Simplified Air-Jet Dispersion Apparatus for Mechanical Analysis of Soils

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THIS paper describes the development of a simplified air-jet dispersion apparatus. A comparison of this apparatus with three other dispersion apparatus in current use is also given. Results of mechanical analyses on a wide variety of soils indicate that the device gives a comparatively high degree of dispersion without causing significant degradation. This apparatus is simple in construction and, consequently, can be built at a relatively low cost. In addition, because of its unique design the procedure for its use is substantially simpler than that for other dispersion apparatus.

● MECHANICAL analysis to determine particle-size distribution in soils is a common test used in civil engineering, ceramic engineering, agricultural, and geological testing laboratories. An essential step in the mechanical-analysis procedure is to disperse the soil sample in water so there are no aggregated or flocculated particles to distort test results. This is usually accomplished by soaking the sample in water for a prescribed length of time and then subjecting it to mechanical agitation in the presence of a deflocculating agent.

Different types of apparatus have been used to disperse soil for mechanical analysis, but none of them has been found entirely satisfactory. Because of this, a project (Project 300) was established at the Soil Research Laboratory of the Iowa Engineering Experiment Station to investigate the possibility of developing a new dispersion apparatus which would be simple in construction, easy to use, and would give the desired dispersion.

Following a brief review of soil-dispersion methods in current use, this paper describes the development and evaluation of a simplified air-jet dispersion apparatus.

REVIEW OF SOIL DISPERSION METHODS

Various techniques have been used to agitate a soaked soil sample for achieving proper dispersion. Among the ones more commonly used are end-over-end shaking, stirring with a high-speed, electric malted-milk mixer, and vigorous agitation by jets of compressed air. These three dispersion methods will be reviewed briefly.

End-over-end shaking of a soaked soil sample in a glass tube or jar is one of the oldest methods for soil dispersion (*1*). It is still widely used in the fields of agriculture, geology, and ceramic engineering. The machine used for shaking rotates at a slow speed, usually 40 to 70 revolutions per minute. This method gives fairly satisfactory results with many types of soil; its main disadvantage is that the period of dispersion is long, usually 24 hr. or more.

The use of an electric malted-milk mixer for stirring a soaked sample was suggested by Bouyoucos (*2*). Both the American Society for Testing Materials (*3*) and the American Association of State Highway Officials (*4*) have adopted this type of apparatus for soil dispersion and specify stirring time as 1 min. High-speed stirring by the use of such apparatus is fairly effective with common types of soil, but with other soils it fails to achieve proper dispersion. Though the effectiveness of dispersion may be improved by allowing a longer stirring period, such prolonged stirring is not advisable because of accompanied increase in the degradation[1] of soil particles (*5*). The stirring paddle is usually made of metal, but rubber paddles have also been used (*6*).

In the Wintermyer soil-dispersion cup (*5*), compressed air directed through either jets or holes is utilized to agitate a soaked sample. It gives satisfactory dispersion with a wide variety of soils without causing significant

[1] The term *degradation* refers to the breaking-up or wearing-down of primary soil particles into smaller ones during dispersion.

degradation. However, the apparatus is quite intricate and is costly to build, and the procedure for soil dispersion requires a comparatively long time. The Wintermyer apparatus has been adopted by AASHO as an alternate for soil dispersion (*4*).

The one shown in Figures 1 and 2 was found most satisfactory. An important feature of this design is that the tube fits into standard AASHO and ASTM hydrometer jars. This enables the whole hydrometer test, including soaking and agitation, to be carried out in the same jar. In other words, repeated transfer of the soil-water mixture from one container to another as required in other dispersion methods is not necessary.

