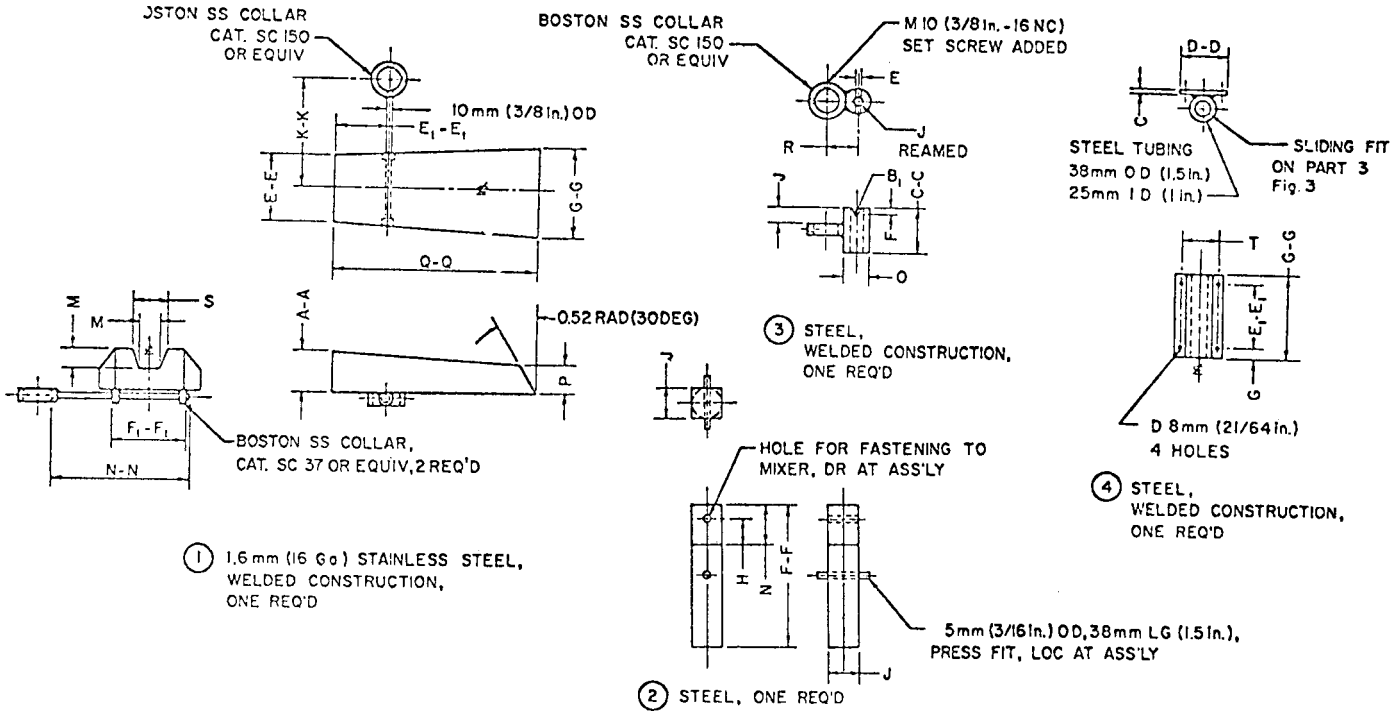
6.6 *Pressing*:

6.6.1 *Semi-automatic Press*, [13] illustrated in Fig. 6, Fig. 7, and Fig. 8 capable of performing the following pressing cycle:

6.6.1.1 *Manual Control* (Refer to Fig. 6—Start with the toggle switch in the OFF position. If contact is maintained on the UP push button, or on the UP foot switch, the press will close. As it closes, the pressure will rise until it reaches a preselected value on the high-pressure relief valve. The press may be opened by pushing the DOWN button, which will open solenoid valve No. 2 and drop the ram, or by opening the manual dump valve.

6.6.1.2 *Automatic Control* (Refer to Fig. 6)—With the toggle switch OFF, timer No. 1 should be set to the required low pressure interval of 105 s. Timer No. 2 should be set for the required high pressure interval of 90 s. Put the toggle switch in the ON position. The cycle may be started by closing either the foot switch or the push button. The following events will occur: (*1*) The top limit switch will close at any required point in the ram travel, the pump will continue to run, and solenoid valve No. 1 will open; (*2*) When the press closes, pressure will rise to the value set on the low pressure relief valve; (*3*) After

[13] Model PW22X, made by Pasadena Hydraulics, Inc., 14955 E. Salt Lake Ave., City of Industry, CA 91746, has been found suitable.



Dimension	mm (in.)	Dimension	mm (in.)	Dimension	mm (in.)
B_1	5 (3/16)	O	38 (1½)	E_1-E_1	100 (4)
C	6 (¼)	P	44 (1¾)	F_1-F_1	105 (4⅛)
E	10 (⅜)	R	48 (1⅞)	F-F	110 (4¼)
F	11 (7/16)	S	50 (1 31/32)	G-G	130 (5)
G	13 (½)	T	58 (2¼)	K-K	165 (6½)
H	20 (¾)	A-A	60 (2 23/64)	N-N	200 (8)
J	22 (⅞)	C-C	63 (2½)	Q-Q	250 (10)
M	30 (1 3/16)	D-D	78 (3)		
N	32 (1¼)	E-E	100 (3 15/16)		

FIG. 3 Additional Wet-Mixer Details

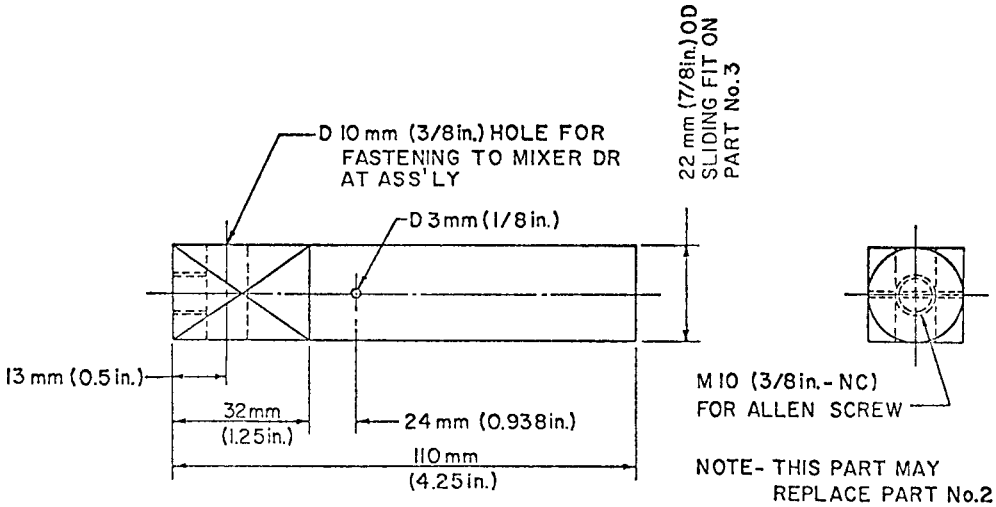


FIG. 4 Modified Motor Mount for Alternative Wet Mixer

the preselected interval (105 s), timer No. 1 times out; (*4*) Timer No. 2 starts automatically Solenoid Valve No. 1 closes and pressure will rise at an adjustable rate to the value set on the high-pressure relief valve; (*5*) At the end of the interval selected on timer No. 2 (90 s), the motor stops and solenoid valve No. 2 opens, permitting the ram to drop; and (*6*) As the ram bottoms, the lower limit switch opens, causing the timers to reset preparatory to another cycle. The rate of pressure rise to the high-pressure relief valve setting may be controlled by adjusting the micrometer valve. This system will operate for some time without overheating but when continuous operation

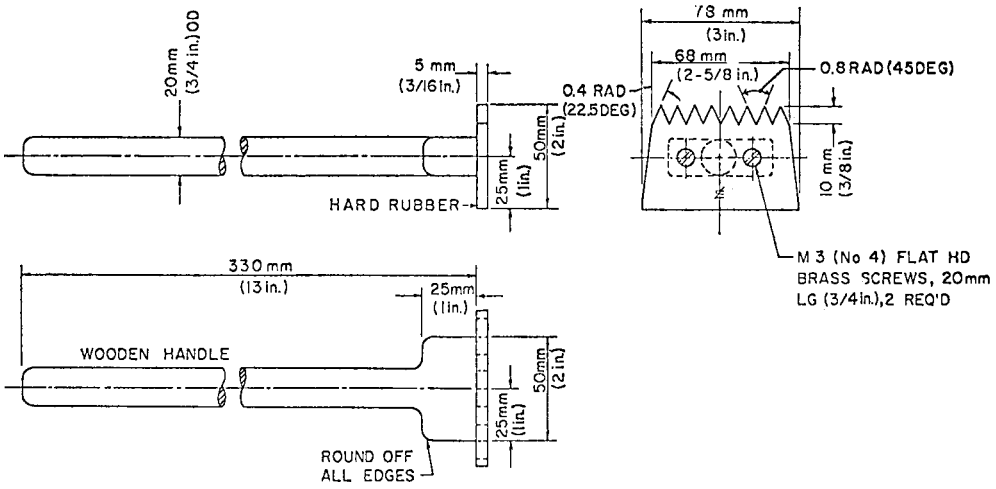


FIG. 5 Rubber Hoe

is planned, water should be circulated through the heat exchanger.

6.6.2 *Holding and Lowering Device*, for confining mold as described in Figs. 9-14, Fig. 7, and Fig. 8.

6.6.3 *Top Platen*, as described in Fig. 15, Fig. 16, Fig. 7, and Fig. 8.

6.6.4 *Confining Mold*, as described in Fig. 7, Fig. 8, Fig. 17, Fig. 18, and Fig. 19.

6.6.5 *Bottom Platen*, as described in Fig. 7, Fig. 8, and Fig. 20.

6.6.6 *Platen Base*, as described in Fig. 7, Fig. 8, Fig. 21, and Fig. 22.

6.6.7 *Phosphor Bronze or Stainless Steel Wire Screen*, corresponding to U.S. Sieve Series No. 40 described in Specification E 11. The screen must measure 240 mm (9.5 in.) in length by 130 mm (5 in.) wide.

NOTE 3—Bronze screening stretching beyond specifications as a result of the pressing operation should be replaced.

6.6.8 *Phosphor Bronze or Stainless Steel Wire Screening*, corresponding to U.S. Sieve Series No. 16 as described in Specification E 11. The screen must measure 240 mm (9.5 in.) long by 130 mm (5 in.) wide.

6.6.9 *Perforated Steel Plate*, measuring 240 mm (9.5 in.) long by 130 mm (5 in.) wide, and conforming to the following specifications:

Thickness	1.24 to 1.68 mm (0.049 to 0.066 in.)
Diameter of perforations	3.18 mm (0.125 in.) ± 5 %
Width of metal between holes	2.38 mm (3⁄32 in.)(0.09375 in.) ± 20 %
Pitch of holes	triangular (equilateral)

6.6.10 *Settling Tank*, 130 mm (5 in.) wide by 640 mm (25 in.) long by 500 mm (20 in.) deep, made of galvanized sheet steel, with an overflow drainage system.

6.6.11 *Asbestos Cement, Plastic, or Stainless Steel Plates*, measuring approximately 90 by 220 by 6 mm (3.5 by 8.5 by 0.25 in.). Ensure that the plates have not become bowed from previous usage nor become bowed under load while in use. See 9.8.2.1.

6.7 *Curing*:

6.7.1 *Humidity Cabinet*, capable of maintaining relative humidity between 90 and 100 % at room temperature (15 to 32°C) (60 to 90°F).

6.7.2 *Autoclave*, approximately 460 mm (18 in.) in internal diameter and 760 mm (30 in.) long, capable of maintaining 689.5 kPa (100 psig) gage pressure of saturated steam (not superheated) at 170°C (338°F) for a period of 20 h.

NOTE 4—**Warning:** The autoclave must be rated at a gage pressure higher than 689.5 kPa (100 psi) in order to permit this pressure to be maintained. Refer to local government regulations for pressure vessels prior to purchase and installation of an autoclave.

6.7.2.1 *Autoclave Trays*, steel plate, 610 by 355 by 6 mm (24 by 14 by 0.25 in.), with a handle at one end.

6.7.2.2 *Autoclave Baskets*, as described in Fig. 23.