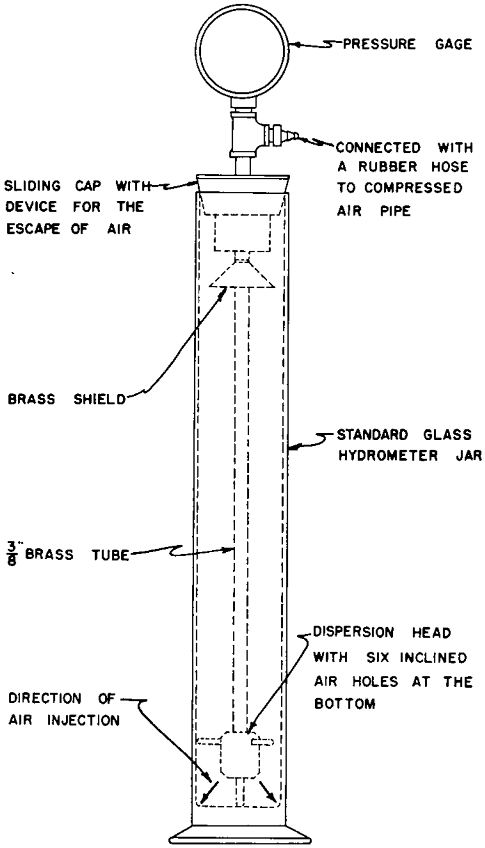

Figure 1. Soil-dispersion tube for mechanical agitation of soil-water mixtures.

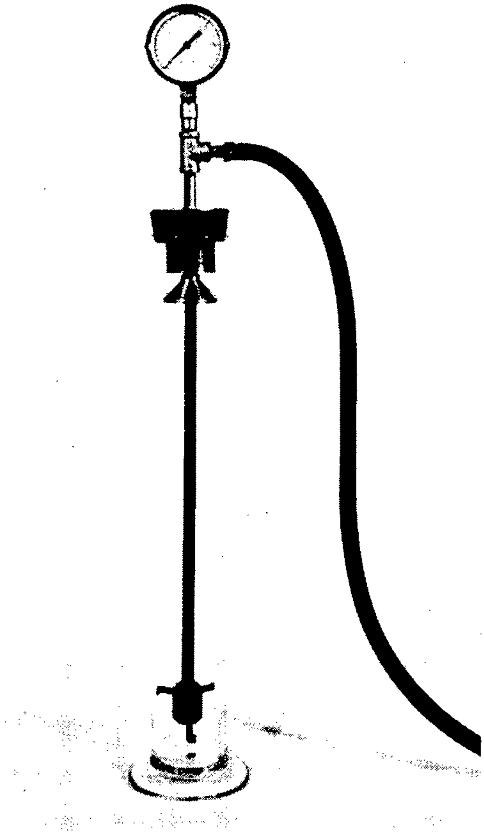

Figure 2. Soil-dispersion tube, showing the tube and glass hydrometer jar.

DEVELOPMENT OF SOIL-DISPERSION TUBE

As discussed above, the Wintermyer soil-dispersion apparatus appeared to be satisfactory for use with a wide variety of soils. Because of this, the air-jet principle was used in the development of a simplified apparatus, called the soil-dispersion tube. Actually, as shown in Figures 1 and 2, the soil-dispersion tube consists of two components, the tube and a glass hydrometer jar.

In developing the soil-dispersion tube, various designs were tried out in the laboratory.

Before developing a procedure for using the tube, the amount of soil-water mixture to be used during dispersion, the duration of dispersion, and the amount of air pressure needed to achieve optimum results were determined. Mechanical analyses were performed to compare the effects caused by variations in the amount of soil-water mixture, in the dispersion period, and in the air pressure. Sandy, silty, and clayey soils collected from different parts of the United States were used in these tests.

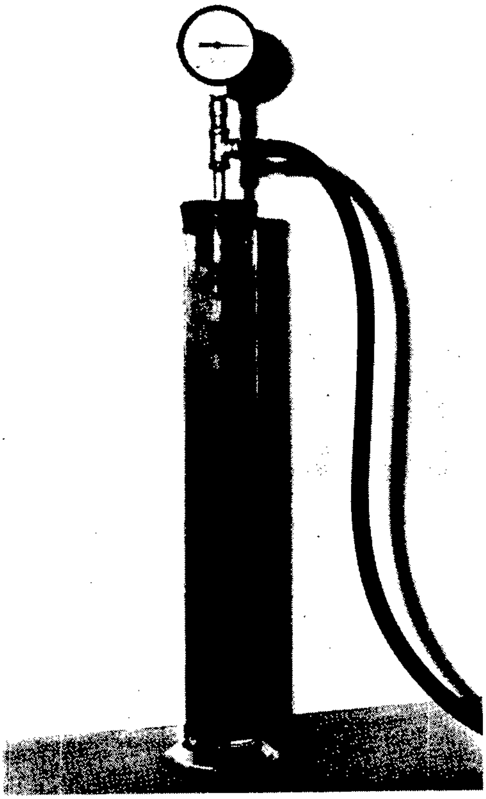

Figure 3. Soil-water mixture being agitated by the S.D.T.