6.7.2.3 *Asbestos-Cement Cover Sheets*, approximately 360 by 610 by 6 mm (14 by 24 by 0.25 in.).

6.7.3 *Saturating Tank*, large enough to saturate one day's production of test specimens, each measuring approximately 75 by 200 by 6 mm (3 by 8 by 0.25 in.). One press produces up to 90 test specimens each 8-h shift.

6.8 *Testing and Measuring*:

6.8.1 *Flexural Testing Machine*, capable of applying a load of 730 N at the rate of 5.88 ± 0.29 N/s. For testing machines with a constant rate of extension, as opposed to a constant rate of loading, these must be capable of extending at the rate of 0.1 mm/s (3.93×10^{-3} in./s). The dynamometer must read to 1 N (0.2 lbf) and must be equipped with a trailing needle or other mechanism to record maximum load attained on each test.

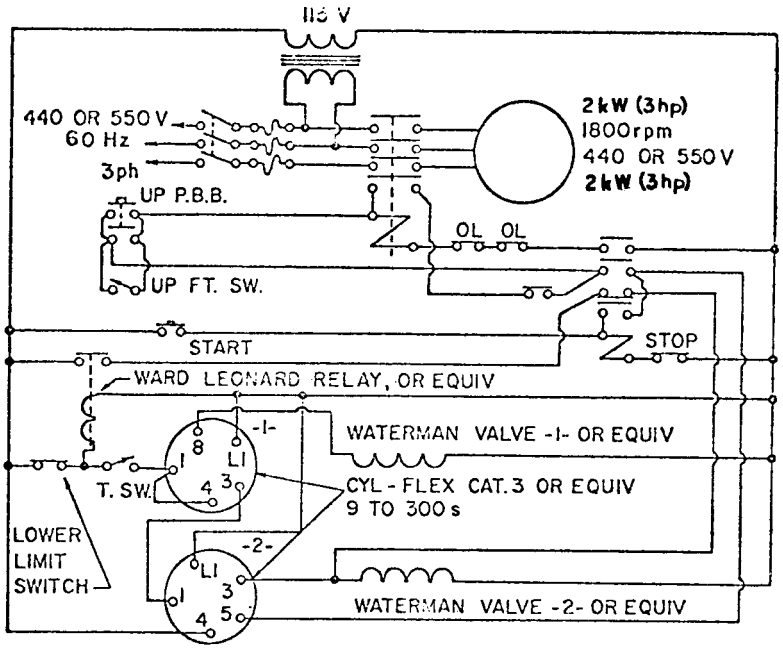
6.8.1.1 The specimen grips on the flexural tester must be of the third point loading type to apply the load equally and simultaneously to both third-points of the span, and the bearing edges of the loading bars must have a radius of 6.35 mm (0.25 in.) and must be free to rotate in a plane perpendicular to the test specimen and load direction.

6.8.2 *Micrometer*, 0 to 25 mm (0 to 1 in.) range, reading to 0.01 mm (5×10^{-4} in.). The micrometer spindle and anvil must be flat and must be either 6 mm or 0.25 in. nominal diameter.

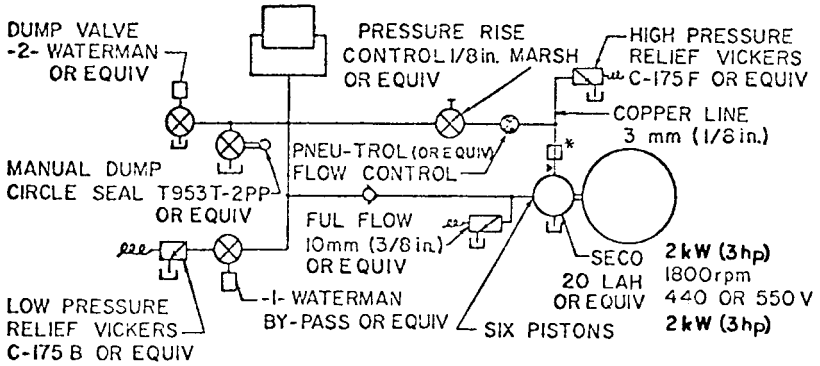
6.8.3 *Drying Oven*, capable of maintaining a temperature of 105 to 110°C (220 to 230°F) and of sufficient size to hold one day's production of test specimens.

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be



(a) ELECTRIC CONTROL CIRCUIT FOR MODIFIED P.H.I. PRESS



* STEEL COUPLING 19 mm (3/4 in.)

▸ ONE PISTON

NOTE: ALL RELIEF VALVES TO RESERVOIR THROUGH No 200-8 ROSS HEAT EXCHANGER OR EQUIV

(b) HYDRAULIC CONTROL CIRCUIT

FIG. 6 Control Circuit for P.H.I. Press as Modified for F.S.U. Testing

used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[14] Other grades may be used, provided it is first ascertained that the reagent is of

[14] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

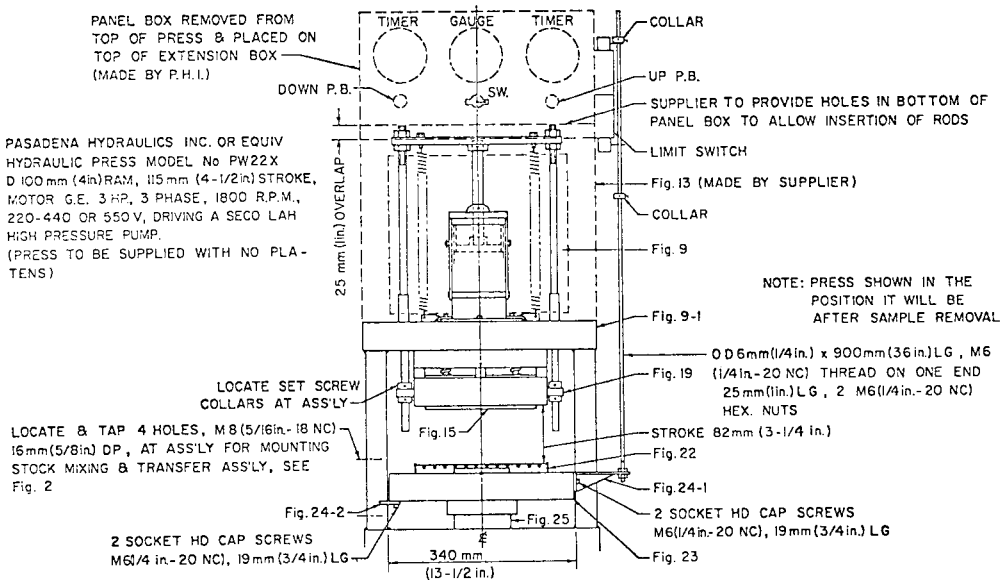


FIG. 7 General Press Assembly (Front Elevation)

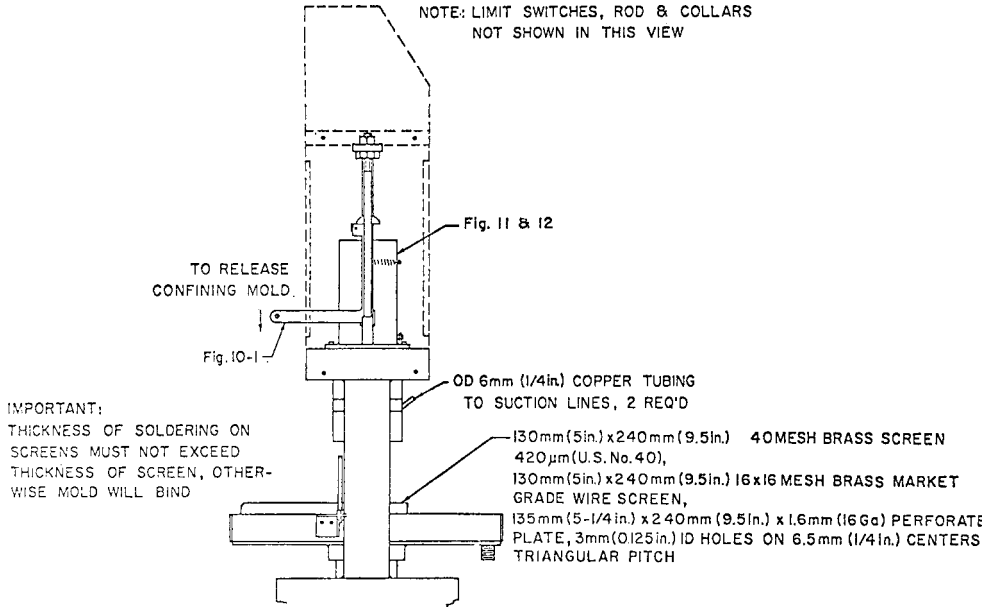


FIG. 8 General Press Assembly (Right Elevation)

sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean Type IV reagent water as defined in Specification D 1193.

7.3 *Calcium Hydroxide* [$Ca(OH)_2$].

7.4 *Calcium Sulfate* (*Gypsum*) ($CaSO_4 \cdot 2H_2O$).

7.5 Silica (Ground Quartz) (SiO_2), conforming to the following specifications:

SiO_2 content	99 % min

Wet-sieve analysis by the technique described in Test Method C 430:

U. S. Sieve No.	Percent Passing
80	99
100	90
200	85

NOTE 5—Silica with a specific surface area between 253 and 420 m^2/kg, as determined by Test Method C 204, has been used for this purpose. Differences in Strength Unit results have been observed when using different lots of silica (or cement) from the same supplier. Correlation must be made by testing a reference fiber when changing from one lot to another. See Annex A1.

NOTE 6—**Caution:** When handling silica, avoid creating dust, or use a respiratory protector. Prolonged or frequent breathing of significant airborne concentrations of silica dust may cause serious bodily harm.

7.6 *Portland Cement, Type I*, conforming to Specification C 150. Screen the cement to remove lumps prior to use on a

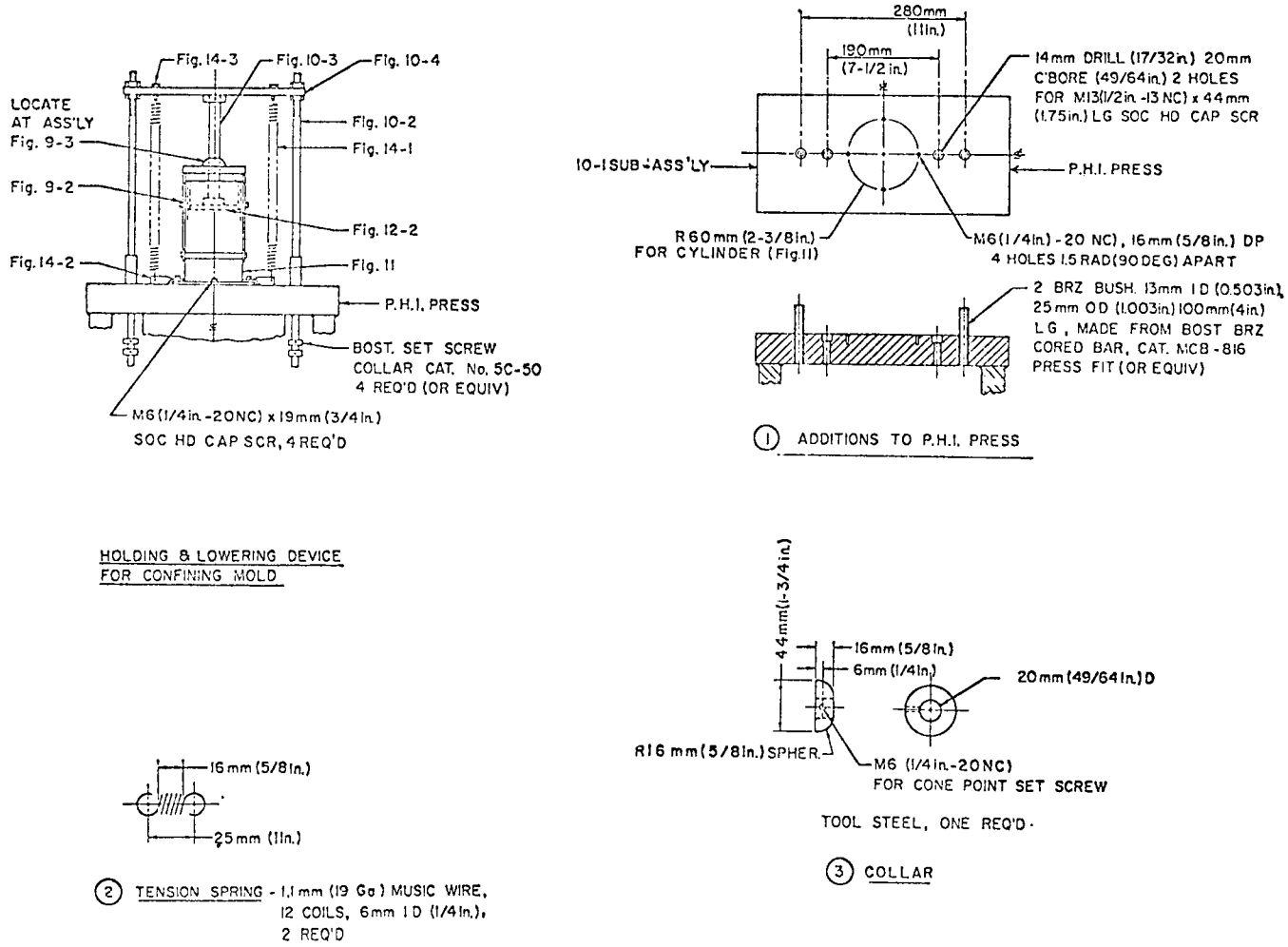


FIG. 9 Holding and Lowering Device Assembly and Details for Parts 2 and 3 of the Assembly

U.S. No. 18 sieve, using the technique described in Test Method C 184 or by any equivalent technique.

NOTE 7—For better interlaboratory reproducibility of results, it may be advisable to procure the Portland cement from a common source of supply.[15]

NOTE 8—Portland cements with specific surface areas between 330 and 372 m^2/kg, as determined by Test Method C 204, have been used for this purpose.

7.7 *Kerosine*, corresponding to Jet A Kerosine described in Specification D 1655.

7.8 *Raw Linseed Oil*.

7.9 *Saturated Water*:

7.9.1 Prepare saturated water by adding 2 kg (4.4 lb) of $Ca(OH)_2$ and 3 kg (6.6 lb) of $CaSO_4 \cdot 2H_2O/m^3$(264 U.S. gal) of distilled water at 24 ± 1°C (75 ± 2°F).

7.9.2 Allow to stand 24 h, agitating the water from time to time.

7.9.3 Siphon off the saturated water into clean containers.

7.9.4 If the temperature of the saturated water fluctuates, precipitation of the dissolved salts may occur. For this reason, it is preferable to filter this water at the point of use for wet mixing purposes.

[15] Canada Cement Lafarge Co. Ltd., 606 Cathcart Street, Montreal, P.Q. Canada, has been found a suitable source of supply.

8. Sampling

8.1 Sample in accordance with Test Method D 2590.

8.1.1 **Caution:** When handling asbestos fibers, avoid creating dust or use a respiratory protector. Breathing asbestos dust may cause serious bodily harm.

8.2 The quantity of fiber required may range from 0.3 to 0.6 kg (0.66 to 1.32 lb) for higher and lower strength-imparting samples, respectively, assuming that retesting will not be required.

8.3 A 0.3-kg (0.66-lb) asbestos sample charged to the ballmill may be expected to yield approximately 0.25 kg (0.55 lb) after various losses due to the fiber preparation steps.

8.4 The quantity of prepared fiber required to give standard strength (defined in 1.4 and 10.1.5) must be predicted approximately in advance.

8.4.1 Predictions may be based upon previous fiber strength unit results obtained on the same grade, or on a similar grade of asbestos, as described in 10.1.5.2.

8.4.2 Alternatively, predictions may be correlated to other test results or combinations of same provided by approved test methods (such as Test Methods C 1120, C 1121, C 1162, D 2589, D 3752, the Alpine Air Sieve, and the Demontigny).

8.4.3 If no previous knowledge is available for predicting the strength unit value of the sample under test, assume that

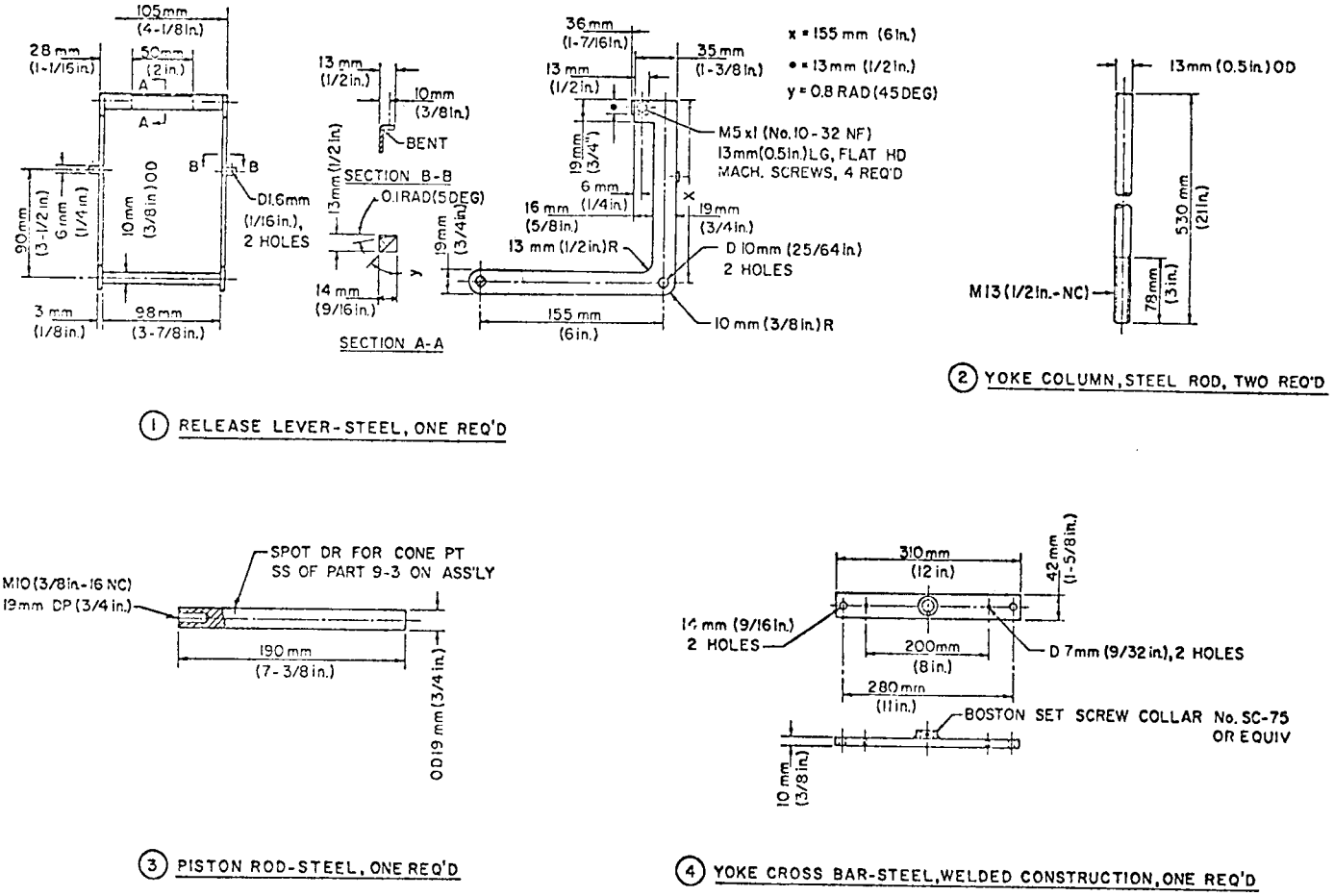
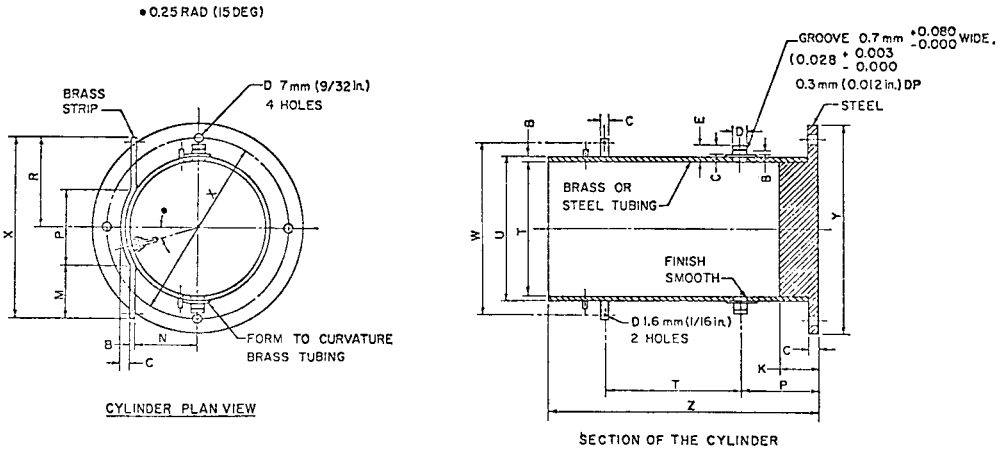


FIG. 10 Holding and Lowering Device Details



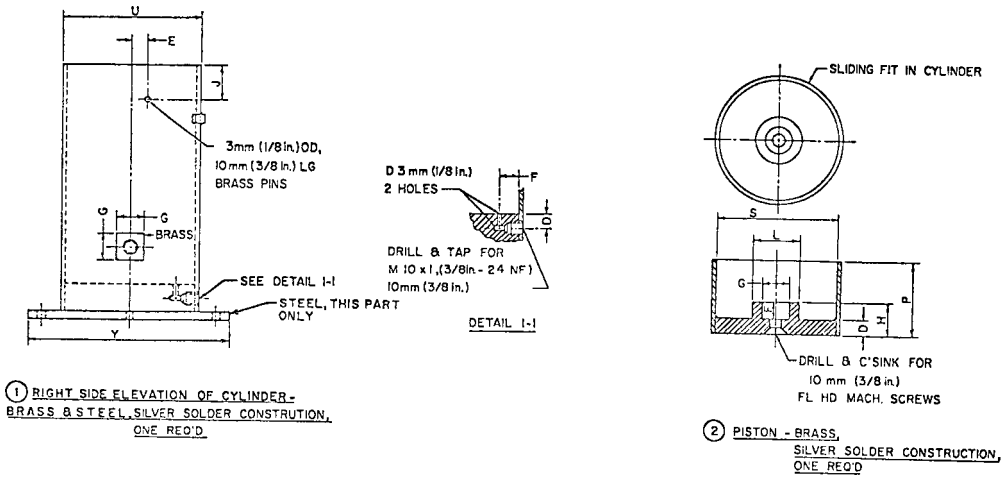
Dimension	mm (in.)	Dimension	mm (in.)	Dimension	mm (in.)
B	3 (⅛)	M	35 (1⅜)	U	95 (3¾)
C	6 (¼)	N	42 (1⅝)	W	115 (4½)
D	10 (⅜)	P	50 (2)	X	120 (4¾)
E	11 (7/16)	R	60 (2⅜)	Y	140 (5½)
K	25 (1)	T	90 (3½)	Z	180 (7)

FIG. 11 Holding and Lowering Device Cylinder

this value is 100 as a first approximation, and calculate the asbestos requirements as follows:

8.4.3.1 Mass of prepared fiber, in kilograms, required is equal to 17 divided by (strength units) in kilograms.

8.4.3.2 The equivalent mass in pounds is equal to 37.5 divided by (strength units).



Dimension	mm (in.)	Dimension	mm (in.)	Dimension	mm (in.)
D	10 (⅜)	H	22 (⅞)	S	82 (3¼)
E	11 (⁷⁄₁₆)	J	24 (¹⁵⁄₁₆)	U	95 (3¾)
F	13 (½)	L	32 (1¼)	Y	140 (5½)
G	19 (¾)	P	50 (2)		

FIG. 12 Holding and Lowering Device Cylinder and Piston

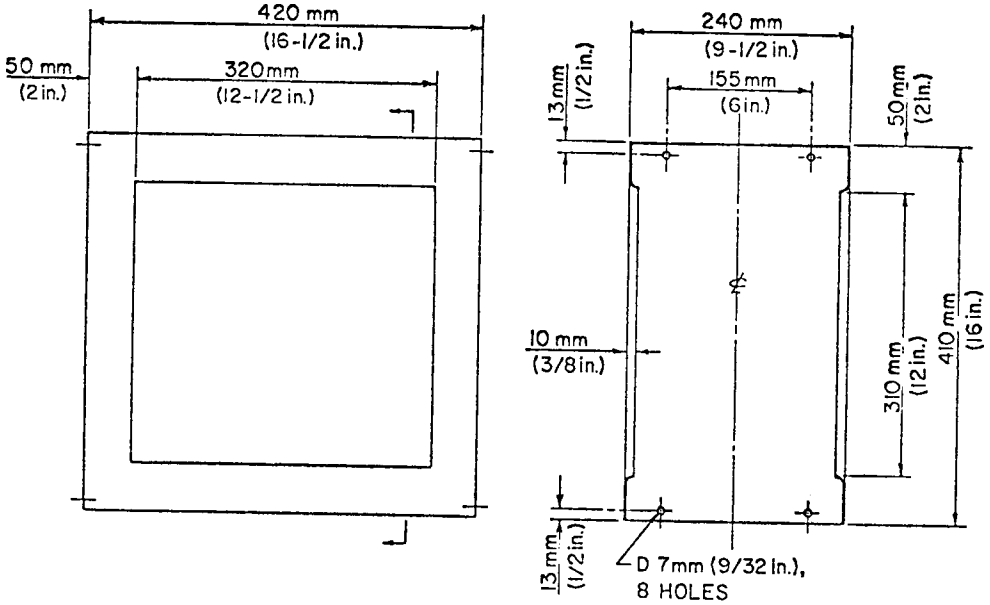


FIG. 13 Holding and Lowering Device Housing

8.4.4 If prepared fiber requirements exceed 0.25 kg (0.55 lb), select an additional 0.3 kg (0.66 lb) aliquot from the sample. This additional aliquot must be ball-milled separately in accordance with 9.1.2.