Results indicate that the optimum amount of soil-water mixture for dispersion is 250 ml. Conclusions regarding dispersion periods and air pressures are: (1) a pressure of 25 psi. and a dispersion period of 5 min. should be used to disperse silty and clayey soils and (2) a pressure of 10 psi. and a dispersion period of 5 min. should be used to disperse sandy soils.

Since AASHO and ASTM specify the use of a 50-gm. sample for clayey and silty soils and a 100-gm. sample for sandy soils, another way to remember the amount of pressure is 25 psi. for 50-gm. samples and 10 psi. for 100-gm. samples. Figure 3 shows a clayey soil sample being agitated by the tube with a pressure of 25 psi.

A tentative procedure for using the soil-dispersion tube in the hydrometer method for particle-size determination is suggested in the appendix. The tube can also be adapted to other methods of particle-size measurement (*7*).

EVALUATION OF SOIL-DISPERSION TUBE

It has been pointed out that different types of apparatus may give different degrees of dispersion and, at the same time, may cause varying amounts of degradation. In dispersing a soil sample for mechanical analysis,

TABLE 1
SOURCE AND PROPERTIES OF SOIL SAMPLES[a]

Sample No.	Source	Textural[b] Classification	Plasticity Index	Remarks
1	Iowa	Clay	51.7	
2	Virginia	Clay	35.3	
3	California	Clay	38.7	
4	New York	Clay	13.1	
5	Texas	Clay Loam	3.6	
6	Iowa	Silty Loam	6.2	
7	New York	Sandy Loam	NP	
8	Virginia	Sand	NP	High content of mica
9	Iowa	Sand	NP	
10	Iowa	Sand	NP	Silt and clay removed by washing
11	Iowa	Sand	NP	Silt and clay removed by washing

[a] Only material passing No. 10 sieve was used in this study.
[b] Textural classifications are based upon the Bureau of Public Roads system except that 0.074 mm. was used as the lower limit of the sand fraction.

a high degree of dispersion and a minimum amount of degradation are desired; therefore, the degree of dispersion and the amount of degradation obtained with different dispersion apparatus may be used as criteria for comparing these apparatus.

When a soil sample containing sand, silt, and clay-size material is dispersed for particle-size determinations, the results obtained will reflect both the degree of dispersion and the extent of degradation. For the comparison of the degree of dispersion and of the extent of degradation, soil samples which are more sensitive to one than to the other should be used.

Since clayey soils are probably more sensitive to the dispersion factor than to the degradation factor, they can best be used to study the degree of dispersion. The degree of dispersion obtained with different apparatus may then be rated on the basis of particle-size measurements, particularly the 0.005 mm. and 0.001 mm. sizes. For example, the higher the content of material finer than 0.005 mm. or 0.001 mm., the higher the degree of dispersion.

Sandy soils which have been washed free of silt and clay-size material may be used for determining the effects of degradation. The use of a washed-sand sample eliminates, for the most part, the dispersion factor. With such a sample, the degradation of sand-size material caused by the use of different apparatus may be compared on the basis of sieve analysis results. In general, the larger the amount of material passing each sieve, the greater the degradation. The comparison of degradation

TABLE 2
MECHANICAL ANALYSES OF ELEVEN SAMPLES DISPERSED BY DIFFERENT APPARATUS

Sample No.	Weight of test sample (gm.)	Type of Dispersion Apparatus[a]	Percent of Particles Finer Than[b]							
			2.0 mm. (No. 10 Sieve)	0.84 mm. (No. 20 Sieve)	0.42 mm. (No. 40 sieve)	0.25 mm. (No. 60 Sieve)	0.149 mm. (No. 100 Sieve)	0.074 mm. (No. 200 Sieve)	0.005 mm.	0.001 mm.
1	50	A					100.0	97.4	57.0	34.8
		B					100.0	98.6	57.7	33.4
		C					100.0	98.8	63.0	48.5
		D					100.0	98.8	63.1	51.1
2	50	A			100.0	95.9	91.6	84.1	51.8	25.4
		B			100.0	96.2	91.7	84.8	54.5	40.0
		C			100.0	96.1	91.7	84.7	56.4	43.9
		D			100.0	96.7	92.7	86.2	58.6	45.9
3	50	A	100.0	98.3	95.9	94.1	92.3	89.5	43.9	16.8
		B	100.0	98.4	96.2	94.4	92.6	89.8	52.4	29.3
		C	100.0	98.3	96.1	94.3	92.5	89.7	52.9	38.9
		D	100.0	98.2	95.9	94.2	92.5	89.8	53.7	40.8
4	50	A	100.0	99.0	98.0	97.1	96.2	94.0	55.3	27.3
		B	100.0	99.2	98.2	97.3	96.4	94.1	52.5	26.1
		C	100.0	99.0	98.0	97.1	96.2	94.0	55.1	28.5
		D	100.0	99.3	98.5	97.7	96.9	94.9	56.9	29.8
5	50	A	100.0	99.2	97.6	92.7	82.5	65.8	20.1	2.6
		B	100.0	98.9	97.1	92.3	82.5	66.5	24.0	4.5
		C	100.0	98.8	97.1	92.1	82.1	65.7	21.8	4.6
		D	100.0	99.3	98.1	93.9	85.1	70.4	28.8	7.1
6	50	A					100.0	99.3	11.3	4.2
		B					100.0	99.3	13.6	7.3
		C					100.0	99.4	12.9	6.2
		D					100.0	99.4	17.8	10.4
7	100	A	100.0	97.3	90.5	78.3	59.3	38.6	10.0	2.1
		B	100.0	95.5	89.3	78.7	61.2	40.6	11.3	5.0
		C	100.0	97.1	90.3	78.2	59.2	38.5	11.2	4.0
		D	100.0	95.1	88.6	78.1	60.8	40.6	10.6	3.8
8	100	A	100.0	99.1	71.4	50.2	42.0	25.6	3.8	1.8
		B	100.0	97.6	66.9	44.2	37.1	24.5	5.6	4.0
		C	100.0	96.9	64.3	41.1	33.7	21.0	3.8	1.3
		D	100.0	97.6	64.4	41.0	34.1	21.5	4.8	2.7
9	100	A	100.0	98.9	79.6	38.0	19.9	16.0	3.0	1.2
		B	100.0	98.8	81.8	41.4	19.5	15.6	3.8	1.9
		C	100.0	98.8	79.1	36.9	18.8	15.0	2.8	1.3
		D	100.0	98.9	79.6	38.2	19.3	15.3	3.5	1.3
10	100	A	100.0	74.6	33.9	15.0	7.6	1.8	Trace	Trace
		B	100.0	74.3	34.6	16.1	8.2	2.8	Trace	Trace
		C	100.0	74.4	34.0	14.8	7.3	1.0	Trace	Trace
		D	100.0	73.4	32.6	14.2	6.8	1.0	Trace	Trace
11	100	A	100.0	72.7	51.9	37.9	27.3	17.0	Trace	Trace
		B	100.0	66.4	42.6	29.8	20.7	10.4	Trace	Trace
		C	100.0	65.0	40.8	27.5	17.6	5.9	Trace	Trace
		D	100.0	65.1	40.8	27.3	17.5	5.7	Trace	Trace

[a] Type A, ASTM stirring apparatus; Type B, end-over-end shaker; Type C, Wintermyer soil-dispersion cup; Type D, soil dispersion tube.
[b] All percentages are the average of results from duplicate tests.

on the basis of sand-size material is purely a matter of convenience, since the degradation of silt-size and clay-size materials is comparatively difficult to evaluate.

In evaluating the soil-dispersion tube by the method discussed above, mechanical analyses were performed on soil samples dispersed by the tube as well as the three types of dispersion apparatus in current use. The procedure for the use of the malted-milk-mixer-type apparatus, referred to later as the ASTM stirring apparatus, is described in both the ASTM and AASHO standard methods (*3*, *4*). The end-over-end shaker used in the evaluation study rotates at a rate of 65 revolutions per minute. With this apparatus, soaked soil samples were shaken for 24 hr. The Wintermyer Soil-Dispersion Cup B was used in all comparisons; the procedure for its use is given by AASHO (*4*).