9. Procedure

9.1 *Ball-Milling*:

9.1.1 Place 6 ± 0.04 kg (13.24 ± 0.09 lb) of porcelain balls in a ball-mill jar, add 0.3 kg (0.66 lb) of asbestos on top of the balls, close the jar securely, and place it on a roll table.

9.1.2 If sample requirements exceed 0.3 kg of asbestos, ball-mill a second aliquot of 0.3 kg (0.66 lb) in a second ball-mill jar.

9.1.3 Roll the jars at 6.81 ± 0.21 rad/s (65 ± 2 r/min) for that time which ultimately gives the highest strength to the asbestos-cement specimens produced therefrom. For chrysotile asbestos produced in the province of Quebec, Canada, 60 min

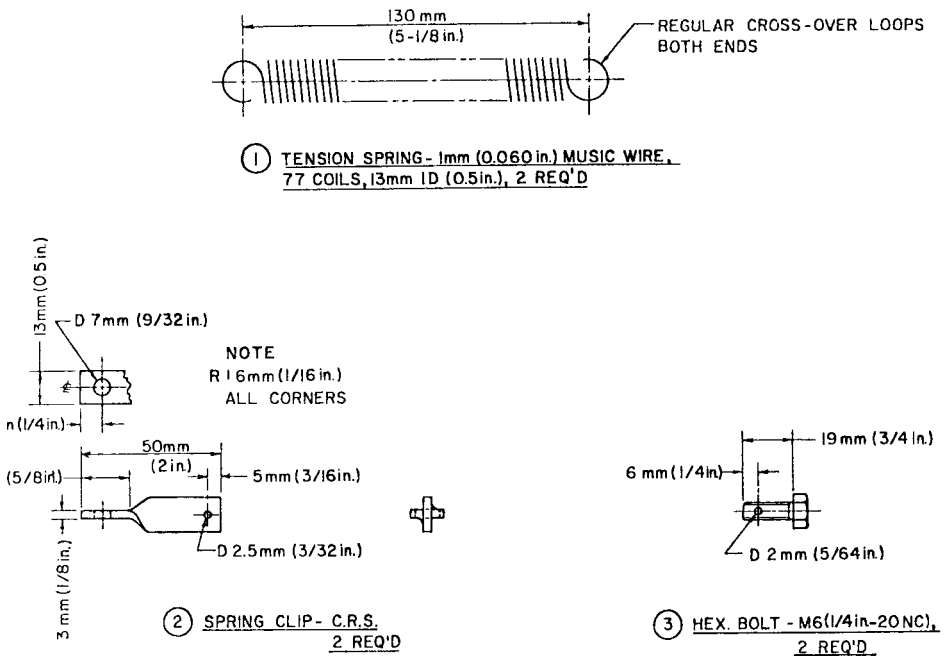


FIG. 14 Holding and Lowering Device (Additional Details)

ball-milling time has been found to give the maximum strength for most grades. It is significant to recognize that the degree of conditioning required by the ball-milling phase of this particular preparational treatment procedure is dependent on specific fiber characteristics of recognizable fiber types of the fibers produced from individual ore bodies and, indeed, from differing separate mining areas within these individual ore bodies. The optimum ball-milling time required for Canadian chrysotile fibers is generally found to be within the range of 30 to 90 min and although a 60-min time may be most suitable for some fiber types, the inherent potential of others can only be fully exploited by employing the longer or shorter times indicated by the individual fiber type characteristics. The asbestos fiber supplier may indicate this time.

9.1.4 For referee testing, ball-milling time shall be agreed upon by the purchaser and supplier.

9.1.5 Discharge the contents of the ball-mills into a clean container and brush or wipe clean of fiber each ball, as well as the interior of the jars.

9.2 *Fiberizing*:

9.2.1 Select the appropriate disintegrator discharge plate in accordance with Table 1. Mount this plate onto the B.O.P. disintegrator, close the access port and fasten it securely, and start the motor.

9.2.2 Feed the ball-milled asbestos directly into the inlet chute of the disintegrator, bypassing the feed hopper (which has a tendency to clog) by means of a feeding pan such as shown in Fig. 24. Feed the sample at a rate of 0.3 kg (0.66 lb)/90 to 120 s (1.5 to 2 min) in a uniform flow so as to maintain a constant disintegrator speed. Changes in speed may be detected from changes in the pitch of the sound emitted by the machine. **Caution:** Wear ear protectors.

9.2.3 Stop the motor and dislodge any agglomerations of asbestos that may have accumulated on the stator lugs and in interior cavities. Add these clots to the sample.

9.2.4 Pass the sample through the disintegrator a second time and discard any asbestos which remains hung up inside the disintegrator.

9.3 *Blending*:

9.3.1 Place the fiberized sample in a blending jar and roll at 5.87 ± 0.21 rad/s (56 ± 2 r/min) on a roll table for 10 min.

9.3.2 If two separate ball-mill charges of 0.3 kg (0.66 lb) each are required, then split the disintegrated sample approximately in half, and blend each half in a separate blending jar. In this case, mix the contents of both jars after blending by means of the rolling sheet in such a way as to prevent segregation and to minimize stratification.

9.4 *Dry Mixing*:

9.4.1 Based upon the fiber mass determined in 8.4.3.1 or 8.4.3.2, calculate the mass of portland cement required as follows:

$$\text{Kilograms of portland cement} = 0.6 \times [1.7 - (\text{fiber mass in kilograms})] \quad (1)$$

or

$$\text{Pounds of portland cement} = 0.6 \times [3.74 - (\text{fiber mass in pounds})] \quad (2)$$

9.4.2 Based upon the fiber mass determined in 8.4.3.1 or 8.4.3.2, calculate the mass of silica required as follows (see the example in 10.1.7.1):

$$\text{Kilograms of silica} = 0.4\,[1.7 - (\text{fiber mass in kilograms})] \quad (3)$$

$$\text{Pounds of silica} = 0.4\,[3.74 - (\text{fiber mass in pounds})] \quad (4)$$

9.4.3 Add the masses of prepared asbestos fiber, portland cement, and silica, as determined in 8.4.3.1, 8.4.3.2, 9.4.1, and 9.4.2, to the dry mixing jar, secure the cover, and roll on the roll

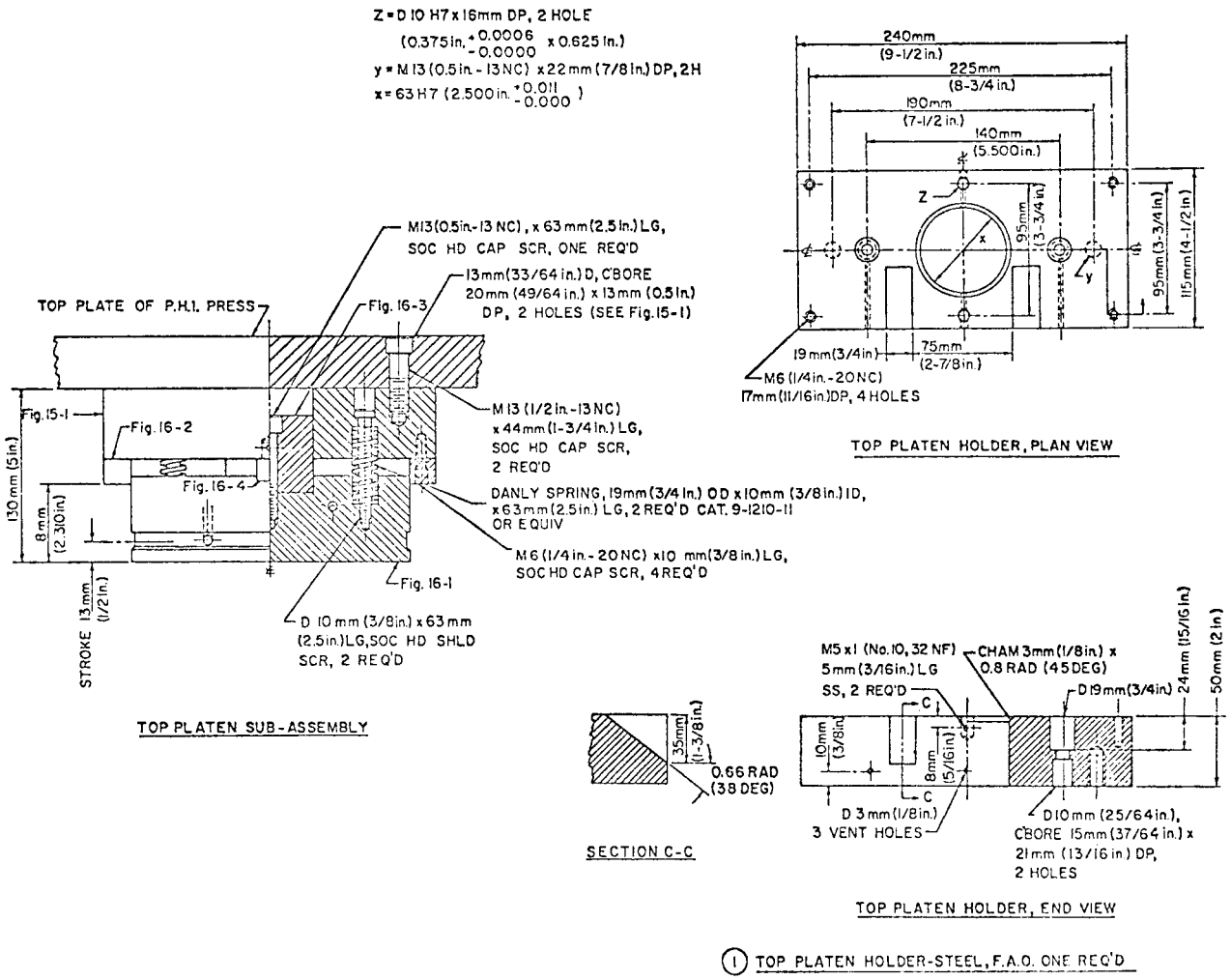


FIG. 15 Top Platen Subassembly and Part No. 1

table at 8.17 ± 0.21 rad/s (78 ± 2 r/min) for 5 min.

9.4.4 Discharge the dry mixing jar onto the rolling sheet, and roll the dry mix by lifting opposite ends of the sheet alternately, using two rolls for each end for a total of four rolls.

9.4.5 Repeat this rolling technique before taking each portion of dry mix during the pressing of the individual specimens made from the mix. Alternate the direction of rolling after taking each specimen.

NOTE 9—It is preferable to process the test specimens as soon as possible after dry mixing to limit the deleterious effects of the prehydration of the portland cement by contact with moisture in the asbestos or in the atmosphere.

NOTE 10—Dry-mixed samples containing cement may not be exposed to the atmosphere for more than 2 h.