A large number of soil samples obtained from different parts of the United States were used for comparing the various types of dispersion apparatus. Reported in this paper are results obtained with 11 samples representing soils which are difficult to disperse or highly susceptible to degradation. Table 1 shows the sources of the 11 samples and gives their textural classifications and plasticity indices. Four clayey soils, Samples 1 to 4, were selected to rate apparatus on the basis of degree of dispersion. Two washed sands, Samples 10 and 11, were used for comparing the amount of degradation caused by the different apparatus. The other five soil samples were used for general comparison of the effectiveness of dispersion.

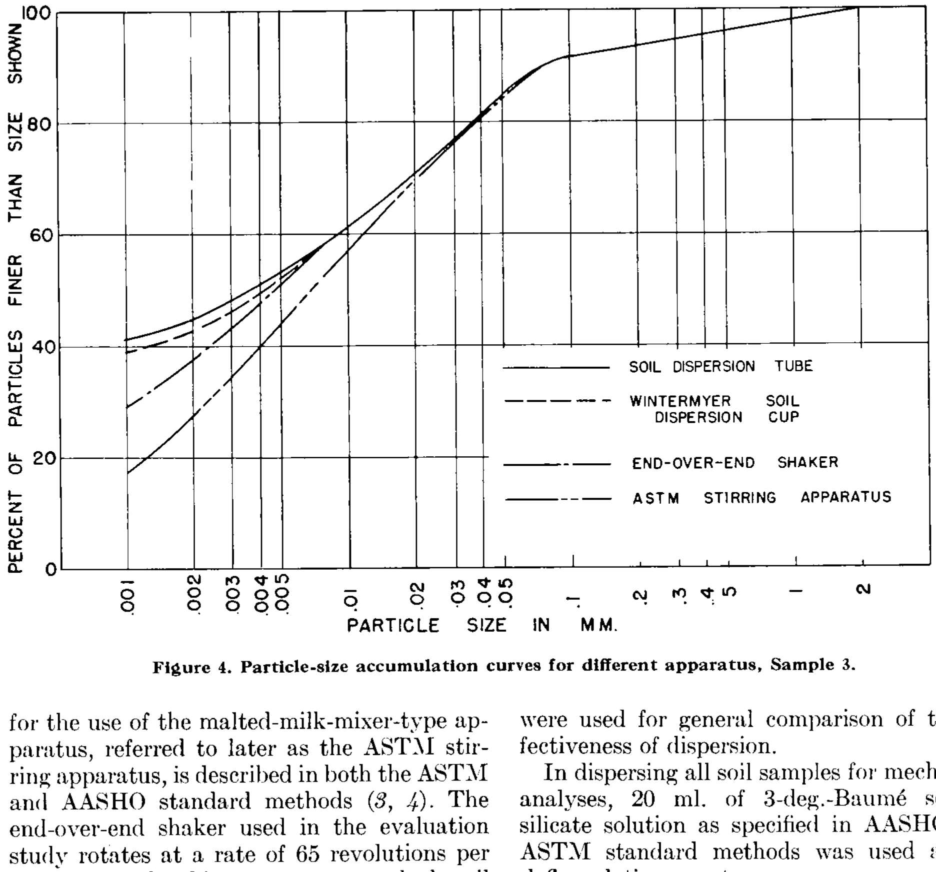

Figure 4. Particle-size accumulation curves for different apparatus, Sample 3.

In dispersing all soil samples for mechanical analyses, 20 ml. of 3-deg.-Baumé sodium silicate solution as specified in AASHO and ASTM standard methods was used as the deflocculating agent.

Table 2 summarizes the results of mechanical analyses on the 11 samples. Particle size measurements on Samples 1 to 4, especially the 0.001 mm. values, indicate that the soil-dispersion tube and the Wintermyer soil-dispersion cup give the highest degree of dispersion; the tube rates slightly higher. The difference in the degree of dispersion in the case of Sample 3 is illustrated graphically in Figure 4. Note that the greatest differences in particle-size measurements exist in the amount of material finer than 0.001 mm.