NOTE 11—Dry-mixed samples may be kept in storage in plastic or moisture-proof containers for periods not exceeding 1 week.

9.4.6 Do not compress the dry mix in any way.

9.4.7 Preweighing of the dry mix for each test specimen and subsequent storage prior to use is permissible. See Note 9, Note 10, and Note 11.

9.5 *Preliminary Steps for Pressing Test Specimens*:

9.5.1 Clean the press screens and the perforated plate before each pressing cycle, using running water and a stiff bristle brush.

9.5.2 Oil the bottom surface of the top platen die by means of a brush dipped into a mixture of ten parts kerosine to one part raw linseed oil.

9.5.3 Place the lower platen in position on the platen base, and pull it forward as far as it will go.

9.5.4 Stack the following items on top of the lower platen, in the following order (see 6.6.7 to 6.6.9 for specifications): (*1*) Perforated plate, (*2*) No. 16 wire-mesh screen, (*3*) No. 40 wire-mesh screen, and (*4*) Retaining mold (Fig. 17).

9.5.5 *Press Adjustments and Settings*:

9.5.5.1 Control the pressure attained during the dewatering phase on the press by turning the low-pressure relief valve handle counterclockwise to obtain minimum pressure. This gage pressure may not exceed 6.9 MPa (1000 psi).

9.5.5.2 Control the rate of rise by adjusting the full-flow valve in the hydraulic circuit of the press, as shown in Fig. 6. Set the full-flow valve to fully compress the top platen springs as close as possible to 30 s before the end of the low pressure cycle. This is to minimize loss of material without affecting the high-pressure cycle rate of rise. Measure rate of rise by means of a 6 mm (0.236 in.) thick metal plate to replace the slurry.

9.5.5.3 Adjust the limit switch that starts the low pressure timer so that it starts timing when the top of the confining mold

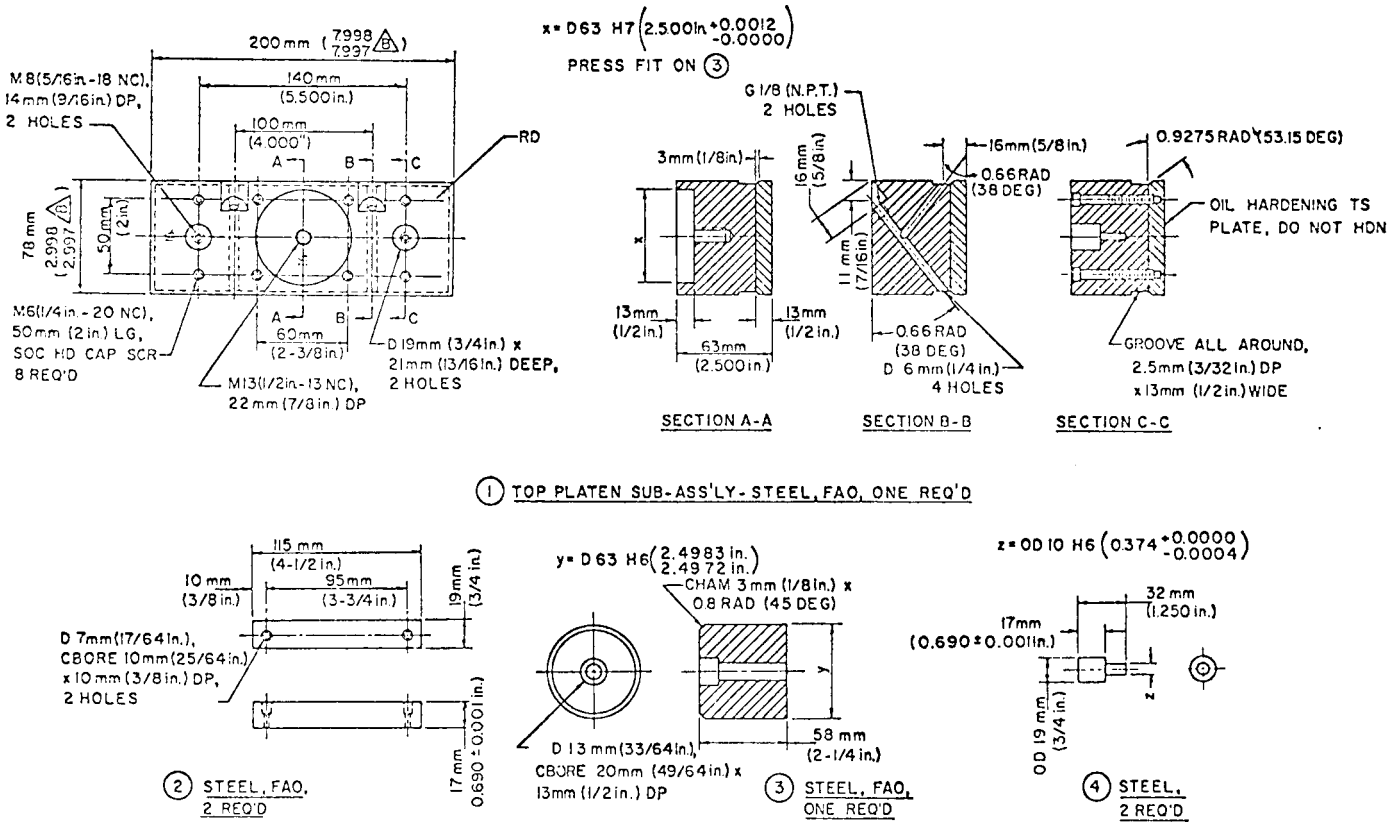


FIG. 16 Top Platen Details

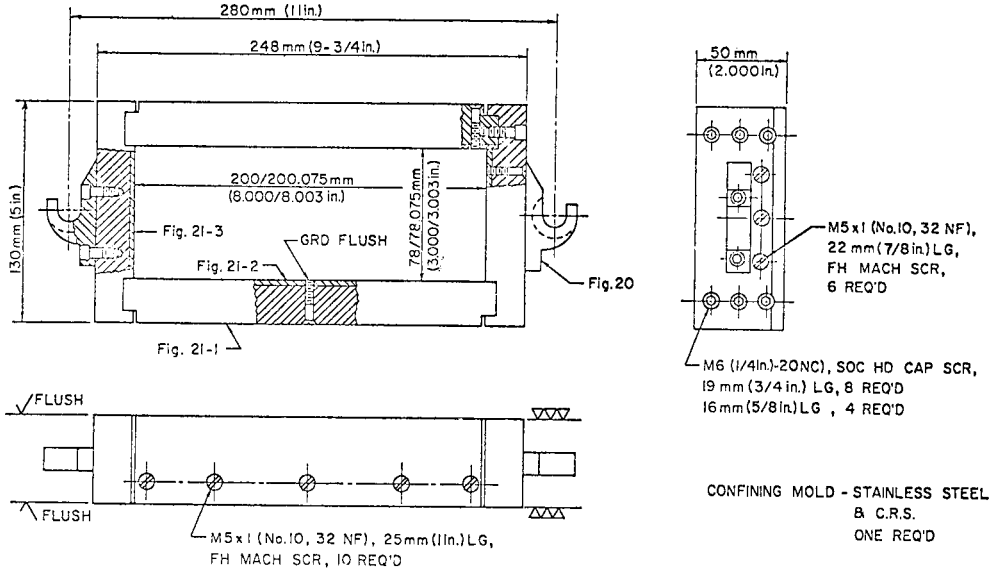


FIG. 17 Confining Mold Assembly

(Fig. 17) is in the same horizontal plane as the bottom of the upper platen (Fig. 15).

9.5.5.4 The upper platen die is fitted with suction nozzles (Fig. 15 and Fig. 16) that serve to aspirate water that is forced out between the mold and the die when it comes into contact with the slurry. These nozzles must be connected, through a liquid trap, by means of hoses, to a source of vacuum. A vacuum of 75 mm (3 in.) Hg has been found satisfactory, when set with pinched suction lines, 8 mm (5⁄16 in.) bore, by means of a diaphragm-type regulator[16] located 1.2 m (4 ft) from the suction nozzle outlets. Connect the suction nozzles on the mold to a suction flask by means of two separate parallel hoses which are led through the rubber stopper of the suction flask by means of metal tubes. A 4-dm^3 suction flask is recommended.

[16] The Strates-vacuum regulator model 16, made by Fairchild Hiller, Industrial Products Div., 1501 Fairchild Drive, Winston Salem, NC 27105, has been found satisfactory for this purpose.

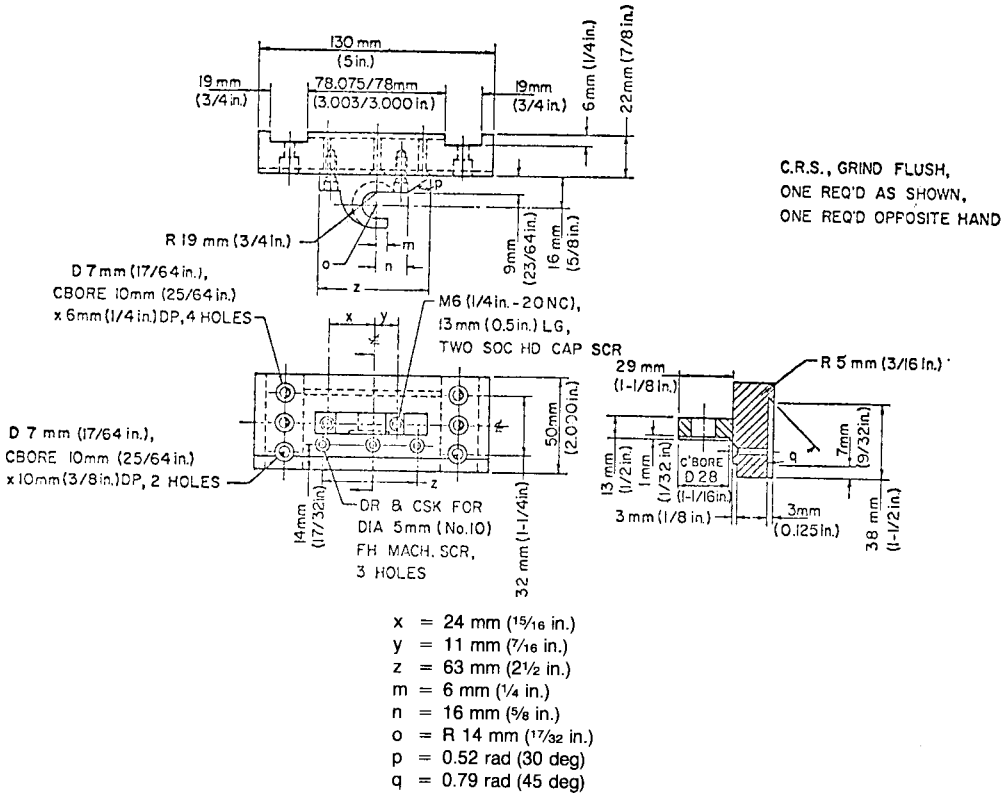


FIG. 18 Confining Mold Detail

Installation of the vacuum regulator as close as convenient to the suction flask outlet nozzle has been found satisfactory. Tap the vacuum manometer directly into the rubber stopper of the suction flask.

9.5.5.5 The lower platen base is fitted with a drainage nozzle to dispose of the water that is forced out through the screens when the die contacts the slurry in the mold. Connect this nozzle with a hose to the settling tank.

9.5.5.6 Set the rate of rise control valve shown on Fig. 6 so that a gage pressure of 234.4 MPa (34 000 psi) will be attained after 30 s in the high-pressure cycle.

9.5.5.7 Adjust the high-pressure relief valve to maintain a gage pressure of 234.4 MPa (34 000 psi) throughout the last 60 s of the cake formation phase (time from 300 to 360 s (5 to 6 min)).

9.5.5.8 Adjust the extension of the upper platen springs by means of the socket head shoulder screws which retain them. (See Fig. 15.) Set the extension so that the top die will extrude the specimen cake from the confining mold at the end of the pressing cycle such that the bottom of the die will project below the bottom surface of the confining mold by a distance of 0.2032 ± 0.0508 mm (0.008 ± 0.002 in.).

9.5.5.9 Adjust the spacers shown as part 4 in Fig. 16 so that cake thickness will be 6 ± 0.25 mm (0.236 ± 0.010 in.). Thickness may be decreased by surface-grinding the spacers. Increased thickness may be obtained by the use of steel shims of appropriate thickness.

9.5.5.10 Check the brass loading bars for wear and replace these if wear exceeds 0.127 mm (0.005 in. on the bottom platen (Fig. 20)).

9.6 *Wet Mixing*:

9.6.1 Rinse the wet-mixing cone and insert a No. 6 rubber stopper at the bottom.

9.6.2 Pour 400 cm^3 of saturated water at 297 K (75°F) into the cone.

9.6.3 For the wet mixing of the test specimens in each batch, proceed as follows:

9.6.3.1 For the wet mixing of the first test specimen, start the wet-mixer motor and immediately add 0.145 kg (0.32 lb) of dry mix. (See Note 12.) If splashing is expected, start the mixer at a slow speed and bring it to 600 r/min gradually within 10 s. A device to control the speed of the mixer is required for such cases.

9.6.3.2 For the wet mixing of subsequent test specimens, wait until the start of the high-pressure cycle on the specimen press, then immediately start the wet-mixer motor and immediately add 0.145 kg (0.32 lb) of dry mix. (See Note 10.)

NOTE 12—The timing for the sequence of test specimen formation is continuous from this point; the time at which the mixer is started being zero.

9.6.4 Add an additional 50 cm^3 of saturated water to rinse down the walls of the cone while the mixer motor is running.

9.6.5 When the end of the 2-min wet-mixing period approaches, swing the wet mixer on its swivel support so that the discharge chute leads directly to the specimen mold on the press.

9.6.6 *Transfer of Slurry (Time: 120 to 165 s (2 to 2.75 min))*:

9.6.6.1 When the time reaches 120 s (2 min), stop the mixer motor and simultaneously remove the stopper at the bottom of the cone to discharge the slurry into the mold by means of the chute.

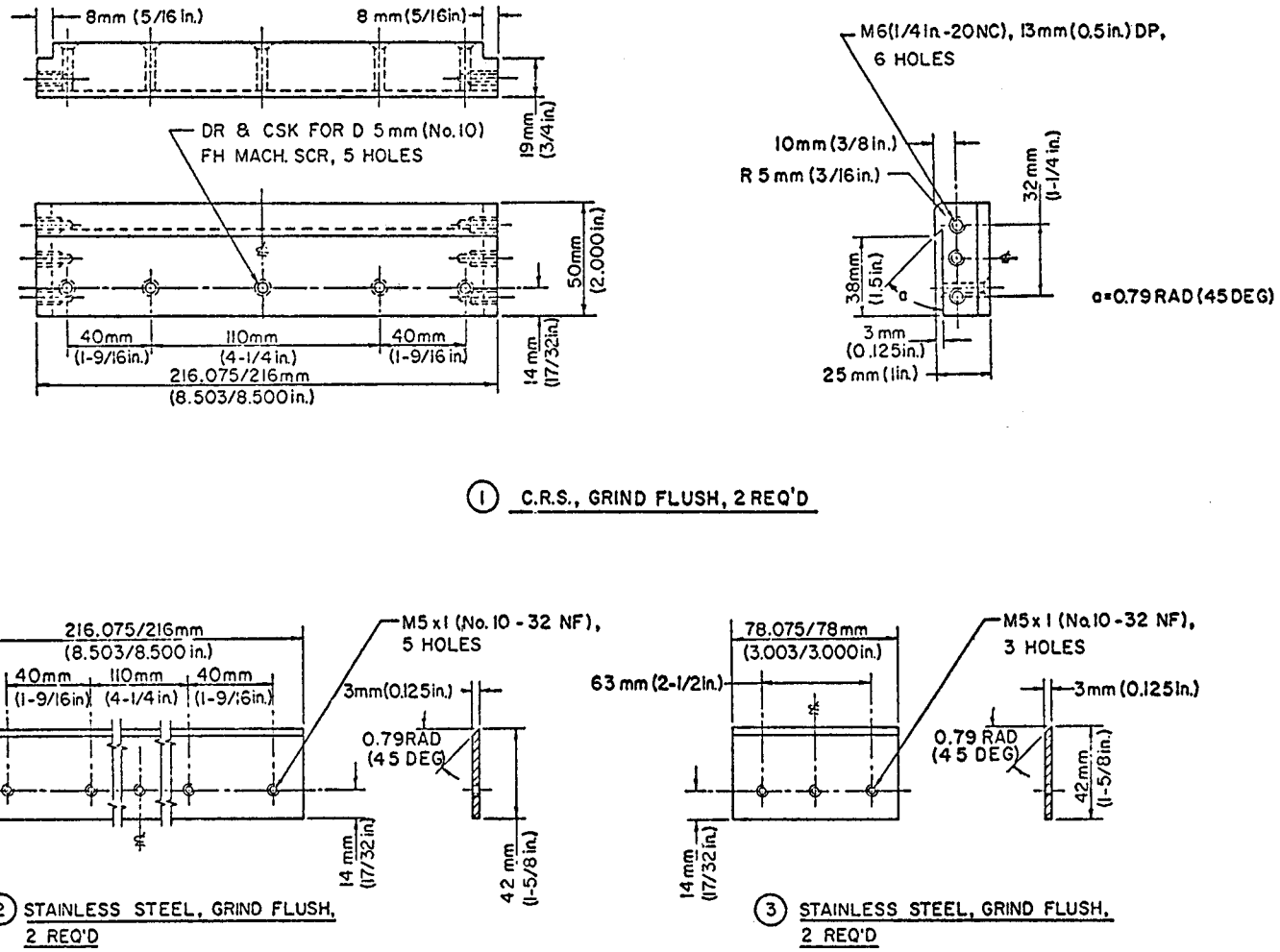


FIG. 19 Confining Mold (Additional Detail)

9.6.6.2 After the slurry has discharged, spin the mixer motor briefly to clean the impeller by centrifugal force.

9.6.6.3 Clean the walls of the cone by means of a rubber spatula.

9.6.6.4 Scrape the chute clean by means of the straight edge on the rubber hoe (Fig. 5).

9.6.6.5 Distribute the slurry evenly in the mold by means of the toothed edge on the rubber hoe. Carry out this operation in as few strokes as possible to prevent segregation. Do not use more than three strokes. The entire slurry transfer time should be 45 s.

9.6.7 Swing the wet mixer and chute out of the way and above a suitable container to receive the rinsings.

9.6.8 Rinse the cone and impeller with running water and discard the rinsings. This operation may be carried out later, during the pressing cycle, when convenient.

9.7 *Pressing*—After the preliminary steps in 9.5 and the transfer of the slurry in 9.6.6 and 9.6.7, push back the confining mold and bottom platen assembly together until they are directly beneath the top platen die, and the confining mold hooks contact the yoke rods between the set screw collars. (See Fig. 9, Fig. 7, Fig. 8, Fig. 17 and Fig. 18.)

9.7.1 *Dewatering (Time: 165 to 270 s (2.75 to 4.5 min))*—Start the cycle by opening the safety switch and closing the foot switch. The low-pressure timer is thus activated.

9.7.2 *Cake Formation (Time: 270 to 360 s (4.5 to 6 min))*:

9.7.2.1 After the dewatering interval, timer No. 1 automatically shuts off and starts timer No. 2 which controls the cake formation period.

9.7.2.2 The pressure will rise to a gage pressure of 234.4 MPa (34 000 psi) in 30 s and remain at that pressure for a dwell time of 60 s.

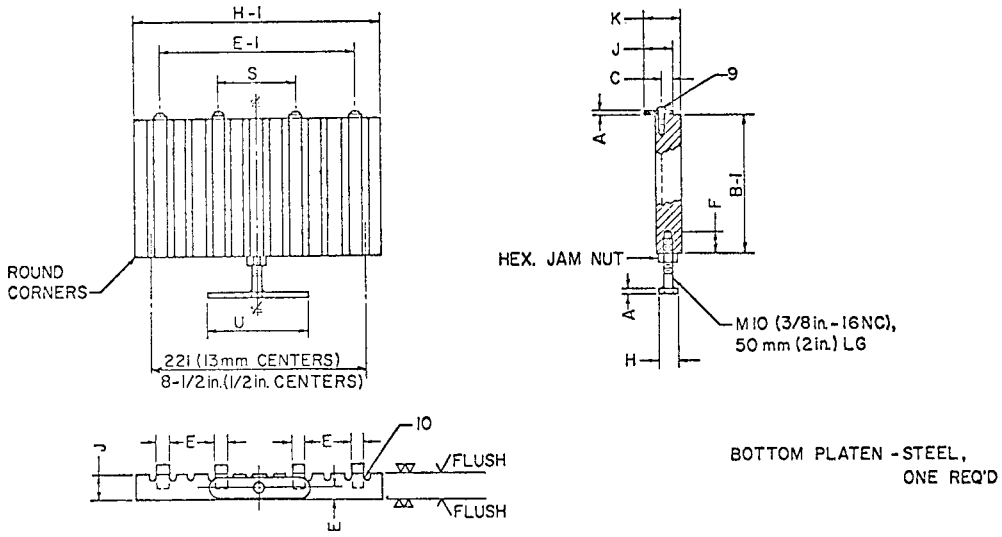
9.7.3 *Specimen Cake Discharge*:

9.7.3.1 At the end of the dwell time interval 360 s (6 min) of the continuous timing sequence, timer No. 2 times out and the press pump motor stops.

9.7.3.2 The ram will drop and the top die will be forced away from the supporting plate of the top platen by the springs shown in Fig. 15. Since the confining mold is supported rigidly by the holding device (Fig. 9), the top die will pass through the confining mold, exposing the specimen cake for removal.

9.7.3.3 As the ram drops, insert a flat asbestos-cement or rigid plastic sheet between the specimen and the top of the screen on the bottom platen to receive the specimen. The maximum clearance between the bottom of the cake and the top of the receiving sheet should be 6 mm (0.25 in.) in order to protect the specimen from excessive flexing.

9.7.3.4 If the specimen does not fall of its own accord, strip it carefully from the die by inserting a thin spatula between the cake and the die. It is permissible for experienced technicians



Dimension	mm (in.)	Dimension	mm (in.)	Dimension	Specification
A	3 (⅛)	K	35 (1⅜)	9	M5 × 1 No. 10-32 NF, 13 mm (½in.) large, roundhead machined screw, (four required).
C	8 (5⁄16)	S	78 (3)		
E	13 (½)	U	100 (4)		
F	16 (⅝)	B-1	135 (5¼)		
H	19 (¾)	E-1	180 (7)	10	18 grooves, R1.5 mm (1⁄16 in.) by 3 mm (⅛in.) DP
J	25 (1)	H-1	240 (9½)		

FIG. 20 Bottom Platen Assembly

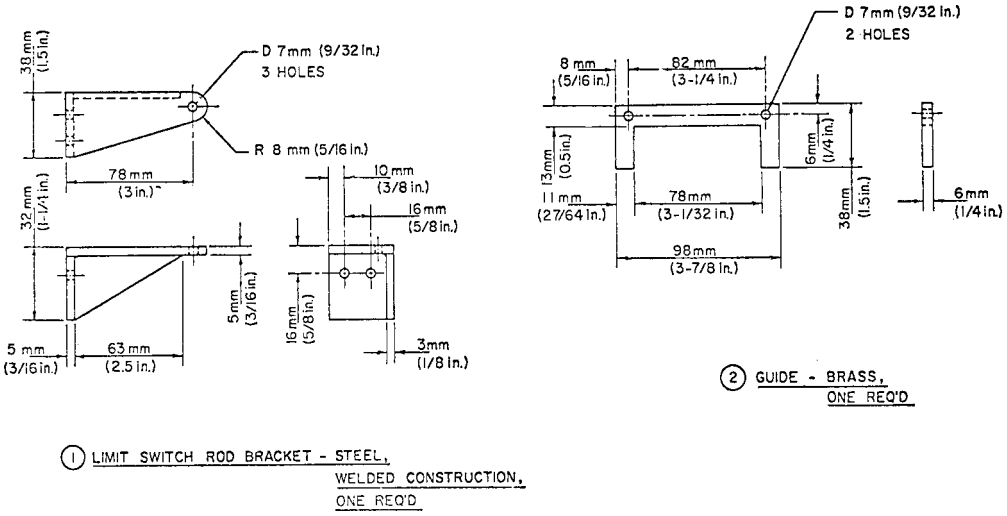


FIG. 21 Platen Base Detail

to hold the receiving sheet in contact with the specimen while the latter is stripped from the die.