Results of sieve analyses on Samples 10 and 11, as shown in Table 2, indicate that the tube and the Wintermyer cup cause the least amount of degradation. Sample 11 is a sand which is extremely susceptible to degradation. Figure 5 compares graphically the amount of degradation of this soil caused by

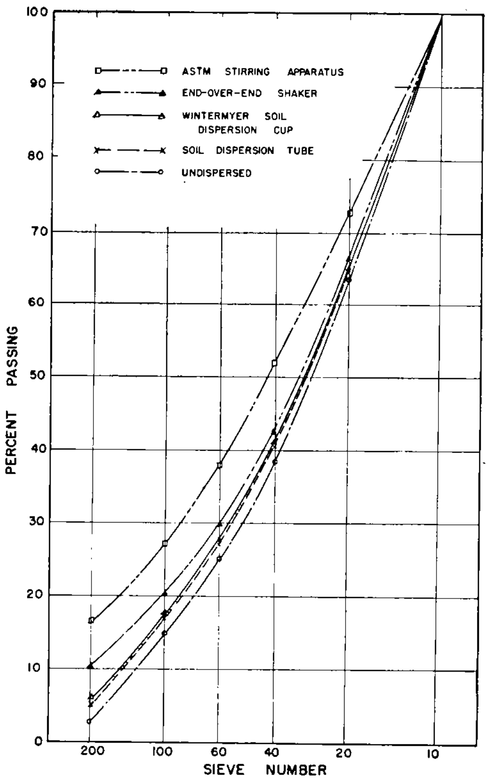

Figure 5. Particle-size accumulation curves for different apparatus, Sample 11.

the four dispersion apparatus. Particle size accumulation curves are plotted only for material retained on the No. 200 sieve. The "undispersed" curve in Figure 5 represents the gradation of Sample 11 unaffected by the degrading action of the dispersion apparatus. By comparing the other curves with it, the approximate amount of degradation caused by each type of apparatus can be obtained. It is seen in Figure 5 that the amount of degradation caused by the tube is small. This would be especially true with common types of soil which are usually much less susceptible to degradation than the sample used in this study.

Among the other five soil samples used for the purpose of general comparison, Sample 8 is of special significance. Because of a high mica content, it is extremely susceptible to degradation. In the procedure for using the Wintermyer apparatus (*4*), an exceptionally short dispersion period is specified for samples containing large percentages of mica. Data shown in Table 2 indicate that the use of the tube and the Wintermyer apparatus results in approximately the same particle-size measurements in the sand fraction of Sample 8. Because of this, it is believed that the soil-dispersion tube with the regular dispersion period of 5 min. may give satisfactory results even for soils with high mica content.

CONCLUSION

1. The soil-dispersion tube is a promising dispersion apparatus for mechanical analysis of soils.
2. The comparative experiments presented indicate that the two dispersion apparatus utilizing compressed air, the tube, and the Wintermyer soil-dispersion cup, give a comparatively high degree of dispersion without causing significant degradation.
3. The tube is a simplified air-jet dispersion apparatus. Consequently, it can be built at a relatively low cost. In addition, because of the unique design of the soil-dispersion tube, the procedure for its use is substantially simpler than that for any other dispersion apparatus in current use.

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APPENDIX

Tentative Procedure for Using the Soil-Dispersion Tube to Disperse Soil Samples for Hydrometer Tests

For most soils, a representative sample of 50 gm. shall be secured and placed in a hydrometer jar. Add about 150 ml. of distilled water and stir the soil-water mixture thoroughly. After the soil has soaked for at least 18 hrs., add a deflocculating agent and a sufficient amount of distilled water to make the resulting mixture approximately 250 ml.

Note: An alternate soaking procedure is to add the deflocculating agent and a sufficient amount of distilled water to the soil sample to make a mixture of 250 ml. before soaking. Agitate the mixture with the S.D.T. at the end of the prescribed period of soaking.

Both soaking procedures appear to result in the same degree of dispersion. The alternate procedure is convenient to use when different amounts of a deflocculating agent are being tried out.

Before using the tube, open the control valve on the compressed air pipe until a pressure of about 1 psi. is registered on the pressure gauge.[2] Then, insert the tube into the hydrometer jar and increase the pressure to 25 psi. At this pressure, the soil-water mixture shall be agitated for 5 min.

At the end of the 5-min. dispersion period, reduce the pressure to 1 psi., lift the tube out of the soil-water mixture, and wash all particles clinging to it back into the hydrometer jar. Add more distilled water to the dispersed sample until the mixture attains a volume of 1,000 ml. It is then ready for hydrometer measurements.

For very sandy soils, use a sample weighing 100 gm. and a dispersion pressure of 10 psi.; otherwise the procedure shall be the same.

[2] The initial air pressure of 1 psi. is required to prevent the soil-water mixture from entering the dispersion head of the tube.