9.7.3.5 Remove the asbestos-cement or plastic sheet, with the specimen cake on top, from the press and smooth any rough edges or flashing with the spatula. Ensure that the bottom of the spacer does not carry water to the top of the preceding cake.

9.7.3.6 Stamp a number at both ends of the specimen by means of a band number, or otherwise identify the specimen by any suitable means. If ink or pigments are used, make sure that these will withstand the subsequent curing steps without fading beyond use.

9.7.3.7 Clean the screens and the perforated plate by brushing them in running water, and return to the grooved lower platen for the next test.

9.7.3.8 Lower the confining mold (Fig. 17) by releasing the holding device (Fig. 9).

9.7.3.9 Wipe remnants of the slurry from the confining mold and the die, with emphasis on the sides of the die, in order to prevent clogging of the suction system channels. The latter *must* be kept clean to obtain reproducible results.

9.8 *Specimen Curing*:

9.8.1 *Moist Cure*:

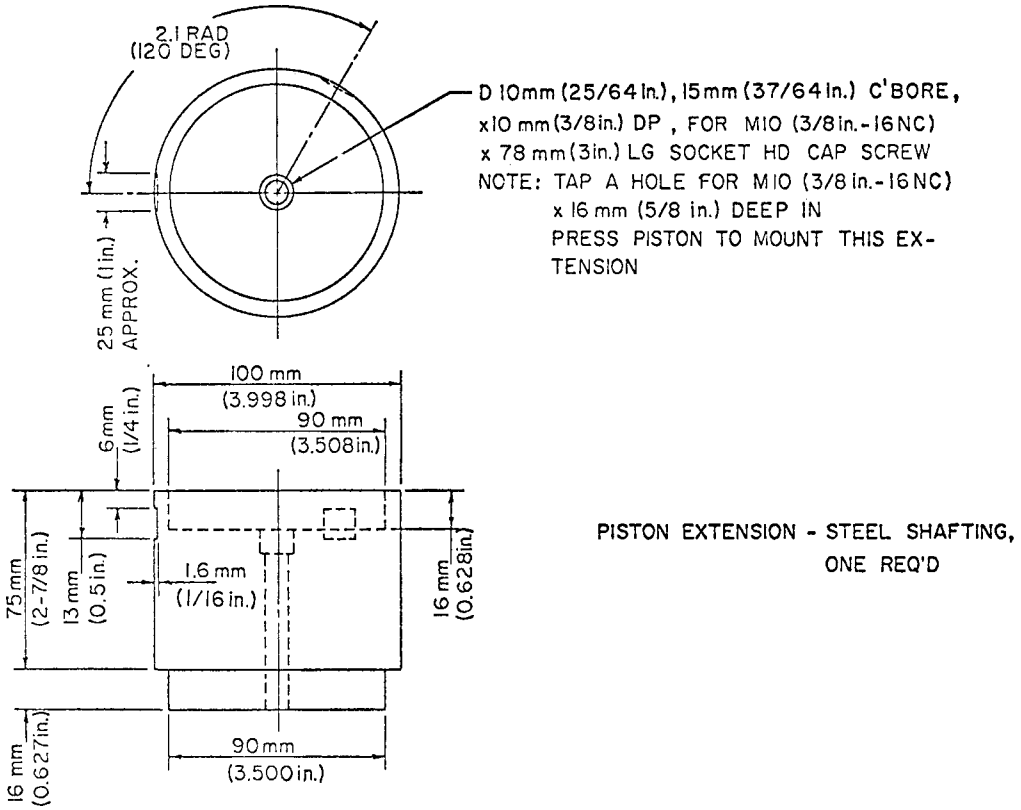


FIG. 22 Platen Base (Additional Detail)

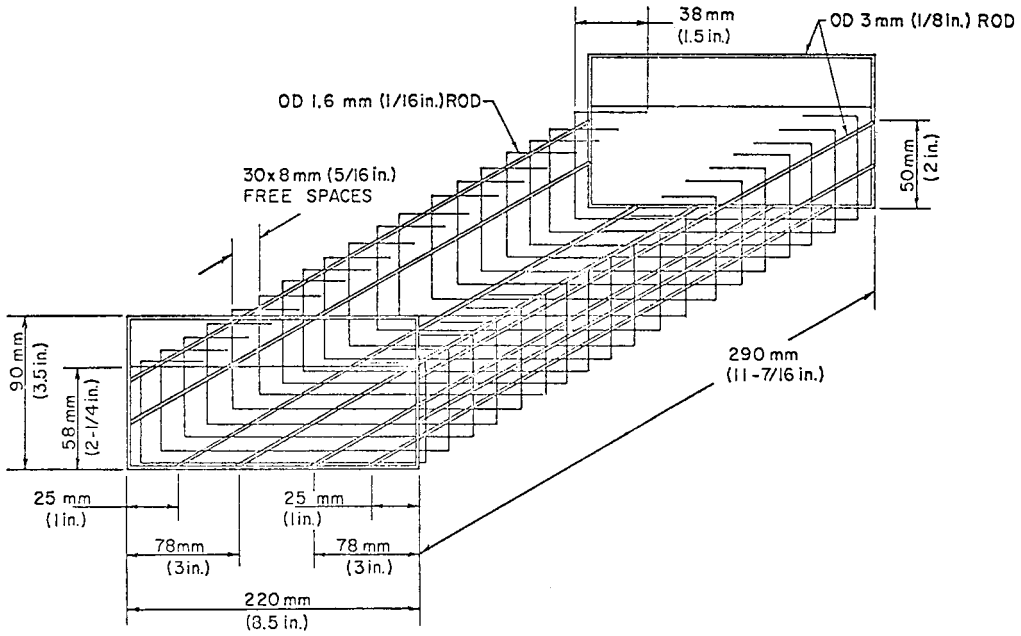


FIG. 23 Specimen Basket

9.8.1.1 Stack the receiving sheets bearing the pressed specimens one above the other, and keep the pile covered with a wet cloth during the pressing of the other specimens from the same batch.

9.8.1.2 When the entire batch has been pressed, transfer the pile of specimens and receiving sheets to the humidity cabinet. A wet cloth may be left wrapped around the pile while it is in the humidity cabinet.

9.8.1.3 Keep specimens in the humidity cabinet for a minimum period of 16 h and a maximum period of 72 h. For referee testing, hold the specimens in the humidity cabinet for a period of 24 ± 2 h.

9.8.1.4 Operate the humidity cabinet at 90 to 100 % relative humidity, at 15 to 32°C (60 to 90°F).

9.8.2 *Autoclaving*:

9.8.2.1 After the moist curing period is completed, remove

TABLE 1 Fiberizer Discharge Plate Openings

Quebec Standard Group[A] or Equivalent	Diameter of Holes in Perforated Plates[B,C], mm (in. (approximate))
3	10 (0.394)
4	7 (0.275)
5	5 (0.197)
6	3 (0.118)

[A] Quebec Standard (Q.S.) designation of chrysotile asbestos grades (measured by Test Method D 3639 and classified in accordance with 2.2.

[B] A 10-mm plate size is optional for 4-Group fibers of types that benefit by resulting in ultimately higher strength results.

[C] The asbestos fiber supplier may indicate the appropriate hole diameter.

the specimens from the humidity cabinet, and separate the specimens from the receiving sheets. If the specimens adhere to the sheets, tap the latter, on edge, sharply against a table top; this will dislodge the specimens.

NOTE 13—Wax the receiving sheets, as required, to prevent this occurrence.

9.8.2.2 Stack the specimens in a wire basket shown in Fig. 23, and place the basket on the autoclave tray mentioned in 6.7.2.1. Alternatively, stack manually.

9.8.2.3 Close the autoclave and raise the gage pressure to 689 ± 7 kPa (100 ± 1 psi) within a 2-h period.

9.8.2.4 Bleed off steam from the autoclave to remove all of the air which was enclosed initially. When all the air has been purged, the saturated steam temperature of 170 ± 5°C (338 ± 8°F) will be indicated on the autoclave thermometer. Since thermometers are inherently more reliable than common pressure gages, operate the autoclave on the temperature basis. Make sure that the steam supplied consists only of saturated steam.

9.8.2.5 Cure the specimens at 170 ± 5°C (338± 8°F) for 20 h.

9.8.3 *Saturation*:

9.8.3.1 After autoclaving, immediately remove the cakes from the autoclave and allow them to cool sufficiently in air at room temperature to prevent warming the immersion water mentioned in 9.8.3.2 beyond the limits allowed.

9.8.3.2 Immerse the cakes in clean water at 25 ± 3°C (77 ± 5°F) so that the specimens are completely covered for 24 h. Leave the cakes in the baskets during the immersion. Alternatively, stack the cakes manually.

9.8.3.3 The formation of a film of scum on the surface of the water is normal and may be attributed to pressing oil and other matter washed from the specimens. Discard the water each time, after using it once.

9.9 *Specimen Measurement and Testing*:

9.9.1 *Immersed Specimen Mass*:

9.9.1.1 Weigh each specimen while it is completely immersed in clean water at 25 ± 1°C (77 ± 2°F).

9.9.1.2 Suspend the weighing platform or specimen-holding hooks by means of small diameter monofilament impermeable thread or wire, at the point where the suspension system traverses the water surface.

9.9.1.3 Record immersed weights for each specimen to the nearest 0.1 g, and return each specimen to the saturating tank while the other specimens are being weighed.

9.9.2 *Saturated Specimen Mass*:

9.9.2.1 After immersed masses for all the specimens in a basket have been determined, remove the basket from the saturating tank and support it at a compound angle of 0.78 rad (45°) from the vertical, that is, at 0.78 rad (45°) from the front elevation and 0.78 rad (45°) from the side elevation. Alternatively, stack manually.

9.9.2.2 Allow the specimens to drip-dry for a period extending from 7 to 15 min, and determine the saturated mass (drip-dry weight). Start weighing specimens after 7 min and continue weighings until all specimens have been weighed, or until the time limit of 15 min has been reached, whichever occurs first. If the specimens cannot be weighed in the allowed time, return the unweighed specimens to the saturating tank for an additional period of 15 min before repeating the drip-dry step.

9.9.2.3 Record the saturated masses for each specimen to the nearest 0.1 g, and reimmerse the specimens or cover them with a wet cloth until flexural testing is begun.

9.9.3 *Flexural Testing*:

9.9.3.1 Load each specimen in flexure until fracture of the specimen occurs. Load at the constant rate of 5.89 ± 0.29 N/s. Alternatively, a flexural tester with a constant rate of extension may be used. In the latter case, set the rate of extension at 0.1 mm/s (14.17 in./h).

9.9.3.2 Flexural-tester dynamometers equipped with a trailing needle to record the maximum load attained are preferable. Otherwise, make every effort to observe the maximum load attained before incipient failure deformation of the specimen occurs.

9.9.3.3 Only fractures that occur in the middle third of the span between the loading bars are acceptable. Record the maximum load, called the breaking load, to the nearest 1 N (0.5 lbf) for each specimen.

9.9.4 *Specimen Thickness*:

9.9.4.1 Measure specimen thickness near the fracture on one of the broken halves as follows:

9.9.4.2 Place the center of the micrometer anvils at approximately 13 mm (0.5 in.) from the fracture at midwidth, and measure thickness to the nearest 0.01 mm (0.0005 in.). Then locate the center of the micrometer anvils at approximately 13 mm (0.5 in.) from the fracture, at approximately 13 mm (0.5 in.) from each side of the specimen, and measure thickness at both locations.

9.9.4.3 Take care that the micrometer anvils are not too near the cake sides (not the fracture edge) because thickness is usually greater at these points.

9.9.4.4 Record the three thicknesses for each specimen. If results are consistently different for the two side measurements, this may indicate that the specimens do not have parallel faces, and the alignment of the press platens should be checked.

9.9.5 *Specimen Width*:

9.9.5.1 Specimen width is assumed constant for the purpose of this test. However, optional determination of specimen width may be made at this point to allow the determination of true modulus of rupture if this information is desired.

9.9.5.2 Use calipers with long thin parallel jaws that are perpendicular to the direction of extension. These will permit measurement of specimen width even with diagonal fracture.

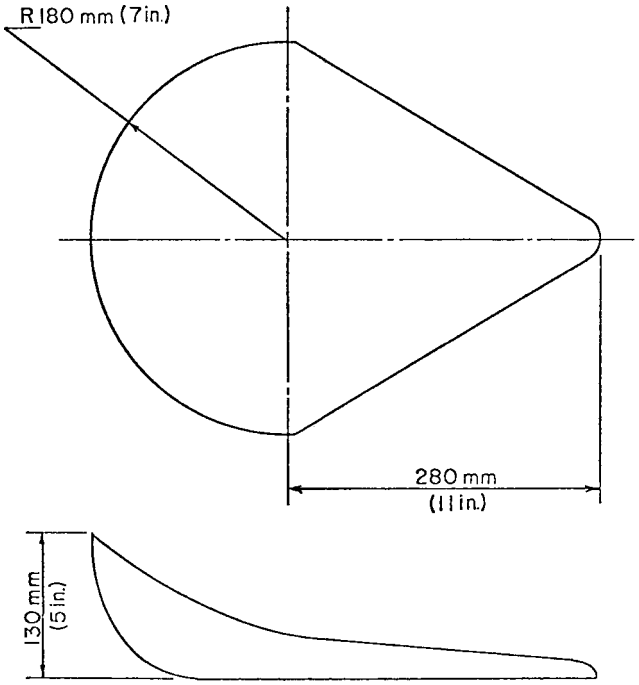


FIG. 24 Fiberizer Feeding Pan

9.9.5.3 Record the width to the nearest 0.2 mm (0.01 in.) for each cake.

9.9.6 *Dry Specimen Mass*:

9.9.6.1 After testing and measuring, return the broken specimens to the wire basket and place them in the drying oven. Alternatively, stack manually.

9.9.6.2 Dry the specimens at 105 to 110°C (220 to 230°F) for 24 h, excluding the time required to reach the specified temperature. Allow cakes to cool for 1.8 ks (30 min) minimum, but not longer than 7.2 ks (2 h). Weigh cakes as soon as they can be handled with bare hands.

9.9.6.3 Weigh both halves of each broken cake together to the nearest 0.0001 kg (0.1 g) and record this mass for each specimen. Then discard the specimens.

10. Calculation

10.1 *Standard Calculation*:

10.1.1 *Specimen Volume*— Determine the volume of each specimen from the following equation:

$$V = (S - I)D \tag{5}$$

where:
V = volume of specimen, m^3,
I = immersed mass, Mg,
S = saturated mass, Mg, and
D = density of water, 1.0 Mg/m^3.

10.1.2 *Dry Specimen Density*—Determine the dry density of each specimen from the following equation:

$$A = B/V = BD/(S - I) \tag{6}$$

where:
A = dry specimen density, Mg/m^3,
B = dry specimen mass, Mg, and
V = volume of specimen, m^3.

10.1.3 *Flexural Strength*:

10.1.3.1 Calculate the flexural strength of each specimen in accordance with 10.1.3.2 to 10.1.3.5.

10.1.3.2 Determine the flexural modulus of rupture from the following equation for a simple beam with third point loading:

$$MR = \frac{Pl}{bt^2} \tag{7}$$

where:
MR = modulus of rupture, Pa,
P = maximum load attained, N,
l = span, m,
b = width, m, and
t = average thickness, m.

10.1.3.3 Determine the test modulus of rupture from the following equation:

$$MR_T = \frac{(P)(0.152)}{(0.0762)(t^2)} = \frac{2P}{t^2} \tag{8}$$

where:
MR_T = test modulus of rupture, Pa,
P = maximum load attained, N,
t = average thickness, m,
0.152 = nominal span, m, and
0.0762 = nominal width, m.

Example—For a specimen with a 588-N breaking load and an average thickness of 6.00 mm:

$$MR_T = \frac{2(588)}{(0.006)^2} = 32.7\ MPa \tag{9}$$

10.1.3.4 Correct the test modulus of rupture $(MR_T)$to a common density basis as follows, based upon the arbitrary choice of a standard density of 1.6 Mg/m^3(1.60 g/cm^3): (For an alternative method of calculation see Annex A2.)

$$MR_A = \frac{(1.6)^2(MR_T)}{A^2} \quad (10)$$

where:
MR_A = adjusted modulus of rupture, Pa,
MR_T = test modulus of rupture, Pa,
A = dry specimen density, Mg/m^3, and
1.60 = standard density, Mg/m^3.

Example—For a dry specimen density of 1.58 Mg/m^3 and MR_T of 32.7 MPa. In keeping with the limits on thickness imposed in 9.5.5.9, the density may not exceed 1.6 ± 0.07 Mg/m^3 to permit valid density corrections.

$$MR_A = \frac{(1.60)^2}{(1.58)^2} \times 32.7 = 20.9\ MPa \quad (11)$$

Since this strength exceeds the allowable range described in 10.1.3.5 and 10.1.4, this specimen is not valid and results derived therefrom may not be used in the calculations of average batch performance.

10.1.3.5 Eliminate any individual value of MR_A varying from the mean by more than ±1.833 standard deviations from the mean (including results on ten specimens) and calculate a new average strength. If more than three such specimens must be eliminated, repeat the whole test.

10.1.4 *Reference Strength Level*—A standard reference strength for the specimens has been arbitrarily chosen as that which corresponds to a test modulus of rupture of 26.97 MPa at a dry cake density of 1.60 Mg/m^3.

10.1.5 *Calculating Fiber Content to Give Standard Strength*:

10.1.5.1 The asbestos fiber content of the dry mix should be chosen so that the adjusted modulus of rupture (MR_A) lies in the range from 25.6 to 28.2 MPa. If the MR_A exceeds this range, prepare a new series of test specimens at a different fiber content, as determined in 10.1.5.2.

10.1.5.2 Calculate the asbestos fiber weight required from the following equation:

$$F_A = \frac{(0.145 - F_A)(F_T)(4.05 \times 10^5)}{(0.145 - F_T)(MR_A)} \quad (12)$$

where:
F_A = adjusted asbestos fiber mass in the dry mix, for each specimen, to give standard strength, Mg,
F_T = mass of asbestos fiber for each specimen tested, Mg,
MR_A = adjusted modulus of rupture, Pa,
0.145 = total mass of dry mix for each specimen, Mg, and
4.05×10^5 = standard reference strength, Pa.

10.1.5.3 Calculate the percent asbestos fiber required in the dry mix to give standard strength as follows:

$$\text{Asbestos fiber, \%} = F_A \times 100/0.145 \quad (13)$$

$$= \frac{(4.05 \times 10^5 F_T)(100)}{MR_A(0.145 - F_T) + 4.05 \times 10^5 F_T}$$

$$= \frac{(4.05 \times 10^5 Q_f)(100)}{MR_A(1.00 - Q_f) + 4.05 \times 10^5 Q_f}$$

where:
Q_f = ratio of asbestos fiber mass to total dry-mix mass.

10.1.6 *Calculation of Strength Units*—An asbestos fiber that gives the standard strength at the standard density when used as 10% of the furnish is defined as having 100 strength units. Therefore, by knowing the percent asbestos fiber required in the mix to give standard strength (obtained in 10.1.5.3), it is possible to calculate the strength units of the fiber sample from the following equation:

Strength units = 1000/(% fiber required in dry mix)

10.1.7 *Sample Calculation*—The following are general examples which covers the analysis of typical test data:

10.1.7.1 *Mix Composition*:

Q_f = 0.125
F_T = fiber mass in kilograms per specimen
= $0.145 \times 0.125 = 0.0181$ kg
C_T = cement mass in kilograms per specimen
= $0.6 \times (0.145 - 0.0181) = 0.0761$ kg
S_T = silica mass in kilograms per specimen
= $0.4 \times (0.145 - 0.0181) = 0.0508$ kg

$$\text{Total mass per specimen} = 0.0181 + 0.0761 + 0.0508$$

$$= 0.145\ kg \quad (14)$$

10.1.7.2 *Average Strength Data*:

P = breaking load = 4.56 N
T = average thickness at break = ⅓ (5.90 + 5.90 + 6.20) mm
= 6.00×10^{-3} m
A = dry specimen density = 1.58 Mg/m^3

10.1.7.3 *Flexural Moduli of Rupture*:

$$MR_T = \frac{2P}{t^2} = \frac{2(4.56)}{(6.00 \times 10^{-3})^2} = 0.253\ MPa \quad (15)$$

$$MR_A = \frac{(1.60)^2(MR_T)}{A^2} = \frac{(1.60)^2(0.253 \times 10^6)}{(1.58)^2} = 0.260\ MP\ a \quad (16)$$

10.1.7.4 *Percent Fiber Required (F_R)*:

$$F_R = \frac{(4.05 \times 10^5)(F_T)(100)}{MR_A(0.145 - F_T) + 4.05 \times 10^5 F_T} \quad (17)$$

$$= \frac{(4.05 \times 10^5)(0.0181)(100)}{(260 \times 10^3)(0.145 - 0.0181) + 4.05 \times 10^5 (0.0181)(100)} = 12.9\%,$$

or

$$F_R = \frac{(4.05 \times 10^5)(Q_f)(100)}{MR_A(1.00 - Q_f) + 4.05 \times 10^5 Q_f} \quad (18)$$

$$= \frac{(4.05 \times 10^5)(0.125)(100)}{(260 \times 10^3)(1.00 - 0.125) + 4.05 \times 10^5 (0.125)} = 12.9\%,$$

10.1.7.5 *Strength Units (SU)*:

$$S.U. = 1000/(F_R) \quad (19)$$

$$= 1000/12.9 = 78\ units$$

10.2 *True Flexural Modulus of Rupture*—If the true width has been measured, determine the true flexural modulus of rupture from the following equation which is applicable to a simple beam with third-point loading:

$$MR = Pl/bt^2 \quad (20)$$

where:
MR = true flexural modulus of rupture, Pa,
P = maximum load attained, N,
l = span, m,
b = width, m, and
t = average thickness, m.

10.3 *Point Value*— Point value is considered, by some segments of the industry, as an index of commercial value. Several formulas for the calculation of point value are presently in use. However, only one will be given here to prevent the dissemination of undesirable practices.

10.3.1 Calculate point value from the following equation:

$$PV = (SU - 10.0)/1.39 \quad (21)$$

where:
PV = point value, in points, and
SU = strength value, in units.

11. Report

11.1 Fully identify the designation and origin of the sample tested.

11.2 Report the following data:

11.2.1 Ratio of asbestos fiber mass to total dry-mix mass (Q_f) tested,

11.2.2 Ratio of asbestos fiber mass to total dry-mix mass (Q_f) required,

11.2.3 Adjusted modulus of rupture (MR_A) average,

11.2.4 Number of specimens acceptable, and

11.2.5 Strength Units (SU).

11.3 If any option or alternative calculations are carried out, remarks to this effect must be contained in the report. If point value is calculated, report this as well.

12. Precision and Bias

12.1 *Precision*—Round-robin testing indicates that interlaboratory reproducibility within 5 % of the mean strength unit may be attained in 98 % of the cases, using the same cement, silica, and fiber ratio.

12.2 *Bias*—No justifiable statement can be made on the bias of this method for testing the strength of asbestos-cement products since the true value of the property cannot be established by an accepted referee method.

13. Keywords

13.1 asbestos; asbestos-cement; determination; evaluation; point value; reinforcement potential; strength; strength unit

ANNEXES

(Mandatory Information)

A1. SUITABILITY OF CEMENT AND SILICA

A1.1 It is recognized that cement and silica cannot be supplied practically and consistently within the narrow specification range of 300 ± 20 m^2/kg. It is recommended that a correlation be carried out to evaluate the suitability of various shipments of cement and silica received. This can be done by testing a reference fiber when changing from one lot to another.

A2. ALTERNATIVE METHOD OF CALCULATING THE ADJUSTED MODULUS OF RUPTURE

A2.1 This test method may be used for "in-house" testing, but the method in 10.1.3.4 shall be used for any referee purpose.

A2.2 Calculate the adjusted modulus of rupture by means of the following equation:

$$MR_A = 37.7\ PlL^2b/w^2 \quad (A2.1)$$

where:
MR_A = adjusted modulus of rupture, MPa,
P = breaking load, kg,
l = span, 0.152 m,
L = length of specimen, m,
b = breadth of specimen, m, and
w = dry mass of specimen, kg.

A2.3 For higher precision, measure L, l, and b for each cake. **Caution:** Correlate the results from this short form of calculation, using an adjustment factor, to results obtained from the prescribed form of calculation presented in 10.1.3.4.

A2.4 The report must include a statement of which form of calculation was used.